Surgical simulation in robot-assisted thoracoscopic surgery: future strategy

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Abstract: Robot-assisted thoracoscopic surgery (RATS) is used worldwide and has become an established approach for primary lung cancer and other chest diseases. Complicated and unique surgical skills needed for RATS, which are different from those for open thoracotomy and video-assisted thoracoscopic surgery, make it necessary for thoracic surgeons to undergo surgical training and obtain such skills using via surgical simulators. In this brief review, we outline and discuss current surgical simulations for RATS and provide an outlook of the future, when technical innovations will yield further developments for thoracic surgery.

Keywords: Robot-assisted thoracoscopic surgery (RATS); training; surgical simulation

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Introduction

In recent years, robotic surgery has been widely conducted not only in the abdominal and pelvic regions, but also in the chest region. Robot-assisted thoracoscopic surgery (RATS) is now used worldwide and has become a standard surgical approach for primary lung cancer and other chest diseases. The da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA), as a representative of such systems, has several clear technical advantages: (I) a three-dimensional (3D) visual field that can be magnified up to 10 times; (II) articulated joint forceps with seven degrees of freedom; and (III) use of a motion scaling function that prevents camera shaking (1,2). Despite these assets, it is also true that most surgical robots provide no tactile feedback from their arm instruments and 3D vision is the only feedback provided to the surgeon during a robotic-assisted procedure. This lack of tactile sense is a major disadvantage of robotic surgery; therefore, it is important for thoracic surgeons to perform training via virtual reality as well as actual practice on rubber or plastic parts before performing RATS (3). Linsky *et al.* stated surgical simulation is a highly important aspect of training in RATS, and thoracic surgeons should know how to maneuver and use the surgical robot before operating on a live patient. They also suggested the robotic platform is likely superior to other modes of thoracic surgery with regard to training (4). Bareeq *et al.* demonstrated that the development of complex skills training models and simulators has started to facilitate transfer of robotic surgical skills to novice surgeons without increasing risk to patients' safety (5). Borgersen also stated that simulation models, such as virtual reality simulators, offer safe environments for training and evaluation of surgical technical skills without compromising patient safety (6). Although various surgical technical simulators for RATS currently exist, it is important that thoracic surgeons know about them, and important to learn how to use them for robotic surgical training.

In this brief review, we outline and discuss current surgical simulations in RATS and future strategy on this topic.

Figure 1 Intuitive Surgical manufactures the da Vinci Skills Simulator™, a unique surgical simulator that provides comprehensive da Vinci surgical adoption.

Surgical simulation in RATS: training for RATS using the surgical simulator

Surgical simulator modalities are generally divided into five categories: (I) inanimate; (II) animal; (III) augmented reality; (IV) virtual reality; and (V) cadaveric simulation (6). Training for robotic surgery takes place in both real and simulated environments. A real environment involves patients, cadavers, or animals, while a simulated one involves dry lab (plastic parts) or virtual reality. Because of high initial costs and ethical issues in robotic training in real environments, various virtual reality training systems have been developed to help surgeons improve their technical and non-technical skills required for performing robotic surgery.

Intuitive Surgical manufactures its unique surgical simulator, the da Vinci Skills Simulator, which facilitates comprehensive da Vinci surgical adoption (*Figure 1*) (1). This portable and practical simulator includes various tasks and scenarios for users to improve their techniques using a da Vinci surgeon console. Surgeons and surgical teams can use the simulator to undertake training with the system with exercises and 3D videos to align training pathways to specific surgical specialties. The simulator exercises range from basic to advanced and are designed to be pertinent for surgeons in any area of specialization. All the simulations are an indispensable element in learning surgical technology, and they permit recreation of the important steps for operating instruments so surgeons can hone their skills in a nonclinical setting. Each exercise covers at least one of the da Vinci surgical skill categories, including EndoWrist® Manipulation, Camera and Clutching, Fourth Arm Integration, System settings, Needle Control and Driving, and Energy and Dissection. Metrics can also be tracked automatically through the simulator curriculum tab to receive immediate feedback and review progress and proficiency.

Additionally, the simulator can be customized with the latest versions of procedural simulation found in the Simulation Marketplace. The company 3D Systems partnered with Intuitive Surgical and developed training modules, called the Robotix Mentor, for robotic skills, procedural tasks, and complete robotic procedures. The realistic virtual reality modules were designed for cost-effective integration in surgical curricula across multiple disciplines and technologies. The simulation enables hands-on training of the key steps of complete surgical procedures including robotic-assisted thoracoscopic lobectomy, using the newest robotic technology, with the goal of increasing patient safety. Using this robotic lobectomy module, surgeons can practice a complicated robotic-assisted thoracoscopic lobectomy (right upper lobe) and acquire the skills and knowledge required to perform the key components of the procedure, including inspection of the thoracic cavity and dissection of the hilum to expose and divide the blood vessels and bronchus. The module includes simulation of complications and emergency situations, such as injury to the pulmonary artery and vein, phrenic nerve, and pericardium. A fully responsive anatomical environment features breathing and pulse movements with highly realistic graphics (*Figure 2*).

Although this simulator has many benefits for robotic training, it is disadvantageous in that it requires da Vinci Surgeon console units. Simpler simulators are needed for robotic surgeons to gain familiarity with robotic surgical training. Bovo *et al.* reported on a compact, lightweight, and portable robot-assisted surgery simulator, called Actaeon, developed by BBZ, a spinoff company from the University of Verona (Italy) (*Figure 3*) (3). The device simulates the da Vinci master console's features and integrates the Xron software package from BBZ. The hardware is extremely compact and well-ordered, and can provide all the required features of the da Vinci console. The system takes less than 5 minutes to set up, weighs less than 10 kg, and can be carried as standard carry-on luggage (55 cm × 40 cm ×

Figure 2 "Robotic lobectomy complete procedure" by 3D Systems Simbionix (7).
Available online: http://www.asvide.com/article/view/27997

Figure 3 A compact, lightweight and portable system of robot-assisted surgery simulator, "Actaeon", developed by BBZ, a spinoff company from the University of Verona (Italy).

20 cm). It enables setting up of classrooms where users can work on several consoles under the direct supervision of a single expert surgeon, while at the same time performing remote training directly at the surgeon's home. The training tasks of this simulator take advantage of the high degree of realism of the physics simulation, which allows increased effectiveness of training and reduced training time. They also demonstrated that this simulator will help novices improve their skills before attempting robot-assisted surgery.

Development of new robotic surgical systems and a range of innovations can be expected in the near future. However, it will be essential to develop coupled simulator hardware and software to perform safe and accurate robotic surgery. At the same time, surgeons should always undergo sufficient training using those simulators when they attempt to use those new surgical systems and techniques.

Figure 4 The TilePro™ function of the da Vinci Surgical System (10). The TilePro™ function can enable surgeons and surgical teams to view a three-dimensional video of the operative field along with additional imaging sources, such as reconstructed three-dimensional structures.
Available online: http://www.asvide.com/article/view/27998

Surgical simulation in RATS: imaging simulation in RATS

It has become more common recently for thoracic surgeons to make 3D computed tomography (CT) imaging of anatomical structures in the thoracic cavity, such as the pulmonary vessels and bronchus. Especially in minimally invasive surgery including RATS, surgeons recently prefer to perform preoperative surgical simulation and/or navigation using these 3D-CT technologies. Globally, several software programs exist for obtaining 3D imaging of lung structures. Synapse Vincent (Fuji Film Corporation, Tokyo, Japan) is one of the most widely used image-analyzing workstations in Japan. This system automatically extracts information on pulmonary structures and displays 3D imaging at high speed and with high quality (8). The system enables viewing of the reconstructed images on monitors during the preoperative planning steps, which allows surgeons to mentally rehearse before a procedure. It is also possible to save application states and return to them during the procedure.

The TilePro™ function of the da Vinci Surgical System lets surgeons and surgical teams view a 3D video of the operative field along with additional imaging sources, such as reconstructed 3D structures (9). Surgeons can even use this function to return to pre-saved application states saved during the preoperative planning steps (*Figure 4*). While some previous reports exist on the surgical system using the

TilePro™ function, such reports are only in the fields of general surgery and urology (11,12). However, this platform can give an improved appreciation of pulmonary hilar and tumor anatomy, and thoracic surgeons who master this useful function will also be able to perform safe and high-quality intraoperative procedures, especially in delicate operations, such as complicated segmentectomies.

The feature of 3D rapid prototyping also offers many benefits for simulating surgical procedures (13). Some newly developed multi-material 3D printers can produce models with multiple tissue types, including pulmonary vessels and bronchus. Morikawa *et al.* developed 3D printed lung models and reported that that these allowed for realistic simulation of surgical procedures (14). These models produced by rapid prototyping can replicate actual patients' anatomical structures at a remarkable degree of realism. In the future, 3D lung models will be routinely printed to plan RATS procedures preoperatively and improve patient outcomes.

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