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Original Research

Development and Validation of an Objective Scoring Tool for Robot-Assisted Partial Nephrectomy: Scoring for Partial Nephrectomy

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Abstract

Objective: To develop a structured and objective scoring tool for assessment of robot-assisted partial nephrectomy (RAPN): Scoring for Partial Nephrectomy (SPaN).

Materials and Methods: *Content development*: RAPN was deconstructed into 6 domains by a multi-institutional panel of 10 expert robotic surgeons. Performance on each domain was represented on a Likert scale of 1 to 5, with specific descriptions of anchors 1, 3, and 5. *Content validation*: The Delphi methodology was utilized to achieve consensus about the description of each anchor for each domain in terms of appropriateness of the skill assessed, objectiveness, clarity, and unambiguous wording. The content validity index (CVI) of ≥0.75 was set as cutoff for consensus. *Reliability*: 15 de-identified videos of RAPN were utilized to determine the inter-rater reliability using linearly weighted percent agreement, and *Construct validation* of SPaN was described in terms of median scores and odds ratios.

Results: The expert panel reached consensus (CVI ≥0.75) after 2 rounds. Consensus was achieved for 36 (67%) statements in the first round and 18 (33%) after the second round. The final six-domain SPaN included Exposure of the kidney; Identification and dissection of the ureter and gonadal vessels; Dissection of the hilum; Tumor localization and exposure; Clamping and tumor resection; and Renorrhaphy. The linearly weighted percent agreement was >0.75 for all domains. There was no difference between median scores for any domain between attendings and trainees.

Conclusion: Despite the lack of significant construct validity, SPaN is a structured, reliable, and procedure-specific tool that can objectively assesses technical proficiency for RAPN.

Keywords: robot-assisted, partial nephrectomy, scoring tool, surgical training, assessment

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Introduction

Nephron sparing surgery or partial nephrectomy (PN) is the treatment of choice for renal masses whenever feasible, especially in bilateral or hereditary tumors, solitary kidneys, or in patients with limited renal reserve.[1] Robot-assisted partial nephrectomy (RAPN) has shown superiority in terms of reduced blood loss and faster recovery.[2,3] A review from the National Cancer Data Base database reported increased utilization of robot-assisted approach to PN in up to 63% cases in 2013.[4] The increased adoption of robotics is urologic surgery that has necessitated the development of benchmarks for training and credentialing purposes. The American Urologic Association has emphasized the need for supervised and modular training for robotic procedures before granting independent privileges.[5]

A review by Lee and colleagues strongly recommended development of validated and structured procedure-specific tools for credentialing purposes.[6] They suggested the breakdown of each procedure into predefined steps and the trainee moving from low to high complexity step under structured evaluation and feedback from the mentor.

New robotic surgeons face several challenges; the restriction of working hours imposed by Accreditation Council for Graduate Medical Education resulting in decrease of overall training time, limited access to simulators due to associated prohibitive cost of setting up simulators, and/or animal laboratories for robotic surgery, especially for many training hospitals.[7,8] In addition, the lack of physical proximity during robotic surgery can further affect the training process due to the diminished role of gestures and visual cues in training.[9]

Global Evaluative Assessment of Robotic Skills (GEARS), Assessment of Robotic Console Skills, and Structured Assessment of Robotic Microsurgical Skills are some of the tools for grading technical proficiency of robotic surgeons.[10–13] However, these tools are extremely broad based and do not appreciate the procedure-specific nuance and complexities.[13] RAPN remains a complex procedure with a prolonged learning curve. A study by Larcher and colleagues suggested that while improvement in most parameters plateaued at 150 cases, the learning curve for reducing complications extended even beyond 300 cases.[14] Structured and objective scoring tools that deconstruct such complex procedures can facilitate training, provide specific feedback to improve, and possibly shorten the learning curve.[13] Our group has led expert-based consensus to develop objective and structured procedure specific tools for robot-assisted prostatectomy, cystectomy, hysterectomy, and pelvic lymph node dissection.[15–18] The same principles were utilized in the current study.

In this context, we sought to develop and validate a structured scoring tool, the Scoring for Partial Nephrectomy (SPaN), for objective evaluation and assessment of technical proficiency during RAPN.

Materials and Methods

A multi-institutional collaboration was undertaken between 2018 and 2020 using de-identified videos of 15 RAPNs performed by surgeons of various experience (I-53605). The study comprised three phases:

Phase 1: Content development and validation

An expert panel of 10 experienced robotic surgeons deconstructed the critical steps of RAPN into 6 key steps or domains (Fig. 1). Each domain was assessed on a 1 to 5 Likert scale. Specific descriptions of anchors 1, 3, and 5 were provided on the Likert scale. The description accounted for surgical principles, technical proficiency, and safety of the patient. Anchor 1 represented the worst performance and anchor 5 represented ideal performance for each domain.

The Delphi methodology was utilized for content validation of SPaN structure and content. The anchor descriptions for each of the 6 domains were assessed by the panel for 3 aspects: the appropriateness of the skill assessed; concordance between statement and score assigned; the clarity and unambiguousness of the wording used. Panel members rated each anchor description in terms of the 3 aspects on a Likert score from 1 (strongly disagree) to 5 (strongly agree). An independent coordinator collected the responses and comments from each member of the panel and calculated the content validity index (CVI) for each aspect of each anchor.[19]

CVI is the proportion of experts that rated each anchor description as 4 or 5 on Likert scale. Consensus was achieved if CVI reached ≥0.75 and then the statement was removed from the next round. If CVI was <0.75, the coordinator incorporated the suggestions and redistributed it again to the panel. The process was repeated until consensus was achieved for all statements (Supplementary Fig. S1). Panel members were blinded from each other's review to minimize cognitive bias or the "Bandwagon effect."[20] All surgeons included had 15+ years of experience and all trainees were fellows in their first or second year of fellowship.

Phase 2: Inter-rater reliability

Once consensus was achieved for all anchors for all domains, the next phase was to test the inter-rater reliability (IRR) of SPaN. IRR refers to the ability of SPaN to yield consistent scores when applied by different raters. A total of 15 recorded RAPNs, performed by surgeons with various experience and technical proficiency (attending surgeons and trainees), were further deconstructed into each domain to yield a total of 90 videos (15 videos per domain). Each domain included at least 7 videos for trainees and 7 for attending surgeons (Supplementary Table S1). Randomization of the videos was done at the domain level. Each video was rated by at least 3 members of the panel. Performance scores from 1 to 5 Likert scale were compared between trainee and attending surgeons with an expected difference of at least one point between the two groups.

Each domain had a total of 51 ratings, which resulted in a power of 90%. Each member of the 10-surgeon panel, in addition to 4 more surgeons that were included later, rated 22 videos on average. Our design was balanced in that the minimum number of ratings for the attending and trainee group was 23 and the maximum was 28. Also, scores given between each rater had a standard deviation of 1.1, meaning scores adequately reflected the true score for each video (Supplementary Table S2). The raters were blinded to the operator's level of experience.

Surgeon: ______________________ Trainee: ______________________

Date of Surgery: ______________

Off clamp: Yes ☐ No ☐ Selective Arterial Clamping: Yes ☐ No ☐

Total Ischemia time: ______________

Scoring for Partial Nephrectomy (SPaN)

DOMAINS 1	2	3	4	5
Exposure of the Kidney		**Console surgeon:**		
• Injury to liver, colon,duodenum, spleen, pancreas • Traumatic tissue handling, excessive cautery or traction resulting in bleeding or causing concern for potential injury/thermal injury.		• Inadequate dissection and mobilization of bowel, liver or spleen obscuring safe access to kidney/tumor and hilum. • Poorly defined dissection in/out of surgical planes (i.e. Gerota's fascia or mesentery)		• Adequate dissection and mobilization with full exposure of the kidney and/or tumor and hilum* • Intentional and purposeful dissection along surgical planes. *not all tumors require full mobilization
Identification and Dissection of the Ureter and Gonadal Vessels		**Console surgeon:**		
• Avulsion injury to the gonadal vessels or ureter • Crush or thermal Trauma to ureter • Inability to lift the ureter and kidney to clear psoas attachments		• Early improper entry into Gerota's fascia • Excessive dissection/skeletonization or use of cautery on or near ureter concerning for potential injury • Mishandling of gonadal vein causing bleeding • Ureter not fully cleared off psoas attachments		• Identification and dissection of ureter and gonadal vessels without major bleeding or trauma. • Right: ureter cleared from psoas attachments enabling lateral retraction of the kidney and access to hilum • Left: Gonadal vessels and ureter cleared from psoas attachments enabling lateral retraction of the kidney and access to hilum
Dissection of the Hilum		**Console surgeon:**		
• Hilum obscured by tissue • Injury to the aorta, IVC, renal, adrenal or lumbar vessels • No retraction provided during hilar dissection		• Incomplete dissection and exposure of renal artery or its branches jeopardizing clamping • Minor bleeding but adequately controlled • Partially obscured hilum limiting ability to discern existence of additional vessels • Inadequate clearance of posterior attachments to psoas • Inadequate traction during hilar dissection raising concern for vascular injury during dissection.		• Adequate exposure of hilum with complete visualization of renal artery/branches for clamping
Tumor Localization and Exposure		**Console surgeon:**		
• Gross disruption of the renal capsule due to renal handling (not due to sticky fat) requiring cautery or mobilization • Violation of the tumor • Inability to define the tumor • Failure to define endophytic tumors with Ultrasound		• Minor disruption of capsule due to renal handling(not due to sticky fat) not requiring renorrhaphy or hemostasis • Inadequate renal capsule/fat exposure adjacent to the intended resection margin • Difficulty withtumor margin identification using Ultrasound		• Defatting allowing visualization and access of tumor and surrounding tissue • No renal capsular injury or tumor violation • Optimal utilization of Ultrasound to define tumor margins
Clamping and Tumor Resection		**Console surgeon:**		
• Uncontrollable bleeding resulting in inadequate visualization • Gross entry into the tumor • Improper placement and removal of the vascular clamp • Excessive removal of normal parenchyma (>1 cm margin) • Failure of tumor resection significantly delaying warm ischemia time (twice as long as the expected)		• Arterial bleeding obscuring the field (addressed by readjusting the clamps) • Excessive removal of parenchymal (<1cm) with subsequent correction of anatomic plane during tumor resection • Slow tumor resection due to uncertainty of tumor margins adding to warm ischemia time (50% longer than expected time) • Rough handling of the tumor raising concerns about potential violation of the tumor		• Complete tumor removal without excessive renal parenchymal excision • Gentle and appropriate handling of the kidney • Optimal vascular control • Efficient tumor resection of tumor margins with acceptable warm ischemia time
Renorrhaphy		**Console surgeon:**		
• Ongoing arterial bleeding requiring re-clamping • Collecting system defect not addressed • Major Renal trauma (poor needle handling technique) resulting in significant bleeding • Cortical laceration/suture tear through resulting in major bleeding • Inefficient renorrhaphy resulting in significant addition of warm ischemia time (twice as expected time).		• Suboptimal hemostasis (requiring additional sutures but not re-clamping) • Suboptimal/incomplete closure of the collecting system • Minor Renal trauma (poor needle handling technique) without significant bleeding • Cortical laceration/suture tear through resulting without significant bleeding • Suboptimal capsular closure concerning for future bleeding • Difficulty in renorrhaphy adding to warm ischemia time (50% of expected time)		• Complete hemostasis • Adequate closure of the collecting system • No significant parenchymal injury solid • Outer layer closure without concern for subsequent bleeding • Efficient renorrhaphy with minimal warm ischemia time

FIG. 1. Scoring for Partial Nephrectomy.

Phase 3: Construct validation

Construct validity is the ability of SPaN to differentiate between attending surgeons and trainees, based on the score received. Scores for each domain were compared between attending surgeons and trainees.

Statistical analysis

Descriptive statistics were utilized to depict the scores for each domain. IRR was assessed using linearly weighted percent agreement. Construct validation was assessed by comparing median scores between attending surgeons and trainees using Wilcoxon rank sum and computing odds ratios (ORs). Statistical significance was set at α level 0.05. All statistical analyses were performed using SAS® software (version 9.4; SAS Institute Inc., Cary, NC).

Results

Content development and validation

The expert panel reached consensus (CVI ≥0.75) after two rounds on all aspects for all anchors (Table 1). Consensus was achieved for 36 (67%) statements in the first round and 18 (33%) after the second round. A seventh domain dedicated for examining ischemia time was combined with renorrhaphy based on the panel consensus. The final domains of SPaN included Exposure of the kidney; Identification and dissection of the ureter and gonadal vessels; Dissection of the hilum; Tumor localization and exposure; Clamping and tumor resection; and Renorrhaphy (Fig. 1).

Reliability

The linearly weighted percent agreement was substantial (>75%) for all domains. The agreement was highest for domain 4 (Tumor localization and exposure) at 0.82, and lowest for domain 2 (identification and dissection of the ureter and gonadal vessels) at 0.76 (Table 2).

Construct validation

Attending surgeons achieved higher scores for domain 2 (identification and localization of the gonadal vessels and the ureter) (4 *vs* 3 OR 1.16, 95% confidence interval [CI] 0.73–1.85) and domain 6 (Renorrhaphy) (5 *vs* 4; OR 1.73; 95% CI 0.89–3.36) but did not reach statistical significance. Both groups achieved similar median scores for the remaining domains (Table 3).

Discussion

Training, mentorship, assessment, and feedback in the real operating room environment continue to be the gold standard for surgical training. This necessitates the development of objective and reliable methods to supervise the safe transfer of surgical skills in the operating room. Utilization of robot-assisted approach has significantly increased for major urologic procedures in past two decades.[21] However, there is lack of standardized definitions of what constitutes technical proficiency, and lack of objective tools for competency evaluation.[6] Traditionally, the number of surgeries performed or console hours have been used as surrogates of technical competence, despite the limited evidence to support this approach.[22] General scores, such as GEARS have been developed and validated for assessment of generic robotic skills. The modular-based training approach suggested by the European Association of Urology Robotic Urology Section (ERUS) incorporates the use of GEARS in evaluation of technical proficiency.[11]

Table 1. Characteristics of the 10-Surgeon Panel That Participated in Scoring for Partial Nephrectomy Content Development and Validation

Panel characteristics	n *(%)*
Age (years)	
40–55	9 (90)
>55	1 (10)
Experience (years)	
<10	3 (30)
10–20	6 (60)
>20	1 (10)
Training in robotic surgery	
Robotic surgeries performed	
250–500	1 (10)
>500	9 (90)
Robotic partial nephrectomies performed	
<250	3 (30)
250–500	3 (30)
>500	4 (40)
Procedural preferences	
Selective clamping	
Yes	1 (10)
No	4 (40)
Sometimes	5 (50)
Use ICG	
Yes	3 (30)
No	5 (50)
Sometimes	2 (20)
Off-clamping	
Yes	1 (10)
No	2 (20)
Sometimes	7 (70)
Institutional characteristics	
Annual urologic procedures >500	7 (70)
Annual PN volume >50	10 (100)
Proportion of RAPN >50%	9 (90)
All PN performed robot-assisted	6 (60)

ICG = indocyanine green; PN = partial nephrectomy; RAPN = robot-assisted partial nephrectomy.

Table 2. Inter-Rater Reliability for Each Domain of Scoring for Partial Nephrectomy, Using Linearly Weighted Percent Agreement

Domains	*Agreement*
Exposure of the kidney	0.78
Identification and dissection of the ureter and gonadal vessels	0.76
Dissection of the hilum	0.77
Tumor localization and exposure	0.82
Clamping and tumor resection	0.78
Renorrhaphy	0.78

TABLE 3. CONSTRUCT VALIDATION FOR SCORING FOR PARTIAL NEPHRECTOMY: MEDIAN SCORE FOR TRAINEES AND ATTENDINGS

Domains	*Median (IQR) trainee score*	*Median (IQR) attending surgeon score*	*OR*	*95% CI*
Exposure of the kidney	4 (3–5)	4 (3–4)	0.67	0.40–1.14
Identification and dissection of the ureter and gonadal vessels	3 (3–4)	4 (3–5)	1.16	0.73–1.85
Dissection of the hilum	4 (3–5)	4 (3–4)	0.88	0.50–1.53
Tumor localization and exposure	4 (3–5)	4 (4–5)	1.13	0.70–1.81
Clamping and tumor resection	4 (3–5)	4 (3–4)	0.81	0.49–1.35
Renorrhaphy	4 (3–5)	5 (3–5)	1.73	0.89–3.36

CI = confidence interval; IQR = interquartile range; OR = odds ratio.

Other automated and objective tools that utilize surgical kinematics, pupillary response, and intrasurgery cognitive assessment have also shown promise in skill assessment.[23–25] However, they lack assessment of procedure-specific skills.[11] While generalized assessment tools are helpful, especially at the beginning of training, there is need for more detailed procedure-specific tools as training progresses. These should address and account for specific nuances and complexities of a procedure. The goal of SPaN as a training tool for partial nephrectomy aligns with the objectives and training approaches suggested by ERUS while providing a procedure-specific scoring method to assess technical proficiency. Compared to the generalized scoring tool GEARS, SPaN can identify specific weaknesses in technical performance given its procedure-specific approach. Utilization of SPaN in the training setting can aid mentors in providing objective and useful advice and help tailor training activities based on individual weaknesses.

We utilized the Delphi methodology to achieve a consensus among a panel of expert robotic surgeons for each domain and its respective anchors. This was done with emphasis on sound surgical technique, meeting oncologic principles, and maintaining patient safety. RAPN remains a challenging procedure with a prolonged learning curve. Deconstruction of the procedure into well-defined surgical steps, complying with the principles of modular training (where trainees move to a more complex surgical step after mastering the simpler ones), can therefore facilitate the training and may help shorten the learning curve.

While SPaN yielded consistent results when applied by different raters, construct validation was not statistically significant. Attending surgeons outperformed trainees in only two domains that did not reach statistical significance. Trainees achieved similar scores to attending surgeons in the remaining four domains. One explanation is that since RAPN remains one of the most challenging procedures, usually trainees with relatively higher experience, such as graduating fellows, will be performing parts of RAPN and are proficient enough to receive similar scores to that of an attending, limiting the differences between attending surgeons and trainees.

In addition, owing to the complexity of the procedure, there is greater oversight of the trainee with immediate correction by the supervising surgeon if there is any deviation from the correct technique. Also, smaller differences may require larger sample size to detect. In this study, the concept of construct validation was based on the assumption that a more experienced surgeon (an attending) will outperform a less experienced surgeon (fellow), which is likely true in most, but not essentially all cases. This is considered a limitation for our approach.

Review of surgical videos by expert surgeons has an established role in surgical training.[26] However, this remains subject to variation because of the lack of standardized criteria for what constitutes technical proficiency. The use of predefined criteria established by expert surgeons consensus with an associated score can help solve this problem, provide objective and structured feedback for trainees, and help tailoring the training process, with more focus on the less proficient steps.[27] Specific descriptions facilitate and improve assessment, even when performed by lay person. There has been increased interest for crowdsourced assessment of surgical skills.[28] Apart from monitoring trainee progress, SPaN may also have a role in auditing, credentialing, and helping with surgeon remediation.

There is growing interest in automating the evaluation of surgical skills. Attempts have been made to use motion tracking, computer vision, and machine learning techniques to assess surgical performance.[29,30] Automated evaluation often relies on deconstruction of the surgery into subcomponents and use of validated scoring tools, followed by machine learning.[31] The development of SPaN may serve as a platform for the development of automated method for evaluation of RAPN.

While SPaN provides a reliable, user-friendly, and structured tool to assess RAPN, some limitations exist. The relatively small sample size may have contributed to the lack of construct validation. Power calculation was based on the differences expected from our previous studies. However, the differences observed between the attendings and trainees were smaller than expected, which would require a larger sampler size to elucidate. SPaN did not provide account for specific technical variations, such as enucleation *vs* wide resection, selective clamping, or off-clamp PN, or the fact that some surgeons do not necessarily dissect the ureter or gonadal vein during partial nephrectomy. SPaN does not account for patient (e.g., body mass index or prior surgery) or procedural complexity (e.g., Nephrometry score) and, also, the lack of predictive validity and correlation with clinical outcomes, which were not the focus of the current study.

All trainees were in their first or second year of fellowship, but specific demographics were not collected. Finally, SPaN focused on technical proficiency and does not include other important nontechnical skills such as communication, teamwork, leadership, and decision-making. Time to complete each task was not used as a metric as the focus was on the technical aspect of the task and not on the time to complete the task.

Conclusion

SPaN is a structured, reliable, and procedure-specific tool that assesses the technical proficiency of RAPN. It can be used to provide specific feedback to trainees and help tailor training activities despite lack of construct validity.

Authors' Contributions

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the article. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the Journal of Endourology.

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Supplementary Material

Supplementary Table S1
Supplementary Table S2
Supplementary Figure S1

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Abbreviations Used

CI = confidence interval
CVI = content validity index
ERUS = European Association of urology Robotic Urology Section
GEARS = Global Evaluative Assessment of Robotic Skills
ICG = indocyanine green
IQR = interquartile range
IRR = inter-rater reliability
ORs = odds ratios
PN = partial nephrectomy
RAPN = robot-assisted partial nephrectomy
SPaN = Scoring for Partial Nephrectomy