Use of Automated Performance Metrics to Measure Surgeon Performance during Robotic Vesicourethral Anastomosis and Methodical Development of a Training Tutorial

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Purpose: We sought to develop and validate automated performance metrics to measure surgeon performance of vesicourethral anastomosis during robotic assisted radical prostatectomy. Furthermore, we sought to methodically develop a standardized training tutorial for robotic vesicourethral anastomosis.

Materials and Methods: We captured automated performance metrics for motion tracking and system events data, and synchronized surgical video during robotic assisted radical prostatectomy. Nonautomated performance metrics were manually annotated by video review. Automated and nonautomated performance metrics were compared between experts with 100 or more console cases and novices with fewer than 100 cases. Needle driving gestures were classified and compared. We then applied task deconstruction, cognitive task analysis and Delphi methodology to develop a standardized robotic vesicourethral anastomosis tutorial.

Results: We analyzed 70 vesicourethral anastomoses with a total of 1,745 stitches. For automated performance metrics experts outperformed novices in completion time ($p < 0.01$), EndoWrist® articulation ($p < 0.03$), instrument movement efficiency ($p < 0.02$) and camera manipulation ($p < 0.01$). For nonautomated performance metrics experts had more optimal needle to needle driver positioning, fewer needle driving attempts, a more optimal needle entry angle and less tissue trauma (each $p < 0.01$). We identified 14 common robotic needle driving gestures. Random gestures were associated with lower efficiency ($p < 0.01$), more attempts ($p < 0.04$) and more trauma ($p < 0.01$). The finalized tutorial contained 66 statements and figures. Consensus among 8 expert surgeons was achieved after 2 rounds, including among 58 (88%) after round 1 and 8 (12%) after round 2.

Conclusions: Automated performance metrics can distinguish surgeon expertise during vesicourethral anastomosis. The expert vesicourethral anastomosis technique was associated with more efficient movement and less tissue trauma. Standardizing robotic vesicourethral anastomosis and using a methodically developed tutorial may help improve robotic surgical training.

Key Words: prostatic neoplasms; robotic surgical procedures; anastomosis, surgical; education; task performance and analysis

Abbreviations and Acronyms

APM = automated performance metric

CTA = cognitive task analysis

CVI = content validity index

NAPM = nonAPM

RRP = robotic assisted radical prostatectomy

VUA = vesicourethral anastomosis

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To view the accompanying video, please see the online version of this article (Volume 200, Number 4) at http://jurology.com/.

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PROSTATE cancer is the second most prevalent cancer to affect males in the United States and it is the third most common cause of cancer death.[1] Based on internal estimates of the NIS (Nationwide Inpatient Sample) (https://www.hcup-us.ahrq.gov/nisoverview.jsp), the HCUP (Healthcare Cost and Utilization Project) (https://www.ahrq.gov/research/data/hcup/index.html), Truven Health Analytics (https://truvenhealth.com/) and Intuitive Surgical® (https://www.intuitivesurgical.com/) RRP accounts for 87% of surgeries performed for prostate cancer in the United States. VUA is the critical reconstructive step of RRP for it directly affects patient Foley catheter duration[2] and urinary continence recovery.[3,4] VUA is also one of the technically demanding steps of RRP requiring sophisticated bimanual dexterity and instrument manipulation.

Our experience with structured learning in robotic surgery illustrates the benefit of graduated stepwise teaching of surgery.[5] By deconstructing the entire complex procedure into relatively simple tasks trainees mastered surgical skills more effectively and efficiently. Surgical technical skill assessment tools provide feedback on surgical skills and knowledge but they are mostly not procedure specific or deconstructed.[6–8] Procedure specific assessment such as the PACE (Prostatectomy Assessment and Competency Evaluation) offers stepwise surgical skill evaluation and knowledge feedback for RRP in a relatively broad stroke.[9] The RACE (Robotic Anastomosis Competency Evaluation) provides general instructions on robotic anastomosis technique.[10] However, due to the complex nature of the anastomosis we believe that the technique required to perform an excellent VUA needs to be further explored.

Using a novel data recording device, the dVLogger (Intuitive Surgical, Norcross, Georgia), automated robotic performance metrics including instrument motion tracking metrics and system events recorded in Cartesian coordinates as well as synchronized surgical footage can be captured directly from the da Vinci® robotic surgical system in real time during the live surgical procedure. In our original pilot study we identified and validated certain metrics during RRP that can distinguish surgeon expertise.[11]

CTA is the extension of traditional task analysis techniques to yield knowledge from observable task performance.[12] CTA uses various interview and observation strategies to capture a description of the explicit and implicit knowledge that experts use to perform complex tasks.

In this study we evaluated robotic VUA performance via APMs and NAPMs. We also proposed a needle driving gesture classification system and compared the efficiency of gestures using APMs and NAPMs. Finally we applied surgical task deconstruction, CTA and Delphi methodology to develop a standardized VUA tutorial for training purposes at our institution.

MATERIALS AND METHODS

Phase 1: Construct Validation of Automated and Nonautomated Performance Metrics during Vesicourethral Anastomosis

We reviewed and studied VUAs during RRPs recorded by the dVLogger from August 2016 to May 2017. The dVLogger recorded APMs at 50 Hz, including robotic kinematic data (suturing completion time and instruments path length), system event data (camera movement) and EndoWrist® instrument articulation (fig. 1).[11] Additionally, synchronized surgical videos were captured as endoscopic views at 30 frames per second. These VUA videos were blindly and independently reviewed by 2 research associates (JC and NC) to manually capture NAPMs (see Appendix).

The suturing movement of each stitch placed in the VUA was broadly categorized into 3 phases, including needle positioning, needle driving and suture cinching (fig. 2). Needle positioning was further delineated by needle to needle driver position and needle entry angle. The optimal needle position was the posterior third of the needle in the driver with a perpendicular needle entry. Needle driving was assessed in the context of tissue trauma and the robotic needle driving gesture that was used. Tissue trauma was categorized as any visible tissue tearing, accidental suture disruption or more than 3 attempts required to successfully drive a needle.

Any disagreements on the NAPM value assignment were then resolved by discussion between the 2 research assistants until consensus was reached. APMs and NAPMs were compared between experts with 100 or more console cases and novices with fewer than 100 using a mixed effect statistical model (construct validation).

Phase 2: Development of Needle Driving Gesture Classification System

Robotic needle driving gestures were manually annotated stitch by stitch (fig. 3). Movement with the palm of

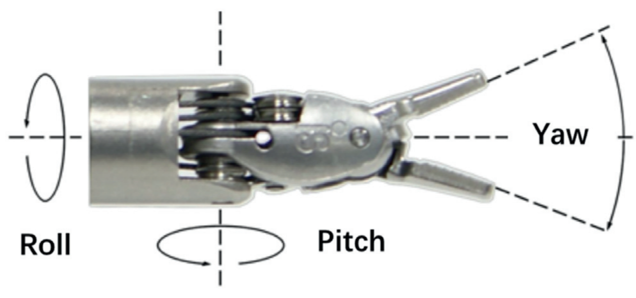

Figure 1. EndoWrist needle driver motion, including roll (rotation along instrument shaft), pitch (instrument wrist joint rotation) and yaw (instruction jaw opening).