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Nathan Schuler

Lauren Shepard

Tyler Holler

Craig G. Rogers

Riccardo Autorino

See next page for additional authors

Authors

Nathan Schuler, Lauren Shepard, Tyler Holler, Craig G. Rogers, Riccardo Autorino, Sammy Elsamra, Simone Crivellaro, Jean Joseph, and Ahmed Ghazi

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Pilot evaluation of a perfused robot-assisted partial nephrectomy procedural simulation platform for single port robotic retroperitoneal approaches

Nathan Schuler [a,*], Lauren Shepard [a], Tyler Holler [a], Craig Rogers [b], Riccardo Autorino [c], Sammy Elsamra [d], Simone Crivellaro [e], Jean Joseph [f], Ahmed Ghazi [a,f]

[a] *University of Rochester Medical Center, Department of Urology, Simulation Innovation Lab, Rochester, NY, USA*
[b] *Henry Ford Health System, Detroit, MI, USA*
[c] *Case Western Reserve University, Department of Biomedical Engineering, Cleveland, OH, USA*
[d] *Department of Urology, Rush University, Chicago, IL, USA*
[e] *Health Sciences System, Department of Urology, University of Illinois Hospital, Chicago, IL, USA*
[f] *University of Rochester Medical Center, Department of Urology, Rochester, NY, USA*

A B S T R A C T

Objective: In this study our objective was to develop a simulation platform for use cases in Laparoendoscopic Single Site (LESS) Surgery intended for patient-specific rehearsal prior to Robot-assisted Partial nephrectomy procedures.
Patients and Surgical Procedure: This represents a simulation platform requiring no patients, although the fabrication process allows for the platform to be patient-specific. Tissue phantom 3D models were developed from de-identified CT imaging fulfilling the criteria of tumors located in the posterior lower pole of the kidney.
Results: Respondents completed surveys on platform novelty and effectiveness. Agreement on simulator novelty was unanimously positive (100% agree or better). Performance evaluations reached a minimum of 80% agreement for all categories, with zero respondents
Conclusions: We have developed a highly realistic simulation platform for use in single-port robot-assisted partial nephrectomy that can be produced in a patient specific manner, which we believe will be highly useful for trainees as well as experts attempting to transfer skills to the newer platform.

Introduction

In the past few years, single-site surgery has been adopted to reduce port-related complications, improve recovery time, lessen pain and improve cosmesis [1]. Single-site robot assisted partial nephrectomy using the standard robot has shown limited diffusion even by experienced surgeons [2]. However, the recent introduction of the da Vinci SP (Intuitive Surgical, Sunnyvale, CA) surgical platform has shown promising results with the added benefit of its ability to conform to small spaces that would be ideal for a retroperitoneal kidney approach [3]. Our objective was to develop a simulation platform for training in SP retroperitoneal RAPN using similar technology to our validated transperitonal robotic partial nephrectomy model, using the same 3D printing and hydrogel casting technology.

Design and model assembly

Segmenting patient-specific kidney to generate 3D models

The patient CT DICOM images were loaded into Materialize Mimics Innovation Suite and segmented to generate patient-specific 3D CAD model of the kidney, tumor, calyx, vein, and artery. Postprocessing generated injection molds from negatives of the kidney, tumor, and hilar structures.

Design of the molding box

A contoured box was designed using 3D modeling software, replicating the intra-abdominal space surrounding the kidney. Included were contours for the lower ribs, iliac crest, spine, and psoas, emphasizing realistic interactions while making initial incisions and during balloon

* Corresponding author.
E-mail address: nathan.a.schuler@gmail.com (N. Schuler).

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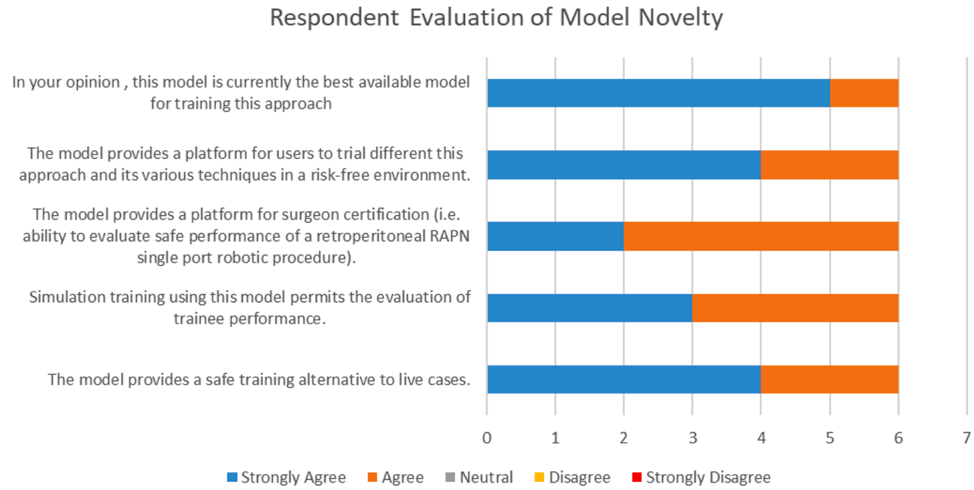

Fig. 1a. Survey data on simulator novelty.

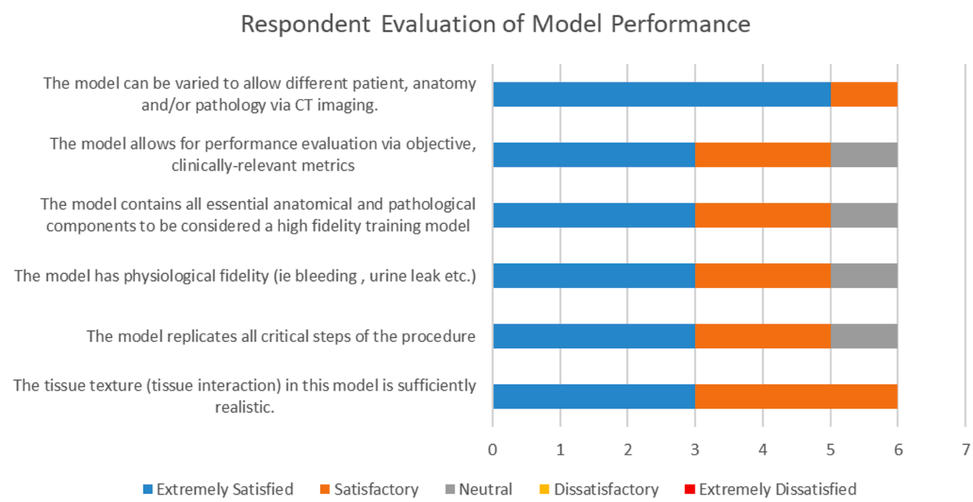

Fig. 1b. Survey data on simulator performance
No patients were used, thus no consent needed.

dilatation. Rib contours were derived from bone structures segmented using Mimics Innovation Suite. Additional considerations were made for locations of the Abdominal Aorta (AA) and Inferior vena cava (IVC).

Model production

Patient specific vasculature was created by molding Poly-vinyl alcohol (PVA) hydrogels, which was then used to create a realistic replica of the patient kidney, with respect to both patient anatomy and mechanical properties of the hydrogel kidney. Previous work with force testing on PVA hydrogels validated their ability to mimic the physical properties of renal tissue [4]. The kidney wrapped in a simulated Gerota's Fascia, attached to a simulated muscle sheet, and connected to the hydrogel AA and IVC. After fixing the complete model to the 3D-printed holder, a hydrogel abdominal wall with a simulated peritoneal pouch containing hydrogel bowels was fixed to the outer edges of the holder with sufficient tension to mimic the elastic rebound of an insufflated abdomen.

Results

Respondents completed surveys on the novelty and effectiveness of the platform. Agreement on simulator novelty was unanimously positive (100% agree or better) (Fig. 1a). Performance evaluations reached a minimum of 80% agreement for all categories, with 100% of feedback rated as neutral or better (Fig. 1b).

Discussion

Use of 3D printing for patient-specific applications in partial nephrectomies is not a new phenomenon [5], however these technologies are typically limited to hard plastic models, and not related to physical simulations for procedural rehearsal. Our previous work created a simulation platform for use in multi-port RAPN applications, but without whole-procedural complexity [6]. Substantial differences exist here with the inclusion of access, finger dissection, port insertion, and improved realism in tissue interactions. Specifically, port location placement represents a known challenge associated with the single port platform [7]. Single Port robots are a recently developed technology, with availability limited to centers of excellence around the country. Low availability of both robots and surgeons with expert-level proficiency in their use has contributed to slow adoption, and limited ability to train new surgeons [8]. Differences between the multi-port and single-port robot movement and instrumentation highlight challenges in adapting existing training curricula to fit single port robots, and there are no standardized curricula for single port training. Our previous work showed that surgical skills do not completely transfer between single port and multi-port platforms, even among experienced surgeons, necessitating curricula for novices as well as bridge curricula for experienced surgeons [9]. This hydrogel-based platform offers the ability to train in an environment with high fidelity to live cases, without incurring any risk to patients. One limitation of this study is a small sample size, however this study represents a pilot evaluation of a training platform in an emerging field.

Conclusions

This realistic simulation procedural platform for robot assisted single port retroperitoneal renal surgery provides a suitable training medium for training and experienced urologists to improve the skills required to adopt this approach using the single port robotic platform. As adoption of these technologies becomes more widespread, there will be increased need for safe, effective training in their use. Similar validation to our transperitoneal multiport platforms regarding the ability of this platform to differentiate between various levels of experience and the effectiveness of this platform to transfer skills acquired in the simulated environment to the live surgical environment is required.

The video related to this article can be found online at: doi:10.1016/j.urolvj.2023.100225.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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