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BRIEF COMMUNICATION

Novel simulator for robotic surgery

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Abstract Surgical simulation avoids practicing skills in patients, allowing trainees to learn in a safe, controlled, and standardized environment. Current robotic surgical simulators available include virtual reality simulators, human cadavers, and live animals. The use of cadavers has the highest possible fidelity available to practice entire operations. Nevertheless, their cost, availability, tissue compliance, and infection risk outweigh the advantages of cadaver models. Drawbacks of using live animals include anatomical differences with humans, high costs due to their housing and handling requirements, and ethical concerns. We designed a novel robotic surgical simulator based on porcine perfused tissue blocks that allows the simulation of entire surgical procedures. Our simulation allows trainees to increase familiarity with the robotic console and its controls, as well as with the docking process. It provides an opportunity to learn not only universal skills needed in robotic surgery, such as camera and instrument targeting, but also to perform complete surgical procedures such as an antireflux procedure. The adoption of robotic simulation curricula with realistic models will decrease overall operative time while increasing resident participation.

Keywords Simulation · Training · Robotic surgery

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Surgical simulation is particularly attractive because it avoids practicing skills in patients, allowing trainees to learn such skills in a safe, controlled, and standardized environment [1, 2]. In addition, changes in the health care system such as a decrease in the work hours for residents, a decrease in available operating room (OR) time, and hospital safety regulations, make almost impossible to acquire all necessary skills in a purely clinical environment [3].

The number of robotic surgical procedures continues to increase rapidly worldwide [4, 5]. Advantages of robotic-assisted surgery include improved visibility of the operative field with three-dimensional imaging, increased degrees of freedom of surgical movements, and improved ergonomics. Robotic surgical skills are unique and not derivative of either open or laparoscopic surgery. Acquisition of those skills in a simulation laboratory, rather than in the OR, has significant advantages for trainees, hospitals, and patients. Current robotic surgical simulators available include virtual reality simulators, human cadavers, and live animals. A number of virtual reality simulators are commercially available, being the Da Vinci skill simulator (dVSS) the most preferred in terms of ergonomics and usability [6]. While the dVSS has been shown to offer high-fidelity training [7], it does not allow the replication of entire surgical procedures, and has a very high initial cost of system acquisition. The use of cadavers has the highest possible fidelity available to practice entire operations. Nevertheless, their cost, availability, tissue compliance, infection risk, and inability to simulate complications such as bleeding outweigh the advantages of cadaver models. Live animal models, on the other hand, provide access to a wide variety of procedures and allow training in realistic conditions. Drawbacks of using live porcine models include anatomical differences with humans, and high costs due to their housing and handling requirements.

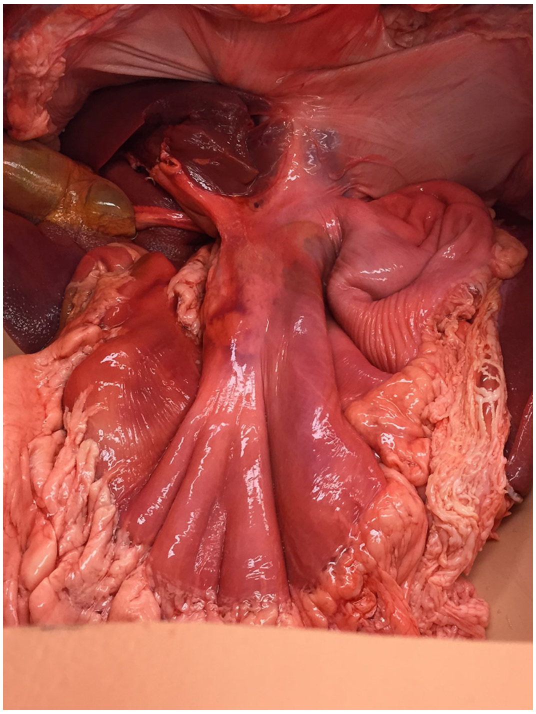

Fig. 1 Tissue block mounted in a human mannequin

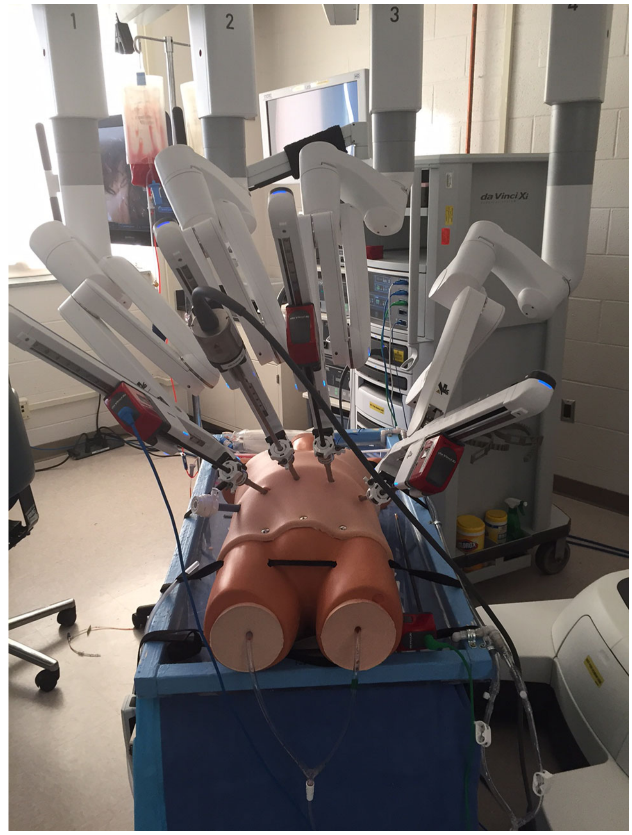

Fig. 2 Port placement and docking on the simulation model

Rehman et al. [8] reported that utilizing live porcine model for robotic training represented a per lab cost of $1093.40 without accounting for veterinarian, technician, and surgical educator personnel expenditures. In addition, live animals are not universally available because of ethical or national legal restrictions.

We designed a novel robotic surgical simulator that allows the simulation of entire surgical procedures. The simulation model is based on porcine tissue blocks that include lungs, heart, aorta, esophagus, diaphragm, stomach, duodenum, liver, and spleen. The tissue is preserved in an alcohol-based solution (alcohol 20%) that retains fresh tissue characteristics for several weeks. We perform anatomical modifications to the block, to counteract the pig's anatomy differences as compared to humans: the liver and the spleen are reduced in size to simulate the human anatomy, and part of the thick muscular portion of the diaphragmatic pillars is resected to mimic a human diaphragmatic hiatus. The abdominal aorta is cannulated, and the tissue block is perfused with artificial blood (Crime scene thin blood, Manhattan Wardrobe Supply). The tissue block is then mounted in a mannequin (Fig. 1). The anterior abdominal wall is constructed with a smooth-on product (Dragon Skin FX-Pro) which is poured into a thin sheet about ¼″ thick and attached to the mannequin with marine grade snaps to secure it in place. The thickness of the silicone allows for the placement of trocars for robotic surgical training (Fig. 2). The model is then covered with surgical drapes to simulate a clinical environment (Fig. 3).

We conducted a three-day robotic simulation course using our model at the University of North Carolina. Ten senior residents participated in the course, and each of them performed a Nissen fundoplication with the Da Vinci Surgical System Si (Intuitive Surgical, Inc.) under the supervision of three attending surgeons. The gastrohepatic ligament was divided into the right pillar of the crus. The peritoneum and the phreno-esophageal membrane overlying the esophagus were transected and the left pillar of the crus was then separated from the esophagus. The short gastric vessels were divided, starting midway along the greater curvature of the stomach towards the left pillar of the crus. The posterior and anterior vagus nerves were clearly identified and preserved. A window was created between the stomach, the left pillar of the crus and the esophagus. A Penrose drain was placed around the esophagus, also incorporating the anterior and posterior vagus nerves. The right and left pillar of the crus were approximated using non-absorbable sutures, placed posterior to the esophagus. The stomach was passed behind the esophagus and a shoe-shine maneuver was performed to verify sufficient fundic mobilization. A 360° fundoplication was created by placing three stitches at 1-cm intervals to approximate the right and left side of the fundoplication (Fig. 4).

All the participants considered that the model was very realistic in terms of operative space and feedback during

Fig. 3 Setup of the simulation laboratory offering a realistic clinical setting

suturing and while using energy devices. In addition, all the instructors thought that the model was an excellent training tool for residents, and that it should replace live-animal models. Our simulation allows trainees to increase familiarity with the robotic console and its controls, as well as with the docking process. It provides an opportunity to learn not only universal skills needed in robotic surgery, such as camera and instrument targeting, but also to perform complete surgical procedures such as an antireflux procedure. This model also allows to train in Heller myotomy and sleeve gastrectomy. We are currently working on perfused tissue blocks with large bowel that will allow to train in robotic colonic resections.

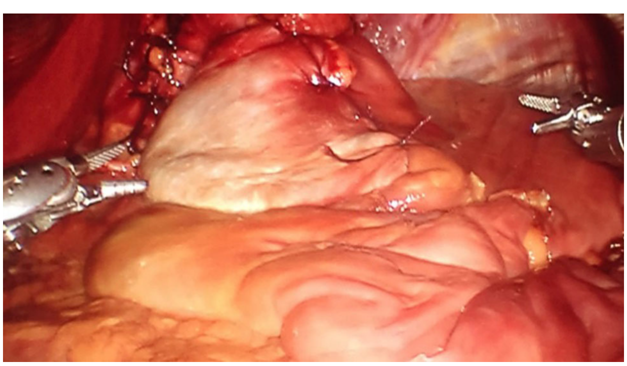

Fig. 4 Robotic Nissen fundoplication on the simulation model

The adoption of robotic surgery in a residency program can be challenging. Mehaffey et al. [9] reported that the introduction of robotic surgery had a considerable negative impact on laparoscopic case volume and significantly decreased resident participation. At their institution, trainees participate in every laparoscopic case, whereas residents only operated at the console in 22% of the robotic cases [9]. We strongly believe that the adoption of robotic simulation curricula with realistic models will decrease overall operative time while increasing resident participation.

To our knowledge, this is the first report regarding the use of perfused tissue blocks to train in robotic surgery. We believe that this model can avoid the use of live animals for robotic surgical training, offering realistic simulation without high expenses and ethical concerns. Further validation studies are needed to assess if skills acquired by our surgical simulator are transferable to the clinical setting.

Compliance with ethical standards

Conflict of interest Francisco Schlottmann, MD declares that he has no conflict of interest. Marco G. Patti, MD declares that he has no conflict of interest.

Ethical approval All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Statement of human and animal rights This study does not contain any studies with human participants performed by any of the authors.

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