Resident education in robotic thoracic surgery

Brandon A. Guenthart, Natalie S. Lui

Department of Cardiothoracic Surgery, Stanford University, Stanford, CA, USA

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Correspondence to: Natalie Lui, MD, MAS. Department of Cardiothoracic Surgery, Stanford University Medical Center, Falk Building, 300 Pasteur Dr., Stanford, CA 94305, USA. Email: natalielui@stanford.edu.

Abstract: As the role of robotics in thoracic surgery continues to expand and evolve, its incorporation into resident education and training requires careful review. Currently, there is no standardized curriculum or path to credentialing. Here we examine the literature and evidence regarding optimal training and education, and describe essential elements necessary for the successful implementation of a thoracic surgery robotic training program. A formalized curriculum, proficient faculty mentors, dual-console platforms, dedicated bedside assistants, robotics nursing team, simulation, and annual training are all necessary components to maintain an effective training program. As technology continues to improve, robotics will undoubtably become an increasingly important skill set. The next generation of thoracic surgeons should be proficient in open, video-assisted thoracoscopic surgery (VATS), and robotic techniques.

Keywords: Robotics; robotic thoracic surgery; robotic education; simulation

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Introduction

For nearly two decades, the integration and clinical use of robotics has undergone continual growth and evolution. The Food and Drug Administration (FDA) approved the first robot-assisted platform in 2000, and as of March 2019, there are 5,114 da Vinci Surgical Systems (Intuitive Surgical Inc., Sunnyvale, CA, USA) in use. The first reported case of robotic lobectomy came in 2002 (1) and since that time robotic thoracic procedures have expanded in numbers and complexity. Many experienced surgeons already adept at open or video-assisted thoracoscopic surgery (VATS) have incorporated robotics into their practice. A review of The Society of Thoracic Surgeons (STS) database from 2006 to 2016 showed 271 thoracic surgeons had performed a total of 5,619 robotic lobectomies (2).

Robotic surgery offers several important advantages including: (I) three-dimensional view; (II) enhanced magnification; (III) improved precision and degrees of movement; (IV) surgeon-controlled retraction and camera platform; eliminating variability in assistant skill level; (V) surgeon ergonomics and comfort; (VI) ease of hilar and mediastinal lymph node dissection. Disadvantages include the cost of acquisition (approximately \$1.8 million) with an additional 10% annual service fee and instrument cost (\$700–\$1,000 per case) (3). Lack of haptic feedback has also been cited as a disadvantage; however, it has not been shown to correlate with poorer outcomes.

Early studies comparing robot-assisted procedures to traditional minimally invasive techniques consistently demonstrated safety and equivalent outcomes, however robotics was associated with increased expense and prolonged operative times (4-7). This led many to argue that robotics simply resulted in increased cost while yielding similar results. However, with more widespread adoption, advancements in technology, and new market competition it is foreseeable that the cost of robotics will continue to come down and advantages will become more apparent.

Despite the popularity and growth in robotic thoracic procedures, there is no standardized training curriculum

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and a paucity of research exists in regards to the optimal training paradigm. In a survey of recent cardiothoracic graduates, the majority of respondents reported they lacked confidence in robotic pulmonary operations (55.8%) and robotic esophageal operations (61.5%) (8). The aim of this review is to discuss the increasing role of robotics in thoracic surgery, examine the literature and evidence in other surgical specialties regarding optimal training and education, and describe essential elements necessary for the successful implementation of a thoracic surgery robotic training program.

Robotic surgery education and training

Robotics has been adopted by numerous specialties including gynecology, urology, general surgery, colorectal surgery, and cardiothoracic surgery. It is estimated that over 1.5 million robotic surgeries have already been performed (9). Currently, general surgery represents the fastest growing field in robotics (10,11). A national survey of general surgery residents reports 96% of residents have a robotic platform where they train, however only 18% reported operating at the console (12). A recent study of general surgery program directors found a need for increased emphasis on robotic surgery and training, and a more standardized path to competency. Most programs (80%) relied on industry to assist in resident education, as cost and simulation access was a noted to be a major obstacle (13).

Training in laparoscopy includes the Fundamentals of Laparoscopic Surgery (FLS) training curriculum, which tests both cognitive and technical skills and is a requirement for certification as a general surgeon. While similar programs such as Fundamental Skills of Robot-Assisted Surgery (FSRS) and Fundamentals of Robotic Surgery (FRS) have been developed, they have not been similarly implemented or mandated (13,14). Some have argued the integration of robotics has significant educational and financial opportunity cost to trainees which should be considered. In one report, robotics led to an upward shift in the level of residents performing operations, and a reduction in overall resident participation (11). This potential pitfall should be addressed when building and incorporating robotics into any training program.

Training paradigms in other specialties have been well described (15-17). Although not-standardized, they generally consist of three distinct training phases: first, a preclinical phase which includes online didactics, and skill acquisition with simulation models. Second, is the bedside assistant phase. Trainees learn port placement, docking, instrument exchange, and troubleshooting. Lastly, trainees progress to the console phase and participate in parts of the robotic operation in a progressive fashion. In general surgery training, phase one typically occurs during PGY1, phase two as a PGY2–3, and phase 3 during the PGY4–5 years (13). There is a growing sentiment, however, to push for earlier exposure and progression through each phase.

Current paradigms in robotic thoracic training

Adopting new technology is a challenge in any training program. There is currently no standardized robotic curriculum or case requirement for thoracic surgery trainees (18). However, several institutions have reported their experience and strategy in regards to building a robotic curriculum (19-21). The goal of these programs is to provide a balanced experience so that trainees become proficient in open, VATS, and robotic thoracic techniques.

The University of Alabama has reported extensively on their robotic experience and educational approach (22-25). In a series of 520 consecutive robotic lobectomies, authors demonstrate resident involvement increased over time and did not negatively impact patient outcomes (26). While operative time initially was longer, that tended to decrease overtime with experience. Resident involvement was tracked by breaking each lobectomy down into a series of steps, and each step was allotted a set amount of time (for example, residents were given 7 min to remove lymph nodes at stations 9, 8, and 7) (26). This enabled accurate data collection, and acted as a measure to track individual trainee progression.

Other institutions have reported their results following implementation of robotics into their thoracic surgery curriculum. The University of Michigan reported results following their first 100 robotic cases (38% lung resections, 23% esophageal operations, and 20% sympathectomies). Resident involvement increased in the later cohort (33% to 59%). Operative time and postoperative complications were similar regardless of the level of resident participation (9).

The variability in resident experience and prior training in robotics is an important consideration which is unique to thoracic surgery training programs. There are currently several pathways in cardiothoracic surgery including traditional fellowship following completion of general surgery residency, integrated I-6, and 4+3 programs (27).

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Table 1 Robotic certification requirements for residents and fellows: online resources and training found at da Vinci Surgery Community website (https://www.davincisurgerycommunity.com/Training?tab1=TR)

Didactics (online)
Overview of system components, instruments, accessories, advanced technology
Complete online assessment
In-service & skills practicum (hands-on)
System overview, docking, port placement, console overview, emergency procedures
Simulation exercises (each skill has various exercises and score requirements)
EndoWrist manipulation
Camera control
Energy control
Needle driving
Case observations
Online review (4) full length procedure videos
Case participation
Bedside assistant (min 10)
Primary console surgeon (>50% of case, min 20)
Letter of verification of system training and procedures completed
Chief of surgery or program director
Application
Submit a copy of online training certificates, simulation log, case log, and letter of verification to intuitive representative

This adds additional complexity when designing an educational curriculum, as it must be flexible and tailored to the individual trainee.

Thoracic robotic program—essential elements

While standardization within residency training programs is lacking, there is a clear pathway for resident and fellows to obtain da Vinci certification (*Table 1*). Ideally this would be obtained during general surgery training and prior to thoracic surgery fellowship. However, for fellows with limited robotic exposure or for integrated residents within a thoracic surgery training program, this should be pursued as early as possible. This training essentially follows previously established modular curriculums which include pre-clinical, bedside assistant, and console phases, and can be used to frame a resident curriculum.

Following successful completion of a training program, trainees should possess the skills and certifications necessary for hospital credentialing. Although these requirements vary widely based on the institution, a rigorous training program will provide graduates with an easy pathway (28). Identification of key elements for a thoracic surgery training program (*Table 2*) were derived from literature review and the authors' own institutional experience.

Faculty mentors

Teaching is a skill, and the best teachers are master surgeons who possess the passion and dedication to training the next generation of surgeons. A successful robotic training program should have robotic surgeons who are beyond their own learning curve in order to be effective resident educators. For those still learning, a classification system for thoracic operations and a pathway to competency in robotic thoracic surgery has been proposed (25). Many surgeons who are adept at teaching VATS may struggle to provide equivalent autonomy during robotics until they gain sufficient experience and comfort. While the number varies, the learning curve for an already proficient VATS

Table 2 Requirements for a successful training program in robotic thoracic surgery
Volume/faculty mentors
Min 50–150 robotic cases per year
Faculty members outside of their own learning curve dedicated to resident education
Dual console
After obtaining the necessary 10 case min as the bedside assistant, cardiothoracic trainees should be learning at the console
Dedicated bedside assistants
NP/PA, RNFA
Multi-disciplinary team and training
Anesthesia, RNs, Scrub tech
Robotics team approach
Enhance safety and efficiency in the robotic OR
Simulation
Level appropriate resident curriculum
Dedicated simulator with 24-h access
Wet/dry labs
Annual participation in hands-on course, cadaver or animal lab
NP, nurse practitioner; PA, physician assistants; RNFA, registered nurse first assistant.

surgeon is approximately 20 robotic lobectomies (29,30). Annual volume is also important to offer a robust training experience, a minimum volume of 50-150 robotic cases per year is required.

To succeed, faculty mentors also require institutional support. This includes dedicated robotic operative time each week and recognition that teaching is an investment. In today's atmosphere there is pressure to limit operative time, drive down cost, and increase volume all while outcomes are under heightened scrutiny. These factors have been recognized as reasons faculty members have become "disincentivized" to teach (31).

Robotic procedures can easily be recorded and reviewed at a later date. Video-based coaching has been shown to aid in skill development and operative technique (32). Faculty mentors should review surgical videos and provide feedback to residents as well as their bedside assistants. This review process can also inform the mentor by providing valuable feedback on coaching style and allow for reflection on the quantity and quality of teaching they are providing (31).

Dual console

Training residents using a single-console system has several

important disadvantages. The observer monitor is two dimensional and the trainee is required to switch seats with the mentor to resume control of the console. This requires time, changes to console ergonomics, and forces the mentor and trainee to be physically apart. A dual-console system (Figure 1) enables the trainee and mentor to have the same three-dimensional view, easily swap controls, or operate simultaneously. Simultaneous operation, while more advanced, can give the trainee control of three arms while the mentor controls a retracting arm for example.

Mentors can also utilize on-screen pointers, and resume control without changing sides of the table as in traditional surgery. Studies on dual-console experience in gynecology and urology have demonstrated increased collaboration between trainee and mentor, decreased operative times, and decreased intraoperative and postoperative complications (33-35).

Dedicated bedside assistants

Robotic surgeons, while in close proximity are physically away from the bedside, and therefore must place trust in the bedside assistant. The impact of an experienced bedside assistant cannot be understated. They maintain consistency, help orient unfamiliar operating room staff, ensure proper



Figure 1 Dual-console in use: thoracic trainee (left), faculty mentor (right).



Figure 2 Bedside assistant. APP performing robotic docking and targeting procedures. APP, advanced practice provider.

positioning, port placement, docking, instrument exchange, and in many cases perform critical tasks throughout the case via an assistant port.

In many academic centers, surgical residents with varying levels of experience function as the "bedside surgeon." Some have suggested this has led to a decline in operative autonomy, case volume, and concluded that implementation of robotics into a training program comes at a "cost (11)." It is our belief that permanent highly trained and experienced bedside assistants are critical for any robotic thoracic surgery program (*Figure 2*). They help maintain consistency, safety, and allow residents to train on the console. In the United States, a variety of advanced practice providers (APPs) such as physician assistants (PAs), or registered nurses (RNs) or nurse practitioners (NPs) who have trained as registered nurse first assistants (RNFAs). In Europe, surgical care practitioners (SCPs) have similar training and analogous function. New bedside assistants should complete the same online didactics and hands-on training sessions required for residents and fellows (*Table 1*).

Robotics team

Surgery is a team sport, and that sentiment is perhaps most evident in robotic thoracic surgery. It is essential that a multi-disciplinary approach be taken to training and preparation. Having a dedicated team of anesthesiologists, surgeons, bedside assistants, nurses, and technicians is instrumental to the success of a thoracic surgery robotic training program. Training a smaller number of team members establishes familiarity and helps improve efficiency. Nurses and technicians must master several perioperative competencies: arranging the robotic system and all its components in the OR, assembling system components, starting the system, draping the patient cart, setting up and calibrating the vision system, setting up the surgeon console, driving and positioning the patient cart over the patient, identifying safety features, and performing system shutdown (36).

Robotic surgery poses unique challenges to effective communication. There are physical, visual, and auditory barriers unique to robotic surgery, and traditional nonverbal communication tools cannot be deployed (37). To ensure proper flow of information, instructions from the console surgeon should be clear, and the bedside assistant should repeat those instructions back for confirmation. Reduction in ambient noise, as well as adjuncts to the da Vinci audio system such as the use of headsets, may be needed to improve intraoperative team communication.

Previous reports have shown that having an established robotic team can decrease the learning curve for individual surgeons (38). This team is a necessary component for a robotic thoracic training program in order to teach good practices and maintain an optimal learning environment for trainees.

Simulation

The development and expansion of simulation-based education is taking place in nearly every surgical specialty. The ability to reduce adverse and life-threatening events has been demonstrated in multiple fields including avionics and medicine. With increasing demands to improve patient safety, simulation is playing a larger role in skills acquisition.



Figure 3 Robotic simulation. (A) Table top simulation model; (B) suturing training exercise with da Vinci Skills Simulator (photos used with permission from Intuitive Surgical Inc.).

Simulation is devoid of risk to the patient, and shortening the learning curve prior to patient contact has the goal of improved operative experience and outcomes. Various forms of simulation exist and include: robotic table top models (*Figure 3*), virtual reality (VR) surgical simulators, live animal labs, and cadaveric training. With simulation, thoracic trainees can gain familiarity with the robotic platform as well as learn anatomy and surgical approach to thoracic procedures (e.g., lobectomy, mediastinal dissection).

Like laparoscopy, many robotic skills can first be learned in a laboratory. However, unlike laparoscopy which has numerous inexpensive platforms and even take-home mobile box-trainers (39), robotic simulators come at a substantial cost. The initial acquisition cost of a da Vinci skills simulator (dVSS) is approximately \$85,000 with additional annual maintenance fees (40). Importantly, the dVSS cannot function independently and requires a da Vinci Surgical system console. In comparison, the estimated cost of establishing a laparoscopic simulation lab is \$7,706 with an annual maintenance cost of \$5,036 (41).

VR simulation ranges from basic skills with performance analysis to procedural based simulation (e.g., lobectomy simulation). Computer based VR simulation has the added advantage of measurable competence-based tasks. These metrics can be tracked and used to ensure a basic level of competence and exposure prior to resident involvement in robotic cases. There are currently a handful of commercially available platforms in addition to the da Vinci Skills Simulator. These include the robotic surgical simulator (RoSS; Simulated Surgical Systems LLC, San Jose, CA, USA), dV-Trainer (Mimic Technologies, Seattle, WA, USA), and the SEP Robot (SimSurgery, Oslo, Norway). These other stand-alone simulation platforms have been shown to offer similar attributes at a comparable cost (range \$40,000–100,000) (40,42).

Simulation has now become an essential component for any robotic thoracic training program. To be the most effective, simulation must be available and easily accessible to surgical trainees who are often inundated with demands of patient care and training. Ideally, simulators should be housed in a simulation center with 24-hour access and have a vision monitor that allows a user or tutor to observe and provide feedback. For many programs this is cost prohibitive and a major limitation. Some institutions have made the investment by making a single simulator available across departments as a shared resource.

Hands-on training labs

In order to maintain proficiency and get exposure to new technology annual attendance of some form handson robotics training is recommended. These can include industry or institution sponsored cadaveric or animal labs, or implementation of mock dry runs and use of table top models. On-site training is also available through SAGES Robotics Masters Series, FSRS training program, and the robotics training network (RTN) curriculum (43).

The American Association for Thoracic Surgery (AATS) offers a surgical robotics fellowship providing advanced educational experiences for thoracic trainees and attendings surgeons in a two-day course. Advanced robotic lobectomy courses are also available to fellows who meet the case requirements. In addition, Intuitive offers a variety of mentorship, proctoring, and observation opportunities for fellows and faculty.

Future directions

Currently, robotic surgery generates nearly \$3 billion in annual revenue and that number is projected to climb. Intuitive Surgical has led the field with innovative technology and advanced platforms such as their newest robot, the da Vinci Xi. Aggressive marketing and various forms of sponsorship have also likely contributed to the popularization of robotics for surgeons, hospitals, and patients. Given the financial incentives involved, it is imperative that unbiased research be conducted to evaluate these novel technologies, and authors must declare any financial conflicts of interest to improve transparency (44).

Intuitive has now developed the da Vinci SP, a singleport access robotic using a single arm to manipulate 3 arms and a camera, and in February of 2019, they received FDA clearance for the Ion Endoluminal system. The Ion is a flexible robotic-assisted catheter system for gaining access to distal airways. Advancements in these systems have exciting implications for robotic thoracic surgery, creating both challenge and opportunity for surgeons in training and the programs tasked with integrating innovation into their curriculum.

Given the growth in popularity and potential revenue it is not surprising that robotic competitors are emerging. Unique robotic platforms have been developed by companies such as TransEnterix, Titan Medical, Human Xtensions, and Medrobotics (45). The Senhance system (TransEnterix Surgical Inc. Morrisville, NC, USA) received FDA clearance in 2017 and has been in use in Europe and now the US. This system features a console with an eye-tracking feature, providing the possibility of moving the camera with eye movement, and incorporates haptic feedback. Importantly, to reduce cost this platform also has reusable instruments and is designed to work with commercially available trocars (46).

In addition to already established competitive platforms, there are several others under development. VERB Surgical is a robotic collaboration between Google and Johnson and Johnson. Their stated goal is to advance digital surgery claiming, "surgical technology is about to take a giant leap forward." However, no detailed information has been released to date. Finally, it is anticipated that Medtronics, in collaboration with Karl Storz SE &Co., will introduce their robotic platform within the year. Like VERB surgical, little is known in terms of specifics but many anticipate compatibility with existing laparoscopic towers and instruments (45,47). As more systems become available perhaps one of the largest drawbacks to robotics will be addressed – the cost. Reducing upfront acquisition and per case cost will ensure robotics continues to expand. New challenges will need to be confronted as robotic training, credentialing, and outcomes research will become inherently more complex with multiple platforms being introduced.

Conclusions

As the role of robotics in thoracic surgery continues to evolve, educators must maintain their proficiency and deliver training utilizing the newest minimally invasive techniques. Thoracic surgery training programs should include a robust experience in robotic surgery, and to maximize success should incorporate the key elements outlined in this article. As with any new technology, priority is first to provide optimal patient outcomes with oncologically sound operations. However, there is little doubt that robotic platforms will continue to improve and become an increasingly important skill set in the thoracic surgeons' repertoire.

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Footnote

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