The Training and Assessment of Surgical Skills in Robot Assisted Surgery

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IN ROBOT ASSISTED SURGERY**

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Introduction

Healthcare is constantly moving towards the improvement of quality of care and safety for patients. Increasing attention is being paid to the relocation of complex treatments, such as robot assisted surgery, to high-volume centres as it is expected to improve the quality of care and increases patient safety due to the increased exposure of surgeon and staff.[1–3] In the Netherlands, a move to large high-volume centres is seen in some specialties including Urology.[4] This change is influenced by recent studies linking hospital volumes to surgical outcome.[1–3] With the increasing call for the formation of high-volume centres in order to improve quality of care the question remains whether the higher number of surgeries per hospital or the quality of the surgeon influences outcome. There are large variations in postoperative complication rates amongst surgeons with similar surgical volumes per centre or even in the same centre.[5,6] The qualification and certification of surgical skills are still in a preliminary phase within all surgical specialties, also in urology.

The skills of a surgeon assessed by surgical video analysis has been correlated to the prevalence of major complications (i.e. readmissions) in the past.[7] This initial study has sparked a new field of research into surgical skills and the use of surgical videos analysis.[8–10] In more recent studies, surgical skills have been associated with functional outcome.[2,6,11] Systematic evaluation of surgical skills, both technical and non-technical, is thought possible through video analysis methods. A description of the surgical steps in the procedure is needed in order to use the surgical videos for the assessment of surgical skills, and detect possible errors for the association with adverse outcomes.

Problem statement

With the increasing number of procedures and the increasing technical difficulty of procedures, the current challenge for both novice and expert surgeons is to learn how to analyse past performances and subsequently use this as a lesson for the future.

We therefore describe surgical skills needed for robot assisted surgery and its shortcomings, next the educational and training status of novice and experienced robotic surgeons, and resume with a list of research questions related to the overall problem of how to test robotic skills and the impact of those tests. The methodology of testing and evaluation are shortly introduced at the end of the introduction.

Surgical Skills in Robot Assisted Surgery

Although laparoscopic surgery has it benefits, it also has its technical challenges. Examples of these challenges are such as a limited range of motion of the instruments and related loss of dexterity, fixed instrument tips, and an inadequate visual field associated with an unstable camera view.[12,13] In order to improve these limitations, new methods of minimal invasive surgery were investigated. This resulted in the development of so-called robot assisted surgery. The introduction of this technique could potentially overcome some of the drawbacks of laparoscopic surgery through the improvement of ergonomics and enhanced dexterity with tremor filtration. Even for those surgeons transferring from laparoscopy, slow learning curves were described based on operating time, complication rates and surgical margins.[14,15] The effect of a surgeons' skills during these robots assisted surgeries on the outcome of the surgery has sparsely been investigated.

In many clinics in the United States and Europe, the Robot Assisted Radical Prostatectomy (RARP) has replaced the open radical prostatectomy and laparoscopic radical prostatectomy. The RARP is a complex and highly specialized operation in which the surgical robot is used to remove the prostate. Multiple ports are placed in the abdomen to facilitate robotic access to the prostate. Since the removal of the prostate leads to the separation of the bladder neck and the urethra a new bladder neck/urethra anastomosis is created. The combination of the removal of the prostate with the new anastomosis can lead to severe post-operative incontinence. Due to the relative position of the neurovascular bundle to the prostate, erectile dysfunction is another common post-operative complication.[16–18]

Since the RARP is a video recorded procedure and one of the most performed procedures in urology, the RARP seems an optimal procedure to develop and validate competency assessment. This process could be used as an example for other operations within and outside the field of urology.

Even though the RARP surgery could be used for competency assessment it remains unclear how this surgical skills analysis using surgical videos should be performed. It remains unclear if video analysis is a valid measuring tool to assess the competency of expert surgeons. The additional questions are "who should assess the video's?" since it is a time-consuming method of analysis and "how do you define the competency of a surgeon?" since multiple assessment methods have been developed using different levels of detail.

Basic Proficiency Requirements for Robot assisted surgery

In 2010, the Dutch health care inspectorate (Inspectie Gezondheidszorg en Jeugd, IGJ) published a report stating ‘insufficient carefulness at the introduction of surgical robots. In this report, the IGJ expressed their concern over the lack of clearly stated criteria for starting robot–assisted laparoscopy. It is increasingly accepted by the medical community to safeguard a minimal competency level for residents. The majority of robot assisted surgeons in the Netherlands agree that the basics in robotic surgery should be incorporated in a structured training program to guarantee the quality of the surgeon and the safety of the patient.[19]

The lack of structured training program and defined skills-criteria results in a training programme developed by the novice surgeons based on their perceived lack of knowledge.[20,21] This, by the novice developed, training programme could result in a hiatus of knowledge due to overconfidence biases, an over-assessment of skills compared to the objective assessment of skills by an external observer.[22]

The lack of defined skills-criteria resulted in a study by the Netherlands institute for health services research (NIVEL), commissioned by the Dutch Ministry of Health, Welfare and Sport, in collaboration with a number of experts in which the ‘Basic proficiency requirements for the safe use of robotic surgery’ were investigated.[23]. The existence of these Basic Proficiency Requirements enables the specific development of training curricula for novice surgeons and the structured evaluation surgical skills in both novice and expert surgeons. The Basic Proficiency Requirements are a first step towards defining surgical skills and in enabling surgical skills assessment for both novice and expert surgeons. The question remains how these Basic Proficiency Requirements can be integrated into existing training programs and competency assessment methods.

Surgical Skills in novice surgeons

Different methods of training in robot assisted surgery have been researched.[24–28] These results have been developed into multiple training curricula, some of which are implemented by the European Association of Urology Robotic Urology Section (ERUS) robotic urology fellowship curriculum, Fundamental Skills of Robotic Surgery (FSRS), Fundamentals of Robotic Surgery (FRS) and the Basic Skills Training Curriculum (BSTC). Although these curricula need thorough validation these are promising steps in the development of standardized robot surgery curricula.[29]

A well described and often cited modular training pathway for the laparoscopic prostatectomy is described by Stolzenburg et al.(2005).[30] This training pathway nevertheless does not describe an assessment method. Apart from the general intra-operative checklist, such as the Objective structured assessment of technical skills (OSATS) [31] limited assessment tools specific for radical prostatectomy are developed. Recently, the validation of the RARP Assessment Score and Learning Curve Assessment was published.[24] This multi-institutional (Europe, Australia, and United States) observational prospective study identified the high-risk steps of RARP. A specialist focus group enabled validation. Fifteen trainees who underwent European Association of Urology robotic surgery curriculum training performed RARP and were assessed by mentors using the tool developed. It remains unclear if the combination of standardized robot surgery curriculum with structured feedback using competency assessment methods influence the surgical skills of novice robot assisted surgeons and on the long-term influence postoperative outcome of patients.

Surgical Skills in Expert surgeons

The safety of the patient is not only guaranteed by a proper initial training, there is also an increasing demand for the implementation of clinical assessments of surgeons. Only limited initiatives have been installed to implement clinical assessment of surgeons using surgical videos.[32,33]

In order to optimize video assessment, it is primarily important to study the performance of the surgeon and focus on critical steps. In general surgery, several studies have been published describing assessment of intra-operative performance.[34–36] Multiple standardized surgical skills assessment tools have been developed which could be used to investigate whether the differences in surgical skills in experts influence postoperative outcomes of the patients.[34,37–39]

Surgical skills analysis using surgical videos

Analysis of past performance is a mandatory component of continues learning in many industries, yet still in its infancy in surgical assessment. Systematic evaluation of surgical skills, both technical and non-technical, is possible through video analysis methods, since laparoscopy and robot assisted surgery offer intraoperative video recordings. Post-operative outcomes in surgery could be related to surgical performance7,40, review of intraoperative videos allows for detailed analysis and improvement of skills and systems that contribute to patient safety. A detailed description of the surgery is needed in order to use the surgical videos for the assessment of surgical skills and the detection of adverse outcomes.

In the past, multiple groups have devised a schedule defining the individual steps of the RARP.[30,37,41] These schedules mostly are used to train new robot surgeons or to evaluate the skill of current robot surgeons but no specific schedule has been developed to investigate the link between surgeons' skills in the RARP as assessed on video and post-operative adverse outcomes. Other research has shown that it is possible to relate surgical skills in general to post-operative adverse outcomes.[7,40,42] Little research has been done to evaluate the skills of robot surgeons and define which parts of the intervention could be related to adverse outcomes, post-operative complications, erectly dysfunction, incontinence and lower urinary tract symptoms.

A recent study into the combination of video data with the movement of the surgical robot with the dVlogger system led to greater insight into the performance of the surgeons and could accurately identify novices and experts.[8] These types of surgical skills analysis could increase our understanding of the origins of complications and help to investigate whether the differences in surgical skills influence postoperative outcome.

Non-technical skills analysis

Although the analysis of technical surgical skills in robot assisted surgery can lead to major improvements of postoperative outcomes[40], the possible influence of Non-Technical-Skills (NTS) on postoperative outcomes also merits attention. The NTS needed for a successful robot assisted surgery probably differ from the NTS needed for open surgery.

The introduction of the surgical robot has profoundly altered the traditional set-up of the operating room, since the scrub nurse and the surgeon are no longer on opposite sides of the patient. In robot assisted surgery, the surgeon is located in a separate control console for most of the surgical procedure, and thus direct communication with the team members could be hampered. It is conceivable that loss of non-verbal communication can influence the workflow and therefore the quality of the performance including patients' safety.

Two systematic reviews have been published concerning studies of NTS in minimal invasive surgery (i.e. conventional laparoscopy and robot assisted surgery).[43,44] A wide variety in assessments of NTS was used which makes comparison of tools difficult.[43,44]

Even though several general assessment methods have been developed for both the entire team[45–47] and individual team members[48–50] the question remains whether these tools can accurately assess NTS in complex robot assisted surgeries such as robot assisted radical cystectomy. With the introduction of the Interpersonal and Cognitive Assessment for Robotic Surgery (ICARS)[51], adaptation to the robot assisted surgical setting has started. The question remains whether the introduction of robot assisted surgery leads to a change in NTS which could influence the outcome of the surgery.

Research questions

In this thesis the following general research question is answered: 1. What are the best methods to educate surgeons in robotic surgery? and 2. How can the performance of robotic surgeon's best be assessed? 3. What is the relation between a surgeon's performance and a patient's postoperative outcomes

These questions will be answered by answering the following research questions in 11 chapters (figure 1).

1. Are novice robot surgeons able to accurately self-assess their knowledge and dexterity skills?
2. What is the influence of structured skills training and structured feedback on the surgical skills of novice robot assisted surgeons?
3. What are the effects of structured robotic surgery skills training and structured feedback?
4. Which technical and non-technical skills factors in robot assisted surgery (competence, teamwork, dedicated OR team, patient factors, environmental factors) influence clinical and patient-related outcomes?
5. Is video analysis a valid measuring tool to assess the competence of surgeons?
6. Is it possible to find differences between surgeries that are relevant to the outcome of the intervention by analysing video material?

Methodology

In this thesis we focus on the training of new surgical skills in novice surgeons and the implementation of surgical skills analysis in novice and expert surgeons.

Different forms of **surgical skill analyses** were investigated in both novice surgeons (surgical skills simulation) and expert surgeons (surgical video analysis). to determine which form of analysis is more functional in either group.

The **surgical skills simulation** was used to gain insight into the effects of different forms of guidance and training on the technical skills of novice surgeons.

Surgical video analysis in expert surgeons was used to identify if surgical skills could be related to postoperative outcome in robot assisted radical prostatectomy patients.

Multiple surveys and a Delphi process were used in the studies represented in this thesis to gain insight into the effects of surgical skills training in novice surgeons and the opinions of urologist who perform robot assisted surgery on the origins of complications and the use of postoperative results analysis.

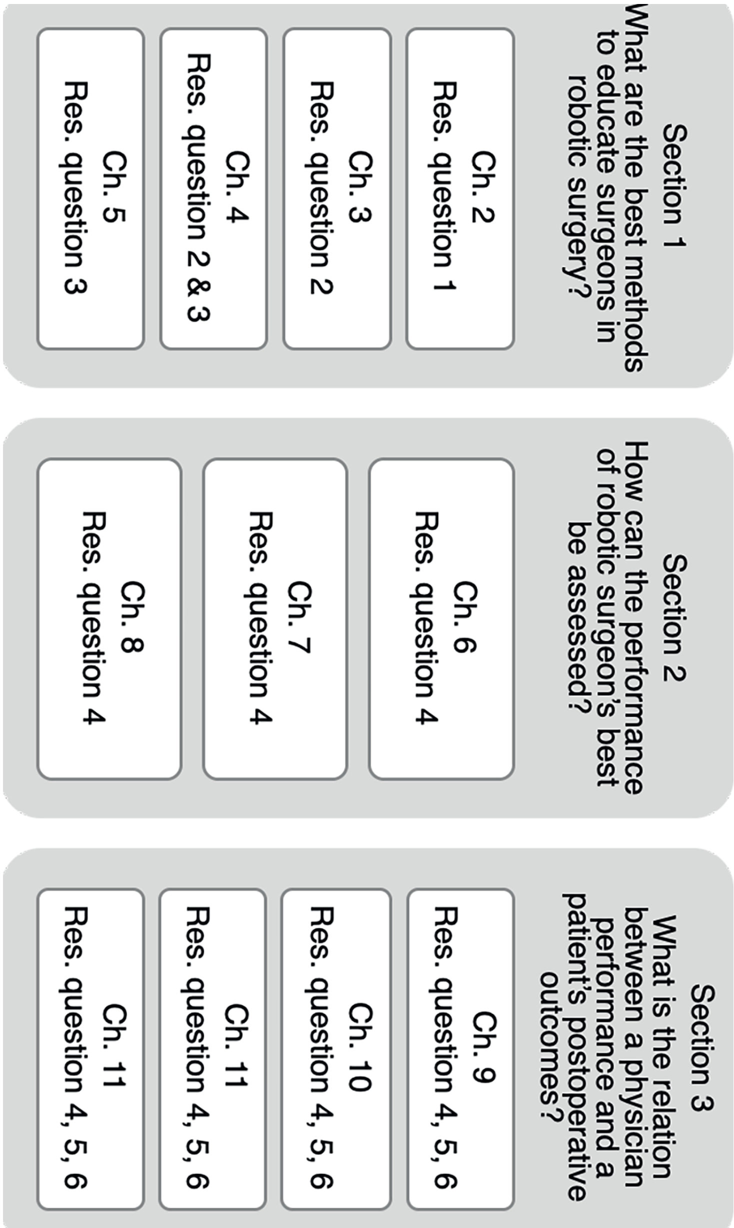


Figure 1: Thesis overview

Outline of the thesis

The **first section** of the thesis focusses on surgical training. In this section four chapters will focus on the different aspects of surgical training and evaluation of the short-term and long-term effects of surgical training. In this section research questions one, two and three will be answered in multiple chapters (figure 1).

In **Chapter 2** we investigate research question 1 *'Are novice robot surgeons able to accurately self-assess their knowledge and dexterity skills?'* by investigating the ability of novice robot surgeons to assess their own robot assisted surgery skills and knowledge of robot assisted surgery. We compare the results of the surgical skills simulation exercises to the self-assessment of their own dexterity skills after a one-day robot assisted surgery training.

Chapter 3 investigates research question 2 '*What is the influence of structured skills training and structured feedback on the surgical skills of novice robot assisted surgeons?'* in order to evaluate the effectiveness of a simulation based surgical skills training in the vesico-urethral anastomosis of the Robot Assisted Radical Prostatectomy (RARP) in novice robot surgeons. In order to evaluate the effects of expert proctoring or simulation-based training by the simulator on technical skills and participant satisfaction.

In **Chapter 4** research question 2 *'What is the influence of structured skills training and structured feedback on the surgical skills of novice robot assisted surgeons?'* and research question 3 *'What are the effects of structured robotic surgery skills training and structured feedback?'*are investigated. In this chapter, the results of a snap shot survey amongst Dutch residents and recently graduated urologist are combined with the results of residents who participated in an advanced course in Robot Assisted Surgery. This chapter provides valuable insight into the current state of robot assisted surgery training and the requirements set by the educators before the residents are allowed to take their first steps in robot assisted surgery. In addition, the short-term and long-term effect of structured robot assisted surgery training on novice robot surgeons was reviewed.

Chapter 5 focusses on research question 3 *'What are the effects of structured robotic surgery skills training and structured feedback?'*. In this chapter, we evaluate the long-term effects of a robot assisted surgery fellowship. The evaluation consisted of a questionnaire amongst the participants of a robot assisted surgery fellowship in order to investigate the long-term influence of this fellowship on the surgeons work and their patient's outcome.

The **second section** of the thesis focusses on the assessment of the performance of robotic surgeons. In this section research questions will be answered in multiple chapters (figure 1).

Chapter 6 focusses on research question 6 *'Is it possible to find differences between surgeries that are relevant to the outcome of the intervention by analysing video material?'*, it describes which aspects of the RARP are of influence in the origin of postoperative outcome according to the opinion of RARP experts. The results of this Delphi process were used to develop an assessment template which can be used in the technical skills assessment of RARP surgery.

Chapter 7 describes the research protocol for a prospective observational multicenter study concerning non-technical skills in robot assisted radical cystectomy versus open radical cystectomy. This study was designed to evaluate the differences in NTS between open and robot assisted surgery.

In **Chapter 8** we review the opinions of surgeons who perform Robot Assisted Radical Prostatectomy on the influence of postoperative results analysis and surgical video review. This study gives insight into the use of surgical video review in daily practice which provides insight for further research.

The **third section** of the thesis focusses on the relation between a surgeon's performance and a patient's postoperative outcomes. In this section research questions will be answered in multiple chapters (figure 1).

In **Chapter 9** and **Chapter 10** research question 4 *'Which technical and non-technical skills factors in robot assisted surgery (competence, teamwork, dedicated OR team, patient factors, environmental factors) influence clinical and patient-related outcomes?'*, research question 5 *'Is video analysis a valid measuring tool to assess the competence of surgeons?'* and research question 6 *'Is it possible to find differences between surgeries that are relevant to the outcome of the intervention by analysing video material?'* are answered in order to identify which factors of RARP using different methods of surgical video assessment influence postoperative outcome. Different methods of surgical video analysis, including assessment by expert surgeons, were used to identify differences in surgical skill and relating them to the postoperative outcome of the patient.

In **Chapter 11** we investigate research question 4 *'Which technical and non-technical skills factors in robot assisted surgery (competence, teamwork, dedicated OR team, patient factors, environmental factors) influence clinical and patient-related outcomes?'*, research question 5 *'Is video analysis a valid measuring tool to assess the competence of surgeons?'* and research question 6 *'Is it possible to find differences between surgeries that are relevant to the outcome of the intervention by analysing video material?'* by evaluating the use of a video motion tracking system to assess surgical movements during robot-assisted radical prostatectomy. The results of this surgical movements analyses were compared to the postoperative outcome of the patients to asses if this type of analysis could be used to predict postoperative outcome.

Chapter 12 studies research question 4 *'Which technical and non-technical skills factors in robot assisted surgery (competence, teamwork, dedicated OR team, patient factors, environmental factors) influence clinical and patient-related outcomes?'*, research question 5 *'Is video analysis a valid measuring tool to assess the competence of surgeons?'* and research question 6 *'Is it possible to find differences between surgeries that are relevant to the outcome of the intervention by analysing video material?'* by investigating the relationship between postoperative urinary continence and residual urethra stump measurements in robot assisted radical prostatectomy patients. This chapter describes the comparison of intra-operative measurements of the urethra stump to postoperative outcome of the patients.

Finally, the findings of the preceding chapters will be summarized and discussed in **Chapter 13.** Moreover, this chapter will report our recommendations, practical implications, and suggestions for further research.

References

1. Trinh QD, Bjartell A, Freedland SJ, Hollenbeck BK, Hu JC, Shariat SF, Sun M, Vickers AJ. A systematic review of the volume-outcome relationship for radical prostatectomy. Eur Urol [Internet]. 2013;64(5):786–98.

2. Gershman B, Meier SK, Jeffery MM, Moreira DM, Tollefson MK, Kim SP, Karnes RJ, Shah ND. Redefining and Contextualizing the Hospital Volume-Outcome Relationship for Robot-Assisted Radical Prostatectomy: Implications for Centralization of Care. J Urol [Internet]. 2017 Jul 1 [cited 2018 Jul 23];198(1):92–9.

3. Stitzenberg KB, Wong YN, Nielsen ME, Egleston BL, Uzzo RG. Trends in radical prostatectomy: Centralization, robotics, and access to urologic cancer care. Cancer. 2012;118(1):54–62.

4. Inspectie voor de Gezondheidszorg. Het resultaat telt; Ziekenhuizen 2015. 2017;247.

5. Bianco FJ, Vickers AJ, Cronin AM, Klein EA, Eastham JA, Pontes JE, Scardino PT. Variations Among Experienced Surgeons in Cancer Control After Open Radical Prostatectomy. J Urol [Internet]. 2010;183(3):977–83.

6. Vickers A, Savage C, Bianco F, Mulhall J, Guillonneau B, Cronin A, Scardino P, Sandhu J, Guillonneau B, Cronin A, Scardino P. Cancer control and functional outcomes after radical prostatectomy as markers of surgical quality: Analysis of heterogeneity between surgeons at a single cancer center. Eur Urol [Internet]. 2011;59(3):317–22.

7. Birkmeyer JD, Finks JF, O ’reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.

8. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.

9. Ghani KR, Miller DC, Linsell S, Brachulis A, Lane B, Sarle R, Dalela D, Menon M, Comstock B, Lendvay TS, Montie J, Peabody JO. Measuring to improve: Peer and crowd-sourced assessments of technical skill with robot-assisted radical prostatectomy. Eur Urol [Internet]. 2016 [cited 2017 Jun 12];69(4):547–50.

10. Goldenberg MG, Lee JY, Kwong JCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence. Vol. 122, BJU International. 2018.

11. Cathcart P, Sridhara A, Ramachandran N, Briggs T, Nathan S, Kelly J. Achieving quality assurance of prostate cancer surgery during reorganisation of cancer services. Eur Urol [Internet]. 2015 Jul 1 [cited 2018 Apr 5];68(1):22–9.

12. Roh HF, Nam SH, Kim JM. Robot-assisted laparoscopic surgery versus conventional laparoscopic surgery in randomized controlled trials: A systematic review and meta-analysis. PLoS One [Internet]. 2018 [cited 2020 Mar 19];13(1).

13. Tekkis PP, Senagore AJ, Delaney CP, Fazio VW. Evaluation of the learning curve in laparoscopic colorectal surgery: Comparison of right-sided and left-sided resections. Ann Surg. 2005;242(1):83–91.

14. Atug F, Castle EP, Srivastav SK, Burgess S V, Thomas R, Davis R. Positive surgical margins in robotic-assisted radical prostatectomy: impact of learning curve on oncologic outcomes. Eur Urol [Internet]. 2006 May [cited 2017 Dec 28];49(5):866–71; discussion 871-2.

15. Ou Y-C, Yang C-R, Wang J, Yang C-K, Cheng C-L, Patel VR, Tewari AK. The learning curve for reducing complications of robotic-assisted laparoscopic radical prostatectomy by a single surgeon. BJU Int [Internet]. 2011 Aug 1 [cited 2017 Dec 28];108(3):420–5.

16. Barocas DA, Alvarez J, Resnick MJ, Koyama T, Hoffman KE, Tyson MD, Conwill R, McCollum D, Cooperberg MR, Goodman M, Greenfield S, Hamilton AS, Hashibe M, Kaplan SH, Paddock LE, Stroup AM, Wu X-C, Penson DF. Association Between Radiation Therapy, Surgery, or Observation for Localized Prostate Cancer and Patient-Reported Outcomes After 3 Years. JAMA. 2017 Mar;317(11):1126.

17. Donovan JL, Hamdy FC, Lane JA, Mason M, Metcalfe C, Walsh E, Blazeby JM, Peters TJ, Holding P, Bonnington S, Lennon T, Bradshaw L, Cooper D, Herbert P, Howson J, Jones A, Lyons N, Salter E, Thompson P, et al. Patient-Reported Outcomes after Monitoring, Surgery, or Radiotherapy for Prostate Cancer. N Engl J Med. 2016 Oct;375(15):1425–37.

18. Lardas M, Liew M, van den Bergh RC, De Santis M, Bellmunt J, Van den Broeck T, Cornford P, Cumberbatch MG, Fossati N, Gross T, Henry AM, Bolla M, Briers E, Joniau S, Lam TB, Mason MD, Mottet N, van der Poel HG, Rouvière O, et al. Quality of Life Outcomes after Primary Treatment for Clinically Localised Prostate Cancer: A Systematic Review. Eur Urol. 2017 Dec;72(6):869–85.

19. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.

20. Kruger J, Dunning D. Unskilled and unaware of it: How difficulties in recognizing one’s own incompetence lead to inflated self-assessments. J Pers Soc Psychol [Internet]. 1999 [cited 2018 Mar 22];77(6):1121–34.

21. Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX, Sriprasad S. Partial vs radical nephrectomy for T1 renal tumours: an analysis from the British Association of Urological Surgeons Nephrectomy Audit. BJU Int [Internet]. 2016 Jan [cited 2017 Jan 7];117(1):62–71.

22. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers’ Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377.

23. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP,

Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];

24. Lovegrove C, Novara G, Mottrie A, Guru KA, Brown M, Challacombe B, Popert R, Raza J, Van der Poel H, Peabody J, Dasgupta P, Ahmed K, Catto J. Structured and Modular Training Pathway for Robot-assisted Radical Prostatectomy (RARP): Validation of the RARP Assessment Score and Learning Curve Assessment. Eur Urol [Internet]. 2016 Mar [cited 2017 Jun 11];69(3):526–35.

25. Montorsi F, Wilson TG, Rosen RC, Ahlering TE, Artibani W, Carroll PR, Costello A, Eastham JA, Ficarra V, Guazzoni G, Menon M, Novara G, Patel VR, Stolzenburg JU, Van Der Poel H, Van Poppel H, Mottrie A. Best practices in robot-assisted radical prostatectomy: Recommendations of the Pasadena consensus panel [Internet]. Vol. 62, European Urology. Elsevier; 2012 [cited 2017 Dec 28]. p. 368–81.

26. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. Eur Urol [Internet]. 2015 [cited 2017 Jun 12];68(2):9–2.

27. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101.

28. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Platinum Priority – Education Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. 2015;8(2):9–2.

29. Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg [Internet]. 2015 Jan [cited 2017 Aug 17];13:115–23.

30. Stolzenburg J-U, Schwaibold H, Bhanot SM, Rabenalt R, Do M, Truss M, Ho K, Anderson C. Modular surgical training for endoscopic extraperitoneal radical prostatectomy. BJU Int [Internet]. 2005 Nov 1 [cited 2017 Dec 28];96(7):1022–7.

31. Martin JA, Regehr G, Reznick R, MacRae H, Murnaghan J, Hutchison C, Brown M. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg [Internet]. 1997 Feb [cited 2017 Dec 28];84(2):273–8.

32. Matsuda T, Kanayama H, Ono Y, Kawauchi A, Mizoguchi H, Nakagawa K, Iwamura M, Shigeta M, Habuchi T, Terachi T, Referee Committee of the Endoscopic Surgical Skill Qualification System in Urological Laparoscopy. Reliability of Laparoscopic Skills Assessment on Video: 8-Year Results of the Endoscopic Surgical Skill Qualification System in Japan. J Endourol [Internet]. 2014 Nov [cited 2017 Dec 28];28(11):1374–8.

33. Matsuda T, Ono Y, Terachi T, Naito S, Baba S, Miki T, Hirao Y, Okuyama A. The Endoscopic Surgical Skill Qualification System in Urological Laparoscopy: A Novel System in Japan. J Urol [Internet]. 2006 [cited 2017 Dec 28];176(5):2168–72.

34. Tang B, Hanna GB, Joice P, Cuschieri A. Identification and categorization of technical errors by Observational Clinical Human Reliability Assessment (OCHRA) during laparoscopic cholecystectomy. Arch Surg. 2004;139(11):1215–20.

35. Miskovic D, Ni M, Wyles SM, Parvaiz A, Hanna GB. Observational clinical human reliability analysis (OCHRA) for competency assessment in laparoscopic colorectal surgery at the specialist level. Surg Endosc [Internet]. 2012 Mar 1 [cited 2017 Aug 29];26(3):796–803.

36. Miskovic D, Ni M, Wyles SM, Kennedy RH, Francis NK, Parvaiz A, Cunningham C, Rockall TA, Gudgeon AM, Coleman MG, Hanna GB, National Training Programme in Laparoscopic Colorectal Surgery in England. Is Competency Assessment at the Specialist Level Achievable? A Study for the National Training Programme in Laparoscopic Colorectal Surgery in England. Ann Surg [Internet]. 2013 Mar [cited 2017 Dec 28];257(3):476–82.

37. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.

38. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.

39. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.

40. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.

41. Morris C, Hoogenes J, Shayegan B, Matsumoto ED. Towards development and validation of an intraoperative assessment tool for robot-assisted radical prostatectomy training: results of a Delphi study. Int Braz J Urol [Internet]. 2017 [cited 2017 Dec 28];43(4):661–70.

42. Raza SJ, Field E, Jay C, Eun D, Fumo M, Hu JC, Lee D, Mehboob Z, Nyquist J, Peabody JO, Sarle R, Stricker H, Yang Z, Wilding G, Mohler JL, Guru KA. Surgical competency for urethrovesical anastomosis during robot-assisted radical prostatectomy: Development and validation of the robotic anastomosis competency evaluation. Urology [Internet]. 2015 Jan 1 [cited 2017 Dec 28];85(1):27–32.

43. Gjeraa K, Spanager L, Konge L, Petersen RH, Østergaard D. Non-technical skills in minimally invasive surgery teams: a systematic review. Surg Endosc. 2016;30(12):5185–99.

44. van der Vliet WJ, Haenen SM, Solis-Velasco M, Dejong CHC, Neumann UP, Moser AJ, van Dam RM. Systematic review of team performance in minimally invasive abdominal surgery. BJS Open. 2019;3(3):252–9.

45. Robertson ER, Hadi M, Morgan LJ, Pickering SP, Collins G, New S, Griffin D, McCulloch P, Catchpole KC. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System. Roma PG, editor. PLoS One [Internet]. 2014 Mar 4 [cited 2018 Oct 26];9(3):e90320.

46. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care [Internet]. 2009 Apr 1 [cited 2018 Oct 26];18(2):104–8.

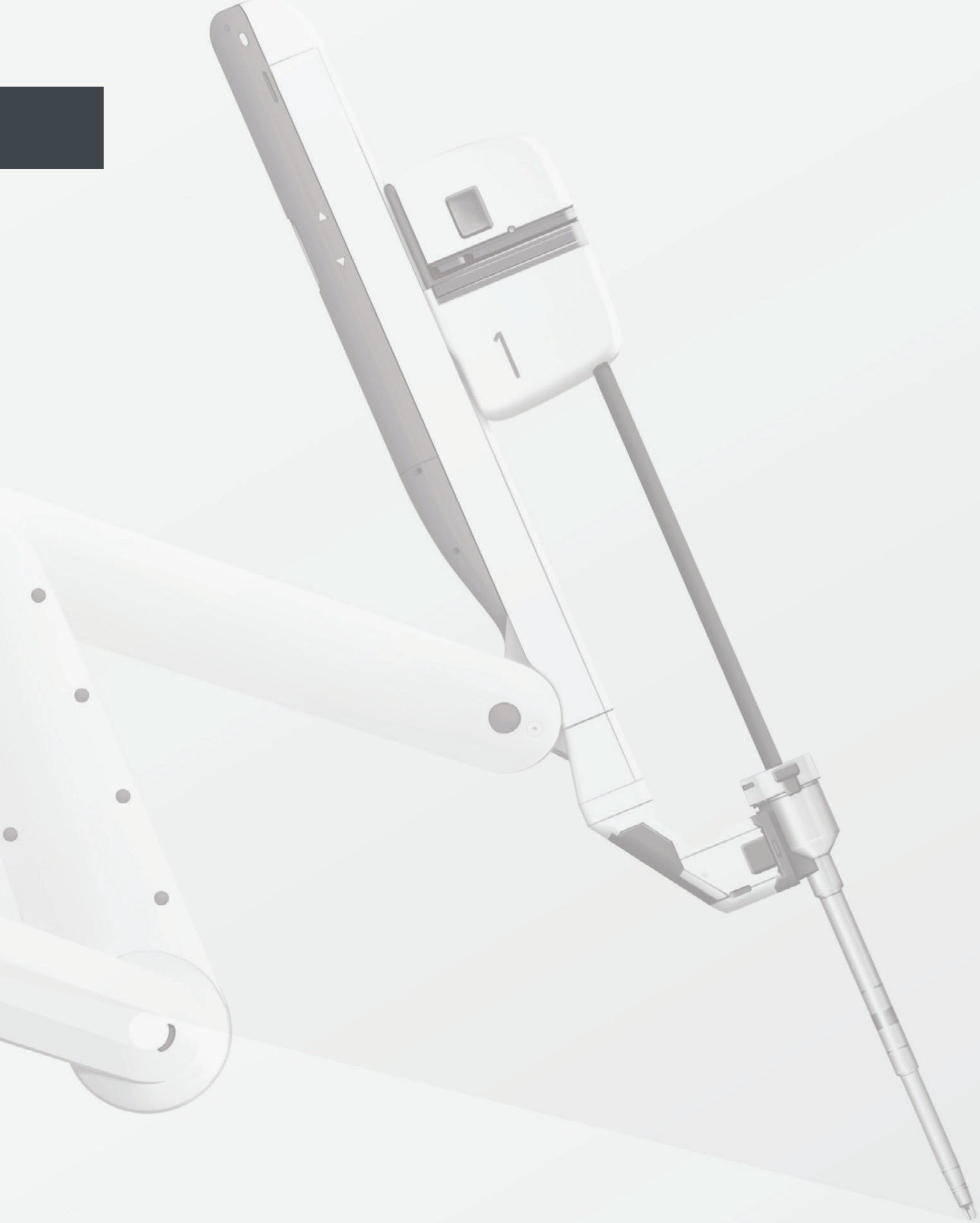
47. Moorthy K, Munz Y, Adams S, Pandey V, Darzi A. A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. Ann Surg [Internet]. 2005 Nov [cited 2018 Oct 26];242(5):631–9.

48. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. Best Pract Res Clin Anaesthesiol [Internet]. 2011 Jun 1 [cited 2018 Oct 26];25(2):215–27.

49. Mitchell L, Flin R, Yule S, Mitchell J, Coutts K, Youngson G. Development of a behavioural marker system for scrub practitioners' non-technical skills (SPLINTS system). J Eval Clin Pract [Internet]. 2013 Apr 1 [cited 2018 Oct 26];19(2):317–23.

50. Sharma B, Mishra A, Aggarwal R, Grantcharov TP. Non-technical skills assessment in surgery. Surg Oncol [Internet]. 2011;20(3):169–77.

51. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Shamim M, Giacomo K. Development and validation of a tool for non-technical skills evaluation in robotic surgery — the ICARS system. Surg Endosc. 2017;31(12):5403–10.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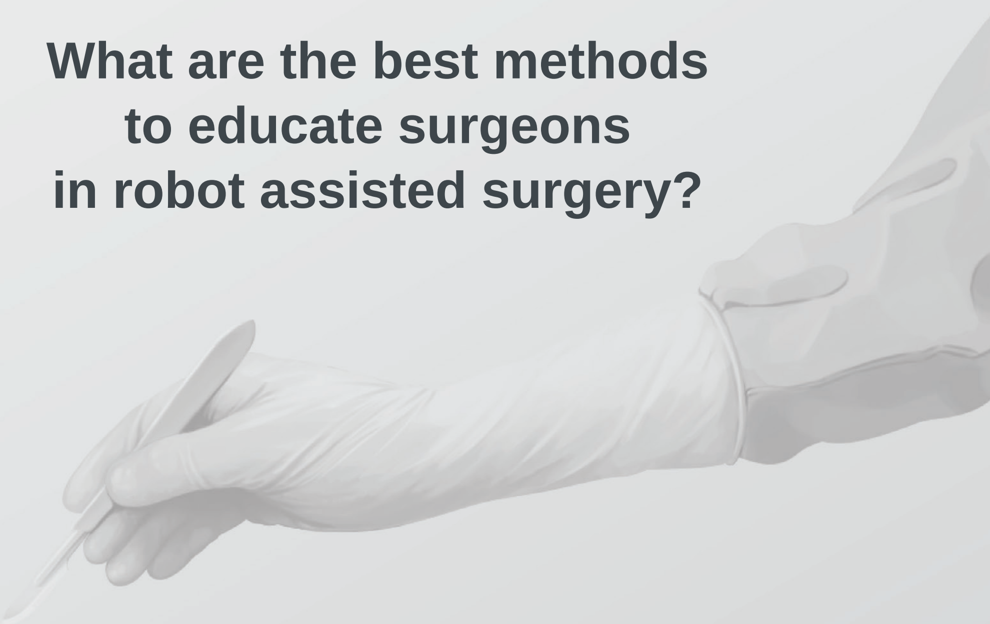
Section I

What are the best methods to educate surgeons in robot assisted surgery?



Chapter 2

The value of a 1-day multidisciplinary robot surgery training for novice robot surgeons

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Abstract

Introduction

To fulfil the need for a basic level of competence in robotic surgery the NIVEL (Netherlands Institute for Healthcare Research) developed the 'Basic proficiency requirements for the safe use of robotic surgery' (BPR). Based on the BPR a 1-day robotic surgery training was organised to answer the following research questions: (1) Are novice robot surgeons able to accurately self-assess their knowledge and dexterity skills? (2) Is it possible to include the teaching of all BPRs in a 1-day training?

Materials and methods

Based on the BPR, a robot surgery course was developed for residents and specialists (surgery, gynaecology and urology). In preparation, the participants completed an online e-module. The 1-day training consisted of a practical part on robot set-up, a theoretical section, and hands-on exercises on virtual reality robot simulators. Multiple online questionnaire was filled out by the participants at the end of the training to evaluate the perceived educational value of the course and to self-assess the degree to which BPRs were reached.

Results

20 participants completed the training during the conference of the Dutch Association for Endoscopic Surgery (NVEC) in 2017. Participants indicated nearly all competency requirements were mastered at the end of the training. The competency requirements not mastered were, however, critical requirements for the safe use of the surgical robot. Skill simulation results show a majority of participants are unable to reach a proficient simulation score in basic skill simulation exercises.

Conclusion

Results show novice robot surgeons are too positive in the self-assessment of their own dexterity skills after a 1-day training. Self-assessment revealed uncertainty of the obtained knowledge level on requirements for the safe use of the surgical robot. Basic courses on robotic training should inform trainees about their results to enhance learning and inform them of their competence levels.

Introduction

Over the past years, much has changed for robot surgeons. Where the first robot surgeons received a short mandatory training in the basics of robotic surgery by the manufacturer, the next generation of robot surgeons has the possible advantage of a supervisor at their hospital to train them in their specific field of robotic surgery. Not all of these new robot surgeons do have access to the manufacturers basic training program since they are not necessarily new consumers of a robotic system. This could result in a gap in the training of residents and fellows since training of the basics of robotic surgery is currently not routinely implemented in their curricula.

In 2010, the Dutch Health Care Inspectorate (IGZ) published a report stating 'insufficient carefulness at the introduction of surgical robots'. In this report, the IGZ expressed its concern regarding robot-assisted laparoscopy. This report stated that in most hospitals, the criteria for novice robot-assisted laparoscopy were either vague or completely lacking.[2,3] The lack of structured training, defined skill-criteria, and a systematic training needs analysis results in a personal training programme developed by the novice surgeons based on their own perceived lack of knowledge.[4,5] This could result in a hiatus of knowledge due to overconfidence biases, an over-assessment of their own skill compared to the objective assessment of skill by an external observer[6].

To clarify criteria for starting robot-assisted surgery, the Netherlands Institute for Health Services Research (NIVEL) developed the 'Basic proficiency requirements for the safe use of robotic surgery (BPR).[7] As it was developed in co-operation with a surgeon, urologist, and a gynaecologist, these requirements transcend each of these individual disciplines and provide a guide to ensure each surgeon using a surgical robot has the required minimum of knowledge and skill to start preforming robot-assisted surgery.[7]

In earlier research, we investigated whether the current specialists think a basic training in robot surgery should be developed to guarantee a basic level of skills for all new robot surgeons.[1] The majority of robot professionals in the Netherlands agree that the basics in robotic surgery should be learned in a structured training program to guarantee the quality of the surgeon and the safety of the patient. Since basic robot training could be similar for the different specialties such as general surgery, gynaecology, and urology a multidisciplinary basic robotic skills training could be a feasible and effective training method. To safeguard the quality the programme can be developed using the proficiency criteria defined by the NIVEL.[1] Although several authors have investigated the development of a basic training in robotic surgery, no actual accepted basic robot surgery training has been implemented yet.[8,9]

In this study, we aim to answer the following research questions (1) Are novice robot surgeons able to accurately self-assess their knowledge and dexterity skills? (2) Is it possible to include the teaching of all BPRs in a 1-day training? We will answer both questions by evaluating the outcomes of a 1-day multidisciplinary robot surgery training.

Methods

Participants

As part of the Dutch Association for Endoscopic Surgery (NVEC) conference of March 2017 in Amsterdam a multidisciplinary robot surgery training was organized. The training was given 1 day before the conference. Specialists and residents from urology, general surgery and gynaecology were invited to participate in the training. A total of 20 participants pre-registered for this training.

Materials

For this training different types of materials were used to instruct the participants. Prior to the training all participants were invited to complete a specific e-learning module (http://www.davincisurgerycommunity.com), to become more familiar with the Intuitive Surgical da Vinci Xi robotic system.

During the training three types of virtual reality simulators (The MIMIC dV-Trainer, Intuitive surgical da Vinci skills simulator, and the 3D Systems RobotiX Mentor) were used to test the participants' dexterity skills on the robot surgery system. An Intuitive Surgical da Vinci Xi system was used during a hands-on draping and docking train-

Questionnaire 1: Pre-training questionnaire, demographic data

1. What is your profession?
A. Specialist
B. residents

2. What is your specialism
A. Surgery
B. Gynecology
C. Urology

3. How much experience do you have with the da Vinci Robot?
A. Assist during surgery and practice on a simulator
B. only assisting during surgery
C. only practice on a simulator
D. surgery on a real patient
E. No experience with the da Vinci Robot

4. How many hours did you practice with the simulator or robot exercises?
A. <10 hours
B. 10-20 hours
C. 20-30 hours
D >30 hours

5. How many hours did you operate on a real patient with the da Vinci Robot?
A. 0 hours
B. 1-10 hours
C. 10-20 hours
E. 20-30 hours
D. >30 hours

ing, and an interactive presentation was given by an experienced (robot)-anaesthetist.

During the training multiple questionnaires were filled out by the participant. An online Pre-training questionnaire on demographics and prior robot surgery or robot surgery simulation experience (questionnaire 1).

An online BPR questionnaire based on the BPRs developed by NIVEL (see "Questionnaire 2"). The questionnaire consisted of 37 questions on the participants self-assessed competence of the basic proficiency requirements. This questionnaire was used to assess if the participants were prone to accurately assess their own dexterity skills compared to the objective assessment of simulator skill (overconfidence bias). The questionnaires were developed by a group of urologists and the overall perceived educational value of the training was examined.

Questionnaire 2: questionnaire on basic requirements based on the basic proficiency requirements for the safe use of robotic surgery as developed by the NIVEL

1. Do you know the advantages and limitations of using the surgical robot?
A. Yes
B. No

2. Do you know how the arms are put in position?
A. Yes
B. No

3. Do you know how the trocars can be connected to the arms?
A. Yes
B. No

4. Do you know the possibilities and degrees of freedom of the arms?
A. Yes
B. No

5. Do you know the functionalities of the tower?
A. Yes
B. No

6. Do you know the functionalities of the robot?
A. Yes
B. No

7. Do you know the functionalities of the console?
A. Yes
B. No

8. Do you know how to solve collisions between the arms of the robot?
A. Yes
B. No

9. Do you know how the check of the poor can be taken over from the console?
A. Yes
B. No

Questionnaire 2: continued
10. Do you know how to act if the instruments do not move / respond properly?
A. Yes
B. No

11. Do you know how the laparoscopic instruments can be inserted correctly under vision?
A. Yes
B. No

12. Do you know why the instruments need to be searched out of vision with the Camera?
A. Yes
B. No

13. Do you know what the various icons on the screen mean?
A. Yes
B. No

14. Do you know how the robot can be safely moved?
A. Yes
B. No

15. Do you know how the robot can be safely connected?
A. Yes
B. No

16. Do you know how all articulating instruments can be checked?
A. Yes
B. No

17. Do you know how the robot is positioned?
A. Yes
B. No

18. Do you know how the robot is docked?
A. Yes
B. No

19. Do you know how instruments can be Placed and exchanged?
A. Yes
B. No

20. Do you know how the number of lives of the instruments can be controlled?
A. Yes
B. No

21. Do you know how you can take into account in advance that the table cannot be moved after docking?
A. Yes
B. No

22. Do you know how to position the patient in a safe way?
A. Yes
B. No

23. Do you know how the patient can be fixed?
A. Yes
B. No

24.Do you know how the face of patients is protected during the procedure?
A. Yes
B. No

Questionnaire 2: continued
25. Do you know how the console can be adjusted in terms of ergonomics?
A. Yes
B. No

26. Do you know how the Camera is operated from the console?
A. Yes
B. No

27. Do you know how the Camera can be moved and zoomed in and out?
A. Yes
B. No

28. Do you know how the instruments can be moved?
A. Yes
B. No

29. Do you know how between arms can be changed?
A. Yes
B. No

30.Do you know how mono-polar and bipolar coagulation can be activated?
A. Yes
B. No

31.Do you know what needs to be discussed with the anesthetist specifically in the area of robot surgery?
A. Yes
B. No

32.Do you know how to give good instructions according to the closed-loop principle (because of the lack of eye contact and the view of the operator on the patient)?
A. Yes
B. No

33.Do you know how to convert in an emergency situation?
A. Yes
B. No

34. Do you know how the robot can be disconnected with the help of an Allen key?
A. Yes
B. No

35.Do you know where the emergency stop of the robot is?
A. Yes
B. No

36.Do you know how pressing the emergency stop can be undone?
A. Yes
B. No

37. Do you know how to deal with power outages?
A. Yes
B. No

Using a third online questionnaire, the perceived educational value questionnaire (see “Questionnaire 3”). All questionnaires were validated using face validity by a panel of experts in the field of surgical robotics.

Questionnaire 3: Questionnaire on educational value of the training
1. If you have to give this training a grade of 1-10? What grade would you give?
2. what could be improved in this training?

During the introduction of the training the participants were informed that all data would be analysed anonymously. Informed consent was given by all participants. Under Dutch law no ethical review is necessary for this type of study.

Procedure

The training consisted of pre-training preparation, a theoretical session, a practical session on the robot set-up and a simulation session on virtual reality simulators (figure 1)

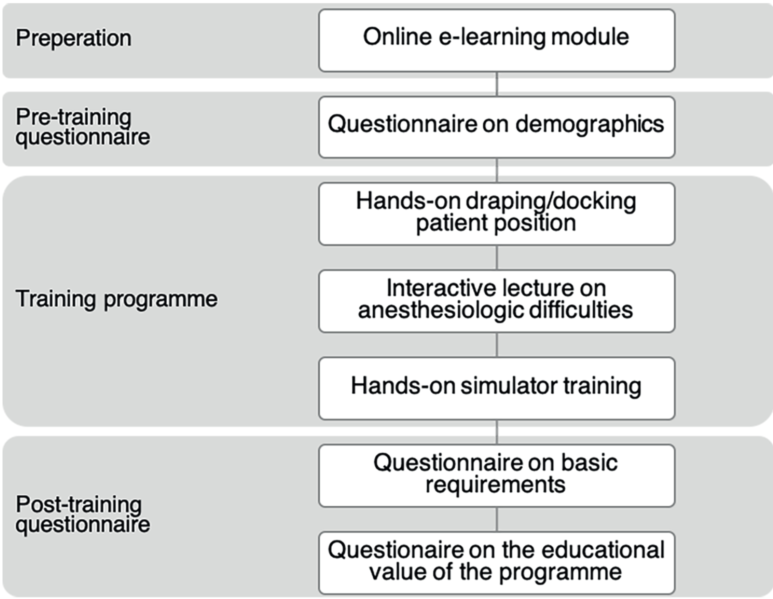

Figure 1 Program flow diagram

Pre-training preparation

The pre-training preparation consisted of an e-learning module (http://www.davincisurgerycommunity.com), and basic skills training at the participants' own hospital. The e-learning helped participants to become familiar with the specific robot platform and took approximately 2 h to complete. Since research shows at least 10 h of basic skills training is needed to become proficient in basic robot surgery skills [10], participants were recommended to do at least 10 h of basic skills training in their own hospital, on both simulator and dry lab facilities if available.

Training

Participants commenced the training by filling out an online Pre-training questionnaire ("Questionnaire 1").

The first part of the training was a hands-on training using the Intuitive Surgical da Vinci Xi system taking 80 min. During this part of the training draping and docking and patient positioning were explained with demonstrations and hands-on training. It covered requirements of the 'BPR' about 'robot functionalities', 'image' and 'preparation[7].

The second part of the training consisted of an interactive presentation was given taking 30 min. This presentation dealt with general safety issues and anaesthetic difficulties, addressed by an (robot)-anaesthesiologist. This part of the training covered requirements of the "BPR"[7] about 'communication', 'emergency situations', 'power supply', and 'preparation'.

The third part of the training consisted of Simulation sessions were organized to test the participants skill in robot assisted procedures and to test requirements of the 'BPR' about console functionality [7] taking 70 min. During this simulation session, multiple exercises were performed. Participants were instructed to do their best at these

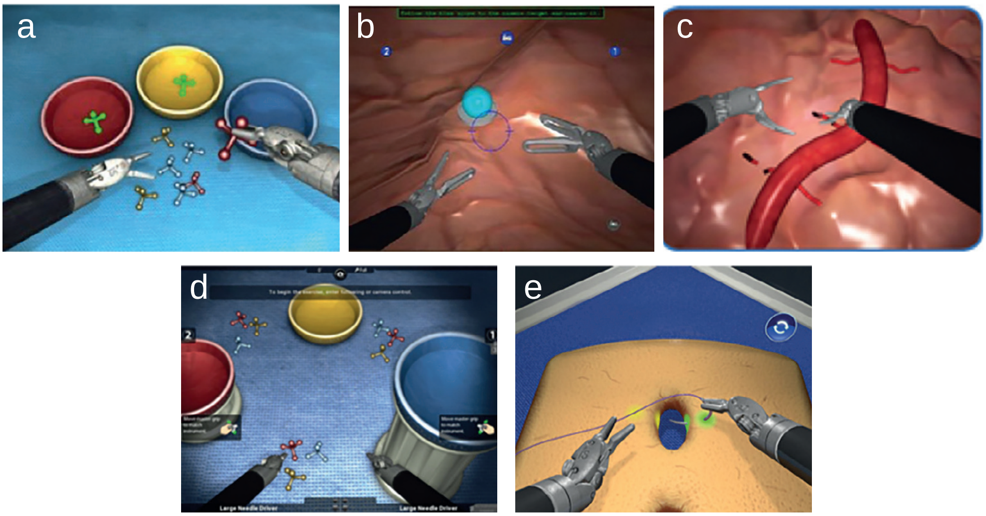

Figure 2. Examples of the simulation exercises; a pick and place exercise, b camera targeting I exercise, c pick and place clutching exercise, d energy and dissection II exercise, e suturing exercise

exercises, they were aware this was not an opportunity for training. To include all essential robotic skills, exercises were selected based on four categories of essential robotic skills (Camera navigation and clutch control, wrist manipulation, needle driving, and suturing) identified at the fundamentals of robotic surgery (FRS) consortium meetings.[8] The following exercises were performed by the participants:

On the MIMIC dV-Trainer:

• Pick and Place exercise (Figure. 2a), this exercise simulates the ability to move the arms of the robot.

• Camera Targeting I exercise (Figure. 2b), this exercise simulates the ability to move the arms and camera of the robot.

• Pick and Place clutching exercise (Figure. 2c), this exercise simulates the ability to move the arms and camera of the robot.

On the Intuitive surgical da Vinci skills simulator

• Energy and Dissection II exercise (Figure. 2d), this exercise simulates the ability to move the arms, the camera of the robot, and to used coagulation of blood vessels.

On the 3D Systems RobotiX Mentor

• Suturing exercise (Figure 2e), this exercise simulates the ability to move the arms and camera of the robot.

All exercises resulted in simulator generated performance scores, which were used to assess the skills of the participant. These scores were based on a multitude of variables, for example, the mastery of the workspace, instrument collisions, economy of motion, and use of excessive force. To determine which of the participants passed the individual exercises the scores of the MIMIC dV-Trainer were analysed by the developer of the simulator.[11]

The threshold scores used are the same as the regular thresholds for the simulation exercises on the MIMIC dV-Trainer system. This means participant passed the exercise if their scores were equal or higher than the median score of data collected from more than 100 experienced surgeons with over 75 robotic cases completed.[11] Each simulator and exercise had its own scale of scores and threshold score to indicate proficient comprehension of the exercise. Participants were kept unaware of their results of the skill simulation exercises. No reference scores were provided for participants for the individual skill simulation exercises.

At the end of the training, the participants were asked to complete an online BPR questionnaire (“Questionnaire 2”) and the perceived educational value questionnaire (“Questionnaire 3”).

Data analysis

Statistical package for the social sciences (SPSS) version 24 was used for the analysis. Non-parametric tests were used to compare the difference in simulation scores from the first and second attempt at the skill simulation exercises to evaluate progress of the participants. Correlations between self-assessment scores and simulation scores were calculated using the bivariate correlation tests giving the Pearson correlation. The alpha level was set at 0.05.

Results

Participants

Of the 20 physicians who participated in the multidisciplinary robot surgery training, fourteen completed the demographics questionnaire ("Questionnaire 1"), the results are shown in Table 1.

Table 1 Participant characteristics

Characteristics	Participants (n=14)
Occupation	
Specialists	5
Residents	9
Discipline	
Urology	2
General Surgery	9
Gynaecology	3
Robot simulation experience	
<10 hours	11
>30 hours	3
Surgical robot experience	
0 hours	6
1-10 hours	6
10-20 hours	1
>30 hours	1

All participants completed the hands-on draping and docking exercises and visited the interactive lecture of the robot anaesthesiologist. There was no significant difference in both simulation and real-life robot experience between residents and specialists. Most participants (11/14) did not complete the suggested 10 h of skill simulator training as preparation of the multidisciplinary robot surgery training.

Table 2 Simulation scores per exercise comparing the median scores of the first and second attempt

Exercise	Attempt, median (min/max)		p-value
	1	2	
Pick and Place	619 (462 – 1125)	NA	NA
Pick and Place clutching	461 (183 – 639)	560 (296 – 688)	0.002
Camera Targeting I	512 (219 – 940)	780 (286 – 939)	0.293
Energy dissection	38 (0 – 65)	67 (22 – 83)	0.001
Suture exercise			
Total time to complete	670 (21 – 1257)	292 (24 – 566)	0.002
Needle drops	16 (0 – 30)	9 (0 – 20)	0.016
accurate needle passes	92 (0 – 100)	95 (0 – 100)	0.449

Simulation test results

All participants had the opportunity to repeat each exercise once to practice the tasks. The results of both attempts (Table 5) were compared in order to evaluate progress (Table 2).

The Pick and Place exercise (performed on the MIMIC dV-Trainer) provides insight in the participants' ability to move the robot arms. This exercise was performed once as a warm up by all participants. Based on the criteria the developer of the simulator set for the exercise 8 (44%) of the participants obtained a passing score (Table 3).

Table 3 Passed results for the MIMIC dV-Trainer simulation exercises

Exercise	Attempt 1, n (%)	Attempt 2, n (%)
Pick and Place		
Pass	8 (44)	NA
Pick and Place clutching		
Pass	0 (0)	0 (0)
Camera Targeting I		
Pass	9 (47)	10 (58)

The Pick and Place clutching exercise (performed on the MIMIC dV-Trainer) provides insight into the participants ability to move the arms of the robot. When comparing the scores of the first and second attempt (Table 2), the second attempt showed a significant improvement in the overall score ($p = 0.002$). Based on the criteria the developer of the simulator set for the exercise, none of the participants obtained a passing simulation score (Table 3).

The Camera Targeting I exercise (performed on the MIMIC dV-Trainer) provides insight into the participant's ability to move the arms of the robot and how the camera is operated. Based on the criteria the developer of the simulator set for the exercise, 9 (47%) participants obtained a passing score on the first attempt and 10 (58%) participants obtained a passing score on the second attempt (Table 4). When comparing the scores of the first and second attempt (Table 2) no significant difference in median simulation scores were found.

The Intuitive surgical da Vinci skills simulator was used to perform the Energy and Dissection II exercise. The Energy and Dissection II exercise provides insight into the participants ability to move the arms, the operation and movement of the camera, and the use of mono-polar and bipolar coagulation. The comparison (Table 2) showed a significant improvement in the overall score for the second attempt ($p = 0.001$).

The suturing exercise (performed on the 3D Systems RobotiX Mentor) provides in-

Table 4 correlation between number of mastered requirements and simulation scores, r = Pearson correlation, # significant correlation ($p<0.05$)

Exercise	Attempt	r (p)
Pick and Place	1	0.35 (0.915)
Pick and Place clutching	1	-0.235 (0.440)
	2	-0.169 (0.582)
Camera Targeting I	1	-0.315 (0.294)
	2	-0.222, (0.512)
Energy dissection	1	-0.587 (0.097)
	2	-0.285 (0.457)
Suture exercise		
Total time to complete	1	-0.707 (0.033)#
	2	-0.007 (0.988)
Needle drops	1	-0.456 (0.217)
	2	-0.397 (0.330)
accurate needle passes	1	0.085 (0.828)
	2	-0.044 (0.918)

sight into the participants ability to move the arms of the robot and the operation and movement of the camera. For this exercise, results from different variables were analysed. These variables included the total time to complete the exercise, the number of needle drops during the exercise, and the percentage of accurate needle passes. The total time to complete the exercise showed a significant decrease in the second attempt (p = 0.002) (Table 2). The number of needle drops showed a significant decrease of needle drops in the second attempt (p = 0.016) (Table 2).

Questionnaire results

The BPR questionnaire ("Questionnaire 2") was based on the 'BPR' developed by the NIVEL [7]. The questions investigated the participants self-assessed competence in each of the basic proficiency requirements at the end of the training. The questions can be divided into 7 categories; 'Robot functionalities', 'image', 'preparation', 'console functionalities', 'communication', 'emergency situations', and 'power supply'.

A majority of the participants (71.4%) reported most requirements (32 of the 37 situations) as mastered (Table 5) The five situations which were reported as not mastered by a large portion of the participants were; how to undo an emergency stop of the robot (not mastered by 75% of the participants), how to act in case of a power failure (not mastered by 62.5% of the participants), how to check all the articulating instruments (not mastered by 56.3% of the participants), the meaning of the different icons on the display (not mastered by 43.8% of the participants), and how to take into account in advance that the table cannot be moved after docking (not mastered by

35.7% of the participants).

All participants responded they mastered the basic proficiency requirements[7] (console functionality) corresponding to the MIMIC dv-Simulator scores. Whilst MIMIC dv-Simulator simulation exercises were performed proficiently by 0%, 44% and 58% of the participants (in order, Pick and place clutching exercise, Pick and Place exercise, and Camera Targeting exercise).

In almost all exercises the correlation between number of mastered requirements and the simulation scores (Table 4) was lacking. The only significant correlation was found in the first attempt of the suture exercise. The total time to complete the exercise was shorter for participants who reported they mastered more requirements.

The perceived educational value of the multidisciplinary robot surgery training was investigated using the perceived educational value questionnaire in “Questionnaire 3”. The participants graded the training with an 8.19 out of 10.

Table 5 Occupation, specialty, simulation experience, and robot surgery experience, number of mastered BPR, and simulation scores per participant # = a proficient overall simulation score. NA =not available

Participant number	Occupation	Specialty	Previous experience on simulator	Previous experience on surgical robot	Number of mastered BPR
1	Specialist	Surgery	< 10 hours	1-10 hours	36
2	Resident	Gynaecology	< 10 hours	1-10 hours	32
3	Resident	Gynaecology	< 10 hours	1-10 hours	34
4	NA	NA	NA	NA	NA
5	Resident	Surgery	< 10 hours	0 hours	26
6	Specialist	Surgery	< 10 hours	1-10 hours	32
7	Resident	Surgery	< 10 hours	0 hours	34
8	NA	NA	NA	NA	29
9	Resident	Urology	> 30 hours	1-10 hours	32
10	Resident	Gynaecology	< 10 hours	1-10 hours	NA
11	Specialist	Surgery	< 10 hours	0 hours	30
12	Specialist	Surgery	< 10 hours	0 hours	20
13	Resident	Surgery	< 10 hours	0 hours	35
14	Resident	Urology	> 30 hours	>30 hours	37
15	Resident	Surgery	> 30 hours	10-20 hours	35
16	NA	NA	NA	NA	NA
17	Specialist	Surgery	<10 hours	0 hours	34
18	NA	NA	NA	NA	NA
19	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA

Table 5 continued

Participant number	MIMIC dV-Trainer					The Intuitive surgical da Vinci skills simulator	
	Pick and Place	Pick and Place clutching Attempt 1	Pick and Place clutching Attempt 2	Camera Targeting I Attempt 1	Camera Targeting I Attempt 2	Energy and Dis-section II Attempt 1	Energy and Dis-section II Attempt 2
1	619	334	391	219	842#	10.8	47.1
2	570	259	573	477	474	10.9	81.9
3	NA	633	654	270	286	63.6	82.2
4	NA	232	396	859#	453	49.5	80.2
5	1121#	461	553	855#	900#	55.5	58.1
6	958#	521	497	846#	897#	44.2	67.3
7	1049#	539	553	394	NA	38.3	74.3
8	NA	NA	NA	NA	NA	64.9	78.5
9	1070#	438	687	881#	924#	31.5	51.6
10	1125#	242	296	468	499	21.3	36.9
11	1081#	639	679	497	873#	NA	NA
12	564	594	636	881#	780#	NA	NA
13	619	422	661	748#	492	0	21.9
14	1011#	557	688	940#	939#	NA	NA
15	614	486	571	886#	NA	NA	NA
16	488	183	453	373	735#	NA	NA
17	948#	517	436	510	484	NA	NA
18	471	367	343	499	454	NA	NA
19	490	343	628	869#	900#	NA	NA
20	462	607	560	512	878#	NA	NA

Table 5 continued

Participant number	3D Systems RobotiX Mentor					
	Total time to complete exercise Attempt 1	Total time to complete exercise Attempt 2	Number of dropped needles Attempt 1	Number of dropped needles Attempt 2	Percentage of accurate needle passages Attempt 1	Percentage of accurate needle passages Attempt 1
1	526	337	11	0	62.5	100
2	900	371	30	13	95	100
3	NA	NA	NA	NA	NA	NA
4	1257	282	27	13	70	81.25
5	NA	NA	NA	NA	NA	NA
6	793	327	16	7	92	100
7	NA	NA	NA	NA	NA	NA
8	686	213	4	12	92	87.5
9	653	204	23	4	100	100
10	NA	NA	NA	NA	NA	NA
11	NA	NA	NA	NA	NA	NA
12	391	302	23	20	90	90
13	594	277	10	5	100	75
14	527	NA	14	NA	100	NA
15	NA	NA	NA	NA	NA	NA
16	21	24	0	0	0	0
17	802	566	18	11	93.7	100
18	861	NA	15	NA	73	NA
19	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA	NA

Discussion

In this study, we aimed to answer the following research questions: (1) Are novice robot surgeons able to accurately estimate their knowledge and dexterity skills after initial training? (2) Is it possible to include the basic proficiency requirements for the safe use of robotic surgery as developed by the NIVEL in a 1 day training? To answer these questions, we analysed the results of a 1-day training programme which included BPR.

To answer if novice robot surgeons are able to accurately estimate their theoretical knowledge and dexterity skills the questionnaire results are compared to the results from the MIMIC dv-Simulator simulation exercises. Although the questionnaire results are based on a self-reported competence judgement by the participants, and not the result of a test or simulation exercise, it illustrates participants feel competent to deal with the provided situations at the end of training. However, this feeling might not be completely justified as the results of the MIMIC dv-Simulator simulation exercises were performed proficiently by 0%, 44% and 58% of the participants. Participants were kept unaware of their skill simulation scores and the corresponding reference scores. Since all participants responded they, in their opinion, mastered the requirements corresponding to these simulation exercises this could be a case of over-assessment of their own skill compared to the objective assessment of this skill (overconfidence biases). This phenomenon has been described in multiple studies.[6,12]

Since the questionnaire about the basic proficiency requirements was not filled out until after the training, and no pre-training-measurement was performed it is difficult to say if this self-reported mastery of the basic proficiency requirements can only be attributed to over-assessment of the participants in their skill alone or if the participants mastery of the simulation exercises is not a valid measurement for the mastery of the basic proficiency requirements developed by the NIVEL. Although face validity of the questionnaire was investigated using a panel of expert in the field of robotic surgery further validation of the questionnaire was not possible since no similar questionnaires exist and the response was too small to perform statistical validation of the questionnaire.

Participant’s theoretical knowledge was not tested during the training. We assume the results of their self-reported evaluation are influenced by the same principle of overconfidence bias. To investigate if this is the case testing of theoretical knowledge has to be integrated in a further implementation of the training.

To answer if it is possible to include the basic proficiency requirements for the safe use of robotic surgery as developed by the NIVEL in one training the results of the questionnaire and skill simulation results were used.

The questionnaire results, based on a self-reported competence judgement by the participants, show that almost all (32/37) requirements for the safe use of the surgical robot are mastered in the opinion of the participants. It is worrying a large proportion of the participants feel they did not master critical requirements for the safe use of the surgical robot (i.e., how to act in case of a power failure and to undo an emergency stop). Although results are based on a small number of respondents, these situations need to be addressed more in further implementation of the training.

Based on the skill simulation results none of the participants were competent in the MIMIC dV-Trainer basic skill simulation exercises after 1 day of training, which could be the result of the lack of skill simulator experience in most participants. Although all participants were instructed to train at least 10 h.[10], a large portion of participants attended the training without prior simulator experience. Participants do show an improvement in the scores of the second repetition of almost all exercises. This could also be the result of the warming up effect after the first attempt at the exercise. To investigate the origin of this improvement in simulation scores, multiple repetitions of the exercise would be required.

Based on the results presented in this article we are unable to asses if participants were proficient in all BPR after the 1-day training programme. We do believe this training covers all important aspects of system training (containing different modality's of training, i.e., hands-on training combined with theoretical information) as indicated by previous research.[14] Although this training was completed by a small group of participants who did not all provided their demographic data and answers to the questionnaires based on the BPR[7], this study gave insights into the further development of a training based on basic proficiency requirements and the use of simulation scores to get more insight in the mastery of the basic proficiency requirements. It remains unclear if, with proper preparation, participants could be proficient in all BPR after the 1-day training programme.

Although all participants did report they mastered the basic proficiency requirements which could be related to the simulation exercises, a majority of participants did not achieve a proficient score in the simulation exercises. To investigate if this discrepancy can be attributed to overconfidence bias or if simulation exercises are a valid measurement for the mastery the BPR[7] further research in larger groups of participants with a more thoroughly validated questionnaire is needed.

Based on our observations we may conclude that objective assessment of knowledge and dexterity skills is mandatory and results should be discussed with the trainees to tailor further training accordingly.

Conclusion

Results show novice robot surgeons are unable to accurately self-assess their obtained dexterity skills. Since theoretical knowledge was not tested it is impossible to conclude if participants are able to adequately asses their theoretical knowledge of the basic proficiency requirements. Further testing of both theoretical knowledge and dexterity skills is advised in further implementation of the training to asses if it is possible to incorporate all BPR in a 1-day multi-disciplinary robot surgery training.

References

1. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, et al. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.
2. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;
3. Khan R, Aydin A, Khan MS, Dasgupta P, Ahmed K. Simulation-based training for prostate surgery. BJU Int [Internet]. 2015 Oct 1 [cited 2018 Mar 27];116(4):665–74. Available from: http://doi.wiley.com/10.1111/bju.12721
4. Kruger J, Dunning D. Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. J Pers Soc Psychol [Internet]. 1999 [cited 2018 Mar 22];77(6):1121–34. Available from: http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.77.6.1121
5. Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX, Sriprasad S. Partial vs.. radical nephrectomy for T1 renal tumours: an analysis from the British Association of Urological Surgeons Nephrectomy Audit. BJU Int [Internet]. 2016 Jan [cited 2017 Jan 7];117(1):62–71. Available from: http://doi.wiley.com/10.1111/bju.13114
6. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers' Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377. Available from: http://www.ncbi.nlm.nih.gov/pubmed/28861015
7. Porte P.J., Verweij L.M., Bekkers R.L.M., Consten E.C.J., Lichtenberg H., van der Poel, H.G., van Swol C.F.P. Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22]; Available from: https://www.nivel.nl/sites/default/files/bestanden/Roboticsurgery_MedicalSpecialists.pdf
8. Smith R, Patel V, Satava R. Fundamentals of robotic surgery: A course of basic robotic surgery skills based upon a 14-society consensus template of outcomes measures and curriculum development. Int J Med Robot Comput Assist Surg [Internet]. 2014 Sep 1 [cited 2017 Aug 17];10(3):379–84. Available from: http://doi.wiley.com/10.1002/rcs.1559
9. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25359658
10. Wiener S, Haddock P, Shichman S, Dorin R. Construction of a Urologic Robotic Surgery Training Curriculum: How Many Simulator Sessions Are Required for Residents to Achieve Proficiency? J Endourol [Internet]. 2015 Nov [cited 2017 Dec 5];29(11):1289–93. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26154108
11. Mimic Technologies Inc. dv Trainer by MIMIC User Guide. Rev 3.5.
12. Krueger J, Mueller RA. Unskilled, unaware, or both? The better-than-average heuristic and statistical regression predict errors in estimates of own performance. J Pers Soc Psychol [Internet]. 2002 Feb [cited 2018 Mar 23];82(2):180–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11831408
13. Perrenot C, Perez M, Tran N, Jehl J-P, Felblinger J, Bresler L, et al. The virtual reality simulator dV-Trainer® is a valid assessment tool for robotic surgical skills. Surg Endosc [Internet]. 2012 Sep 5 [cited 2017 Aug 9];26(9):2587–93. Available from: http://link.springer.com/10.1007/s00464-012-2237-0
14. Schreuder HWR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHM. Training and learning robotic surgery, time for a more structured approach: a systematic review. BJOG [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49. Available from: http://doi.wiley.com/10.1111/j.1471-0528.2011.03139.x

Chapter 3

Training novice robot surgeons: Proctoring provides same results as simulator-generated guidance

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Abstract

Objective

To understand the influence of proctored guidance versus Simulator generated guidance (SGG) on the acquisition dexterity skills in novice surgeons learning RAS (Robot Assisted Surgery).

Design

A Prospective non-blinded 3-arm randomised controlled trial (RTC). Exclusion criteria: previous experience in RAS or robotic surgery simulation. The participants were assigned to three different intervention groups and received a different form of guidance: (1) proctored guidance, (2) Simulator generated guidance, (3) no guidance, during training on virtual reality (VR) simulator. All participants were asked to complete multiple questionnaires. The training was the same in all groups with the exception of the intervention part.

Setting

Catharina Hospital Eindhoven, The Netherlands.

Participants

A total of 70 Dutch medical students, PhD-students, and surgical residents were included in the study. The participants were randomly assigned to one of the three groups.

Results

Overall, all the participants showed a significant improvement in their dexterity skills after the training. There was no significant difference in the improvement of surgical skills between the three different intervention groups. The proctored guidance group reported a higher participant satisfaction compared to the simulator-generated guidance group, which could indicate a higher motivation to continue the training.

Conclusions

This study showed that novice surgeons. Significantly increase their dexterity skills in RAS after a short time of practicing on simulator. The lack of difference in results between the intervention groups could indicate there is a limited impact of “human proctoring” on dexterity skills during surgical simulation training. Since there is no difference between the intervention groups the exposure alone of novice surgeons to the robotic surgery simulator could possibly be sufficient to achieve a significant improvement of dexterity skills during the initial steps of RAS learning.

Introduction

The advent of robotic surgery has dramatically changed the landscape of minimally invasive surgery. The number of robotic procedures performed per year is rapidly increasing all over the world with more and more centres equipping with the robotic technology.[1] For the Da Vinci surgical systems, a basic robotic surgery training with "the introduction to the robotic system" is usually provided by the manufacturer to surgeons starting with robot-assisted surgery (RAS). However, not all the novice robotic surgeons have the access to this basic training programme which could result in a serious gap of knowledge. Moreover, the basic training in robotic surgery is not included standard in most of the resident and fellowship curricula. [2,3]

In 2010, the Dutch Health Care Inspectorate (IGJ) published a report stating 'insufficient carefulness at the introduction of surgical robots. In this report, the IGJ expressed its concern regarding RAS.[2,4] The report stated that in most hospitals, the criteria for the training of novice robot-assisted surgeons were either vague or even completely lacking.[2,3] To clarify criteria for starting robot-assisted surgery, the Netherlands Institute for Health Services Research (NIVEL) developed, in cooperation with urologists, gynaecologists and surgeons, the 'Basic Proficiency Requirements for the safe use of robotic surgery' (BPR).[5] This provides a guide to ensure that all surgeons who are using a surgical robot have a minimum required skills for RAS.

Most of the Dutch urologists agreed that the basics of RAS should be learned in the context of well-defined structured training programmes, in order to guarantee quality and safety to patients and OR-personnel .[6] Therefore, it is crucial that novice surgeons are appropriately trained before operating on patients.[7,8]

Simulation-based education (SBE) has been proven to be an effective method for surgical training. SBE is a teaching method where simulation mimics aspects of clinical care and various real-live scenarios are used for learning purposes. This allows to save the costs of operating rooms occupancy and avoid the risks related to training on patients to avoid patients being exposed to a training situation).[9–12] Simulators have become more sophisticated providing high-fidelity simulation and (video) real-time feedback. The most advanced surgical simulators allow training of advanced surgical skill allowing the performance of complete procedures with a stepwise learning method.[13]

Proctoring is a form of training where an experienced trainer supervises the trainee during the procedure and provides real-time feedback, in order to guide and assist the trainee during the acquisition of new skills. Proctoring is widely used in the operating room to train novice surgeons but is scarcely implemented in simulator based training due to time consumption and related costs.[14–16]

An alternative to human proctoring is the interactive task and procedural guidance by the simulator. Simulator generated guidance (SGG) is an option available on the newest simulation systems. Procedural guidance is provided by the simulator to guide the trainee trough the steps of a surgical procedure using visual cues.17 An advantage of SGG is the possibility to assess the effect of various training curricula on the progress of the surgeon's surgical skills. It remains unclear if the effect of SGG is comparable to proctoring on the learning curve of the novice surgeon.

The main aim of this study was to investigate the influence of individual personalised in-time guidance and feedback (proctored guidance) by an experienced trainer and of interactive task and procedural guidance by the simulator SGG on the development of dexterity skills (the ability to perform RAS) during the vesicourethral anastomosis. Moreover, we assess the satisfaction of the participants during different teaching modalities. Finally, we investigate the effect of general characteristics of the participants on the learning curve of a specific task.

The research questions are: (1) Are novice surgeons able to learn the skills required to perform the vesicourethral anastomosis simulator step of the RARP during a short two-hour training session? (2) What is the influence of individual personalised in-time guidance and feedback (proctoring) by an experienced trainer, or interactive task and procedural guidance by the simulator (SGG) compared to no guidance on the learning curve of novice surgeons who were asked to perform the vesicourethral anastomosis step of the RARP on a robotic surgery simulation system? (3) What is the influence of individual personalised in-time feedback (proctoring) by an experienced trainer, or interactive task and procedural guidance by the simulator (SGG) compared to no guidance on the participant satisfaction of novice surgeons who were asked to perform the vesicourethral anastomosis step of the RARP on a robotic surgery simulation system? (4) Is there a difference in the effect of participant's characteristics (i.e. age, gender, laparoscopic surgery experience, surgical experience in general, etc.) on the learning curve of novice surgeons? These questions will be answered by performing an intervention study amongst medical students, residents and PhD-candidates.

Methods

Participants

In this study, Dutch medical students, PhD-students, and surgical residents were trained at Catharina Hospital in Eindhoven between January and February 2020. Participants were recruited at several medical faculties and hospitals in the Netherlands. Those with previous experience in RAS and robot assisted simulation were excluded from the study. Considering this we assumed that there were no differences in baseline robot-assisted surgical skills among the participants.[19] To each participant a study number was assigned in order to anonymise their data.

Materials

Robot-assisted surgery simulation system

The Robotix Mentor simulation system designed by 3Dsystems was used for the simulation-based training (Figure 1). This surgical simulator allows to train basic robotic skill exercises needed to approach the real surgical consol. Moreover, it allows to train advanced robotic skill exercises including step by step (modular) procedural training. During our training five basic skill exercises were selected because they best reflect the skills needed to perform the vesicourethral anastomosis (Figure 3f).

Figure 1. 3Dsystems Robotix Mentor simulation system.

Two barbed sutures were given to the participant to complete the anastomosis between the bladder neck and the urethral stump. The suturing technique used included a running suture starting at the posterior aspect of the bladder neck. The stitches through the bladder neck were performed in an outside-in, while the stitches through the urethral stump were performed with an inside-out fashion. During the performance of the exercise the trainee received feedback by the simulator regarding the suturing direction, injuries of the structures within the pelvis and excessive force used during suturing. The exercise was finished once the anastomosis was completed.

Simulator-generated guidance

In one of the intervention groups (the SGG group) the guided version of the vesicourethral anastomosis exercise was used (Figure 3g). In this adapted version of the exercise the participant was provided with guidance on the place (position) and depth of the sutures. This was demonstrated by glowing orbs on the tissue. The orbs were yellow when indicating the location of the needle placement, turned green when the needle was placed correctly and turned red in case of incorrect needle placement.

Proctor guided training (Proctoring)

In one of the intervention groups the proctoring was provided directly by the trainer. The two involved trainers were researchers with a broad experience in simulation and training. They have been trained trough several hours of watching surgical videos and performing surgical simulation until reaching proficiency.

No-guidance group

In one of the intervention groups no proctoring or guidance was provided.

Presentation (lecture)

All participants attended a 15-minute presentation (lecture) given by the trainers. During this presentation an overview of the training, the use of the simulator and basic simulation exercises were given. A lesson on pelvic anatomy and vesicourethral anastomosis technique was carried out including a pre-recorded video performed by an expert robotic surgeon (>2100 RARPs). Furthermore, an instructional video of the simulator's manufacturer showing the simulated vesicourethral anastomosis was included.

Questionnaires

During the training, the participants were asked to complete multiple questionnaires. The Baseline questionnaire included the general characteristics and surgical experience of the participants. Personal information consisted of age, gender, faculty of medical training, and hospital of employment/training. Information about surgical

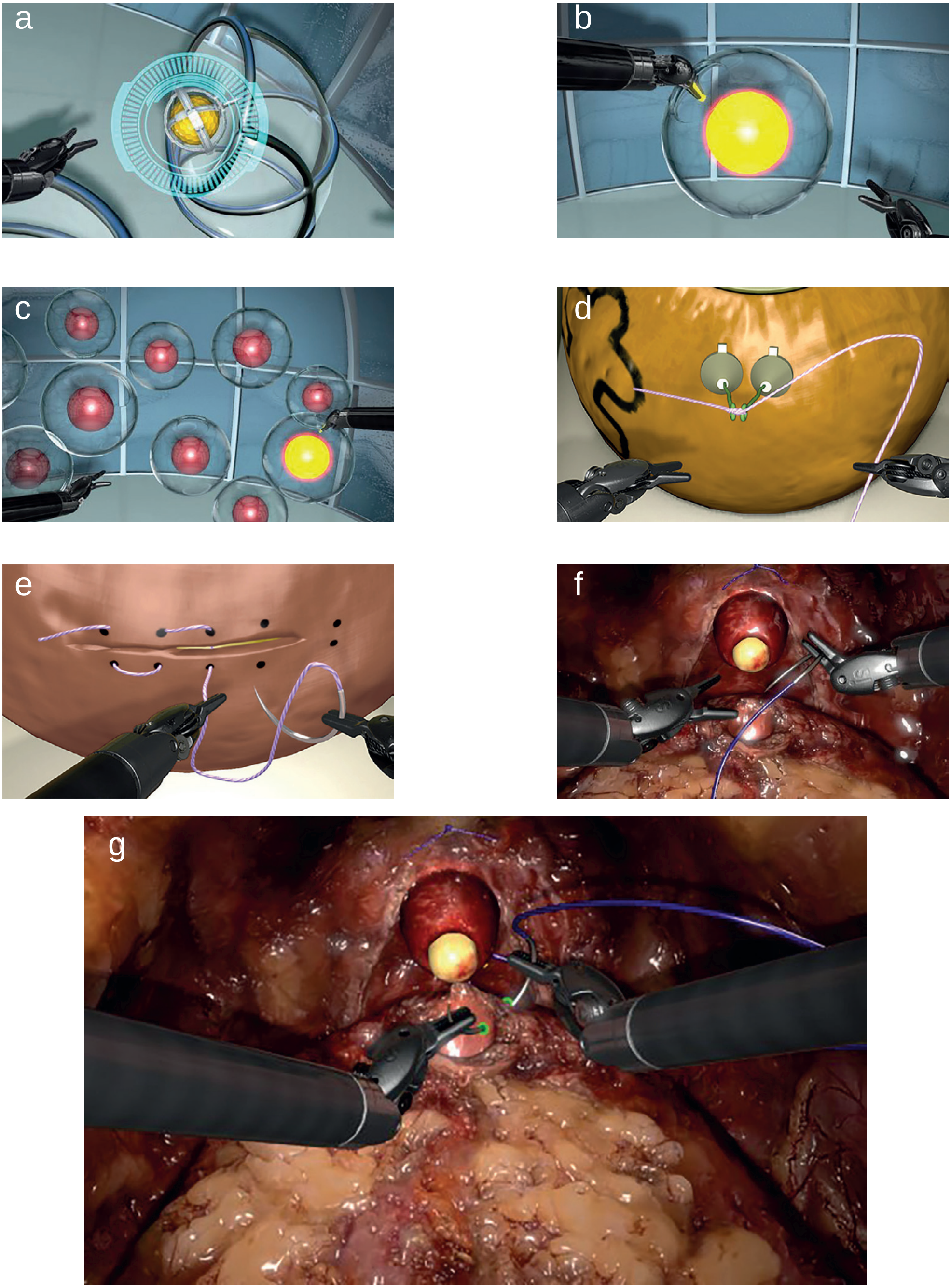

Figure 2. Examples of the simulation exercises; A) Camera 0, B) Wristed Manipulation 1, C) Wristed Manipulation 2, D) Knot Tying, E) Railroad track, F) Freehand vesico-urethral anastomosis, G) Guided vesico-urethral anastomosis with the guidance dots (green) around the needle.

experience consisted of completion of surgical rotation, experience with laparoscopy, and experience with RAS.

The Participant satisfaction questionnaire was used to have a feedback and ensure a high quality of the training programme. The Kirkpatrick's (KP) model was used to assess participant's satisfaction and it was filled at the end of the training by all the participants.

Informed consent

Although participants were not subjected to any study actions, the Medical Ethics Committee deemed the Medical Research Involving Human Subjects Act did not apply since no physically and psychological invasive interventions were performed. Informed consent was obtained from all participants and the study was granted approval from the institutional medical committee.

Procedure

Design

This prospective non-blinded 3-arm randomised controlled trial investigated different methods of teaching RAS using simulation. After a basic skill and an un-guided procedural simulator training the participants were randomly divided into three different intervention groups (proctored guided, simulator-generated guidance and no guided). During this phase the participants received a different training and at the end were asked to perform again the same task (vesicourethral anastomosis) autonomously. All parts of the training were the same for all the trainees with the exception of the intervention phase. During the training all participants were asked to complete multiple questionnaires.

Training program

The training program is displayed in figure 2. The training was given in timeslots of three hours and a maximum two participants per timeslot were included. A minimum of one trainer was present during the training. The proctor guided group received individual guidance by one of the two trainers.

All the participants started with the completion of the baseline questionnaire and with the signature of the consent form.

The randomization was performed using a simple randomization, prior to the start of the study a sequence of 72 random numbers ranging 1-3 was created using www.randomizer.org. The numbers in this sequence automatically received a place marker (1-72), this place marker corresponded to a study number (1-72). The study numbers were assigned to the participants in numerical sequence once the participant com-

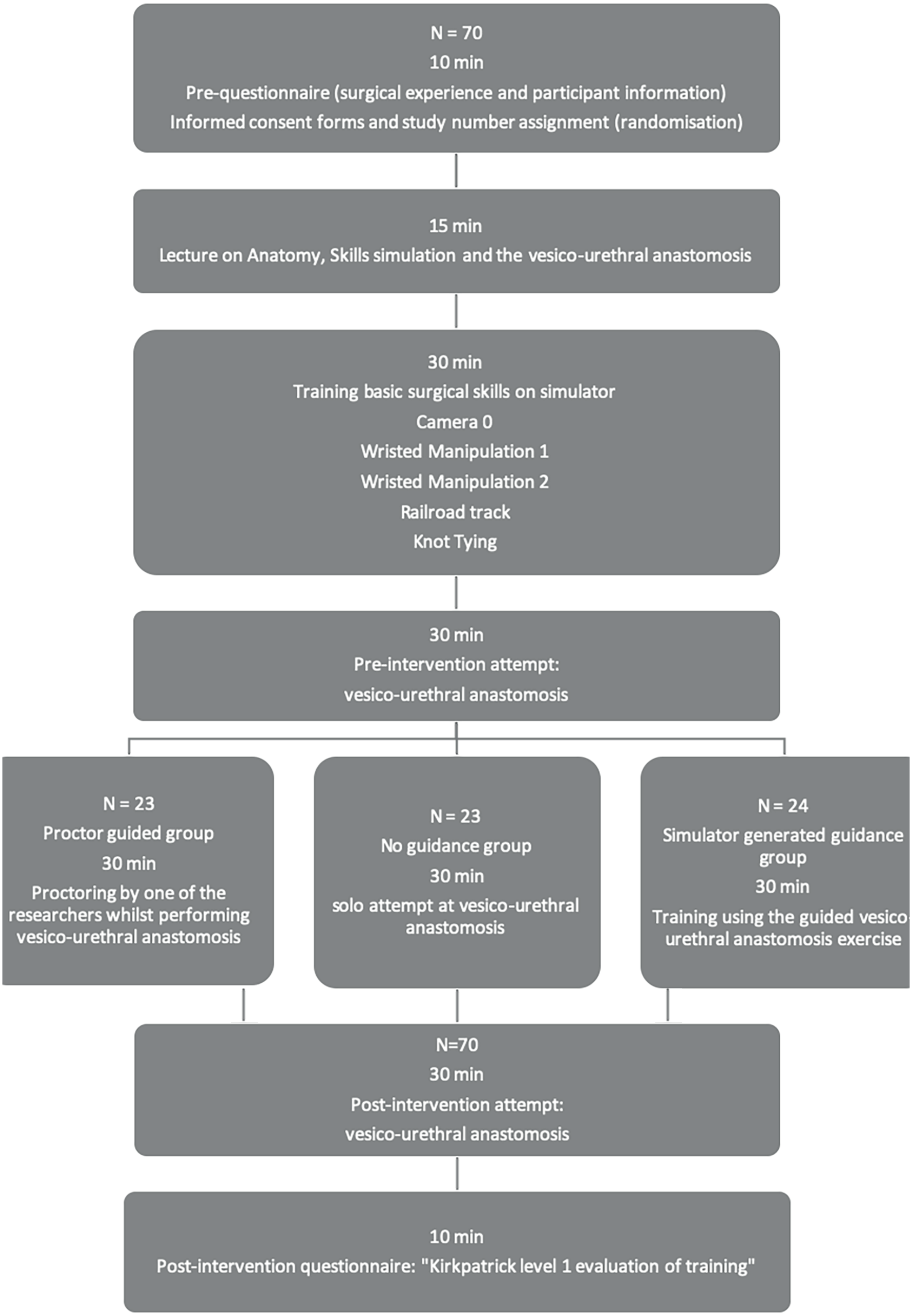

Figure 3. Study design.

pleted their informed consent form.

After this the participants attended the presentation (lecture) on the simulator, the simulation exercises and the anatomy of the pelvic region.

The participants had 30 minutes for the basic simulation training and the following exercises were practiced during this time at least once per person:

- Camera 0 (figure 3A): camera control training
- Wristed manipulation 1 (figure 3B): Endowrist manipulation training
- Wristed manipulation 2 (figure 3C): camera control and Endowrist manipulation training
- Knot tying (figure 3D): surgical knot tying training
- Railroad track (figure 3E): suturing training

After completing these exercises, the participants were asked to train autonomously the vesicourethral anastomosis exercise on the simulator for 30 minutes (pre-intervention phase) (figure 3f). During this phase no additional explanation was provided by the trainers and after 30 minutes the training was interrupted also in the case of non-completion of the exercise.

After this initial attempt all groups received a total of 30 minutes to train on the vesicourethral anastomosis exercise under different or no guidance according to the assigned group. In all cases, the participants received the standard automated feedback from the simulator.

The first group was the proctor guided group, this group performed the vesicourethral anastomosis exercise under the guidance of a trainer (proctor) (figure 3F). The proctor provided the participants guidance by monitoring the real-life progress of the participants on a nearby screen and gave in-time oral feedback during the procedure. Tips and tricks were provided by the proctor on how to avoid tissue damage and how to safely perform the surgical steps.

The second group is the simulator-generated guidance group, this group performed the vesicourethral anastomosis exercise under the guidance of the simulator (figure 3G). The simulator provided them with pre-programmed guided feedback which mainly helped participants with correct needle placement and the use of appropriate force during stitching and tissue handling. Guidance was automatically disabled when the participant repeatedly ignored the simulator’s guidance. In this case the participants had to complete the procedure without guidance. The participants were informed about this feature by the researchers at the start of the training.

The third group was the no-guidance group, this group was asked to train the vesicourethral anastomosis exercise (figure 3F) for 30 minutes without guidance. The participants did not receive any guidance, both from the proctor and the simulator

After the intervention, all groups were asked to perform the vesicourethral anastomosis exercise again for 30 minutes without any additional proctoring or guidance by the simulator (post-intervention phase). Finally, the participants were asked to complete the questionnaire on the participant's satisfaction and then the training was completed.

Threshold scores for the vesicourethral anastomosis simulation exercise.

In a recent publication by Harrison et al. threshold scores are published in order to pass the vesicourethral anastomosis simulation exercise.[13] These scores are represented in tables 3 and 4. These threshold scores are based on the mean scores of the experts included in the study by Harrison et al.[13] The results of our study will be compared to these threshold scores in order to investigate if any of our participants are able to pass the vesicourethral anastomosis simulation exercise according to these standards. Additional analysis will be performed to investigate if baseline characteristics of the participants influence the likeliness of the participant reaching the threshold scores.

Sample size analysis

The sample size analysis was based on a publication of Shim et-al.[3] Their results showed that it is possible to detect a difference in populations means of 66 seconds on the mean time for completing the task. The time of the procedure is one of the threshold scores as set by Harrison et al.[13] Using the program PS: Power and Sample Size Calculation version 3.1.6, a sample size calculation was performed. Using 0.05 as Alpha, a Power of 0.80, and an effect size of 66, a sample size of 23 patients per subgroup would be sufficient for this study.

Data analysis

Data analysis was performed using SPSS statistics v24 (IBM, NY). Frequency statistics were used to present categorical variables. Statistical significance in differences in categorical variables were calculated using the Pearson Chi-square test, in case of small numbers the Fisher exact test was used. Statistical significance in differences in case of continuous variables were calculated using a one-way ANOVA test, in case of in-homogeneity of variance the Brown – Forsythe test was used. Significance in difference between the three groups were calculated using the Turkey HSD test, in case of in-homogeneity of variance the Games-Howell Post-Hoc Test was used. The Wilcoxon signed-rank test (in case of non-normal distributed data) or a two-sided t-test for paired samples (in case of normal distributed data) was used to compare differences in results between the pre-intervention and post-intervention simulation scores. Linear regression analysis was performed in order to identify factors influencing simulation scores. Statistical significance was set at $p < 0.05$ based on a two-tailed comparison. Due to the level of multiple comparisons a Benjamini-Hochberg procedure was performed critical value for a false discovery rate of 0.20.

Results

A total of 70 participants were included in the study. The post intervention data of three partici-pants were lost due to a malfunction of the software (two from the non-guidance group and one from the SGG group). In some variables data of par-ticipants were missing in either pre- or post-intervention results (appendix 2), these missing data points were evenly distributed among the groups.

The baseline characteristics of the participants are displayed in Table 1. There was no differ-ence in RAS experience between the groups (22 vs 23 vs 22, p=1). The majority of the participants were female reflecting the growing number of female med-ical students and young physicians in the Netherlands (48 vs 29 p=0.148). Most of the participants were medical students (n=49), followed by PhD candidates (n=13) and residents (n=5). There were no PhD candidates in the no guidance group (0 vs 8 and 5, p=0,005), while most of the medical students were randomly assigned to the no guid-ance group (22 vs 13 and 14, p=0,005). In the simulation trained group more participants had pre-vious laparoscopic surgery experience compared to the remain-ing groups (15 vs 6 and 6, p=0,004).

Pre-intervention vesicourethral anastomosis simulation exercise scores.

The results of the pre-intervention vesicourethral anastomosis simulation exercise showed an overall difference between the three groups in the number of times the tis-sue was grasped (p=0,018) and in the number of unnecessary needle piercing points (p=0,021) (figure 4a, 4b). However, no statistical significative differences were found

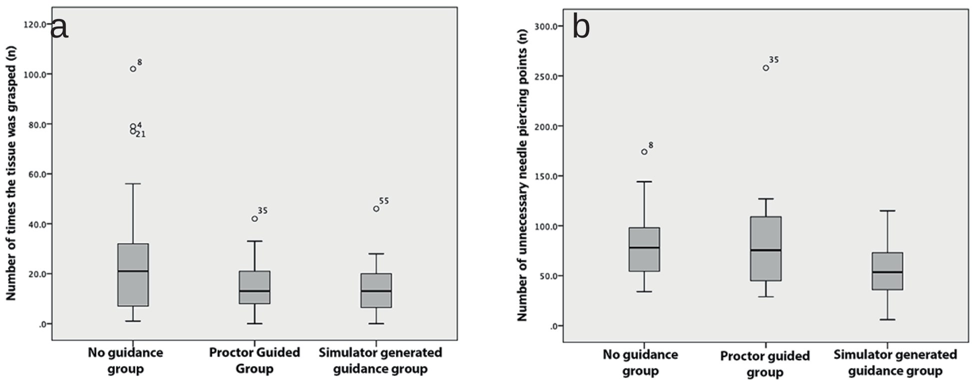

Figure 4: Box and Whisker plots show significant differences in the pre-intervention simulation scores between the study groups. A) number of times the tissue was grasped (p=0,018), B) number of un-necessary needle piercing points (0,021).

Table 1. Participants' baseline characteristics

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs… Proctor guided group	P-value Non-No guidance group vs… Simulator generated guidance group	P-value Proctor guided group vs… Simulator generated guidance group
Gender, n										
Male	9	8	3	-	-	-	0.148#	-	-	-
Female	14	15	19							
Occupation, n										
Medical Student	22	13	14	-	-	-	0.005*	-	-	-
Resident	1	1	3							
PhD Candidate	0	8	5							
Age, median (IQR)	21 (19-25)	26 (24-28)	25 (23-28)	9.194@	2@	65@	<0.0001@	<0.0001^	0.004^	0.789^
Laparoscopic surgery experience, n										
No	17	17	7	-	-	-	0.004#	-	-	-
Yes	6	6	15							
RAS experience, n										
No	22	23	22	-	-	-	1.000*	-	-	-
Yes	1	0	0							
Completed surgical internship, n										
No	15	6	2	-	-	-	0.004#	-	-	-
Yes	7	7	13							

*Fishers exact # Pearson Chi-square @One-way Anova, ^Turkey HSD, DF1 = degrees of freedom between groups, DF 2 = degrees of freedom within groups, n = number

between the groups during an in-depth analysis. (Appendix 1).

Difference in pre-intervention and post-intervention vesicourethral anastomosis simulation exercise scores

There were no statistically significant differences in the improvement in surgical skills between the three different intervention groups (Table 2). When comparing the overall scores results of the pre- and post-intervention simulation no significant differences were found in the number of metrics among participants (Appendix 2). There was a significative decrease in number of injuries to the urethra (p=0,0017) (Figure 5a) and wound separation (p<0,001) in the post-intervention simulation exercise (Figure 5a and 5b). Fewer episodes of improper suturing technique (p=0,002) and a lower number of unnecessary needle piercing points (p=0,003) were found in the post-intervention exer-cises (Figure 5c and 5d). Interestingly, there was an increase in the total number of entrance and exit points of the in the post-intervention exercises (p=0,005) (Figure 5c).

A comparison of the pre- and post-intervention simulation scores for each of the interven-tion groups showed significant differences in multiple metrics among the groups (Appendix 3). Among all intervention groups a significant decrease in wound separation was found (p=0,001, 0,009 and 0,002) and this decrease was the highest

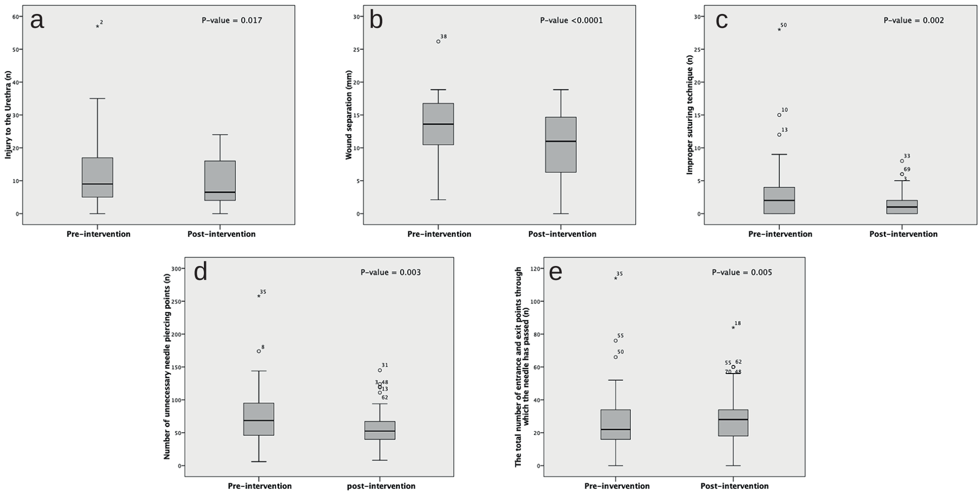

Figure 5: Box and Whisker plot representing the metrics which showed significant differences when comparing the results of the pre-intervention to the post-intervention overall simulation scores A) number of injuries to the urethra (p=0,017), B) wound separation (p<0,001), C) improper suturing technique (p=0,002), D) number of unnecessary needle piercing points (p=0,003), E) increase in the total number of entrance and exit points through which the needle has passed (p=0,005).

in the non-intervention group (Figures 6a-6c). A significant decrease in clutch usage (p=0,003), number of times the tissue was grasped (p=0,015) and the number of movements of the right-instrument (p=0,011) was observed in the no guidance group (Figures 6d-6f). The proctor guided group showed a significative drop in the number of inju-ries to both the urethra (p=0,017) and the bladder neck (p=0,016) (Figure 6g-6h). This group also showed a lower number of unnecessary needle piercing points after the intervention (p=0,017) (Figure 6l).

Table 2. Difference between pre- and post-intervention vesicourethral anastomosis simulation exercise scores in the study groups.

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Time and Economy										
Total time (sec)	242.9 (486.9)	-24.9 (503.4)	12.5 (355.9)	0.749@	2@	63@	.477@	.445^	.845^	.771^
Number of movements - left instrument (n)	68.0 (499)	27.5 (426)	-20.0 (332)	0.580@	2@	63@	.563@	.544^	.751^	.935^
Number of movements - right instrument (n)	188.0 (542)	-42.0 (537)	-47.0 (286)	1.079@	2@	63@	.346@	.318^	.637^	.836^
Path length - left instrument (mm)	1232.3 (6042)	-290.8 (4684)	-1249.0 (3198)	0.245@	2@	63@	.783@	.800^	.833^	.997^
Path length - right instrument (mm)	985.9 (5569)	1599.9 (5980)	-849.1 (3547)	0.661@	2@	63@	.520@	.647^	.529^	.982^
Distance by camera (mm)	157.9 (1159)	-14.7 (1622)	1.1 (954)	0.665@	2@	63@	.518@	.568^	.998^	.594^
Instrument collisions (n)	13.0 (77)	16.0 (63)	-8.0 (84)	0.760@	2@	63@	.472@	.475^	.620^	.966^
Total path of instruments traveled out of view (mm)	190.3 (1948)	113.0 (1995)	-299.8 (1537)	0.378@	2@	63@	.687@	.662^	.912^	.883^

Table 2. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Number of times instruments are out of view (n)	-3.0 (55)	-1.0 (77)	-12.0 (53)	1.362@	2@	63@	.264@	.280^	.956^	.409^
Total time instruments are out of view (seconds)	4.7 (125.1)	-49.0 (207.9)	-21.0 (156.9)	0.600@	2@	63@	.552@	.611^	1.00^	.613^
Clutch usage (n)	7.0 (12)	0.0 (11)	0.0 (15)	2.240@	2@	63@	.115@	.103^	.752^	.350^
Safety and Complications										
Injury to the Urethra (n)	3.0 (13)	4.0 (10)	2.0 (9)	1.252@	2@	63@	.293@	.332^	.986^	.399^
Injury to Bladder Neck (n)	0.0 (3)	0.5 (5)	-1.0 (6)	2.180*	2*	20.0*	.145*	.342$	.320$	.053$
Suspected injury to the Bladder (n)	0.0 (1)	0.0 (0)	0.0 (0)	1.570*	2*	15.3*	.252*	.462$	.444$	.964$
Suspected injury to the Neurovascular Bundle (n)	0.0 (1)	0.0 (2)	0.0 (1)	0.791@	2@	54@	.459@	.758^	.426^	.819^
Suspected injury to the Ureteral Orifices (n)	0.0 (1)	0.0 (1)	0.0 (2)	0.182@	2@	57@	.834@	.930^	.819^	.966^

Table 2. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)	1.5 (7)	0.0 (9)	2.0 (10)	0.439@	2@	58@	.647@	.623^	.889^	.861^
Wound separation (mm)	5.2 (7.9)	3.1 (6.3)	3.1 (6.3)	1.706@	2@	63@	.190@	.289^	.219^	987^
Improper suturing technique (n)	0.0 (4)	1.0 (4)	0.0 (2)	0.901@	2@	55@	.412@	.413^	.907^	.609^
Needle handling										
Percentage of stitches within optimal depth (%)	-1.1 (44.4)	-3.0 (50.0)	-14.6 (37.5)	1.338@	2@	63@	.270@	.997^	.329^	.358^
Number of unnecessary needle piercing points (n)	18.0 (51)	29.5 (75)	8.0 (38)	0526@	2@	63@	.594@	.941^	.789^	.576^
The total number of entrance and exit points through which the needle has passed (n)	-2.0 (15)	-6.0 (15)	-4.0 (16)	0.163@	2@	63@	.850@	.852^	.992^	.903^

Table 2. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Suture handling										
Excessive force - Suture breakage (n)	0.0 (1)	0.0 (0)	0.0 (0)	0.922@	2@	63@	.403@	.823^	.742^	.371^
Tissue handling										
Number of times the tissue was grasped (n)	3.0 (18)	6.5 (16)	-2.0 (14)	3.000@	2@	63@	.057@	.795^	.055^	.204^

@One-way Anova, ^Turkey HSD *Brown – Forsythe test, $ Games-Howell Post-Hoc Test, DF1 = degrees of freedom between groups, DF 2 = degrees of freedom within groups, n = number, mm= millimeters

Threshold scores achievement during vesicourethral anastomosis simulation exer-cise.

Pre-intervention

The results in Table 3 shows no significant differences in the number of participants among the dif-ferent study groups who achieved the threshold scores for the vesi-courethral anastomosis simula-tion exercise. None of the participants achieved all criteria set by Harrison et al. The highest num-ber of achieved threshold scores were in the number of movements of the right instrument (68,6%), number of unnecessary needle piercing points (54,3%), total time the out of view instru-ments (52,8%) , and path length of the right instrument (50%). None of the participants reached the wound separation and total time threshold scores.

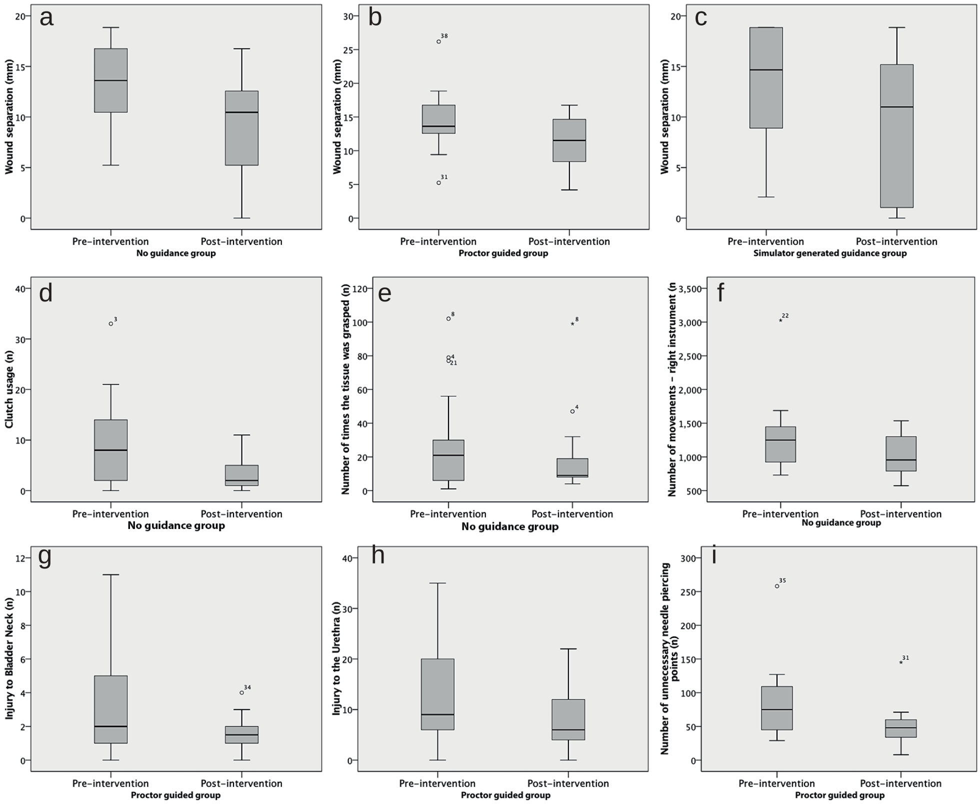

Figure 6: Box and whisker plot representing the metrics which showed significant differences when comparing the results of the pre-intervention to the post-intervention simulation scores for each intervention group. A-C) wound separation in all intervention groups (p=0,001, 0,009 and 0,002), D-F) clutch usage (p=0,003), number of times the tissue was grasped (p=0,015) and number of movements of the right instrument (p=0,011) in the non-intervention group, G-I) number of injuries to the bladder neck (p=0,017), number of injuries to the urethra (p=0,016) and number of unnecessary needle piercing points (0,017) in the proctor guided group.

Post-intervention

The results in Table 4 shows no significant differences in the number of participants that achieved the threshold scores for the vesicourethral anastomosis simulation exercise. None of the partici-pants reached all criteria set by Harrison et. al.13 The highest number of achieved threshold scores were found in the right-handed instru-ment (72,8%), number of unnecessary needle piercing points (80%), and path length of the right-handed instrument (58,6%) . After the intervention some partic-ipants were able to reach the minimum scores according to criteria in the wound separa-tion but rates were similar for all intervention groups (10%). None of the participants achieved the total time threshold scores.

Table 3 Pre-intervention threshold scores achievement during vesico-urethral anastomosis simulation exercise among the groups.[19]

Variable	Criteria	No guidance group Passed criteria, n (%)	Proctor guided group Passed criteria, n (%)	Simulator generated guidance group Passed criteria, n (%)	p-value
Number of unnecessary needle piercing points	<=74	9 (39.1)	12 (54.5)	17 (70.8)	0.092#
Total time	<= 1158 [sec]	0	0	0	n.a.
Instrument collision	<= 30	4 (17.4)	4 (18.2)	4 (16.7)	0.991#
Total time instruments are out of view	<= 120 [sec]	14 (60.9)	13 (59.1)	10 (41.7)	0.345#
Number of movements right instrument	<= 1321 movements	15 (65.2)	15 (68.2)	18 (75.0)	0.756#
Path length right instrument	<= 11428 [mm]	11 (47.8)	10 (45.5)	14 (58.3)	0.644#
Wound separation	<= 1 [mm]	0	0	0	n.a.
Passed all criteria *		0	0	0	n.a.

Pearson Chi-square* excluding total time since all participants were required to practice a total time of 30 minutes at the console

Factors predicting the achievement of threshold scores during the vesicourethral anastomosis simu-lation

Table 5 shows the results of the univariate analysis of factors that could have influenced the gain in surgical skills among all participants. None of the included variables had a significant impact on achievement of the threshold scores during the vesicourethral anastomosis simulation among the participants.

Participant satisfaction

The results of the participant's satisfaction of the training are shown in Table 6. The participants in the no guidance group found the first attempt at the vesicourethral anastomosis more useful com-pared to the participants in the SGG group, while, the satisfaction of this part of the training of the proctor guided group did not differ significantly from the other two groups (Appendix 3). The proc-tor guided group found the intervention more useful compared to both the non-intervention group and the simulation trained group. The results showed the proctor guided group indicated they felt more as if they were really performing the surgical step compared to the non-intervention group. The proctor guided group found the training more appropriate for the current learning goals and felt more that there were enough trainers for the training compared to the non-intervention group. The overall scores and participant satisfaction were significantly higher in the proctor guided group compared to the simulator trained group. The results show there is a statistically significant difference in the responses of the participants to the question: 'The trainers had enough experience in medical aspects' but when comparing the groups separately no significant differences were found.

Table 4 Post-intervention threshold scores achievement during vesico-urethral anastomosis simulation exercise among the groups[19]

Variable	Criteria	No guidance group Passed criteria, n (%)	Proctor guided group Passed criteria, n (%)	Simulator generated guidance group Passed criteria, n (%)	p-value
Number of unnecessary needle piercing points	<=74	18 (78.3)	19 (86.4)	19 (79.2)	0.749#
Total time	<= 1158 [sec]	0	0	0	n.a.
Instrument collision	<= 30	3 (13.0)	3 (13.6)	1 (4.2)	0.485#
Total time instruments are out of view	<= 120 [sec]	10 (43.5)	8 (36.4)	9 (37.5)	0.869#
Number of movements right instrument	<= 1321 movements	18 (78.3)	18 (81.8)	15 (62.5)	0.278#
Path length right instrument	<= 11428 [mm]	17 (73.9)	12 (54.5)	12 (50.0)	0.212#
Wound separation	<= 1 [mm]	1 (4.3)	2 (9.1)	4 (16.7)	0.369#
Passed all criteria*		0	0	0	n.a.

Pearson Chi-square* excluding total time since all participants were required to practice a total time of 30 minutes at the console

Table 5. Factors predicting the achievement of the threshold scores during the vesicourethral anastomosis simulation exercise.19

Variable	Age of the participant			Laparoscopic Experience (Yes)		
	OR	95% C.I. for OR	P-value	OR	95% C.I. for OR	P-value
Total time (seconds)	-.143	-134.900 – 37.179	.261	.122	-33.034 – 813.114	.378
Number of movements - right instrument (n)	-.145	-86.558 – 23.235	.253	.067	-265.289 – 456.390	.598
Path length - right instrument (mm)	-.147	-902.242 – 234.564	.245	.037	-3203.634 – 4283.458	.774
Instrument collisions (n)	-.104	-6.686 – 2.789	.414	.079	-21.336 – 40.571	0.537
Total time instruments are out of view (seconds)	-.063	-21.987 – 13.257	.622	.054	-90.596 – 139.264	.674
Wound separation (mm)	-.016	-.402 - .354	.900	.286	.418 – 5.138	.022
Number of unnecessary needle piercing points (n)	-.034	-4.161 - 3.190	.793	.025	-21.606 – 26.323	.845

Table 5. continued

Variable	Gender (Female)			Completed surgical internship (Yes)		
	OR	95% C.I. for OR	P-value	OR	95% C.I. for OR	P-value
Total time (seconds)	.071	-437.786 – 777.4017	.578	-.278	-917.267 – 16.438	.058
Number of movements - right instrument (n)	.091	-247.543 – 526.752	.474	-.240	-599.745 – 58.738	.105
Path length - right instrument (mm)	.101	-2403.694 – 5608.870	.427	-.280	-7323.033 – 102.255	.056
Instrument collisions (n)	.009	-32.198 – 34.553	.944	-.011	-35.733 – 33.202	.941
Total time instruments are out of view (seconds)	.098	-75.229 – 171.021	.440	-.217	-217.911 – 32.523	.143
Wound separation (mm)	-.181	-4.487 - .721	.153	.048	-2.376 – 3.283	.749
Number of unnecessary needle piercing points (n)	.043	-21.389 – 30.102	.736	-.053	-28.325 – 19.831	.724

Table 6. Results of the participant satisfaction questionnaire.

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Participant satisfaction										
The presentation about the project was useful	4 (0)	4 (1)	4 (0)	1.241@	2@	67@	.296@	.565^	.863^	.274^
The demonstration by the master trainers was useful	4 (5)	4 (1)	4 (0)	1.874*	2*	60.660*	.162*	.158$	.765$	.385$
The basic simulation exercises were useful	5 (1)	5 (1)	5 (1)	.791@	2@	67@	.457@	.570^	.485^	.991^
The first attempt at the vesicourethral anastomosis was useful	4 (1)	4 (2)	4 (3)	4.168*	2*	52.229*	.021*	.157$	.028$	.426$
The intervention was useful	4 (2)	5 (1)	4 (2)	7.311*	2*	41.126*	.002*	.004$	.172$	.048$
The questionnaire on the basic proficiency requirements for the safe use of robotic surgery was usefull	3 (1)	3 (2)	3 (0)	1.925*	2*	45.847*	.158*	.204^	.685^	.321^

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
The learning goals were clear	4 (0)	4 (1)	4 (1)	1.252@	2@	67@	.293@	.355^	.999^	.367^
The interven-tion will help decreasing the learning curve	4 (1)	4 (2)	4 (1)	.516@	2@	67@	.599@	.570^	.852^	.878^
Materials										
The presenta-tions helped me to learn how to teach the simulated scenarios	4 (1)	4 (0)	4 (1)	.685*	2*	57.336*	.508*	.380$	.920$	.742$
The simulator is a good tool to teach RARP methods	4 (1)	4.5 (1)	4 (1)	.390@	2@	64@	.678@	.982^	.789^	.680^
I understood the possibilities of the simulator before training the scenarios	3 (2)	3 (1)	3 (2)	1.524@	2@	67@	.225@	.319^	.266^	.995^

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs… Proctor guided group	P-value Non-No guidance group vs… Simulator generated guidance group	P-value Proctor guided group vs… Simulator generated guidance group
The simulator is too complicated to use	2 (0)	2 (1)	2 (1)	.133@	2@	67@	.876@	.895^	.897^	1.00^
The simulation exercises were realistic	4 (1)	4 (0)	4 (0)	1.073@	2@	67@	.348@	.603^	.887^	.327^
I felt engaged during the simulation exercises	4 (1)	4 (1)	4 (0)	.507@	2@	67@	.604@	1.00^	.661^	.661^
The simulation exercises were comparable with real clinical scenarios	3 (2)	4 (1)	4 (1)	1.705@	2@	67@	.190@	.320^	.206^	.966^
I performed as if I was really performing the surgical step	3 (2)	4 (2)	4 (1)	6.209@	2@	67@	.003@	.002	.242^	.138^
Learning (goals)										
The learning goals were clear at the beginning of the day	4 (1)	4 (1)	4 (1)	4.626@	2@	66@	.013@	.013^	.766^	.070^

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
The training is appropriate for the current learning goals	4 (1)	4 (1)	4 (1)	3.367@	2@	66@	.041@	.031^	.447^	.339^
The course was challenging enough	5 (1)	5 (0)	5 (1)	.979@	2@	66@	.381@	.858^	.667^	.356^
The course showed my strengths	4 (1)	4 (1)	4 (2)	.539@	2@	66@	.586@	.576^	.750^	.952^
The course showed my weaknesses	4 (1)	5 (1)	5 (1)	.908@	2@	57@	.409@	.420^	.920^	.577^
The course focused too much on knowledge	2 (0	2 (0)	2 (1)	.146*	2*	52.551*	.865*	.880$	.866$	.991$
The course focused too much on technical skills	3 (2)	3 (1)	3 (1)	2.083@	2@	57@	.134@	.497^	.112^	.604^

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
The focused too much on simulation exercises	2 (1)	2 (1)	2 (1)	.446@	2@	57@	.642@	.633^	.743^	.973^
The course is practical and fits current situations of patient care at my hospital	4 (1)	4 (1)	4 (0)	1.257@	2@	57@	.292@	.261^	.663^	.683^
Future trainings will equip medical students and novice surgeons with appropriate knowledge, attitudes and skills of managing RARPs.	4 (1)	5 (1)	4 (1)	2.542@	2@	57@	.088@	.108^	.873^	.185^
Experts										
There were enough experts for the number of learners	4 (1)	5 (1)	4 (1)	3.562@	2@	57@	.035@	.027	.327^	.335^

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
The trainers created a safe learning environment	5 (1)	5 (1)	5 (1)	1.876@	2@	57@	.163@	.166^	.814^	.345^
The trainers had enough experience in medical aspects	4 (1)	5 (1)	4 (1)	3.248@	2@	57@	.046@	.108^	1.00^	.064^
Effects of the training										
The future trainings will contribute to reducing the learning curve for RARPs	4 (2)	5 (1)	4 (1)	.470@	2@	57@	.628@	.602^	.868^	.856^
I would like to do simulation-based training in the future	5 (1)	5 (1)	4 (1)	1.201@	2@	57@	.308@	.594^	.925^	.289^
I would recommend the course to other colleagues	4 (1)	5 (1)	4.5 (1)	1.158@	2@	57@	.321@	.447^	1.00^	.359^
Overall satisfaction on the different aspects of the course										

Table 6. continued

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Participant satisfaction	8 (2)	9 (2)	8 (2)	3.514@	2@	52@	.037@	.129^	.965^	.041^
Materials	8 (1)	9 (1)	8 (2)	2.131@	2@	52@	.129@	.581^	.666^	.107^
Experts	8 (1)	9 (1)	8 (1)	1.618@	2@	52@	.208@	.459^	.928^	.197^
Effects of the training	8 (2)	8 (1)	8 (2)	1.920@	2@	54@	.157@	.811^	.515^	.138^
Overall score course	8 (1)	9 (1)	8 (2)	2.954@	2@	54@	.061@	.412^	.663^	.049^

@One-way Anova, ^Turkey HSD *Brown – Forsythe test, $ Games-Howell Post-Hoc Test, DF1 = degrees of freedom between groups, DF 2 = degrees of freedom within groups, n = number, mm= millimeters

Discussion

In this study, we organised a training in robot simulation skills in order to investigate the influence of three different educational methods: proctoring, simulation guided training and self-study on the training of dexterity skills in novice surgeons. A total of 70 participants were included in the study. The participants were randomly divided in three groups.

(1) The ability of novice robotic surgeons to learn the skills required to perform the vesicourethral anastomosis step of the RARP during a 2-hour training session.

When comparing the pre-intervention results to the post-intervention results over-all, all of the participants grew in their surgical skills during the training. The partic-ipants showed fewer instances of improper suturing technique and a decrease in the number of unnecessary needle piercing points in the post-intervention exercise. These metrics show the participants had a greater under-standing of the techniques required to perform RAS and especially how to suture using the surgical robot. The decrease in number of injuries to the urethra is also a sign of a better understanding of the technique required to perform a vesicourethral anastomosis. The participants were able to, through better understanding of the simulator and the exercise, in-crease the total number of en-trance and exit points through which the needle has passed which lead to a decrease in separation of the wound (anastomosis) after the intervention. This was done in the same period of time which shows the growth the participants experienced during the training.

A separate analysis of the changes in simulation scores per intervention group shows some groups showed more growth than others. All groups showed a decrease in wound (anastomosis) separation in the post intervention scores compared to the pre-intervention scores. The non-intervention group showed a decrease in the clutch usage, the number of times the tissue was grabbed and in the number of movements with the right instrument.

The proctor guided group showed a decrease in damage to the vital structures (ure-thra and bladder neck) and a decrease in the number of unnecessary needle piercing points. This could be the result of the proctoring since they received direct feedback by the proctor on their actions in order to adjust their behaviour accordingly.

(2) The influence of the intervention on the learning curve of novice robotic surgeons.

There was no significant difference in development of surgical skills between the three interven-tion groups. This shows the exposure to the robotic surgery skills simulator alone could possibly be sufficient to achieve the required dexterity skills when approaching RAS. This could indicate that novice surgeons have little use of proctoring or training by use of simulation guided exercises be-cause they are too focussed on learning the basic skills needed for performing robot-assisted sur-gery. This result could be an indication of cognitive overload in the participants. Cognitive overload is the point in which the complexity of the task or the combination of external input (proctoring or added feedback from the simulator) with the task its self puts too much strain (cognitive load) on the learner.[18] This cognitive overload could be detrimental to the learning process of novice sur-geons.[18,19] A study by Andersen et al. shows cognitive overload could lead to an inhibition of the learning process itself.[19] Our observations may therefore indicate that the exercise selected is less suited to the included trainee's experience and further basis skills training is required before em-barking on an advanced simulation exercises as the VU anastomosis exercise. The notion is sup-ported by the fact that none of the trainees passed all threshold criteria set by Harrison et al during the post-intervention exercise.[13] Another explanation could be the difference between the groups could lie in other factors not measured by the simulator. It is possible analysis of the videos of the simulation exercises could result in different findings for example a difference in depth perception, efficiency, force sensitivity and robotic control.

(3) The influence of the intervention on the participant's satisfaction of novice robotic surgeons

Based on the evaluation of the participant's satisfaction the proctor guided group felt more like they were actually performing a surgical step compared to the non-intervention group, this could also be the effect of the proctoring, as novice doctors are used to someone proctoring them during surgery in order to be taught the specific step of the surgery, it could be that having someone next to them doing the same during simulation exercises helps create a similar atmosphere as in the operating room. The learning goals were less clear to the non-intervention group compared to the proctor guided group which could also be an effect of added explanation by the proctor during the intervention.

(4) The effect of participants' characteristics (i.e. age, gender, laparoscopic surgery experience, sur-gical experience, etc.) on the learning curve of novice surgeons.

The univariate analysis of the effect of the baseline characteristics on the change in simulation scores shows there is no relation between the change in surgical skills after the intervention and the individual baseline characteristics, these results are in line with the findings of Meier et al.[20]

Strengths and limitations

The current study is a prospective randomised non-blinded randomized control trail. The partici-pants were aware on the existence of other study groups. However, they were not aware on the details of the other study groups. One of the challenges of this study was the inclusion of partici-pants, even though there are enough interns, PhDs and residents in the vicinity of the study loca-tion, it seems the subject of the study or the duration of the training (2 hours) had a deterring ef-fect on the participants. After multiple reminders the required number of participants was includ-ed. The randomization was performed using a simple randomization, prior to the start of the study.

The trainers who have been training the participants from the proctor guided group, were not ex-pert robotic surgeons. They were researches who received a specific training including intensive simulation and extensive surgical procedures video watching. However due to the high time in-vestment (23 times 2 hours) it was not possible to use expert robotic surgeons as proctor in this study.

The duration of the training was 2 hours, breaks were not included. This could have resulted in an excessive tiredness of the participants with a negative impact on the performance. At the same time the inclusion of breaks could have had a negative impact (distributed practice) on train-ees in particular between the intervention and post-intervention phase training 19,21 To our knowledge, in literature there are no data regarding the tiredness of surgeons during laparoscopic surgery[22,23] and similar studies have not been performed either for RAS.

The sample size was based on a publication of Sung Shim et al.[3] They compared different types of simulation (independent learning, proctoring, and video guided learning) used during a training session focused on the performance of the vesicourethral anastomosis. The main outcome of the study was the time to complete the task and when comparing it with the results from Harri-son et al.[21] it is noticeable that they are significantly different (253.47 vs. 2055.83 seconds). Based on this difference, we choose to use a fixed duration for the performance of the vesicourethral anastomosis. Based on the results of Harrison et al. a maximum time of 30 minutes per repetition is an acceptable timing to perform a vesicourethral anastomosis

Conclusion

The results of the present study showed that novice surgeons can significantly increase their dexterity skills (the ability to perform RAS) in a short time of practicing advanced robotic surgery skills on a simulator. The proctor guided group reported a higher participant's satisfaction scores compared to the simulation trained group and this could indicate a higher motivation to continue their training. The lack of difference in simulation results between the intervention groups showed that the im-pact of proctored guidance and simulator-generated guidance during the initial phase of learning robotic assisted surgery (RAS) is limited. Since there is no difference between the intervention groups, the exposure to the robotic surgery skills simulator alone could possibly be sufficient to achieve the required dexterity skills when approaching RAS. Further research is needed to investi-gate if early skills on simulator could represent an indicator for robotic surgery aptitude and talent.

Appendix

Appendix 1. Pre-intervention vesicourethral anastomosis simulation exercise scores.

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Time and Economy										
Total time (seconds)	1739.4 (307.3)	1709.4 (275.0)	1597.1 (566.6)	1.671@	2@	66@	0.196@	0.643^	0.623^	0.169^
Number of movements - left instrument (n)	1089.0 (2013.0)	1025.0 (482.3)	1019.5 (480.0)	1.207@	2@	66@	0.305@	0.748^	0.688^	0.274^
Number of movements - right instrument (n)	1250.0 (759.0)	1053.0 (549.5)	1151.5 (451.5)	0.947@	2@	66@	0.393@	0.909^	0.624^	0.380^
Path length - left instrument (mm)	11343.3 (6945.7)	10905.3 (8368.0)	9276.2 (4213.0)	1.712@	2@	66@	0.188@	0.541^	0.715^	0.163^
Path length - right instrument (mm)	12481.9 (6854.2)	11578.4 (8574.2)	10382..7 (5228.2)	1.454@	2@	66@	0.241@	0.657^	0.686^	0.211^
Distance by camera (mm)	1030.7 (2004.1)	1003.4 (1053.3)	847.8 (871.5)	0.618@	2@	66@	0.542@	0.809^	0.878^	0.511^
Instrument collisions (n)	83.0 (94.0)	72.0 (52.8)	74.0 (72.8)	0.364@	2@	66@	0.697@	0.854^	0.678^	0.954^
Total path of instruments traveled out of view (mm)	1214.1 (3208.9)	1342.9 (3668.5)	1183.7 (1476.6)	0.559@	2@	66@	0.574@	0.778^	0.929^	0.551^
Number of times instruments are out of view (n)	43.0 (83.0)	47.0 (64.3)	33.5 (76.0)	0.008@	2@	66@	0.992@	1.000^	0.993^	0.995^

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Total time instruments are out of view (seconds)	82.5 (267.3)	121.5 (317.2)	98.3 (129.5)	0.873@	2@	66@	0.422@	0.724^	0.848^	0.391^
Clutch usage (n)	8.0 (13.0)	4.5 (15.8)	4.5 (11.8)	0.391@	2@	66@	0.678@	0.721^	1.000^	0.724^
Safety and Complications										
Injury to the Urethra (n)	9.0 (12.0)	11.5 (14.3)	9.0 (9.5)	0.974@	2@	66@	0.393@	0.953^	0.394^	0.581^
Injury to Bladder Neck (n)	2.0 (6.0)	2.0 (4.5)	1.0 (4.0)	1.654@	2@	62@	0.200@	0.887^	0.402^	0.195^
Suspected injury to the Bladder (n)	1.0 (2.0)	0.0 (0.0)	0.0 (1.0)	4.011*	2*	24.602*	0.031*	0.078$	0.189$	0.502$
Suspected injury to the Neurovascular Bundle (n)	1.0 (3.0)	1.0 (3.0)	0.0 (1.0)	1.937*	2*	42.173*	0.157*	0.977$	0.159$	0.178$
Suspected injury to the Ureteral Orifices (n)	0.5 (1.3)	0.0 (1.0)	0.0 (1.0)	0.608@	2@	56@	0.548*	0.994^	0.658^	0.571^
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)	6.0 (7.0)	7.0 (15.5)	3.0 (8.0)	2.264*	2*	36.198*	0.118*	0.454$	0.556$	0.168$
Wound separation (mm)	13.6 (7.3)	13.6 (4.5)	14.6 (10.2)	0.746@	2@	66@	0.478@	0.530^	0.999^	0.550^
Improper suturing technique (n)	4.0 (5.0)	3.0 (4.0)	1.0 (3.0)	0.635@	2@	57@	0.534@	0.600^	0.583^	0.999^

Variable	No guidance group (n=23)	Proctor guided group (n=23)	Simulator generated guidance group (n=24)	F-value	DF 1	DF 2	p-value overall	P-value Non-No guidance group vs... Proctor guided group	P-value Non-No guidance group vs... Simulator generated guidance group	P-value Proctor guided group vs... Simulator generated guidance group
Needle handling										
Percentage of stitches within optimal depth (%)	66.7 (47.1)	50.0 (25.9)	51.8 (57.8)	1.731*	2*	58.030*	0.186*	0.304$	0.232$	0.869$
Number of unnecessary needle piercing points (n)	78.0 (45.0)	75.5 (65.8)	53.5 (38.0)	3.353@	2@	66@	0.021@	1.000^	0.041^	0.043^
The total number of entrance and exit points through which the needle has passed (n)	24.0 (14.0)	18.0 (16.0)	23.0 (26.0)	0.083@	2@	66@	0.921@	0.977^	0.913^	0.980^
Suture handling										
Excessive force - Suture breakage (n)	0.0 (1.0)	0.0 (0.0)	0 (0.0)	0.446@	2@	66@	0.642@	0.616^	0.913^	0.847^
Tissue handling										
Number of times the tissue was grasped (n)	21.0 (28.0)	13.0 (13.3)	13.0 (14.3)	3.398*	2*	35.710*	0.018*	0.088$	0.070$	0.980$

@One-way Anova, ^Turkey HSD *Brown – Forsythe test, $ Games-Howell Post-Hoc Test, DF1 = degrees of freedom between groups, DF 2 = degrees of freedom within groups, n = number, mm= millimeters

Appendix 2. Comparison of the pre-intervention and post-intervention vesicourethral anastomosis simulation exercise overall scores.

Variable	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Time and Economy						
Total time (seconds)$	66	1714.7 (466.9)	1679.9 (497.3)	81.9 (472.1)	-1.409	.159
Number of movements - left instrument (n)$	66	1025.0 (593.0)	1036.0 (404.5)	-3.0 (433.0)	-0.297	.766
Number of movements - right instrument (n)$	66	133.0 (516.5)	1138.0 (461.0)	8.0 (473.0)	-0.866	.387
Path length - left instrument (mm)$	66	10184.8 (6776.2)	10782.0 (5770.6)	-803.2 (4315.6)	-0.393	.694
Path length - right instrument (mm)$	66	11285.7 (6438.4)	10873.5 (4801.5)	-403.5 (5853.2)	-0.105	.916
Distance by camera (mm)$	66	984.65 (1221.8)	762.56 (1446.4)	1.419 (1115.0)	-0.719	.472
Instrument collisions (n)$	66	74.0 (81.0)	67.0 (54.0)	6.0 (74.0)	-1.054	.292
Total path of instruments travelled out of view (mm)$	66	1308.4 (2553.1)	1404.6 (2160.6)	-118.2 (2066.9)	-0.227	.821
Number of times instruments are out of view (n)$	66	41.0 (74.0)	46.0 (66.5)	-9.0 (61.0)	-0.862	.388

Variable	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time instruments are out of view (seconds)$	66	106.7 (205.5)	154.5 (212.9)	-21.0 (135.0)	-1.230	.219
Clutch usage (n)$	66	5.00 (12.5)	4 (7.3)	1 (11)	-1.972	.049
Safety and Complications						
Injury to the Urethra (n)$	66	9.0 (12.5)	7.0 (12.5)	3.0 (10.0)	-2.382	.017
Injury to Bladder Neck (n)$	62	2.0 (3.0)	2.0 (2.5)	0.0 (4.0)	-0.226	.821
Suspected injury to the Bladder (n)$	54	0.0 (0.8)	0.0 (0.0)	0.0 (0.0)	-0.389	.697
Suspected injury to the Neurovascular Bundle (n)$	54	0.5 (2.0)	0.0 (1.0)	0.0 (1.0)	-1.328	.184
Suspected injury to the Ureteral Orifices (n)$	53	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	-0.965	.334
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)$	60	4.0 (9.5)	5.0 (5.5)	2.0 (7.0)	-2.176	.030
Wound separation (mm) *	66	14.0 (6.3)	11.5 (8.4)	4.2 (7.3)	6.790	<.0001
Improper suturing technique (n)$	52	2.0 (4.0)	1.0 (2.0)	0.0 (3.0)	-3.047	.002

Variable	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Needle handling						
Percentage of stitches within optimal depth (%) *	66	54.5 (40.5)	63.6 (43.4)	-6.2 (46.0)	-1.035	.304
Number of unnecessary needle piercing points (n)$	66	69.0 (48.5)	53.0 (28.5)	11.0 (54.0)	-2.932	.003
The total number of entrance and exit points through which the needle has passed (n)$	66	22.0 (18.0)	28.0 (16.0)	-6.0 (15.0)	-2.793	.005
Suture handling						
Excessive force - Suture breakage (n) $	66	0.0	(0.0)	0.0 (0.0)	0.0 (0.0)	-0.6113
Tissue handling						
Number of times the tissue was grasped (n)$	66	13.0 (17.0)	11.0 (15.5)	2.0 (17.0)	-1.254	.210

*two-sided t-test for paired samples, $Wilcoxon Signed Ranks Test

Appendix 3a. Comparison of the pre-intervention and post-intervention vesicourethral anastomosis simulation exercise scores for the no guidance group

Variable	No guidance group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Time and Economy						
Total time (seconds)	21	1739.4 (307.3)	1387.5 (594.2)	242.9 (486.9)	-1.929	.054
Number of movements - left instrument (n)	21	1089.0 (2013.0)	880.0 (416.0)	68.0 (499)	-2.068	0.039
Number of movements - right instrument (n)	21	1250.0 (759.0)	955.0 (522.5)	188.0 (542)	-2.538	.011
Path length - left instrument (mm)	21	11343.3 (6945.7)	9395.6 (5234.0)	1232.3 (6042.0)	-1.199	.230
Path length - right instrument (mm)	21	12481.9 (6854.2)	9569.3 (4814.2)	985.9 (5569.0)	-1.755	.079
Distance by camera (mm)	21	1030.7 (2004.1)	389.9 (1982.9)	157.9 (1159.5)	-1.964	.050
Instrument collisions (n)	21	83.0 (94.0)	73.0 (54.0)	13.0 (77)	-1.668	.095
Total path of instruments traveled out of view (mm)	21	1214.1 (3208.9)	867.0 (1202.9)	190.3 (1948.7)	-1.447	.140
Number of times instruments are out of view (n)	21	43.0 (83.0)	35.0 (59.0)	-3.0 (55)	-0.747	.455

Variable	No guidance group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time instruments are out of view (seconds)	21	82.5 (267.3)	94.3 (224.1)	4.7 (125.1)	-0.122	.903
Clutch usage (n)	21	8.0 (13.0)	2.0 (4.5)	7.0 (12)	-2.939	.003
Safety and Complications						
Injury to the Urethra (n)	21	9.0 (12.0)	6.0 (16.0)	3.0 (13)	-1.383	.167
Injury to Bladder Neck (n)	20	2.0 (6.0)	2.0 (4.5)	0.0 (3)	-0.208	.835
Suspected injury to the Bladder (n)	14	1.0 (2.0)	0.0 (3.3)	0.0 (1)	-1.913	.056
Suspected injury to the Neurovascular Bundle (n)	12	1.0 (3.0)	1.0 (2.0)	0.0 (1)	-0.604	.546
Suspected injury to the Ureteral Orifices (n)	14	0.5 (1.3)	1.0 (1.8)	0.0 (1)	-0.979	.327
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)	17	6.0 (7.0)	3.0 (3.5)	1.5 (7)	-1.880	.060

Variable	No guidance group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Wound separation (mm)	21	13.6 (7.3)	10.47 (8.4)	5.2 (7.9)	-3.375	.001
Improper suturing technique (n)	12	4.0 (5.0)	1.0 (2.8)	0.0 (4)	-2.089	0.036
Needle handling						
Percentage of stitches within optimal depth (%)	21	66.7 (47.1)	70.0 (42.6)	-1.1 (44.4)	-0.156	.876
Number of unnecessary needle piercing points (n)	21	78.0 (45.0)	63.0 (31.5)	18.0 (51)	-2.207	.027
The total number of entrance and exit points through which the needle has passed (n)	21	24.0 (14.0)	30.0 (14.0)	-2.0 (15)	-0.591	.555
Suture handling						
Excessive force - Suture breakage (n)	21	0.0 (1.0)	0.0 (0.5)	0.0 (1)	-0.540	.589
Tissue handling						
Number of times the tissue was grasped (n)	21	21.0 (28.0)	9.0 (15.0)	3.0 (18)	-2.440	.015

Wilcoxon Signed Ranks Test

Appendix 3b. Comparison of the pre-intervention and post-intervention vesicourethral anastomosis simulation exercise scores for the proctor guided group

Variable	Proctor guided group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time (seconds)						
Number of movements - left instrument (n)	21	1709.4 (275.0)	1733.7 (365.6)	-24.9 (503.4)	-0.747	.455
Number of movements - right instrument (n)	21	1025.0 (482.3)	1023.0 (496.0)	27.5 (426)	-0.017	.986
Path length - left instrument (mm)	21	1053.0 (549.5)	1197.0 (329.5)	-42.0 (537)	-0.087	.931
Path length - right instrument (mm)	21	10905.3 (8368.0)	11135.9 (4832.4)	-290.8 (4684.8)	-0.122	.903
Distance by camera (mm)	21	11578.4 (8574.2)	11659.2 (5145.8)	1599.9 (5979.8)	-0.017	.986
Instrument collisions (n)	21	1003.4 (1053.3)	860.3 (1417.9)	-14.7 (1622.5)	-0.608	.543
Total path of instruments traveled out of view (mm)	21	72.0 (52.8)	58.0 (40.0)	16.0 (63)	-1.304	.192
Number of times instruments are out of view (n)	21	1342.9 (3668.5)	1987.1 (1767.8)	113.0 (1995.6)	-0.052	0.958

Variable	Proctor guided group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time instruments are out of view (seconds)	21	47.0 (64.3)	53.0 (59.0)	-1.0 (77)	-1.061	.289
Total time instruments are out of view (seconds)	21	121.5 (317.2)	145.7 (157.9)	-49.0 (207.9)	-0.400	.689
Clutch usage (n)	21	4.5 (15.8)	5.0 (12.5)	0.0 (11)	-.087	.931
Safety and Complications						
Injury to the Urethra (n)	21	11.5 (14.3)	6.0 (10.0)	4.0 (10)	-2.401	.016
Injury to Bladder Neck (n)	20	2.0 (4.5)	2.0 (1.0)	0.5 (5)	-2.389	.017
Suspected injury to the Bladder (n)	19	0.0 (0.0)	0.0 (0.0)	0.0 (0)	-1.732	.083
Suspected injury to the Neurovascular Bundle (n)	21	1.0 (3.0)	1.0 (2.0)	0.0 (2)	-0.837	.403
Suspected injury to the Ureteral Orifices (n)	19	0.0 (1.0)	0.0 (1.0)	0.0 (1)	-0.489	.625
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)	20	7.0 (15.5)	6.0 (6.0)	0.0 (9)	-1.283	.200

Variable	Proctor guided group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Wound separation (mm)	21	13.6 (4.5)	11.519 (6.8)	3.1 (6.3)	-2.597	.009
Improper suturing technique (n)	20	3.0 (4.0)	0.5 (2.0)	1.0 (4)	-2.108	.035
Needle handling						
Percentage of stitches within optimal depth (%)	21	50.0 (25.9)	60.0 (54.0)	-3.0 (50.0)	0.000	1.000
Number of unnecessary needle piercing points (n)	21	75.5 (65.8)	48.0 (29.0)	29.5 (75)	-2.381	.017
The total number of entrance and exit points through which the needle has passed (n)	21	18.0 (16.0)	24.0 (14.0)	-6.0 (15)	-0.898	.369
Suture handling						
Excessive force - Suture breakage (n)	21	0.0 (0.0)	0.0 (0.0)	0.0 (0)	-1.000	.317
Tissue handling						
Number of times the tissue was grasped (n)	21	13.0 (13.3)	11.0 (11.0)	6.5 (16)	-0.785	.433

Wilcoxon Signed Ranks Test

Appendix 3c. Comparison of the pre-intervention and post-intervention vesicourethral anastomosis simulation exercise scores for the Simulator generated guidance group

Variable	**Simulator generated guidance group**					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time (seconds)						
Number of movements - left instrument (n)	24	1597.1 (566.6)	1675.3 (442.2)	12.5 (355.9)	-0.286	.775
Number of movements - right instrument (n)	24	1019.5 (480.0)	1089.0 (457.8)	-20.0 (332)	-1.314	.189
Path length - left instrument (mm)	24	1151.5 (451.5)	1191.5 (486.0)	-47.0 (286)	-1.429	.153
Path length - right instrument (mm)	24	9276.2 (4213.0)	12509.3 (6156.3)	-1249.0 (3198.0)	-2.171	.030
Distance by camera (mm)	24	10382..7 (5228.2)	11422.6 (5964.7)	-849.1 (3547.3)	-2.114	.034
Instrument collisions (n)	24	847.8 (871.5)	1163.8 (1618.3)	1.1 (954.2)	-1.400	.162
Total path of instruments traveled out of view (mm)	24	74.0 (72.8)	69.5 (64.3)	-8.0 (84)	-0.986	.324
Number of times instruments are out of view (n)	24	1183.7 (1476.6)	2069.9 (2580.5)	-299.8 (1537.4)	-1.029	.304

Variable	**Simulator generated guidance group**					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Total time instruments are out of view (seconds)	24	33.5 (76.0)	66.5 (73.0)	-12.0 (53)	-0.900	.368
Total time instruments are out of view (seconds)	24	98.3 (129.5)	167.6 (236.2)	-21.0 (156.9)	-1.714	.086
Clutch usage (n)	24	4.5 (11.8)	4.5 (7.5)	0.0 (15)	-0.574	.566
Safety and Complications						
Injury to the Urethra (n)	24	9.0 (9.5)	8.5 (11.5)	2.0 (9)	-0.470	.638
Injury to Bladder Neck (n)	22	1.0 (4.0)	2.0 (7.0)	-1.0 (6)	-2.186	.029
Suspected injury to the Bladder (n)	21	0.0 (1.0)	0.0 (0.0)	0.0 (0)	-1.414	.157
Suspected injury to the Neurovascular Bundle (n)	21	0.0 (1.0)	0.0 (1.0)	0.0 (1)	-0.990	.322
Suspected injury to the Ureteral Orifices (n)	20	0.0 (1.0)	0.0 (2.0)	0.0 (2)	-1.096	.237
Suspected injury to the Endopelvic Fascia/Urethral Sphincter (n)	23	3.0 (8.0)	5.0 (6.0)	2.0 (10)	-0.593	.533

Variable	Simulator generated guidance group					
	Number of participants of which data was available	Pre-intervention score, Median (IQR)	Post-intervention score, Median (IQR)	Difference in score, Median (IQR)	Z-value$ / T-value*	p-value
Wound separation (mm)	24	14.6 (10.2)	11.0 (14.9)	3.1 (6.3)	-3.102	.002
Improper suturing technique (n)	20	1.0 (3.0)	0.0 (3.0)	0.0 (2)	-0.981	.326
Needle handling						
Percentage of stitches within optimal depth (%)	24	51.8 (57.8)	57.3 (43.7)	-14.6 (37.5)	-1.347	.178
Number of unnecessary needle piercing points (n)	24	53.5 (38.0)	53.0 (28.5)	8.0 (38)	-0.143	.886
The total number of entrance and exit points through which the needle has passed (n)	24	23.0 (26.0)	31.0 (37.0)	-4.0 (16)	-2.731	.006
Suture handling						
Excessive force - Suture breakage (n)	24	0.0 (0.0)	0.0 (0.8)	0.0 (0)	-0.877	.380
Tissue handling						
Number of times the tissue was grasped (n)	24	13.0 (14.3)	13.0 (22.0)	-2.0 (14)	-0.815	.415

Wilcoxon Signed Ranks Test

References

1. Leal Ghezzi T, Campos Corleta O. 30 Years of Robotic Surgery. World J Surg. 2016;40(10):2550–7.
2. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;
3. Khan R, Aydin A, Khan MS, Dasgupta P, Ahmed K. Simulation-based training for prostate surgery. BJU Int [Internet]. 2015 Oct 1 [cited 2018 Mar 27];116(4):665–74.
4. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers' Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377.
5. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP, Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];
6. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.
7. Rehman S, Raza SJ, Stegemann AP, Zeeck K, Din R, Llewellyn A, Dio L, Trznadel M, Seo YW, Chowriappa AJ, Kesavadas T, Ahmed K, Guru KA. Simulation-based robot-assisted surgical training: A health economic evaluation. Int J Surg [Internet]. 2013;11(9):841–6.
8. Larcher A, Turri F, Bianchi L, Dell'Oglio P, Collins J, Capitanio U, Montorsi F, Mottrie A. Virtual Reality Validation of the ERUS Simulation-based Training Programmes: Results from a High-volume Training Centre for Robot-assisted Surgery. Eur Urol [Internet]. 2019;75(5):885–7.
9. Goldenberg MG, Lee JY, Kwong JCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence. Vol. 122, BJU International. 2018.
10. Watkinson W, Raison N, Abe T, Harrison P, Khan S, Van der Poel H, Dasgupta P, Ahmed K. Establishing objective benchmarks in robotic virtual reality simulation at the level of a competent surgeon using the RobotiX Mentor simulator. Postgrad Med J [Internet]. 2018;postgradmedj-2017-135351.
11. Lovegrove CE, Elhage O, Khan MS, Novara G, Mottrie A, Dasgupta P, Ahmed K. Training Modalities in Robot-assisted Urologic Surgery: A Systematic Review. Eur Urol Focus [Internet]. 2017;3(1):102–16.
12. Puliatti S, Mazzone E, Dell'Oglio P. Training in robot-assisted surgery. Curr Opin Urol. 2020;30(1):65–72.
13. Harrison P, Raison N, Abe T, Watkinson W, Dar F, Challacombe B, Van Der Poel H, Khan MS, Dasgupa P, Ahmed K. The Validation of a Novel Robot-Assisted Radical Prostatectomy Virtual Reality Module. J Surg Educ [Internet]. 2018;75(3):758–66.
14. Shim JS, Kim JY, Pyun JH, Cho S, Oh MM, Kang SH, Lee JG, Kim JJ, Cheon J, Kang SG. Comparison of effective teaching methods to achieve skill acquisition using a robotic virtual reality simulator Expert proctoring versus an educational video versus independent training. Med (United States). 2018;97(51):1–5.
15. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.
16. Lee JY, Mucksavage P, Sundaram CP, McDougall EM. Best practices for robotic surgery training and credentialing. J Urol [Internet]. 2011;185(4):1191–7.
17. Wijewickrema S, Zhou Y, Bailey J, Kennedy G, O'Leary S. Provision of automated step-by-step procedural guidance in virtual reality surgery simulation. In: Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology - VRST '16 [Internet]. New York, New York, USA: ACM Press; 2016 [cited 2020 Apr 20]. p. 69–72.
18. Sweller J. Cognitive Load During Problem Solving: Effects on Learning - Sweller - 2010 - Cognitive Science - Wiley Online Library. Cogn Sci [Internet]. 1988;285:257–85.
19. Andersen SAW, Mikkelsen PT, Konge L, Cayé-Thomasen P, Sørensen MS. Cognitive load in distributed and massed practice in virtual reality mastoidectomy simulation. Laryngoscope. 2016;126(2):E74–9.
20. Meier M, Horton K, John H. Da Vinci© Skills SimulatorTM: is an early selection of talented console surgeons possible? J Robot Surg. 2016;10(4):289–96.
21. Andersen SAW, Konge L, Cayé-Thomasen P, Sørensen MS. Learning curves of virtual mastoidectomy in distributed and massed practice. JAMA Otolaryngol - Head Neck Surg. 2015;141(10):913–8.
22. Mackay S, Morgan P, Datta V, Chang A, Darzi A. Practice distribution in procedural skills training: A randomized controlled trial. Surg Endosc Other Interv Tech. 2002;16(6):957–61.
23. Ritter FE, Yeh MKC, Yan Y, Siu KC, Oleynikov D. Effects of Varied Surgical Simulation Training Schedules on Motor-Skill Acquisition. Surg Innov. 2020;27(1):68–80.

Chapter 4

Structured robot-assisted surgery training curriculum for residents in Urology and impact on future surgical activity

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Abstract

Objective

To gain insight into the availability of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency curriculum and to analyze the effects on surgical skills of the introduction of an advanced course in robot assisted surgery for residents.

Design

A combination of a validated snap shot survey and a prospective cohort study

Setting

Structured advanced RAS training including virtual reality (VR) simulation, dry and wet lab facility at ORSI academy (Belgium).

Participants

A snap-shot survey has been sent to all the residents and specialists in Urology graduated during the years 2017, 2018, 2019 and 2020 in Netherlands. Among residents only last year residents (5th and 6th year) have been considered for the RAS training

Results

Although most of the residents (88.2%) and young urologists (95%) were asked to follow a basic training or meet basic requirements before starting RAS, the requirements set by the educators were different from center to center. Some of them were required to attend only an online course on RAS, whereas others were asked to achieve threshold scores at VR simulator and participate in a standardized course at a training institute. The attendance to a structured advanced course in RAS showed a significant increase in surgical skills. The results of this study show 7 out of 10 trainees are allowed to perform RAS in their own hospital after the course.

Conclusions

Our study shows residents in urology are allowed to perform robot assisted surgery during their residency. Criteria for starting RAS differ significantly amongst the teaching hospitals. To guarantee a basic level of skills and knowledge a structured (multi-step) training and certification program for RAS should be implemented. Residents who participated in a structured RAS course show a significant increase in surgical skills, after the course a majority of participants were allowed to perform RAS in their own hospital.

Introduction

The introduction of robotic-surgery dramatically changed the approach to the patient with urologic pathologies over the last decade.[1–7] Initially, the novice robotic surgeon was receiving a short compulsory course in the basics of robotic surgery by the manufacturer. Nowadays the next generation of robotic surgeons have many opportunities to learn robot assisted surgery (RAS) before operating on patients. Indeed, many training methods are available including the possibility of mentoring by an expert surgeon during the initial phase of the learning curve.

A basic robotic surgery training with "the introduction to the robotic system" is usually provided by the manufacturer to surgeons starting with RAS. However not all the novice robotic surgeons have access to this basic training programme which could result in a serious gap of knowledge. The Dutch Healthcare Inspectorate (IGJ) published a report in 2010 entitled 'Inadequate preparation in the introduction of surgical robots.' This reports states that the starting criteria were undefined for autonomously performing robotic surgery and advocates education, proven capability and competency for 'robotic surgeons'.[2,8]

The lack of a structured curriculum and a defined set of skill-criteria during the residency program, results in an unofficial not certified training based on the own perception of knowledge and surgical skills acquired by the novice surgeon.[9–11] This results in a burden of non-standardized training pathways that can differ significantly from trainee to trainee.[12,13] Indeed previous research has shown that novice robotic surgeons are unable to accurately self-assess their skills.[12] Based on the results of this study the objective assessment of dexterity and surgical skills should be included and the results discussed with the trainees to identify the need of further training accordingly to the progress of the trainee.[12] In earlier research, we investigated whether the current specialists agreed that a basic training in to guarantee a basic level of skills for all new robot surgeons.[3] The majority of robot professionals in the Netherlands agreed that robotic surgery should be learned in a structured training program to guarantee the surgical quality and safety to the patient.[3]

In a recent study by the group of Satava et al, a randomized controlled trial was performed amongst inexperienced surgical trainees.[14] This study showed that a well-structured curriculum where threshold scores are used to assess the participants (up to proficiency levels) resulted in a better performance on the avian tissue model (transfer test) compared to the control group which was trained without a structured training. This showed that a structured training program is able to contributes significantly to surgical skills of novice robot surgeons.[14]

In order to provide a structured training program in robot-assisted surgery the European Robotic Urological Society developed a curriculum (CC-ERUS) focused on the performance of robot-assisted radical prostatectomy (RARP).[5,6,15,16] After its initial conception in 2014, the program has evolved into a structured training curriculum. Indeed, it includes all the aspects of training, from the most basic ones as live case observation and table-side assistance, to the most advanced training facilities as virtual reality (VR), dry and wet lab with the most complex and advanced training models available today. Moreover, it provides six months of modular training at a certified host center, and the performance of a full RARP case with the video assessment by expert surgeons.[15] Currently, this curriculum is available for fellows who train in CC-ERUS host centers. Since the implementation of training curricula for fellows is a step into the right direction, but, the training is demanding and expensive and therefore normally not available for residents. An increasing number of residents are allowed to train RAS on patients under the supervision of an experienced robotic surgeon during internship, however most of them do not have the possibility to receive a well-structured training and simulation before that. Thus, a structured curriculum during the residency program is also needed. For this reason, The Dutch and Belgian Association of Urology organize yearly a one-week training at ORSI Academy (https://www.orsi-online.com/en) in order to provide a structured and supervised training for residents. The question arises whether residents poses a sufficient background to effectively participate in the course and in order to meet educational goals.

We therefore asked ourselves the following questions: (1) What is the current availability of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency in urology curriculum? (2) Do residents show a significant increase in Simulation-based surgical skills following the curriculum? (3) Are residents able/allowed by their trainers to perform robot assisted surgery after the curriculum?

Methods

Study design and participant selection

The study contains two separate study populations for the survey and for the training.

Snap shot survey study population.

Participants included in this study were residents and young specialists in Urology. A snap-shot survey has been sent to all the residents and young specialists in Urology graduated in the Netherland during the years 2017, 2018, 2019 and 2020.

The snapshot survey structure.

The survey was designed to gain insights into the position of robot-assisted surgery in the urology curriculum and the manner of training received by the residents before their first robot-assisted procedure. The questionnaire, developed using Google forms (https://www.google.com/forms/about/) was distributed by the Dutch Society of Urology via E-mail. The questions are presented in table 1. The questionnaires were developed by a group of urologists, the questionnaire was validated using face validity by a panel of experts in the field of surgical robotics.

Advanced training course study population.

Residents from the last year of residency program and young Urologists have been selected to participate to an advanced course in RAS at ORSI Academy (Belgium). The selection process has been performed using a questionnaire and specific criteria based on the motivation/interest in RAS, the successful completion of the DaVinci online training module, the availability of a supervisor at their institution, and the possibility to perform RAS after the course,(Appendix 1).

The proposed advanced course in RAS was based on the training curriculum for Robot-assisted Radical Prostatectomy (RARP) developed by Mottrie et al. (CC-ERUS = Certified Curriculum from the European Association of Urology - Robotic Urology Section) (Appendix 2).[15] The participants' surgical skills have been assessed before and after the course. Moreover, they have been asked to complete specific questionnaires immediately after and at different follow-up periods after the course.

Advanced training course structure

The structure of the advanced RAS course (part of the CC-ERUS curriculum) is well displayed in Appendix 2. The advanced RAS course is an intensive 5-day course performed at ORSI Academy in Belgium. It contemplated VR simulation, dry lab, and web lab facility.

The first day of the course included a half-day introductory session given by a technician who explained all the main features of the robotic system in order to familiarize with the equipment and face troubleshooting. The remaining part of the day was dedicated to VR simulation and dry lab training on specific models as the suturing pad, the vesico-urethral anastomosis model and the Venezuelan Chicken.

During the second day, half of the participants attended a live case observation at OLV hospital in Aalst. There was the possibility to directly interact with the mentors/trainers and at the same time, the participants were continuously stimulated watching important surgical details. 3D screens and double console were available in order to allow the trainees the same vision of the surgical field of the operating surgeon. The remaining part of the group had cadaver lab training on canine model. The participants trained the main steps of the radical prostatectomy and pelvic lymphadenectomy under the guidance of an expert trainer. One dog was available for three participants. The group who had live case observation during the second day of the course received the cadaver lab training on the fourth day of the course and vice versa.

The third day and the fifth (last) day of the course were based on dry lab for all the participants. The model used was the living pig model and the trainees had the opportunity to train the main steps of the radical prostatectomy and pelvic lymphadenectomy under the guidance of an expert trainer. Before starting the participants were advised about the main features of the model receiving specific warnings about the fragility of the model (bleeding, urine extravasation etc.). One pig was available for three participants.

Surgical skills assessment method

The participants have been assessed before and at the end of the training. The assessment method was based on the performance of pre-selected exercises on virtual reality (VR) simulator.

The exercises were selected based on a publication of Larcher et al.[17]

The selected exercises are listed below.

- Endowrist Manipulation 2- Match Board 2
- Energy and dissection-Energy Switch 2
- Camera and clutching - Ring Walk 3
- Needle Driving - Suture Sponge 2
- Needle Driving - Tubes

Questionnaires used during the advanced course

Prior to the training program, all participants were asked to complete an online pre-training questionnaire (table 2). After 6 and 12 months additional online follow-up questionnaires (table 3) were sent to the participants to gain insight about the RAS exposure of the participants. The questionnaires were sent automatically by the self-service function of the Data Management module developed by Research Manager https://my-researchmanager.com/en/home-2/. The questionnaires were developed by a group of urologists all questionnaires were validated using face validity by a panel of experts in the field of surgical robotics.

Data analysis

Descriptive statistics were calculated for all available variables. Population sample size was determined by the logistical and financial aspects of the training provided as well as the number of eligible Dutch and Belgian residents. Mean and standard deviation or median and interquartile range were reported for continuous variables as indicated, depending on the distribution of the variables. Frequencies and proportions were used to describe categorical variables. The Wilcoxon signed-rank test (in case of non-normal distributed data) or a two-sided t-test for paired samples (in case of normal distributed data) was used to compare differences in results between the pre and post measurements of the Simulation-based performance scores. Linear regression analysis was performed in order to investigate the relations between the skills simulation scores and post training surgery exposure. Statistical significance will be set at $p < .05$ based on a two-tailed comparison. Statistical analysis was performed with SPSS software v. 24 (SPSS Inc., Chicago, IL, USA)

Results

Snapshot questionnaire amongst Dutch residents and recently graduated specialists in Urology

The questionnaire was sent to a total of 137 residents and 55 specialists in Urology who graduated in the year 2017, 2018, 2019, and 2020. 56 (40.1%) residents and 41 (74.5%) urologists have responded.

Results of the questionnaire are displayed in Table 1. Most of the young urologists who responded to the questionnaire graduated in the years 2018 and 2019 and most of them (61%) have a job as a staff member at their hospitals. More than half of them had performed or were performing Robot Assisted Surgery (RAS) at the moment of the survey.

Table 1 the results of the questionnaire on the availability of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency curriculum.

	Residents, n (%)	Urologists, n (%)
Number of respondents	56 (57.7)	41 (42.3)
Age, median (IQR)	32 (3)	36 (3)
Gender		
Male	26 (46.4)	28 (68.3)
Female	30 (53.6)	13 (31.7)
Year of graduation		
<2018	-	6 (14.6)
2018	-	13 (31.7)
2019	-	16 (39.0)
2020	-	6 (14.6)
Current job		
Staff member	-	25 (61.0)
Fellow	-	6 (14.6)
Urologist,Temporary position	-	10 (24.4)
Currently performing or in the past performed RAS		
Yes	-	23 (56.1)
No	-	18 (43.9)
Year of residency		
1st	8 (14.3)	-
2nd	6 (10.7)	-
3rd	9 (16.1)	-
4th	12 (21.4)	-
5th	9 (16.1)	-
6th	12 (21.4)	-

Table 1 continued

	Residents, n (%)	Urologists, n (%)
Interested in performing RAS as a urologist?		
Yes	45 (80.4)	-
No	11 (19.6)	-
Current type of hospital		
Academic hospital	14 (31.1)	6 (26.1)
Teaching peripheral hospital	28 (62.2)	14 (60.9)
Rural hospital	3 (6.7)	3 (13.0)
Surgical robot present at hospital		
Yes	40 (88.9)	19 (82.6)
No	5 (11.1)	4 (17.4)
Dual Console present at hospital		
Yes	19 (47.5)	9 (47.4)
No	21 (52.5)	10 (52.6)
Robotic skills simulator present at hospital		
Yes	27 (67.5)	12 (63.2)
No	8 (20.0)	4 (21.1)
Sometimes	5 (12.5)	3 (15.8)
Do you use the Robotic skills simulator		
Yes	23 (71.9)	7 (46.7)
No	9 (28.1)	8 (53.3)
Did you participate in the Advanced Course Robot Assisted Surgery at ORSI Academy?		
Yes	7 (15.6)	10 (43.5)
No	36 (80.0)	10 (43.5)
I was rejected	2 (4.4)	3 (13.0)
Were you aloud to perform RAS during your residency?		
Yes	17 (37.8)	20 (87.0)
No	28 (62.2)	3 (13.0)
In what year of your residency were you aloud to perform RAS for the first time?		
1st	2 (11.8)	-
2nd	1 (5.9)	-
3rd	3 (17.6)	6 (30.0)
4th	7 (41.2)	8 (40.0)
5th	3 (17.6)	5 (25.0)
6th	1 (5.9)	1 (5.0)
Did you have to follow a basic training or meet basic requirements before starting robot-assisted surgery?		
Yes	15 (88.2)	19 (95.0)
No	2 (11.8)	1 (5.0)

Table 1 continued

	Residents, n (%)	Urologists, n (%)
What basic requirements were set before starting robot-assisted surgery?		
Online course developed by the manufacturer of the system	4 (26.7)	4 (21.1)
Simulator, training, not specified	0	2 (10.5)
Simulator, training, own initiative	2 (13.3)	0
Simulator, all exercises.	2 (13.3)	2 (10.5)
Basic robot training NVU	0	1 (5.3)
Standardized course at training institute	1 (6.7)	2 (10.5)
Course on technical aspects of the robot	1 (6.7)	0
Online course not specified	0	1 (5.3)
Online course by Intuitive + instructions at the OR	0	2 (10.5)
Simulator, all exercises + Standardized course at training institute	1 (6.7)	1 (5.3)
Online course not specified + Standardized course at training institute	0	2 (10.5)
Online course by Intuitive + Simulator, training, not specified	1 (6.7)	1 (5.3)
Simulator, training, not specified + Standardized course at training institute	1 (6.7)	0
Simulator, training, not specified + HOT course	1 (6.7)	0
Course on technical knowledge of the robot + Simulator, all exercises.	1 (6.7)	0
Anatomy knowledge + Surgical movies + 10 surgeries beside assisting + Simulator, all exercises.	0	1 (5.3)
Do you believe that basic robot assisted surgery training should be part of the curriculum?		
Yes	10 (66.7)	9 (47.4)
No	5 (33.3)	10 (52.6)

Table 1 continued

	Residents, n (%)	Urologists, n (%)
In which year of the curriculum would you implement this training?		
3rd	7 (70)	1 (11.1)
4th	2 (20)	4 (44.4)
5th	1 (10)	3 (33.3)
6th	0	1 (11.1)
Would you implement this training for all residents or only for the residents who are subspecializing in RAS?		
All residents	8 (80)	5 (55.6)
subspecializing in RAS	2 (20)	4 (44.4)
Have you performed robot assisted surgery in the past 6 months?		
Yes	12 (70.6)	9 (45.0)
No	5 (8.9)	11 (55.0)
How many robot-assisted procedures have you been allowed to partially operate in the past 6 months?		
<10	8 (53.3)	2 (20)
10-20	5 (33.3)	1 (10)
20-30	1 (6.7)	1 (10)
>30	1 (6.7)	5 (50)
How many robot assisted procedures did you perform as the first surgeon in the past 6 months?		
<5	13 (86.7)	4 (40)
5-10	1 (6.7)	0
10-15	1 (6.7)	0
>15	0	6 (60)
Which type of procedures did you perform in the past six months?		
Robot Assisted Radical Prosta-tectomy	5 (33.3)	6 (60.0)
Robot Assisted Radical Cystec-tomy	1 (6.7)	4 (40.0)
Robot Assisted Partial Ne-phrectomy	7 (46.7)	4 (40.0)
Robot Assisted Radical Ne-phrectomy	6 (40)	6 (60.0)
Robot Assisted Radical Nephro-Ureterectomy	1 (6.7)	1 (10.0)
Robot Assisted Plevic Lymphe node Dissection	1 (6.7)	3 (30.0)
Robot Assisted Pyelo-Plasty	4 (26.7)	1 (10.0)
Other	1 96.7)	1 (10.0)

Of the residents who responded to the questionnaire almost 60% were in their 4th year or higher. Most of the residents (80.4%) were interested to perform RAS after graduation. More than 80% of the residents who are interested in RAS and urologists who were performing RAS had a surgical robot in their hospital. Almost 90% of the urologist who are currently performing RAS were allowed to perform RAS during their residency, 70% were allowed to perform RAS before their 5th year of residency. Of the residents who responded to be interested in RAS less than 40% were involved in RAS during their residency program. Of the residents who were allowed to participate in RAS 76% did this before their 5th year. Although most of the residents (88.2%) and young urologists (95%) were asked to follow a basic training or meet basic requirements before starting robot-assisted surgery, the requirements set by the educators were different from center to center. Some of them were required to attend only an online course on RAS, whereas others were asked to achieve threshold scores at VR simulator and participate in a standardized course at a training institute. Most of the residents (66,7%) and nearly half of the young urologists (47,4%) agreed that RAS training should be included as a standard part within the residency program.

The former claimed it should be included within the 3rd year of the residency program (70%) and it should be made available for all residents (80%), while the latter sustained that it should be implemented in the 4th (44.4%) or 5th year (33.3%) of the residency program and 55.6% of the urologists agree the training should be available for all residents.

The advanced course in Robot Assisted Surgery

A total of 29 participants were selected for the course (6 in 2018, 8 in 2019, and 15 in 2020). The baseline characteristics of all participants are shown in table 2. The 72.4% of the residents selected for the course were male (21 participants) and 55.2% were Dutch (16 participants). In the Netherlands 61% of the applicants (16/26 applications) were selected for the course. More than 90% of the participants were residents at the time of the course, 2 participants just ended their residency program and

Table 2 Baseline Characteristics, Laparoscopic experience and robot assisted surgery experience for the residents who were selected for the course with specifications per year of the course.

	2018 (n=6)	2019 (n=8)	2020 (n=15)	Overall (n=29)
Age, median (IQR)	34 (33-34)	32 (30 - 32)	31 (30 – 32)	32 (30 – 33)
Sex, n (%)				
Male	5 (83.3)	5 (62.5)	11 (73.3)	21 (72.4)
Female	1 (16.7)	3 (37.5)	4 (26.7)	8 (27.6)

Table 2 continued.

	2018 (n=6)	2019 (n=8)	2020 (n=15)	Overall (n=29)
Nationality, n (%)				
Belgian	0	4 (50)	9 (60.0)	13 (44.8)
Dutch	6 (100)	4 (50)	6 (40.0)	16 (55.2)
Occupation, n (%)				
Resident	5 (83.3)	8 (100)	14 (93.3)	27 (93.1)
Fellow	0	0	1 (6.7)	1 (3.4)
Urologist	1 (16.7)	0	0	1 (3.4)
Year of Residency, n (%)				
5th	3 (60)	2 (25)	0	5 (18.5)
6th	2 (40)	6 (75)	14 (100)	22 (81.5)
Experience laparoscopic surgery, n (%)				
Surgery on real patients	5 (83.3)	7 (87.5)	14 (93.3)	26 (89.7)
Assisted during laparoscopic surgery	1 (16.7)	3 (37.5)	5 (33.3)	9 (31.0)
Experience laparoscopic surgery on real patients, n (%)				
<10 hours	0	0	2 (13.3)	2 (6.9)
10-30 hours	1 (16.7)	2 (25.0)	4 (26.7)	7 (24.1)
30-60 hours	5 (83.3)	3 (37.5)	3 (20.0)	11 (37.9)
60-90 hours	0	2 (25.0)	4 (26.7)	6 (20.7)
>90 hours	0	0	1 (6.7)	1 (3.4)
Experience robot assisted surgery, n (%)				
Assisted during robot assisted surgery	2 (33.3)	4 (50.0)	4 (46.7)	10 (34.4)
Simulation expe-rience	3 (50.0)	0	6 (40.0)	9 (31.0)
Surgery on real patients	2 (33.3)	5 (62.5)	9 (60.0)	16 (55.2)
No experience using the surgical robot	0	1 (12.5)	0	1 (3.4)
Experience robot assisted surgery on real patients, n (%)				
0 hours	0	3 (37.5)	6 (40.0)	9 (31.0)
<10 hours	2 (33.3)	0	1 (6.7)	3 (10.3)
10-20 hours	2 (33.3)	1 (12.5)	6 (40.0)	9 (31.0)
20-30 hours	1 (16.7)	4 (50)	2 (13.3)	7 (24.1)
>30 hours	1 (16.7)	0	0	1 (3.4)

were fellows at the time of the course. Most of the residents selected for the course (81.5%) were attending last year (sixth year).

Most (89.7%) of the participants had experience in laparoscopic surgery on real patients (Table 2). More than half of the participants reported to have performed more than 30 hours of laparoscopic surgery on patients prior to the training. More than half of the participants had experience with RAS on patients, only one participant did not have any experience with RAS of Robot-assisted simulation. Of the participants, 58% had more than 10 hours or RAS experience on real patients prior to their participation in the course.

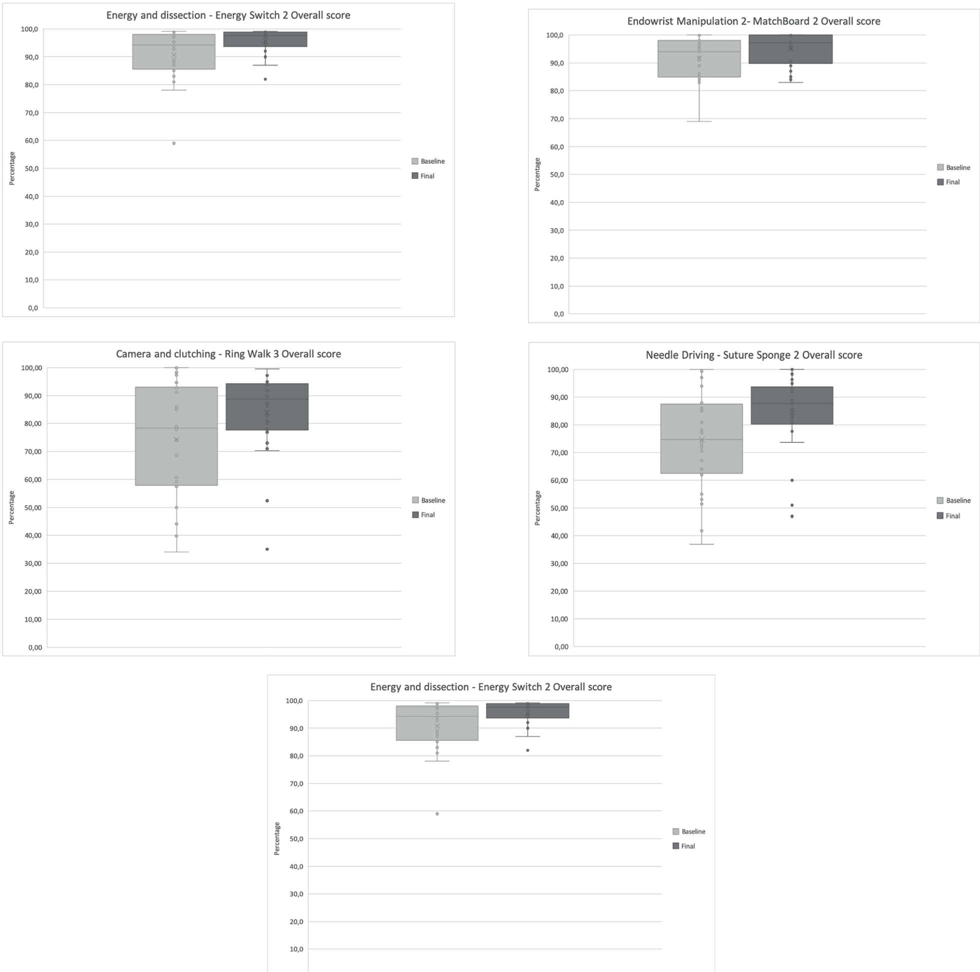

Figure 1 Box and whisker plot representing the overall score for all participants on the virtual reality da Vinci skills simulator before (light grey) and after (dark grey) the training.

Scores on the simulation exercises

The overall scores of the simulation exercises on the VR simulator are represented in Appendix 3 and Figure 1. All participants show a significant increase in overall score following the training. The highest increase in simulator scores were seen in the camera and clutching and needle driving exercises (78.40 vs 87.40, p=0.040). The lowest increase was seen in the Endowrist manipulation exercises (93.40 vs 97.65, p=0.045).

Follow-up data of the participants

A total of 11 participants (78,6%) have responded to the follow-up questionnaire administered 6 months after the course (Table 3). 10 out of the 11 respondents have performed RAS on a real patient in the first six months after the course. More than half of the respondents (6 out of 10) have performed 10 or more robot assisted surgery procedures as a first surgeon in this time. Most of the respondents (90%) performed robot assisted radical prostatectomy's in this period. Some also performed robot assisted radical cystectomy's (36.6%), robot assisted partial nephrectomy's (36.6%) or robot assisted radical nephrectomy's (27,3%) in the first six months after the course.

A total of 11 participants out of 14 responded to the questionnaire administered 12 months after the course (Table 5). More than 90% of the respondents have performed robot assisted surgery on a real patient in the first year after the course. Half of the respondents (5 out of 10) have performed 10 or more robot assisted surgery procedures as a first surgeon in this period. Seven out of 10 respondents performed robot assisted radical prostatectomies in the 12 months after the course. Five respondents also performed robot assisted radical nephrectomies, 3 performed robot assisted radical cystectomies and 2 performed robot assisted partial nephrectomies.

Factors predicting exposure to robot assisted surgery during follow-up

A total of 10 respondents indicated how many RAS procedures they performed as first surgeons during the first 6 months after the course. The results in appendix 4 show the baseline and final overall scores of the simulation exercises. The scores do not predict the chance of a participant performing more than 10 RAS procedures as a first surgeon.

Table 3 General information and robot assisted surgery experience for the residents who responded to the 6 months and 12 months questionnaires

	2018 at 6 months (n=6)	2019 at 6 months (n=5)	2018 at 12 months (n=5)	2019 at 12 months (n=6)
Occupation, n (%)				
Resident	3 (50)	1 (20)	3 (60)	2 (33.3)
Urologist	2 (33.3)	1 (20)	1 (20)	3 (50)
Fellow	1 (16.7)	3 (60)	1 (20)	1 (16.7)
Year of Residency, n (%)				
5th	3 (100)	1 (100)	3 (100)	0
6th	0	0	0	2 (100)
Sex, n (%)				
Male	5 (83.3)	3 (60)	4 (80)	3 (50)
Female	1 (16.7)	2 (40)	1 (20)	3 (50)
Nationality, n (%)				
Belgian	0	3 (60)	0	3 (50)
Dutch	6 (100)	2 (40)	5 (100)	3 (50)
Experience robot assisted surgery, n (%)				
Assisted during robot assisted surgery only	1 (16.7)	2 (40)	0	1 (16.7)
Only simulation experience	1 (16.7)	0	0	0
Surgery on real patients	6 (100)	4 (80)	5 (100)	5 (83.3)
Robot assisted surgery's on real patients as first surgeon, n (%)				
< 5	2 (33.3)	0	3 (60)	2 (40)
5-10	1 (16.7)	1 (20)	0	
10-15	2 (33.3)	1 (20)	1 (20)	
>15	1 (16.7)	2 (40)	1 (20)	3 (60)
Types of Robot assisted surgery, n (%)				
Radical Cystectomy	3 (50)	1 (20)	1 (20)	2 (40)
Radical Prostatectomy	6 (100)	4 (80)	5 (100)	2 (40)
Partial Nephrectomy	2 (33.3)	2 (40)	1 (20)	1 (20)
Radical Nephrectomy	2 (33.3)	1 (20)	2(40)	3 (60)

Discussion

In this study, we combine the results of a snap shot survey amongst Dutch residents and recently graduated urologists with the results of residents who participated in an advanced course in Robot Assisted Surgery in order to answer the following research questions:

(1) What is the current availability of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency in urology curriculum? (2) Do residents show a significant increase in Simulation-based surgical skills following the curriculum? (3) Are residents able/allowed by their trainers to perform robot assisted surgery as first surgeon after the curriculum?

What is the current availability of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency in urology curriculum?

A majority of the residents and more than half of the urologists who responded to the questionnaire were interested in the field of robot assisted surgery.

The results of the questionnaire show the majority of respondents were working in hospitals which have a surgical robot available. Almost half of these robots have a Dual console attached to them. The presence of a dual console gives the opportunity to learn on site robot assisted surgery in a safe and controlled manner.[4,18] Thus reducing the risk for the patient and increasing the novice surgeons ability to learn.

A majority of the urologists were allowed to perform robot assisted surgery during their residency. This percentage was lower in the group of residents which could be explained by the fact that 25% of the responding residents were in the first two years of their residency. None of the urologists performed robot assisted surgery during the first two years of their residency. In both the urologist and residents group the majority of the respondents was allowed to perform robot assisted surgery before their fifth year of residency. This sparks the discussion whether a basic RAS skills course should be implemented in an earlier stage of the urological curriculum (i.e. in year 3 or 4) in order to provide the residents with a basic understanding of RAS and the robot system. This basic RAS skills course could consist of the basic aspects of the robot system (i.e., hands-on training, combined with theoretical information) and basic surgical skills for RAS (i.e. draping and docking and simulation training).

Even though almost all respondents who were allowed to perform robot assisted surgery during their residency had to pass some form of basic requirements before being allowed to perform parts of the surgery. The level of these requirements varied significantly from an online training course developed by the manufacturer of the system to the requirement to pass all skills simulator exercises and participate in a standardized course at a training institute (i.e. ORSI academy). These results are in line with the results of Brinkman et al.[3] and show there is a need for implementation of structured robot assisted surgery training during the residency. The implementation of a multi-step training and certification divided in online knowledge training, basic skills training (i.e. basic skills training, draping and docking, patient positioning, and general safety issues) and procedure-specific training could prepare the residents to safely take their first steps in robot assisted surgery thus reducing the risks for the patients.[3] Most of the residents and almost half of the urologists agree robot assisted surgery training should be implemented in the residency of urologist.

The advanced course in Robot Assisted Surgery

A total of 29 participants with varying experience with both laparoscopic and robot assisted surgery completed the training curriculum. Results show most participants had extensive experience in laparoscopic surgery prior to the start of the training. The level of robot assisted surgery experience varied amongst participants, more than half of the participants had more than 10 hours of robot assisted surgery clinical experience as first surgeon prior to the start of the course of Robot Advanced Surgery.

During the advanced course in Robot Assisted Surgery the dog and pig models were used. The dog cadaver is an excellent anatomical model because the dog's prostate is quite similar to human regarding shape and size and the anatomical structures are easily recognizable. It is also good for training on constructing the urethro-vesical anastomosis. The length of its urethra, and the possibility to perform leakage-test, are important added values. Lymph nodes are easy detectable as they appear as agglomerated beans, clearly distinguishable from fatty tissue. A disadvantage of this dog cadaver model is absence of the seminal vesicles, and the absence of bleeding and peristalsis of the ureters.

When the live-pig model is used, the life-threatening maneuvers must be carefully avoided. This makes the training on the pig model more challenging and closer to real surgery compared to the dog model. The live-pig model, in comparison to the cadaver-dog model, presents large seminal vesicles which permits proper dissection training. However, it also presents disadvantages. The prostate gland is tiny, and its shape is different in comparison to the human one. For this reason, the prostate dissection in the pig is less didactic than in the dog model. Moreover, a leakage test cannot be performed because of the impossibility to insert a catheter. Lastly, the pig's bladder must be repeatedly and carefully emptied to avoid urine leakage and reabsorption. Excessive reabsorption of urea can result in the animal's death.

Do residents show a significant increase in Simulation-based surgical skills following the curriculum?

Even though the baseline skills simulation results of the current study are high, the participants were still able to show a significant increase in overall scores of all skills simulation exercises during the final assessment. When comparing this increase to the study of Larcher et al.[17] the increase in skills simulation exercise scores in the current study is 7 - 11 % lower, only in the Suture sponge 2 exercise was the median increase in skills simulation exercise scores in this study approximately 3% higher.[17] This difference in increase in scores could be the results of high baseline skills simulation results of the participants in the current study which leaves less room to increase in simulation skills. Since the participants in the current study received the same training in ORSI as the participants in the study by Larcher et al. this could not be of influence on the increase in scores on the skills simulation exercises.[17]

Are residents allowed by their trainers to perform robot assisted surgery after the curriculum?

The results of the follow-up data show residents were allowed by their trainers to perform robot assisted surgery after participating in the current course. At 6 and 12 months after the course, almost all respondents were allowed to perform robot assisted surgeries as first surgeon. More than half of the respondents were able to do 10 or more surgeries in the first 12 months after the course. All of the participants were able to do Robot Assisted Radical Prostatectomies six months after the course, at 12 months after the course 7 out of 10 were allowed to perform Robot Assisted Radical Prostatectomies. Some of the participants were allowed to do other urological surgeries using the robot i.e. nephrectomies, partial nephrectomies and cystectomies. This shows that even though the course was designed to train the participants in the skills needed for Robot Assisted Radical Prostatectomy, the participants were able to apply the skills they learned to different types of surgery. This is in line with the follow-up of the fellows of the CC-ERUS fellowship.[19]

Analysis shows the baseline skills simulation exercise scores and final skills simulation exercise scores cannot be used to predict the chances of a participant to perform 10 or more robot assisted surgeries in the first 6 months after the course. This could be explained by the fact that there is some discussion on the transference of simulator skills to real life situation.[20] Although there are multiple studies showing expert robotic surgeons have a shorter learning curve[21] or higher overall scores in simulator exercises[21–24], only limited studies have proven the transference of skills learned during simulator training to real life situations.[25,26] Despite this, the fact that most residents from the training group continued with robotic surgery in the period right after their training supports the chosen timing of the course in the residents curriculum. Of course, the possibility to perform robot assisted surgery is also dependent on external factors such as the availability of the surgery's and competition for OR time with other residents or fellows.

Strengths and limitations

The results of the snapshot questionnaire give insight into the current state of training for robot assisted surgery and the possibility to perform robot assisted surgery during Dutch residency curriculum. Although the group studied was a selection (50 %) of all Dutch residents in urology and recently graduated urologist, they do show the implementation of robot assisted surgery training and the requirements set by the educators before the residents are allowed to take their first steps in robot assisted surgery. At several steps some of the respondents were directed to the end of the questionnaire based on their responses, for example residents who are not interested in performing robot assisted surgery and urologists who never performed robot assisted surgery were sent to the end of the questionnaire, this explains the reduction of the number of responses during the questionnaire. The goal of the questionnaire is to provide an overview of the availability of robot assisted surgery training and the possibility to perform robot assisted surgery during Dutch residency curriculum, the addition of participants who don't find robot assisted surgery interesting or who never performed robot assisted surgery does not add to the strengths of the results.

The performance of residents during a structured Advanced Course in Robot Assisted Surgery at ORSI academy combined with the 12-month follow-up of the participants provides information on the usefulness of the course and the chances of performing robot assisted surgery after completing the course. Although only a small number of residents participated in the course and some did not respond to the questionnaires the results do give a unique insight into the opportunities for residents to perform robot assisted surgery. A limitation of the follow-up using questionnaires could be an over representation of the success rate of the course, since it could be possible some of the participants of the course who did not responded were unable to perform robot assisted surgery and thus do not wish to respond to the questionnaires.

Although participants show an increase in simulation-based surgical skills the question remains whether these results translate to real life surgery. It remains unclear if participants of a structured training program as provided in this study show significantly better postoperative outcomes (both functional outcome and complication rates) compared to colleagues who did not participate in this type of course. Additional research into the long-term effects of a structured training program should answer this question.

nificantly better postoperative outcomes (both functional outcome and complication rates) compared to colleagues who did not participate in this type of course. Additional research into the long-term effects of a structured training program should answer this question.

Conclusion

The results of our study show residents in urology are allowed to perform robot assisted surgery during their residency whilst criteria for starting RAS differ significantly amongst the teaching hospitals. In order to guarantee a basic level of skills and knowledge a structured (multi-step) training and certification program for RAS should be implemented. To ensure patient safety, reduce the risks for patients, and prepare the resident for his or her first attempt at surgery on a real patient. The option of an advanced structured course equipped with all training models showed to be attractive for enthusiastic novice RAS surgeons. The participation to a well-structured advanced training course in robotic surgery implies an improvement of surgical skills and permits most of the senior residents and young specialists in Urology to perform/practice/continue their career in RAS at their hospitals after the course.

Appendix

Appendix 1: Criteria for participation in the Robot assisted surgery course for residents.

1. A document signed by your University supervisor, stating that you are in your last year of residency.
2. A letter of recommendation by one of your former or current (onco/robot) supervisors.
3. A statement by the person who will be your supervisor after the course, which confirms that you will have access to robotic surgery in the near future (ideally you should be able to take part in at least 9 robotic procedures in the next 3 months). We will ask you to log these procedures.
4. A certificate or other proof that you attended at least one practical course in robotic surgery (such as ESRU Starter's package, ESU/ERUS Hand-on training in Robotic surgery, WRSE24, other).
5. A letter of motivation that explains why you apply for this course.
6. Successful completion of the online training module for the Da Vinci Xi (attach certificate). Link: https://www.davincisurgerycommunity.com/Clinical/Urology-?tab1=CL

Appendix 2 advanced course in Robot Assisted Surgery curriculum

Duration	5 days
Day 1	
• Introduction of the training program • System overview of the Da Vinci Xi and X; Docking, port placement • Simulator exercises and tests of the ERUS Curriculum • Simulation training and docking exercises • Exercises on the Pelvic Model & suturing pad, vesico-urethral anastomosis kit • Venezuelan Chicken model & vesico-urethral anastomosis exercises	
Day 2	
Half group	Half group
All steps of the prostatectomy on a canine cadaver	**Live Case Observations**
Radical prostatectomy • Endopelvic fascia incision and pre-prostatic adipose tissue removal • Bladder neck incision • Ductus deferentes identification and section • Denonviller's fascia detachment and sparing • Prostatic vascular pedicles sparing • Urethro-vescical anastomosis • Pelvic Lymphadenectomy • Dissection of pelvic arteries and veins • Fat tissue removal • Ureter re-implantation • Ureter isolation and section	**Location: OLV hospital Aalst, Moorselbaan 164, 9300 Aalst** Live case observations with dual bay console. Procedures and techniques that will be used during the training week are demonstrated. Logistical organization of the surgery room is highlighted. Surgery program dependent on planning hospital. Minimum 4 procedures.

<table>
<tr><td colspan="2">Day 3</td></tr>
<tr><td colspan="2">All steps of the prostatectomy on a living pig model

Radical prostatectomy
• Endopelvic fascia incision and pre-prostatic adipose tissue removal
• Bladder neck incision
• Seminal vesicles identification and dissection
• Denonviller’s fascia detachment and sparing
• Urethro-vesical anastomosis
• Pelvic Lymphadenectomy
• Dissection of pelvic arteries and veins
• Fat tissue removal / Ureter re-implantation
• Ureter isolation and section
• Urethro-vesical anastomosis</td></tr>
<tr><td colspan="2">Day 4</td></tr>
<tr><td>Half group</td><td>Half group</td></tr>
<tr><td>Live Case Observations</td><td>All steps of the prostatectomy on a canine cadaver</td></tr>
<tr><td>Location: OLV hospital Aalst, Moorselbaan 164, 9300 Aalst

Live case observations with dual bay console. Procedures and techniques that will be used during the training week are demonstrated. Logistical organization of the surgery room is highlighted.

Surgery program dependent on planning hospital. Minimum 4 procedures.</td><td>Radical prostatectomy
• Endopelvic fascia incision and pre-prostatic adipose tissue removal
• Bladder neck incision
• Ductus deferentes identification and section
• Denonviller’s fascia detachment and sparing
• Prostatic vascular pedicles sparing
• Urethro-vescical anastomosis
• Pelvic Lymphadenectomy
• Dissection of pelvic arteries and veins
• Fat tissue removal
• Ureter re-implantation
• Ureter isolation and section</td></tr>
</table>

Day 5
All steps of the prostatectomy on a living pig model **Radical prostatectomy** • Endopelvic fascia incision and pre-prostatic adipose tissue removal • Bladder neck incision • Seminal vesicles identification and dissection • Denonvillier’s fascia detachment and sparing • Urethro-vesical anastomosis • Pelvic Lymphadenectomy • Dissection of pelvic arteries and veins • Fat tissue removal / Ureter re-implantation • Ureter isolation and section • Urethro-vesical anastomosis
Simulator exercises and tests of the ERUS Curriculum

Appendix 3 The baseline, final and difference in overall score for all participants on the virtual reality da Vinci skills simulator

Exercise	Metric	Number of participants of which data was available	Baseline		Final		Difference in score		P-value	Z score
			Median	25th - 75th percentile	Median	25th - 75th percentile	Median	25th - 75th percentile		
Endowrist Manip-ulation 2- Match Board 2	Overall score (%)	24	94.00	84.25 -98.00	98.60	89.43 - 100.00	2.50	.03 - 7.68	0.043	-2.024
Energy and dis-section-Energy Switch 2	Overall score (%)	24	93.40	85.20 – 97.80	97.65	92.55 – 98.90	1.75	-2.25 – 12.48	0.045	-2.000
Camera and clutching - Ring Walk 3	Overall score (%)	24	78.40	58.28 – 92.40	87.40	77.18 – 94.78	11.95	-0.93 – 20.83	0.040	-2.057
Needle Driving - Suture Sponge 2	Overall score (%)	25	74.40	63.00 – 86.10	87.80	81.65 – 94.05	10.30	2.20 – 22.10	0.002	-3.054
Needle Driving - Tubes	Overall score (%)	24	78.75	63.68 – 85.90	88.50	76.15 – 94.98	6.10	0.55 – 26.35	0.010	-2.572
Average overall scores	Overall score (%)	22	82.15	76.52 – 87.59	89.14	83.60 – 93.86	6.65	1.43 – 15.82	0.002	-3.068

Appendix 4 Univariate analysis of factors predicting the chance of performing 10 or more robot assisted surgery procedures as a first surgeon in the first 6 months

	OR	95.0% C.I. for OR	P-value
Endowrist Manipulation 2- Match Board 2 exercise - baseline overall score	0.943	0.758 – 1.174	0.600
Energy and dissection-Energy Switch 2 exercise - baseline overall score	0.937	0.866 – 1.094	0.651
Camera and clutching - Ring Walk 3 exercise - baseline overall score	1.074	0.982 – 1.176	0.119
Needle Driving - Suture Sponge 2 exercise - baseline overall score	1.021	0.954 – 1.092	0.550
Needle Driving – Tubes exercise - final overall baseline overall score	1.041	0.957 – 1.133	0.352
Endowrist Manipulation 2- Match Board 2 exercise - final overall score	1.304	0.708 – 2.403	0.394
Energy and dissection-Energy Switch 2 exercise - final overall score	3.724	0.386 – 35.906	0.256
Camera and clutching - Ring Walk 3 exercise - final overall score	1.108	0.912 – 1.346	0.302
Needle Driving - Suture Sponge 2 exercise - final overall score	1.083	0.958 - 1.224	0.203
Needle Driving – Tubes exercise - final overall score	1.114	0.922 – 1.347	0.263

References

1. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP, Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];

2. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;

3. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.

4. Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg [Internet]. 2015 Jan [cited 2017 Aug 17];13:115–23.

5. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Platinum Priority – Education Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. 2015;8(2):9–2.

6. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101.

7. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.

8. Khan R, Aydin A, Khan MS, Dasgupta P, Ahmed K. Simulation-based training for prostate surgery. BJU Int [Internet]. 2015 Oct 1 [cited 2018 Mar 27];116(4):665–74.

9. Kruger J, Dunning D. Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. J Pers Soc Psychol [Internet]. 1999 [cited 2018 Mar 22];77(6):1121–34.

10. Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX, Sriprasad S. Partial vs radical nephrectomy for T1 renal tumours: an analysis from the British Association of Urological Surgeons Nephrectomy Audit. BJU Int [Internet]. 2016 Jan [cited 2017 Jan 7];117(1):62–71.

11. Puliatti S, Mazzone E, Dell'Oglio P. Training in robot-assisted surgery. Curr Opin Urol. 2020;30(1):65–72.

12. Beulens AJW, Brinkman W, Porte P, Meijer R, Van Merriënboer J, Van Der Poel H, Wagner C. The value of a one-day multidisciplinary robot surgery training for novice robot surgeons. J Robot Surg. 2018;

13. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers' Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377.

14. Satava RM, Stefanidis D, Levy JS, Smith R, Martin JR, Monfared S, Timsina LR, Darzi AW, Moglia A, Brand TC, Dorin RP, Dumon KR, Francone TD, Georgiou E, Goh AC, Marcet JE, Martino MA, Sudan R, Vale J, et al. Proving the Effectiveness of the Fundamentals of Robotic Surgery (FRS) Skills Curriculum: A Single-blinded, Multispecialty, Multi-institutional Randomized Control Trial. Ann Surg [Internet]. 2019 Jan 31 [cited 2020 Feb 19];

15. Mottrie A, Novara G, van der Poel H, Dasgupta P, Montorsi F, Gandaglia G. The European Association of Urology Robotic Training Curriculum: An Update. Eur Urol Focus [Internet]. 2016;2(1):105–8.

16. Stolzenburg JU, Qazi HAR, Rai BP. The European Association of Urology Robotic Training Curriculum: The Journey Has only Just Begun. Eur Urol [Internet]. 2015;68(2):300–1.

17. Larcher A, Turri F, Bianchi L, Dell'Oglio P, Collins J, Capitanio U, Montorsi F, Mottrie A. Virtual Reality Validation of the ERUS Simulation-based Training Programmes: Results from a High-volume Training Centre for Robot-assisted Surgery. Eur Urol [Internet]. 2019;75(5):885–7.

18. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.

19. Beulens AJW, Dell'Oglio P, Kiss H, Brinkman WM, Larcherd A, Mottrie A, Wagner C, Poel HG van der. Five Years of the CC-ERUS Fellowship: A Survey of the Experiences and Post-fellowship Work of the Fellows. Eur Urol OPEN Sci. 2020;9–11.

20. Moglia A, Ferrari V, Morelli L, Ferrari M, Mosca F, Cuschieri A. A Systematic Review of Virtual Reality Simulators for Robot-assisted Surgery. Eur Urol [Internet]. 2016 Jun [cited 2020 Apr 22];69(6):1065–80.

21. Meier M, Horton K, John H. Da Vinci© Skills SimulatorTM: is an early selection of talented console surgeons possible? J Robot Surg. 2016;10(4):289–96.

22. Ramos P, Montez J, Tripp A, Ng CK, Gill IS, Hung AJ. Face, content, construct and concurrent validity of dry laboratory exercises for robotic training using a global assessment tool. BJU Int [Internet]. 2014 May 1 [cited 2020 Apr 22];113(5):836–42.

23. Kenney PA, Wszolek MF, Gould JJ, Libertino JA, Moinzadeh A. Face, Content, and Construct Validity of dV-Trainer, a Novel Virtual Reality Simulator for Robotic Surgery. Urology [Internet]. 2009 Jun 1 [cited 2020 Apr 22];73(6):1288–92.

24. Lee JY, Mucksavage P, Kerbl DC, Huynh VB, Etafy M, McDougall EM. Validation Study of a Virtual Reality Robotic Simulator—Role as an Assessment Tool? J Urol [Internet]. 2012 Mar [cited 2020 Apr 22];187(3):998–1002.

25. Aghazadeh MA, Mercado MA, Pan MM, Miles BJ, Goh AC. Performance of robotic simulated skills tasks is positively associated with clinical robotic surgical performance. BJU Int [Internet]. 2016 Sep [cited 2017 Aug 9];118(3):475–81.

26. Schout BMA, Ananias HJK, Bemelmans BLH, D'Ancona FCH, Muijtjens AMM, Dolmans VEMG, Scherpbier AJJA, Hendrikx AJM. Transfer of cysto-urethroscopy skills from a virtual-reality simulator to the operating room: a randomized controlled trial. BJU Int [Internet]. 2009 Nov 12 [cited 2020 Apr 22];106(2):226–31.

Chapter 5

Five Years of the CC-ERUS Fellowship: A Survey of the Experiences and Post-fellowship Work of the Fellows

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Abstract

A web-based survey was delivered to European Robotic Curriculum (CC-ERUS) Fellows in order to gain insights into the experiences of the participants during and after the fellowship. Frequency and proportions were used to describe the outcome of the survey. Overall, 63% completed the survey. Over 90% of respondents still perform robot assisted surgery after the fellowship. Of these, 91% still perform Robot assisted radical prostatectomy (RARP), 36% are performing Robot assisted radical cystectomy (RARC), 42% are performing Robot assisted partial nephrectomy (RAPN). All respondents recommended ccERUS to peers. Overall, almost two-thirds are unaware of functional postoperative results of the patients treated with RARP. One-third of respondents are unaware of the oncological results of the patients after RARP. Additional focus should be put on the benefits of results awareness for surgeons during the fellowship program and on follow-up surveys to monitor need to continuous education.

Patient summary

A web-based survey was performed amongst participants of a robot assisted surgery course. We observed that most participants still perform robot assisted surgery after completion of the course. All participants would recommend the course to their colleagues.

Introduction

With the introduction of Robot assisted surgery there is an impending need to develop structured training in order to assist naïve surgeons during their learning process and improve patients outcomes.[1–8] in response to this call multiple short courses have been designed to train (novice) surgeons in different urological procedures.[9–11] The European Association of Urology Robotic Urology Section (ERUS) has developed the first long term structured and validated curriculum in urology that specifically focuses on Robot assisted radical prostatectomy (RARP).[5,6,12,13] After its initial conception in 2014 the program has evolved into a structured training program including live case observation and table-side assistance, an advanced robotic skills course (CC-ERUS), three or six months modular training at a host centre, and an expert assessment of the video of a full RARP performed by the fellow.[12] With the specific intent to expand such paradigm also to other setting in which clinical outcomes are importantly affected by surgeon's[14], the ERUS Curriculum for robot-assisted partial nephrectomy[15] and for robot-assisted radical cystectomy were further developed.[16] However, to validate the benefit of such structured training programs, the clinical outcomes of patients treated after the training program by the surgeons involved in the ERUS Curricula deserves special attention. The aim of the current study was to investigate and report the experiences of the RARP fellowship.

Method

A web-based survey was developed by a group of six experts in urology. Participants who participated in the 5-Day advanced Robotic Skills Course for the RARP at ORSI Academy were contacted. Since it is possible to participate in this course as part of a fellowship at a CC-ERUS Host centre and as a standalone course all participants were contacted in order to not miss any CC-ERUS fellows.

A survey was sent in order to assess their learning process and their present robotic practices. The survey was divided into three modules containing 62 questions (Supplementary data). The questionnaires were sent to the participants using the self-service function of the Data Management module developed by de Research Manager (https://my-researchmanager.com/en/home-2/). Mailing lists were verified with EAU-membership data. All participants in the 5-Day advanced Robotic Skills Course (CC-ERUS) received the survey. After a period of 4 months the survey was closed and results were analysed. Frequency and proportions were used to describe the outcome of the survey. Data analysis was performed using SPSS statistics v24 (IBM, NY).

Results

A total of 143 people received the survey. Overall, 63% (n=90) responded and 50% of these respondents underwent CC-ERUS RARP fellowship. Almost 50% of the respondents were residents in training at the start of the CC-ERUS fellowship. Of the remaining fellows more than half have less than 2 years of experience as a certified urologist. 49% and 71% of the respondents had no experience as a first surgeon in laparoscopic and robotic surgery, respectively. Most of the participants (55.6%) had a clinical fellowship of more than six months, 8.9% had a clinical fellowship of three months.

During the fellowship, 76% of the respondents were 3 or more days a week in the operating room. 47% of the respondents performed more than 5 robotic cases per week, not all of these cases were RARP (table 1). Almost all respondents (96%) felt there was enough progression in difficulty in the steps of the RARP they were allowed to perform. 73% of the respondents performed or assisted in more than 45 cases during their fellowship. Almost all participants (86.7%) were able to perform a complete RARP case during their fellowship. Overall, 20 and 8.9% of the responders were able to perform a complete RAPN and RARC case, respectively (table 1).

Table 1 Activities of the respondents during their clinical fellowship

	Number of participants	%
Number of robotic cases in an average week during the clinical fellowship		
1 case per week	5	11.1
2-5 cases per week	19	42.2
>5 cases per week	21	46.7
Number of RARP cases in an average week during the clinical fellowship		
1 case per week	6	13.3
2-5 cases per week	24	53.5
>5 cases per week	15	33.3
Number of RARC cases in an average week during the clinical fellowship		
1 case per week	40	88.9
2-5 cases per week	4	8.9
>5 cases per week	1	2.2
Number of RAPN cases in an average week during the clinical fellowship		
1 case per week	33	73.3
2-5 cases per week	11	24.4
>5 cases per week	1	2.2
participants who had the opportunity to perform a complete case		
RARP	39	86.7
RARC	4	8.9
RAPN	9	20.0

At the end of the fellowship the participants were asked to provide a full case video to evaluate by certified independent examiners in blind-review process. A total of 28 (62%) handed in an index video for review, of these only 12 (43%) received a score from the experts. All respondents would recommend the CC-ERUS fellowship to their colleagues.

The results in table 2 show the activities of the respondents after their clinical fellowship. Less than half of the fellows were able to stay in the institute of their training after the fellowship. After the fellowship 93% of the respondents had access to a

Table 2 Activities of the respondents during and after their clinical fellowship

	Number of participants	%
Number of participants who stayed in their training institute after the fellowship		
No	23	51.1
Yes, less than 3 months	1	2.2
Yes, more than 3 months	21	46.7
Number of participants who had access to a surgical robot after the fellowship	42	93.3
Currently performing robot assisted surgery	41	91.1
Currently performing RARP	39	86.7
Currently performing RARC	16	35.6
Currently performing RAPN	19	42.2
Currently performing Laparoscopic prostatectomy	5	11.1
Currently performing Open prostatectomy	8	17.8

surgical robot, of these 91% are currently still performing robot assisted surgery. Thirty-nine respondents (91%) are performing RARP surgery, 16 (36%) are performing RARC and 19 (42%) are performing RAPN surgery.

A minority of the respondents are performing open (18%) or laparoscopic prostatectomy (11%).

Table 3 shows the functional and oncological outcomes of the most recent surgeries performed by the fellows involved in the CC-ERUS RARP fellowship. More than 50% of the participants to the fellowship are unaware of the continence and erectile function recovery of the patients treated in the last six months. The participants were more aware of the positive surgical margins in their last 10 pT2 and pT3 patients (Table 3).

Table 3 Functional and oncological outcomes of the most recent surgeries performed by the fellows

	Number of participants	%
Percentage of patients that use more than one inlay/diaper per day of surgeries performed in the last 6 months		
1-10%	10	22.2
11-20%	7	15.6
21-30%	1	2.2
31-40%	1	2.2
unknown	26	57.8
Percentage of patients that have adequate erectile function of surgeries performed in the last 6 months		
11-20%	3	6.7
21-30%	2	4.4
31-40%	5	11.1
41-50%	5	11.1
51-60%	2	4.4
71-80%	1	2.2
unknown	27	60.0
Number of patients with a positive surgical margin in the last 10 pT2 cases		
0 patients	5	11.1
1 patient	5	11.1
2 patients	11	24.4
3 patients	8	17.8
4 patients	2	4.4
Unknown margins	14	31.1
Number of patients with a positive surgical margin in the last 10 pT3 cases		
0 patients	12	26.7
1 patient	13	28.9
2 patients	6	13.3
3 patients	2	4.4
unknown	12	26.7

Discussion

Although not all fellows responded to the survey, the results of this questionnaire give insights into the experiences of the respondents during and after the CC-ERUS fellowship. Many of the respondents were resident at the start of the CC-ERUS fellowship. Although almost two-thirds of the respondents participated in the video review at the end of the course not even half of them received a score on their video. All respondents recommend the CC-ERUS fellowship to their colleagues. Most of the respondents to this survey continue to practice robot assisted surgery, this is in line with earlier research on this subject which showed most of the participant still performed robot assisted surgery based on short term (14 months) and long term (up to 3 years post training) follow-up data.17,18 Even though the course was designed to train the fellows in RARP some respondents have gained experience in RAPN and RARC surgery during and after the fellowship. This endorses the need for specialized fellowship programs for both RAPN and RARC procedure in order to provide a structured training program for urologists. Remarkably results show almost two thirds of the respondents are unaware of the functional outcomes of their patients. One third of the respondents were unaware of the oncological outcomes of their surgeries. We recommend to have a more rigorous follow-up of trainees in surgical fellowship to improve elements of the fellowship program and monitor the need for continuous education after the fellowship.

Conclusion

Results of this survey show additional focus should be put on both functional and oncological outcomes during the fellowship. Most respondents are still practicing robot assisted surgery. Specialized fellowship programs for both RAPN and RARC procedure should be developed in order to provide structured training in these procedures.

References

1. Porte P.J., Verweij L.M., Bekkers R.L.M., Consten E.C.J., Lichtenberg H., van der Poel, H.G., van Swol C.F.P. Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];

2. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;

3. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.

4. Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg [Internet]. 2015 Jan [cited 2017 Aug 17];13:115–23.

5. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Platinum Priority – Education Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. 2015;8(2):9–2.

6. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101.

7. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.

8. Palagonia E, Mazzone E, De Naeyer G, D'Hondt F, Collins J, Wisz P, Van Leeuwen FWB, Van Der Poel H, Schatteman P, Mottrie A, Dell'Oglio P. The safety of urologic robotic surgery depends on the skills of the surgeon. World J Urol [Internet]. 2019;

9. Beulens AJW, Brinkman W, Porte P, Meijer R, Van Merriënboer J, Van Der Poel H, Wagner C. The value of a one-day multidisciplinary robot surgery training for novice robot surgeons. J Robot Surg. 2018;

10. Altunrende F, Autorino R, Haber G-P, Laydner H, White MA, Khanna R, Stein RJ, Kaouk JH. Immediate impact of a robotic kidney surgery course on attendees practice patterns. Int J Med Robot [Internet]. 2011 Jun [cited 2020 Mar 4];7(2):165–9.

11. Bertolo R, Garisto J, Dagenais J, Sagalovich D, Kaouk JH. Single Session of Robotic Human Cadaver Training: The Immediate Impact on Urology Residents in a Teaching Hospital. J Laparoendosc Adv Surg Tech. 2018;28(10):1157–62.

12. Mottrie A, Novara G, van der Poel H, Dasgupta P, Montorsi F, Gandaglia G. The European Association of Urology Robotic Training Curriculum: An Update. Eur Urol Focus [Internet]. 2016;2(1):105–8.

13. Stolzenburg JU, Qazi HAR, Rai BP. The European Association of Urology Robotic Training Curriculum: The Journey Has only Just Begun. Eur Urol [Internet]. 2015;68(2):300–1.

14. Larcher A, Muttin F, Peyronnet B, De Naeyer G, Khene ZE, Dell'Oglio P, Ferreiro C, Schatteman P, Capitanio U, D'Hondt F, Montorsi F, Bensalah K, Mottrie A. The Learning Curve for Robot-assisted Partial Nephrectomy: Impact of Surgical Experience on Peri-operative Outcomes. Eur Urol [Internet]. 2019;75(2):253–6.

15. Larcher A, De Naeyer G, Turri F, Dell'Oglio P, Capitanio U, Collins JW, Wiklund P, Van Der Poel H, Montorsi F, Mottrie A. The ERUS Curriculum for Robot-assisted Partial Nephrectomy: Structure Definition and Pilot Clinical Validation. Eur Urol. 2019;75(6):1023–31.

16. Dell'Oglio P, Turri F, Larcher A, D'Hondt F, Sanchez-Salas R, Bochner B, Paolou J, Weston R, Hosseini A, Canda A, Bjerggaard J, Cacciamani G, Ørding Olsen K, Gill I, Piechaud T, Artibani W, Stenzl A, Kelly J, Dasgupta P, et al. Definition of a structured training curriculum for robot-assisted radical cystectomy: A Delphi-consensus study led by the ERUS Educational Board. Eur Urol Suppl [Internet]. 2019;18(1):e1116–9.

17. Gamboa AJR, Santos RT, Sargent ER, Louie MK, Box GN, Sohn KH, Truong H, Lin R, Khosravi A, Santos R, Ornstein DK, Ahlering TE, Tyson DR, Clayman R V., McDougall EM. Long-Term Impact of a Robot Assisted Laparoscopic Prostatectomy Mini Fellowship Training Program on Postgraduate Urological Practice Patterns. J Urol [Internet]. 2009;181(2):778–82.

18. McDougall EM, Corica FA, Chou DS, Abdelshehid CS, Uribe CA, Stoliar G, Sala LG, Khonsari SS, Eichel L, Boker JR, Ahlering TE, Clayman R V. Short-term impact of a robot-assisted laparoscopic prostatectomy 'mini-residency' experience on postgraduate urologists' practice patterns. Int J Med Robot Comput Assist Surg [Internet]. 2006 Mar [cited 2020 Mar 4];2(1):70–4.


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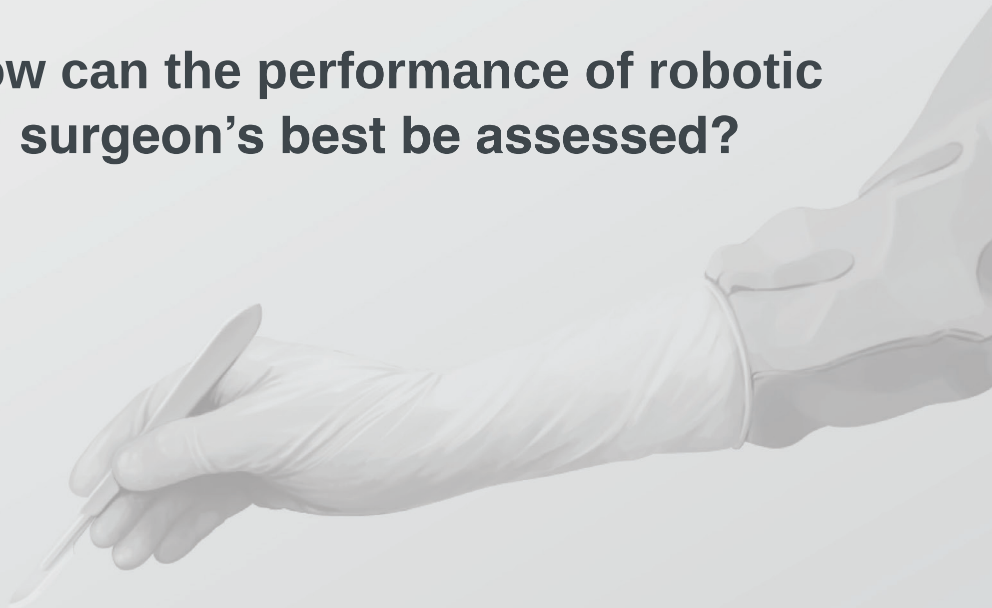
Section II

How can the performance of robotic surgeon’s best be assessed?



Chapter 6

Linking surgical skills to postoperative outcomes: a Delphi study on the robot assisted radical prostatectomy

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Abstract

Objective

To develop an assessment instrument for the evaluation of surgical videos to elucidate the association between surgical skills and postoperative outcomes after a robot-assisted radical prostatectomy (RARP).

Design

A Delphi study consisting of two consecutive online surveys and a consensus group meeting.

Setting

Urology departments of general, teaching and university hospitals in the Netherlands.

Participants

All Dutch urologists with a specialization in RARP.

Results

Of 18 invited experts, 12 (67%) participated in the first online survey. In the second round, 9 of the 18 invited experts participated (50%). The Delphi meeting was attended by 5 of the 18 (27%) invited experts. The panel identified seven surgical steps with a possible association to postoperative outcomes. The experts also expected an association between adverse postoperative outcomes and the frequency of camera removals, the number of stitches placed, the amount of bleeding, and the extent of coagulation. These factors were incorporated into an assessment instrument.

Conclusions

Experts in the field of RARP achieved consensus on 7 surgical steps and 4 aspects of the RARP procedure that may be related to adverse postoperative outcomes. The resulting assessment instrument will be tested in future research to determine its validity.

Introduction

In the Netherlands, approximately 2500 radical prostatectomies are performed annually of which 90% are performed using the surgical robot, i.e. robot-assisted radical prostatectomy (RARP). The RARP is a complex but highly standardized operation to cure local prostate cancer. However, RARP is hampered by serious side-effects[1–3] such as urinary incontinence, which occurs in 4 to 26% of the patients[4–6], and erectile dysfunction, which occurs in 14 to 90% of the patients.[7,8]

Previous research has shown that greater surgical experience is associated with better postoperative outcomes.[9-11] Therefore, the Dutch Society of Urology (NVU) increased the minimally required number of annual RARP per hospital from 50 to 100 procedures to improve functional results and reduce complications. However, at the moment there is no minimum annual number of procedures per surgeon.

Various authors suggested that systematic evaluation of skills, both technical (surgical) and non-technical (communication and teamwork) may be more effective in improving the surgeons' skills than a quota alone.[12,13] Thorough analysis of surgical videos can possibly elucidate which steps or facets of surgery may be related to disadvantageous results such as postoperative complications (i.e. bleeding and leakage of the vesico-urethral anastomosis) and adverse functional outcomes (i.e. erectile dysfunction, incontinence).[12,14]

To standardize video analysis, a detailed description of all the separate surgical steps is needed. In the past, different assessment instruments containing individual steps of the RARP have been defined[15–17], but these methods are mostly intended for providing feedback during training of new robotic surgeons or to evaluate the skills of more experienced robotic surgeons by means of video analysis. So far, no specific method has been developed to investigate how a surgeon's skills and surgical events as assessed on video are related to adverse postoperative outcomes of RARP.

The present Delphi study is designed to evaluate whether experts in the field of RARP can identify the surgical and non-surgical factors in RARP that are potentially associated with negative aspects of postoperative outcomes.

The following key questions were to be answered: which steps of the RARP and which peri-operative events (i.e. bleeding, usage of coagulation, usage of haemostatic clips and suturing) are most likely associated with postoperative complications (i.e. bleeding and leakage of the vesicourethral anastomosis) and adverse functional outcomes (i.e. erectile dysfunction, incontinence)? How can these steps of the RARP and these peri-operative events be incorporated in an RARP assessment instrument?

Methods

During a focus group consisting of three Dutch urologists, one urologist in training, and one cognitive task analysis expert a list of statements was created, describing the surgical steps and possible peri-operative events of the RARP procedure as well as their possible association with (1) direct postoperative complications and (2) functional outcomes.

These statements were formulated in order to investigate which steps of the surgery and which peri-operative events should be included in an instrument for video analysis. This assessment instrument will form the basis for further research on the possible associations between surgical skills and adverse postoperative outcomes.

Expert panel

The expert panel for the Delphi study was selected based on recommendations of three separate independent urologists who are experts in the field of robotic surgery. Based on these recommendations, 18 experts in the field of robot-assisted radical prostatectomy were selected. In this group, multiple proctors and educators of different fellowships in robotic surgery were included since they have intricate knowledge of the possible origins of complications in surgeons with all levels of experience. The experts were invited by e-mail. If no response was given the experts were contacted by telephone to ask whether they were interested to participate in the Delphi study.

Consensus procedure

To achieve consensus, a two-step procedure was used (figure 1): the first step was an online two-round Delphi Survey involving Dutch urologists experienced in RARP.

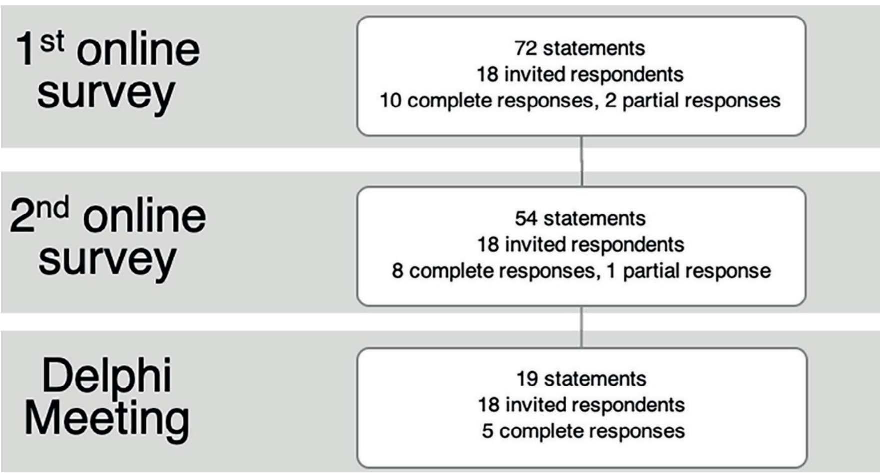

Fig 1. Visual representation of the Delphi survey.

The second step was a consensus group meeting with the same Dutch urologists to discuss the results of the online survey and to identify the aspects of the surgery and the perioperative events which might be associated with postoperative adverse outcomes. The steps of the Delphi process are based on protocols for consensus finding.[18–21]

Online two-round Delphi Survey

The results of the initial focus group were used to define seven domains in which the statements could be categorized. The domains were organized as follows:

1. The relation of the statement to postoperative complications;
2. The relation of the statement to functional results;
3. Surgical steps associated with complications (i.e. bleeding and leakage of the vesico-urethral anastomosis);
4. Surgical steps associated with postoperative erectile dysfunction;
5. Surgical steps associated with postoperative urinary incontinence;
6. Factors that play a role in the origins of postoperative complications;
7. Elements that should certainly be included in the training of novice surgeons.

The statements were used to design a two-round online Delphi Survey to obtain consensus on identifying the relevant steps of the RARP procedure and their possible causal relation to postoperative complications and adverse functional outcomes.

The panel members were asked to rate the relevance of each statement using a 9-point Likert scale according to the discriminatory power of each surgical step to correspond with the specified postoperative complication. A rating of 1 was defined as “extremely disagree” and a rating of 9 was defined as “extremely agree”. As described in the RAND/ UCLA

Appropriateness Method[22], for each item, the median agreement score, lower limit inter-percentile range (IPR), and upper limit IPR and Disagreement Index (DI) were calculated. A median agreement score of 1.0–3.0 was considered to be “disagree”, 3.1–6.9 as “uncertain”, and 7.0–9.0 as “agree”. A DI value above one (> 1) indicated a lack of consensus among the participants regarding the association between the statement and the postoperative complication.

In addition to the consensus statements, seven general questions were included in the first online survey to assess the experts opinions on the project and their willingness to cooperate in further research. In the first round, the participants were invited to suggest additional items that should be included in the second-round survey. The second survey consisted of the consensus statements. After each round, the scores for each item were anonymized to a mean ranking score for the whole group and reported back to the participants.

Consensus group meeting

During a consensus panel meeting, the statements on which consensus had been reached in the two-round online survey were reviewed and statements on which no consensus had been reached were discussed and voted on. The meeting was chaired by a urologist of the Dutch Cancer Institute, Amsterdam (HvdP).

The statements from the online survey were presented to the panel, and participants were asked to motivate their opinions on each of the statements for which no consensus had been reached previously. The list of approved steps and aspects was then categorized to develop an initial RARP assessment instrument for evaluating the surgical procedure on video. This assessment instrument was subsequently judged on face validity by the 12 experts who participated in the Delphi process.

Informed consent

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.[23] Informed consent was obtained from all participants for being included in the study.

Results

Delphi Survey

The results of the preliminary focus group meeting were used to formulate 72 statements on surgical steps and possible peri-operative events of the RARP procedure and their possible association with (1) direct postoperative complications and (2)

Table 1 Domains of statements used in the online Delphi Survey and consensus meeting

Domain	Statements in Survey (n)	Consensus in Survey (n)	Consensus Survey (%)	Statements in Delphi panel (n)	Consensus Delphi panel (n)	Consensus Delphi panel (%)	Consensus combined Delphi survey and panel (%)
The relation of the statement to post-operative complications	14	9	64	6	3	50	79
The relation of the statement to functional results	14	7	50	7	2	29	64
Steps of the surgery associated with complications	11	9	82	2	0	0	82
Steps of the surgery associated with postoperative erectile dysfunction	11	9	82	2	1	50	91
Steps of the surgery associated with postoperative urinary incontinence	11	8	73	3	2	66	91
Factors that play a role in the origins of postoperative complications	4	4	100	-	-	-	100
Elements that are essential for the training of novice surgeons	7	7	100	-	-	-	100

functional outcomes. These statements were divided over seven domains and incorporated in an online survey (Table 1).

A total of 18 Dutch experts in robot-assisted radical prostatectomy (RARP) were identified and invited to participate in the two-round online Delphi Survey. In the first round, 12 of the 18 (67%) invited experts participated in the survey. Of these 12 participants, 10 experts responded to all statements, and two participants reported difficulties with the survey resulting in a partial response to the statements.

In the first round, participants did not propose any additional statements. Of the 72 statements reviewed in the first round, 18 statements on which a clear consensus had been reached (i.e. a median agreement score of 1 or 9) were excluded from the second round. The remaining 54 statements were incorporated in the second online survey round.

Table 2 Results of general questions about video analysis, registration of postoperative outcomes, and intention to participate in the analysis of RARP videos

Question	Percentage of respondents (n)
Do you believe that it is useful to analyse surgical factors in order to improve the outcomes of patients (several options possible)	
yes, because we can learn from mistakes made	83,33 (10)
yes, because we can develop new and better surgical techniques.	83,33 (10)
no, because there is a chance that the considerations of the surgeon and patient selection play a more important role than the actual operation	8,33 (1)
Is it possible in your view to predict possible peri-operative and postoperative complications by means of video assessments?	
Yes	75 (9)
Is it possible in your view to predict postoperative (functional) outcomes by means of video assessments?	
Yes	83,33 (10)
Is it possible in your view to reduce the risk of complications by means of data obtained by video analysis?	
Yes	92% (11)
Are you prepared to participate in the analysis of surgical videos?	
Yes	100% (11)
Do you record the Robot-assisted radical prostatectomy procedure on videos?	
Yes	80% (8)
Do you have the option to correlate outcome data such as complications and functional outcomes to surgical videos?	
Yes	90,1% (10)

In the second round, nine of the 12 participants of the first round participated in the survey. Of these nine participants, eight completed the survey and one reported difficulty with the survey resulting in a partial response to the questionnaire.

General questions

Results of the general questionnaire (Table 2) show that 83.0% of the experts believe that patient outcome can be improved by analysis of critical surgical factors.

According to 75.0% and 83.3% of the experts who participated in this study, video

Table 3 consensus meeting participants and their institute, occupation and voting status

Participant	Institute	Occupation	Voting status
H. van der Poel	Antoni van Leeuwenhoek Hospital, Amsterdam/ Netherlands Cancer Institute, Amsterdam	Urologist	Voting
R. Meijer	University Medical Centre Utrecht	Urologist	Voting
H. Beerlage	Jeroen Bosch Hospital, Den Bosch	Urologist	Voting
M. Busstra	Erasmus Medical Centre, Rotterdam	Urologist	Voting
C. Wijburg	Rijnstate Hospital, Arnhem	Urologist	Voting
A. Hendrikx	Catharina Hospital, Eindhoven	Urologist N.P	Non-voting
J. van Merienboer	Maastricht University	Educational Expert	Non-voting
W. Brinkman	Erasmus Medical Centre, Rotterdam	Urologist in training	Non-voting
A. Beulens	Catharina Hospital, Eindhoven / Netherlands institute for health services research (NIVEL), Utrecht	PhD -student	Non-voting

assessment is suitable for predicting complications and functional patient outcomes, respectively. According to 92.0% of the experts, the use of video assessment could reduce the risk of complications. All experts were interested in participating in the analysis of surgical videos. Most experts had the means to record surgical videos (80.0%) and can link these videos to surgical data (90.1%).

Table 4 Results of the first and second online Delphi survey and combined consensus results after Delphi meeting. *MAS = Median agreement Score

Statement	MAS* Round 1	Consensus Round 1	MAS* Round 2	Consensus Round 2	Combined Consensus after Delphi meeting
The relation of the statement to postoperative complications					
Operating quickly results in better outcomes for the patient (speed is related to insight and therefore a good measure) in terms of complications	5	no	6	no	no
Shorter operating times result in fewer complications	6,5	no	7	agree	agree
The use of as few different instruments as possible lead to fewer complications	3	disagree	3	disagree	disagree
Not to using the 3rd arm of the robot leads to fewer complications.	1	disagree			disagree

Table 4 continued

Statement	MAS* Round 1	Consensus Round 1	MAS* Round 2	Consensus Round 2	Combined Consensus after Delphi meeting
Zooming in more on the operation field is better (closer gives better vision) as it leads to fewer complications.	5	no	5	no	no
More zooming out of the operating field is better (further away gives better overview and less dirt on the camera lens) as it leads to fewer complications.	3	disagree	3	disagree	disagree
The suture material used has an influence on the development of complications.	4,5	no	5	no	no
Fewer camera movements result in fewer complications.	5	no	3	disagree	disagree
Fewer instrument movements result in fewer complications	5	no	6	no	agree
A lower estimated blood loss results in fewer complications.	5	no	6	no	agree
A shorter duration of coagulation results in fewer complications	6	no	7	agree	agree
Placing fewer stitches results in fewer complications.	3	disagree	3	disagree	disagree
Placing fewer clips results in fewer complications.	3	disagree	4	disagree	disagree
Inspection of the abdomen leads to fewer complications	7	agree	8	agree	agree
The relation of the statement to functional results					
Operating quickly results in better functional outcomes for the patient (speed is related to insight and therefore a good measure)	4	no	5	no	no
Shorter operating times results in improved functional results.	4	no	5	no	no

Table 4 continued

Statement	MAS* Round 1	Consensus Round 1	MAS* Round 2	Consensus Round 2	Combined Consensus after Delphi meeting
The use of as few different instruments as possible leads to better functional results	3,5	no	3	disagree	disagree
Not to using the 3rd arm of the robot leads to better functional results.	2	disagree	2	disagree	disagree
Zooming in more on the operation field is better (closer gives better vision) as it leads to better functional results.	7	agree	7	agree	agree
More zooming out of the operating field is better (further away gives better overview and less dirty of the camera lens) as it leads to better functional results	4	no	2,5	disagree	disagree
The suture material used has an influence on the functional results	6	no	6	no	no
Fewer camera movements result in improved functional results	3	disagree	5,5	no	no
Fewer instrument movements result in improved functional results	5	no	6,5	no	agree
A lower estimated blood loss results in improved functional results.	4	no	6	no	no
A shorter duration of coagulation results in improved functional results	7	agree	7	agree	agree
Placing fewer stitches results in improved functional results.	4	no	4	no	disagree
Placing fewer clips results in improved functional results	5	no	3	disagree	disagree
Inspection of the abdomen results in improved functional results	3	disagree	2,5	disagree	disagree
Steps of the surgery associated with complications					
Abdominal cavity approach/port placement	5	no	6	no	no

Table 4 continued

Statement	MAS* Round 1	Consensus Round 1	MAS* Round 2	Consensus Round 2	Combined Consensus after Delphi meeting
Retropubic space approach/mobilisation of Retzius	3	disagree	2	disagree	disagree
Pelvic floor muscle exposure/opening of the endopelvic fascia	5	no	5,5	no	no
Bladder neck dissection	7	agree	7,5	agree	agree
Ligation of prostate pedicles	7,5	agree	8,5	agree	agree
Nerve preservation	8	agree	8	agree	agree
Management of prostate apex/urethra	8	agree	8,5	agree	agree
Prostate removal	3	disagree	2,5	disagree	disagree
Urethro-vesical anastomosis	8	agree	8	agree	agree
Lymph node dissection	7,5	agree	8	agree	agree
Wound closure and specimen removal	7,5	agree	7	agree	agree
Steps of the surgery associated with postoperative erectile dysfunction					
Abdominal cavity approach/port placement	1	disagree			disagree
Retropubic space approach/mobilisation of Retzius	1	disagree			disagree
Pelvic floor muscle exposure/opening of the endopelvic fascia	6	no	6,5	no	no
Bladder neck dissection	3	disagree	2,5	disagree	disagree
Ligation of prostate pedicles	8	agree	8	agree	agree
Nerve preservation	9	agree			agree
Management of prostate apex/urethra	9	agree			agree
Prostate removal	1	disagree			disagree
Urethro-vesical anastomosis	7	agree	7	agree	agree
Lymph node dissection	4,5	no	4	no	agree
Wound closure and specimen removal	1	disagree			disagree
Steps of the surgery associated with postoperative urinary incontinence					
Abdominal cavity approach/port placement	1	disagree			disagree
Retropubic space approach/mobilisation of Retzius	1	disagree			disagree
Pelvic floor muscle exposure/opening of the endopelvic fascia	7	agree	7	agree	agree
Bladder neck dissection	6,5	no	6.5	no	no

Table 4 continued

Statement	MAS* Round 1	Consensus Round 1	MAS* Round 2	Consensus Round 2	Combined Consensus after Delphi meeting
Ligation of prostate pedicles	5	no	4,5	no	disagree
Nerve preservation	7	agree	6,5	no	agree
Management of prostate apex/urethra	9	agree			agree
Prostate removal	1	disagree			disagree
Urethro-vesical anastomosis	8,5	agree	9	agree	agree
Lymph node dissection	2	disagree	3	disagree	disagree
Wound closure and specimen removal	1	disagree		disagree	disagree
Factors that play a role in the origins of postoperative complications					
Teamwork	9	agree			agree
Communication between the surgeon and the surgical team	9	agree			agree
Surgical skills of the surgeon	9	agree			agree
Patient factors (i.e. Age, BMI, tumour size)	8	agree	7,5	agree	agree
Elements that are essential for the training of novice surgeons					
Theoretical education	8	agree	8,5	agree	agree
Simulator training, practice on virtual reality simulators	8	agree	8,5	agree	agree
Wetlab practice, training on animals	8	agree	8	agree	agree
Cadaver training	7	agree	7	agree	agree
Drylab training, practice on models	7	agree	7	agree	agree
Supervised practice on real patients	9	agree			agree
Fellowship	9	agree			agree

Consensus group meeting

Of the 18 invited experts, five participated in the consensus group meeting. In total, this meeting was attended by nine participants, whose occupation and voting status are presented in Table 3.

Final consensus statements

Table 4 shows the statements on which consensus was reached, organized per domain. The results of the Delphi Survey and the consensus group meeting were used to develop the assessment instrument PROTEST (PRostatectomy video Observation to Evaluate and Score Technical skill) (Table 5). This instrument contains the seven steps of the RARP surgery and the peri-operative measurements that are considered to be most likely to be related to complications and adverse postoperative outcomes

The relation between the statements and postoperative complications

Consensus of ‘agreement’ was reached on three out of 14 statements (Table 2) regarding the relation of the statement to postoperative complications. Consensus of ‘disagreement’ was reached on six out of 14 statements, one of which received a unanimous ‘disagreement’ score (i.e. median score of 1 and disagreement index = 0).

No consensus was reached on the five remaining statements. The panel agreed on the following statements: “Shorter operating times result in fewer complications” and “Shorter duration of coagulation results in fewer complications”. All participants disagreed with the statement “It is better not to use the third arm of the robot when looking at complications”.

The relation between the statements and functional results

The participants of the Delphi Survey reached consensus of ‘agreement’ on two out of 14 statements concerning functional results (Table 2). The panel reached a consensus of ‘disagreement’ on five out of 14 statements. None of the statements received a unanimous score. No consensus was reached on the seven remaining statements. The panel agreed on the following statements: “Zooming in more on the operation field provides better vision as it leads to better functional results.” and “A shorter duration of coagulation results in improved functional results.”

Steps of the surgery associated with complications

During the Delphi Survey, consensus of ‘agreement’ was reached on seven out of 11 statements regarding the steps of the surgery that might be associated with compli-

Table 5 PROTEST Assessment instrument

PROTEST assessment instrument						
Pelvic floor muscle exposure	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					

Bladder neck dissection	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					
Ligation of prostatic pedicles	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					
Nerve preservation	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					
Management of prostatic apex/urethra	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					

Vesico-urethral anastomosis	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					
Lymph node dissection (If applicable)	Surgical Skill	1 = Uncoordinated	2	3	4	5 = Perfect coordination
		1 = Inaccurate	2	3	4	5 = Perfectly accurate
	Total time step (sec)					
	Time bleeding (sec)					
	Time coagulating (sec)					
	Time suturing (sec)					
	Number of times camera removal (n)					
	Comments					
	Events					
Was bladder neck preservation attempted (Y/N)						
Where both ureteral orifices in sight during preparation of the bladder neck? (Y/N)						
Was the capsula damaged during nerve sparing? (Y/N)						
Was there a tear in the vesiculae during preparation? (Y/N)						
Was the diathermia used during transection of the plexus of Santorini? (Y/N)						
Was the diathermia used during transection of the urethra? (Y/N)						
Was the colliculus in sight during transection of the urethra? (Y/N)						
Was a bladder neck reconstruction performed? (Y/N)						
Was the Rocco stitch (median fibrous raphe) reconstruction used? (Y/N)						
Was a barbed suture used for the bladder/urethra anastomosis? (Y/N)						
How many stitch throws were used in the anastomosis (n)						
Total Time surgery (sec)						
Total Time Bleeding (sec)						
Total Time coagulation (sec)						
Total Time Suturing (sec)						
Total number of camera removals (n)						
Total number of events (n)						
Average score surgical skills						
2d/3d images						
Nerve sparing						
BMI						
Date of surgery						
Age of patient						
Tumour stage						
Prostate size						

cations. The panel reached consensus of 'disagreement' on two out of 11 statements (Table 2). No statements received a unanimous score. No consensus was reached on two remaining statements.

The panel agreed that the following steps of the surgery might be associated with complications: "Bladder neck dissection", "Ligation of prostate pedicles", "Nerve preservation", "Management of prostate apex/urethra", "Vesico-urethral anastomosis", "Lymph node dissection", and "Wound closure and specimen removal".

Steps of the surgery associated with postoperative erectile dysfunction

The Delphi Survey panel reached a consensus of 'agreement' on four out of 11 statements regarding the steps of the surgery that might be associated with postoperative erectile dysfunction (Table 2).

The experts unanimously agreed that "Nerve preservation" and "Management of prostate apex/ urethra" might be associated with the incidence of postoperative erectile dysfunction. A consensus of 'disagreement' was reached on five out of 11 statements, four of which received a unanimous 'disagreement' score. No consensus was reached on the two remaining statements.

Steps of the surgery associated with postoperative urinary incontinence

During the Delphi Survey, the panel reached a consensus of 'agreement' on two out of 11 statements (Table 2) regarding steps of the surgery that might be related to postoperative urinary incontinence. The panel reached a consensus of 'disagreement' on five out of 11 of these statements. No consensus was reached on the four remaining statements. A unanimous consensus of 'agreement' was reached on one of these steps, and a unanimous consensus of disagreement was reached on three of these steps.

The panel agreed that the following steps of the surgery might be associated with postoperative urinary incontinence: "Pelvic floor muscle exposure/opening of the endopelvic fascia", and "Vesico-urethral anastomosis".

Factors that play a role in the origins of postoperative complications

Both the Delphi Survey and the consensus meeting reached a consensus of 'agreement' that all (four out of four) the proposed factors (Table 2) could play a role in the origins of postoperative complications. The experts unanimously agreed on the relevance of the following factors: "Teamwork", "Communication between the surgeon and the surgical team”, and “Surgical skills of the surgeon”.

Elements that are essential for the training of novice surgeons

The participants of both the Delphi Survey and the consensus meeting reached a consensus of ‘agreement’ that all (seven out of seven) proposed elements of training (Table 2) are essential for the training of novice surgeons. There was unanimous agreement on the need to implement the following training assessment methods: “Supervised practice on real patients”, and “Fellowship”.

Discussion

The aim of this study was to develop an assessment instrument for the evaluation of surgical videos to elucidate the association between surgical skills and postoperative outcomes after a robot-assisted radical prostatectomy (RARP). To investigate this association, we invited all Dutch experts in RARP to participate in a standardized Delphi procedure in order to identify surgical and non-surgical factors in RARP that are potentially associated with an adverse postoperative course and to assess whether any of these parameters may be worth evaluating for the prediction of postoperative outcomes.

We found that the majority of Dutch urologists specialized in RARP are interested in an instrument for video analysis of their surgical skills in relation to the postoperative outcomes. These urologists indicated that they were interested to participate in the current study because they considered video analysis to be useful for the improvement of surgical skills and the subsequent reduction of postoperative complications.

Consensus group meeting

During the consensus group meeting the panel members agreed that the duration of the surgical procedure and the duration of coagulation could be causally related to the rate of postoperative complications. They advised to investigate whether such a causal relation exists. The panel also agreed there could be a causal relation between the duration of coagulation and the level of adverse postoperative functional results.

The panel agreed that postoperative complications, postoperative erectile dysfunction and postoperative urinary incontinence could result from events during the following steps of the RARP procedure: “Pelvic floor muscle exposure/opening of the endopelvic fascia”, “Bladder neck dissection”, “Ligation of prostate pedicles”, “Nerve preservation”, “Management of prostate apex/urethra”, “Vesico-urethral anastomosis”, “Lymph node dissection”, and “Wound closure and specimen removal”. The panel agreed that these steps should be incorporated in an assessment instrument to investigate whether they are related to adverse postoperative outcomes.

PROTEST assessment instrument

Based on the consensus reached during the Delphi Survey and the consensus meeting, the PROTEST assessment instrument was developed (Table 5). This instrument can be used to assess the skills of a surgeon through analysis of a video recording of the surgery.

This assessment instrument was developed with the input of the panel members and was reviewed by all panel members in order to give them the opportunity to refine and clarify the assessment instrument. One item, “Wound closure and specimen removal”, was not included in the PROTEST assessment instrument, because this step is not recorded on surgical videos.

When comparing the results of the current Delphi study to existing assessment instruments[15,24,25], the developed PROTEST assessment instrument shows a combination of subjective surgical skills assessment and objective metrics of procedural steps and events. The developed PROTEST assessment instrument is different from the GEARS assessment instrument where the focus lies solely on the subjective scoring of 5 technical domains of surgical skill, with no objective measurements.[23] The GERT assessment instrument comparable to the PROTEST assessment instrument as it focusses on different features of the surgery (i.e. clipping, suturing, use of the retractors and use of suction), but it only gives feedback on possible errors whilst performing this feature, there is no room to score subjective surgical skills.[24] The PACE assessment instrument is similar to the GERT assessment instrument as it evaluates specific steps of the RARP procedure, similar to the PROTEST assessment instrument, but only gives feedback based on errors whilst performing these steps and there is no room for subjective surgical skill analysis.[15]

Implications of study findings for clinical practice and research

This Delphi procedure resulted in an overview of possible origins of complications after RARP and in a new assessment instrument that can be used to objectively assess a surgeon’s skills.

The PROTEST assessment instrument gives detailed insight into the proficiency of the surgeon on each of the individual surgical steps of the RARP. It combines the answers to two general subjective questions with multiple objective measurements in order to provide detailed feedback to the surgeon.

Future studies should explore whether the factors identified in this Delphi process are indeed causally related to postoperative complications and whether video assessments by means of the PROTEST instrument can help in the training of novice surgeons and improving the skills of RARP surgeons.

Limitations

A limitation of this study is that we consulted all the urologists specialized in RARP who are registered in the Netherlands. Future studies with larger panels and international participants might add other factors that could contribute to complications after RARP.

A second limitation is that the answers to the general questions might be subject to participation bias and hence they cannot be generalized to the total group of Dutch urologists. Finally, the responses of panel members could have been influenced by the fact that the consensus meeting was not led by an independent chair.

Conclusion

Dutch experts in the field of RARP have reached consensus on seven surgical steps and four aspects of the RARP procedure that may be related to postoperative complications after RARP. The resulting assessment instrument, PROTEST, can be used to assess surgical skill. The resulting assessment instrument will be tested in future research to determine its validity for assessing the relationship between surgical skills and adverse postoperative outcomes after RARP.

References

1. Barocas DA, Alvarez J, Resnick MJ, Koyama T, Hoffman KE, Tyson MD, Conwill R, McCollum D, Cooperberg MR, Goodman M, Greenfield S, Hamilton AS, Hashibe M, Kaplan SH, Paddock LE, Stroup AM, Wu X-C, Penson DF. Association Between Radiation Therapy, Surgery, or Observation for Localized Prostate Cancer and Patient-Reported Outcomes After 3 Years. JAMA [Internet]. 2017 Mar 21 [cited 2018 Jun 10];317(11):1126.
2. Donovan JL, Hamdy FC, Lane JA, Mason M, Metcalfe C, Walsh E, Blazeby JM, Peters TJ, Holding P, Bonnington S, Lennon T, Bradshaw L, Cooper D, Herbert P, Howson J, Jones A, Lyons N, Salter E, Thompson P, et al. Patient-Reported Outcomes after Monitoring, Surgery, or Radiotherapy for Prostate Cancer. N Engl J Med [Internet]. 2016 Oct 13 [cited 2018 Jun 10];375(15):1425–37.
3. Lardas M, Liew M, van den Bergh RC, De Santis M, Bellmunt J, Van den Broeck T, Cornford P, Cumberbatch MG, Fossati N, Gross T, Henry AM, Bolla M, Briers E, Joniau S, Lam TB, Mason MD, Mottet N, van der Poel HG, Rouvière O, et al. Quality of Life Outcomes after Primary Treatment for Clinically Localised Prostate Cancer: A Systematic Review. Eur Urol [Internet]. 2017 Dec 1 [cited 2018 Apr 5];72(6):869–85.
4. Maike H.J. Schepens, Cathelijne M.P. Ziedses des Plantes, D.M. (Rik) Somford, Judith A. van Erkelens, Ruben G. Cremers, Sytske de Vries, Katja K.H. Aben, René Hoekstra, Jozette J.C. Stienen, Bart P. Wijsman MBB en J van L. Hoe vaak incontinentie na radicale prostatectomie? Ned Tijdschr Geneeskd. 2018;162:D2294.
5. Wilson LC, Gilling PJ. Post-prostatectomy urinary incontinence: a review of surgical treatment options. BJU Int [Internet]. 2011 Apr [cited 2018 Sep 3];107:7–10.
6. Goluboff ET, Saidi JA, Mazer S, Bagiella E, Heitjan DF, Benson MC, Olsson CA. Urinary continence after radical prostatectomy: the Columbia experience. J Urol [Internet]. 1998 Apr [cited 2018 Sep 3];159(4):1276–80.
7. Tollefson MK, Gettman MT, Karnes RJ, Frank I. Administrative Data Sets are Inaccurate for Assessing Functional Outcomes After Radical Prostatectomy. J Urol [Internet]. 2011 May 1 [cited 2018 Jul 23];185(5):1686–90.
8. Salonia A, Burnett AL, Graefen M, Hatzimouratidis K, Montorsi F, Mulhall JP, Stief C. Prevention and management of postprostatectomy sexual dysfunctions. Part 1: choosing the right patient at the right time for the right surgery. Eur Urol [Internet]. 2012 Aug [cited 2018 Jul 23];62(2):261–72.
9. Vickers A, Savage C, Bianco F, Mulhall J, Guillonneau B, Cronin A, Scardino P. Cancer Control and Functional Outcomes After Radical Prostatectomy as Markers of Surgical Quality: Analysis of Heterogeneity Between Surgeons at a Single Cancer Centre. 2011;59(3):317–22.
10. Cathcart P, Sridhara A, Ramachandran N, Briggs T, Nathan S, Kelly J. Achieving quality assurance of prostate cancer surgery during reorganisation of cancer services. Eur Urol [Internet]. 2015 Jul 1 [cited 2018 Apr 5];68(1):22–9.
11. Gershman B, Meier SK, Jeffery MM, Moreira DM, Tollefson MK, Kim SP, Karnes RJ, Shah ND. Redefining and Contextualizing the Hospital Volume-Outcome Relationship for Robot-Assisted Radical Prostatectomy: Implications for Centralization of Care. J Urol [Internet]. 2017 Jul 1 [cited 2018 Jul 23];198(1):92–9.
12. Birkmeyer JD, Finks JF, O ’reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.
13. Goldenberg MG, Lee JY, Kwong JC, Grantcharov TP, Costello A. Implementing Assessments of Robotic-Assisted Technical Skill in Urologic Education: A Systematic Review and Synthesis of the Validity Evidence. BJU Int [Internet]. 2018 Mar 31 [cited 2018 Apr 5];
14. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
15. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
16. Morris C, Hoogenes J, Shayegan B, Matsumoto ED. Towards development and validation of an intra-operative assessment tool for robot-assisted radical prostatectomy training: results of a Delphi study. Int Braz J Urol [Internet]. 2017 [cited 2017 Dec 28];43(4):661–70.
17. Stolzenburg J-U, Schwaibold H, Bhanot SM, Rabenalt R, Do M, Truss M, Ho K, Anderson C. Modular surgical training for endoscopic extraperitoneal radical prostatectomy. BJU Int [Internet]. 2005 Nov 1 [cited 2017 Dec 28];96(7):1022–7.
18. Gillessen S, Attard G, Beer TM, Beltran H, Bossi A, Bristow R, Carver B, Castellano D, Chung BH, Clarke N, Daugaard G, Davis ID, de Bono J, Borges dos Reis R, Drake CG, Eeles R, Efstathiou E, Evans CP, Fanti S, et al. Management of Patients with Advanced Prostate Cancer: The Report of the Advanced Prostate Cancer Consensus Conference APCCC 2017. Eur Urol [Internet]. 2018 Feb [cited 2018 Jun 12];73(2):178–211.

19. van den Bos W, Muller BG, Ahmed H, Bangma CH, Barret E, Crouzet S, Eggener SE, Gill IS, Joniau S, Kovacs G, Pahernik S, de la Rosette JJ, Rouvière O, Salomon G, Ward JF, Scardino PT. Focal Therapy in Prostate Cancer: International Multidisciplinary Consensus on Trial Design. Eur Urol [Internet]. 2014 Jun [cited 2018 Jun 12];65(6):1078–83.

20. Lutkenhaus LJ, van Os RM, Bel A, Hulshof MCCM. Clinical results of conformal versus intensity-modulated radiotherapy using a focal simultaneous boost for muscle-invasive bladder cancer in elderly or medically unfit patients. Radiat Oncol [Internet]. 2016 [cited 2017 Mar 21];11(1):45.

21. MacLennan S, Bekema HJ, Williamson PR, Campbell MK, Stewart F, MacLennan SJ, N'Dow JM, Lam TB. A core outcome set for localised prostate cancer effectiveness trials: protocol for a systematic review of the literature and stakeholder involvement through interviews and a Delphi survey. Trials [Internet]. 2015 Dec 4 [cited 2018 Jun 12];16(1):76.

22. Fitch K, Bernstein SJJ, Aguilar MDD, Burnand B, LaCalle JRR, Lazaro P, Van Het Loo M, Mcdonnell J, Vader JPP, Kahan JPP, Loo M Van Het. The RAND / UCLA Appropriateness Method User ' s Manual [Internet]. Transformation. 2001. 109 p.

23. Kong H, West S. WMA DECLARATION OF HELSINKI – ETHICAL PRINCIPLES FOR Scienti c Requirements and Research Protocols. W [Internet]. 2013;(June 1964):29–32.

24. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.

25. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.

Chapter 7

A prospective observational multicentre study concerning non-technical skills in robot assisted radical cystectomy versus open radical cystectomy.

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Abstract:

Introduction and Hypotheses

valuation of surgical skills, both technical and non- technical, is possible through observations and video analysis. Besides technical failures, adverse outcomes in surgery can also be related to hampered communi- cation, moderate teamwork, lack of leadership, and loss of situational awareness. Even though some surgeons are convinced about nontechnical skills being an important part of their professionalisation, there is paucity of data about a possible relationship between nontechnical skills and surgical outcome. In robot-assisted surgery, the surgeon sits behind the console and is at a remote position from the surgical field and team, making communication more important than in open surgery and conventional laparoscopy. A lack of structured research makes it difficult to assess the value of the different analysis methods for nontechnical skills, particularly in robot-assisted surgery. Our hypothesis includes the following: (1) introduction of robot-assisted surgery leads to an initial decay in nontechnical skills behaviour during the learning curve of the team, (2) nontechnical skills behaviour is more explicitly expressed in experienced robot-assisted surgery teams than in experienced open surgery teams, and (3) introduction of robot-assisted surgery leads to the development of different forms of nontechnical skills behav- iour compared with open surgery.

Design

This study is a prospective, observational, multicentre, nonrandomised, case-control study including bladder cancer patients undergoing either an open radical cystectomy or a robot-assisted radical cystectomy at the Catharina Hospital Eindhoven, the Netherlands, or at the Netherlands Cancer Institute, Antoni van Leeuwenhoek Hospital Amsterdam. All patients are eligible for inclusion; there are no exclusion criteria. The Catharina Hospital Eindhoven, the Netherlands, performs on average 35 radical cystectomies a year. The Netherlands Cancer Institute, Antoni van Leeuwenhoek Hospital Amsterdam, performs on average 100 radical cystec- tomies a year.

Protocol Overview

The choice of treatment is at the discretion of the patient and the surgeon. Patient results will be obtained prospectively. Pathology results as well as complications occurring within 90 d following surgery will be registered. Surgical complications will be registered according to the Clavien-Dindo system.

Measurements

Nontechnical skills will be observed using five different methods: (1) NOTSS: Non-technical Skills for Surgeons; (2) Oxford NOTECHS II: a modified theatre team non-technical skills scoring system; (3) OTAS: Observational Team- work Assessment for Surgery; (4) Interpersonal and Cognitive Assessment for Robotic Surgery (ICARS): evaluation of nontechnical skills in robotic surgery; and (5) analysis of human factors. Technical skills in robot-assisted radical cystec- tomy will be analysed using two different methods: (1) GEARS: Global Evaluative Assessment of Robotic Skill and (2) GERT: Generic Error Rating Tool.

Safety criteria and reporting

Formal ethical approval has been provided by Medi- cal research Ethics Committees United (MEC-U), The Netherlands (reference num- ber W19.048). We hope to present the results of this study to the scientific community at conferences and in peer-reviewed journals.

Statistical Analysis

Frequency statistics will be calculated for patient demograph- ical data, and a Shapiro-Wilk test with $p > 0.05$ will be used to define normal distribution. Univariate analysis will be conducted to test for statistically significant differences in observation scores between open radical cystectomy and robot- assisted radical cystectomy cohorts across all variables, using independent sample t tests and Mann-Whitney U testing, as appropriate. A variable-selection strategy will be used to create multivariate models. Binary logistic regression will be conducted to calculate odds ratios and 95% confidence intervals for significant predictors on univariate analysis and clinically relevant covariates. Statistical significance is set at $p < 0.05$ based on a two-tailed comparison.

Summary

This study uses a structured approach to the analysis of nontechnical skills using extracorporeal videos of both open radical cystectomy and robot- assisted radical cystectomy surgeries, in order to obtain detailed data on nontech- nical skills during open and minimally invasive surgeries. The results of this study could possibly be used to develop team-training programmes, specifically for the introduction of the surgical robot in relation to changes in nontechnical skills. Additional analysis of technical skills using the intracorporeal footage of the surgical robot will be used to elucidate the role of surgical skills and surgical events in nontechnical skills.

Introduction and Hypotheses

Qualification and certification of surgical skills performance are still in a preliminary phase within all surgical specialties, including urology. There are, however, urgent calls from the government and patient organizations for well-defined proficiency standards to safeguard the quality of care.[1,2] Also, professionals themselves are increasingly interested to define their qualifications and to improve skills.[3]

Multiple research groups are investigating the relation between surgeons' technical skills and postoperative outcome.[4–6] With the introduction of laparoscopy and the surgical robot new and improved assessment tools of surgical skills have been developed.[5,7–9]

Although the analysis of technical surgical skills in robot assisted surgery can lead to major improvements of postoperative outcomes[10], the possible influence of Non-Technical-Skills on postoperative outcomes also merits attention

The Non-Technical Skills needed for a successful Robot Assisted Radical Cystectomy probably differ from the Non-Technical Skills needed for Open Radical Cystectomy.

Even though several general assessment methods have been developed for both the entire team[11–13] and individual team members[14–16] the question remains if these tools can accurately assess Non-Technical Skills in such complex robot assisted surgeries as Robot Assisted Radical Cystectomy. With the introduction of the Interpersonal and Cognitive Assessment for Robotic Surgery (ICARS)[17], adaptation to the robot assisted surgical setting has started.

The introduction of the surgical robot has totally changed the traditional set-up of the operating room, since scrub nurse and surgeon are no longer on opposite sides of the patient. In robot assisted surgery the surgeon is located in a separate control console during most of the surgery, and therefore direct communication with the team members could be hampered. It is conceivable that loss of non-verbal communication can influence the work-flow and therefore the quality of the performance including patient's safety.

Two systematic reviews have been published concerning studies of Non-Technical Skills in minimal invasive surgery (i.e. conventional laparoscopy and robot assisted surgery).[18,19] A wide variety in assessments of Non-Technical Skills was used which makes comparison of tools difficult.[18,19]

Van der Vliet et al.[19] advises additional Non-Technical Skills research to be performed in the different surgical approaches (open, laparoscopic, robot-assisted) . Moreover, it is advised to use of multiple trained observers to assess audio-visual recordings of the surgical environment to identify and quantify possible inter-observer reliability. The group of Gjeraa et al[18]. advises the systematic identification of Non-Technical Skills skills in minimal invasive surgery in order to develop effective, evidence-based team training programs for minimal invasive surgeries.

The present study aims to perform a structured evaluation of Non-Technical Skills in both open and robot assisted complex surgery. To investigate the manner in which the introduction of the surgical robot influences both Non-Technical Skills and outcomes surgical outcome during the first year of Robot Assisted Radical Cystectomy compared to Open Radical Cystectomy.

In addition, technical skills analysis in Robot Assisted Radical Cystectomy will be performed to evaluate the possible relation between technical skills and Non-Technical Skills. The radical cystectomy was chosen for this analysis because it is a lengthy, complex and demanding surgery for surgeon and other team members.

Since radical cystectomy surgeries takes many hours, a long-term and detailed analysis is possible per procedure. The radical cystectomy is traditionally performed open (Open Radical Cystectomy) at the Catharina hospital Eindhoven, but recently a shift is made to Robot Assisted Radical Cystectomy. This shift enables us to investigated in which manner Non-Technical Skills changes during the introduction of Robot Assisted Radical Cystectomy. The Non-Technical Skills during learning curve of Robot Assisted Radical Cystectomy in the Catharina Hospital Eindhoven will be compared to the Non-Technical Skills during the Open Radical Cystectomy in the same hospital as well Non-Technical Skills of an experienced Robot Assisted Radical Cystectomy team in the Antoni van Leeuwenhoek Hospital.

These analyses will be performed in order to investigate in which matter Non-Technical Skills change during the introduction of the Robot Assisted Radical Cystectomy and which factors contribute to the learning curve. Results obtained during this study could be beyond Robot Assisted Radical Cystectomy since the changes in OR setup and the loss of non-verbal communication are universal when making the shift from open to robot assisted surgery.

Our hypothesis are:

1. The introduction of Robot assisted surgery leads to an initial decay in Non-Technical Skills behaviour during the learning curve of the team.
2. In experienced robot assisted surgery teams Non-Technical Skills behaviour is more explicitly expressed compared to experienced open surgery teams.
3. The introduction of Robot assisted surgery leads to the development of different forms of Non-Technical Skills behaviour compared to open surgery.

The results of this study could possibly be used to develop team-training programs specifically for the introduction of the surgical robot in relation to changes in Non-Technical Skills. Additional technical skills analysis using the intra-corporal footage of the surgical robot will be used to elucidate the role of surgical skills and surgical events on Non-Technical Skills.

Design

The present study is a prospective observational multicentre non-randomised case control study that will include all patients undergoing either an Open Radical Cystectomy (Open Radical Cystectomy) or Robot Assisted Radical Cystectomy (Robot Assisted Radical Cystectomy) in Catharina Hospital Eindhoven and in Antoni van Leeuwenhoek Hospital.

Time line

The inclusion will be from January 2021 until August 2022 in both hospitals simultaneously (figure 1). The video collection will start once the first patient is included and will continue until the last patient has had his surgery. Follow-up data collection will start in February of 2021 and will continue until December of 2022. Data analysis will start in January 2022.

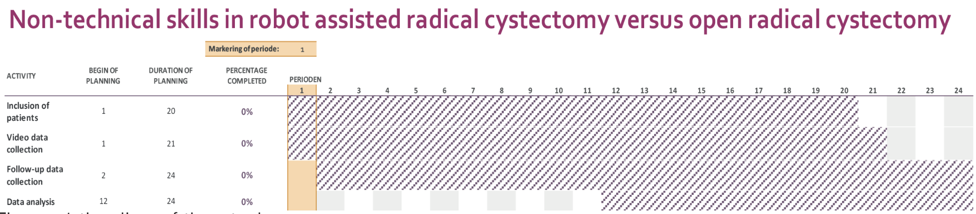

Figure 1 timeline of the study

Study population

The surgical team on the OR will be the study population. Individual permissions will be obtained from all members of the surgical team, i.e. urologists, OR nurses, and anaesthesiologists. The surgeries will be performed by three urologists, one surgeon will perform all open radical cystectomy's (Open Radical Cystectomy), one surgeon will perform all Robot Assisted Radical Cystectomy's in the Catharina Hospital Eindhoven, and one surgeon will perform all Robot Assisted Radical Cystectomy's and Open Radical Cystectomy's in the Antoni van Leeuwenhoek hospital. The OR nurses for each Open Radical Cystectomy and Robot Assisted Radical Cystectomy in the Catharina Hospital Eindhoven will be selected based on shift schedules from the experienced dedicated team of six urology OR nurses. The OR nurses for each surgery in the Antoni van Leeuwenhoek hospital will be selected from the experienced dedicated team of six urology OR nurses. The anaesthesiologists will be randomly selected for each surgery form the total number of anaesthesiologists who have signed an informed consent form. All team members have worked together before.

After five Robot Assisted Radical Cystectomy procedures a survey based on the survey developed by McBride, et al.[24] (appendix 1) will be held with the OR nurses in the Catharina Hospital Eindhoven in order to investigate the view of the OR nurses on the potential benefits of Robot assisted surgery. All surgeons will be asked what level of prior experience/training they have prior to the start of the study.

Inclusion criteria

Patients who will undergo either an Open Radical Cystectomy (Open Radical Cystectomy) or Robot Assisted Radical Cystectomy (Robot Assisted Radical Cystectomy) in Catharina Hospital Eindhoven or Antoni van Leeuwenhoek hospital are eligible for this study. The choice of treatment is at the discretion of the patient and the surgeon.

For study inclusion, the following criteria must be met:

- Patients must be at least 18 years of age.

- patients must be able to understand and sign an informed consent.

- Patients who will undergo either an Open Radical Cystectomy (Open Radical Cystectomy) or Robot Assisted Radical Cystectomy (Robot Assisted Radical Cystectomy) in Catharina Hospital Eindhoven or Antoni van Leeuwenhoek hospital.

- Indication for the radical cystectomy must be urothelial cell carcinoma of the bladder.

- Informed consent of the patient to gather data and perform observations during surgery.

Exclusion criteria

No exclusion criteria will be used for this study.

Recruitment and consent

Informed consent from both patient and OR staff will be obtained allowing observation of the surgical procedure and obtaining patients data.

Withdrawal of individual subjects/employee

Both the subject of the surgery and all employees present during the surgery can always withdraw their consent to the use of their personal data/recording of the surgery. The data collected up to the moment of withdrawal of consent and the recording of the surgery will be destroyed after consent has been withdrawn. Consent can be withdrawn up to 6 months after surgery in order to have the recorded surgery destroyed. After 6 months, the recorded surgery will be automatically destroyed

Centre details

Based on prior data, on average a total of 35 ORCs is performed yearly in the Catharina Hospital Eindhoven. Since the Robot Assisted Radical Cystectomy has just been introduced the total number of Open Radical Cystectomy will be divided over the Open Radical Cystectomy and the Robot Assisted Radical Cystectomy modalities, it is expected that half of the radical cystectomies will be performed robot assisted. In the Antoni van Leeuwenhoek hospital, on average a total of 50 RARCs and 50 ORCs are performed each year. It is possible to include further hospitals in the future.

Protocol Overview

Patient results will be obtained prospectively. Pathology results will be registered as well as complications occurring within 90 days following surgery. Complication will be registered according to the Clavien Dindo system surgery.

Measurements

Non-technical skills will be observed using five different methods.

1. NOTSS: Non-Technical Skills for Surgeons.[16]

2. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System.[11,12]

3. OTAS: Observational Teamwork Assessment for Surgery.[20]

4. ICARS: non-technical skills evaluation in robotic surgery.[17]

5. Human factors analysis[21]

Technical skills in Robot Assisted Radical Cystectomy will be analysed using two different methods:

Since no intra-corporal videos of the Open Radical Cystectomy can be recorded due to blocking of the image by the surgeons and the OR lights, and difficulty getting a clear view into the surgical area in the pelvic region from a distance. The technical skills analysis will only be performed on the Robot assisted radical prostatectomy videos. This method of analysis will be performed to investigate the influence of robot assisted surgery experience on Non-technical skills and outcome of the surgery.

1. GEARS: Global Evaluative Assessment of Robotic Skill.[7]
2. GERT: Generic Error Rating Tool.[5]

Data Collection and handling

Data collection will consist of video capturing and analysis of patient records. Two trained observers (observer 1 and 2 bot have a background in medicine), with orientation and training in both Non-Technical Skills and technical assessment methods, will independently observe surgical videos. All video's will be analysed by both researchers. In case of disagreement a third independent expert with a psychology and leadership assessment background (observer 3) will be asked to perform a third analysis. Interrater reliability will be analysed using Cohens Kappa.

The surgical video will be assessed in multiple phases, in each phase an Non-Tech-

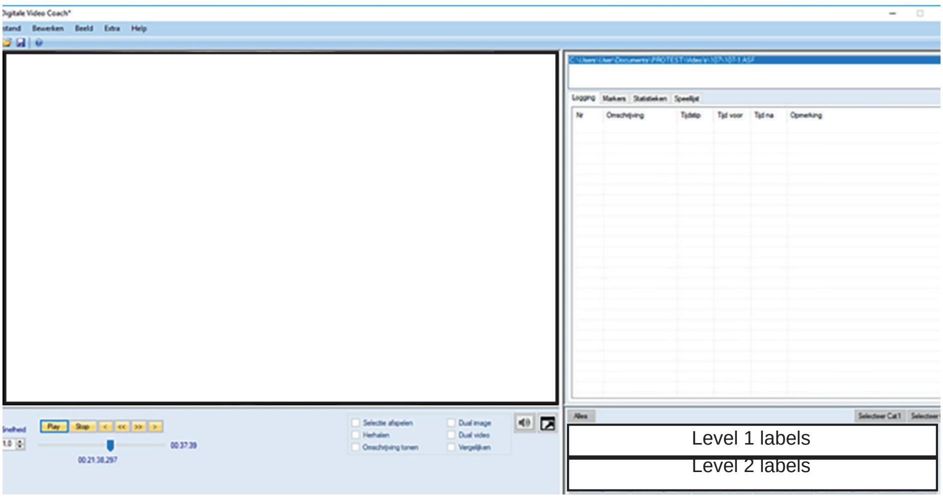

Figure 2 overview of the video analysis software Digital Video Coach.

nical Skills-assessment method will be used to assess non-technical skills. The surgical videos will be analysed using a customizable video analysis software "digital Video Coach" developed by ZEAL IT (figure 2).

The video analysis software "Digital Video Coach" makes it possible to register the occurrence of Non-Technical Skills behaviour and peri-operative events (i.e. people entering or leaving the OR, phone calls, etc.) Two sets of labels will be created in order to define the different Non-Technical Skills behaviour and peri-operative events present during the surgery. The selection of one of the labels automatically marks the time code corresponding to the moment the label was pressed. This makes it possible to measure the duration of the Non-Technical Skills behaviour and peri-operative events. The labels used for this analysis will be Non-Technical Skills-assessment method specific.

Training of the two observers (observer 1 and 2) will be performed using the NOTSS introductory course and advanced course (NOTSS for Trainees and NOTSS in a Box) as developed by the Royal College of Surgeons of Edinburgh.[23] Further training in the remaining analysis methods will be performed by a specialist in Non-Technical Skills assessment (observer 3).

The technical skills assessment training will be performed by an expert on technical skills analysis with expert knowledge of the procedure and Robot Assisted Surgery (observer 4, is a surgeon who has performed over 200 Open Radical Cystectomy and Robot Assisted Radical Cystectomy procedures and a trainer of new and experienced surgeons). Observer 4 will act as independent expert in case of disagreement between the two observers (observer 1 and 2).

The videos will be recorded using three cameras installed in three different point in the OR. Objects which should be in view are: the OR table, in case of robot assisted surgery the robot console, the anaesthesiology equipment, the OR door to the non-sterile area of the OR complex, the OR door to the sterile area of the OR. Recording from three different angles in the OR will assure there will be a 360-degree view of the proceedings in the OR. The cameras used have a 170-degree image angle with high definition imaging so maximum coverage can be achieved.

Voice data will be collected using personalized voice recorders per staff member present in the OR. The audio feed on the cameras is strong enough to get a general view of the conversations during the surgery, for detailed analysis the recording of personal voice recorder will be used to gain insight into the orders given during difficult of abnormal phases of the surgery.

Surgeon specific data will be recorded at the start of the OR, these include but are not limited to: Age of the surgeon, Gender, right or left handedness, gaming experience and prior surgical and robot assisted surgery experience. If multiple surgeons will operate during the same surgery all will be asked to complete the above-mentioned questionnaire, changes in lead surgeon will be recorded during the surgery.

Cases will be de-identified and labelled with study codes. Patient data will be recorded during regular follow-up visits by an oncology nurse or the patient's physician. Since all outcome measures are standard data recorded for these surgeries, no additional strain will be put on the participating patients. This study was granted approval from the institutional medical committee.

Data from the anaesthesiologist continuous monitoring is automatically saved in the patients' medical file. This data will be used to identify moments in which the patient is in distress, i.e. a sudden decrease of blood pressure, a sudden increase in heart rate, a sudden decrease in oxygen saturation of the patient. These moments will be of special interest to the observers in order to observe the reaction of the team to sudden adverse events during surgery.

Data will be handled strictly confidential and will be coded during the extraction of either patient characteristics or video analyses. It will be stored in a secure and encrypted database (research manager) and code lists will exclusively be stored at the hospital of consultation or treatment until video analysis results and patient characteristics have been matched. Afterwards they will be destroyed. The video and audio data will be stored for a maximum period of 6 months.

Statistical Analysis

Frequency statistics will be calculated for patient demographical data, and a Shapiro-Wilk test with $p > 0.05$ will be used to define normal distribution. Univariate analysis will be conducted to test for statistically significant differences in observation scores between Open Radical Cystectomy and Robot Assisted Radical Cystectomy cohorts across all variables, using Independent Sample T-Tests and Mann–Whitney U testing as appropriate. A variable-selection strategy will be used to create multivariate models. Binary logistic regression will be conducted to calculate odds ratios (OR) and 95% confidence intervals (CIs) for significant predictors on univariate analysis and clinically relevant covariates. Statistical significance is set at $p < 0.05$ based on a two-tailed comparison. Statistical analyses will be performed using SPSS Statistics version 24 (IBM, NY).

Primary outcome measurements

The following outcomes will be reported.

Non-technical skills will be observed using five different methods.

1. NOTSS: Non-Technical Skills for Surgeons.[16]

The focus of the NOTSS assessment method lies on the following aspects of Non-Technical Skills:

- Situation Awareness: Developing and maintaining a dynamic awareness of the situation in operating theatre based on assembling data from the environment, understanding what they mean, and thinking ahead about what may happen next.

- Decision Making: Skills for diagnosing the situation and reaching a judgement in order to choose an appropriate course of action.

- Communication and Teamwork: Skills for working in a team context to ensure that the team has an acceptable shared overview of the situation and can complete tasks effectively.

- Leadership: Leading the team and providing direction, demonstrating high standards of clinical practice and care, and being considerate about the needs of individual team members.

2. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System.[11,12]

The focus of the NOTECHS II assessment method lies on the following aspects of Non-Technical Skills:

- leadership and management
- teamwork and co-operation
- problem-solving and decision-making
- situation awareness

3. OTAS: Observational Teamwork Assessment for Surgery.[20]

The focus of the OTAS assessment method lies on the following aspects of Non-Technical Skills:

- communication
- coordination
- cooperation and back up behaviour
- leadership
- team monitoring and situational awareness

4. ICARS: non-technical skills evaluation in robotic surgery.[17]

The focus of the ICARS assessment method lies on the following aspects of Non-Technical Skills:

- checklist and equipment
- interpersonal skills (communication and team skills & leadership)
- cognitive skills (decision-making & situational awareness)
- resource skills (stress and distractors)

5. Human factors analysis.[21]

Human factors analysis consists of 4 levels of system failure: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences.

6. Peri-operative events (i.e. people entering or leaving the OR, phone calls, etc.)

Technical skills in Robot Assisted Radical Cystectomy will be analysed using two different methods:

1. GEARS: Global Evaluative Assessment of Robotic Skill.[7]

The focus of the GEARS assessment method lies on general robot surgical principals, i.e. Depth perception, bi-manual dexterity, efficiency, force sensitivity, autonomy, and robotic control

2. GERT: Generic Error Rating Tool.[5]

The focus of the GERT assessment method lies on the capture and analysis of technical errors and resulting events during laparoscopic procedures.

Secondary outcome measurements

Age, WHO performance status, Charlson comorbidity index, neoadjuvant chemotherapy, prior local treatment, prior radiation therapy in the surgical field, diagnosis, prior abdominal and/or pelvic surgery, the indication of surgery, per-operative complications, postoperative complications according to the Clavien-Dindo system[22], length of hospital stay, ICU stay, blood loss, PREMS, PROMS, method of surgery, and oncological outcome (Surgical margins and number of resected lymph nodes, and pathology results) will be registered prospectively. Patient follow-up will be at least 30 days. Surgeon specific data will be recorded (i.e. Age of the surgeon, Gender, right or left handedness, gaming experience and prior surgical and robot assisted surgery experience)

Regulation statement

As this is a prospective observational non-invasive study, participants will not be subject to any study treatments or actions. Even though, the Medical Research Involving Human Subjects Act (in Dutch: Wet Medisch-wetenschappelijk Onderzoek met Mensen) does not apply informed consent will be obtained. This study will be conducted in accordance to the "Code Goed Gebruik" (January 2002). Formal ethical approval has been provided by Medical research Ethics Committees United (MEC-U), Nieuwegein, reference number W19.048. The study protocol is registered at the Netherlands Trail Registry under reference number NL8537.

Privacy

Observations will be performed during surgery by two members of the urology in-house staff (Medically trained researchers with training in both Non-Technical Skills and Technical skills analysis) none of the observers have a hierarchical relationship with any of the team members.

As discussion of planned surgeries are part of daily staff meetings there are no additional privacy concerns.

The observations do not contain the name of the patient, nor the date and time of surgery. This is in accordance with the General Data Protection Regulation, GDPR.

Handling and storage of data and documents

Data will be handled strictly confidential and will be coded during the extraction of patient characteristics and video analysis. It will be stored in a secure and encrypted database (research manager) and code lists will exclusively be stored at the hospital of consultation or treatment until video analysis results and patient characteristics have been matched. The data will be stored for a maximum period of 6 months. Afterwards they will be destroyed

Appendix 1: Survey on potential benefits of Robot assisted surgery developed by McBride, et al.[24]

1. Benefits of RAS for patients:	Disagree	Neutral	Agree
Robotic surgery will help reduce overall length of stay	O	O	O
Robotic surgery will reduce patient post-operative pain	O	O	O
Robotic surgery will reduce intraoperative complications (e.g. blood loss) compared to current procedures	O	O	O

2. Benefits of RAS for staff:	Disagree	Neutral	Agree
Robotic surgery increases the value of staff roles	O	O	O
Robotic surgery will increase my job satisfaction	O	O	O
Being involved in robotic surgery enhances overall staff knowledge	O	O	O

3 Benefits of RAS for workplace Environment:	Disagree	Neutral	Agree
Robotic surgery is a Work Health and Safety (WH&S) concern (additional equipment in the operating theatre)	O	O	O
Care and handling of specialized robotic surgery equipment concerns me	O	O	O
I am concerned about maintenance of sterile field when assisting in robotic surgery cases more so than when assisting in other cases	O	O	O
I am concerned about a decrease in my direct involvement in the case intraoperatively during robotic surgery compared to other procedures	O	O	O
I am concerned that robotic surgery will increase operating time	O	O	O
I am concerned regarding space and location of the robot	O	O	O
I am concerned that robotic surgery will negatively affect current team dynamics in the operating theatre	O	O	O
I am concerned that robotic surgery will add significant cost and financial pressure on our facility	O	O	O

4. Facilitators towards the implementation of new technology:	**Disagree**	**Neutral**	**Agree**
Formal, theoretical training	○	○	○
Practical training (i.e. simulation)	○	○	○
Educational guides and references for use intraoperatively	○	○	○
Support staff available when required	○	○	○

References

1. Gjeraa K, Spanager L, Konge L, Petersen RH, Østergaard D. Non-technical skills in minimally invasive surgery teams: a systematic review. Surg Endosc. 2016;30(12):5185–99.
2. van der Vliet WJ, Haenen SM, Solis-Velasco M, Dejong CHC, Neumann UP, Moser AJ, van Dam RM. Systematic review of team performance in minimally invasive abdominal surgery. BJS Open. 2019;3(3):252–9.
3. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;
4. Porte P.J., Verweij L.M., Bekkers R.L.M., Consten E.C.J., Lichtenberg H., van der Poel, H.G., van Swol C.F.P. Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];
5. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.
6. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.
7. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.
8. Goldenberg MG, Lee JY, Kwong JCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence. Vol. 122, BJU International. 2018.
9. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.
10. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
11. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;
12. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
13. Robertson ER, Hadi M, Morgan LJ, Pickering SP, Collins G, New S, Griffin D, McCulloch P, Catchpole KC. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System. Roma PG, editor. PLoS One [Internet]. 2014 Mar 4 [cited 2018 Oct 26];9(3):e90320.
14. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care [Internet]. 2009 Apr 1 [cited 2018 Oct 26];18(2):104–8.
15. Moorthy K, Munz Y, Adams S, Pandey V, Darzi A. A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. Ann Surg [Internet]. 2005 Nov [cited 2018 Oct 26];242(5):631–9.
16. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. Best Pract Res Clin Anaesthesiol [Internet]. 2011 Jun 1 [cited 2018 Oct 26];25(2):215–27.
17. Mitchell L, Flin R, Yule S, Mitchell J, Coutts K, Youngson G. Development of a behavioural marker system for scrub practitioners' non-technical skills (SPLINTS system). J Eval Clin Pract [Internet]. 2013 Apr 1 [cited 2018 Oct 26];19(2):317–23.
18. Sharma B, Mishra A, Aggarwal R, Grantcharov TP. Non-technical skills assessment in surgery. Surg Oncol [Internet]. 2011;20(3):169–77.
19. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Shamim M, Giacomo K. Development and validation of a tool for non-technical skills evaluation in robotic surgery — the ICARS system. Surg Endosc. 2017;31(12):5403–10.
20. Undre S, Sevdalis N, Healey AN, Darzi A, Vincent CA. Observational Teamwork Assessment for Surgery (OTAS): Refinement and Application in Urological Surgery. World J Surg [Internet]. 2007 Jun 16 [cited 2018 Oct 26];31(7):1373–81.
21. Cohen TN, Wiegmann DA, Reeves ST, Boquet AJ, Shappell SA. Coding Human Factors Observations in Surgery. Am J Med Qual. 2017;32(5):556–62.
22. Non-Technical Skills for Surgeons (NOTSS) [Internet]. [cited 2019 Nov 26].
23. McBride KE, Steffens D, Duncan K, Bannon PG, Solomon J. Knowledge and attitudes of theatre staff prior to the implementation of robotic-assisted surgery in the public sector. PLoS One. 2019;14(3):1–8.

A prospective observational multicentre study concerning non-technical skills in robot assisted radical cystectomy versus open radical cystectomy.

Chapter 8

Robot-Assisted Radical Prostatectomy: A survery on the influence of postoperative results analysis and surgical video review on postoperative complications and functional results.

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Abstract

Objective

To investigate the experiences and opinions of surgeons in the field of Robot-assisted Radical Prostatectomy (RARP) on the influence of video reviews and postoperative results analysis on postoperative complications and functional results (i.e. urinary continence and erectile function).

Design, Setting, and Participants

RARP surgeons who were expected to perform video reviews and postoperative results analysis were identified. A total of 93 RARP surgeons were invited to participate in this survey. Online questionnaires were distributed.

Outcome Measurements and Statistical Analysis

The questionnaire contained the following domains: background information of the RARP surgeons, evaluation of the use of postoperative results analysis and surgical video review, and future recommendations.

Results and Limitations

A total of 30 RARP surgeons responded to the questionnaire. 27 respondents organized periodical results analyses, 17 of them reviewed edited videos as part of standard clinical practice in their hospital. Most respondents recommend video review, and are convinced it improves outcomes through self-reflection, feedback from a colleague, or from seeing different techniques and 'tricks'. The reviewed videos were watched in a group of surgeons, the videos had various subjects: outlined complications, salvage treatments, unusual/important findings or specific phases of surgery. The respondents agreed on the effect of the various phases of RARP on complications and postoperative outcomes. Their opinion of the influence of some surgical steps was ambiguous.

Conclusion

RARP surgeons have accepted the implementation of postoperative results analysis and surgical video review as forms of quality assurance and self-reflection. They use edited surgical videos during team meetings in order to gain insight into the specific facets (surgical steps) of RARP related to postoperative complications and functional outcomes (i.e. urinary continence and erectile function).

Introduction

In the USA, approximately 90% of the radical prostatectomy surgeries are performed using the surgical robot,[1] i.e. Robot-Assisted Radical Prostatectomy (RARP). The influence of the surgical skills during RARP on surgical complications and functional outcomes has been investigated, but the specific surgical steps influencing urinary continence and erectile function remain unclear so far.[1–3]

In general, laparoscopic and robotic surgery provides the possibility to evaluate surgeons' skills based on intra-corporal surgical videos.[4,5] Analysis of these videos offers the opportunity to gain insight into past performance and to relate intra-operative events to adverse postoperative outcomes to learn for the future.[6–9]

Effective training and assessment of performance are fundamental to ensuring that surgeons reach their intended goal and operate safely with maximum preservation of functions.[7,10,11] The field of video review and postoperative results analysis is focused on predicting postoperative results and reducing complications.[1,2,12,13] Even though multiple groups have investigated the possibility of video review it is unclear if video review has found its place in daily clinical practice. Earlier research of our group has shown Dutch experts are willing to participate in surgical video review.[1] Results have shown 92% of the respondents assume the use of surgical video review leads to recognition of errors and identification of possible improvements which can result in an improvement in surgical technique which can, in turn, contribute to the reduction of postoperative complications.[1]

To gain insight into the use, extent and possible effect of postoperative results analysis and surgical video review in daily clinical practice, a survey was performed amongst international RARP surgeons. The following key questions had to be answered:

Is postoperative results analysis and surgical video review implemented in daily practice RARP surgeons?

What different strategies of postoperative results analysis and surgical video review are used by the RARP surgeons?

Do these surgeons assume postoperative results analysis and surgical video review to be useful in improving daily practice and reduce complications?

Can RARP surgeons indicate which factors have their interest during postoperative results analysis and surgical video review related to improvement of postoperative functional outcomes and reduction complications?

Method

To obtain information on the experienced influence of video reviews and postoperative results analysis on complications and postoperative functional outcome, a questionnaire (supplementary data 1) was sent to investigate the opinions of RARP surgeons.

Surgeon panel

The surgeons were identified based on a multitude of factors: expected to perform video reviews and postoperative results analysis, have a known scientific interest in RARP through publications, have a high caseload, recommendation by an expert (HvdP), being a proctor or educator of a robotic fellowship, or being a staff member in one of the CC-ERUS-EAU host centers. Based on these (soft) criteria 93 RARP surgeons were invited to participate in this survey. Informed consent was obtained from all participants included in the study.

Questionnaire

The questionnaire (supplementary data 1) contained questions on: background information about the respondents, evaluation of the use of postoperative results analysis, evaluation of the use of surgical video review, the influence of postoperative results analysis and surgical video review on daily practice, and future recommendations on postoperative results analysis and surgical video review. The questionnaire was sent using the self-service function of the Data Management module developed by Research Manager https://my-researchmanager.com/en/home-2/.

Statistical analysis

In this descriptive study, data was presented as frequency distribution with percentages. Data was analysed with SPSS v25 (IBM Corp., Armonk, NY, USA).

Results

A total of 30 RARP surgeons (32%) responded to the survey, two responses were incomplete (figure 1). A total of 24 (80%) had at least five (or more) years of experience (Table 1). A total of 22 (73%) participants performed more than 500 RARPs in their

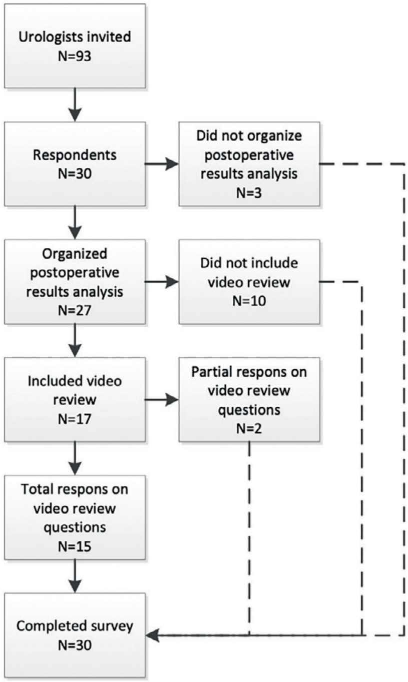

Figure 1. Flow diagram of response

career. The hospitals of 14 (47%) respondents were part of a combination of medical centers that work together in the field of prostate cancer care. The surgeons originated from all over the world (Table 1). Of the respondents 19 (63%) worked in a ERUS Robotic Certified Host centre.

The use of postoperative results analysis and surgical video review in daily practice

All respondents record surgical videos of their cases. Twenty-seven of the 30 (90%) respondents organized periodical postoperative result analysis meetings, of whom 17

(56%) included surgical video review (Table 2). One respondent was in the process of including surgical video review in their clinic. The postoperative results analyses were held at various intervals. Two respondents analysed and reviewed the data alone. Twenty-five (83%) respondents held the meetings in a team, of which eight only with urology staff, 13 with urology staff and residents, and four held one-on-one meetings. None invited nurses or operating room staff to the review meeting.

Table 1. Respondent characteristics

Question	n (%)
Total respondents (%/invitees)	30 (32)
Occupation*	
Fellow	1 (3.3)
Urologist	29 (97)
Professor	12 (40)
Chief	9 (30)
Trainer	9 (30)
Years of experience	
0 to 5	6 (20)
6 to 10	4 (13)
11 to 15	10 (33)
16 to 20	8 (27)
More than 20	2 (6.7)
RARPs performed personally	
<500	8 (27)
501 to 1000	4 (13)
1001 to 1500	3 (10)
1501 to 2000	5 (17)
2001 to 2500	5 (17)
2501 to 3000	3 (10)
>3500	2 (6.7)
RARPs performed in centre/network yearly	
<500	20 (67)
501 to 1000	5 (17)
1001 to 1500	1 (3.3)
1501 to 2000	2 (6.7)
2501 to 3000	1 (3.3)
>3500	1 (3.3)
Urologists performing RARP in your centre/network	
1 to 3	9 (30)
4 to 6	17 (57)
7 to 9	3 (10)
10 to 12	1 (3.3)

Table 1. continued

Question	n (%)
Country of origin	
Belgium	4 (13)
Great Britain	4 (13)
Italy	4 (13)
Germany	3 (10)
France	3 (10)
The Netherlands	3 (10)
Australia	1 (3.3)
Greece	1 (3.3)
India	1 (3.3)
Spain	1 (3.3)
Turkey	1 (3.3)
Czech Republic	1 (3.3)
United States	1 (3.3)
Sweden	1 (3.3)
Switzerland	1 (3.3)

*Seven respondents had multiple occupations.

*Three respondents were professor, chief and trainer. Two respondents were professor and chief. One respondent was professor and trainer. One respondent was chief and trainer.

Different strategies of postoperative results analysis and surgical video review

All of the respondents who incorporated video review showed either fast-forwarded or edited videos (i.e. specific phases of the surgery of fast-forwarded videos). Respondents reported several limitations of video review: lack of storage capacity, lack of structured video database, no structured analysis of videos, lack of time to edit and view videos, and privacy issues. Three respondents reported no limitations and one respondent stated they have staff editing the video material and have extra servers to store video cases. Other respondents would tackle stated limitations by clearing time schedule of staff and residents to view videos, hiring staff to edit videos to only see the relevant frames, creating a structured database with easy storage and acces to videos that meets privacy standards.

All but one respondents (96%) recommended implementation of video review, even those who did not yet practice it. They assumed it improves outcomes through self-reflection, feedback from a colleague who might see details they did not, or from observing different techniques and 'tricks' of a colleague. The participants stated it is important for both residents and staff to take a step back and view their own and others' techniques. It made them realize their limitations and where to focus their

Table 2. Organization of postoperative result analysis

Question	n (%)
Do you organize postoperative result analysis?	
Yes	27 (90)
Interval	
Once a month	7 (26%)
Once every two months	1 (3.7)
Once every three months	9 (30)
Twice a year	9 (30)
Once a year	3 (11)
Setting	
Alone	2 (7.4)
Group meeting, staff only	8 (30)
Group meeting including residents	13 (48)
One on one	4 (15)
Do you include video reviews?	
Always	7 (41)
75% of the time	7 (41)
50% of the time	2 (12)
25% of the time	1 (5.9)
In what way are videos shown?	
Edited videos, only certain phases	11 (65)
Fast forwarded video's	6 (35)
Are videos shown of one surgeon or multiple surgeons	
One surgeon	3 (18)
Multiple surgeons	14 (82)
Provision of background information during video reviews	
Blind	1 (5.9)
Yes case information after preliminary discussion	1 (5.9)
Yes, case information only	4 (24)
Yes, case information and surgeon information	11 (65)
Provision of feedback based on video review	
Yes, at a later time one-on-one verbally	4 (24)
Yes, during the meeting	11 (65)
No	2 (12)

improvement. The respondents believe video reviewing improves skills such as dexterity, speed, tissue handling. One respondent who incorporated video reviewing in the training program of residents stated ‘’Changes [in skills] happen in real time. I see the benefits of their efforts with each succeeding case.’’ The respondents advised similar formats: choose videos of complications or specific surgical steps, periodically review and discuss these videos in a panel of experts/colleagues or with mentor and residents, be open-minded to feedback and apply the feedback to improve daily clinical practice. Some participants suggested virtual messenger based groups to share short, deidentified videos with other experts or to send a video to an expert for reviewing. Future recommendations to improve the video review process were: standardized measurements (definition of failure), standardized reporting system, relating errors and complications to functional outcomes, relating specific surgical steps to outcomes.

The use of postoperative results analysis and surgical video review in improving daily practice and reduction of complications.

All respondents intended to adapt daily practice based on their periodical postopera-

Table 3. Respondents' perception of the influence of surgical steps on outcomes

Question	n (%)
Total respondents answering the following questions	17
Which of the surgical steps are of interest to you when looking at continence? (multiple answers possible)	
Abdominal cavity approach/port placement	1 (5.9)
Retropubic space approach/mobilisation of Retzius	4 (24)
Pelvic floor muscle exposure/opening of the endopelvic fascia	10 (59)
Bladder neck dissection	12 (71)
Ligation of prostate pedicles	4 (24)
Nerve preservation	14 (82)
Management of prostate apex/urethra	16 (94)
Prostate removal	2 (12)
Urethro-vesical anastomosis	15 (88)
Lymph node dissection	3 (18)
75% of the time	7 (41)
50% of the time	2 (12)
25% of the time	1 (5.9)
Which of the surgical steps are of interest to you when looking at erectile function? (multiple answers possible)	
Pelvic floor muscle exposure/opening of the endopelvic fascia	9 (53)
Bladder neck dissection	4 (24)
Ligation of prostate pedicles	11 (65)
Nerve preservation	17 (100)
Management of prostate apex/urethra	14 (82)
Urethro-vesical anastomosis	5 (29)
Lymph node dissection	4 (24)
Retropubic space approach/mobilisation of Retzius	1 (5.9)

tive results analysis. Two respondents required their urologists and urologists in training to perform RARP under guidance through a dual console Da Vinci robot, either at random or when they do not meet self-constructed quality criteria. Eight respondent (26%) specifically stated they adapted the surgical approach and postoperative care based on postoperative result analysis, video review and team discussions. They adapted surgical techniques in specific steps of the surgery, rejected techniques of limited benefit and analysed the results after a set number of months to create a continuous feedback loop. This has also led to changes in patient selection, due to the fact that some techniques are less suitable for specific cases.

During the meetings, topics of interest were challenging cases (such as patients with high BMI, large prostate volumes), margin status, functional outcomes and surgical complications based on Clavien Dindo classification. When assessing functional

Table 4: Factors associated with complications and outcomes

Beneficial	Detrimental
Lower age	Higher age
Narrow bladder neck	Overweight
Moment of surgery	Comorbidity
Patient positioning	Prior abdominal surgery
Surgical technique	Previous transurethral resection of the prostate or Salvage prostatectomy
Surgeon experience	Pelvic radiation
Peri-operative checks e.g. bladder filling to check for leakage	Surgical errors
Peri-operative anesthesiologic planning	Pelvic lymph node dissection
Expertise of and communication with bedside assistance	Extensive blood loss
Postoperative care	Coagulation during ‘management of prostate apex/urethra’, ‘urethro-vesical anastomosis’ and ‘nerve preservation

outcomes, most respondents reviewed those cases with optimal and bad outcomes and compared the surgical techniques on the videos. The reviewed cases had various subjects: outlined surgical complications, salvage treatments, unusual/important findings or specific phases of surgery.

Factors of interest in postoperative results analysis and surgical video review related to improvement of postoperative functional outcomes and reduction complications

Seventeen participants answered the following questions (Table 3). When asked what steps of the RARP possibly influence postoperative continence, 16 (94%) respondents answered ‘management of prostate apex/urethra’ and ‘urethro-vesical anastomosis.’ Fourteen (82%) respondents assumed ‘nerve preservation’ to influence recovery of continence. Twelve (71%) thought that ‘bladder neck dissection’ and 15 (88%) thought that ‘urethro-vesical anastomosis’ influences continence. All respondents believed ‘neurovascular bundles preservation’ and 14 (82%) believed that ‘management of prostate apex/urethra’ influences postoperative erectile function. Four (24%) respondents regard ‘bladder neck dissection’ and 11 (65%) regarded ‘ligation of prostate pedicles’ as important steps in preservation of erectile function. Factors regarded as being positively or negatively associated with complications and outcomes are represented in table 4.

Discussion

A survey was performed amongst international RARP surgeons to gain insight into the use, extent and possible effect of postoperative results analysis and surgical video review in daily clinical practice.

The use of postoperative results analysis and surgical video review in daily practice

Results of this study show both postoperative results analysis and surgical video review are used in the daily practice of most experts surveyed. Most of the respondents select cases for video review based on the postoperative results. Those respondents who have not yet implemented surgical video review are interested in implementation of video review in their practice. Three respondents did not use postoperative results analysis or surgical video review in their practice.

Different strategies of postoperative results analysis and surgical video review

Although the frequency and structure of these meetings vary, results of this study show RARP surgeons assume video analysis benefits postoperative results. Most RARP surgeons do not use entire videos but only use phases of videos during the video review. They edit the video to only show phases that the RARP surgeons feel are of interest concerning the outcome of the specific case. During the review meetings in the clinics of the surgeons included in this study, most teams show videos of different urologists of their centre whilst discussing data of the patient and surgeon. In one clinic, case information is presented without identifying the surgeon. In most clinics, feedback on the surgical techniques observed in the videos is given during these meetings.

The use of postoperative results analysis and surgical video review in improving daily practice and reduction of complications.

All surgeons included in this study think surgical video review should be implemented not only for trainees but also as a form of self-reflection for established surgeons. This is in agreement with the results of our previous publication.[1] RARP surgeons feel the implementation of postoperative results analysis and surgical video review could reduce complications and improve outcomes, this is similar to the results of the study by Schlomm et al.[8] and Cathcart et al.[9]

Multiple RARP surgeons use the postoperative results analysis and surgical video review as a manner to evaluate their surgical results and check the effects of changes in surgical approach. Two respondents use a dual console of the robot to perform live reviews of random surgeries as a form of quality assurance.

Factors of interest in postoperative results analysis and surgical video review related to improvement of postoperative functional outcomes and reduction complications

Results of the current study may be compared to the results of an earlier Delphi study performed by our group.[1] The results of the current study are in contrast to our earlier study in which 'management of prostate apex/urethra' and 'nerve preservation' are not mentioned as a factor influencing postoperative urinary continence.[1] In both studies agreement was reached on the role perceived quality of the 'urethro-vesical anastomosis' concerning postoperative recovery of urinary continence.[1] Goldenberg et al. evaluated the influence of surgical skills on functional outcomes using GEARS[15], an assessment tool scoring surgical performance with a 5-point Likert scale in six domains (perception, dexterity, efficiency, force sensitivity, autonomy, robotic control). They found significantly higher GEARS scores for the steps 'bladder neck dissection' and 'urethro-vesical anastomosis' in continent vs... incontinent patients[2].

Factors indicated to influence complications and outcomes by the surgeons in this study match the results of our earlier Delphi study in a group of Dutch experts.[1] This study adds insight into how video review can be used to learn how to influence these factors in order to improve outcome. Earlier research by Birkmeyer et al. has shown it is possible to use surgical videos to predict complications and postoperative outcome.[6]

A possible influence to the use of postoperative results analysis and surgical video review in daily practice not raised by the RARP surgeons could be the new and more stringent General Data Protection Regulation (GDPR) in the European Union.[16] Systems should be put in place to assure safe data storage and privacy protection of the patient. Further investigation into the influence of the new GDRP on the use of postoperative results analysis and surgical video review should be performed. One solution is the anonymization of both surgical video and patient data but this makes correlation of additional follow-up information to the peri-operative data and the surgical video impossible.

Limitations

The relatively low overall response rate (32%) may reflect the interest in this topic in the urological field. Whereas the responders were generally positive towards data review, the majority of surveyed centers did not respond. If this observation reflects reduced time availability for data review this is reason for concern given the positive effects of structured data review. The results of this study give the first insights into the experienced value of postoperative results analysis and surgical video review in the daily practice of RARP surgeons worldwide and a significant number of urologists were invited for the survey. Although the experts originated from 15 different countries, the majority of surgeons who completed the questionnaire came from western European country's. Although it is possible that we missed urologists who use postoperative results analysis and surgical video review, we expect that, since the responses of these participants were homogenous, the results in this study represent a near complete overview on the topic. Potentially, 63 more respondents could have given their insight into video review analysis. Two respondents did not fully answer the video review questions.

Suggestions for future research

Although there is some discrepancy between the results of this study and the results of our previous Delphi survey amongst Dutch experts[1], the results of the present study give additional insights into the acceptance of postoperative results analysis and surgical video review amongst European experts in RARP. The level of detail in the surgical and anatomical factors indicated by the experts gives more insight into which specific factors experts assume to be associated with surgical complications and negative functional outcomes. This information can give rise to additional fields of research such as the training of artificial intelligence to recognize surgical errors and events in order to help in the selection of surgical videos for review. Additionally, factors identified by the experts could be used to train human observers or Machine learning algorithms to observe and analyse the surgical videos, and to evaluate whether the relation between postoperative outcomes and the factors identified by the experts could be objectified.

Conclusion

The majority of interviewed RARP surgeons have adopted the implementation of postoperative results analysis and surgical video review in their daily practice as a form of quality assurance and as a form of self-reflection. Since only a minority of surgeons responded to the survey this raises concern on the application of data review in daily practice in non-responders. Most of the responding surgeons use edited surgical videos during team meetings to discuss RARP cases and gain insights into surgical handling and postoperative results. The information provided in this survey gives information on the best method of implementation of video review and gives rise to additional fields of research on the origins of surgical complications and adverse postoperative functional results.

References

1. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;
2. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
3. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44.
4. Varban OA, Niemann A, Stricklen A, Ross R, Ghaferi AA, Finks JF, Dimick JB. Far from Standardized: Using Surgical Videos to Identify Variation in Technique for Laparoscopic Sleeve Gastrectomy. J Laparoendosc Adv Surg Tech [Internet]. 2017 Aug 1 [cited 2017 Aug 18];27(8):761–7.
5. Oussi N, Loukas C, Kjellin A, Lahanas V, Georgiou K, Henningsohn L, Felländer-Tsai L, Georgiou E, Enochsson L. Video analysis in basic skills training: a way to expand the value and use of BlackBox training? Surg Endosc [Internet]. 2017 Jun 29 [cited 2017 Aug 18];1–9.
6. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.
7. Goldenberg MG, Lee JY, Kwong JCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence. Vol. 122, BJU International. 2018.
8. Schlomm T, Huland H, Graefen M. Improving outcome of surgical procedures is not possible without adequate quality measurement. Eur Urol [Internet]. 2014;65(6):1017–9.
9. Cathcart P, Sridhara A, Ramachandran N, Briggs T, Nathan S, Kelly J. Achieving quality assurance of prostate cancer surgery during reorganisation of cancer services. Eur Urol [Internet]. 2015 Jul 1 [cited 2018 Apr 5];68(1):22–9.
10. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.
11. Beulens AJW, Brinkman W, Porte P, Meijer R, Van Merriënboer J, Van Der Poel H, Wagner C. The value of a one-day multidisciplinary robot surgery training for novice robot surgeons. J Robot Surg. 2018;
12. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
13. van Basten JPA, Somford RM, de Baaij J, Sedelaar M, Vrijhof E. Initiatief Comprehensive Prostate Cancer Network (CPCN) in Zuidoost Nederland. Tijdschr voor Urol. 2017;7(6–7):134–44.
14. Kong H, West S. WMA DECLARATION OF HELSINKI – ETHICAL PRINCIPLES FOR Scienti c Requirements and Research Protocols. W [Internet]. 2013;(June 1964):29–32.
15. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.
16. European Parliament and of the Council. Regulation (EU) 2016/679 of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Off J Eur Communities [Internet]. 2016;OJ L 119/1:1–88.


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Section III

What is the relation between a surgeon’s performance and a patient’s postoperative outcomes?

Chapter 9

Identifying surgical factors predicting postoperative urinary continence in robot-assisted radical prostatectomy

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Abstract

Background

Surgical technique in robot assisted radical prostatectomy (RARP) may determine in a significant extent the postoperative recovery of urinary continence and erectile function. This raises the question whether an experienced urologist can predict these functional outcomes based on the observation of the used surgical technique by video analysis.

Our research questions are: (1) Are expert surgeons able to predict postoperative urinary continence of RARP by performing surgical video analysis of the nerve sparing technique, apical dissection, and construction of the vesico-urethral anastomosis? (2) Can results of the templated assessment methods (GEARS, PACE and PROTEST) be related to postoperative urinary continence?

Methods

Two subgroups of patients were selected from an institutional database, the subgroups were matched based on their postoperative reported urinary continence levels (continency group; continency vs. incontinence). Surgical skills were measured by a single trained assessor using three different templated assessment methods; the global evaluative assessment of robotic skill (GEARS), the Prostatectomy Assessment and Competence Evaluation (PACE), and the PROTEST method. As a fourth assessment method the videos were analysed by two expert surgeons, and they were asked to predict postoperative continence levels in all surgeries.

Results

The different aspects of GEARS, PACE, and PROTEST methods showed no differences in the continency and potency groups. Expert 1 was able to correctly assess continence in 66.7% (8/12 patients) of the patients. Expert 2 was able to correctly assess continence in 33.3% (4/12 patients) of the patients.

Conclusion

Results of this study show the prediction of continence levels by expert surgeons gives insight into peri-operative factors which according to expert opinion influence postoperative urinary continence.

Introduction

The introduction of laparoscopy and robot assisted laparoscopy facilitates the recording of intra-corporal surgical videos.[1,2] Analysis of these videos offers the opportunity to gain insight into past performance and review previous adverse postoperative outcomes to learn for the future.[3,4] Effective training and assessment of performance are fundamental ensuring that surgeons reach their intended goal and operate safely.[4,5]

Different template-based video assessment methods have been developed in order to assess surgical skill in Robot Assisted Radical Prostatectomy (RARP). The Prostatectomy Assessment and Competency Evaluation (PACE) developed by the group of Hussein et al.[6] has its focus on objective and procedure specific assessment of skills. The Global Evaluative Assessment of Robotic Skill (GEARS) method can be used to evaluate both live surgeries and videos of (robot assisted) laparoscopic surgery. The Generic Error Rating Tool (GERT) can be used to score intra-operative errors made by the surgeon. Most of these assessment methods are currently used to assess the effectiveness of training (PACE [7]) or the basic surgical skill (GEARS/GERT [8]).

Multiple groups are performing different types of analysis into surgical skills in order to improve postoperative outcome and reduce complications.[9–13] The group of van Basten et al. reviews surgical videos in order to learn from past performance by expert surgeons as part of their cyclical quality improvement analysis in order to reduce complications and improve postoperative outcome[11].

The group of Goldenberg et al. used the GEARS[8] assessment method and (generic error rating tool) GERT[14] to assess specific sections of the RARP in order to evaluate if there is a possible correlation between surgical skills and postoperative outcome, mainly the early continence after RARP.[9]

The group of Hung et al. have used kinematic and events data (automated performance metrics) in order to evaluate surgical skills.[10,15,16] In a recent study Hung et al. used automated performance metrics to train Machine Learning algorithms in order to predict clinical outcomes.[10]

The PRostatectomy video Observation to Evaluate and Score Technical skill (PROTEST) assessment method was developed by our research group using a Delphi method. It can be used to assess both surgical skill and peri-operative events. So, it may help individual surgeons to improve their skills.[17] The correlation between the different video assessment methods (GEARS/GERT, PACE, and PROTEST) and postoperative outcome could give more insight into the possible origins of adverse postoperative outcome.

Moreover, to gain more insight into which aspects of the surgical skills as assessed by the different assessment methods could be related to specific postoperative outcomes the following research questions will be investigated: (1) Are expert surgeons able to predict postoperative urinary continence by performing surgical video analysis of the preservation of the neurovascular bundles, apical dissection, and vesico-urethral anastomosis phase of the RARP? (2) Can aspects of task performance as measured by either GEARS, PACE or PROTEST assessment methods be related to postoperative urinary continence? These questions will be answered by performing an exploratory study.

Method

Subject selection

Patients who underwent a robot assisted radical prostatectomy in the Antoni van Leeuwenhoek Hospital in Amsterdam between June 2009 and February 2017, the Netherlands, were eligible for this study. All of the selected patients were operated by the same expert robotic surgeon (HvdP), who had performed over 200 RARP's using the daVinci Si surgical robot by Intuitive in June 2009 and over 1400 RARP's in February 2017.

An initial selection was made based on available Patient-reported outcome measures (PROMS) records of the patients. In 227 patient's complete PROMS data were available at 6 or 12 months postoperative. Two groups of patients (continency and incontinency) were selected and matched (figure 1).

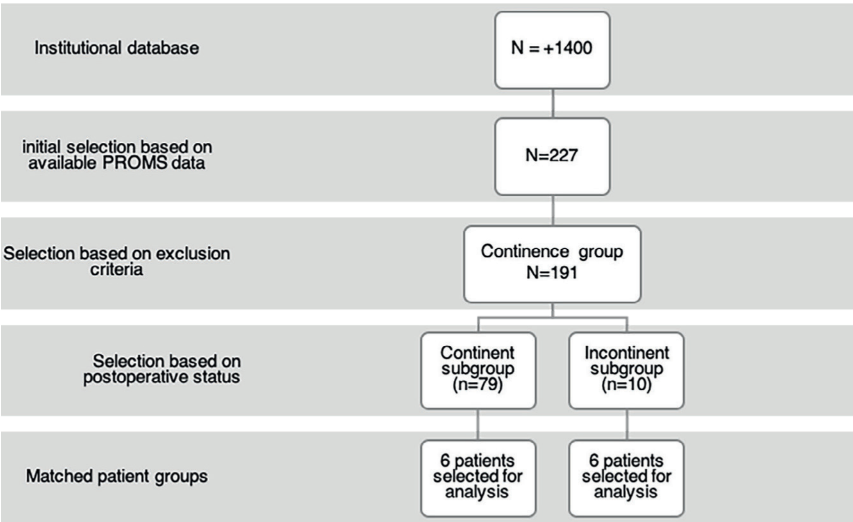

Figure 1 study design

Power analysis

Since this is a pilot study a power analysis was performed based: on the measures from one of the methods (GEARS) used during this study. The sample size analysis was based on a publication of Volpe et al.[18] in this study both experts and fellows were observed during a RARP using the GEARS score in order to determine their ability to perform a RARP. The results show a significant higher score for the experts compared to the fellows.

These results show it is possible to detect a difference in sample means of 2.65 on the total GEARS score.

For this study we assume the GEARS score in the incontinent patients is similar to that of a fellow and the GEARS score in the continent patients is similar to that of an expert. Based on a power calculation using .05 as Alpha, a Power of .80, and an effect size of 2.65 a sample size of 6 patients per subgroup would be sufficient for the main objective of this study.

Selection and Matching

The patients were selected based on the patients' pre-operative and post-operative urinary continence as measured using the International Consultation Incontinence Modular Questionnaire-short form (ICIQ-SF-score). The ICIQ-SF is a Patient-reported outcome measures (PROMS) questionnaire which registers the patient's urinary incontinence on three domains, the frequency of urine leakage (0-5 points), the amount of leakage according to the patient (0-6 points), and the interference of the urine leakage with everyday life (0-10 points). An additional question which asks in which situation the urine leaks gives more insight into the type of incontinence. The cumulative scores of the three question (0-21 points) represent the patient's experience of urinary incontinence. In this study an ICIQ-SF score of 0 at 6 and 12 months postoperative was defined as continent, whilst and ICIQ-SF of >10 at 6 and 12 months postoperative was defined as incontinent. Exclusion criteria were urinary incontinence prior to surgery, and surgical procedures where no or incomplete video material was available.

The patients in the continency group were matched according to the date of the surgery, the age of the patient, BMI of the patient and the preoperative intentions of saving the neurovascular bundles during surgery. All incontinent patients were manually compared to the continent patients by the researcher (AB). Based on the number of variables in which the pairs matched a matching score of zero to four was given to the patients, each matched variable resulted in a point in the total matching score. The patients were matched based on age (difference of <5 years = 1 matching point), BMI (difference <3 points = 1 matching point), date of the surgery (difference <3 months = 1 matching point), and preoperative intentions of saving the neurovascular bundles during surgery on both sides (NVB sparing the same in both patients = 1 matching point). A matching score of 4 was the best possible match. Based on the matching scores the best matched patient pairs were selected for analysis, since almost no perfect matches existed (Appendix 1a). If matched pairs with similar matching scores existed a definitive choice was made based on the variable on which the patients matched (appendix 1a).

Prediction of continence by the surgeon who performed the surgery and the independent expert surgeon

The videos were evaluated by two expert surgeons (the surgeon who performed the surgery (HvdP, self-assessment, hereafter called Expert 1) and an independent expert in RARP (JPvB, expert assessment, hereafter called Expert 2)). The experts were blinded for the patients' postoperative status and were asked to evaluate all pro-

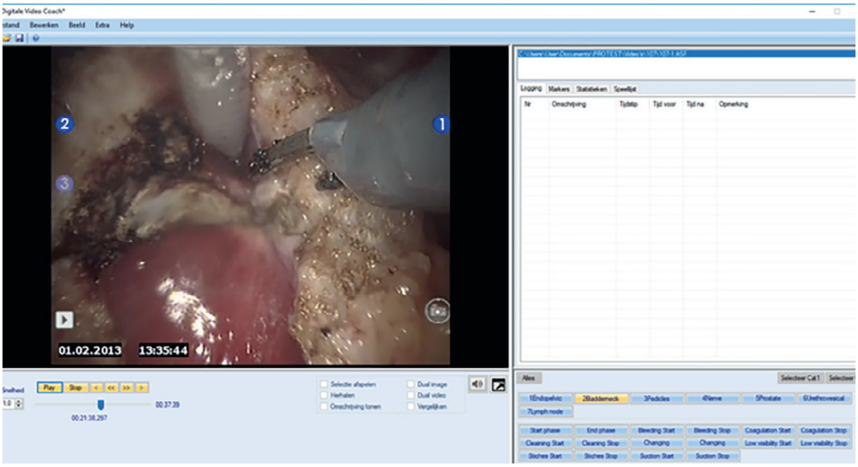

Figure 2 overview of the video analysis software Digital Video Coach.

cedures. The predictions were performed on the prostate apical dissection phase and vesico-urethral anastomosis phase of the RARP procedure for continency prediction, and neurovascular bundle dissection for potency prediction. The experts were asked to predict the likely postoperative outcome of the patient in absolute terms of continency/incontinence. Additional information concerning the basis of this prediction was asked during analysis of the surgical video. After prediction the results of the experts were compared with the postoperative status of the patients.

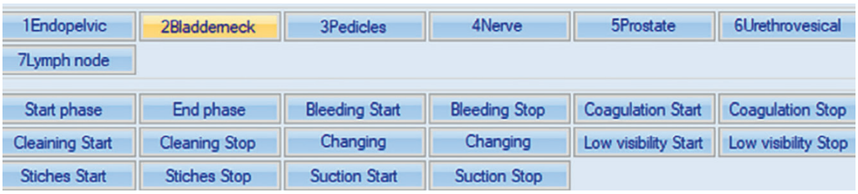

Figure 3 overview of the labels used in the PROTEST analysis using software Digital Video Coach

Surgical skills analysis using different methods of video assessment templates.

Surgical videos were analysed by a single rater (AB) with training in surgical video analysis and expertise of the surgical procedure. This rater performed the surgical video analysis using GEARS, PACE and PROTEST. Since we did not expect any sequence effects due to the differences in focus in the assessment methods no counterbalancing or randomisation of assessment methods was performed.

1. Videos were evaluated using the Global Evaluative Assessment of Robotic Skill (GEARS).[8] The focus of the GEARS assessment method lies on general robot surgical principals, i.e. depth perception, bi-manual dexterity, efficiency, force sensitivity, autonomy, and robotic control.8 The GEARS assessment method is scored on 5 aspects of surgical skills (Depth perception, Bi-manual dexterity, Efficiency, Force sensitivity, Robotic control) using a 5-point Likert scale; minimum score is 5 the maximum score is 25.

2. Videos were evaluated using the Prostatectomy Assessment and Competence Evaluation (PACE).[6] The PACE assessment method focusses on surgical skills using specified steps of the RARP procedure. This method is mainly used to define deficits in the surgeon's skills in order to provide surgeon specific training to improve surgical skill. The PACE assessment method consists of assessment of six domains with 10 sub-domains which are scored on 5-point Likert scales; minimum score is 10 the maximum score is 50.

3. Videos were evaluated using the PRostatectomy video Observation to Evaluate and Score Technical skill (PROTEST) Assessment method developed by this research group.[17] The PROTEST assessment method gives detailed insight into the proficiency of the surgeon on each of the individual surgical steps of the RARP. It combines the answers to two general subjective questions with multiple objective measurements in order to provide detailed feedback to the surgeon.

The process of surgical video analysis

The surgical video was assessed in two phases, first the PROTEST assessment was performed for the entire surgical video using customizable video analysis software "digital Video Coach" developed by ZEAL IT (figure 2). Secondly the PACE and GEARS assessments were performed simultaneously by reviewing the surgical video in a normal media player. The GEARS score was calculated for the entire surgery.

The video analysis software "Digital Video Coach" made it possible to measure the length of the phases of the surgery and the length of the different peri-operative events. Two sets of labels were created in order to define the different phases of the surgery and the different peri-operative events. The selection of one of the labels automatically marked the time code corresponding to the moment the label was pressed. This made it possible to measure the duration of the phases and peri-operative events. The labels used for this analysis are given in figure 3. The steps correspond to the different steps in the PROTEST assessment method[17]. The second category encompassed peri-operative events which could be related to postoperative outcomes. These events were defined in the PROTEST Assessment method.[17]

Data analysis

Data analysis was performed using SPSS statistics v24 (IBM, NY). Frequency statistics were calculated for patient demographic data and surgeon scores. Correlation between observed scores on the one hand and postoperative functional outcome on the other hand were calculated using a Spearman Rho test. Odds ratios (OR) and 95% confidence intervals (CIs) were calculated. The Wilcoxon signed-rank test was used to compare differences in results between the matched patient groups. The McNemar's test was used in order to compare differences in results between the matched patient groups in case of dichotomous variables. The predictions by the experts were correlated with the postoperative status of the patients using a crosstab, to determine any significant correlations between variables the Pearson chi square or fishers' exact tests were used. Inter-observer agreement was calculated using Cohen's kappa, which was interpreted using the guidelines from Landis & Koch[19,20]. Statistical significance was set at $p < .05$ based on a two-tailed comparison.

Due to the retrospective nature of the study, participants were not subjected to any study treatments or actions. Surgical videos and medical information used were registered as standard of care in the patients' medical file. Therefore, the Medical Research Involving Human Subjects Act does not apply and no informed consent was obtained. However, during the screening of patients, the medical records will be carefully checked for objection to medical research. This study was granted approval from the institutional medical committee.

Results

In the continence group 191 of the 227 patients were eligible for inclusion. Based on selection criteria 79 patients were included in the continent subgroup, 10 patients in the incontinent subgroup.

Matching and selection

Based on the matching criteria for the continency group the 10 incontinent patients were manually matched with the 79 continent patients. Based on the power calculation 6 pairs were selected based on the date of the surgery, BMI, age, and preoperative intention of saving the neurovascular bundles during surgery on both sides (see appendix 1). A total of 12 individual patients were selected for analysis.

Table 1: Baseline characteristics of the selected patients

Characteristics	Postoperative incontinent patients (n=6) Median (min - max)	Postoperative continent patients (n=6) Median (min - max)	P-value	Z-Value
Age (years)	64 (57 - 67)	62.5 (53 - 66)	0.674	-0.420
Body Mass Index (kg/m2)	26.86 (20.45 – 32.55)	25.99 (22.50 – 32.11)	0.917	-0.105
Prostate size (ml)	50 (39 - 81)	38 (35 - 82)	0.225	-1.214
Gleason score	7 (6 - 8)	6 (6 - 7)	0.157	-1.414
Membranous urethral length (mm)	11.07 (8.69 – 13.10)	13.58 (10.48 – 16.15)	0.273	-1.095
Surgery date, median (IQR)	15-02-2014 (02-02-2013 – 15-03-2015)	27-04-2014 (06-12-2012 – 29-01-2015	0.600	-0.524
Preoperative IPSS score	3 (0 - 7)	2.5 (0 – 8.5)	0.892	-0.135
6 months postoperative IPSS score	15 (0 - 19)	3 (0 - 5)	0.042	-2.032
12 months postoperative IPSS score	10 (6 - 16)	2 (0 - 5)	0.043	-2.023
Preoperative ICIQ score	0 (0 - 0)	0 (0 - 0)	1.000	0.000
6 months ICIQ score	15 (11 - 20)	0 (0 - 0)	0.027	-2.207
12 months ICIQ score	14 (12 - 17)	0 (0 - 0)	0.026	-2.232

Baseline characteristics

When comparing the 6 and 12 months postoperative IPSS scores, postoperative ICIQ scores, and postoperative EORTC QLQ-PR25 scores, the continent subgroup had significantly lower IPSS scores, ICIQ scores, and EORTC QLQ-PR25 scores than the incontinent subgroup (Table 1).

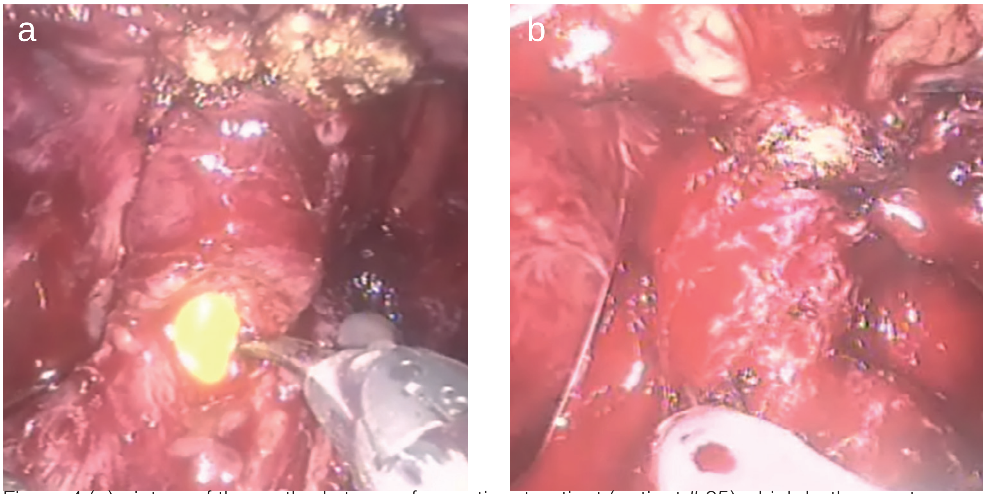

Figure 4 (a) picture of the urethral stump of a continent patient (patient # 35) which both experts judged as continent. (b) shows the urethral stump of an incontinent patient which expert 1 judged as incontinent and expert 2 judged as continent (patient # 82).

Prediction of continence by the surgeon who performed the surgery and the independent expert surgeon

The predictions of both Expert 1 and Expert 2 were related to the actual patient outcomes for continence. This analysis has been performed for the 12 patients selected. Figure 4a shows a picture of the urethral stump of a continent patient, figure 4b

Table 2: Results of the video evaluation by two experts in the field of RARP, presenting the prediction of continence based on apical dissection and urethero-vesical anastomosis. P-value calculated using Fisher's Exact Test.

	Patients included,, n=12 (%)	P-value
Expert 1 correct assessment	8 (66.7)	0.048
Expert 1: undetermined	3 (25.0)	
Expert 2: correct assessment	4 (33.3)	1.000
Expert 2: undetermined	3 (25.0)	

shows the urethral stump of an incontinent patient.

The results in table 2 show the results of the analysis of continence group. These results show Expert 1 was able to correctly predict the postoperative continence in 88.9% (8 out of 12 patients (p-value = .048)) of the patients. Expert 1 was undetermined in case of three patients.

Expert 2 was able to correctly predict the postoperative continence in 33.3 % (4 out of 12 patients) of the patients. Expert 2 was undetermined about three patients. For the continency group, Cohens Kappa level of inter-observer agreement on predicted continence between Expert 1 and Expert 2 was slight at .087

Factors predicting continency and potency according to the analysis of two expert surgeons

The experts predicted the expected continency in all patients. They were able to identify some factors in patients which they felt had an influence on continence of the patients.

In case of continence the length and thickness of the urethral stump (a longer and wider stump predicted better continency according to the experts), level of coagulation during the apical dissection (more coagulation predicted less continency according to the experts), and bladder neck preservation/reconstruction were mentioned as factors influencing the level of postoperative continence in patients (appendix 2). The presence of a short urethral stump was mentioned in most patients in which the experts were undetermined.

Surgical skills analysis using different methods of video assessment templates.

The GEARS, PACE and PROTEST assessment methods were used to determine whether aspects of task performance as measured by either assessment templates can be related to postoperative outcomes.

Using the GEARS Assessment method aspects of depth perception, bi-manual dexterity, efficiency, force sensitivity, autonomy and robotic control were assessed. The results of the comparison between incontinent and continent patients (continency group) can be found in supplementary data 1, no significant differences in the aspects of the GEARS assessment method were found.

The results of the PACE assessment are shown in supplementary data 2. No significant differences between groups in PACE scores were found.

The results of the general aspects of the PROTEST assessment method showed no significant differences between continency group (supplementary data 3a). The results of the in-depth analysis of different phases of the surgery according to the PROTEST assessment method for continency group can be found in supplementary data 3b, in these results no significant differences were found between incontinent and continent patients.

Discussion

In this study we investigated whether the assessment of surgical videos is useful to predict functional outcomes after prostatectomy. Existing scoring methods were compared to expert surgeons' opinion by video-analysis of RARP surgeries of the prostate apical dissection phase, and vesico-urethral anastomosis phase and assessment of the neurovascular bundles?

Are expert surgeons able to predict postoperative functional outcomes by performing surgical video analysis?

This study shows both experts were able to predict potency in most patients. Expert 1 was able to predict the postoperative continence status in 66.7% of the patients. This is represented in the almost perfect level of agreement between the postoperative status and the results of Expert 1. Expert 2 was able to predict the postoperative continence status in 33.3% of the patients. Especially the prediction of incontinence in patients seemed more difficult for Expert 2. The self-assessment of Expert 1 and independent assessment of Expert 2 reached a slight level of agreement between their assessments.

In case of continency both experts agree a good length and thickness of the urethral stump could be associated with increased chances of continence. Although the influence of the urethral length on postoperative continence has been reported in both MRI and pathological studies [21–24] this relation has not yet been investigated using surgical video assessment.

In addition, Expert 2 felt the use of thermal dissection during the dissection of the urethra could negatively influence the continence of patients. Expert 1 focussed more on the level of bladder neck preservation and/or reconstruction in patients, a narrower bladder neck/bladder neck reconstruction prior to anastomosis could be associated with higher incidences of continence.

The fact that Expert 1 was better able to correctly predict both incontinence and continence in patients could be due to the fact that this type of assessment is a type of self-assessment, although the most recent surgery was of July 2016 (with an average of 200 surgery's per year), Expert 1 could recognise some surgical techniques which could help him in predicting the continence status of the patients. Another reason for the success of Expert 1 could be due to the fact that he looked at different peri-operative factors than expert 2. This could indicate a higher influence of a narrower bladder neck/bladder neck reconstruction[25,26] on the level of continence compared to the influence of thermal dissection during the dissection of the urethra. It is difficult to prove this statement based on the results of this study due the small size of the study population.

The comments from the experts to the relatively accurate prediction of continence outcome learned that urethral length and urethra thickness were considered when continence was scored by experts. Urethral sphincter length as assessed by MUL assessed on MRI and in the removed prostate specimens was found a strong predictor of post-prostatectomy continence[21–23.] Therefore, objectively measuring intra-operative urethra stump length may improve prediction and is subject of further study. The results of these assessment methods combined with intra-operative measurements and automated performance metrics analysis developed by Hung et.al.[10] could be used to improve surgeons' skills and improve the patient's postoperative outcome. A combination of patient and surgeon data could be used to develop a personalized prediction model for both continence and potency after RARP.

The group of Stern et.al. have performed a study into a single surgeon's prediction of continence based on the quality of bladder neck preservation, cavernous nerve sparing, urethral length, quality of anastomosis, striated sphincter thickness, quality of posterior reconstruction, and quality of bladder neck plication stitch.[27] The surgeon was asked to score each factor directly after the surgery with either the verdict "bad", "average" or "good". They did not find any correlation between the investigated factors and postoperative continence. Since the assessment of the surgeon was directly postoperative and not based on the revision of the surgical video the verdict of the surgeon could have been influenced by other factors, for example, distracting factors in the operating room, rather than solely the factors analysed during the surgery.

Surgical video assessment templates

The second objective of this study was to investigate whether results of the GEARS, PACE and PROTEST assessment methods could be related to postoperative outcome defined as continence and erectile function. Although the GEARS, PACE, and PROTEST analysis can be used to assess surgical skills, results showed no significant difference between the incontinent and continent patients nor between impotent and potent patients. The factors assessed by the experts are not included in either templated assessment method, addition of factors in the templated assessment methods such as assessment of the urethral length could increase their use in the prediction of postoperative outcome.

Although the results of this study do not show it, the factors analysed in the different assessment methods have been found to be of influence in other studies in the origins of poor postoperative outcome. The group of Goldenberg et al. have reported the mean overall GEARS scores as an independent predictor of postoperative continence in 47 patients (24 incontinent vs. 23 continent).[9] A possible explanation for the fact that our study did not show this difference is the sample size. It is possible further research in larger groups of patients could give more insight into the relation between the different factors of the assessment methods and postoperative outcomes.

Limitations

Our study is a retrospective study in which patients of a single surgeon were analysed. The sample size was based on the difference between novice and expert surgeon, since in this study the comparison was made in one expert surgeon the sample size might be to small. We tried to reduce the influence of selection bias by matching the patient subgroups. Since no perfect matches existed in the continency group best alternatives were sought. .

Since the experts had different focus points during the assessment of the videos (i.e. the influence of bladder neck vs. coagulation of the urethra) it remains difficult to say if the differences in outcomes are related to the field of interest of the experts. Another explanation of the difference could lie in the fact that expert 1 is the surgeon who performed the surgery, it could be that since he is more familiar with his own techniques and outcomes and could there for assess the patient's postoperative status more accurately. Although we did not expect any sequence effects in the templated assessments of the surgical videos, the results could have been influenced by the sequence of assessment.

Conclusion

Both experts were able to accurately predict postoperative potency based on the surgical videos. One of the experts was able to correctly predict continence. Further research into the use of objective measurements in surgical video analysis could clarify the relation between the factors identified by experts and postoperative continence status. Although in this study the use of template-based video assessment did not reveal any factors related to postoperative outcome, the results could be used to improve surgeons' skills since these assessment methods give a detailed overview of the surgeon's performance which is important in both novice and expert surgeons.

Appendix

Appendix 1 matching scores per pair of patients.

The patients were matched based on age (difference of < 5 years = 1 matching point), BMI (difference <3 points = 1 matching point), date of the surgery (difference <90 days = 1 matching point), and preoperative intentions of saving the neurovascular bundles during surgery on both sides (NVB sparing the same in bot patients = 1 matching point).

Study # incontinent	Study # continent pair	Difference OR date (days)	Match point OR date	Difference BMI (points)	Match point BMI	Difference age (years)	Match point age	Difference NVB	Match point NVB	Total score match point	Matched pair selected (yes/No)
82	84	38	1	1.20	1	3	1	None	1	4	Y
212	213	1	1	2.05	1	3	1	None	1	4	Y
140	143	42	1	1.45	1	13	0	None	1	3	Y
167	153	89	1	0.59	1	4	1	None	1	3	Y
116	107	90	1	0.44	1	7	0	None	1	3	Y
147	155	130	0	1.42	1	1	1	None	1	3	Y
128	129	7	1	1.23	1	1	1	None	1	4	N
136	141	50	1	0.15	1	10	0	None	1	3	N
140	155	203	0	0.88	1	7	0	None	1	2	N
32	30	2	1	0.13	1	13	0	None	1	3	N
200	178	276	0	0.02	1	2	1	None	1	3	N
116	121	49	1	5.13	0	0	1	None	1	3	N

A total 12 possible match pairs were identified for the 10 incontinent patients. The match pairs 82/84, 128/129, and 212/213 were chosen because of their maximum match score of 4. During review the video of patient 129 did not work, this was a reason to exclude this matched pair and replace it with another matched pair. Individual patients were part of multiple matched pairs in case of five matched pairs (147/155, 140/155, 140/143 and 116/121, 116/107). Of these matched pairs 140/155 was not chosen because match pair 140/143 matched better on date of the surgery which reduces the influence of the learning curve on the postoperative results. Match pair 147/155 was chosen because there is a shorter interval between dates of the surgery compared to 140/155. Match pair 116/121 was not chosen because match pair 116/107 matched similar on date of the surgery and better on BMI of the patient which could reduce the influence of BMI on the postoperative results. The match pairs 140/143, 167/153, and 116/107 were chosen because they matched on the date of the surgery and BMI. Match pair 200/178 was not chosen because of the large interval between dates of the surgery which could increase the influence of the learning curve on the postoperative results.

Appendix 2 assessment of continency per patient with factors predicting continency according to the analysis of two expert surgeons

Pt. ID.	Group	Post-op continence	Expert 1 continence	Expert 2 continence	Expert 1 factors				Expert 2 factors			
					Stump thickness	Stump length	Bladder neck	Additional comments	Stump thickness	Stump length	Bladder neck	Additional comments
82	1	I	I	C		Short	Wide bladder necks no recon-struction		Thick			
84	1	C	C	C	Thick	short			Good	Good		Good anastomo-sis
107	1	C	U	C		short			Thin	Suffi-cient		
116	1	I	U	C		short	small bladder neck		Thick			
140	1	I	I	C	rea-sona-ble	rea-sona-ble			Thick			Poor vis-ualisation due to bleeding
143	1	C	U	U		short				Short		
147	1	I	I	U	thick	short	Wide, multiple anasto-mosis stitches, no recon-struction		Thick	Short		

153	1	C	C	I	reasonable	reasonable	narrow bladder neck					Extensive coagulation
155	1	C	C	C	medium	medium			Fair	Short		
167	1	I	C	C	thick	short	BN preservation			Short		
212	1	C	C	U	normal	Normal				Short		
213	1	I	I	I		short		median fibrous raphe reconstruction				Extensive coagulation

C = Continent, I = Incontinent, U = Undetermined

References

1. Varban OA, Niemann A, Stricklen A, Ross R, Ghaferi AA, Finks JF, Dimick JB. Far from Standardized: Using Surgical Videos to Identify Variation in Technique for Laparoscopic Sleeve Gastrectomy. J Laparoendosc Adv Surg Tech [Internet]. 2017 Aug 1 [cited 2017 Aug 18];27(8):761–7.
2. Oussi N, Loukas C, Kjellin A, Lahanas V, Georgiou K, Henningsohn L, Felländer-Tsai L, Georgiou E, Enochsson L. Video analysis in basic skills training: a way to expand the value and use of BlackBox training? Surg Endosc [Internet]. 2017 Jun 29 [cited 2017 Aug 18];1–9.
3. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.
4. Goldenberg MG, Lee JY, Kwong JCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence. Vol. 122, BJU International. 2018.
5. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.
6. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
7. Mayr R, Fritsche H-M, Pycha AA, Pycha AA. Radical cystectomy and the implications of comorbidity. Expert Rev Anticancer Ther [Internet]. 2014 Mar 8 [cited 2017 Jan 24];14(3):289–95.
8. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.
9. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
10. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44.
11. van Basten JPA, Somford RM, de Baaij J, Sedelaar M, Vrijhof E. Initiatief Comprehensive Prostate Cancer Network (CPCN) in Zuidoost Nederland. Tijdschr voor Urol. 2017;7(6–7):134–44.
12. Sotelo RJRJ, Haese A, Machuca V, Medina L, Nuñez L, Santinelli F, Hernandez AA, Kural AR, Mottrie A, Giedelman C, Mirandolino M, Palmer K, Abaza R, Ghavamian R, Shalhav A, Moinzadeh A, Patel V, Stifelman M, Tuerk I, et al. Safer Surgery by Learning from Complications: A Focus on Robotic Prostate Surgery. Eur Urol [Internet]. 2016 Feb 1 [cited 2017 Jun 11];69(2):334–44.
13. Chen J, Cheng N, Cacciamani G, Oh P, Lin-Brande M, Remulla D, Gill IS, Hung AJ. Objective Assessment of Robotic Surgical Technical Skill: A Systematic Review. J Urol. 2019;201(3):461–9.
14. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.
15. Hung AJ, Oh PJ, Chen J, Ghodoussipour S, Lane C, Jarc A, Gill IS. Experts vs.. super-experts: differences in automated performance metrics and clinical outcomes for robot-assisted radical prostatectomy. BJU Int [Internet]. 2019 May;123(5):861–8.
16. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.
17. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;
18. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. Eur Urol [Internet]. 2015 [cited 2017 Jun 12];68(2):9–2.
19. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. Biometrics. 1977;33(1):159.
20. Altman DG. Practical statistics for medical research. Chapman and Hall; 1991. 611 p.
21. Kohjimoto Y, Yamashita S, Kikkawa K, Iba A, Matsumura N, Hara I. The association of length of the resected membranous urethra with urinary incontinence after radical prostatectomy. Urol J. 2019;epub(c):2–6.
22. Haga N, Ogawa S, Yabe M, Akaihata H, Hata J, Sato Y, Ishibashi K, Hasegawa O, Kikuchi K, Shishido F, Kojima Y. Factors Contributing to Early Recovery of Urinary Continence Analysed by Pre- and Postoperative Pelvic Anatomical Features at Robot-Assisted Laparoscopic Radical Prostatectomy. J Endourol. 2014;29(6):683–90.
23. Grivas N, van der Roest R, Tillier C, Schouten D, van Muilekom E, Schoots I, van der Poel H, Heijmink S. Patterns of Benign Prostate Hyperplasia Based on Magnetic Resonance Imaging Are

Correlated With Lower Urinary Tract Symptoms and Continence in Men Undergoing a Robot-assisted Radical Prostatectomy for Prostate Cancer. Urology [Internet]. 2017;107:196–201.

24. Song W, Kim CK, Park BK, Jeon HG, Jeong BC, Seo S Il, Jeon SS, Choi HY, Lee HM. Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy. Can Urol Assoc J. 2017;11(3–4):E93–9.

25. Bartoletti R, Mogorovich A, Francesca F, Pomara G, Selli C. Combined bladder neck preservation and posterior musculofascial reconstruction during robotic assisted radical prostatectomy: Effects on early and long term urinary continence recovery. BMC Urol. 2017;17(1):1–7.

26. Lee Z, Sehgal SS, Graves R V., Su YK, Llukani E, Monahan K, McGill A, Eun D, Lee DI. Functional and oncologic outcomes of graded bladder neck preservation during robot-assisted radical prostatectomy. J Endourol. 2014;28(1):48–55.

27. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.

Chapter 10

Identifying surgical factors predicting postoperative potency in robot-assisted radical prostatectomy

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Abstract

Background

Surgical technique in robot assisted radical prostatectomy (RARP) may determine in a significant extent the postoperative recovery of erectile function.

Our research questions are: (1) Are expert surgeons able to predict postoperative potency after RARP by performing surgical video analysis? (2) Can results of the templated assessment methods (Global Evaluative Assessment of Robotic Skills (GEARS), Prostatectomy Assessment and Competence (PACE) and PRostatectomy video Observation to Evaluate and Score Technical skill (PROTEST)) be related to postoperative potency levels?

Methods

Patients were selected and matched based on their reported potency. Surgical skills were measured by a single trained assessor using the GEARS, PACE, and the PROTEST method. In addition, two expert surgeons (Expert 1 and 2) predicted postoperative potency levels of the patient.

Results

Assessment of the surgical videos by the trained assessor using the GEARS, PACE, and PROTEST methods showed no differences in results between the potency groups. Expert 1 correctly assessed potency in 83.3% (10/12 patients) of the patients. Expert 2 correctly assessed potency in 58.3% (7/12 patients) of the patients.

Conclusion

The results of this study show expert analysis gives insight into perioperative factors which influence postoperative functional results. Although the same factors were used by the experts to predict the postoperative status of the patient the variance in the interpretation of these factors show there is a need for objective measurements in surgical video analysis in order to clarify the influence of the factors identified by the experts on the patient's postoperative potency status.

Introduction

Healthcare is constantly moving towards improvement in the quality of care and safety for patients. Increasing attention is being paid to the relocation of complex treatments to high-volume centres, as it is expected to improve the quality of care and increase patient safety due to the increased exposure of surgeons and staff.[1–3] In the Netherlands, a move to high-volume centres has been seen in some specialties, including Urology.[4] The Dutch Society of Urology (NVU) has, in a bid to improve functional results and reduce complications, decided to increase the minimal number of robot-assisted radical prostatectomy (RARP) surgeries per hospital from 50 surgeries a year to 100 surgeries a year. The question remains whether the higher number of surgeries per hospital or the quality of the surgeon influences outcome, since there are large variations in postoperative complication rates amongst surgeons with similar surgical volumes per centre[5] or even in the same centre.[6]

The RARP is a complex but highly standardized procedure performed to cure localized prostate cancer. In the Netherlands, about 2500 men every year undergo surgical removal of the prostate to prevent progression of the disease. More than 90% of the prostatectomies in the Netherlands are performed with the surgical robot, and worldwide, the prostatectomy is the most performed procedure with the surgical robot. However, RARP is hampered by serious side-effects[7–9] that have a large influence on the quality of life of those affected, such as urinary incontinence, which is present in 26% of the patients[10] and erectile dysfunction in 14–90% of the patients.[11,12]

During RARP, as in all endoscopic procedures, the intracorporal surgical video can be recorded.[13,14] These surgical videos can be analysed in order to gain insight into past performance and review previous procedures with adverse postoperative outcomes to learn for the future.[15–18] Systematic evaluation of skills through the analysis of recorded surgical videos is believed to give more insight into the surgeons skills than a quota alone.[15,16,18] Research has shown these results can be related to postoperative outcomes.[15,18,19] The assessment of videos recorded during RARP might help in evaluating the surgical steps that are potentially linked to aspects of postoperative outcomes, such as surgical complications or functional outcomes (urinary incontinence and erectile dysfunction).

In order to standardize surgical skills assessment using video analysis, multiple templates have been developed by different research groups.[20–23] The correlation between these different video assessment methods and postoperative outcomes has been sparsely investigated. In a recent study, Goldenberg et al. found a correlation between the results of the Global Evaluative Assessment of Robotic Skills (GEARS) method and early continence after RARP.[19] Additional studies using different assessment methods could give more insight into the use of these templated assessment methods in order to find the possible origins of adverse postoperative outcomes.

Review of surgical videos has been used by surgeons to learn from past performance and by expert surgeons as part of their cyclical quality improvement analysis in order to reduce complications and improve postoperative outcomes.[17,24] Although the effects of these structured surgical video reviews seem promising, it remains unclear if experts are able to predict the postoperative potency status of a patient, as well as identify factors involved in the postoperative potency status of a patient based on the surgical video analysis. Stern et al. performed a study asking the surgeon at the end of the RARP to predict long-term postoperative continence of the patients.[25] The results showed the surgeon was unable to predict postoperative continence. Since the prediction by the surgeon was done directly postoperative and not based on the revision of the surgical video, the verdict of the surgeon could have been influenced by other factors, for example, distracting factors in the operating room, rather than solely the factors analysed during the surgery.

The following research questions will be investigated to gain more insight into the ability of surgeons to predict postoperative outcomes and to investigate which factors could be related to specific postoperative outcomes:

1. Are expert surgeons able to predict postoperative potency by performing surgical video analysis of the preservation of the neurovascular bundles (NVBs), apical dissection, and vesicourethral anastomosis phase of the RARP?
2. Can aspects of surgical skills as measured by either the (Global Evaluative Assessment of Robotic Skills (GEARS) , Prostatectomy Assessment and Competence (PACE) and PRostatectomy video Observation to Evaluate and Score Technical skill (PROTEST) method be related to outcomes regarding erectile function?

These questions will be answered by performing an exploratory study.

Method

Subject selection and Matching

Patients who underwent a RARP in the Antoni van Leeuwenhoek Hospital in Amsterdam, the Netherlands, between June 2009 and February 2017 were eligible for this study. All of the selected patients were operated on by the same expert robotic surgeon (HvdP), who had performed over 200 RARPs using the daVinci Si surgical robot by Intuitive in June 2009 and over 1400 RARPs in February 2017.

The groups were selected based on the patient's preoperative and postoperative potency as measured using the Potency area of the International Index of Potency Questionnaire (IIEF-EF- score). The IIEF-EF is a patient-reported outcome measure (PROM) questionnaire that registers the patient's erectile function over the last 4 weeks by asking six questions:

(i) How often were you able to get an erection during sexual activity? (0–5 points)

(ii) When you had erections with sexual stimulation, how often were your erections hard enough for penetration? (0–5 points)

(iii) When you attempted intercourse, how often were you able to penetrate (enter) your partner? (0–5 points)

(iv) During sexual intercourse, how often were you able to maintain your erection after you had penetrated (entered) your partner? (0–5 points)

(v) During sexual intercourse, how difficult was it to maintain your erection to completion of intercourse? (0–5 points)

(vi) How do you rate your confidence that you could get and keep an erection? (0–5 points)

The cumulative score of the six questions (0–30 points) represents the patient's experience of potency. In this study, an IIEF-EF score < 19 at 6 and 12 months after surgery was defined as impotent, whilst an IIEF-EF score of > 20 at 6 and 12 months after surgery was defined as potent. Exclusion criteria were suffering from potency complaints prior to surgery (IIEF-EF score > 20), and surgical procedures where no or incomplete video material was available. In 227 patients, a surgical video and complete PROM data were available at 6 or 12 months after surgery. Two groups (potent and impotent) were selected and matched (Fig. 1).

The patients in the potent group were matched according to preoperative factors, which in the literature have been shown to influence the chances of the patient's

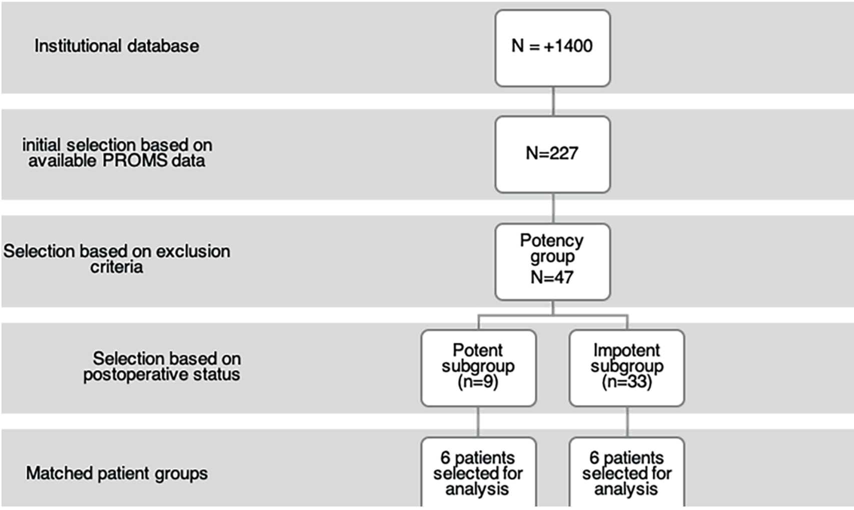

Figure 1 study design

postoperative potency in order to reduce the influence of these factors on the postoperative status of the patients.[26–28] The matching factors include the date of the surgery (the learning curve of the surgeon has been shown to influence chances of postoperative potency[26]), the age of the patient (shown to influence the chances of postoperative potency[27,28]), body mass index (BMI) of the patient (shown to influence the chances of postoperative potency[27,28]), and the preoperative intentions of saving the NVBs during surgery (shown to influence the chances of postoperative potency[27]).

All potent patients were manually compared to the impotent patients. Based on the number of variables in which the pairs matched a matching score of 0 to 4 was given to the patients, and each matched variable resulted in a point in the total matching score. The patients were matched in the same manner as in the selection of the continency-group (based on age, difference < 5 years = 1 matching point), BMI (difference < 3 points = 1 matching point), date of the surgery (difference < 3 months = 1 matching point), and preoperative intention of saving the NVBs during surgery on both sides sparing the same in both patients = 1 matching point). A matching score of 4 was the best possible match. Based on the matching scores, the best matched patient pairs were selected for analysis, since almost no perfect matches existed (Appendix A). If matched pairs with similar matching scores existed, a definitive choice was made based on the variable on which the patients matched (Appendix A).

Power analysis

Since this is a pilot study, a power analysis was performed based on the measures from one of the methods (GEARS) used during this study. The sample size analysis was based on a publication by Volpe et al.29 In this study, both experts and fellows were observed during a RARP using the GEARS score in order to determine their ability to perform a RARP. The results showed a significant higher score for the experts compared to the fellows. These results show it is possible to detect a difference in sample means of 2.65 on the total GEARS score (range 6–30). For this study, we assume the GEARS scores in the incontinent patients are similar to that of a fellow, and the GEARS scores in the continent patients are similar to that of an expert. Based on a power calculation using 0.05 as alpha, a power of 0.80, and an effect size of 2.65, a sample size of 6 patients per subgroup would be sufficient for the main objective of this study.

Prediction of continence by the surgeon who performed the surgery and the independent expert surgeon

The surgical videos were evaluated by two expert surgeons (the surgeon who performed the surgery (HvdP, self-assessment, hereafter called Expert 1) and an independent expert in RARP (JPvB, expert assessment, hereafter called Expert 2). The experts were asked to base their predictions on the prostate apical dissection phase, vesicourethral anastomosis phase, and NVB dissection of the RARP procedure. The entirety of the surgical videos were provided to the experts. The experts were blinded to the postoperative status of patients. The experts were asked to predict the likely postoperative outcome of the patient in absolute terms of potency/impotency or undetermined. The experts were asked to describe the factors on which they based their predictions during analysis of the surgical video. After prediction, the results of the experts were compared with the postoperative status of the patients.

The video assessment templates used for Surgical skills analysis.

Surgical videos were analysed by a single rater (AB) with training in surgical video analysis and expertise of the surgical procedure. This rater performed the surgical video analysis using GEARS, PACE and PROTEST methods. Since we did not expect any sequence effects due to the differences in focus in the assessment methods, no counterbalancing or randomization of assessment methods was performed. The rater was blinded to the postoperative status of the patients. The surgical video analysis was performed by watching the video and completing the different templated assessment methods. The surgical videos were watched a total of three times, since only one templated assessment method was assessed each time the video was watched. The assessment methods used during this study are described below:

(i) The GEARS.[21] The focus of the GEARS method lies in general robot surgical principals (i.e., depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy, and robotic control).[21] The GEARS method is scored on five aspects of surgical skills (depth perception, bimanual dexterity, efficiency, force sensitivity, and robotic control) using a 5-point Likert scale; the minimum score is 5, while the maximum score is 25. The GEARS score was calculated for the entire surgery. The score represents the surgeon's mastery of and surgical skills on the surgical robot.

(ii) The Prostatectomy Assessment and Competence Evaluation (PACE).[23] The PACE method focuses on surgical skills using specified steps of the RARP procedure. This method is mainly used to define deficits in the surgeon's skills in order to provide surgeon-specific training to improve surgical skill. The PACE method consists of an assessment of 10 subdomains divided over six domains, which are scored on 5-point Likert scales; the minimum score is 10, while the maximum score is 50.

(iii) The PRostatectomy video Observation To Evaluate and Score Technical skill (PROTEST) method was developed by this research group.[22] The PROTEST method gives detailed insight into the proficiency of the surgeon on each of the individual surgical steps of the RARP. This assessment method consists of two general subjective questions, multiple objective measurements, and 11 surgery-specific questions in order to provide detailed feedback to the surgeon. The two general subjective questions provide an assessment of the coordination and accuracy of the surgeon. These questions are scored on 5-point Likert scales, with the minimum score per phase being 2 and the maximum score being 10. Per surgery, the minimum score is 14, while the maximum score is 70.

The objective measurements consist of the total duration of a phase, the instances and total duration of bleeding during a phase, the instances and total duration of coagulation during a phase, the instances and total duration of suturing during a phase, and the instances and total duration of camera removal during a phase. In addition, the rater was able to record comments and or events that were remarkable during the phase.

The 11 surgery-specific questions consist of 10 Yes/No questions and one counting question. These questions focus on if some technical aspects of the surgery were either visible or performed during this specific surgery. The following subjects were covered in this part of the assessment method:

(i) Was bladder neck preservation attempted (Y/N)?

(ii) Were both ureteral orifices in sight during preparation of the bladder neck? (Y/N)

(iii) Was the capsule damaged during nerve-sparing? (Y/N)

(iv) Was there a tear in the vesiculae during preparation? (Y/N)

(v) Was diathermy used during transection of the plexus of Santorini? (Y/N)

(vi) Was diathermy used during transection of the urethra? (Y/N)

(vii) Was the colliculus in sight during transection of the urethra? (Y/N)

(viii) Was a bladder neck reconstruction performed? (Y/N)

(ix) Was the Rocco stitch (median fibrous raphe) reconstruction used? (Y/N)

(x) Was a barbed suture used for the bladder/urethra anastomosis? (Y/N)

(xi) How many stitch throws were used in the anastomosis? (n)

The procedure for surgical video analysis.

The surgical video was assessed in three phases. First, the GEARS assessment was performed on all surgical videos by reviewing the surgical video in a normal media player. Second, the PACE assessment was performed on all surgical videos. For this assessment, the video was also shown using a normal media player. For both the GEARS and PACE assessment methods, the video was run at normal speed, and the assessment templates were filled in by hand by the rater (AB). Third, the PRO-TEST assessment was performed for the entire surgical video using customizable video analysis software “digital Video Coach” developed by ZEAL IT (Eindhoven, The Netherlands) (Fig. 2). The surgical video was assessed at 50% of the normal speed, since this is a more detailed assessment and running the video at normal speed proved to be too quick for the assessment.

TThe video analysis software “Digital Video Coach” made it possible to measure the length of the phases of the surgery and the length of the different perioperative events. Two sets of labels were created in order to define the different phases of

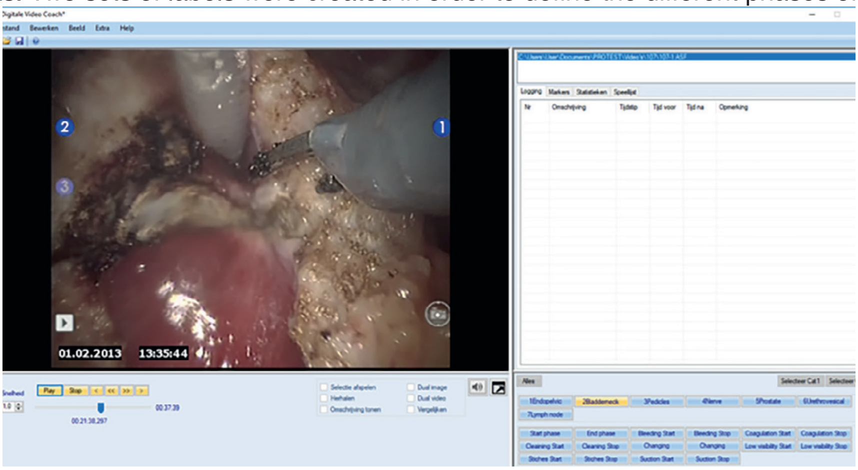

Figure 2 overview of the video analysis software Digital Video Coach.

the surgery and the different perioperative events. The selection of one of the labels automatically marked the time code corresponding to the moment the label was pressed. This made it possible to measure the duration of the phases and perioperative events. The labels used for this analysis are given in Fig. 3. The steps correspond to the different steps in the PROTEST assessment method.[22] The second category encompassed perioperative events that could be related to postoperative outcomes. These events were defined in the PROTEST assessment method.[22]

Data analysis

Data analysis was performed using SPSS statistics v24 (IBM, NY). Frequency statistics were calculated for patient demographic data and surgeon scores. Correlation between observed scores on the one hand and postoperative functional outcome on the other hand were calculated using a Spearman Rho test. Odd ratios (OR) and 95% confidence intervals (CIs) were calculated. The Wilcoxon signed-rank test was used to compare differences in results between the matched patient groups. McNemar's test was used in order to compare differences in results between the matched patient groups in case of dichotomous variables. The predictions by the experts were correlated with the postoperative status of the patients using a crosstab. To determine any significant correlations between variables, Pearson's chi square or Fisher's exact tests were used. Interobserver agreement was calculated using Cohen's kappa, which was interpreted using the guidelines from Landis and Koch[30,31]. Statistical significance was set at $p < 0.05$ based on a two-tailed comparison.

Due to the retrospective nature of the study, participants were not subjected to any study treatments or actions. Surgical videos and medical information used were registered as the standard of care in the medical files of the patients. Therefore, the Medical Research Involving Human Subjects Act does not apply, and no informed consent was obtained. However, during the screening of patients, the medical records were carefully checked for objection to medical research. This study was granted approval from the institutional medical committee.

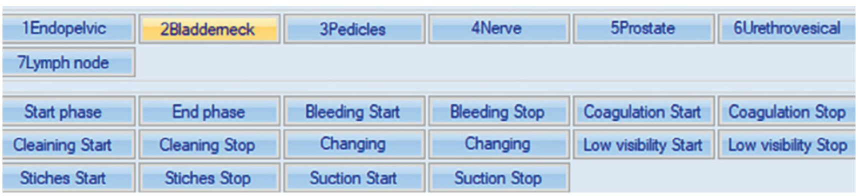

Figure 3 overview of the labels used in the PROTEST analysis using software Digital Video Coach

Results

A total of 47 of the 227 patients were eligible for inclusion. A total of five patients were excluded based on the exclusion criteria (these patients were impotent prior to surgery). In the potent subgroup, nine patients remained, while 33 patients remained in the impotent subgroup.

Matching and selection

Based on the matching criteria for the potent group, nine potent patients were manually matched with the 33 impotent patients. Based on the power calculation, six pairs were selected based on the date of the surgery, BMI, age, and preoperative intention of saving the NVBs during surgery on both sides (Appendix A.1). A total of 12 individual patients were selected for analysis.

Baseline characteristics

Based on the selection of patients, the IIEF-EF score at 6 and 12 months after surgery showed a significant difference (Table 1). No additional significant differences between the impotent and potent subgroups were found.

Table 1: Baseline characteristics of the selected patients

Characteristics	Postoperative impotent patients (n=6) Median (min - max)	Postoperative potent patients (n=6) Median (min - max)	P-value	Z-Value
Age (years)	58 (51 - 61)	53.5 (42 – 66)	0.345	-0.944
Body Mass Index (kg/m2)	27.29 (21.63- 28.01)	25.97 (23.27 – 28.98)	0.753	-0.314
Prostate size (ml)	33 (29 - 50)	36.59 (25 - 49)	0.854	-0.184
Gleason score	6 (6 - 7)	6 (6 - 7)	0.317	-1.000
Nerve sparing side				
Both	6	6	-	-
Preoperative IIEF-EF	30 (24 – 30)	30 (29 -30)	0.180	-1.342
6 months IIEF-EF	6.5 (5-16)	29.5 (26 - 30)	0.028	-2.201
12 months IIEF-EF	7.0 (4 - 16)	29.0 (20 - 30)	0.028	-2.201

Prediction of potency by the surgeon who performed the surgery and the independent expert surgeon

The predictions of both Expert 1 and Expert 2 were related to the actual patient outcomes for erectile function (Appendix B).

The results in Table 2 show the results of the analysis by the experts. These results show Expert 1 was able to correctly predict the postoperative potency in 83.3% (10/12) of the patients (p = 0.015). Expert 1 was undetermined about one patient. Expert 2 was able to correctly predict the postoperative potency in 58.3% (7/12) of the patients. Expert 2 was undetermined about one patient.

Interobserver agreement in the prediction of potency by two expert surgeons

For the potency group, Cohen's kappa level of interobserver agreement on predicted potency between Expert 1 and Expert 2 was poor at -0.241

Table 2: Results of the predictions by Expert 1 and Expert 2, presenting the prediction of potency based on apical dissection and urethro-vesical anastomosis in patients in potent vs. impotent patients. P-value calculated using Fisher's Exact Test.

	Patients included,, n=12 (%)	P-value
Expert 1 correct assessment	8 (66.7)	0.048
Expert 1: undetermined	3 (25.0)	
Expert 2: correct assessment	4 (33.3)	1.000
Expert 2: undetermined	3 (25.0)	

Factors predicting continency and potency according to the analysis of two expert surgeons

The experts predicted the expected potency in all patients. They were able to identify some factors in patients that they felt had an influence on the potency of the patients.

In case of potency, a higher quality of NVB preservation leads to better erections according to the experts, and the method of haemostasis during NVB preservation (the use of the stapler, metal clips, Hem-o-lock clips, or coagulation) were mentioned as factors influencing the level of postoperative potency in patients (Appendix C).

Surgical skills analysis using different methods of video assessment templates.

The GEARS, PACE and PROTEST assessment methods were used to determine whether aspects of task performance as measured by assessment templates can be related to postoperative outcomes.

Using the GEARS assessment method, depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy and robotic control were assessed. The results of the GEARS assessment analysis of the impotent and potent patients are shown in Supplementary Data 1. No significant differences between groups with regard to the GEARS assessment method were found.

Using the PACE assessment method, different aspects of the following phases of the surgery were assessed, including bladder drop; preparation of the prostate; bladder neck dissection; dissection of the seminal vesicles; posterior anatomical plane development; NVB preservation; apical dissection; and during the urethrovesical anastomosis, needle entry, needle driving, tissue trauma, and urethrovesical approximation. The results of the PACE assessment are shown in Supplementary Data 2. No significant differences between groups in the PACE scores were found.

The results of the general aspects of the PROTEST assessment method showed no significant differences between potent and impotent patients (Supplementary Data 3a). The results of the in-depth analysis of different phases of the surgery according to the PROTEST assessment method for the potent group (Supplementary Data 3b) showed no significant differences.

Discussion

There is an increasing interest in the use of surgical video analysis in research.32 In order to standardize surgical skills assessment using video analysis, multiple templates have been developed by different research groups.[20–23] In this study, we investigated whether the multiple assessment methods for surgical videos can be used to identify factors that could influence potency levels after prostatectomy. Existing video assessment methods were compared to the opinions of expert surgeons by video analysis of RARP surgeries.

Are expert surgeons able to predict postoperative potency levels by performing surgical video analysis?

The results of this study show the expert who performed the surgery was able to correctly assess the potency status of the patients in most cases. Expert 2 was less successful in the assessment of the potency status of the patients. Both surgeons were asked to describe the factors of the surgery that they used to predict the potency of the patients. Although these factors were similar for both surgeons, the interpretation of these factors seemed to differ per surgeon. Both experts felt the level of NVB preservation, the quality of the NVBs and the means of haemostasis during NVB preservation were associated with the level of potency of the patients. It is known, based on a study by Ong et al., haemostatic energy sources in proximity to the prostate in dog models can lead to a decrease in erectile function in comparison to dogs where no haemostatic energy sources were used during dissection.[33]

The result shows there is a difference in the interpretation of the level of NVB preservation, since Expert 1 and Expert 2 disagree on the level of nerve-sparing in multiple patients. There is also a difference in the interpretation of the method of haemostasis in the patients. Since Expert 2 indicates the use of a haemostatic energy source in more patients compared to Expert 1, this shows there is a difference in the interpretation of the use of a haemostatic energy source between the experts. The differences in interpretation of the experts of the use of a haemostatic energy source and the level of NVB preservation between the experts could thus explain the differences in the ability of the experts to predict postoperative outcomes. This is the first study showing the difference in the interpretation of the dimensions of structures in surgical videos by different surgeons. This shows there is a need for the development of objective measurements in surgical video analysis in order to standardize assessment and clarify the influence of the factors identified by the experts on the patient's postoperative potency status. Multiple groups are investigating the use of objective surgical skills assessment in robot-assisted surgery.[34–40] These initial studies are a first step in the development of the objective assessment of surgical skills and eventually the development of postoperative prediction of the functional outcomes of patients.

The difference in the ability of the surgeons to predict potency could also be explained by the fact that Expert 1 was the surgeon who performed the surgery and Expert 2 was an independent surgeon. It could be that Expert 1 is more familiar with his own techniques and outcomes and could therefore assess the patient's postoperative status more accurately. This is in contrast to the findings of Stern et al. who performed a study asking the surgeon at the end of the RARP to predict long-term postoperative continence in the patients.[25] The results showed the surgeon was unable to predict postoperative continence. Further studies should be performed with multiple experts assessing surgical videos of multiple surgeons to identify if the difference between the experts found in this study is the result of the difference in interpretation of the factors of the surgery assessed by the experts or a result of Expert 1 being the surgeon who performed the surgeries.

Surgical video assessment templates

Although the GEARS, PACE, and PROTEST assessment methods can be used to assess surgical skills, results showed no significant difference between the impotent and potent patients. This could be because the surgeon's skill did not differ between the surgeries and thus no difference should be found between the potent and impotent patients. This is in contrast to the findings of Goldenberg et al. who performed a retrospective one-to-one matched case-control study with a single surgeon and reported the mean overall GEARS scores as an independent predictor of early postoperative continence (3 months after surgery) in 47 patients (24 incontinent vs. 23 continent) operated on by the same surgeon.[19] These results showed that there is a difference in surgical skills in the same surgeon, which could influence postoperative continence results.

Limitations

TThis study is a retrospective study in which patients of a single surgeon were analysed. The sample size was based on the difference between novice and expert surgeon, since (in this study) the comparison was made with one expert surgeon the sample size might be too small. We tried to reduce the influence of preoperative factors which in the literature have been shown to influence the chances of the patient's postoperative potency[26–28] by matching the patient subgroups. Since no perfect matches existed, the best alternatives were sought. Patients who had a non-nerve-sparing procedure on either side were excluded from selection, since it is known that this has major effects on postoperative potency.[41] Although we did not expect any sequence effects in the templated assessments of the surgical videos, the results could have been influenced by the sequence of assessment.

Conclusion

The results of this study show expert analysis into the level of NVB preservation, the quality of the NVBs and the means of haemostasis during the NVB preservation could be used to predict the postoperative potency status of a patient. Although the same factors were used by the experts to predict the postoperative status of the patient, the variance in the interpretation of these factors show there is a need for objective measurements in surgical video analysis in order to clarify the influence of the factors identified by the experts on the patient's postoperative potency status. This pilot study shows surgical video analysis by expert surgeons could be used to assess surgical processes and surgical techniques. This form of expert analysis could provide overviews of a surgeon's performance and aid in improving the skills of surgeons.

Appendix

Appendix 1 matching scores per pair of patients.

The patients were matched based on age (difference < 5 years = 1 matching point), BMI (difference < 3 points = 1 matching point), date of the surgery (difference < 3 months = 1 matching point), and preoperative intention of saving the neurovascular bundles during surgery on both sides (NVB sparing the same in both patients = 1 matching point). N= None, NI = Not Identical, * Non-nerve-sparing on one or both sides.

Study # impotent	Study # potent pair	Difference OR date (days)	Match point OR date	Difference NVB	Match point NVB	Difference BMI (points)	Match point BMI	Difference age (years)	Match point age	Total score match point	Matched pair selected (yes/No)
12	35	435	0	None	1	0.97	1	0	1	3	Y
33	27	81	1	None	1	3.77	0	19	0	2	Y
67	71	33	1	None	1	0.61	1	10	0	3	Y
77	78	2	1	None	1	1.06	1	7	0	3	Y
143	121	246	0	None	1	0.98	1	4	1	3	Y
109	119	98	0	None	1	0.83	1	3	1	3	Y
77	71	40	1	None	1	1.81	1	6	0	3	N
79	103	243	0	None*	1	10.0	0	2	1	2	N
97	103	56	1	None*	1	17.45	0	3	1	3	N
179	180	7	1	Not identi-cal*	0	1.11	1	1	1	3	N
67	58	70	1	None	1	0.78	1	12	0	3	N

A total 11 possible match pairs were identified for the nine potent patients. Individual patients were part of multiple matched pairs in the case of six matched pairs (67/58, 67/71, 77/71, 77/78, 79/103, and 97/103). Of these matched pairs, 67/58 and 77/71 were not chosen, because match pair 67/71 and 77/78 matched better on the date of the surgery, which reduces the influence of the learning curve on the postoperative results.

The matched pairs 179/180, 79/103, and 97/103 were not chosen, since these surgeries were non-nerve-sparing on one or both sides. The residual matched pairs were chosen since they were the only remaining matches.

Appendix 2 assessment of potency per patient according to the analysis of two expert surgeons

Pt. ID.	Group	Post-op Potency	Expert 1	Expert 2
12	2	Potent	Potent	Undetermined
27	2	Impotent	Impotent	Impotent
33	2	Potent	Potent	Impotent
35	2	Impotent	Impotent	potent
67	2	Potent	Impotent	Potent
71	2	Impotent	Undetermined	Potent
77	2	Potent	Potent	Potent
78	2	Impotent	Impotent	Potent
109	2	Potent	Potent	Potent
119	2	Impotent	Impotent	Impotent
121	2	Impotent	Impotent	Impotent
143	2	Potent	Potent	Potent

Appendix 3 factors used for assessment of potency according to the analysis of two expert surgeons

Patient ID.	Expert 1			Expert 2		
	Nerve sparing	Bundle	Haemostasis management	Nerve sparing	Bundle	Haemostasis management
12	fair		clips	Left fair, right limited		monopolar coagulation right
27	reasonable		clips	reasonable		monopolar coagulation left
33	fair		clips	poor		monopolar coagulation both sides
35		thin	clips	fair		No coagulation
67	partial		hemolocks	fair		coagulation left, right no coagulation
71	Partial		clips	Fair		
77			clips	Fair		
78			Clips, monopolar coagulation	Fair		
109			clips, additional coagulation + stiches	Good	Good	
119		partial preservation	clips+bipolar,	Limited		Stapler
121	Limited right reasonable left		Stapler	Poor		Stapler
143		thick	clips	Fair		Clips

References

1. Trinh QD, Bjartell A, Freedland SJ, Hollenbeck BK, Hu JC, Shariat SF, Sun M, Vickers AJ. A systematic review of the volume-outcome relationship for radical prostatectomy. Eur Urol [Internet]. 2013;64(5):786–98.

2. Gershman B, Meier SK, Jeffery MM, Moreira DM, Tollefson MK, Kim SP, Karnes RJ, Shah ND. Redefining and Contextualizing the Hospital Volume-Outcome Relationship for Robot-Assisted Radical Prostatectomy: Implications for Centralization of Care. J Urol [Internet]. 2017 Jul 1 [cited 2018 Jul 23];198(1):92–9.

3. Stitzenberg KB, Wong YN, Nielsen ME, Egleston BL, Uzzo RG. Trends in radical prostatectomy: Centralization, robotics, and access to urologic cancer care. Cancer. 2012;118(1):54–62.

4. Inspectie voor de Gezondheidszorg. Het resultaat telt; Ziekenhuizen 2015. 2017;247.

5. Bianco FJ, Vickers AJ, Cronin AM, Klein EA, Eastham JA, Pontes JE, Scardino PT. Variations Among Experienced Surgeons in Cancer Control After Open Radical Prostatectomy. J Urol [Internet]. 2010;183(3):977–83.

6. Vickers A, Savage C, Bianco F, Mulhall J, Guillonneau B, Cronin A, Scardino P, Sandhu J, Guillonneau B, Cronin A, Scardino P. Cancer control and functional outcomes after radical prostatectomy as markers of surgical quality: Analysis of heterogeneity between surgeons at a single cancer center. Eur Urol [Internet]. 2011;59(3):317–22.

7. Barocas DA, Alvarez J, Resnick MJ, Koyama T, Hoffman KE, Tyson MD, Conwill R, McCollum D, Cooperberg MR, Goodman M, Greenfield S, Hamilton AS, Hashibe M, Kaplan SH, Paddock LE, Stroup AM, Wu X-C, Penson DF. Association Between Radiation Therapy, Surgery, or Observation for Localized Prostate Cancer and Patient-Reported Outcomes After 3 Years. JAMA. 2017 Mar;317(11):1126.

8. Donovan JL, Hamdy FC, Lane JA, Mason M, Metcalfe C, Walsh E, Blazeby JM, Peters TJ, Holding P, Bonnington S, Lennon T, Bradshaw L, Cooper D, Herbert P, Howson J, Jones A, Lyons N, Salter E, Thompson P, et al. Patient-Reported Outcomes after Monitoring, Surgery, or Radiotherapy for Prostate Cancer. N Engl J Med. 2016 Oct;375(15):1425–37.

9. Lardas M, Liew M, van den Bergh RC, De Santis M, Bellmunt J, Van den Broeck T, Cornford P, Cumberbatch MG, Fossati N, Gross T, Henry AM, Bolla M, Briers E, Joniau S, Lam TB, Mason MD, Mottet N, van der Poel HG, Rouvière O, et al. Quality of Life Outcomes after Primary Treatment for Clinically Localised Prostate Cancer: A Systematic Review. Eur Urol. 2017 Dec;72(6):869–85.

10. Maike H.J. Schepens, Cathelijne M.P. Ziedses des Plantes, D.M. (Rik) Somford, Judith A. van Erkelens, Ruben G. Cremers, Sytske de Vries, Katja K.H. Aben, René Hoekstra, Jozette J.C. Stienen, Bart P. Wijsman MBB en J van L. Hoe vaak incontinentie na radicale prostatectomie? Ned Tijdschr Geneeskd. 2018;162:D2294.

11. Tollefson MK, Gettman MT, Karnes RJ, Frank I. Administrative data sets are inaccurate for assessing functional outcomes after radical prostatectomy. J Urol [Internet]. 2011 May 1 [cited 2018 Jul 23];185(5):1686–90.

12. Salonia A, Burnett AL, Graefen M, Hatzimouratidis K, Montorsi F, Mulhall JP, Stief C. Prevention and management of postprostatectomy sexual dysfunctions. Part 1: choosing the right patient at the right time for the right surgery. Eur Urol [Internet]. 2012 Aug [cited 2018 Jul 23];62(2):261–72.

13. Varban OA, Niemann A, Stricklen A, Ross R, Ghaferi AA, Finks JF, Dimick JB. Far from Standardized: Using Surgical Videos to Identify Variation in Technique for Laparoscopic Sleeve Gastrectomy. J Laparoendosc Adv Surg Tech [Internet]. 2017 Aug 1 [cited 2017 Aug 18];27(8):761–7.

14. Oussi N, Loukas C, Kjellin A, Lahanas V, Georgiou K, Henningsohn L, Felländer-Tsai L, Georgiou E, Enochsson L. Video analysis in basic skills training: a way to expand the value and use of BlackBox training? Surg Endosc [Internet]. 2017 Jun 29 [cited 2017 Aug 18];1–9.

15. Birkmeyer JD, Finks JF, O ’reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.

16. Goldenberg MG, Lee JY, Kwong JCCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence [Internet]. BJU International Mar 31, 2018.

17. Touijer K, Kuroiwa K, Saranchuk JW, Hassen WA, Trabulsi EJ, Reuter VE, Guillonneau B. Quality improvement in laparoscopic radical prostatectomy for pT2 prostate cancer: Impact of video documentation review on positive surgical margin. In: Journal of Urology [Internet]. Wolters KluwerPhiladelphia, PA; 2005 [cited 2020 Jun 12]. p. 765–8.

18. Walsh PC, Marschke P, Ricker D, Burnett AL. Use of intraoperative video documentation to improve sexual function after radical retropubic prostatectomy. Urology. 2000;55(99):62–7.

19. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.

20. Mayr R, Fritsche H-M, Pycha AA, Pycha AA. Radical cystectomy and the implications of comorbidity. Expert Rev Anticancer Ther [Internet]. 2014 Mar 8 [cited 2017 Jan 24];14(3):289–95.

21. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.

22. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;

23. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.

24. van Basten JPA, Somford RM, de Baaij J, Sedelaar M, Vrijhof E. Initiatief Comprehensive Prostate Cancer Network (CPCN) in Zuidoost Nederland. Tijdschr voor Urol. 2017;7(6–7):134–44.

25. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.

26. Gumus E, Boylu U, Turan T, Onol FF. The learning curve of robot-assisted radical prostatectomy. J Endourol. 2011;25(10):1633–7.

27. Ficarra V, Novara G, Ahlering TE, Costello A, Eastham JA, Graefen M, Guazzoni G, Menon M, Mottrie A, Patel VR, Van der Poel H, Rosen RC, Tewari AK, Wilson TG, Zattoni F, Montorsi F. Systematic review and meta-analysis of studies reporting potency rates after robot-assisted radical prostatectomy. Eur Urol [Internet]. 2012 Sep [cited 2020 Jun 12];62(3):418–30.

28. Neumaier MF, Segall Júnior CH, Hisano M, Rocha FET, Arap S, Arap MA. Factors affecting urinary continence and sexual potency recovery after robotic-assisted radical prostatectomy. Int Braz J Urol. 2019;45(4):703–12.

29. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. Eur Urol [Internet]. 2015 [cited 2017 Jun 12];68(2):9–2.

30. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. Biometrics. 1977;33(1):159.

31. Altman DG. Practical statistics for medical research. Chapman and Hall; 1991. 611 p.

32. Prebay ZJ, Peabody JO, Miller DC, Ghani KR. Video review for measuring and improving skill in urological surgery. Nat Rev Urol [Internet]. 2019;16(4):261–7.

33. Ong AM, Su LM, Varkarakis I, Inagaki T, Link RE, Bhayani SB, Patriciu A, Crain B, Walsh PC. Nerve sparing radical prostatectomy: Effects of hemostatic energy sources on the recovery of cavernous nerve function in a canine model. J Urol. 2004;172(4 I):1318–22.

34. Beulens AJWJW, Namba HF, Brinkman WM, Meijer RP, Koldewijn EL, Hendrikx AJM, Basten V, Bangma C, Wagner C. Analysis of the video motion tracking system ‘ Kinovea ’ to assess surgical movements during robot-assisted radical prostatectomy . Int J Med Robot Comput Assist Surg. 2020;

35. Andras I, Mazzone E, Leeuwen FWB Van, Naeyer G De, Oosterom MN Van, Beato S, Buckle T, Sullivan SO, Leeuwen PJ Van, Beulens A, Crisan N, Hondt FD, Schatteman P, Poel H Van Der, Dell P, Mottrie A. Artificial intelligence and robotics : a combination that is changing the operating room. World J Urol [Internet]. 2019;(0123456789).

36. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44.

37. Chen J, Cheng N, Cacciamani G, Oh P, Lin-Brande M, Remulla D, Gill IS, Hung AJ. Objective Assessment of Robotic Surgical Technical Skill: A Systematic Review. J Urol. 2019;201(3):461–9.

38. Wang Z, Majewicz Fey A. Deep learning with convolutional neural network for objective skill evaluation in robot-assisted surgery. Int J Comput Assist Radiol Surg [Internet]. 2018;13(12):1959–70.

39. Ershad M, Rege R, Majewicz Fey A. Automatic and near real-time stylistic behavior assessment in robotic surgery. Int J Comput Assist Radiol Surg [Internet]. 2019 Apr [cited 2020 Jun 16];14(4):635–43.

40. Fairey AS, Kassouf W, Estey E, Tanguay S, Rendon R, Bell D, Izawa J, Chin J, Kapoor A, Matsumoto E, Black P, So A, Lattouf J-B, Saad F, Drachenberg D, Cagiannos I, Lacombe L, Fradet Y, Jacobsen N-EB. Comparison of oncological outcomes for open and laparoscopic radical nephroureterectomy: results from the Canadian Upper Tract Collaboration. BJU Int [Internet]. 2013 Oct [cited 2017 May 26];112(6):791–7.

41. Montorsi F, Wilson TG, Rosen RC, Ahlering TE, Artibani W, Carroll PR, Costello A, Eastham JA, Ficarra V, Guazzoni G, Menon M, Novara G, Patel VR, Stolzenburg JU, Van Der Poel H, Van Poppel H, Mottrie A. Best practices in robot-assisted radical prostatectomy: Recommendations of the Pasadena consensus panel [Internet]. Vol. 62, European Urology. Elsevier; 2012 [cited 2017 Dec 28]. p. 368–81.

Chapter 11

Identifying the relationship between postoperative urinary continence and residual urethra stump measurements in robot assisted radical prostatectomy patients

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Abstract

Background

Recent research has shown there might be a correlation between the length and thickness of the urethral stump and the postoperative urinary continence.

The co-primary outcomes of this study were to verify the feasibility to measure accurately the length and the width of the urethral stump from recorded videos of robot assisted radical prostatectomy (RARP) procedures using the kinovea software and to assess if these measurements could be used as predictors of postoperative urinary continence.

Methods

53 patients were selected from an institutional database of 1400 cases and included in the study. Patients without rarp recorded video, preoperative-mri and complete continence data were excluded from the study. All the videos were analysed by a trained researcher using the computer software “kinovea”. All the measurements were performed while the bladder catheter was inserted into the urethral stump using it as a reference point. Urethral measurements were compared to pre-operative mri measurements and correlated to the postoperative continence status of the patients.

Results

In 20 out of 53 patients it was not possible to obtain the measurements due to lack of a reference structure during video assessment. Data of 33 patients were available for analysis. Results showed a statistical significative correlation between the surgical urethral length (sul) and the length of the membranous urethra (mul) on mri images ($r=0.390$; p value $=0.025$). The median sul was significantly higher in the continent group (10,50 vs. 12,94 mm, $p= 0.018$). No significant correlation was found between the urethral width and postoperative urinary continence.

Conclusions

The results of this study show that the length and the width of the urethra can be measured in surgical videos using a software. A comparison to the postoperative continence status of the patients underwent rarp showed a significantly longer median surgical urethral length in continent patients.

Introduction

Urinary incontinence after a robot assisted radical prostatectomy (RARP) appears to have a multifactorial origin[1–5] Several studies have identified factors that contribute to early urinary continence in patients that underwent RARP.[1,2,6–10] One of these factors is the length of the membranous urethra (MUL).[4,11,12] There appears to be a correlation between the length of the MUL in pre and post-operative magnetic resonance imaging (MRI) and urinary continence.[4,12] The group of Song showed that a preoperative MU ≤13.5 mm and postoperative MU ≤13 mm had a negative impact on urinary continence 12 months after the surgery. The group of Kohjimoto retrospectively investigated the relation between urinary continence and the length of the resected MU evaluating the amount of rhabdomyo sphincter on the hematoxylin and eosin sections of the apical margin of prostate specimens.[11] This study showed the length of resected MUL specimen was an independent predictor of urinary incontinence. This raises the question whether assessment of the urethral length could be objectified intraoperatively by the surgeon to optimize the length of the urethra in order to reduce the risk of postoperative incontinence after RARP.

In another study by the group of Ganni, Kinovea software was used to provide an objective assessment of surgical skills during laparoscopic cholecystectomy.[13] Kinovea is a software-based video analysis system used in sports to track trajectories and speeds of moving items,. The authors showed that the system can be used for tracking analysis of pre-recorded surgical videos and is viable method for the objective assessment of surgical performance.[13]

Since Kinovea uses a reference line to measure the distance, we hypothesized it could be used to measure the size of an item from a video frame, relating the measurements to the reference line. More specifically, we hypothesize Kinovea can use the diameter of the trans-urethral catheter during dissection of the apex of the prostate in RARP as a reference line in order to be able to measure the dimensions of the urethral stump.

The research questions are: (1) Is it possible to accurately assess the length and width of the urethral stump in the surgical videos of robot assisted radical prostatectomy patients using the Kinovea software? (2) Can urethral stump measurements be used to predict postoperative continence in patients after robot assisted radical prostatectomy? These questions will be answered using Kinovea, a software-based system to measure the urethral stump in surgical videos of patients who underwent RARP.

Materials and methods

Study population

The population of our study consisted of 1400 patients who underwent RARP in the Antoni van Leeuwenhoek Hospital in Amsterdam (the Netherlands) between June 2009 and February 2017. Considering the inclusion and exclusion criteria (Figure 1), a group of patients was selected from the institutional database. All patients had localized prostate cancer (cT1c-cT3a, Nx-N0, Mx-M0) and in all cases the full-length pre-recorded video of the procedure was available. Only patients with 6 and 12-month postoperative PROMS data available were included. In case of unavailable surgical video or MRI patients were excluded from the study. Patients who underwent a salvage prostatectomy after radiation therapy[14] or who received adjuvant radiation therapy within 12 months from the surgery[15] were excluded from analysis due to a significant impact of these treatments on the continence status. In our study a patient with an ICQI-SF score of 0 was defined as continent, while a patient with an ICIQ-SF score of 10 or more was defined as incontinent.[16] Patients with ICIQ-SF scores at 6 and 12 months from 1 to 9 were excluded from the study in order to have a clear distinction between continent and incontinent patients. If the catheter was not adequately in place during the apical dissection of the prostate, the case was excluded from analysis since there was no reference point (no visualization of the trans-urethral catheter during dissection) available for the calibration of the Kinovea system.

Variations in the peri-operative process

The surgeries of the selected patients were performed by one expert surgeon (HvdP) who had overcome the surgical learning curve before the year 2009 and has standardized the way he performs each surgery. Part of this standardization is the dorsal reconstruction, this is performed using the “median fibrous raphe” reconstruction or “Rocco stitch”.[17,18] The method of nerve sparing is standardized based on the publication of van der Poel et. al, intrafascial dissection was performed where feasible.[19] The peri-operative implementation of physiotherapy was standardized in all patients, no additional sessions of physiotherapy were provided for incontinent patients.

Design

Data as BMI, Charlson comorbidity index (CCI), prostate volume, positive surgical margins, International Prostate Symptom Score (IPSS), International Consultation Incontinence Modular Questionnaire -Short Form (ICIQ-SF score), Fascia preservation score, and MRI measurements were collected.

Pre-operative and post-operative continence were defined according to the International Consultation Incontinence Modular Questionnaire -Short Form (ICIQ-SF score).16 The ICIQ-SF is a patient-reported outcome measures (PROMs) questionnaire that assesses the patient's urinary incontinence status with three questions. The cumulative scores of the three questions (0-21 points) represents the patient's experience of urinary incontinence. The study was designed as a retrospective feasibility study of patients from our institutional database.

Methods of measurement

The automated surgical movements tracking was performed using Kinovea 0.8.15. Kinovea was used to assess the length and width of the urethra in pre-recorded videos. In all the patients the urethral stump was measured on a video frame taken during the dissection of the urethra when the circumference of the catheter was well visible. The software was able to measure the length and width of the urethra by calibrating these measurements to the width of the transurethral catheter as shown in figure 2b. A standardized 16 Charriere (width = 5,3333 mm) latex or silicone Foley catheter was used in all patients. Anatomical structures are represented in figure 2a, figure 2c and figure 2f.

The width of the catheter was subtracted from the SUW to obtain the accurate thickness of the urethral tissue. The measurements were performed by one rater (AB) who underwent a specific training in both the surgical procedure and the use of Kinovea software. The rater was blinded to the patient's self-reported postoperative continence status.

Pre-operative MRI measurements of the urethra were performed according to the study by Grivas (figure 2).4 In this study, the MUL was measured from the apex of the prostate to the bulbus (midsagittal T2, figure 2d), the Maximal Urethral Width (MUW) was defined as maximal diameter of urethra (axial T2), the Ventral Urethral Length (VUL) was measured from the apex of prostate to the pelvic floor muscles (coronal T2-weighted, figure 2e), and the Ventral Urethral width (VUW) was defined as maximal diameter of urethra at the location of the VUL measurement (axial T2, figure 2g). These measurements were used to verify the results of the Kinovea measurements.

Ethical approval

This study was granted approval from and was in accordance with the institutional medical ethics committee. Informed consent was obtained from all participants

Data analysis

Descriptive statistics was performed for all available patients and tumour variables.

Mean and standard deviation or median and interquartile ranges were reported for continuous variables as indicated, depending on the distribution of the variables. Frequencies and proportions were used to describe categorical variables. The Pearson correlation coefficient test was used to assess the accuracy of the Kinovea measurements comparing them to the pre-operative MRI measurements. The Mann-Whitney U test was used to compare differences between continent and incontinent patients for the continuous variables and Fishers exact test for the categorical variables. Statistical significance was set at $p<0.05$ based on a two-tailed comparison. Univariate logistic regression analysis of preoperative variables was used to identify factors that have influenced the patient's continence status. P-value for the univariate logistic regression analysis was set at 0.10. Statistical analysis was performed with SPSS software v. 23 (SPSS Inc., Chicago, IL, USA).Results

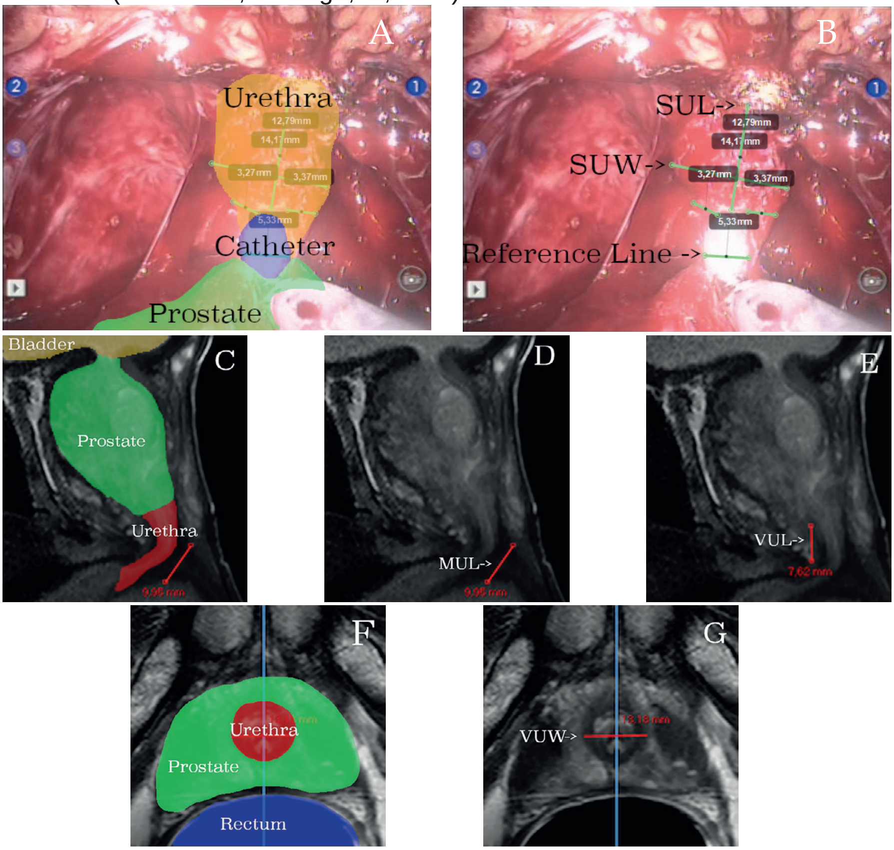

Figure 1. (A) Intra-operative image – representation of important anatomical structures used as landmarks during the measurements of the urethral stump; (B) intra-operative image – calibration lines overlapping the urethral stump with Foley 16 Ch catheter inserted used as reference structure; (C) axial and F: coronal MRI image - representation of important anatomical structures used as landmarks during the measurements of the urethral stump; (D) MUL, (E) VUL and (G) VUW measurement method on MRI images.

Results

A total of 53 patients were eligible based on the inclusion and exclusion criteria (Figure 1). Twenty patients were excluded from analysis after reviewing the videos as they lacked the reference structure to calibrate the measurements, and were excluded from the analysis. The remaining 33 patients were divided in a continent (N=26) and an incontinent group (N=7). Baseline characteristics of the patients are represented in Table 1. There were no statistically significant differences in the baseline characteristics between the two groups.

A significant positive correlation of the Kinovea (MUL) and preoperative MRI (SUL) measurements of the urethral stump length (r=0.390; p =0.025) was found. The correlation of the VUL and SUL and urethral width measurements were not statistically significative. Moreover, a correlation between the Kinovea (SUW) and MRI (MUW)

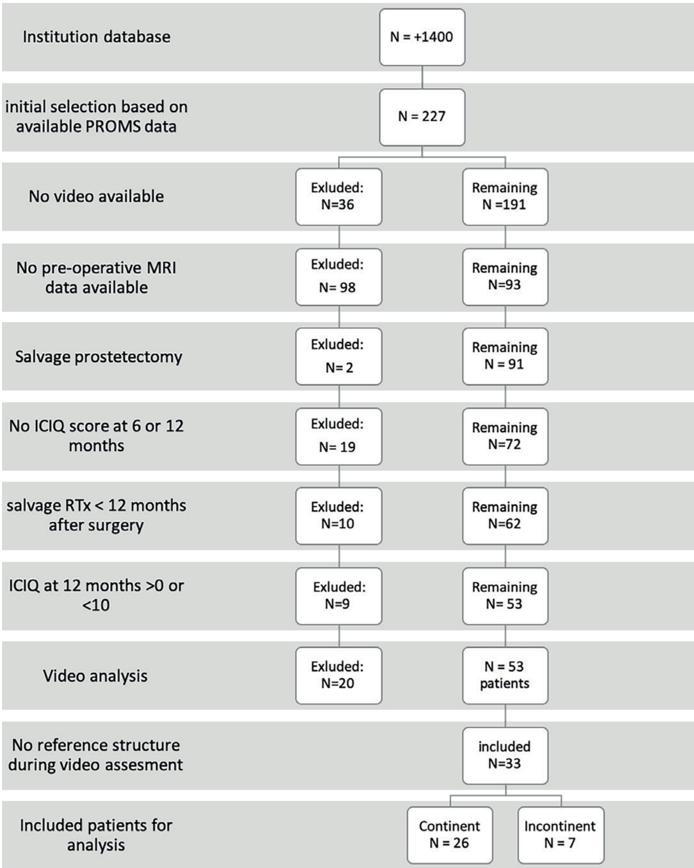

Figure 2: Study flow diagram – Study population selection flowchart

Table 1: Baseline characteristics of the selected patients

	Postoperative incontinent patients (ICIQ-SF>10) (n=7) Median (min - max)	Postoperative continent patients (ICIQ-SF=0) (n=26) Median (min - max)	P-value	Z-Value
Age (years)	65 (57 - 69)	61.5 (51 - 75)	0.308	-0.944
Body Mass Index (kg/m2)	26.59 (20.45 – 32.55)	25.31 (21.15 – 35.06	0.880	-0.314
Prostate size (ml)	50 (18 - 81)	43 (21 - 90)	0.375	-0.184
TUC duration (days)	14 (12 – 41)	12.00 (7 – 39)	0.183	-1.000
Clinical tumor stage, N (%)			0.558#	
cT1c	2 (28.6)	10 (38.5)		-
cT2a	0	3 (11.5)		-1.342
cT2b	1 (14.3)	6 (23.1)		-2.201
cT2c	2 (28.6)	4 (15.4)		-2.201
cT3a	2 (28.6)	2 (7.7)		0.000
cT4a	0	1 (3.0)		-2.207
Nerve sparing, N (%)			0.117#	-2.232
Both	3 (42.9)	10 (38.5)		
Left only	0	7 (26.9)		
Right only	0	4 (15.4)		
Preoperative ICIQ-SF score	0 (0 - 0)	0 (0 - 0)	1.000	
Preoperative Pad use	0 (0-0)	0 (0-0)	1.000	
6 months ICIQ-SF score	16 (16 - 20)	0 (0 - 0)	<0.001	
12 months ICIQ-SF score	14 (11 - 18)	0 (0 - 0)	<0.001	
6 months postoperative Pad use	4 (3-4)	0 (0-1)	<0.001	
12 months postoperative Pad use	3 (3-4)	0 (0-0)	<0.001	

urethral width measurement was observed (r=0.107; p=0.046) (Table 2).

The results of the pre-operative MRI-measurements showed a significantly longer MUL (13.18 vs 9.87 mm, p=0.001) and VUL (10,74 vs 6,47 mm, p=0,009) in continent patients compared to those with incontinence. The VUW and MUW did not show significant difference among the continent and incontinent patients (Table 3).

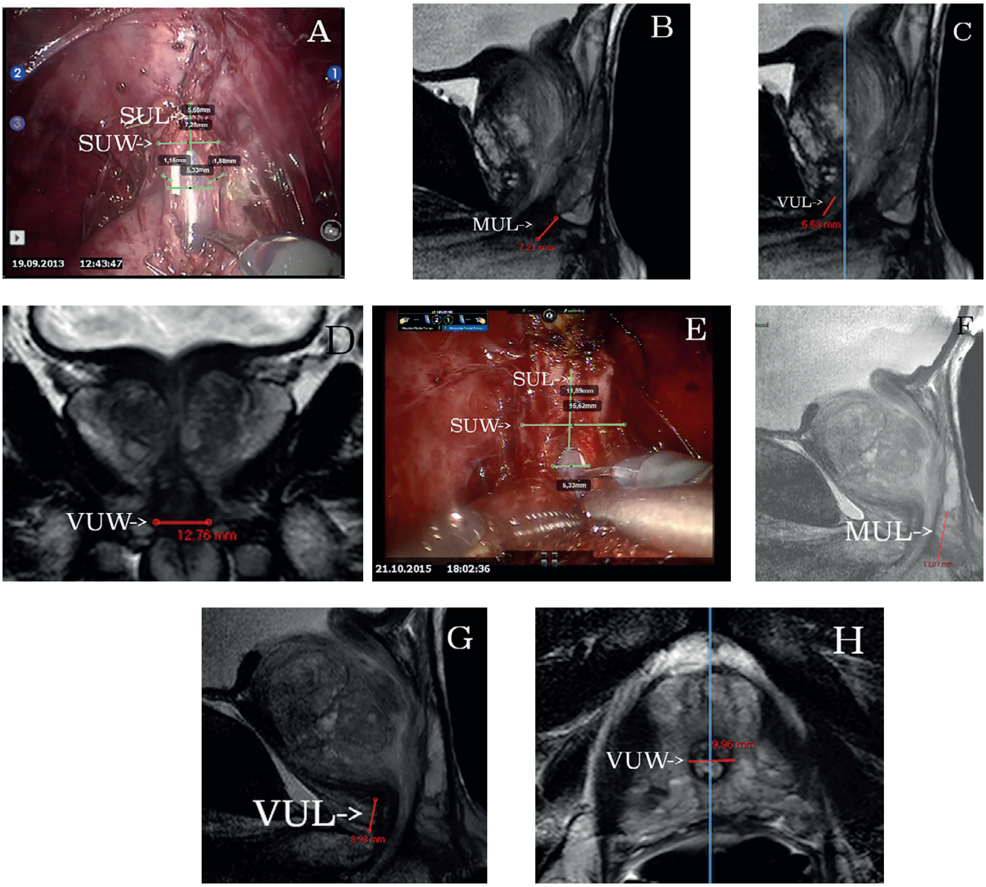

Figure 2 (A,E) Measurement of the SUL and SUW using Kinovea software in a incontinent (A) and continent (E) patient; (B-D) measurement of the MUL (B), VUL (C) and VUW (D) on the MRI images of a incontinent paten; (F-H) measurements of the MUL (F), VUL (G) and VUW (H) on the MRI images of a continent patient.

Table 2 Pearson correlations of Kinovea and the pre-operative MRI measurements in 33 selected patients.

	SUW, Surgical Urethral Width measured using Kinovea (p-value)	SUL, Surgical Urethral Length measured using Kinovea (p-value)
MUL, length of the membranous urethra from the apex of the prostate to the bulbus (midsagittal T2)	-	0.390 (0.025)*
VUL. Ventral Urethral length, measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	-	0.148 (0.412)
VUW, Ventral Urethral width, defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	0.107 (0.553)	-
MUW, Maximal Urethral Width, defined as maximal diameter of urethra (axial T2)	-0.350 (0.046)*	-

Table 3. Difference in pre-operative MRI measurements (MUL, VUL, MUW, and VUW) and surgical urethral measurements with Kinovea software (SUL and SUW) during apical dissection between continent and incontinent patients.

	Postoperative incontinent patients (ICIQ-SF>10) (n=7) Median (min - max)	Postoperative continent patients (ICIQ-SF=0) (n=26) Median (min - max)	P-value
MUL, length (in mm) of the membranous urethra from the apex of the prostate to the bulbus (midsagittal T2)	9.87 (8.69 – 12.97)	13.18 (9.63 – 16.15)	0.001
VUL. Ventral Urethral length, measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	6.47 (3.75 - 10.35)	10.74 (5.79 – 14.50)	0.009
VUW, Ventral Urethral width, defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	12.97 (11.13 – 14.86)	12.38 (9.96 – 13.81)	0.268
MUW, Maximal Urethral Width, defined as maximal diameter of urethra (axial T2)	12.12 (9.22 – 13.15)	11.61 (9.05 – 14.00)	0.914
Surgical urethral length (SUL), mm	10.50 (5.06 – 12.79)	12.94 (6.10 – 24.35)	0.018*
Surgical Urethral Width (SUW), mm	6.83 (1.95 – 11.13)	7.37 (4.26 – 16.78)	0.450

Table 4 Univariate logistic regression analysis of factors possibly influencing the continence status of patients.

	OR	95% C.I. for OR	P-value
VUL. Ventral Urethral length, measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	1.642	1.095 – 2.464	0.017
MUL, length of the membranous urethra from the apex of the prostate to the bulbus (midsagittal T2)	3.156	1.324 – 7.527	0.010
SUL, Surgical Urethral Length Measured using Kinovea	1.314	0.999 – 1.728	0.051
VUW, Ventral Urethral width, defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	0.573	0.237 – 1.385	0.216
MUW, Maximal Urethral Width, defined as maximal diameter of urethra (axial T2)	1.173	0.596 – 2.310	0.644
SUW, Surgical Urethral Width Measured using Kinovea	1.156	0.840 – 1.592	0.374
BMI	0.950	0.768 – 1.174	0.633
Prostate size	0.985	0.945 – 1.027	0.477
Age	0.938	0.812-1.084	0.386
Nerve sparing left	2.519	0.460 – 13.801	0.287
Nerve sparing right	1.556	0.289 – 8.379	0.607
Year of surgery	1.254	0.465 – 3.382	0.655

The results in table 4 show the difference in Surgical urethral measurements, performed with Kinovea software, during apical dissection between continent and incontinent patients. There is a longer SUL (difference of 2.44 mm) in continent patients compared to incontinent patients (12.94 vs 10.50 mm, p=0.018). There was no difference in SUW between the two groups (Table 3).

Factors influencing continence

The results of the univariate logistic regression analysis of preoperatively known variables showed that the VUL (OR=1.642; 95% C.I: 1.095 – 2.464 p-value = 0.017), MUL (OR=3.156, 95% C.I: 1.324 – 7.527, p-value = 0.010), and SUL (OR=1.314, 95% C.I: 0.999 – 1.728, p-value = 0.051) could be used to predict the continence of patients (Table 4).

Discussion

In this study we investigated whether intraoperative urethral stump measurements can be performed using the Kinovea software from pre-recorded RARP videos and if these measurements could be used as predictors of postoperative urinary incontinence.

Our results the Kinovea software can be used to measure urethral dimensions in pre-recorded RARP videos. The results showed a weak positive correlation between the SUL measured using Kinovea and the MUL measured with MRI, the correlation between SUL and the VUL showed no significant results. The lack of correlation between the VUL and SUL could be due to the fact that during dissection of the prostatic apex the urethra is deformed due to the traction of the prostate during this step of the surgery this method could be further improved using a video frame where no tractions are applied on the prostate and on the perineum of the patient i.e. during vesico-urethral anastomosis.

There was a correlation between the urethral width measured with Kinovea software (SUW) and MRI (MUW) The width of SUW using Kinovea showed no correlation with the VUW measured on an MRI. This could possibly be the result of the traction on the prostate during dissection, as the diameter becomes smaller with traction and therefore the urethral tissue thinner. Another reason could be the thinning of the urethra during the apical dissection of the prostate. In this case, the selection of the video frame could have an impact on the quality of measurements of the urethral stump.

The fact that the urethral stump measurements taken with Kinovea (SUL and SUW) were correlated with the MRI measurements (MUL and MUW) validate the Kinovea software as an accurate tool for the measurement of the urethral stump length and width. The performance of the measurements using Kinovea took on average 5 minutes per patient.

In this study in both MRI measurements (MUL and VUL) and the SUL, a significantly longer median urethral length in the continent group compared to the extremely incontinent group. Although the median difference in SUL (2.44 mm) is shorter than the median difference in MUL (3.31 mm) and the median difference in VUL (4.27mm) the preoperative measurements show it is possible to find a measurable difference.

The influence of the urethral length on continence has been proven with different modalities[11,12] including MRI measurements. In a recent study, Kohjimoto et al. demonstrated that the length of resected MUL specimen was an independent predictor of urinary incontinence after RARP.[11] Moreover, in another recent paper Song showed that a longer preoperative and postoperative length of membranous urethra was significantly associated with urinary incontinence after RARP.[12] This shows a longer urethral length of the membranous urethra implies a long urinary sphincter that leads to better postoperative urinary continence.

The univariate logistic regression analysis showed a significant influence of the VUL (OR=1.642; 95% C.I: 1.095 – 2.464), MUL (OR=3.156, 95% C.I: 1.324 – 7.527), and SUL (OR=1.314, 95% C.I: 0.999 – 1.728) on the patient's continence status showing a smaller risk of urinary incontinence in patients with longer urethral stump. Our findings are in contrast with the recent research by Bautista Vidal, which shows there is no correlation between continence and urethral stump length.[20] This could be due to a difference in method used for the measurement of the urethral stump in the surgical videos.[20] Additional research is needed to determine the ideal urethral length for achieving continence. If a cut-off point is determined during additional research, surgical procedures could be adjusted to standardise the dissection and mobilisation of parts of the prostatic urethra in order to increase urethral stump length and increase the chances of urinary continence.

The implementation of real time intra-operative measurements of the urethra integrated in the robotic system could help to adjust the surgical technique in particular during the apical dissection of the prostate. The use of a small ruler could help the surgeon to measure the urethra during surgery which could lead to an increase urethral stump length and increase the chances of urinary continence.[21,22] In the future the introduction of measurement software into the surgical robot system could lead to the implementation of a modified heads-up display in the console which can be used to measure structures during surgery in real time. Using this kind of software, the surgeon could be able to optimize the urethral length and increase the chances of continence for the patient.

The urethral width measurements (SUW, MUW, and VUW) did not show a difference between the continent and incontinent patients. To our knowledge, there are no studies showing a correlation between the intraoperative urethral width and the post-operatory continence status.

Limitations

Our study is a retrospective study in which patients of a single surgeon were analysed. The sample size was relatively small, we tried to reduce the influence of confounders by using exclusion criteria of factors which are known to influence postoperative continence (i.e. salvage RARP[14] and adjuvant radiation therapy after RARP[15]). The results of this pilot study show the absence of surgical videos, MRI measurements and a reference point (no visualization of the trans-urethral catheter during dissection) for Kinovea measurements lead to a relative high number of exclusions. The Kinovea analysis could only be performed when the catheter (reference point) was visible during apical dissection. There is some variation in the placement of the reference line since the diameter of the catheter was sometimes measured in less than ideal circumstances, meaning that not the entire circumference of the catheter was visible during measurement. There is also a possibility of variation in the length and width measurements due to the amount of traction on the tissue during dissection, in order to reduce this variation, the measurements were taken at the same point in the dissection of the urethral stump. The angle of the camera during measurement could influence the results of the measurement, but since the reference line was measured with the camera in the same position as the measurements of the urethra we believe this influence is negligible. The use of an intraoperative object with a known size or a ruler to measure the urethral stump could result in more accurate measurements of the urethral stump. In this study the measurements were taken by a single observer. This study was performed in cases of a single surgeon, results in multiple surgeons could vary due to variability of surgical technique. Further research of the implications of urethral stump length could result in an improvement of postoperative continence for individual patients. If the measurement of the urethral length can be performed during surgery it will be possible to adjust surgical techniques to preserve the maximal surgical urethral length.

Conclusion

In this study we performed intraoperative urethral stump measurements using the Kinovea software on surgical videos. The results of this study show that the length and width of the urethra can be measured in surgical videos and correlated with most of the preoperative MRI measurements. The present measurements demonstrate a longer surgical urethral length in continent patients compared to those suffering from incontinency. Further research on the use of intraoperative urethral length measurements could elucidate whether the length of the urethral stump can be used as a predictor of continence with the surgical challenge to save as much urethral length as possible during robot assisted radical prostatectomy.

References

1. Vis AN, van der Poel HG, Ruiter AEC, Hu JC, Tewari AK, Rocco B, Patel VR, Razdan S, Nieuwenhuijzen JA. Posterior, Anterior, and Periurethral Surgical Reconstruction of Urinary Continence Mechanisms in Robot-assisted Radical Prostatectomy: A Description and Video Compilation of Commonly Performed Surgical Techniques. Eur Urol. 2019;76(6):814–22.
2. Haga N, Ogawa S, Yabe M, Akaihata H, Hata J, Sato Y, Ishibashi K, Hasegawa O, Kikuchi K, Shishido F, Kojima Y. Factors Contributing to Early Recovery of Urinary Continence Analysed by Pre- and Postoperative Pelvic Anatomical Features at Robot-Assisted Laparoscopic Radical Prostatectomy. J Endourol. 2014;29(6):683–90.
3. Grivas N, van der Roest R, Schouten D, Cavicchioli F, Tillier C, Bex A, Schoots I, Artibani W, Heijmink S, Van Der Poel H. Quantitative assessment of fascia preservation improves the prediction of membranous urethral length and inner levator distance on continence outcome after robot-assisted radical prostatectomy. Neurourol Urodyn [Internet]. 2018 Jan 1 [cited 2019 Apr 29];37(1):417–25.
4. Grivas N, van der Roest R, Tillier C, Schouten D, van Muilekom E, Schoots I, van der Poel H, Heijmink S. Patterns of Benign Prostate Hyperplasia Based on Magnetic Resonance Imaging Are Correlated With Lower Urinary Tract Symptoms and Continence in Men Undergoing a Robot-assisted Radical Prostatectomy for Prostate Cancer. Urology [Internet]. 2017;107:196–201.
5. Rajih E, Meskawi M, Alenizi AM, Zorn KC, Alnazari M, Zanaty M, Alhathal N, El-Hakim A. Peri-operative predictors for post-prostatectomy urinary incontinence in prostate cancer patients following robotic-assisted radical prostatectomy: Long-term results of a Canadian prospective cohort. Can Urol Assoc J. 2019;13(5):E125–31.
6. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.
7. Porpiglia F, Bertolo R, Manfredi M, De Luca S, Checcucci E, Morra I, Passera R, Fiori C. Total Anatomical Reconstruction during Robot-assisted Radical Prostatectomy: Implications on Early Recovery of Urinary Continence. Eur Urol [Internet]. 2016 [cited 2017 Jun 11];69(3):485–95.
8. Sammon JD, Sharma P, Trinh QD, Ghani KR, Sukumar S, Menon M. Predictors of immediate continence following robot-assisted radical prostatectomy. J Endourol. 2013;27(4):442–6.
9. Ko YH, Coelho RF, Chauhan S, Sivaraman A, Schatloff O, Cheon J, Patel VR. Factors affecting return of continence 3 months after robot-assisted radical prostatectomy: analysis from a large, prospective data by a single surgeon. J Urol. 2012;187(1):190–5.
10. Bartoletti R, Mogorovich A, Francesca F, Pomara G, Selli C. Combined bladder neck preservation and posterior musculofascial reconstruction during robotic assisted radical prostatectomy: Effects on early and long term urinary continence recovery. BMC Urol. 2017;17(1):1–7.
11. Kohjimoto Y, Yamashita S, Kikkawa K, Iba A, Matsumura N, Hara I. The association of length of the resected membranous urethra with urinary incontinence after radical prostatectomy. Urol J. 2019;epub(c):2–6.
12. Song W, Kim CK, Park BK, Jeon HG, Jeong BC, Seo S Il, Jeon SS, Choi HY, Lee HM. Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy. Can Urol Assoc J. 2017;11(3–4):E93–9.
13. Ganni S, Botden SMBI, Chmarra M, Goossens RHM, Jakimowicz JJ. A software-based tool for video motion tracking in the surgical skills assessment landscape. Surg Endosc [Internet]. 2018 Jun 16 [cited 2018 Jun 21];32(6):2994–9.
14. Avery K, Donovan J, Peters TJ, Shaw C, Gotoh M, Abrams P. ICIQ: A brief and robust measure for evaluating the symptoms and impact of urinary incontinence. Neurourol Urodyn. 2004;23(4):322–30.
15. Ogaya-Pinies G, Linares-Espinos E, Hernandez-Cardona E, Jenson C, Cathelineau X, Sanchez-Salas R, Patel V. Salvage robotic-assisted radical prostatectomy: oncologic and functional outcomes from two high-volume institutions. World J Urol [Internet]. 2018;i:1–7.
16. Suardi N, Gallina A, Lista G, Gandaglia G, Abdollah F, Capitanio U, Dell'Oglio P, Nini A, Salonia A, Montorsi F, Briganti A. Impact of adjuvant radiation therapy on urinary continence recovery after radical prostatectomy. Eur Urol [Internet]. 2014;65(3):546–51.
17. Bautista Vidal JC, García Galisteo E, Barón López J, Sánchez Martínez N, Hernández Alcaraz D, Morales Jiménez P, Vozmediano Chicharro R. Objective assessment of early urinary continence by analysis and visualisation of intra-operative variables of radical robotic prostatectomies with a video editor. Actas Urol Esp [Internet]. 2019;43(2):99–105.
18. Bianchi L, Turri FM, Larcher A, De Groote R, De Bruyne P, De Coninck V, Goossens M, D'Hondt F, De Naeyer G, Schatteman P, Mottrie A. A Novel Approach for Apical Dissection During Robot-assisted Radical Prostatectomy: The "Collar" Technique. Eur Urol Focus [Internet]. 2018;4(5):677–85.
19. Walz J, Epstein JI, Ganzer R, Graefen M, Guazzoni G, Kaouk J, Menon M, Mottrie A, Myers RP, Patel V, Tewari A, Villers A, Artibani W. A Critical Analysis of the Current Knowledge of Surgical Anatomy of the Prostate Related to Optimisation of Cancer Control and Preservation of Continence and Erection in Candidates for Radical Prostatectomy: An Update. Eur Urol [Internet]. 2016;70(2):301–11.

Chapter 12

Analysis of the video motion tracking system 'Kinovea' to assess surgical movements during robot-assisted radical prostatectomy.

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Abstract

Backgrounds:

Robot-assisted surgery facilitated the possibility to evaluate the surgeon’s skills by recording and evaluating the robot surgical images. The aim of this study was to investigate the possibility of using a computer programme (Kinovea) for objective assessment of surgical movements in previously recorded in existing robot-assisted radical prostatectomy (RARP) videos.

Methods

Twelve RARP-videos were analysed by a trained researcher using the computer programme “Kinovea” to perform semiautomated assessment of surgical movements.

Results

Data analysis showed Kinovea was on average only able to automatically assess 22% of the total surgical duration per video of the robot assisted surgery. On average it lasted 4 hours of continued monitoring by the researcher to assess one RARP using Kinovea.

Conclusion

Although we proved it is technically possible to use the Kinovea system in retrospective analysis of surgical movement in robot assisted surgery, the acquired data does not give a comprehensive enough analysis of the video to be used in skills assessment.

Introduction

The introduction of Endoscopic surgery opened the possibility to evaluate the surgeon's skills based on the intra-corporal surgical videos. A standardized assessment method in order to assess the surgeon's skills real-time in surgery was developed by Martin et al. using the Objective Structured Assessment of Technical Skills (OSATS).[1] This type of skill assessment sparked the investigation into the relation between surgical skills and postoperative complications. Birkmeyer etal. were (one of) the first who were able to prove a causal relation between the level of surgical skill[2] and postoperative complications. He demonstrated that the skills of the surgeons in laparoscopic bariatric surgery were associated with lower complication and mortality rates. Moreover, lower ranked surgical skills were associated with prolonged surgical times, higher reoperation rates and higher readmission rates.[2]

After the initial development of OSATS, various other assessment tools have been developed for the evaluation of robotic surgical technical skills, such as the Global Evaluative Assessment of Robotic Skills (GEARS)[3], the Prostatectomy Assessment and Competency Evaluation (PACE)[4], the Generic Error Rating Tool (GERT)[5], and the PROTEST assessment tools.[6] These new assessment tools can be used to assess the surgeon's skills based on the intra-corporal video of the surgical procedure.

In another study conducted by Goldenberg et al., the relationship between surgical skills defined by use of the GEARS assessment tool and patient outcomes in robot-assisted radical prostatectomies (RARP) was investigated.[7] The focus of the GEARS assessment tool lies on general robot surgical principals, i.e. Depth perception, bi-manual dexterity, efficiency, force sensitivity, autonomy, and robotic control.[3] Goldenberg et al. found that surgical skills as measured using the GEARS tool were ranked higher in the postoperative urinary continent group compared to postoperative urinary incontinent group.[7] However, these assessment tools are a time-consuming way of assessing surgeons' skills. Since these methods are based on human review, subjective bias cannot be avoided, leading to reduced interrater reliability.

To objectify the assessment and to reduce the time investment of 'manual assessment' by the observer automated assessment tools are being studied.[8,9] Recently Hung et al. investigated the possibility of the analysis of the movements of the surgical robot with the dVLogger system which led to greater insight into the performance of the surgeons and could be used to predict postoperative outcomes.[8,10] The dVLogger system automatically logs motion tracking and system events data without correlation to the surgery.

In a recent Delphi study by our group6 into the link between surgical skills and postoperative outcome (resulting in the PROTEST assessment tool) a possible relation was suggested between some phases of the RARP surgery and postoperative urinary continence. The Delphi panel agreed that events during the “Pelvic floor muscle exposure/opening of the endopelvic fascia”, and the “Vesico-urethral anastomosis” could be related to postoperative continence. This relation has yet to be proven in further research.

Ganni, et al. researched a computer program, Kinovea, which can be used by researchers to perform semiautomated video motion tracking in laparoscopic cholecystectomy procedures. The system is able to track by the researcher selected pixels on the surgical instrument during the surgical procedure. Kinovea is a software-based system used in sports to track trajectories and speeds of items or human movements. The benefit of this system over the dVlogger is that there is no need of additional hardware systems or sensors on the instruments to measure the movements of the item of interest. This means this system can be used in retrospective studies without any preparation during surgery. The system enables the assessment of the video material during the tracking analysis. This tracking system was used to assess surgeons’ skills using existing surgical videos rather than in a simulator9. This raises the question if Kinovea could be used for similar purposes in robot assisted surgery in order to assess the surgical movements based on the video of the surgical procedure.

The purpose of this study is to determine whether Kinovea is a valid tool for automated surgical movements tracking in RARP and may be used to evaluate a possible relation between surgical movements and postoperative urinary continence in RARP.

The present research questions are: (1) Is Kinovea a valid tool for automated assessment of surgical movements in RARP surgical videos? (2) Can the results found through automated surgical movements tracking using Kinovea be used to predict postoperative continence in RARP? (3) Can results of the Kinovea analysis obtained during the “Pelvic floor muscle exposure/opening of the endopelvic fascia”, and the “Vesico-urethral anastomosis” be used to predict postoperative continence in RARP?

These questions will be answered by analysing surgical movements in RARP videos.

Methods

Subjects

For this study existing videos of RARP procedure were used of patients who underwent a robot assisted radical prostatectomy in a specialized cancer hospital in the Netherlands between June 2009 and February 2017. All of the patients were operated by the same expert robotic surgeon (HvdP), who had performed >220 RARP procedures before June 2009 and has currently performed >2100 RARP procedures using the daVinci Si surgical robot by Intuitive. Exclusion criteria were urinary incontinence prior to surgery, and Surgeries where no or incomplete video material was available. All of the men included had localized prostate cancer (cT1c-cT3a, Nx-N0, Mx-M0).

Design

The study design was a pilot study in order to investigate if Kinovea is suitable to use in robot assisted surgery. Patient results were obtained prospectively. The follow-up was at least 12 months.

Cases were anonymized and labelled with study codes, meaning the researcher was blinded to all patient characteristics and outcomes. This study was granted approval from the institutional medical committee.

Automated surgical movements assessment using Kinovea.

The surgical movements of the instrument were tracked using the Kinovea software. The primary outcome measurements are the total time analysed (minutes), and percentage of surgery analysed (%). The secondary outcome measurements are total path length (cm), number of sudden movements (defined as more than 1 cm movement of the instrument per frame of the surgical video), and average speed (cm/s). The Kinovea software is deemed valid if it is able to track > 80% of the duration of the surgery.

The instrument controlled by the right robotic arm (controlled by the dominant hand of the surgeon) was used for the analysis using Kinovea. For every video excel sheets containing automatic calculations of the total distances and velocities per trajectory were downloaded from Kinovea. These results were compared to the total distances, average velocities and numbers of sudden movements calculated using manual formulas based on Ganni, et al.’s article (Table 1)[9] .

Table 1: Formulas used for manual calculation[9].

Description	Symbol	Formula
Number of frames	N	
Number of frames per second	f	
Scaled x-coordinate at frame n (cm)	x'_n	
Scaled y-coordinate at frame n (cm)	y'_n	
Distance moved between consecutive frames (cm)	d_{n+1}	$\sqrt{(x'_{n+1} - x'_n)^2 + (y'_{n+1} - y'_n)^2}$
Total time taken (s)	T	$\frac{N}{f}$
Total distance travelled (cm)	D	$\sum_{n=1}^{N-1} d_{n+1}$
Average speed (cm/s)	$\bar{S}$	$\frac{D}{T}$
Number of sudden movements	M^e_{n+1}	$\begin{cases} 1 d_{n+1} \geq d_{th} \\ 0 d_{n+1} < d_{th} \end{cases}$
Number of sudden movements	E	$\sum_{n=1}^{N-1} M^e_{n+1}$

Relation between Kinovea results and postoperative continence status

Although patient selection was based on continence, a number of additional outcomes were compared to the video motion tracking data in order to assess if there was a relation. These postoperative outcomes included patient reported outcome measures (PROMs), lower urinary tract symptoms, measured using the International Prostate Symptom Score (IPSS)[11,12], the Lower urinary tract symptoms domain of the EORTC QLQ-PR25 score (EORTC QLQ-PR25 score)[13–15], and postoperative complications, which were registered in the patients' medical files as they occurred.

Relation between Kinovea results of different phases of the surgery and postoperative continence status

The surgery was divided in seven surgical phases which were defined in the PROTEST assessment method[6] developed by this research group. To investigate the relation between Kinovea results and the "Pelvic floor muscle exposure/opening of the endopelvic fascia", and "Vesico-urethral anastomosis" specific analysis for these phases were performed.

Methods of measurement

The automated surgical movements tracking was performed by one researcher using Kinovea 0.8.15. The researcher was instructed in the use of Kinovea and the surgical procedure by a researcher experienced in the use of Kinovea and the RARP procedure.

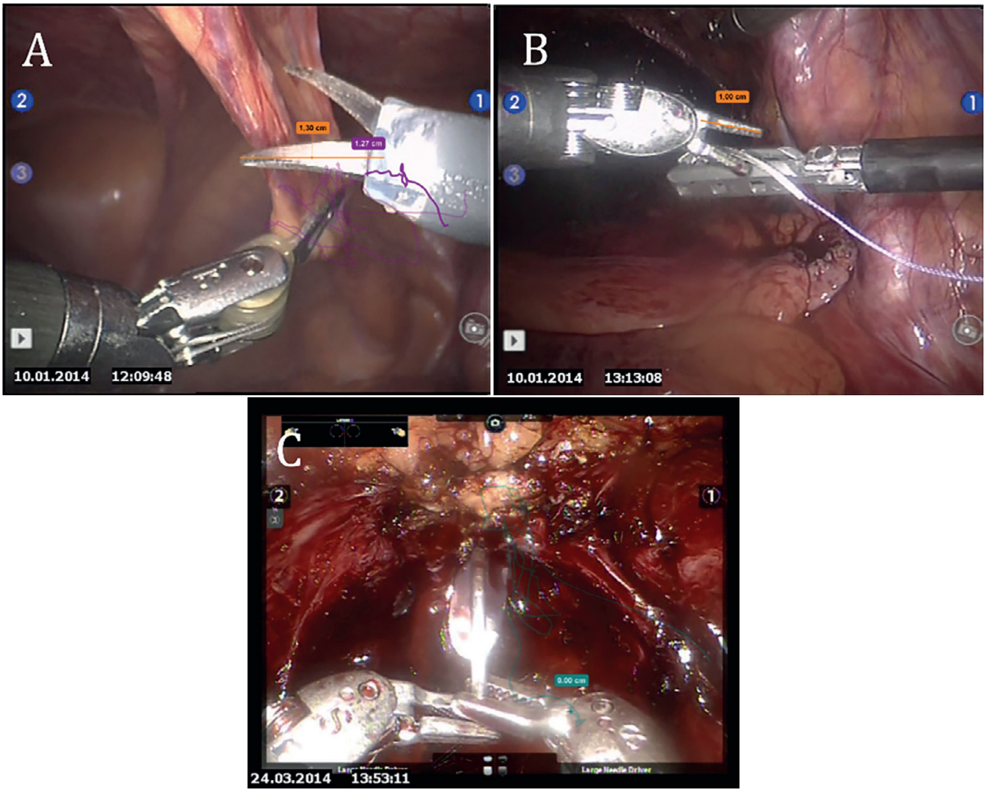

Fig. 1: A) Example of a calibration line (orange line) and tracking point on the Mono-polar Curved Scissors. B) Example of a calibration line on the Large Needle Driver, the purple line is the movement pattern of the instrument. C) Example of a tracking point on the Large Needle Driver, the green line is the movement pattern of the instrument.

The tracked instrument controlled by the right robotic arm in the majority of measurements was the Intuitive Surgical Hot Shears (Mono-polar Curved Scissors). This instrument had a jaw length of 1.3 cm, which was used by the researcher to be able to calibrate the motion tracking software in order to approximate the total distance the surgical instrument has travelled (Fig. 1A). In a few video fragments the Intuitive Surgical Large Needle Driver was used by the right robotic arm. In this case, calibration was done by the researcher using this instrument’s jaw length, consisting of 1 cm (Fig. 1B).

After calibration the researcher only had to manually place a tracking point on the instrument’s first joint and press play, the Kinovea software was designed to be able to follow this tracking point during the procedure based on the selected pixels. The entire surgical procedure from the opening of the peritoneum to the completion of the bladder-urethra anastomosis was automatically tracked by the software (Fig. 1A,

Fig. 1C). Frequently, the software was not able to follow the selected pixels correctly, which was then manually corrected by the researcher by moving the tracking point back to the originally selected point on the instrument. The instrument tracking was manually interrupted if there was something covering it, such as tissue, blood or another instrument. It was also stopped if the instrument was out of view of the camera or if the camera was in movement. If a pelvic lymph node dissection was performed, the instrument was not tracked during this part of the surgery, since not all videos contained a pelvic lymph node dissection.

Patient selection and matching

Patients were selected based on their preoperative and post-operative continence as defined based on the International Consultation Incontinence Modular Questionnaire -Short Form (ICIQ-SF score). The ICIQ-SF is a Patient-reported outcome measures (PROMS) questionnaire which registers the patient's urinary incontinence on three domains, the frequency of urine leakage (0-5 points), the amount of leakage according to the patient (0-6 points), and the interference of the urine leakage with everyday life (0-10 points). An additional question which asks in which situation the urine leaks gives more insight into the type of incontinence. The cumulative scores of the three question (0-21 points) represent the patients experience of urinary incontinence. In this study an ICIQ-SF score of 0 at 6 and 12 months postoperative was defined as continent, whilst and ICIQ-SF of >10 at 6 and 12 months postoperative was defined as incontinent. Two groups of patients were selected. The first group (A) consisted of patients who were continent preoperative and were continent at 6 and 12 months after surgery this group was matched with a second group (B) of patients who were continent preoperative and were incontinent at 6 and 12 months after surgery.

The patients in the continency group were matched according to the date of the surgery, the age of the patient, BMI of the patient and the preoperative intentions of saving the neurovascular bundles during surgery. All incontinent patients were manually compared to the continent patients by two individual researchers (AB and HN). Based on the number of variables in which the pairs matched a matching score of zero to four was given to the patients, each matched variable resulted in a point in the total matching score. The patients were matched based on age (difference of < 5 years = 1 matching point), BMI (difference < 3 points = 1 matching point), date of the surgery (difference <3 months = 1 matching point), and preoperative intentions of saving the neurovascular bundles during surgery on both sides (NVB sparing the same in both patients = 1 matching point). A matching score of four was the best possible match. Based on the matching scores the best matched patient pairs were selected for analysis, since almost no perfect matches existed (Appendix 1). If matched pairs with similar matching scores existed a definitive choice was made based on the variable on which the patients matched (appendix 1).

Power analysis

Ganni, et-al9 observed both experts and novice participants during a basic laparoscopic cholecystectomy procedure using semiautomated video motion tracking via the Kinovea system in order to determine their path length, average instrument movement and number of sudden or extreme movements. This study shows a lower path length for the Experts compared to the novices. These results show it is possible to detect a difference in populations means of 60 cm (127cm for experts, 187 cm in novice analysis) in total path length. For this study we assume the path length in the incontinent patients is similar to that of a novice and the path length in the continent patients is similar to that of an expert. Based on a power calculation using 0.05 as Alpha, a Power of 0.80, and an effect size of 60cm a sample size of 4 patients per subgroup would be sufficient for the main objective of this study.

Data analysis

Data analysis was performed using SPSS statistics v24 (IBM, NY). Frequency statistics were calculated for patient demographic data and surgeon scores. Correlation between Kinovea results on the one hand and ICIQ-scores, IPSS scores, and EORTC QLQ-PR25 scores were calculated using a Spearman's Rho test. The Wilcoxon signed-rank test was used to compare differences in results between the matched patient groups. The McNemar's test was used in order to compare differences in results between the matched patient groups in case of dichotomous variables. Statistical significance was set at $p < 0,05$ based on a two-tailed comparison.

Results

After exclusion based on the exclusion criteria 191 of the 227 patients were eligible for inclusion (figure. 2). Based on continence status 79 patients were included in group A, 10 patients in group B.

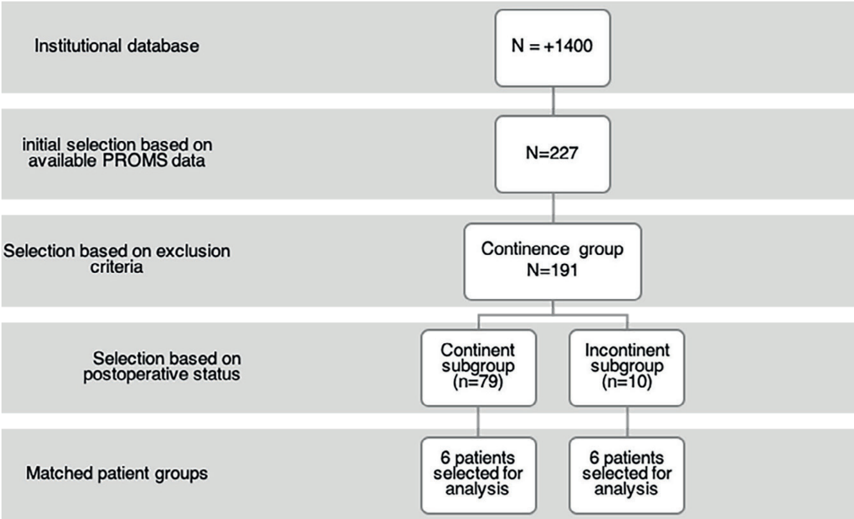

Figure 2 study design

After selection, A total of 6 incontinent and 6 continent patients were selected and matched based on age, BMI, prostate size, Gleason score, clinical and pathologic tumor stage, membranous urethral length, IPSS, ICIQ, and EORTC QLQ-PR25 (Table 2). There were no significant differences between the incontinent and continent group in baseline characteristics, including age, BMI, date of surgery, oncological data, and

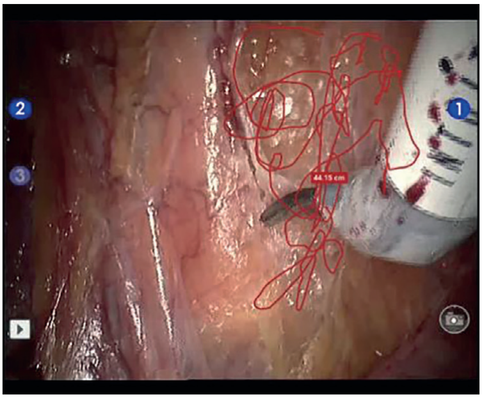

Fig. 3: Example of a fully tracked trajectory of the Mono-polar Curved Scissors.

Table 1: Baseline characteristics of the selected patients

Characteristics	Postoperative incontinent patients (n=6) Median (min - max)	Postoperative continent patients (n=6) Median (min - max)	P-value	Z-Value
Age (years)	64 (57 - 67)	62.5 (53 - 66)	0.674	-0.420
Body Mass Index (kg/m2)	26.86 (20.45 – 32.55)	25.99 (22.50 – 32.11)	0.917	-0.105
Prostate size (ml)	50 (39 - 81)	38 (35 - 82)	0.225	-1.214
Gleason score	7 (6 - 8)	6 (6 - 7)	0.157	-1.414
Membranous urethral length (mm)	11.07 (8.69 – 13.10)	13.58 (10.48 – 16.15)	0.273	-1.095
Surgery date, median (IQR)	15-02-2014 (02-02-2013 – 15-03-2015)	27-04-2014 (06-12-2012 – 29-01-2015	0.600	-0.524
Preoperative IPSS score	3 (0 - 7)	2.5 (0 – 8.5)	0.892	-0.135
6 months postoperative IPSS score	15 (0 - 19)	3 (0 - 5)	0.042	-2.032
12 months postoperative IPSS score	10 (6 - 16)	2 (0 - 5)	0.043	-2.023
Preoperative ICIQ score	0 (0 - 0)	0 (0 - 0)	1.000	0.000
6 months ICIQ score	15 (11 - 20)	0 (0 - 0)	0.027	-2.207
12 months ICIQ score	14 (12 - 17)	0 (0 - 0)	0.026	-2.232

membranous urethral length. The preoperative Patient Reported outcome Measures, i.e. ICIQ-SF, IPSS and EORTC QLQ-PR25 also showed no difference between the incontinent and continent group.

Results of automated surgical movements assessment using Kinovea.

Every surgical video was tracked from the opening of the peritoneum to the completion of the bladder-urethra anastomosis. Of the median duration of the surgery (81.00 minutes), only a median length of 18.22 minutes of the video could be tracked (median 21.74%) (Table 3). Figure 3 shows an example of a trajectory of the movements of the Mono-polar Curved Scissors tracked using Kinovea.

Table 3: Total time analysed, duration of the surgery, percentage of surgery analysed, Automatic and calculated total path length in cm, difference in total path length in %, number of sudden movements and average speed.

	Median	Min	Max
Total time analysed (minutes)	18,22	8,13	27,05
Duration of the surgery (minutes)	81,00	57,00	99,00
Percentage of surgery analysed (%)	21,74	14,26	29,73

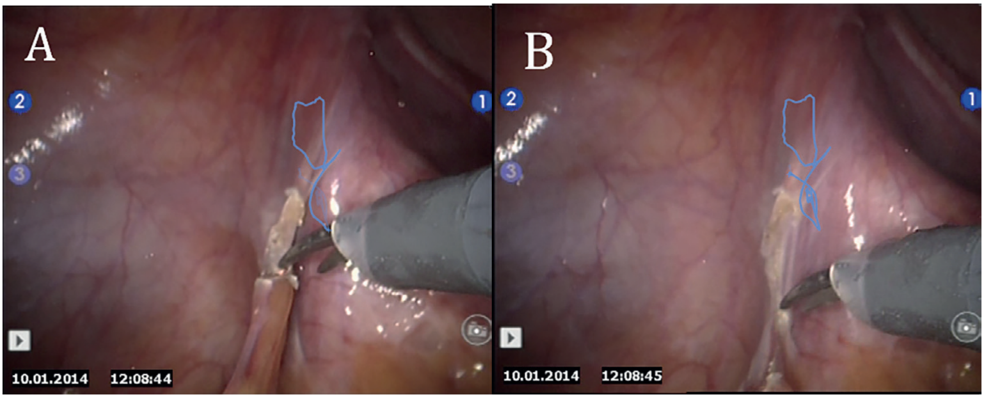

Fig. 4: Tracking point on instrument (A) and tracking point on tissue 48 milliseconds later (B).

We found the computer program could not run fully automatic in RARP surgery since the tracking point could often not correctly identify the instrument's joint, meaning the tracking point had to be manually placed and moved by the researcher. To illustrate this, in figure 4 a tracking point was placed on the instrument manually (figure 4A) after which the tracking program ran automatically. 48 milliseconds later, the tracking

Table 4: Automatic and calculated total path length in cm, difference in total pathlength in %, number of sudden movements and average speed.

	Median	Min	Max
Automatic total path length (cm)	1594,95	949,91	3264,24
Calculated total path length (cm)	2134,99	1585,38	3515,76
Median difference in path length (%)	16,10		
Automatic number of sudden movements	0	0	0
Calculated number of sudden movements	101	45	167
Automatic average speed (cm/s)	1,67	1,22	2,05
Calculated average speed (cm/s)	2,16	1,48	2,63
Median difference in average speed (%)	23,17		

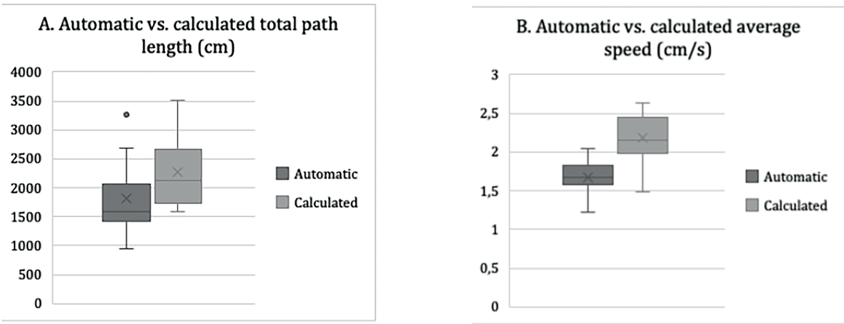

Fig. 5: Summary data of the automatic vs... calculated total path length in cm (A) and the automatic vs... calculated average speed in cm/s (B).

Table 5 results of Patient Reported outcome Measures (PROMS) at 6 and 12 months postoperative in Arm 1, incontinent vs... continent.

	Postoperative incontinent patients (n=6) Median (min - max)	Postoperative continent patients (n=6) Median (min - max)	P-value	Z-Value
6 months postoperative IPSS score	15 (0 - 19)	3 (0 - 5)	0.042	-2.032
12 months postoperative IPSS score	10 (6 - 16)	2 (0 - 5)	0.043	-2.023
6 months ICIQ score	15 (11 - 20)	0 (0 - 0)	0.027	-2.027
12 months ICIQ score	14 (12 - 17)	0 (0 - 0)	0.026	-2.232

point had moved to a pixel in the surrounding tissue (figure 4B).

Table 4 shows the automatic and manually calculated total path length, sudden instrument movements and average speed. The total path length and average speed manually calculated using formulas from Ganni, et al.'s article[9] differed from the automatically calculated results. The median difference in total path length was 16.10% and the median difference in average speed was 23.17%. This data has been summarized in box-and-whisker plots in figure 5A and figure 5B.

Table 6 correlations between Kinovea measurements and postoperative Patient Reported outcome Measures (PROMS) at 6 and 12 months postoperative.

	Total path length (cm)		Average speed (cm/s)	
	Correlation	p-value	Correlation	p-value
6 months postoperative IPSS score	0.035	0.913	0.311	0.324
12 months postoperative IPSS score	0.071	0.845	0.310	0.383
6 months ICIQ score	0.092	0.766	0.193	0.547
12 months ICIQ score	0.155	0.631	0.190	0.555

Relation between Kinovea results and postoperative continence status

When comparing the 6 and 12 months postoperative IPSS and 6 months postoperative EORTC QLQ-PR25 score the postoperative continent group had significantly lower IPSS scores and lower EORTC QLQ-PR25 scores at 6 and 12 months after surgery (Table 5). Based on the selection of patients the ICIQ score at 6 and 12 months after surgery also showed a significant difference.

When correlating the results of the manual Kinovea calculations to the postoperative Patient Reported outcome Measures (PROMS (i.e. the IPSS scores, EORTC QLQ-PR25 scores, and ICIQ scores) no significant correlations were found (table 6).

Table 7: Kinovea metrics for each of the seven surgical steps defined in the PROTEST assessment method

RARP step	Number of videos in which Kinovea data was available	Median speed (cm/s) (min - max)	Median time analysed (seconds) (min - max)	Median phase duration (seconds) (min - max)	Median percentage of phase analysed (%) (min - max)
Pelvic floor muscle exposure RIGHT	11	2.61 (1.69 – 3.54)	9.12 (4.52 – 80.96)	63 (35-202)	18.38 (4.04 – 72.59)
Pelvic floor muscle exposure LEFT	7	2.88 (1.93 – 3.28)	18.56 (3.56 – 44.64)	90 (25-138)	26.11 (5.93-51.31)
Pelvic floor muscle exposure COMBINED	7	2.68 (1.88 – 3.41)	36.40 (12.12 – 125.6)	146 (60 – 289)	24.53 (9.23 – 43.46)
Bladder neck dissection	12	1.89 (1.46 – 2.28)	207.78 (99.44 – 382.40)	447 (286 – 1044)	41.14 (23.49 – 62.06)
Ligation of prostatic pedicles RIGHT	12	2.07 (1.38 – 3.28)	28.48 (18.84 – 73.12)	188 (74 – 435)	16.60 (9.88 – 38.89)
Ligation of prostatic pedicles LEFT	11	1.71 (0.95 – 3.25)	21.92 (5.92 – 50.40)	143 (53 – 370)	15.77 (4.14 – 31.27)
Ligation of prostatic pedicles COMBINED	11	1.81 (1.26 – 3.00)	59.84 (26.00 – 93.36)	281 (222 – 805)	15.60 (7.67 – 29.99)
Nerve preservation RIGHT	9	2.18 (1.17 – 2.47)	19.20 (4.04 – 72.16)	113 (46 – 600)	12.03 (5.38 – 61.48)
Nerve preservation LEFT	7	1.51 (1.42 – 1.93)	20.92 (2.88 – 45.56)	190 (89 – 603)	8.72 (3.24 – 21.90)
Nerve preservation COMBINED	6	1.84 (1.29 – 1.96)	52.34 (15.60 – 96.48)	337 (228 – 764)	11.82 (6.61 – 16.68)
Management of prostatic apex/urethra	12	1.83 (1.17 – 2.79)	125.62 (14.52 – 281.64)	438 (211 – 1070)	28.63 (6.88 – 38.87)

Table 7:Continued

RARP step	Number of videos in which Kinovea data was available	Median speed (cm/s) (min - max)	Median time analysed (seconds) (min - max)	Median phase duration (seconds) (min - max)	Median percentage of phase analysed (%) (min - max)
Vesico-urethral anastomosis	12	1.75 (0.98 – 2.29)	38.58 (7.80 – 187.28)	648 (386 – 1093)	6.86 (1.40 – 19.27)

Relation between Kinovea results of different phases of the surgery and postoperative continence status

Of the seven surgical steps defined in the PROTEST assessment method6 the median speed was highest during the pelvic floor muscle exposure on the left side (2,8 cm/s) and lowest during nerve preservation on the left side (1,51 cm/s) (Table 7). The median percentage analysed was the highest during the bladder neck dissection (41.14%) and the lowest during the ureterovesical anastomosis (6.86%)[6].

The Kinovea results of the "Pelvic floor muscle exposure/opening of the endopelvic fascia" (table 8), and the "Vesico-urethral anastomosis" (table 9) phases to postoperative PROMS showed no significant correlations.

Table 8 correlations between Kinovea measurements of the "Pelvic floor muscle exposure/opening of the endopelvic fascia" and postoperative Patient Reported outcome Measures (PROMS) at 6 and 12 months postoperative.

	Right side of the patient				Left side of the patient			
	Total path length (cm)		Average speed (cm/s)		Total path length (cm)		Average speed (cm/s)	
	Correlation	p-value	Correlation	p-value	Correlation	p-value	Correlation	p-value
6 months postoperative IPSS score	0.264	0.432	0.332	0.319	-0.504	0.249	0.502	0.251
12 months postoperative IPSS score	0.441	0.202	-0.072	0.844	-0.495	0.318	0.055	0.917
6 months ICIQ score	0.049	0.202	-0.072	0.844	-0.495	0.318	0.055	0.917
12 months ICIQ score	0.034	0.921	0.007	0.984	-0.642	0.120	0.040	0.933

Table 9 correlations between Kinovea measurements of the "Vesico-urethral anastomosis" and post-operative Patient Reported outcome Measures (PROMS) at 6 and 12 months postoperative.

	Total path length (cm)		Average speed (cm/s)	
	Correlation	p-value	Correlation	p-value
6 months post-operative IPSS score	-0.196	0.541	0.425	0.169
12 months postoperative IPSS score	-0.328	0.355	0.529	0.116
6 months ICIQ score	-0.318	0.313	0.006	0.985
12 months ICIQ score	-0.331	0.293	0.141	0.661

Discussion

The aim of this study was to determine whether Kinovea is a valid tool for automated surgical movements tracking in RARP and if results could be used to evaluate a possible relation between surgical movements and postoperative urinary continence after RARP.

The value of automated assessment of surgical movements in RARP surgical videos using Kinovea

To answer if Kinovea is a valid tool for assessment of surgical movements in RARP surgical videos an analysis of 12 entire RARP procedures was performed by a trained researcher. The analysis itself was not technically challenging, after manual calibration, the researcher only had to position the tracking point on the most distal hinge of the instrument and press play.

During automated analysis the videos had to be manually adjusted since Kinovea was frequently not able to run fully automatic. In most instances the short distance between camera and tissue (level of zoom), the speed of the surgical instruments, tissue overlapping the instrument and the fact that the instrument has flexible joints, made it difficult to track the instrument correctly. These findings show that it is difficult to use Kinovea for assessment of surgical movements in RARP surgical videos.

The group of Ganni, et al. was able to automatically track the instrument during surgery with Kinovea. They checked a few minutes manually per video in order to confirm their results.[9] We attempted to perform similar analysis in robot assisted surgery as in the study of Ganni, et al. The analysis was based on the same principal by relating the distance moved by the surgical instrument to the relative measurements of the instrument. In our study the frequent manual adjustments raised the need for continued monitoring by the researcher, this meant it was a very time-consuming method of analysis.

In this study we compared two forms of output from the Kinovea program, one form is the automated results (automated output) given by the Kinovea program, the other form of output was the calculated results based on the raw Kinovea data using the formulas as described in the study by Ganni, et al (manual output). An interesting finding was the lack of sudden movements reported in the videos when using the automated output, which did not match the number of sudden movements found using the manual calculations based on the formulas used by Ganni, et al.[9] The automated and manual total path length and average speed also did not match.

These inconsistencies raise the questions why the outputs differ and which method is more reliable. When checking these manual sudden movements, they appeared to be caused by manual repositioning of the tracking point on the instrument by the researcher after the tracking point had lost the instrument's joint during automated analysis by the Kinovea program. During the assessment of the videos an average of 101 manual repositioning's were registered. This makes the sudden movements unreliable for analysis in robot assisted surgery, which could mean the automated results represent a more accurate analysis of the surgical movements. The group of Ganni, et al did not report this problem, either because no manual repositioning was necessary in their study or because they did not manually review the entire surgical video[9].

Relation between Kinovea results and postoperative continence status

This study shows there is no relation between the motion tracking results and the continence status of this patients. The main reason could be the limited quality of the Kinovea Motion tracking results since on average less than a quarter of the videos could be tracked. Another explanation could be there is no relation between the total path length, average speed of the instrument and the continence status of the patient.

Relation between Kinovea results of different phases of the surgery and postoperative continence status

The correlation between Kinovea results of the "Pelvic floor muscle exposure/opening of the endopelvic fascia", and the "Vesico-urethral anastomosis" to the PROMS results also did not give any significant correlations.

Since the value of the results using the Kinovea program is questionable the lack of correlation could be due to the fact that only limited parts of the surgery were analysed or it could mean the results obtained using Kinovea cannot be used to predict postoperative continence. Since the Kinovea software was not able to automatically assess surgical movements in RARP it proved to be an invalid tool for automated surgical movement tracking in robot assisted surgeries.

Strengths and limitations.

To our knowledge this is the first study into the possibilities of using existing surgical videos of real RARP procedures to identify the effects of surgical movements on postoperative outcome. This study shows the results of the first use of Kinovea as a software based surgical motion tracking tool in robot assisted surgery. Although the assessment of the movements using kinovea was time consuming and had its challenges, Kinovea does give the researcher the means to simultaneously assess the anatomy during analysis of the surgical videos. One of the alternatives to Kinovea, the dVlogger, only provides raw movement data without the ability to correlate this to the surgical videos.[8]

The data represented in this study are the results of the parts were automated tracking was possible, no data was interpolated. During tracking the software was frequently not able to follow the selected pixels correctly, which was then manually corrected by the researcher by moving the tracking point back to the originally selected point on the instrument. The movement data due to the repositioning of the tracker point was deleted from the data after manual verification and checking of the path in the video file.

The place of the surgery within the learning curve of the surgeon could influence the results of this type of analysis. Other studies have shown that arm movement analysis can be used to separate beginning surgeons from experts.[9,16] In this study the selection of cases has been adjusted to take into account when the surgery was performed in order to reduce the influence of learning curve on the results of this study.

The Kinovea program was able to assess surgeons' skills using existing surgical videos rather than in a simulator, without needing extra equipment for movement tracking in laparoscopic surgery.[9] The analysis in robot assisted surgery does not appear to be as valid as the analysis in laparoscopic surgery. In Robot assisted surgery the frequent manual replacement and moving of the tracking point during the Kinovea analysis adds a subjective component to an otherwise objective measurement.

Further research with larger groups of patients and a different automated tracking system is needed in order to investigate the relation between surgical movements, surgical skills, and postoperative outcomes. A combination of video assessment and dVlogger data could hold the key to find metrics related to postoperative outcome. To the knowledge of this group no such analysis method is currently available to be used in a retrospective analysis without additional equipment for tracking the movements. The use of artificial intelligence in combining both video assessment and surgical movements assessment could eliminate human interference and lead to an objective and automated assessment of the surgical video.

Conclusion

Kinovea can be used to retrospectively assess instrument movement in laparoscopic surgery without requiring extra equipment[9]. In this study Kinovea was used to assess if this software could be used to automatically measure surgical movement in robot assisted radical prostatectomy videos. Based on the results of this study, because of a more close-up camera position for robotic as compared to laparoscopic surgery, the speed of the surgical instruments, tissue overlapping the instrument, and the fact that the instrument has flexible joints, the Kinovea software cannot be used to automatically assess surgical movements in RARP surgical videos.

Appendix

Appendix 1 matching scores per pair of patients.

The patients were matched based on age (difference of < 5 years = 1 matching point), BMI (difference <3 points = 1 matching point), date of the surgery (difference <90 days = 1 matching point), and preoperative intentions of saving the neurovascular bundles during surgery on both sides (NVB sparing the same in bot patients = 1 matching point).

Study # incontinent	Study # continent pair	Difference OR date (days)	Match point OR date	Difference BMI (points)	Match point BMI	Difference age (years)	Match point age	Difference NVB	Match point NVB	Total score match point	Matched pair selected (yes/No)
82	84	38	1	1.20	1	3	1	None	1	4	Y
212	213	1	1	2.05	1	3	1	None	1	4	Y
140	143	42	1	1.45	1	13	0	None	1	3	Y
167	153	89	1	0.59	1	4	1	None	1	3	Y
116	107	90	1	0.44	1	7	0	None	1	3	Y
147	155	130	0	1.42	1	1	1	None	1	3	Y
128	129	7	1	1.23	1	1	1	None	1	4	N
136	141	50	1	0.15	1	10	0	None	1	3	N
140	155	203	0	0.88	1	7	0	None	1	2	N
32	30	2	1	0.13	1	13	0	None	1	3	N
200	178	276	0	0.02	1	2	1	None	1	3	N
116	121	49	1	5.13	0	0	1	None	1	3	N

A total 12 possible match pairs were identified for the 10 incontinent patients. The match pairs 82/84, 128/129, and 212/213 were chosen because of their maximum match score of 4. During review the video of patient 129 did not work, this was a reason to exclude this matched pair and replace it with another matched pair. Individual patients were part of multiple matched pairs in case of five matched pairs (147/155, 140/155, 140/143 and 116/121, 116/107). Of these matched pairs 140/155 was not chosen because match pair 140/143 matched better on date of the surgery which reduces the influence of the learning curve on the postoperative results. Match pair 147/155 was chosen because there is a shorter interval between dates of the surgery compared to 140/155. Match pair 116/121 was not chosen because match pair 116/107 matched similar on date of the surgery and better on BMI of the patient which could reduce the influence of BMI on the postoperative results. The match pairs 140/143, 167/153, and 116/107 were chosen because they matched on the date of the surgery and BMI. Match pair 200/178 was not chosen because of the large interval between dates of the surgery which could increase the influence of the learning curve on the postoperative results.

References

1. Martin JA, Regehr G, Reznick R, MacRae H, Murnaghan J, Hutchison C, Brown M. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg [Internet]. 1997 Feb [cited 2017 Dec 28];84(2):273–8.
2. Birkmeyer JD, Finks JF, O ’reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.
3. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.
4. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
5. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.
6. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;
7. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
8. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.
9. Ganni S, Botden SMBI, Chmarra M, Goossens RHM, Jakimowicz JJ. A software-based tool for video motion tracking in the surgical skills assessment landscape. Surg Endosc [Internet]. 2018 Jun 16 [cited 2018 Jun 21];32(6):2994–9.
10. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44.
11. Rfd WUN, Hohú DX. International Prostate Symptom Score. 2011;8(3):227–30.
12. Description O. International Prostate Symptom Score (IPSS). 2014;35(January 2009):4–5.
13. van Andel G, Bottomley A, Fosså SD, Efficace F, Coens C, Guerif S, Kynaston H, Gontero P, Thalmann G, Akdas A, D’Haese S, Aaronson NK. An international field study of the EORTC QLQ-PR25: A questionnaire for assessing the health-related quality of life of patients with prostate cancer. Eur J Cancer. 2008;44(16):2418–24.
14. Fayers P, Aaronson N, Bjordal K, Curran D, Groenvold M, EORTC Quality of Life Group. EORTC QLQ-C30 Scoring Manual The EORTC QLQ-C30 Introduction. 2001;30:78.
15. Chang YJ, Chang CH, Peng CL, Wu HC, Lin HC, Wang JY, Li TC, Yeh YC, Liang WM. Measurement equivalence and feasibility of the EORTC QLQ-PR25: Paper-and-pencil versus touch-screen administration. Health Qual Life Outcomes [Internet]. 2014;12(1):1–10.
16. Hung AJ, Oh PJ, Chen J, Ghodoussipour S, Lane C, Jarc A, Gill IS. Experts vs.. super-experts: differences in automated performance metrics and clinical outcomes for robot-assisted radical prostatectomy. BJU Int [Internet]. 2019 May;123(5):861–8.


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Section IV

General Discussion, Conclusions, Future Perspectives, and Summary

Chapter 13

General discussion, conclusions, and future perspectives

General discussion

This thesis focusses on the training and assessment of surgical skills in robot assisted surgery. In the past years the introduction of new technologies such as the surgical robot has resulted in an increasing number and a large variation of procedures together with an enhance level of levels of technical difficulty . The challenge for both novice and expert surgeons is to safely learn how to perform new surgical procedures and to integrate these technologies into existing surgeries. To be sure that these new procedures are safe for patients, surgical practise directed at the new methods of quality assurance should be developed and investigated to guarantee the proficiency of the surgeon and improve surgical outcome. An example of a novel method of quality assurance is the analysis of sugical performance by means of video's to find out how to improve surgical procedures

The aim of this thesis is twofold. First, is to gain insight into the training and assessment of surgical skills of both novice and expert surgeons in robot assisted surgery. Second, is to clarify the relationship between performance of expert robot surgeons and postoperative patient outcomes.

The main research questions of this thesis are:

1. What are the best methods to educate novice surgeons in robotic surgery?

2. How can the performance of robotic surgeon's best be assessed?

3. What is the relation between a surgeon's performance and a patient's postoperative outcomes?

We will discuss the main findings of the thesis per research question, and highlight methodological considerations. We conclude this chapter with a reflection on the main findings of this thesis in relation to the current literature and recommendations for future research and clinical practice.

Research questions 2 and 3 are intrinsically linked, in this thesis we first researched the best method for the assessment of surgical performance using surgical video assessment (research question 2). The results of research question 2 form the basis for the research into question 3 in which we compare the surgical performance results to the patient's postoperative outcome.

What are the best methods to educate novice surgeons in robotic surgery?

The studies presented in this thesis show that there is a need for structured training in robot assisted surgery (RAS). General guidelines and certification criteria have been set for laparoscopic surgery in the form of the European Basic Laparoscopic Urological

Skills (E-BLUS) examination,[1–3] but, no such guidelines exist for RAS.

Since no set criteria or guidelines exist, most novice robot surgeons are left to their own devices when first learning robot assisted surgery. In this thesis we investigated to what extent novice robot surgeons were able to self-assess their own knowledge and dexterity skills. The results showed novice robot surgeons are overconfident in the self-assessment of their own dexterity skills after a 1-day training in robot assisted surgery (with the danger of self-assessment bias). This shows novice robot surgeons should be informed about their competence levels after surgical skills training in order to reduce the chances of self-assessment bias.

There are different forms of feedback to inform novice surgeons of their competence levels during surgery. Examples are simulator generated guidance (instructions and guidance by the virtual reality (VR) simulator) and human proctoring (instruction by an expert surgeon). The effect of these methods of feedback on dexterity skills acquisition and participants satisfaction during surgical skills training in novice robot surgeons was investigated in this thesis. The results show that novice surgeons can significantly increase their dexterity skills in RAS after 2 hours of practicing on a VR simulator. The impact of "human proctoring" seems to be limited compared to "VR simulator generated guidance" on the acquisition of dexterity skills during the initial phase of surgical simulation training since there is no significant difference between the groups. The participant satisfaction was slightly higher in the "human proctoring" group. The exposure of novice surgeons to the robotic surgery simulator alone could possibly be sufficient to significantly improve dexterity skills during the initial steps of RAS learning.

Since, no set criteria or guidelines exist in the Netherlands for starting RAS, it is paramount to gain insight into the current state of RAS training during the urology residency.

The results of this thesis show that criteria for starting RAS differ significantly among teaching hospitals. Questionnaires among all Dutch urology residents show a large portion of residents are allowed to participate in RAS during their residency, after completing a variable set of criteria. In order to provide a standardised training for urology residents an advanced course in RAS was organised. The results of the residents who were selected for this course showed a significant improvement in their surgical skills during the course. The implementation of a (multi-step) training and certification program in the Dutch residency curriculum in urology should be considered. It should be the obligation of teachers/supervisors to ensure a novice surgeon is trained and certified in the skills of RAS[4] before they perform their first surgery on a patient. Although there has been little research into the effects of surgeon training on the postoperative outcome of patients[5,6] structured training should be implemented to ensure a basic skills level for all novice surgeons in order to reduce the risks on complications for the patient.[7–9]

The results of a survey among participants in the structured fellowship in RAS (CC-ERUS fellowship) showed most respondents still perform RAS after the fellowship, which matches results from other studies into the impact of RAS fellowships.[10,11] A remarkable finding of this study is that a large proportion of respondents are unaware of the oncological (33%) and functional outcomes (66%) of their patients. This shows the participants of RAS fellowships should be urged to review their own results in order to learn from their past performance to improve their future surgical results.

How can the performance of robotic surgeon's best be assessed?

The studies performed in this thesis show technical skills assessment can be performed using multiple methods. Where the skills of novice surgeons are commonly assessed using the virtual reality simulator, expert surgeon's commonly use surgical video assessment and postoperative patient outcome analysis. In order to use the surgical video as an assessment method, the steps of the Robot Assisted Radical Prostatectomy (RARP) surgery must be defined to relate adverse postoperative outcome and complications to steps in the surgical process.

In this thesis the steps of the RARP surgery and corresponding peri-operative events with a possible effect on postoperative outcome (urinary continence and potency) of patients were defined. A new assessment template, the PROTEST assessment method, was designed based on these findings. Although several assessment methods exist these methods only focus exclusively on aspects of surgical skills assessment[12–14]. The PROTEST assessment method combines subjective surgical skills assessment, objective metrics of procedural steps, and events in one assessment method.

The analysis of technical surgical skills in RAS can lead to, mayor improvements of postoperative outcomes through the introduction of mandatory periodical assessment and training programs.[15] However, the influence of Non-Technical Skills (NTS) such as communication, teamwork, leadership, and situational awareness on postoperative outcomes should not be forgotten. In this thesis we present a study protocol describing a prospective observational multicentre study into non-technical-skills (NTS) in both Open Radical Cystectomy (ORC) and Robot Assisted Radical Cystectomy (RARC). We propose a structured approach to NTS assessment using video and audio recordings from the operation room to be able to implement all different NTS scoring methods.[16–21] The results of this study can be used to develop team-training programs specifically tailored to the introduction of the surgical robot in relation to changes in

Non-Technical Skills.

A survey among robot surgeons shows while surgical video assessment was traditionally only used in research, it is now accepted as a method of quality assurance and self-reflection in daily practice. Most surgeons use postoperative patient outcome analysis to learn from their past performances. They use edited surgical videos during team meetings in order to gain insight into the specific facets (e.g., surgical steps) of RARP in relation to postoperative complications and functional outcomes (i.e., urinary continence and erectile function).

What is the relation between a surgeon's performance and a patient's postoperative outcomes?

Although surgical video assessment is increasing in popularity, most methods used are still time consuming, subjective and cumbersome. The search for more objective and quicker assessment methods such as automated analysis of the movements of surgical instruments has been difficult. Multiple templated assessment methods (GEARS, PACE, and PROTEST) have been designed, although these assessments are still subjective, they do help the assessor as a guide for surgical skills assessment.

In this thesis we investigated the usefulness of standardised templated assessment methods (the PROTEST, PACE[14] and GEARS[12] assessment methods) for the prediction of postoperative outcomes. None of the factors in these standardised templated assessment methods could be used to predict the urinary continence or potency status of the patients. In contrast to a study by group of Stern et.al.[22], the results do show expert surgeons are able to predict the postoperative continence or potency status of their patients. The results of both studies show expert focus on the quality of the neurovascular bundles in case of potency, and the length of the urethral stump after resection in case of urinary continence in order to predict postoperative outcome.

Further research was performed to objectively assess the influence of the urethral stump length on postoperative continence. The residual urethra stump has effects on urinary continence after a RARP. These findings show the residual urethra stump was significantly longer in the continent group compared to the incontinent group (10,50 vs 12,94 mm, p= 0.018). Although this relation was proven in previous studies using MRI images[23,24] and pathology results[25], we demonstrated that it is possible to measure the residual urethra stump during surgery. If the technique can be adapted for use during surgery instead of in pre-recorded surgical video's, it will be possible to measure the urethral length during surgery in order to adapt surgical techniques to spare as much urethral length as possible.

Further research into the objective assessment of surgical skills was done by investigating the possibility to automatically assess instrument movements in pre-recorded videos of RARP patients. This type of analysis was used to investigate if the movements of the surgical instrument could predict the functional outcome of the surgery. The software can track instrument movements in laparoscopic surgery without requiring extra equipment.[26]

The results presented in this thesis show this software cannot be used in RAS. The speed of the surgical instruments, tissue overlapping the instrument and the fact that the instrument has flexible joints, made it impossible to track the instrument movements in pre-recorded videos.

Methodological considerations

This thesis is divided in three themes, the training of novice robot surgeons, the performance assessment of expert robot surgeons, and the investigation of the relationship between a surgeon's performance and a patient's postoperative outcomes.

A limitation of the studies in this thesis is the use of multiple surveys to gain insight into the experiences of trainees after standardised surgical training programmes, effects of interventions and opinions of robot surgeons. Although the response rate on these surveys was high, the missing responses always form a potential source of bias. The addition of interviews to some of the questionnaires might have resulted in richer data and a higher response rate, but this also could have resulted in more socially desirable answers. Participants for the survey studies were carefully selected, although this careful selection inherently leads to selection bias this choice was made to gain a clear insight into the opinions of experts or the experiences of novice surgeons. Most of the questionnaires used in this thesis were specifically created for this thesis since no pre-validated questionnaires exist on these subjects. A group of 7 experts were asked to assess the face validity of each questionnaire.

A major strength of this thesis is our multidisciplinary approach (multiple urologists, a professor with expertise in Learning and Instruction, and a professor with expertise in patient safety) to our research questions as we focus on training and skills assessment from different perspectives to provide a complete overview of the possible answers for the main questions of this thesis.

The evaluation of surgical skills was performed either by use of a virtual reality simulator, which may provide objective measurements, or by video analysis with a more subjective assessment. We have tried to implement objective assessment methods of surgical video analysis in this thesis but technical limitations (because of a more close-up camera position for robotic surgery as compared to laparoscopic surgery, the speed of the surgical instruments, tissue overlapping the instrument, and the fact that the instrument has flexible joints) resulted in difficulties with automated assessment of surgical movements. The objective measurement of the urethral length was successful although the accuracy of method of measurement is dependent on the level of training of the assessor. All other in literature described methods for video analyses are more subjective methods of assessment since they required action (assessment of videos using assessment templates) by the researcher. None of the results of the templated assessment methods could be used to predict the patient's postoperative outcome. Reason for this might be that the surgical procedures analysed were performed by one single surgeon who is an expert in the field of RAS and has performed over 2000

RARP surgeries to date. Since this surgeon is an expert in RAS less variation in surgical skills is expected which could be the reason no factors for predicting postoperative outcome were found using surgical skills analysis. The additional analysis of surgical procedures from various surgeons with different skill levels could provide insights into the effects of differences in surgical skills on postoperative outcomes.

Reflection and future recommendations

The challenge for novice surgeons is how to learn new surgical procedures in the best possible way, and for expert surgeons how to continuously improve individual performance by analysing past performances and subsequently use this as a lesson for the future.

What are the best methods to educate surgeons in robotic surgery?

No general training guidelines and certification criteria for Robot assisted surgery (RAS) have been set by European, American or National associations for urology. In contrast to laparoscopic surgery where the European Basic Laparoscopic Urological Skills (E-BLUS) examination[1–3] have been accepted, no such initiatives are currently in place for RAS. We showed there is a large difference in the criteria for novices starting RAS between training hospitals in the Netherlands. This shows, in order to guarantee a basic level of RAS skills, there is a need for the implementation of general guidelines and certification criteria.

Although not all residents will perform RAS in their future careers a basic level of RAS skills should be acquired to ensure the residents get acquainted with the possibilities of RAS and are able to counsel patients on RAS surgeries. The certification of residents[1–3] needs to be a mandatory step in the residency curriculum, like the E-BLUS examination, to ensure patient safety and reduce the risks for patients.[7]

To implement training guidelines and certification criteria for starting RAS multiple conditions should be met: validated training curricula should be available, certification criteria need to be set, and the acceptance and feasibility in the clinical practice should be investigated. When implementing an advanced RAS training program for residents the question remains whether all residents should learn how to perform RAS and if not whom we should train.

According to literature, the training of RAS can be stratified by content of training (i.e., system training and procedural training)[27–29] or by phase of the training (i.e., the preclinical phase, the bedside assistant/table side assistant phase, the operative console phase).[27,30] These different methods of training stratification can be used as a template for the design of a multi-step modular structured training program for RAS.

The implementation of a multi-step modular training program could be a first start in the creation of general training guidelines and certification criteria. This multi-step training program should start with a basic RAS skills training consisting of hands-on training combined with theoretical information on the aspects of the robot system (i.e., the preclinical phase or system training), and basic surgical skills for RAS (ii.e., draping and docking and simulation training). A theoretical basis for this training can be found in the basic proficiency requirements for RAS as designed by Porte et.al.4 After this basic training, certification of participants should be pursued. Residents with this certificate should be allowed to start the first steps of RAS in a training hospital under strict supervision of an expert RAS surgeon. This could also mark the start of the procedural training or table side assistance phase of training. In the Certified Curriculum of the European Association of Urology Robotic Urology Section (CC-ERUS) fellowship participants must do a 4-week mandatory live case observation and table side assistance training prior to an advanced robotic skills course.[31] In a modified form and duration this could also be implemented in a residency program. Literature suggests novice surgeons should do a minimal of 10 procedures as table side assistant[32,33] before starting surgery using the surgical robot.

Certification criteria for basic RAS surgical skills should be developed following a similar process as laparoscopic surgery, i.e., the Program for Laparoscopic Urologic Skills (PLUS) or European Basic Laparoscopic Urological Skills (E-BLUS) examination[1–3].

The basic RAS training should be followed by an advanced training in RAS, in the form of a specialty specific or surgery specific training containing different aspects of VR simulation, dry lab training and wet lab training including animal models. The advanced training ensures participants to learn how to perform the surgery and how to react to complications such as bleeding of major vessels. This training could be completed either by VR simulator assessment or surgical video assessment. The completion of this advanced training module should result in a certificate, marking the start of the operative console phase of training.

Since this training program is modular a choice can be made to only allow residents with a specific interest in RAS to participate in the advanced RAS training module. The basic RAS training should be provided for all residents since the skills learned in this module are paramount for a safe use of the surgical robot. Without completing the basic RAS training, residents should not be allowed to be a bedside assistant during RAS surgery, nor take their first steps in RAS under supervision of an expert RAS surgeon.

Another possibility would be the development of a training curriculum based on proficiency-based training, in which the learner can only proceed to the next step after acquiring a specific proficiency level during training. In contrast to conventional training, this training method allows for the possible variability in the learning curve of a novice surgeon. Where in conventional training all novices receive the same time to train a specific aspect of the task, in proficiency based training the novice is only allowed to progress to the next training level if the previous task is performed consistently to a certain pre-defined standard.[34] Recent studies into this method of training have shown it is possible to implement this method of training in novice surgeons courses and in train the trainer courses.[34–37] The addition of a proficiency-based training aspect to a multi-step training program should ensure that all trained surgeons meet the same quality standards and are able to perform the same tasks at the end of their training curriculum.

This proficiency-based multi-step training program could be the start of a lifelong learning program for RAS surgeons. The multi-step training program described above is based on the Dreyfus Five-Stage Model of Adult Skills Acquisition.[38] It contains the novice (basic RAS training) and advanced beginner (advanced RAS training) stages. In order to reach the proficient, expert and master stages further training should be provided in the form of a fellowship or as a lifelong learning program as described by Jones et al.[39,40] With the introduction of new RAS systems this format of training could also be the basis for the training curricula for these new robots assisted surgery systems.[41]

How can the performance of robotic surgeon's best be assessed?

A challenge for the implementation of lifelong learning programs is the assessment of experts. Where surgical skills of novice surgeons are commonly assessed using virtual reality simulators, experts' surgical skills assessment is commonly based on the analysis of surgical videos or postoperative patient outcome analysis. Although postoperative patient outcome analysis gives a crude overview of the outcomes of the surgeries performed by the surgeon, there are a lot of confounders to consider in this type of analysis. The postoperative patient outcomes are not entirely determined by skills of the surgeons since patient characteristics such as prostate weight, age of the patient and the BMI of the patient are known to influence the postoperative outcome.[15]

Analysis of the intracorporal video does give insight into the technical or surgical skills of a surgeon. However, most assessment methods are highly subjective since they are observer based templated assessments (i.e., GEARS[12], GERT[13], and PACE[14]). Furthermore, the structural assessment of skills using observer based templated assessments methods is impractical due to the level of training needed for accurate assessments.

Novel assessment methods need to be developed to allow for objective and consistent assessment of expert's surgeons' skills. The group of Hung et al has made the first steps in using Artificial Intelligence (AI) as a novel method of surgical skills analysis.[42–44] Their research shows that it is possible to identify differences in skill levels among surgeons and correlate these results to postoperative outcome.[42,44] Which is a promising start. Machine learning (ML) can be implemented in the field of surgical skills analysis for a multitude of tasks which were until now, performed manually.

In line with the review by Andras et al. we believe AI will have a growing presence in the operating room[45] AI will not only assist in the assessment of technical surgical skills but also in Non-Technical skills (NTS) assessment.[46] Further development of organ recognition in combination with the use of imaging modalities as MRI and CT-scans could eventually result in the development of surgical devices which can provide intraoperative navigation using augmented reality based on MRI or CT-scan data. This could ensure the surgeon removes the organ or tumour with clean surgical margins and the maximum respect for the surrounding tissues. It is even conceivable the implementation of AI will lead to the development of a surgical robot that can operate with less or no human interference using tissue and landmark recognition.[47,48]

The relation between physician performance and patients' postoperative outcomes

To date, little research has aimed to correlate technical skills assessment using surgical videos to the patient's postoperative outcome[15,42,44,49,50]. The difficulty of this field of research is identification of the factors involved in prediction of postoperative outcome.

In this thesis, multiple techniques of surgical video analysis have been investigated to identify factors involved in the origins of postoperative incontinence and erectile dysfunction. If these analyses of pre-recorded surgical videos could be fully automated using DL and AI objective assessment could be implemented, leading to further insights into the surgeon's performance. The group of Hung et al. has performed multiple studies into this new field of research.[42,44,51] These initial studies using machine learning and automated performance metrics have resulted in new insights into the effects of surgeon's performance on post-operative outcome.[42,44]

Based on the current assessment of the surgical videos by expert surgeons the length of the urethra and the quality of the neuro-vascular bundles could respectively affect incontinence and erectile dysfunction. The relation of the per-operatively measured length of the urethra and postoperative continence has been proven in this thesis. The possibility of urethral length measurements in previously recorded videos (surgical videos of older surgeries) could revolutionize the field of surgery. If DL and AI can be used to recognize structures in the surgical video, the length of the residual urethra stump could be measured accurately and automatically. If this is done in previously recorded surgical videos, the next step will be to implement automated measurements during surgery, enabling the surgeon to maximize the length of the residual urethra and thus maximizing the chances of continence for the patient. This type of research can result in a personalised prediction model combining patient factors and surgical skills data for postoperative incontinence and erectile dysfunction. The combination of technical skills analysis and non-technical skills (NTS) analysis could help improve postoperative outcomes even further. The implementation of non-technical skills analysis could possibly be used to develop team-training programs specifically for the introduction of the surgical robot in relation to changes in NTS, thus reducing the chances of complications due to failure in NTS.

Key future recommendations

- A proficiency-based multi-step training program could be the start of a lifelong learning program for RAS surgeons.
- Novel assessment methods need to be developed to allow for objective and consistent assessment of expert's surgeons' skills.
- The possibility of urethral length measurements in previously recorded videos could revolutionize the field of surgery. If Deep Learning and Artificial Intelligence can be used to recognize anatomy in the surgical video, the length of the residual urethra stump could be measured accurately and automatically.
- The implementation of non-technical skills analysis could possibly be used to develop team-training programs specifically for the introduction of the surgical robot in relation to changes in NTS, thus reducing the chances of complications due to failure in NTS, and improving postoperative outcomes.

References

1. Tjiam IM, Schout BMA, Hendrikx AJM, Muijtjens AMM, Scherpbier AJJA, Witjes JA, Van Der Vleuten CPM. Program for laparoscopic urological skills assessment: Setting certification standards for residents. Minim Invasive Ther Allied Technol [Internet]. 2013 Feb 10 [cited 2020 May 22];22(1):26–32.
2. Tjiam IM, Persoon MC, Hendrikx AJM, Muijtjens AMM, Witjes JA, Scherpbier AJJA. Program for laparoscopic urologic skills: A newly developed and validated educational program. Urology [Internet]. 2012 Apr 1 [cited 2020 May 22];79(4):815–20.
3. Brinkman WM, Tjiam IM, Schout BMA, Muijtjens AMM, Van Cleynenbreugel B, Koldewijn EL, Alfred Witjes J. Results of the European basic laparoscopic urological skills examination. Eur Urol [Internet]. 2014;65(2):490–6.
4. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP, Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];
5. Mazzone E, Dell'oglio P, Mottrie A. Outcomes report of the first erus robotic urology curriculum-trained surgeon in turkey: The importance of structured and validated training programs for global outcomes improvement [Internet]. Vol. 45, Turkish Journal of Urology. Turkish Association of Urology; 2019 [cited 2020 May 21]. p. 189–90.
6. Bedir F, Keske M, Demirdögen SO, Kocatürk H, Koç E, Canda AE, Atmaca AF. Robotic radical prostatectomy in 93 cases: Outcomes of the first ERUS robotic urology curriculum trained surgeon in Turkey. Turkish J Urol [Internet]. 2019 [cited 2020 May 21];45(3):183–8.
7. Puliatti S, Mazzone E, Dell'Oglio P. Training in robot-assisted surgery. Curr Opin Urol. 2020;30(1):65–72.
8. Buffi N, Van Der Poel H, Guazzoni G, Mottrie A. Methods and priorities of robotic surgery training program [Internet]. Vol. 65, European Urology. Eur Urol; 2014 [cited 2020 May 21]. p. 1–2.
9. Sridhar AN, Briggs TP, Kelly JD, Nathan S. Training in Robotic Surgery—an Overview. Curr Urol Rep. 2017;18(8).
10. Gamboa AJR, Santos RT, Sargent ER, Louie MK, Box GN, Sohn KH, Truong H, Lin R, Khosravi A, Santos R, Ornstein DK, Ahlering TE, Tyson DR, Clayman R V., McDougall EM. Long-Term Impact of a Robot Assisted Laparoscopic Prostatectomy Mini Fellowship Training Program on Postgraduate Urological Practice Patterns. J Urol [Internet]. 2009;181(2):778–82.
11. McDougall EM, Corica FA, Chou DS, Abdelshehid CS, Uribe CA, Stoliar G, Sala LG, Khonsari SS, Eichel L, Boker JR, Ahlering TE, Clayman R V. Short-term impact of a robot-assisted laparoscopic prostatectomy 'mini-residency' experience on postgraduate urologists' practice patterns. Int J Med Robot Comput Assist Surg [Internet]. 2006 Mar [cited 2020 Mar 4];2(1):70–4.
12. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.
13. Husslein H, Shirreff L, Shore EM, Lefebvre GG, Grantcharov TP. The Generic Error Rating Tool: A Novel Approach to Assessment of Performance and Surgical Education in Gynecologic Laparoscopy. J Surg Educ [Internet]. 2015 Nov [cited 2018 Jun 22];72(6):1259–65.
14. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.
15. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.
16. Sharma B, Mishra A, Aggarwal R, Grantcharov TP. Non-technical skills assessment in surgery. Surg Oncol [Internet]. 2011;20(3):169–77.
17. Robertson ER, Hadi M, Morgan LJ, Pickering SP, Collins G, New S, Griffin D, McCulloch P, Catchpole KC. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System. Roma PG, editor. PLoS One [Internet]. 2014 Mar 4 [cited 2018 Oct 26];9(3):e90320.
18. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care [Internet]. 2009 Apr 1 [cited 2018 Oct 26];18(2):104–8.
19. Undre S, Sevdalis N, Healey AN, Darzi A, Vincent CA. Observational Teamwork Assessment for Surgery (OTAS): Refinement and Application in Urological Surgery. World J Surg [Internet]. 2007 Jun 16 [cited 2018 Oct 26];31(7):1373–81.
20. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Shamim M, Giacomo K. Development and validation of a tool for non-technical skills evaluation in robotic surgery — the ICARS system. Surg Endosc. 2017;31(12):5403–10.
21. Cohen TN, Wiegmann DA, Reeves ST, Boquet AJ, Shappell SA. Coding Human Factors Observations in Surgery. Am J Med Qual. 2017;32(5):556–62.
22. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.
23. Grivas N, van der Roest R, Tillier C, Schouten D, van Muilekom E, Schoots I, van der Poel H, Heijmink S. Patterns of Benign Prostate Hyperplasia Based on Magnetic Resonance Imaging Are Correlated With Lower Urinary Tract Symptoms and

Continence in Men Undergoing a Robot-assisted Radical Prostatectomy for Prostate Cancer. Urology [Internet]. 2017;107:196–201.

24. Song W, Kim CK, Park BK, Jeon HG, Jeong BC, Seo S Il, Jeon SS, Choi HY, Lee HM. Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy. Can Urol Assoc J. 2017;11(3–4):E93–9.

25. Kohjimoto Y, Yamashita S, Kikkawa K, Iba A, Matsumura N, Hara I. The association of length of the resected membranous urethra with urinary incontinence after radical prostatectomy. Urol J. 2019;epub(c):2–6.

26. Ganni S, Botden SMBI, Chmarra M, Goossens RHM, Jakimowicz JJ. A software-based tool for video motion tracking in the surgical skills assessment landscape. Surg Endosc [Internet]. 2018 Jun 16 [cited 2018 Jun 21];32(6):2994–9.

27. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.

28. Nifong LW, Chitwood WR. Building a surgical robotics program. Am J Surg [Internet]. 2004 Oct 1 [cited 2020 May 29];188(4):16–8.

29. Chitwood WR, Nifong LW, Chapman WHH, Felger JE, Bailey BM, Ballint T, Mendleson KG, Kim VB, Young JA, Albrecht RA. Robotic surgical training in an academic institution. In: Annals of Surgery [Internet]. Lippincott, Williams, and Wilkins; 2001 [cited 2020 May 29]. p. 475–86.

30. Guzzo TJ, Gonzalgo ML. Robotic surgical training of the urologic oncologist. Urol Oncol Semin Orig Investig [Internet]. 2009;27(2):214–7.

31. Mottrie A, Novara G, van der Poel H, Dasgupta P, Montorsi F, Gandaglia G. The European Association of Urology Robotic Training Curriculum: An Update. Eur Urol Focus [Internet]. 2016;2(1):105–8.

32. Samadi D, Levinson A, Hakimi A, Shabsigh R, Benson MC. From proficiency to expert, when does the learning curve for robotic-assisted prostatectomies plateau? The Columbia University experience. World J Urol [Internet]. 2007 Mar [cited 2020 May 30];25(1):105–10.

33. Rashid HH, Leung YYM, Rashid MJ, Oleyourryk G, Valvo JR, Eichel L. Robotic surgical education: A systematic approach to training urology residents to perform robotic-assisted laparoscopic radical prostatectomy. Urology [Internet]. 2006 Jul [cited 2020 May 30];68(1):75–9.

34. Collins JW, Levy J, Stefanidis D, Gallagher A, Coleman M, Cecil T, Ericsson A, Mottrie A, Wiklund P, Ahmed K, Pratschke J, Casali G, Ghazi A, Gomez M, Hung A, Arnold A, Dunning J, Martino M, Vaz C, et al. Utilising the Delphi Process to Develop a Proficiency-based Progression Train-the-trainer Course for Robotic Surgery Training. Eur Urol [Internet]. 2019;75(5):775–85.

35. Dulan G, Rege R V., Hogg DC, Gilberg-Fisher KK, Tesfay ST, Scott DJ. Content and face validity of a comprehensive robotic skills training program for general surgery, urology, and gynecology. Am J Surg [Internet]. 2012;203(4):535–9.

36. Dulan G, Rege R V., Hogg DC, Gilberg-Fisher KM, Arain NA, Tesfay ST, Scott DJ. Proficiency based training for robotic surgery: Construct validity, workload, and expert levels for nine inanimate exercises. Surg Endosc. 2012;26(6):1516–21.

37. Moglia A, Sinceri S, Ferrari V, Ferrari M, Mosca F, Morelli L. Proficiency-based training of medical students using virtual simulators for laparoscopy and robot-assisted surgery: results of a pilot study. Updates Surg [Internet]. 2018;70(3):401–5.

38. Dreyfus SE. The five-stage model of adult skill acquisition. Bull Sci Technol Soc. 2004;24(3):177–81.

39. Jones DB, Stefanidis D, Korndorffer JR, Dimick JB, Jacob BP, Schultz L, Scott DJ. SAGES University MASTERS Program: a structured curriculum for deliberate, lifelong learning. Surg Endosc. 2017;31(8):3061–71.

40. Feldman LS, Pryor AD, Gardner AK, Dunkin BJ, Schultz L, Awad MM, Ritter EM. SAGES Video-Based Assessment (VBA) program: a vision for life-long learning for surgeons. Surg Endosc [Internet]. 2020;34(8):3285–8.

41. Peters BS, Armijo PR, Krause C, Choudhury SA, Oleynikov D. Review of emerging surgical robotic technology [Internet]. Vol. 32, Surgical Endoscopy. Surg Endosc; 2018 [cited 2020 May 30]. p. 1636–55.

42. Hung AJ, Oh PJ, Chen J, Ghodoussipour S, Lane C, Jarc A, Gill IS. Experts vs super-experts: differences in automated performance metrics and clinical outcomes for robot-assisted radical prostatectomy. BJU Int [Internet]. 2019 May;123(5):861–8.

43. Chen J, Cheng N, Cacciamani G, Oh P, Lin-Brande M, Remulla D, Gill IS, Hung AJ. Objective Assessment of Robotic Surgical Technical Skill: A Systematic Review. J Urol. 2019;201(3):461–9.

44. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44.

45. Andras I, Mazzone E, Leeuwen FWB Van, Naeyer G De, Oosterom MN Van, Beato S, Buckle T, Sullivan SO, Leeuwen PJ Van, Beulens A, Crisan N, Hondt FD, Schatteman P, Poel H Van Der, Dell P, Mottrie A. Artificial intelligence and robotics : a combination that is changing the operating room. World J Urol [Internet]. 2019;(0123456789).

46. Cates JA, Bonrath EM, Dedy NJ, Grantcharov TP. Development of a black-box data recording device in the operating room: a proof-of-concept study. J Am Coll Surg [Internet]. 2013 Sep 1 [cited 2018 Jun 22];217(3):S65.

47. Van Oosterom MN, Van Der Poel HG, Navab N, Van De Velde CJH, Van Leeuwen FWB. Computer-assisted surgery: Virtual- and augmented-reality displays for navigation during urological interventions [Internet]. Vol. 28, Current Opinion in Urology. Curr Opin Urol; 2018 [cited 2020 Jun 3]. p. 205–13.

48. Chen CH, Sühn T, Illanes A, Maldonado I, Ahmad H, Wex C, Croner R, Boese A, Friebe M. Proximally placed signal acquisition sensoric for robotic tissue tool interactions. Curr Dir Biomed Eng.

2018;4(1):67–70.

49. Hogg ME, Zenati M, Novak S, Chen Y, Jun Y, Steve J, Kowalsky SJ, Bartlett DL, Zureikat AH, Zeh HJ. Grading of Surgeon Technical Performance Predicts Postoperative Pancreatic Fistula for Pancreaticoduodenectomy Independent of Patient-related Variables. Ann Surg [Internet]. 2016 Sep [cited 2018 Jun 27];264(3):482–91.

50. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.

51. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.

Summary

Summary

Healthcare is constantly moving towards the improvement of quality of care and safety for patients. In the Netherlands, increasing attention is being paid to the relocation of complex treatments such as different types of robot assisted surgery (RAS) to high-volume centres as it is expected to improve the quality of care and increases patient safety due to the increased exposure of surgeon and staff.[1–4] The question remains whether the higher number of surgical procedures per hospital or the quality of the surgeon influences the patients outcome. There are large variations in postoperative complication rates amongst surgeon with similar surgical volumes per centre or even in the same centre.[5,6] The qualification and certification of RAS skills are still in a preliminary phase within all surgical specialties, also in urology.

The introduction of the surgical robot resulted in increasing technical difficulty of these robot assisted surgeries. New methods of training for novice surgeons (residents and fellows) in these highly specialised techniques should be implemented to guarantee patient safety.[7] Where general guidelines and certification criteria have been set for laparoscopic surgery in the form of the European Basic Laparoscopic Urological Skills (E-BLUS) examination,[8–10] no such guidelines exist for RAS.

The challenge for novice surgeons is how to learn new surgical procedures and once the procedure is learned and they become experts how to analyse past performances and subsequently use this as a lesson for the future.

The first part of the thesis focuses on the following research question:

What are the best methods to educate surgeons in robotic surgery?

In response to the introduction of RAS multiple organizations and physicians have called for the development of structured training and basic qualifications for surgeons.[11–17] Although multiple structured training curricula have been developed[14–16,18,19] currently no general criteria are set for starting RAS. If no structured training program or set of basic criteria are provided novice surgeons will design their own training program based on their own perceived lack of knowledge.[20,21] The novices own perceived lack of knowledge and skills can be influenced by overconfidence biases, an over-assessment of skills which can results in a hiatus of training. To provide a guideline for the basic competence level needed to safely perform robotic surgery the 'Basic proficiency requirements for the safe use of robotic surgery' (BPR) was developed by the NIVEL.[11]

The results of a one-day training in basic RAS based on the BPR are presented in **chapter 2**. The training consisted of all important aspects of system training (containing different modality's of training, i.e., hands-on training combined with theoretical

information) as indicated by previous research.[17] During this training novice surgeons were asked to self-assess their own knowledge and surgical skills to assess if novice surgeons are prone to overconfidence biases and over-assessment of skills whilst learning RAS. After participating in the training, the participants were asked if they possessed all competencies described in the BPR.[11] We found novice robot surgeons were too positive in the self-assessment of their own surgical skills after a training in RAS. This is in line with previous studies describing overconfidence biases.[22,23] To prevent overconfidence biases the novice surgeons should be provided with feedback to inform them about their results to enhance learning and inform them of their competence levels.

One method of feedback commonly used in training surgical skills is proctoring. Proctoring is a form of training where an experienced trainer supervises the trainee during the procedure and provides real-time feedback, in order to guide and assist the trainee during the acquisition of new skills.[24] Proctoring is widely used in the operating room to train novice surgeons but is scarcely implemented in simulator based training due to time consumption and related costs.[17,25,26] An alternative to human proctoring is the interactive task and procedural guidance by the simulator (Simulator generated guidance (SGG)) SGG is an option available on the newest simulation systems. SGG is provided by the VR simulators to guide the trainee through the steps of a surgical procedure using visual cues.[27] An advantage of SGG is the possibility to assess the effect of various training curricula on the progress of the surgeon's surgical skills. Effective training and assessment of performance are fundamental for surgeons to reach their goals and operate safely.[13,28] **Chapter 3** focusses on the effects of proctoring and SGG on surgical skills acquisition and participant satisfaction during surgical skills training in novice surgeons. We show that surgical skills in RAS can be significantly increased after practicing basic and advanced simulation exercises for two hours on a VR simulator. This is consistent with the findings of Brinkman et al.[29] Although the participant satisfaction seems to be higher in the "human proctoring" group. The lack of difference in acquisition of surgical skills between the intervention groups seems to indicate there is a limited impact of "human proctoring" and "simulator generated guidance" during the initial phase of surgical simulation training. The exposure of novice surgeons to the robotic surgery simulator alone could possibly be enough to achieve a significant improvement of surgical skills during the initial steps of training RAS.

Although VR simulators have a substantial place in the training of RAS only limited studies have proven the transference of skills learned during VR simulator training to real life situations.[30,31] This is why, even though VR simulators are an integral part of most structured curricula, other modalities of training (dry lab and wet lab training) should be used .[16]

The European Robotic Urological Society developed a curriculum for fellows (CC-ERUS) focused on the performance of robot-assisted radical prostatectomy (RARP).[15,16,18,19] This curriculum includes all the aspects of training, from the most basic ones as live case observation and table-side assistance, to the most advanced training facilities as virtual reality (VR), dry and wet lab with the most complex and advanced training models available today. Currently, this curriculum is available for fellows who train in CC-ERUS host centres. The implementation of training curricula for fellows is a step into the right direction, the next step is the implementation of a structured curriculum during the residency program.

The current state of RAS training during the urology residency and the impact of the advanced course in RAS for residents are investigated in **chapter 4** of the thesis. This chapter shows that most Dutch residents are allowed to perform RAS during their residency, but criteria for starting RAS differ significantly among the teaching hospitals. This shows there is a need for the implementation of a (multi-step) training and certification program in the Dutch urology residency curriculum. The advanced course in RAS could meet this need. The provided training is the advance robotic skills course as described by Mottrie et al.[18] Residents who participated in this week long course show a significant increase in surgical skills. The results of this study show almost all the trainees are allowed to perform RAS in their own hospital after the course. Even though the effects of this week long advanced course in RAS on postoperative outcome of patients remains unclear, initial results of the CC-ERUS curriculum show the completion of the ERUS curriculum leads to an improvement in oncological and functional outcome in patients.[32,33]

In **chapter 5**, the long-term effects of the structured fellowship in RAS (CC-ERUS fellowship) are investigated. The results of the survey showed that most respondents still perform RAS after the fellowship, which matches results from other research into the impact of RAS fellowships.[34,35] A remarkable finding of this study is that a large proportion of respondents is unaware of the oncological (33%) and functional outcomes (66%) of their patients. Thus, participants of RAS fellowships should be coached to review their own results to learn from their past performance and reduce their learning curve. The addition of a portfolio to the curriculum in which the participants record their progress could improve the participants awareness of their patient's postoperative outcome.

The additional costs of training a new surgeons in RAS varies between 95.000 and 1.365.000 dollars depending on the length of the learning curve.[7,36] The implementation of a structured training curriculum does not only reduce possible risks for the patient[7,37–39] it is also cost effective if it reduces the duration of the learning curve. Since the average learning curve of RARP surgeons described in the study by Steinberg et al. is 77 cases costing 217.034 dollars a minimal reduction of the learning curve could cover the cost of the advanced course in RAS.[36] Currently the effect of structured training on the learning curve remains unclear since the study presented in **chapter 5** is a survey no accurate data on the learning curve of the participants is presented. The results do show more than half of the participants performed between 52 and 130 (partial) RARP cases during their fellowship, one third of the participants even performed more than 130 (partial) RARP cases during the fellowship, this could mean some fellows have passed the learning curve during the fellowship under the tutelage of experienced surgeon in a Host centre.[7,37–39]

The second part of the thesis focuses on the following research question:

How can the performance of robotic surgeon's best be assessed?

The use of surgical video assessment to relate a surgeons skills to the patients post-operative outcomes has been proven in the past.[40,41] The analysis of intraoperative videos allows for detailed analysis and assessment of surgical skills. The Robot Assisted Radical Prostatectomy (RARP) is a laparoscopic procedure in which the intra-corporeal images can be recorded. The RARP is one of the most performed procedures in urology. For this reason, we chose the RARP procedure to start with the development of surgical skills assessment using surgical video analysis. A detailed step-by-step description of the surgery is needed to use the surgical videos for the assessment of surgical skills and the detection of adverse outcomes.

The study presented in **chapter 6** shows the steps of the RARP surgery which expert robot surgeons believe are of interest in finding the origins of adverse postoperative outcome and complications. During a Delphi session, peri-operative events that could influence the postoperative outcome (urinary continence and potency) were defined. A new assessment template, the PROTEST assessment method, was designed based on these findings.

The PROTEST assessment method is the only assessment method which combines subjective surgical skills assessment, objective metrics of procedural steps and peri-operative events in one assessment method.

Examples of other template-based video assessment methods are the Prostatectomy Assessment and Competency Evaluation (PACE)[42] and the Global Evaluative Assessment of Robotic Skill (GEARS)[43] method. The PACE method developed by the group of Hussein et.al.[42] has its focus on objective and procedure specific assessment of skills. The GEARS method can be used to differentiate levels of robotic surgical expertise in live surgeries and videos of (robot assisted) laparoscopic surgery.[43] These assessment methods are currently used to assess the effectiveness of training (PACE)[42] or the basic surgical skill (GEARS)[43].

The analysis of technical surgical skills in RAS can lead to mayor improvements of postoperative outcomes.[41] However, the influence of Non-Technical Skills (NTS) such as communication, teamwork, leadership, and situational awareness on post-operative outcomes should not be forgotten. The introduction of the surgical robot has changed the traditional set-up of the operating room: no longer are scrub nurse and surgeon on opposite sides of the patient. Since for the majority of the surgery, the surgeon is in the console of the robot, direct communication with his or her team could be hampered. The loss of non-verbal communication can influence the work-flow and therefore the quality of the performance, as well as patient safety during surgery.

Multiple general assessment methods are designed to assess NTS for both the team as a whole[44–46] and for individual members of the team.[47–49] The question remains if these generic tools can accurately assess NTS in a highly specialized situation such as RAS. Two systematic reviews NTS in minimal invasive surgery.[50,51] Both reviews show a lack of structure in research on NTS: different methods of NTS assessments were used separately which makes comparison of tools difficult.[50,51] In **chapter 7** we present a study protocol describing a prospective observational multicentre study into non-technical-skills (NTS) in both Open Radical Cystectomy (ORC) and Robot Assisted Radical Cystectomy (RARC). In this study we propose a structured approach to NTS assessment using recordings from the OR in order to be able to implement all different NTS scoring methods.[44,45,49,52–54]

Even though the surgery of interest in this study is the radical cystectomy, results obtained during this study can be generalized beyond radical cystectomy since the changes in OR setup and the loss of non-verbal communication are universal when making the shift from open surgery to RAS. The results of this study can be used to develop effective team-training programs specifically for the introduction of the surgical robot in relation to changes in Non-Technical Skills in order to maximize surgeon and team performance.

Effective training and assessment of performance are fundamental to ensuring surgeons reach their intended goal and operate safely with maximum preservation of functions.[13,28,55] The field of video review and postoperative results analysis is focused on predicting postoperative results and reducing complications.[41,42,56,57] Even though multiple groups have investigated the possibility of video review it is unclear if video review has found its place in daily clinical practice. In **chapter 8**, the results of a survey on the acceptance of postoperative results analysis and surgical video analysis amongst surgeons performing RARP are shown. Most surgeons use postoperative results analysis to learn from their past performance. They use edited surgical videos during team meetings to gain insight into the specific facets (surgical steps) of RARP related to postoperative complications and functional outcomes (i.e. urinary continence and erectile function).

The third part of the thesis focuses on the following research question:

What is the relation between a surgeon's performance and a patient's postoperative outcomes?

The group of Goldenberg et al. used the GEARS assessment method to assess specific sections of the RARP they found a possible correlation between surgical skills and postoperative outcome, mainly the early continence after RARP.[58]

The PROTEST, PACE[42] and GEARS[43] assessment methods have been evaluated in two matched case-control pilot studies to investigate if the results of these surgical skills assessment methods can be used to predict postoperative functional outcome (continence and potency). The results of these pilot studies are described in **chapter 9** (continency study) and **chapter 10** (potency study). In **chapter 9** incontinent patients were matched to continent patients to assesses if the surgical skills as assessed using the different templates of one expert differed between the postoperative outcomes. A similar procedure was used in the study presented in **chapter 10**, impotent patients were compared to potent patients. These studies show none of the factors in the templated assessment methods could be used to predict the urinary continence or potency status of the patients. The results do show, in contrast to a study by the group of Stern et.al.[59], experts are able to predict the postoperative continence or potency status of the patients. The results of both studies show expert focus on the quality of the neurovascular bundles in case of potency, and the length of the urethral stump after resection in case of urinary continence. Although the relation between urethral stump length measured in surgical videos and postoperative continence was not proven in earlier research[60], the influence of the urethral measurements on continence was known from in earlier studies in MRI images[61,62] and pathology results.[63]

The study presented in **chapter 11** shows the results of a study correlating measurements of the urethral stump in pre-recorded videos to the postoperative continence of patients. In this study the dimensions of the transurethral catheter (Chr. 16) were used to standardise the measurements. The results of this study show the residual urethra stump was significantly longer in the continent group (10,50 vs 12,94 mm, p= 0.018). We are the first to demonstrate the relationship between the residual urethra stump length measured during surgery and postoperative continence of the patient. The difference in results compared to the study of Bautista Vidal, et al who did not find a relation between the length of the urethral stump and postoperative continence status of the patient could be due to a different method of measurement during surgery.[60] If the technique can be adapted to be used during surgery and not only in the pre-recorded surgical video's a new surgical challenge will be to save as much urethral length as possible during RARP. Additional research is needed to determine the ideal urethral length for achieving continence. If there is such an ideal urethral length, surgical procedure could be adjusted to standardise the dissection and mobilisation of parts of the prostatic urethra to increase urethral stump length and increase the chances of continence of the patient.

The PACE[42], the GEARS[43], and the PROTEST assessment methods used in **chapter 9** and **chapter 10** are time-consuming ways of assessing surgeons' skills. Since these methods are based on human review, subjective bias cannot be avoided, leading to reduced interrater reliability. To objectify the assessment and to reduce the time investment of 'manual assessment' by the observer automated assessment tools are being studied.[64,65] Recently, Hung et al. investigated the possibility of the analysis of the movements of the surgical robot with the dVLogger system which led to greater insight into the performance of the surgeons and could be used to predict postoperative outcomes.[64,66] The dVLlogger system automatically logs motion tracking and system events data in live surgeries. This leaves large datasets and pre-recorded surgical video stock piles useless in this type of research.

In **chapter 12**, we investigate the possibility to automatically assess instrument movements in pre-recorded videos of RARP patients to find if the movements of surgical instruments predict functional outcome of the surgery. The Kinovea software can automatically track instrument movements in laparoscopic surgery without requiring additional equipment.[65] The results presented in **chapter 12** show the speed of the surgical instruments, tissue overlapping the instrument and the fact that the instrument has flexible joints, makes it impossible to track the instrument movements in pre-recorded RARP videos. Further research with larger groups of patients and a different automated tracking system is needed to investigate the possibility of automated surgical movement assessment in pre-recorded surgical videos.

In **Chapter 13** the main findings of the different studies in this thesis are discussed. The answers to the two main research questions were formulated in an overall conclusion. Methodological considerations are given and recommendations for future research are presented.

References

1. Trinh QD, Bjartell A, Freedland SJ, Hollenbeck BK, Hu JC, Shariat SF, Sun M, Vickers AJ. A systematic review of the volume-outcome relationship for radical prostatectomy. Eur Urol [Internet]. 2013;64(5):786–98.

2. Gershman B, Meier SK, Jeffery MM, Moreira DM, Tollefson MK, Kim SP, Karnes RJ, Shah ND. Redefining and Contextualizing the Hospital Volume-Outcome Relationship for Robot-Assisted Radical Prostatectomy: Implications for Centralization of Care. J Urol [Internet]. 2017 Jul 1 [cited 2018 Jul 23];198(1):92–9.

3. Stitzenberg KB, Wong YN, Nielsen ME, Egleston BL, Uzzo RG. Trends in radical prostatectomy: Centralization, robotics, and access to urologic cancer care. Cancer. 2012;118(1):54–62.

4. Inspectie voor de Gezondheidszorg. Het resultaat telt; Ziekenhuizen 2015. 2017;247.

5. Bianco FJ, Vickers AJ, Cronin AM, Klein EA, Eastham JA, Pontes JE, Scardino PT. Variations Among Experienced Surgeons in Cancer Control After Open Radical Prostatectomy. J Urol [Internet]. 2010;183(3):977–83.

6. Vickers A, Savage C, Bianco F, Mulhall J, Guillonneau B, Cronin A, Scardino P, Sandhu J, Guillonneau B, Cronin A, Scardino P. Cancer control and functional outcomes after radical prostatectomy as markers of surgical quality: Analysis of heterogeneity between surgeons at a single cancer center. Eur Urol [Internet]. 2011;59(3):317–22.

7. Puliatti S, Mazzone E, Dell'Oglio P. Training in robot-assisted surgery. Curr Opin Urol. 2020;30(1):65–72.

8. Tjiam IM, Schout BMA, Hendrikx AJM, Muijtjens AMM, Scherpbier AJJA, Witjes JA, Van Der Vleuten CPM. Program for laparoscopic urological skills assessment: Setting certification standards for residents. Minim Invasive Ther Allied Technol [Internet]. 2013 Feb 10 [cited 2020 May 22];22(1):26–32.

9. Tjiam IM, Persoon MC, Hendrikx AJM, Muijtjens AMM, Witjes JA, Scherpbier AJJA. Program for laparoscopic urologic skills: A newly developed and validated educational program. Urology [Internet]. 2012 Apr 1 [cited 2020 May 22];79(4):815–20.

10. Brinkman WM, Tjiam IM, Schout BMA, Muijtjens AMM, Van Cleynenbreugel B, Koldewijn EL, Alfred Witjes J. Results of the European basic laparoscopic urological skills examination. Eur Urol [Internet]. 2014;65(2):490–6.

11. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP, Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];

12. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;

13. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.

14. Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg [Internet]. 2015 Jan [cited 2017 Aug 17];13:115–23.

15. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Platinum Priority – Education Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. 2015;8(2):9–2.

16. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101.

17. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.

18. Mottrie A, Novara G, van der Poel H, Dasgupta P, Montorsi F, Gandaglia G. The European Association of Urology Robotic Training Curriculum: An Update. Eur Urol Focus [Internet]. 2016;2(1):105–8.

19. Stolzenburg JU, Qazi HAR, Rai BP. The European Association of Urology Robotic Training Curriculum: The Journey Has only Just Begun. Eur Urol [Internet]. 2015;68(2):300–1.

20. Kruger J, Dunning D. Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. J Pers Soc Psychol [Internet]. 1999 [cited 2018 Mar 22];77(6):1121–34.

21. Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX, Sriprasad S. Partial vs radical nephrectomy for T1 renal tumours: an analysis from the British Association of Urological Surgeons Nephrectomy Audit. BJU Int [Internet]. 2016 Jan [cited 2017 Jan 7];117(1):62–71.

22. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers' Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377.

23. Krueger J, Mueller RA. Unskilled, unaware, or both? The better-than-average heuristic and statistical regression predict errors in estimates of own performance. J Pers Soc Psychol [Internet]. 2002 Feb [cited 2018 Mar 23];82(2):180–8.

24. Rashid HH, Leung Y-YM, Rashid MJ, Oleyourryk G, Valvo JR, Eichel L. Robotic surgical education: a systematic approach to training urology residents to perform robotic-assisted laparoscopic radical prostatectomy. Urology [Internet]. 2006 Jul

[cited 2020 May 21];68(1):75–9.

25. Shim JS, Kim JY, Pyun JH, Cho S, Oh MM, Kang SH, Lee JG, Kim JJ, Cheon J, Kang SG. Comparison of effective teaching methods to achieve skill acquisition using a robotic virtual reality simulator Expert proctoring versus an educational video versus independent training. Med (United States). 2018;97(51):1–5.

26. Lee JY, Mucksavage P, Sundaram CP, McDougall EM. Best practices for robotic surgery training and credentialing. J Urol [Internet]. 2011;185(4):1191–7.

27. Wijewickrema S, Zhou Y, Bailey J, Kennedy G, O'Leary S. Provision of automated step-by-step procedural guidance in virtual reality surgery simulation. In: Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology - VRST '16 [Internet]. New York, New York, USA: ACM Press; 2016 [cited 2020 Apr 20]. p. 69–72.

28. Goldenberg MG, Lee JY, Kwong JCCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence [Internet]. BJU International Mar 31, 2018.

29. Brinkman WM, Luursema JM, Kengen B, Schout BMA, Witjes JA, Bekkers RL. Da vinci skills simulator for assessing learning curve and criterion-based training of robotic basic skills. Urology [Internet]. 2013;81(3):562–6.

30. Aghazadeh MA, Mercado MA, Pan MM, Miles BJ, Goh AC. Performance of robotic simulated skills tasks is positively associated with clinical robotic surgical performance. BJU Int [Internet]. 2016 Sep [cited 2017 Aug 9];118(3):475–81.

31. Schout BMA, Ananias HJK, Bemelmans BLH, D'Ancona FCH, Muijtjens AMM, Dolmans VEMG, Scherpbier AJJA, Hendrikx AJM. Transfer of cysto-urethroscopy skills from a virtual-reality simulator to the operating room: a randomized controlled trial. BJU Int [Internet]. 2009 Nov 12 [cited 2020 Apr 22];106(2):226–31.

32. Mazzone E, Dell'oglio P, Mottrie A. Outcomes report of the first erus robotic urology curriculum-trained surgeon in turkey: The importance of structured and validated training programs for global outcomes improvement [Internet]. Vol. 45, Turkish Journal of Urology. Turkish Association of Urology; 2019 [cited 2020 May 21]. p. 189–90.

33. Bedir F, Keske M, Demirdögen SO, Kocatürk H, Koç E, Canda AE, Atmaca AF. Robotic radical prostatectomy in 93 cases: Outcomes of the first ERUS robotic urology curriculum trained surgeon in Turkey. Turkish J Urol [Internet]. 2019 [cited 2020 May 21];45(3):183–8.

34. Gamboa AJR, Santos RT, Sargent ER, Louie MK, Box GN, Sohn KH, Truong H, Lin R, Khosravi A, Santos R, Ornstein DK, Ahlering TE, Tyson DR, Clayman R V., McDougall EM. Long-Term Impact of a Robot Assisted Laparoscopic Prostatectomy Mini Fellowship Training Program on Postgraduate Urological Practice Patterns. J Urol [Internet]. 2009;181(2):778–82.

35. McDougall EM, Corica FA, Chou DS, Abdelshehid CS, Uribe CA, Stoliar G, Sala LG, Khonsari SS, Eichel L, Boker JR, Ahlering TE, Clayman R V. Short-term impact of a robot-assisted laparoscopic prostatectomy 'mini-residency' experience on postgraduate urologists' practice patterns. Int J Med Robot Comput Assist Surg [Internet]. 2006 Mar [cited 2020 Mar 4];2(1):70–4.

36. Steinberg PL, Merguerian PA, Bihrle W, Seigne JD. The Cost of Learning Robotic-Assisted Prostatectomy. Urology. 2008;72(5):1068–72.

37. Buffi N, Van Der Poel H, Guazzoni G, Mottrie A. Methods and priorities of robotic surgery training program [Internet]. Vol. 65, European Urology. Eur Urol; 2014 [cited 2020 May 21]. p. 1–2.

38. Sridhar AN, Briggs TP, Kelly JD, Nathan S. Training in Robotic Surgery—an Overview. Curr Urol Rep. 2017;18(8).

39. Brook NR, Dell'Oglio P, Barod R, Collins J, Mottrie A. Comprehensive training in robotic surgery [Internet]. Vol. 29, Current Opinion in Urology. Curr Opin Urol; 2019 [cited 2020 May 21]. p. 1–9.

40. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.

41. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.

42. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.

43. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.

44. Robertson ER, Hadi M, Morgan LJ, Pickering SP, Collins G, New S, Griffin D, McCulloch P, Catchpole KC. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System. Roma PG, editor. PLoS One [Internet]. 2014 Mar 4 [cited 2018 Oct 26];9(3):e90320.

45. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care [Internet]. 2009 Apr 1 [cited 2018 Oct 26];18(2):104–8.

46. Moorthy K, Munz Y, Adams S, Pandey V, Darzi A. A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. Ann Surg [Internet]. 2005 Nov [cited 2018 Oct 26];242(5):631–9.

47. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. Best Pract Res Clin Anaesthesiol [Internet]. 2011 Jun 1 [cited 2018 Oct 26];25(2):215–27.

48. Mitchell L, Flin R, Yule S, Mitchell J, Coutts K, Youngson G. Development of a behavioural marker system for scrub practitioners' non-technical skills (SPLINTS system). J Eval Clin Pract [Internet]. 2013 Apr 1 [cited 2018 Oct 26];19(2):317–23.

49. Sharma B, Mishra A, Aggarwal R, Grantcharov TP. Non-technical skills assessment in surgery. Surg Oncol [Internet]. 2011;20(3):169–77.

50. Gjeraa K, Spanager L, Konge L, Petersen RH, Østergaard D. Non-technical skills in minimally invasive surgery teams: a systematic review. Surg Endosc. 2016;30(12):5185–99.

51. van der Vliet WJ, Haenen SM, Solis-Velasco M, Dejong CHC, Neumann UP, Moser AJ, van Dam RM. Systematic review of team performance in minimally invasive abdominal surgery. BJS Open. 2019;3(3):252–9.

52. Undre S, Sevdalis N, Healey AN, Darzi A, Vincent CA. Observational Teamwork Assessment for Surgery (OTAS): Refinement and Application in Urological Surgery. World J Surg [Internet]. 2007 Jun 16 [cited 2018 Oct 26];31(7):1373–81.

53. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Shamim M, Giacomo K. Development and validation of a tool for non-technical skills evaluation in robotic surgery — the ICARS system. Surg Endosc. 2017;31(12):5403–10.

54. Cohen TN, Wiegmann DA, Reeves ST, Boquet AJ, Shappell SA. Coding Human Factors Observations in Surgery. Am J Med Qual. 2017;32(5):556–62.

55. Beulens AJWAJW, Brinkman WM, Porte PJJ, Meijer RP, Van Merriënboer JJG, Van der Poel HG, Wagner C, Brinkman M, Porte PJJ, Meijer P, Merriënboer JJGVJG Van, Poel HGVDG Van Der. The value of a one-day multidisciplinary robot surgery training for novice robot surgeons. J Robot Surg [Internet]. 2018;13(3):435–47.

56. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;

57. van Basten JPA, Somford RM, de Baaij J, Sedelaar M, Vrijhof E. Initiatief Comprehensive Prostate Cancer Network (CPCN) in Zuidoost Nederland. Tijdschr voor Urol. 2017;7(6–7):134–44.

58. Goldenberg MG, Goldenberg SL, Grantcharov TP. Mp51-15 Surgical Technical Performance Impacts Patient Outcomes in Robotic-Assisted Radical Prostatectomy. J Urol [Internet]. 2017;197(4S):S269–70.

59. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.

60. Bautista Vidal JC, García Galisteo E, Barón López J, Sánchez Martínez N, Hernández Alcaraz D, Morales Jiménez P, Vozmediano Chicharro R. Objective assessment of early urinary continence by analysis and visualisation of intraoperative variables of radical robotic prostatectomies with a video editor. Actas Urol Esp [Internet]. 2019;43(2):99–105.

61. Grivas N, van der Roest R, Tillier C, Schouten D, van Muilekom E, Schoots I, van der Poel H, Heijmink S. Patterns of Benign Prostate Hyperplasia Based on Magnetic Resonance Imaging Are Correlated With Lower Urinary Tract Symptoms and Continence in Men Undergoing a Robot-assisted Radical Prostatectomy for Prostate Cancer. Urology [Internet]. 2017;107:196–201.

62. Song W, Kim CK, Park BK, Jeon HG, Jeong BC, Seo S Il, Jeon SS, Choi HY, Lee HM. Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy. Can Urol Assoc J. 2017;11(3–4):E93–9.

63. Kohjimoto Y, Yamashita S, Kikkawa K, Iba A, Matsumura N, Hara I. The association of length of the resected membranous urethra with urinary incontinence after radical prostatectomy. Urol J. 2019;epub(c):2–6.

64. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.

65. Ganni S, Botden SMBI, Chmarra M, Goossens RHM, Jakimowicz JJ. A software-based tool for video motion tracking in the surgical skills assessment landscape. Surg Endosc [Internet]. 2018 Jun 16 [cited 2018 Jun 21];32(6):2994–9.

66. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44

Nederlandse samenvatting

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De gezondheidszorg is voortdurend in beweging om de kwaliteit en veiligheid van de patiëntenzorg te verbeteren. In Nederland wordt steeds meer aandacht besteed aan de centralisering van complexe behandelingen, zoals verschillende soorten Robot-Geassisteerde Chirurgie (RAS), naar centra met een hoog volume (hoger aantal van deze ingrepen). Omdat dit naar verwachting de kwaliteit van de zorg zal verbeteren en de patiëntveiligheid zal worden vergroot. Dit vanwege de toegenomen blootstelling van de chirurg en het ondersteunend personeel.[1-4] De vraag blijft of een groter aantal chirurgische ingrepen per ziekenhuis of juist de kwaliteit van de chirurg van invloed is op de uitkomst van de patiënt. Uit literatuur blijkt dat er grote verschillen zitten in het aantal postoperatieve complicaties bij chirurgen met vergelijkbare chirurgische volumes per centrum of zelfs in hetzelfde centrum. [5,6]

De introductie van de chirurgische robot heeft geresulteerd in een toenemende technische moeilijkheidsgraad van deze robot geassisteerde operaties. Nieuwe methoden om beginnende chirurgen (assistenten en fellows) te trainen in deze zeer gespecialiseerde technieken moeten worden geïmplementeerd om de veiligheid van de patiënt te waarborgen.[7] Waar algemene richtlijnen en certificeringscriteria zijn vastgelegd voor laparoscopische chirurgie in de vorm van de European Basic Laparoscopic Urological Skills (E -BLUS),[8–10] bestaan dergelijke richtlijnen niet voor RAS. De beoordeling en certificering van RAS-vaardigheden bevinden zich nog in een voorbereidende fase binnen alle chirurgische specialismen. Dit geldt ook binnen de urologie.

De uitdaging voor beginnende chirurgen is op welke manier ze nieuwe chirurgische procedures aan kunnen leren. Voor experts chirurgen is het een uitdaging hoe operatie resultaten geanaliseerd kunnen worden en hoe van deze resultaten geleerd kan worden om zo de kwaliteit te blijven verbeteren.

Het eerste deel van dit proefschrift richt zich op de volgende onderzoeksvraag:

‘’Wat zijn de beste methoden om chirurgen op te leiden in robot-geassisteerde chirurgie?’’

Als reactie op de introductie van RAS hebben meerdere organisaties en artsen opgeroepen tot de ontwikkeling van gestructureerde training en basiskwalificaties voor chirurgen.[11–17] Hoewel er meerdere gestructureerde trainingscurricula zijn ontwikkeld[14–16,18,19] zijn er momenteel geen algemene criteria voor het starten aan RAS. Als er geen gestructureerd trainingsprogramma of een reeks basiscriteria wordt aangeboden, zullen beginnende chirurgen hun eigen trainingsprogramma ontwerpen op basis van hun eigen waargenomen gebrek aan kennis.[20,21] Het eigen waargenomen gebrek aan kennis en vaardigheden van de nieuwe operateurs kan worden beïnvloed door overmoed en overschatting van vaardigheden. Dit kan mogelijk resulteren in onbewust onbekwaam leergedrag. Wat vervolgens weer kan leiden tot een gat in de training van de beginnende chirurg.

Als richtlijn voor het benodigde basiscompetentieniveau om robotchirurgie veilig uit te voeren, is door het NIVEL (Nederlands Instituut voor Onderzoek van de Gezondheidszorg) de 'Basis bekwaamheidseisen voor het veilig gebruik van robotchirurgie' (BPR) ontwikkeld.[11]

In **hoofdstuk 2** worden de resultaten van een eendaagse training in basis-RAS op basis van de BPR gepresenteerd. De training bestond uit diverse belangrijke aspecten van systeemtraining. Er werd gebruik gemaakt van verschillende trainingsmodaliteiten (hands-on training gecombineerd met theoretische informatie).[17]

Tijdens deze training werd aan beginnende chirurgen gevraagd om hun eigen kennis en chirurgische vaardigheden zelf te beoordelen. De door hen aangeven antwoorden werden vergeleken met de resultaten van de simulatie training om vervolgens te kunnen beoordelen of beginnende chirurgen vatbaar zijn voor overmoed en overschatting van vaardigheden tijdens het leren van RAS. Na deelname aan de training werd aan de deelnemers gevraagd of ze over alle competenties beschikten die in de BPR worden beschreven.[11] We vonden dat beginnende robotchirurgen te positief waren in de zelfevaluatie van hun eigen chirurgische vaardigheden na één training in RAS. Dit komt overeen met eerdere studies die overmoed en overschatting bij het aanleren van nieuwe vaardigheden beschrijven.[22,23] Om hiaten in de training door overmoed en overschatting te voorkomen, dienen beginnende chirurgen feedback te ontvangen om hen te informeren over het niveau van hun vaardigheden om het aanleren van nieuwe vaardigheden te verbeteren. Een ander doel is om hen te informeren over hun competentieniveaus.

Een veelgebruikte feedbackmethode bij het trainen van chirurgische vaardigheden is proctoring. Proctoring is een vorm van training waarbij een ervaren trainer de stagiair begeleidt tijdens de procedure en deze live van feedback voorziet, om de stagiair te begeleiden en te ondersteunen bij het aanleren van nieuwe vaardigheden.[24] Proctoring wordt veel gebruikt in de operatiekamer bij beginnende chirurgen, maar wordt vanwege tijdsgebrek en de kosten van deze vorm van training nauwelijks geïmplementeerd in simulator gebaseerde trainingen.[17,25,26] Een alternatief voor menselijke proctoring is de interactieve taak- en procedurele begeleiding door de simulator SGG

(Simulator Generated Guidance). SGG is een optie beschikbaar op de nieuwste simulatiesystemen. SGG wordt verzorgd door de virtual reality (VR)-simulator om de beginnende chirurg te begeleiden door de stappen van een chirurgische ingreep met behulp van visuele aanwijzingen.[27] Een voordeel van SGG is de mogelijkheid om het effect van verschillende trainingscurricula op de voortgang van de chirurgische vaardigheden van de chirurg te bundelen en te kunnen beoordelen. Effectieve training en prestatiebeoordeling zijn van fundamenteel belang voor chirurgen om hun doelen te bereiken en veilig te kunnen opereren.[13,28]

Hoofdstuk 3 richt zich op de effecten van proctoring en SGG op het verwerven van chirurgische vaardigheden en de tevredenheid van deelnemers (beginnende chirurgen) tijdens de chirurgische vaardigheidstraining. We laten zien dat chirurgische vaardigheden in RAS aanzienlijk kunnen worden verbeterd na het oefenen van basis en geavanceerde simulatieoefeningen gedurende twee uur op een VR-simulator. Dit komt overeen met de bevindingen van Brinkman et al.[29] Het blijkt dat de deelnemerstevredenheid hoger is in de groep 'human proctoring'. Het gebrek aan verschil in het verwerven van chirurgische vaardigheden tussen de interventiegroepen lijkt erop te wijzen dat er een beperkte impact is van "human proctoring" en "simulator generated guidance" tijdens de beginfase van chirurgische simulatietraining. Alleen al de blootstelling van beginnende chirurgen aan de VR-simulator zou al voldoende kunnen zijn om een significante verbetering van chirurgische vaardigheden te bereiken tijdens de eerste stappen van het trainen van RAS.

Hoewel VR-simulatoren een substantiële plaats innemen in de training van RAS, hebben slechts een beperkt aantal studies de overdracht van vaardigheden die tijdens VR-simulatortraining zijn geleerd aangetoond in situaties in de realiteit.[30,31] Om deze reden worden naast VR-simulatoren ook andere trainingsmodaliteiten (dry lab en wet lab training) gebruikt in de meeste training curricula.[16]

De European Robotic Urological Society (ERUS) ontwikkelde een curriculum voor fellows (CC-ERUS) gericht op het uitvoeren van de robot geassisteerde radicale prostatectomie (RARP).[15,16,18,19] Dit curriculum omvat alle aspecten van training, van de meest elementaire zoals live case-observatie en assistentie aan tafel, tot de meest geavanceerde trainingsfaciliteiten zoals virtual reality (VR), dry en wet lab met de meest complexe en geavanceerde trainingsmodellen die tot op heden beschikbaar zijn. Momenteel is dit curriculum beschikbaar voor fellows die trainen in CC-ERUS-gastcentra. De implementatie van trainingscurricula voor fellows is een stap in de goede richting. De volgende stap is de implementatie van een gestructureerd curriculum tijdens het AIOS (Arts-assistent in opleiding tot medisch specialist) programma.

De huidige stand van de RAS-training voor de AIOS-urologie en de impact van de vervolgcursus RAS voor AIOS worden onderzocht in **hoofdstuk 4** van dit proefschrift. Dit hoofdstuk laat zien dat de meeste Nederlandse AIOS RAS mogen uitvoeren tijdens hun opleiding, maar dat de criteria voor het starten van RAS aanzienlijke verschillen tonen tussen de opleidingsziekenhuizen. Hieruit blijkt dat er behoefte is aan de implementatie van een (meerstaps) trainings- en certificeringsprogramma in het Nederlandse urologie AIOS-curriculum. De geavanceerde RAS cursus zou in deze behoefte kunnen voorzien. De aangeboden training is de geavanceerde robotvaardigheidscursus zoals beschreven door Mottrie et al.[18] AIOS die aan deze cursus van een week hebben deelgenomen, laten een significante toename in chirurgische vaardigheden zien. Uit de resultaten van dit onderzoek blijkt dat bijna alle AIOS na de cursus RAS in hun eigen ziekenhuis mogen uitvoeren. Hoewel het effect van deze geavanceerde cursus in RAS van een week op de postoperatieve uitkomst van patiënten onduidelijk blijft, tonen de eerste resultaten van het CC-ERUS-curriculum aan dat de voltooiing van het ERUS-curriculum leidt tot een verbetering van de oncologische en functionele uitkomst bij patiënten.[32,33]

In **hoofdstuk 5** zijn de langetermijneffecten van de gestructureerde fellowship in RAS (CC-ERUS fellowship) onderzocht. Uit de resultaten van de enquête blijkt dat de meeste respondenten na het fellowship nog steeds RAS uitvoeren, wat overeenkomt met resultaten uit ander onderzoek naar de impact van RAS-fellowships.[34,35] Een opmerkelijke bevinding van dit onderzoek is dat een groot deel van de respondenten niet op de hoogte is van de oncologische (33%) en functionele uitkomsten (66%) van hun patiënten. Om deze reden dienen deelnemers aan RAS-trainingen te worden gecoacht met als doel zijn of haar eigen resultaten te evalueren met als einddoel om te leren van de uitkomsten uit het verleden en hun leercurve te verkorten. De toevoeging van een portfolio aan het curriculum waarin de deelnemers hun voortgang vastleggen zou de deelnemers meer bewust kunnen maken van de postoperatieve uitkomst van hun patiënt.

De extra kosten voor het opleiden van een nieuwe chirurg in RAS variëren tussen 95.000 en 1.365.000 dollar, afhankelijk van de lengte van de leercurve.[7,36] De implementatie van een gestructureerd trainingscurriculum vermindert niet alleen mogelijke risico’s voor de patiënt [7,37-39] het is ook kostenbesparend als het de duur van de leercurve verkort. De gemiddelde leercurve van RARP-chirurgen is beschreven in de studie van Steinberg et al. Deze blijkt zevenzeventig ingrepen te zijn, wat overeenkomt met kosten van 217.034 dollar, een minimale reductie van de leercurve zou de kosten van de geavanceerde cursus in RAS kunnen dekken.[36]

Momenteel blijft het effect van gestructureerde training op de leercurve onduidelijk, aangezien de studie gepresenteerd in **hoofdstuk 5** een enquête is. Om deze reden kunnen er geen nauwkeurige gegevens van de leercurve van de deelnemers worden gepresenteerd. De resultaten laten zien dat meer dan de helft van de deelnemers tussen de tweeënvijftig en honderdertig (gedeeltelijke) RARP-cases heeft uitgevoerd tijdens hun fellowship. Een derde van de deelnemers heeft zelfs meer dan honderdertig (gedeeltelijke) RARP-cases uitgevoerd tijdens de fellowship. Dit zou kunnen betekenen dat sommige fellows geslaagd zijn de leercurve tijdens de fellowship onder toezicht van een ervaren chirurg in een gastcentrum te doorlopen.[7,37–39]

Het tweede deel van het proefschrift richt zich op de volgende onderzoeksvraag:

''Hoe kan het functioneren van een robotchirurg het beste worden beoordeeld?''

Het gebruik van chirurgische videobeoordeling om de vaardigheden van een chirurg te relateren aan postoperatieve resultaten is in het verleden bewezen.[40,41] De analyse van intra-operatieve video's maakt een gedetailleerde beoordeling van chirurgische vaardigheden mogelijk. De Robot Assisted Radical Prostatectomy (RARP) is een laparoscopische procedure waarbij de beelden van binnen in de patiënt (intra corporele beelden) kunnen worden opgenomen. De RARP is een van de meest uitgevoerde robot geassisteerde procedures binnen de urologie. Om deze reden hebben we de RARP-procedure gekozen om te starten met de ontwikkeling van chirurgische vaardigheidsbeoordelingen met behulp van chirurgische video-analyse. Een gedetailleerde stapsgewijze beschrijving van de operatie is nodig om de chirurgische video's te gebruiken voor de beoordeling van chirurgische vaardigheden en de detectie van complicaties.

De studie gepresenteerd in **hoofdstuk 6** toont de stappen van de RARP-ingreep die volgens deskundige robotchirurgen van belang zijn voor het vinden van de oorzaken van ongunstige postoperatieve uitkomsten en complicaties. Tijdens een Delphi-sessie werden perioperatieve gebeurtenissen gedefinieerd die de postoperatieve uitkomst (urine-continentie en erectile dysfunctie) kunnen beïnvloeden. Op basis van deze bevindingen werd een nieuw beoordelingsmodel ontworpen: de PROTEST-beoordelingsmethode.

De PROTEST-beoordelingsmethode is de enige beoordelingsmethode die subjectieve beoordeling van chirurgische vaardigheden, objectieve metingen van procedurele stappen en perioperatieve gebeurtenissen combineert in één beoordelingsmethode.

Andere voorbeelden van op sjablonen gebaseerde videobeoordelingsmethoden zijn de Prostatectomy Assessment and Competency Evaluation (PACE) [42] en de Global Evaluative Assessment of Robotic Skill (GEARS)[43]-methode. De PACE-methode is ontwikkeld door de groep van Hussein et.al.[42] en richt zich op objectieve en procedure specifieke beoordeling van vaardigheden. De GEARS-methode kan worden gebruikt om niveaus van robot chirurgische expertise te differentiëren in live operaties en video's van (robot geassisteerde) laparoscopische chirurgie.[43] Deze beoordelingsmethoden worden momenteel gebruikt om de effectiviteit van training (PACE[42]) of de chirurgische basisvaardigheid (GEARS[43]) te beoordelen.

De analyse van technische chirurgische vaardigheden in RAS kan leiden tot grote verbeteringen van postoperatieve uitkomsten.[41] De invloed van niet-technische vaardigheden (NTS) zoals communicatie, teamwerk, leiderschap en situationeel bewustzijn op postoperatieve uitkomsten mag echter niet worden vergeten. Met de introductie van de operatierobot is de traditionele inrichting van de operatiekamer veranderd: de operatieassistent(e) en chirurg staan niet langer tegenover elkaar aan weerszijde van de patiënt. Omdat de chirurg voor het grootste deel van de operatie in de console van de robot zit, kan de directe communicatie met zijn of haar team worden belemmerd. Het verlies van non-verbale communicatie kan de workflow en daarmee de kwaliteit van de ingreep en de patiëntveiligheid tijdens de operatie beïnvloeden.

Er zijn meerdere algemene beoordelingsmethoden ontworpen om NTS te beoordelen voor zowel het team als geheel[44-46] als voor individuele leden van het team.[47-49] De vraag blijft of deze generieke tools NTS nauwkeurig genoeg kunnen beoordelen in een zeer gespecialiseerde situatie zoals RAS. Twee systematische reviews beschrijven ervaringen met onderzoek naar NTS bij minimaal invasieve chirurgie.[50,51] Beide reviews laten een gebrek aan structuur zien in het onderzoek naar NTS: verschillende methoden van NTS-beoordelingen werden afzonderlijk gebruikt, wat vergelijking van instrumenten bemoeilijkt.[50,51]

In **hoofdstuk 7** presenteren we een onderzoeksprotocol dat een prospectief observationeel multicenter studie beschrijft naar niet-technische vaardigheden (NTS) in zowel Open Radicale Cystectomie (ORC) als Robot geassisteerde Radicale Cystectomie (RARC). In deze studie stellen we een gestructureerde benadering van NTS-beoordeling voor met behulp van opnames van de Operatie Kamer (OK) om alle verschillende NTS-scoringsmethoden te kunnen implementeren.[44,45,49,52-54]

Hoewel de operatie die van belang is in deze studie de RARC is, kunnen de resultaten die tijdens deze studie zijn verkregen en worden gegeneraliseerd buiten RARC.

Dit omdat de veranderingen in de OK-opstelling en het verlies van non-verbale communicatie universeel zijn bij de overstap van open chirurgie naar RAS.

De resultaten van dit onderzoek kunnen worden gebruikt om effectieve team trainingsprogramma's te ontwikkelen, specifiek voor de introductie van de chirurgische robot in relatie tot veranderingen in niet-technische vaardigheden om de prestaties van chirurg en team te verbeteren.

Effectieve training en prestatiebeoordeling zijn van fundamenteel belang om ervoor te zorgen dat chirurgen hun beoogde doel bereiken en veilig opereren met maximaal behoud van functies.[13,28,55] Het onderzoeksveld van video-evaluatie en analyse van postoperatieve resultaten is gericht op het voorspellen van postoperatieve resultaten en het verminderen van complicaties.[41,42,56,57] Hoewel meerdere groepen de mogelijkheid van video analyse hebben onderzocht, is het onduidelijk of video analyse zijn plaats heeft gevonden in de dagelijkse praktijk.

In **hoofdstuk 8** worden de resultaten getoond van een onderzoek naar de acceptatie van postoperatieve resultaatanalyse en chirurgische video-analyse onder urologen die de RARP uitvoeren. De meeste urologen gebruiken analyses van postoperatieve resultaten om te leren van de uitkomsten van ingrepen. De specialisten gebruiken bewerkte chirurgische video's tijdens teamvergaderingen om inzicht te krijgen in de specifieke facetten (chirurgische stappen) van RARP welke mogelijk relatie hebben tot postoperatieve complicaties en functionele uitkomsten (urine-continentie en erectile functie).

Het derde deel van het proefschrift richt zich op de volgende onderzoeksvraag:

''Wat is de relatie tussen de vaardigheden van een chirurg en de postoperatieve uitkomsten van een patiënt?''

De groep van Goldenberg et al. gebruikten de GEARS-beoordelingsmethode om specifieke secties van de RARP te beoordelen en vonden zij een mogelijke correlatie tussen chirurgische vaardigheden en postoperatieve uitkomst, voornamelijk de vroege continentie na RARP [58]. De PROTEST-, PACE[42]- en GEARS[43]-beoordelingsmethoden zijn geëvalueerd in twee gematchte case-control pilotstudies om te onderzoeken of de resultaten van deze chirurgische vaardigheidsbeoordelingsmethoden kunnen worden gebruikt om het postoperatieve functionele resultaat (continentie en erectile functie) te voorspellen.

De resultaten van deze pilotstudies zijn beschreven in **hoofdstuk 9** (continentieonderzoek) en **hoofdstuk 10** (erectile functie onderzoek). In **hoofdstuk 9** werden postoperatief incontinente patiënten vergeleken met continente patiënten. Deze studie toont aan dat geen van de factoren in de PROTEST-, PACE[42]- en GEARS[43]-beoordelingsmethoden kunnen worden gebruikt om de urine-continentie of erectile functie van de patiënten te voorspellen. De resultaten laten wel zien, in tegenstelling tot een studie van de groep van Stern et.al.[59], dat experts in staat zijn de postoperatieve continentie of erectile functie van de patiënten te voorspellen.

Een soortgelijke opzet werd gebruikt in de studie gepresenteerd in **hoofdstuk 10** hierin werden postoperatief impotente patiënten gekoppeld aan potente patiënten om te beoordelen, doormiddel van video analyse, of de chirurgische vaardigheden van één expert operateur verschilden tussen de postoperatieve uitkomsten. Deze studies tonen aan dat geen van de factoren in de PROTEST-, PACE[42]- en GEARS[43]-beoordelingsmethoden kunnen worden gebruikt om de urine-continentie of erectile functie van patiënten te voorspellen. De resultaten laten wel zien, in tegenstelling tot een studie van de groep van Stern et.al.[59], dat experts in staat zijn de postoperatieve continentie of erectile functie van de patiënten te voorspellen.

De resultaten van beide onderzoeken laten zien dat experts zich richten op de kwaliteit van de neurovasculaire bundels in geval van potentie, en de lengte van de urethrastomp na resectie in geval van urine continentie. Hoewel de relatie tussen urethrastomplengte gemeten in chirurgische video's en postoperatieve continentie niet in eerder onderzoek was aangetoond [60], was de invloed van de urethralengte op continentie bekend uit eerdere studies in MRI-beelden[61,62] en pathologie resultaten[63].

De studie gepresenteerd in **hoofdstuk 11** toont de resultaten van een onderzoek waarin metingen van de urethrastomp in vooraf opgenomen video's werden gecorreleerd met de postoperatieve continentie van patiënten. In dit onderzoek zijn de afmetingen van de transurethrale katheter (Chr. 16) gebruikt om de metingen te standaardiseren. De resultaten van deze studie tonen aan dat de resterende urethrastomp significant langer was in de continentgroep (10,50 vs 12,94 mm, p= 0,018). Wij zijn de eersten die de relatie aantonen tussen de resterende urethra-stomplengte gemeten tijdens de operatie en postoperatieve continentie van de patiënt. Het verschil in resultaten vergeleken met de studie van Bautista Vidal et al. die geen verband vonden tussen de lengte van de urethrastomp en de postoperatieve continentiestatus van de patiënt, zou te wijten kunnen zijn aan een andere meetmethode tijdens de operatie.[60] Als de techniek kan worden aangepast om te worden gebruikt tijdens operaties en niet alleen in de vooraf opgenomen chirurgische video's zal het een nieuwe chirurgische uitdaging zijn om zoveel mogelijk urethrale lengte te besparen tijdens RARP.

Aanvullend onderzoek is nodig om de ideale lengte van de urethra te bepalen om continentie te bereiken. Als er zo'n ideale urethrale lengte is, kan de chirurgische procedure worden aangepast om de dissectie en mobilisatie van delen van de urethra uit te prostaat te standaardiseren om de lengte van de urethrale stomp te vergroten en de kans op continentie van de patiënt te vergroten. De beoordelingsmethoden PACE42, GEARS43 en PROTEST die in **hoofdstuk 9** en **hoofdstuk 10** worden gebruikt zijn tijdrovende manieren om de vaardigheden van chirurgen te beoordelen. Aangezien deze methodes zijn gebaseerd op menselijke beoordeling kan subjectieve bias niet worden vermeden. Dit leidt tot verminderde inter-beoordelaarsbetrouwbaarheid.

Om de beoordeling te objectiveren en de tijdsinvestering van 'handmatige beoordeling' door de waarnemer te verminderen worden geautomatiseerde beoordelingstools bestudeerd[64,65]. Hung et al. hebben recent de mogelijkheid van de analyse van de bewegingen van de chirurgische robot onderzocht met het dVLogger-systeem. Dit onderzoek heeft geleid tot meer inzicht in de prestaties van de chirurgen en kon worden gebruikt om postoperatieve uitkomsten te voorspellen[64,66]. Het dVLlogger-systeem registreert automatisch de bewegingen van de robot en systeemgegevens in live operaties. Hierdoor worden grote datasets met uitkomsten en reeds opgenomen chirurgische video's nutteloos.

In **hoofdstuk 12** onderzoeken we de mogelijkheid om instrumentbewegingen automatisch te beoordelen in vooraf opgenomen video's van RARP-patiënten. Dit om na te gaan of de bewegingen van chirurgische instrumenten tijdens een operatie de functionele uitkomst van de operatie kunnen voorspellen. De Kinovea-software kan instrumentbewegingen bij laparoscopische chirurgie automatisch volgen zonder dat er extra apparatuur nodig is.[65] De resultaten in **hoofdstuk 12** tonen aan dat de snelheid van de chirurgische instrumenten, weefsel dat het instrument overlapt en het feit dat het instrument flexibele gewrichten heeft, het onmogelijk maakt om de instrumentbewegingen te volgen in vooraf opgenomen RARP-video's. Verder onderzoek met grotere groepen patiënten en een ander geautomatiseerd volgsysteem zijn nodig om de mogelijkheid van geautomatiseerde beoordeling van chirurgische bewegingen in vooraf opgenomen chirurgische video's te onderzoeken.

In **hoofdstuk 13** worden de belangrijkste bevindingen van de verschillende onderzoeken in dit proefschrift besproken. De antwoorden op de drie hoofdonderzoeksvragen zijn geformuleerd in een overkoepelende conclusie. Methodologische overwegingen worden gegeven en aanbevelingen voor toekomstig onderzoek worden gepresenteerd.

Referenties

beck BK, Hu JC, Shariat SF, Sun M, Vickers AJ. A systematic review of the volume-outcome relationship for radical prostatectomy. Eur Urol [Internet]. 2013;64(5):786–98.

2. Gershman B, Meier SK, Jeffery MM, Moreira DM, Tollefson MK, Kim SP, Karnes RJ, Shah ND. Redefining and Contextualizing the Hospital Volume-Outcome Relationship for Robot-Assisted Radical Prostatectomy: Implications for Centralization of Care. J Urol [Internet]. 2017 Jul 1 [cited 2018 Jul 23];198(1):92–9.

3. Stitzenberg KB, Wong YN, Nielsen ME, Egleston BL, Uzzo RG. Trends in radical prostatectomy: Centralization, robotics, and access to urologic cancer care. Cancer. 2012;118(1):54–62.

4. Inspectie voor de Gezondheidszorg. Het resultaat telt; Ziekenhuizen 2015. 2017;247.

5. Bianco FJ, Vickers AJ, Cronin AM, Klein EA, Eastham JA, Pontes JE, Scardino PT. Variations Among Experienced Surgeons in Cancer Control After Open Radical Prostatectomy. J Urol [Internet]. 2010;183(3):977–83.

6. Vickers A, Savage C, Bianco F, Mulhall J, Guillonneau B, Cronin A, Scardino P, Sandhu J, Guillonneau B, Cronin A, Scardino P. Cancer control and functional outcomes after radical prostatectomy as markers of surgical quality: Analysis of heterogeneity between surgeons at a single cancer center. Eur Urol [Internet]. 2011;59(3):317–22.

7. Puliatti S, Mazzone E, Dell'Oglio P. Training in robot-assisted surgery. Curr Opin Urol. 2020;30(1):65–72.

8. Tjiam IM, Schout BMA, Hendrikx AJM, Muijtjens AMM, Scherpbier AJJA, Witjes JA, Van Der Vleuten CPM. Program for laparoscopic urological skills assessment: Setting certification standards for residents. Minim Invasive Ther Allied Technol [Internet]. 2013 Feb 10 [cited 2020 May 22];22(1):26–32.

9. Tjiam IM, Persoon MC, Hendrikx AJM, Muijtjens AMM, Witjes JA, Scherpbier AJJA. Program for laparoscopic urologic skills: A newly developed and validated educational program. Urology [Internet]. 2012 Apr 1 [cited 2020 May 22];79(4):815–20.

10. Brinkman WM, Tjiam IM, Schout BMA, Muijtjens AMM, Van Cleynenbreugel B, Koldewijn EL, Alfred Witjes J. Results of the European basic laparoscopic urological skills examination. Eur Urol [Internet]. 2014;65(2):490–6.

11. Porte PJ, Verweij L., Bekkers RL., Consten EC., Lichtenberg H, van der Poel HG, van Swol CFP, Wagner C. Robotic surgery for medical specialists, basic proficiency requirements for the safe use of robotic surgery. Utrecht/Amsterdam: NIVEL/EMGO+ [Internet]. 2017 [cited 2017 Aug 22];

12. Dutch Health inspectorate (Inspectie voor de gezondheidszorg). Insufficient carefulness at the introduction of surgical robots (in Dutch: Onvoldoende zorgvuldigheid bij introductie van operatierobots). Igz. 2010;

13. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendrikx A, van der Poel H. Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? Surg Endosc Other Interv Tech. 2017;31(1):281–7.

14. Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg [Internet]. 2015 Jan [cited 2017 Aug 17];13:115–23.

15. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novara G, Van Der Poel H, Mottrie A. Platinum Priority – Education Pilot Validation Study of the European Association of Urology Robotic Training Curriculum. 2015;8(2):9–2.

16. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, et al. Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int [Internet]. 2015 Jul [cited 2017 Sep 25];116(1):93–101.

17. Schreuder HWRR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHMM. Training and learning robotic surgery, time for a more structured approach: A systematic review. BJOG An Int J Obstet Gynaecol [Internet]. 2012 Jan [cited 2017 Dec 5];119(2):137–49.

18. Mottrie A, Novara G, van der Poel H, Dasgupta P, Montorsi F, Gandaglia G. The European Association of Urology Robotic Training Curriculum: An Update. Eur Urol Focus [Internet]. 2016;2(1):105–8.

19. Stolzenburg JU, Qazi HAR, Rai BP. The European Association of Urology Robotic Training Curriculum: The Journey Has only Just Begun. Eur Urol [Internet]. 2015;68(2):300–1.

20. Kruger J, Dunning D. Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. J Pers Soc Psychol [Internet]. 1999 [cited 2018 Mar 22];77(6):1121–34.

21. Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX, Sriprasad S. Partial vs radical nephrectomy for T1 renal tumours: an analysis from the British Association of Urological Surgeons Nephrectomy Audit. BJU Int [Internet]. 2016 Jan [cited 2017 Jan 7];117(1):62–71.

22. Jaeken M, Zech E, Brison C, Verhofstadt LL, Van Broeck N, Mikolajczak M. Helpers' Self-Assessment Biases Before and after Helping Skills Training. Front Psychol [Internet]. 2017 [cited 2018 Mar 22];8:1377.

23. Krueger J, Mueller RA. Unskilled, unaware, or both? The better-than-average heuristic and statistical regression predict errors in estimates of own performance. J Pers Soc Psychol [Internet]. 2002 Feb [cited 2018 Mar 23];82(2):180–8.

24. Rashid HH, Leung Y-YM, Rashid MJ, Oleyourryk G, Valvo JR, Eichel L. Robotic surgical education: a systematic approach to training urology residents to perform robotic-assisted laparoscopic radical prostatectomy. Urology [Internet]. 2006 Jul [cited 2020 May 21];68(1):75–9.

25. Shim JS, Kim JY, Pyun JH, Cho S, Oh MM, Kang SH, Lee JG, Kim JJ, Cheon J, Kang SG. Comparison of effective teaching methods to achieve skill acquisition using a robotic virtual reality simulator Expert proctoring versus an educational video versus independent training. Med (United States). 2018;97(51):1–5.

26. Lee JY, Mucksavage P, Sundaram CP, McDougall EM. Best practices for robotic surgery training and credentialing. J Urol [Internet]. 2011;185(4):1191–7.

27. Wijewickrema S, Zhou Y, Bailey J, Kennedy G, O'Leary S. Provision of automated step-by-step procedural guidance in virtual reality surgery simulation. In: Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology - VRST '16 [Internet]. New York, New York, USA: ACM Press; 2016 [cited 2020 Apr 20]. p. 69–72.

28. Goldenberg MG, Lee JY, Kwong JCCC, Grantcharov TP, Costello A. Implementing assessments of robot-assisted technical skill in urological education: a systematic review and synthesis of the validity evidence [Internet]. BJU International Mar 31, 2018.

29. Brinkman WM, Luursema JM, Kengen B, Schout BMA, Witjes JA, Bekkers RL. Da vinci skills simulator for assessing learning curve and criterion-based training of robotic basic skills. Urology [Internet]. 2013;81(3):562–6.

30. Aghazadeh MA, Mercado MA, Pan MM, Miles BJ, Goh AC. Performance of robotic simulated skills tasks is positively associated with clinical robotic surgical performance. BJU Int [Internet]. 2016 Sep [cited 2017 Aug 9];118(3):475–81.

31. Schout BMA, Ananias HJK, Bemelmans BLH, D'Ancona FCH, Muijtjens AMM, Dolmans VEMG, Scherpbier AJJA, Hendrikx AJM. Transfer of cysto-urethroscopy skills from a virtual-reality simulator to the operating room: a randomized controlled trial. BJU Int [Internet]. 2009 Nov 12 [cited 2020 Apr 22];106(2):226–31.

32. Mazzone E, Dell'oglio P, Mottrie A. Outcomes report of the first erus robotic urology curriculum-trained surgeon in turkey: The importance of structured and validated training programs for global outcomes improvement [Internet]. Vol. 45, Turkish Journal of Urology. Turkish Association of Urology; 2019 [cited 2020 May 21]. p. 189–90.

33. Bedir F, Keske M, Demirdögen SO, Kocatürk H, Koç E, Canda AE, Atmaca AF. Robotic radical prostatectomy in 93 cases: Outcomes of the first ERUS robotic urology curriculum trained surgeon in Turkey. Turkish J Urol [Internet]. 2019 [cited 2020 May 21];45(3):183–8.

34. Gamboa AJR, Santos RT, Sargent ER, Louie MK, Box GN, Sohn KH, Truong H, Lin R, Khosravi A, Santos R, Ornstein DK, Ahlering TE, Tyson DR, Clayman R V., McDougall EM. Long-Term Impact of a Robot Assisted Laparoscopic Prostatectomy Mini Fellowship Training Program on Postgraduate Urological Practice Patterns. J Urol [Internet]. 2009;181(2):778–82.

35. McDougall EM, Corica FA, Chou DS, Abdelshehid CS, Uribe CA, Stoliar G, Sala LG, Khonsari SS, Eichel L, Boker JR, Ahlering TE, Clayman R V. Short-term impact of a robot-assisted laparoscopic prostatectomy 'mini-residency' experience on postgraduate urologists' practice patterns. Int J Med Robot Comput Assist Surg [Internet]. 2006 Mar [cited 2020 Mar 4];2(1):70–4.

36. Steinberg PL, Merguerian PA, Bihrle W, Seigne JD. The Cost of Learning Robotic-Assisted Prostatectomy. Urology. 2008;72(5):1068–72.

37. Buffi N, Van Der Poel H, Guazzoni G, Mottrie A. Methods and priorities of robotic surgery training program [Internet]. Vol. 65, European Urology. Eur Urol; 2014 [cited 2020 May 21]. p. 1–2.

38. Sridhar AN, Briggs TP, Kelly JD, Nathan S. Training in Robotic Surgery—an Overview. Curr Urol Rep. 2017;18(8).

39. Brook NR, Dell'Oglio P, Barod R, Collins J, Mottrie A. Comprehensive training in robotic surgery [Internet]. Vol. 29, Current Opinion in Urology. Curr Opin Urol; 2019 [cited 2020 May 21]. p. 1–9.

40. Birkmeyer JD, Finks JF, O 'reilly A, Oerline M, Carlin AM, Nunn AR, Dimick J, Banerjee M, Birkmeyer NJO. Surgical Skill and Complication Rates after Bariatric Surgery for the Michigan Bariatric Surgery Collaborative. N Engl J Med [Internet]. 2013 [cited 2017 Nov 17];369:1434–42.

41. Goldenberg MG, Goldenberg L, Grantcharov TP. Surgeon Performance Predicts Early Continence After Robot-Assisted Radical Prostatectomy. J Endourol [Internet]. 2017 Jun 26 [cited 2018 Jun 18];31(9):end.2017.0284.

42. Hussein AA, Ghani KR, Peabody J, Sarle R, Abaza R, Eun D, Hu J, Fumo M, Lane B, Montgomery JS, Hinata N, Rooney D, Comstock B, Chan HK, Mane SS, Mohler JL, Wilding G, Miller D, Guru KA. Development and Validation of an Objective Scoring Tool for Robot-Assisted Radical Prostatectomy: Prostatectomy Assessment and Competency Evaluation. J Urol [Internet]. 2017 [cited 2017 Jun 12];197(5):1237–44.

43. Goh AC, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: Validation of a clinical assessment tool to measure robotic surgical skills. J Urol [Internet]. 2012 Jan 1 [cited 2017 Aug 29];187(1):247–52.

44. Robertson ER, Hadi M, Morgan LJ, Pickering SP, Collins G, New S, Griffin D, McCulloch P, Catchpole KC. Oxford NOTECHS II: A Modified Theatre Team Non-Technical Skills Scoring System. Roma PG, editor. PLoS One [Internet]. 2014 Mar 4 [cited 2018 Oct 26];9(3):e90320.

45. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care [Internet]. 2009 Apr 1 [cited 2018 Oct 26];18(2):104–8.

46. Moorthy K, Munz Y, Adams S, Pandey V, Darzi A. A human factors analysis of technical and team skills among surgical trainees during procedural simulations in a simulated operating theatre. Ann Surg [Internet]. 2005 Nov [cited 2018 Oct 26];242(5):631–9.

47. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. Best Pract Res Clin Anaesthesiol [Internet]. 2011 Jun 1 [cited 2018 Oct 26];25(2):215–27.

48. Mitchell L, Flin R, Yule S, Mitchell J, Coutts K, Youngson G. Development of a behavioural marker

system for scrub practitioners' non-technical skills (SPLINTS system). J Eval Clin Pract [Internet]. 2013 Apr 1 [cited 2018 Oct 26];19(2):317–23.

49. Sharma B, Mishra A, Aggarwal R, Grantcharov TP. Non-technical skills assessment in surgery. Surg Oncol [Internet]. 2011;20(3):169–77.

50. Gjeraa K, Spanager L, Konge L, Petersen RH, Østergaard D. Non-technical skills in minimally invasive surgery teams: a systematic review. Surg Endosc. 2016;30(12):5185–99.

51. van der Vliet WJ, Haenen SM, Solis-Velasco M, Dejong CHC, Neumann UP, Moser AJ, van Dam RM. Systematic review of team performance in minimally invasive abdominal surgery. BJS Open. 2019;3(3):252–9.

52. Undre S, Sevdalis N, Healey AN, Darzi A, Vincent CA. Observational Teamwork Assessment for Surgery (OTAS): Refinement and Application in Urological Surgery. World J Surg [Internet]. 2007 Jun 16 [cited 2018 Oct 26];31(7):1373–81.

53. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Shamim M, Giacomo K. Development and validation of a tool for non-technical skills evaluation in robotic surgery — the ICARS system. Surg Endosc. 2017;31(12):5403–10.

54. Cohen TN, Wiegmann DA, Reeves ST, Boquet AJ, Shappell SA. Coding Human Factors Observations in Surgery. Am J Med Qual. 2017;32(5):556–62.

55. Beulens AJWAJW, Brinkman WM, Porte PJJ, Meijer RP, Van Merriënboer JJG, Van der Poel HG, Wagner C, Brinkman M, Porte PJJ, Meijer P, Merriënboer JJGVJG Van, Poel HGVDG Van Der. The value of a one-day multidisciplinary robot surgery training for novice robot surgeons. J Robot Surg [Internet]. 2018;13(3):435–47.

56. Beulens AJW, Brinkman WM, Van der Poel HG, Vis AN, van Basten JP, Meijer RP, Wijburg CJ, Hendrikx AJM, van Merriënboer JJG, Wagner C. Linking surgical skills to postoperative outcomes: a Delphi study on the robot-assisted radical prostatectomy. J Robot Surg [Internet]. 2019;

57. van Basten JPA, Somford RM, de Baaij J, Sedelaar M, Vrijhof E. Initiatief Comprehensive Prostate Cancer Network (CPCN) in Zuidoost Nederland. Tijdschr voor Urol. 2017;7(6–7):134–44.

58. Goldenberg MG, Goldenberg SL, Grantcharov TP. Mp51-15 Surgical Technical Performance Impacts Patient Outcomes in Robotic-Assisted Radical Prostatectomy. J Urol [Internet]. 2017;197(4S):S269–70.

59. Stern J, Sharma S, Mendoza P, Walicki M, Hastings R, Monahan K, Sheikh B, Wedmid A, Lee DI. Surgeon perception is not a good predictor of peri-operative outcomes in robot-assisted radical prostatectomy. J Robot Surg. 2011;5(4):283–8.

60. Bautista Vidal JC, García Galisteo E, Barón López J, Sánchez Martínez N, Hernández Alcaraz D, Morales Jiménez P, Vozmediano Chicharro R. Objective assessment of early urinary continence by analysis and visualisation of intraoperative variables of radical robotic prostatectomies with a video editor. Actas Urol Esp [Internet]. 2019;43(2):99–105.

61. Grivas N, van der Roest R, Tillier C, Schouten D, van Muilekom E, Schoots I, van der Poel H, Heijmink S. Patterns of Benign Prostate Hyperplasia Based on Magnetic Resonance Imaging Are Correlated With Lower Urinary Tract Symptoms and Continence in Men Undergoing a Robot-assisted Radical Prostatectomy for Prostate Cancer. Urology [Internet]. 2017;107:196–201.

62. Song W, Kim CK, Park BK, Jeon HG, Jeong BC, Seo S Il, Jeon SS, Choi HY, Lee HM. Impact of preoperative and postoperative membranous urethral length measured by 3 Tesla magnetic resonance imaging on urinary continence recovery after robotic-assisted radical prostatectomy. Can Urol Assoc J. 2017;11(3–4):E93–9.

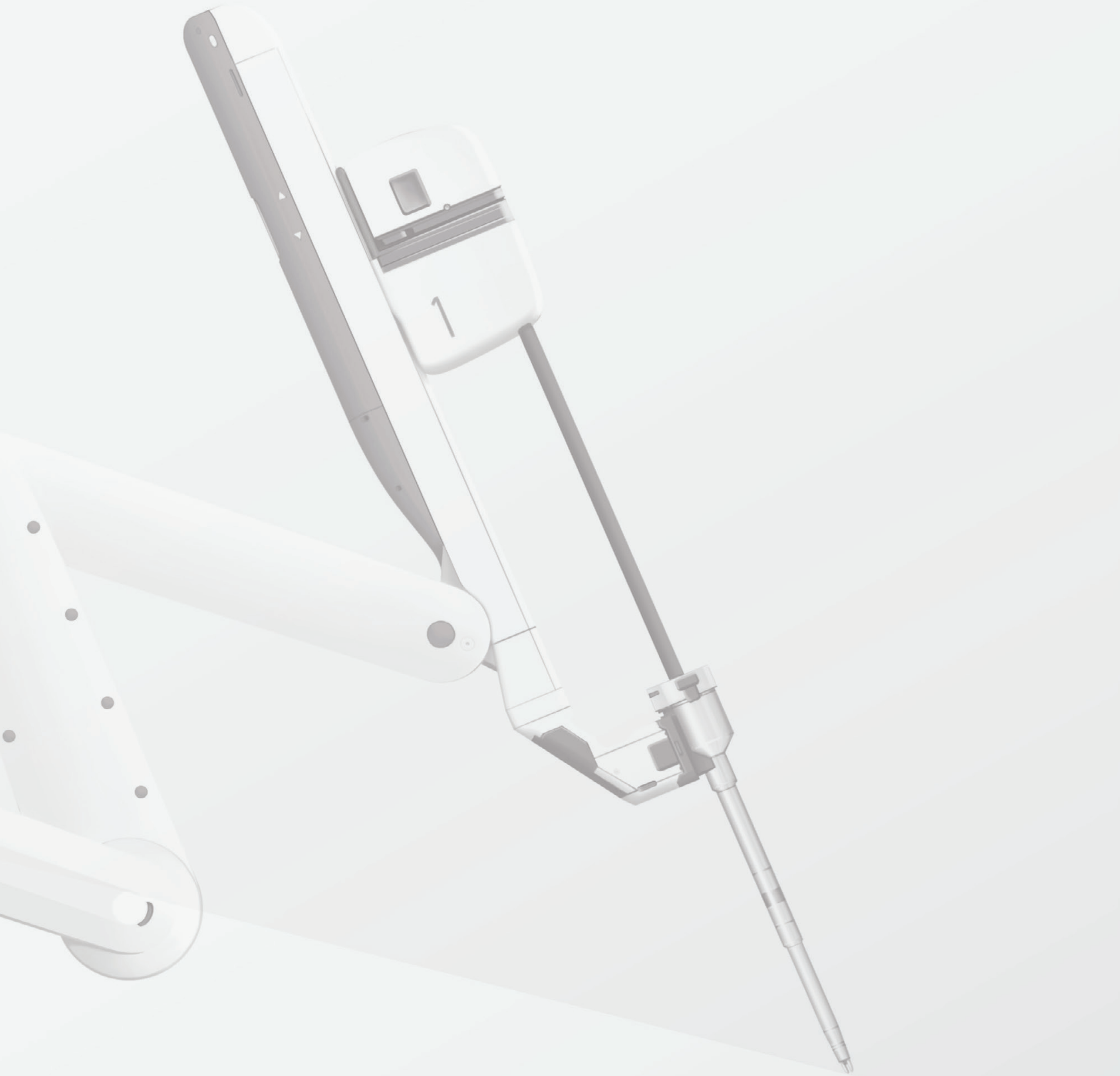
63. Kohjimoto Y, Yamashita S, Kikkawa K, Iba A, Matsumura N, Hara I. The association of length of the resected membranous urethra with urinary incontinence after radical prostatectomy. Urol J. 2019;epub(c):2–6.

64. Hung AJ, Chen J, Jarc A, Hatcher D, Djaladat H, Gill IS. Development and Validation of Objective Performance Metrics for Robot-assisted Radical Prostatectomy – A Pilot Study. J Urol [Internet]. 2017 Jul 29 [cited 2017 Aug 9];199(1):296–304.

65. Ganni S, Botden SMBI, Chmarra M, Goossens RHM, Jakimowicz JJ. A software-based tool for video motion tracking in the surgical skills assessment landscape. Surg Endosc [Internet]. 2018 Jun 16 [cited 2018 Jun 21];32(6):2994–9.

66. Hung AJ, Chen J, Che Z, Nilanon T, Jarc A, Titus M, Oh PJ, Gill IS, Liu Y. Utilizing Machine Learning and Automated Performance Metrics to Evaluate Robot-Assisted Radical Prostatectomy Performance and Predict Outcomes. J Endourol [Internet]. 2018 May [cited 2019 Jul 25];32(5):438–44

Nederlandse samenvatting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Section V

Appendix

Appendix

List of abbreviations

List of abbreviations

BMI	Body mass index
BPR	Basic proficiency requirements for the safe use of robotic surgery
CC-ERUS	European Robotic Curriculum
CCI	Charlson comorbidity index
EAU	European Association of Urology
EORTC QLQ-PR25 scores	European Organization for Research and Treatment of Cancer Quality-of-Life Questionnaire
ERUS	European Association of Urology Robotic Urology Section
GDPR	General Data Protection Regulation
GEARS	Global Evaluative Assessment of Robotic Skills
GERT	Generic Error Rating Tool
ICARS	Interpersonal and Cognitive Assessment for Robotic Surgery
ICIQ-SF-score	International Consultation Incontinence Modular Questionnaire-short form
ICU	Intensive care unit
IGJ	Health and Youth Care Inspectorate
IGZ	Dutch Health Care Inspectorate
IIEF-EF- score	International Index of Potency Questionnaire
IPSS	International Prostate Symptom Score
MRI	Magnetic resonance imaging
MU	membranous urethra
MUL	Membranous Urethral Length
MUL	membranous urethra length
MUW	Maximal Urethral Width
NIVEL	Netherlands Institute for Health Services Research
NOTECHS II	A Modified Theatre Team Non-Technical Skills Scoring System
NOTSS	Non-Technical Skills for Surgeons
NTS	non-technical-skills

NVB	Neuro vascular Bundle
NVEC	Dutch Association for Endoscopic Surgery
NVU	Dutch society of urology
OR	Operating Room
ORC	Open Radical Cystectomy
OSATS	Objective Structured Assessment of Technical Skills
OTAS	Observational Teamwork Assessment for Surgery
PACE	Prostatectomy Assessment and Competence
PREMS	Patient Reported Experience Measures
PROMS	Patient-reported outcome measures
PROTEST	PRostatectomy video Observation to Evaluate and Score Technical skill
RARC	Robot Assisted Radical Cystectomy
RARP	robot assisted radical prostatectomy
RAS	Robot assisted surgery
SBE	Simulation-based education
SGG	Simulator generated guidance
SUL	Surgical urethral length
SUW	Surgical urethral Width
VR	Virtual Reality
VUL	Ventral Urethral Length
VUW	Ventral Urethral width
WHO	World Health Organization

Appendix

List of publications

List of publications

This thesis

1. The value of a 1-day multidisciplinary robot surgery training for novice robot surgeons.

A.J.W. Beulens, W.M. Brinkman, P.J. Porte, R.P. Meijer, J.J.G. van Merriënboer, H.G Van der Poel, and C. Wagner,

Journal of Robotic Surgery (2019), Volume 13, Issue 3, pp 435–447

2. Linking surgical skills to postoperative outcome, a Dutch Delphi meeting into the Robot Assisted Radical Prostatectomy

A.J.W. Beulens, W.M. Brinkman, H.G Van der Poel, A.N. Vis, J.P. van Basten, R.P. Meijer, C.J. Wijburg, A.J.M. Hendrikx, J.J.G. van Merriënboer, and C. Wagner

Journal of Robotic Surgery (2019), Volume 13, Issue 5, pp 675–687

3. Analysis of the video motion tracking system 'Kinovea' to assess surgical movements during robot-assisted radical prostatectomy.

A.J.W. Beulens, H.F. Namba, W.M. Brinkman, R.P. Meijer, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, C. Wagner.

The International Journal of Medical Robotics and Computer Assisted Surgery, (2020), Volume 16, Issue 2, e2090

4. Five years CC- ERUS Fellowship, a survey into the experiences and post fellowship work of the fellows.

A.J.W. Beulens, P. Dell'Oglio, H. Kiss, W.M. Brinkman, A. Larcher, A. Mottrie, C. Wagner, H.G. van der Poel

European Urology Open Science (2020), Volume 19, pp 45-47

5. A prospective observational multicentre study concerning non-technical skills in robot assisted radical cystectomy versus open radical cystectomy.

A.J.W. Beulens, W.M. Brinkman, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, and C. Wagner

European Urology Open Science (2020), Volume 19, pp 37-44

6. Training novice robot surgeons: Proctoring provides same results as simulator-generated guidance

A.J.W. Beulens, Y. Hashish, W.M. Brinkman, P. Umari, S. Puliatti, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, C. Wagner

Journal of Robotic Surgery (2020), Volume 15, pp 397–428

7. Structured robot-assisted surgery training curriculum for residents in Urology and impact on future surgical activity

A.J.W. Beulens, L. Vaartjes, S. Tilli, W.M. Brinkman, P. Umari, S. Puliatti, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, C. Wagner

Journal of Robotic Surgery (2020), Volume 15, pp 497–510

8. Identifying the relationship between postoperative urinary continence and residual urethra stump measurements in robot assisted radical prostatectomy patients

A.J.W. Beulens, W.M. Brinkman, P. Umari, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, C. Wagner

The International Journal of Medical Robotics and Computer Assisted Surgery, (2020), Volume 17, Issue 2, e2196

9. Identifying surgical factors predicting postoperative urinary continence after robot-assisted radical prostatectomy

A.J.W. Beulens, W.M. Brinkman, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, and C. Wagner

Laparoscopic, Endoscopic and Robotic surgery, [Submitted]

10. Identifying surgical factors predicting postoperative potency after robot- assisted radical prostatectomy

A.J.W. Beulens, W.M. Brinkman, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, and C. Wagner

Tijdschrift voor Urologie, [Submitted]

11. Robot-Assisted Radical Prostatectomy: A survey on the influence of postoperative results analysis and surgical video review on postoperative complications and functional results.

A.J.W. Beulens, H. Veerman, W.M. Brinkman, E.L. Koldewijn, A.J.M. Hendrikx, J.P. van Basten, J.J.G. van Merriënboer, H.G. Van der Poel, C. Bangma, and C. Wagner

Laparoscopic, Endoscopic and Robotic surgery, [Submitted]

Other publications

12. Case report. Infarcering van een testis bij een patiënt met sikkelcelanemie

A.J.W. Beulens, M.B.G Kuenen, L.S.F. Yo en E.L. Koldewijn

Tijdschrift voor de Urologie (2017) Volume 7, Issue 8, pp 188–190

13. High precision bladder cancer irradiation in the elderly: clinical results of a plan-of-the-day integrated boost technique with image guidance using lipiodol markers.

Beulens, A.J.W. van der Toorn, P.P, de Wildt, M.J.A.M., and Scheepens, W.A

European Urology Oncology, (2019), Volume 2, Issue 1, pp 39-46

14. Artificial intelligence and robotics: a combination that will forever change the operating room

Iulia Andras; Elio Mazzone; Fijs W.B. van Leeuwen; Geert De Naeyer; Matthias N. van Oosterom; Sergi Garcia Beato; Tessa Buckle; Shane O'Sullivan; Pim J. van Leeuwen; **Alexander Beulens**; Nicolae Crisan; Frederiek D'Hondt; Peter Schatteman; Henk van Der Poel; Paolo Dell'Oglio, M.D.; Alexandre Mottrie

World Journal of Urology, (2020), Volume 38, issue 10, pp 2359–2366.

15. Het nut van een Advanced Robotic skills training voor AIOS.

Alexander Beulens, Willem Brinkman en Henk van der Poel

Urograaf (2020), edition 4, July 31

16. Diagnostic accuracy of ^{18}F-Flucicovine PET/CT in primary lymph node staging of prostate cancer.

R.J. Hoekstra, H.J.E.J. Vrijhof, **A.J.W. Beulens**, D.N.J. Wyndaele, L.J.M. Brouwer, D.M. Somford, J.P.M. Sedelaar, J.P.A. van Basten

Nuclear Medicine Communications, (2021), Volume 42, Number 5, pp 476–481

17. Reassessment of prostate biopsies of referred patients for robot assisted radical prostatectomy rarely influences surgical planning

R.J. Hoekstra, W.J.H. Goossens, **A. Beulens**, H. van Herk, B.M. Hoevenaars, J. de Baaij, D.M. Somford, J.P.M. Sedelaar, J.P.A. van Basten, H.J.E.J. Vrijhof

European Urology Open Science, (2021), Volume 28, pp 36-42

18. Treatment of Mild to Moderate Stress Urinary Incontinence with a Novel Poly-caprolactone-Based Bioresorbable Urethral Bulking Agent

Evert L. Koldewijn, Dennis J.A.J. Oerlemans, **Alexander J.W. Beulens**, Michel J.A.M. de Wildt, Vera Vandoninck, Stefan De Wachter

Urogynaecologia, accepted

Appendix

PHD Portfolio

PHD Portfolio

Name PhD student	Alexander Beulens
PhD Period	July 2017 - June 2020
Name PhD Supervisor	Prof. Dr. C. Wagner

GENERAL COURSES	Year	Workload (ECTS)
VUmc Academy		
Scientific Integrity	2019	2.0
Catharina Hospital Eindhoven		
Good Clinical Practice	2017	0.3
Basic Life support	2017	0.15
Begeleiding van Co-assistenten voor AIOS en ANIOS	2017	0.3
Basis lucht weg	2019	0.15
Expert Bladder catheterization	2018	0.15
Training kwaliteit en veiligheid in onderzoek deel 1 en 2	2018	0.3
European Resuscitation Council		
Intermediate Life Support	2018	1.0
Maastricht University		
Observational research	2019	6.0
EpIdM		
Clinimetrics: Assessing measurement properties of health measurement instruments	2019	0.68

SEMINARS, WORKSHOPS AND MASTER CLASSES	Year	Workload (ECTS)
Catharina Hospital Eindhoven		
Regionale refereeravond: The treatment of Muscle invasive bladder cancer, including presentation	2019	1.0
Regionale refereeravond: Hematuria from the urologists and nephrologist's perspective	2019	0.15
Regionale refereeravond: Robot assisted surgery	2020	0.15
Guideline discussion (4 times a year)	2018 - 2019	1.5
Scientific update (2 times a year)	2017 - 2020	2.0
Symposium, De standaard prostaatkankerbehandeling bestaat niet.	2017	0.15
Integral Cancer Centre Netherlands		
Theme-night "muscle-invasive bladder cancer, alternatives to a cystectomy" including presentation	2017	1.0
Stichting Werkgroep Endo-urologie Nederland (SWEN)		
Scientific program and site visit in General Hospital Toronto and St. Joseph's Hospital London	2018	2.0
ORSI Academy		
Robotic surgery training in Residents	2019	2.0
Robotic surgery training in Residents	2020	2.0

ORAL AND POSTER PRESENTATION	Year	Workload (ECTS)
The value of a one-day multidisciplinary robot surgery training for novice robot surgeons.		
- Congress Medical Simulation, Time for Change, Dutch society for Simulation in Health care, Enschede, Netherland, Oral presentation	2018	
- 15th Meeting of the EAU Robotic Urology Section, Marseille, France, Poster presentation	2018	
The PROTEST PhD-Project, The analysis of the robot surgeon's skills and origins of complications by analysing the video and movements of the surgical robot during the Robot Assisted Radical Prostatectomy (RARP)		
- Site visit in General Hospital Toronto and St. Joseph's Hospital London, Stichting Werkgroep Endo-urologie Nederland (SWEN), Oral presentation	2018	
The use of multiple video assessment methods to determine the influence of surgical skill on potency and continency in patients after robot-assisted radical prostatectomy		
- 16th Meeting of the EAU Robotic Urology Section, Lissabon, Portugal, Poster presentation	2019	
- 37th World Congres of Endourology, Abu Dhabi, Abu Dhabi, Moderated poster presentation	2019	
- 13th International Workshop: Behavioural Science Applied to Surgery, Amsterdam, Netherlands, Poster presentation	2019	
Linking surgical skills to postoperative outcome, a Dutch Delphi meeting into the Robot Assisted Radical Prostatectomy		
- 16th Meeting of the EAU Robotic Urology Section, Lissabon, Portugal, Poster presentation	2019	
- 13th International Workshop: Behavioural Science Applied to Surgery, Amsterdam, Netherlands, Poster presentation	2019	

A survey on postoperative results analysis and surgical video review of robot-assisted radical prostatectomy: How do they do it?		
17th Meeting of the EAU Robotic Urology Section, Virtual Meeting	2020	
Training novice robot surgeons: Proctoring provides same results as simulator-generated guidance		
17th Meeting of the EAU Robotic Urology Section, Virtual Meeting	2020	
Identifying the relationship between postoperative urinary continence and residual urethra stump measurements in robot assisted radical prostatectomy patients		
17th Meeting of the EAU Robotic Urology Section, Virtual Meeting	2020	
Structured robot-assisted surgery training curriculum for residents in Urology and impact on future surgical activity		
17th Meeting of the EAU Robotic Urology Section, Virtual Meeting	2020	

(INTER)NATIONAL CONFERENCES	Year	Workload (ECTS)
Najaarscongres, Nederlandse Vereniging van Urologie, Nieuwegein, Netherlands	2017	1.0
Najaarscongres, Nederlandse Vereniging van Urologie, Nieuwegein, Netherlands	2018	0.3
OK Transparant, Amsterdam UMC, Amsterdam, Netherlands	2018	0.3
Opereren in de nabije toekomst: Feiten & Fictie III, Stichting Collegium Chirurgicum Neerlandicum, Ede, Netherlands	2018	0.3
Congress Medical Simulation, Time for Change, Dutch society for Simulation in Health care, Enschede, Netherlands	2018	1.0
Congress Medical Simulation, Lets Workt Togheter, Dutch society for Simulation in Health care, Rotterdam, Netherlands	2019	1.0
13th International Workshop: Behavioural Science Applied to Surgery, Amsterdam, Netherlands	2019	2.0
15th Meeting of the EAU Robotic Urology Section, Marseille, France	2018	2.0
16th Meeting of the EAU Robotic Urology Section, Lissabon, Portugal	2019	2.0
37th World Congres of Endourology, Abu Dhabi, Abu Dhabi	2019	2.0
17th Meeting of the EAU Robotic Urology Section, Virtual Meeting	2020	2.0
TEACHING	Year	Workload (ECTS)
Teaching urology residents, including 3 research projects, Catharina Hospital Eindhoven	2018 - 2020	3.0
Hands on training Basic robotic surgery at 16th Meeting of the EAU Robotic Urology Section, Lissabon, Portugal	2019	1.0

Appendix

Dankwoord

Dankwoord

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Appendix

About the author

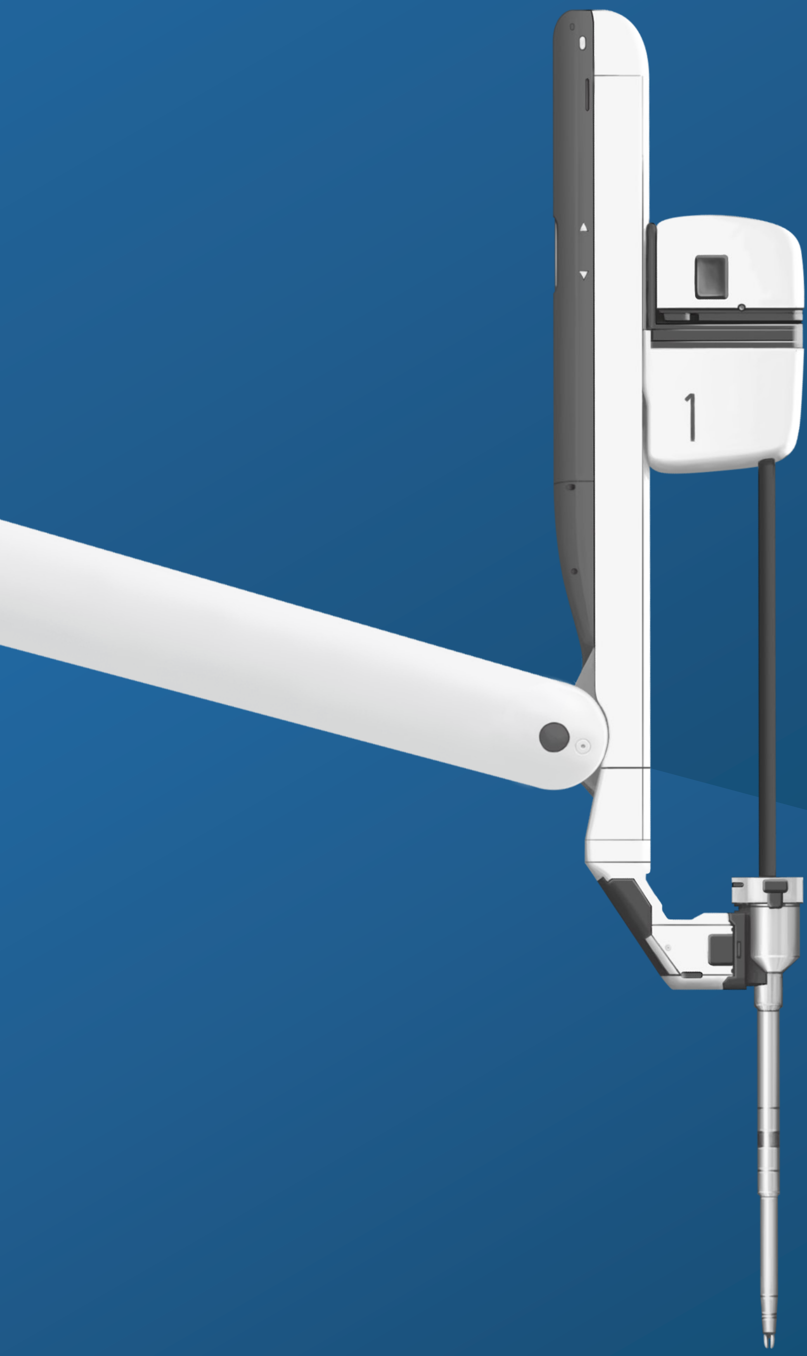
About the author

Alexander Beulens was born in Goes on May 12th 1989. After his General secondary education at St. Willibrordcollege in Goes he studied Biology and Medical Laboratory Research at Avans University of applied sciences in Breda for one year. Thereafter, he completed the last year of secondary education at ROC Vlissingen so he could apply for the study medicine. Since he was not selected to study medicine immediately he started Health Sciences at Maastricht University in 2008. In 2013 he completed his bachelors in General Health Sciences.

In 2011 he was allowed to start medical school at the Maastricht University. From 2014 until 2017, Alexander completed a majority of his rotations at Catharina hospital in Eindhoven. During this period he did multiple elective rotations in Urology at Amphia Hospital, Breda, and Catharina Hospital Eindhoven. Alongside his rotations he started his research activities with Dr. Scheepens in July 2015 at the department of Urology of the Catharina Hospital. After graduation in 2017 he developed and started the “PROTEST” project under supervision of prof. dr. Wagner at the Netherlands Institute for Health Services Research (NIVEL) and Catharina Hospital. At the same time, he fulfilled his clinical activities as resident not in training (ANIOS) at the department of Urology of the Catharina Hospital.

In 2018 he won the Dutch Society for Simulation in Health care (DSSH) International Research Grant. This grant enabled him to go on a academic trip with the Dutch Endo-urology foundation working group (SWEN) to the General Hospital in Toronto, Canada and St. Joseph’s Hospital in London, Canada.

On July 1st 2020 he started the Surgical part (Maxima Medisch Centrum, Veldhoven, programme director: dr. A.J.G. Maaskant) of formal postgraduate training in Urology (cluster South-East Netherlands, Maastricht University Medical Centre, Maastricht, programme director: J.G.H. van Roermund). On March 1st 2022 Alexander resigned from his postgraduate training in Urology, since that date he has started working in the field of Elderly care medicine at Vitalis in Eindhoven. On march 1st 2023 he started his formal postgraduate training in Elderly care medicine at VOSON in Nijmegen and Vitalis in Eindhoven.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