

EXPERT CONSENSUS DOCUMENT

The Society of Thoracic Surgeons Expert Consensus Statements on a Framework for a Standardized National Robotic Curriculum for Thoracic Surgery Trainees



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ABSTRACT

OBJECTIVE With robotic technology's rapid growth and integration, an urgent need to bridge the educational gap in thoracic surgical training has emerged. This document, a result of consensus among a group of experts in the practice and training of robotic surgery from The Society of Thoracic Surgeons, aims to provide a framework for a standardized national robotic curriculum for thoracic surgery trainees.

METHODS The Society of Thoracic Surgeons Task Force on Robotic Thoracic Surgery and Workforce on E-learning and Educational Innovation assembled an expert group with the input of the Thoracic Surgery Director's Association. A focused literature review was performed, and expert consensus statements were developed using a modified Delphi process to address 3 major themes: (1) program expectations, (2) components of training, and (3) assessment and feedback.

RESULTS A consensus was reached on 12 recommendations. These consensus statements reflect updated insights on developing a standardized robotics curriculum based on the latest literature and current educational experience, focusing on program expectations and educational guidelines to develop an optimal training curriculum.

CONCLUSIONS The expert panel provides several key recommendations to provide a framework for developing a standardized national robotic thoracic curriculum, which would improve resident education and abridge any educational disparity that may exist among programs.

(Ann Thorac Surg 2025;119:719-32)

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Accepted for publication Dec 3, 2024.

The Society of Thoracic Surgeons Executive Committee approved this document.

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Abbreviations and Acronyms

AATS = American Association for Thoracic Surgery
 ACGME = Accreditation Council of Graduate Medical Education
 APP = advanced practice provider
 EPAs = Entrustable Professional Activities
 GEARS = Global Evaluative Assessment of Robotic Skills
 NP = nurse practitioner
 OSATS = Objective Structures Assessment of Technical Skill
 PA = physician assistant
 PICO = P, population, patients, or problem; I, intervention; C, comparison; O, outcome
 RN = registered nurse
 STS = The Society of Thoracic Surgeons
 VATS = video-assisted thoracoscopic surgery
 VR = virtual reality

Robotic-assisted thoracic surgery is now the most commonly used approach for routine anatomical lung resection in the United States.¹ Its rapid adoption may be attributed to several factors, including improvements in the robotic software and hardware, refinements in surgical techniques that have made the operation safe and effective, broadened access to robotic systems as a whole, and a comparable or potentially shorter learning curve compared with video-assisted thoracoscopic surgery (VATS).^{2–4}

However, an educational gap in thoracic surgical training has emerged with the rapid growth and integration of robotic technology. According to a report by The Society of Thoracic Surgeons (STS) Workforce on Thoracic Surgery Resident Issues Transition to Practice Taskforce, more than half of the surveyed graduates of thoracic surgery residency programs expressed a lack of confidence in their own proficiency and a need for more instruction in robotic thoracic surgery.⁵

There is wide variability in robotic training among Accreditation Council of Graduate Medical Education (ACGME) programs, with only half offering a formal training curriculum.⁶ Many newly graduated trainees rely on industry-sponsored courses and proctored operations for additional training to gain proficiency and satisfy hospital credentialing requirements, posing potential conflict of interest implications. Moreover, these courses are often expensive, require travel to regional centers, do not consistently report or use proficiency metrics, and do not provide adequate time for deliberate practice.^{7–11}

This document seeks to proffer a consensus among experts in the practice and/or training in robotic surgery from the STS and provide a formal recommendation and framework for a standardized national robotic curriculum for thoracic surgery trainees.

METHODS

ASSEMBLY OF A WRITING GROUP OF EXPERTS. The STS Task Force on Robotic Thoracic Surgery and Workforce on E-learning and Educational Innovation, with input from the Thoracic Surgery Director's Association, assembled an expert group of thoracic surgeon educators and resident representatives interested in robotic education. All members completed the conflict of interest disclosures before embarking on committee work. The STS Quality and Research Council Operating Board reviewed and provided feedback on the expert consensus document and recommendations.

FORMULATION OF OBJECTIVES AND CLINICAL QUESTIONS.

Meetings were held to discuss and develop themes, concepts, and organizational frameworks. This resulted in the creation of subgroups to address 3 major themes: (1) program expectations, (2) components of training, and (3) assessment and feedback. The subgroups met iteratively to formulate questions using the PICO format (P, population, patients, or problem; I, intervention; C, comparison; O, outcome).¹² The questions were reviewed by the entire writing group and were refined to produce a finalized list of focused clinical questions, after which they were returned to the subgroups for literature review and evidence synthesis.

LITERATURE REVIEW AND EVIDENCE SYNTHESIS. Literature searches were performed using PubMed and Google search engines to extract studies published in English between January 2004 and July 2024 for each PICO question. Searches were conducted on a continuous updating basis between November 1, 2023, and April 1, 2024. The task force chair screened the titles and abstracts of the search results for relevance. A total of 156 published studies relevant to the PICO questions were identified. The group members added additional peer reviewed published studies to the body of literature. The members of each subgroup reviewed these full-text studies and extracted and synthesized data to formulate a series of evidence-based recommendations. Each statement was critically examined and revised by the entire group.

DEVELOPMENT OF EXPERT CONSENSUS. The entire expert consensus panel evaluated each statement using a 5-point Likert scale. Consistent with the modified Delphi method,¹² 100% participation was required to achieve an 80% consensus rate ("agree" or "strongly agree"). A second or third round of voting after a thorough revision was used if the threshold was not achieved. Once the 12 consensus statements had been accepted, each

expert member from the subgroups contributed substantially to writing sections. The group then reviewed the document, finalized it, and forwarded it to the STS Workforce on Evidence-Based Surgery for final review and approval.

CONSENSUS STATEMENTS.

A) Program Expectations

1. The ACGME-accredited thoracic training programs should have a standardized robotic thoracic curriculum and a common evaluation platform.

The importance and need for an effective standardized robotic surgery curriculum have been acknowledged and shown to correlate with lowering the learning curve in the quest for proficiency among trainees and improving patient safety.^{13,14} No national standardized curriculum currently exists. Approximately half the training programs reported to have an independent robotic curriculum. Several single-institution experiences with a curriculum have been published, but none of these studies has been validated.^{15,16} More often, programs may have informal, voluntary, unstructured, and ad hoc robotic training curriculums, which have the advantage of prompt implementation but are often ineffective.¹⁷

Despite slow progress, the call for a standardized robotic surgery curriculum has been steadfast across several specialties and organizations.^{18,19} Unlike VATS or open surgery, robotic surgery requires a new training paradigm that cannot be effectively taught or learned by the same methods as traditional thoracoscopic, laparoscopic, or open surgery. Unique challenges in teaching and learning associated with robotic surgery include operating with the use of visual cues because haptic feedback is currently not a feature in contemporary robotic platforms, increased communication with verbal direction and intentional command processes as the surgeon operates from a remote console, overcoming problems of operating while away from the bedside, and the need for a comprehensive understanding of the robotic instruments and platforms to ensure the safety of the operation.^{20,21} Therefore, developing a comprehensive standardized curriculum is imperative to ameliorate training disparity.

2. The training programs are strongly encouraged to provide a dual console for many, if not all, cases with the trainee.

Thoracic training programs are strongly recommended to include a dual console in cases

involving trainees. The learning curve for the robotic thoracic surgery trainee is challenging due not only to the anatomy and complex steps of the case but also to the lack of direct tactile feedback, which can potentially increase the risk of injury during dissection or drifting into surrounding intrathoracic structures. Immediate instrument control by the attending surgeon through a swapping mechanism (akin to a driving instructor) is crucial to avoid a potential iatrogenic injury.²² A dual console allows the attending surgeon to easily switch instrument control with the trainee, facilitating seamless collaboration. Studies have shown that the presence of a dual console enhances robotic surgical training across various specialties, including thoracic surgery.²³ In a study on general surgery resident training, 100% of the faculty and residents (7 and 20, respectively) reported that having a dual console was essential to the training of residents and necessary for maximal learning.²⁴

Schmiederer and colleagues, using a Delphi consensus method, attempted to define essential components necessary for an effective robotic training regimen. Among the key components identified for robotic surgical education, the dual robotic console model was highlighted as 1 of the top 5.²⁵ The study showed that trainees and faculty members agreed a resident's chances of using the robotic console effectively are increased when a dual console model is accessible. Although the dual console incurs additional costs, the benefits of patient safety enhancements and ensuring the proficiency of surgeons in this specialized area are considered ample justification. Using a dual console enhances the educational aspect of the operation and ensures safety, assistance, guidance, and ease of instrument swapping, leading to an improved educational experience for trainees.^{26,27}

3. It is ideal for the training program to provide a trained bedside assistant during teaching cases with trainees.

Current surgical robotic platforms require 2 operators: one to control the robot at the console and the other to serve as a bedside assistant for instrument exchange, suctioning, specimen removal, and additional retraction, among others. The bedside assistant is often a resident or fellow but may be the faculty surgeon (with the trainee at the console) or a surgical colleague. Non-physicians, including a registered nurse (RN) first assistant, a certified surgical first assistant, or an advanced practice provider (APP), such as a

physician assistant (PA) or nurse practitioner (NP), have also been used successfully in various hospital settings.

Experience as a bedside assistant is an important competency for surgical trainees and can be a great way, especially for junior residents, to gradually incorporate and participate in the operation. In a survey of French urology residents and fellows, 87% reported that experience as bedside assistant was useful for advancing to console surgeons, and 48% indicated it is vital.²⁸ In addition, 92% of the respondents reported that formal training in bedside assistance is helpful to becoming a robotic surgeon. Successful time spent as a bedside assistant should be a milestone addressed in a robotic curriculum, but at some point, the trainee must matriculate to the surgeon at the console. Having another trainee or even an American Board of Thoracic Surgery eligible/certified surgeon at the bedside while the trainee is at the console is ideal, although logistically challenging. Nonphysician bedside assistance is a safe option that allows the trainee to serve as a console surgeon.

Nonphysician bedside assistance can safely liberate the trainee to the console. A systematic review reporting on 10 studies revealed no evidence that the type of bedside assistant mattered with respect to operative times and intraoperative blood loss as long as the console surgeon was experienced.²⁹ In a single-institution retrospective study of >2000 patients undergoing robotic surgery, no difference was observed in case length with the use of senior residents, fellows, or PAs. However, deploying a junior resident as the bedside assistant resulted in a mean increase in case duration by 27 minutes.³⁰ A single-institution retrospective study reported that the availability of a dedicated bedside PA increased the percentage of active console time for trainees, although there was no measurable effect on operating room efficiency.³¹

In another retrospective review of a single surgeon's experience of >600 robotic gynecologic procedures, cases in which a bedside nonphysician surgical assistant was involved were faster and associated with less blood loss than those performed with a surgeon bedside assistant.³² Another study reported reduced use of physician bedside assistant surgeons by implementing a gynecologic robotic program through greater reliance on nonphysician bedside assistants.³³

There are little data on the economic cost of bedside assistants. It is conventional wisdom that

employing dedicated APP bedside assistants, RN first assistants, or certified surgical first assistants might financially burden some institutions. Nevertheless, accepting that there is likely educational benefit to trainees of having experienced bedside assistance, uniformly relying on residents and fellows for this role will negatively impact their necessary console learning. Moreover, although the ACGME does not explicitly state that a clinical program should be able to function without residents, its Common Program Requirements emphasize the importance of faculty supervision and involvement in patient care. This suggests that faculty and the institutions in which they practice should be capable of providing clinical services even in the absence of residents. This likely applies to robotic bedside assistance too.

Although nonphysician bedside assistants can significantly enhance the educational value of robotic surgery for trainees, it is essential for training programs to provide clear guidelines for support staff and understand the scope of practice for these assistants. APPs, such as NPs and PAs, can perform a wider range of tasks than RNs. They can manage instrument exchanges, suctioning, specimen removal, additional retraction, and bill for their bedside assistance service when the resident/fellow is present as a console surgeon. When billing for PA or NP services, the specific Current Procedural Terminology (American Medical Association) coding modifier "AS" (physician assistant, nurse practitioner, or clinical nurse specialist services for assistance at surgery) is used to indicate their role in the surgery.

The scope of practice for RNs in many states restricts them from altering/manipulating tissue (eg, applying retractors, direct suctioning, applying clips, or firing staplers). However, RN scope of practice restrictions do not address whether or not they can assist with passing robotic instruments. The lack of specific mention of robotic instrument exchange in regulations leads to varying interpretations across institutions. Ultimately, the program director and their graduate medical education office are responsible for reviewing the scope of practice rules for nurses, APPs, and other nonphysician practitioners serving as bedside assistants in robotic teaching cases and adhering to their local state and hospital regulatory requirements. This careful planning ensures compliance and optimizes the educational experience for surgical trainees.

B) Components of Training

Simulations:

4. The trainee must complete the online modules to learn about the robot's components and complete hands-on in-service before operating as the console surgeon.

With the complexity and intricacies of the robotic platform, it is vital for the resident to have a thorough understanding of the components of the robotic system being used. Additionally, the importance of the resident undergoing hands-on in-service on the robotic platform before participating in the operation as the console surgeon cannot be understated. This in-service can be performed in conjunction with the attending surgeon or designated robotic coordinator, nursing staff, or industry representative.³⁴ This aspect of the robotic training curriculum results in a subjective improvement in resident confidence and satisfaction with their ability to begin the surgeon console aspect of the procedure. Furthermore, it has been shown to objectively improve overall operative efficiency.

Despite the increasing use of robotics in minimally invasive cardiothoracic surgery and further implementation into postgraduate education, residents report significant barriers to transitioning into robotic console surgeons. The barriers reported often stem from limited exposure to robotic operations, leading to the residents' poor perception and satisfaction with robotics and, subsequently, the attending surgeons' trust in the resident's skill to perform as console surgeons.³⁵ In 2 studies by Castaldi and colleagues, the authors used faculty-led, one-on-one resident hands-on training on components of the robotic platform, docking, and instrument exchanges, among others, that was incorporated into the robotic curriculum for the general surgery residency. According to the post-implementation surveys, these tasks subjectively improved residents' positive perception of robotic surgery and their confidence to perform as console surgeons.^{36,37} Moreover, the attending surgeons' confidence in the resident's familiarity with the robotic system further allowed the resident to perform as a console surgeon. According to Merriman, hands-on training in their obstetrics-gynecology residency training program increased the attending surgeons' perception of resident preparedness for live surgery from 17% to 100%.³⁸

Adding hands-on training into the surgical residency robotic curriculum objectively improves operative efficiency. In the 2 studies mentioned

above by Castaldi and colleagues, the faculty-led hands-on curriculum resulted in a 54% reduction in docking time and a 51% reduction in resident console time on similar tasks.^{36,37} Similarly, in a Swiss study of obstetrics/gynecology residents, the use of a hands-on curriculum led to a decrease in docking time from 45.3 to 27.3 minutes ($P < .001$) and mean operating time from 235 to 179 minutes ($P = .0071$), with no difference in perioperative complications.³⁴

5. Achieving proficiency with a 90% or higher score in digital/virtual reality (VR) simulation modules, such as camera control, energy use, "tissue and object" manipulation, and needle driving, should be prerequisites before operating as the console surgeon.

The main goal of digital/VR simulation is to develop both familiarity and reflex muscle memory to proficiently use the current equipment at the surgeon's console. Dry or wet laboratory simulation training has been used to teach basic surgical skills, but substantial financial and ethical burdens are associated with these efforts.³⁹ The benefit of augmenting, or even replacing, components of traditional surgical training formats with a VR simulator is a promising option. Studies have demonstrated that a VR simulator is a valid assessment tool that improves basic robotic surgical skills.⁴⁰ The skills gained from VR training are similar to those attained by traditional robotic dry laboratory simulation training, and VR training is substantially less expensive than dry laboratory training.^{39,41}

Several studies showed that surgical proficiency demonstrated by rapid improvement in task completion with 90% or higher scores correlated with increased repetitions (≥ 5) and 10 hours of practice in the simulator.⁴² The literature shows that a competency-based curriculum is more effective than a time-based curriculum in surgical skill development⁴³; therefore, the VR curriculum design should focus on teaching and assessing competency in basic robotic surgical skills, and training modules should present the opportunity to use a variety of standard instruments such as energy dissector, camera control, switching instruments/arms, and tissue and needle manipulation.

The residents who complete general surgery residency and enroll in cardiothoracic surgery programs are better equipped with robotic skills than before, because there has been increased access and improved robotic training opportunities in general surgery.⁴⁴ If cardiothoracic

trainees completed the basic VR simulations before entering thoracic residency, the basic VR simulation would not need to be repeated because differences between the postgraduate level of training and specialty-specific robotic skills become insignificant upon successful completion of basic VR skill acquisition.⁴⁵ Evidence also shows that basic skill training and procedure-related skill training during simulation are preserved when transferred to a wet laboratory.⁴⁶

6. The training programs are strongly encouraged to provide the trainees with wet laboratory sessions at a minimum of once per year. This includes various programs and fellowships provided through the thoracic surgical societies (eg, STS Boot Camp, American Association for Thoracic Surgery [AATS] Robotic Fellowship, STS robotic courses).

The traditional surgical training adage of “watch one, do one, teach one” is not ideal in the current training environment because the training of surgical residents is constrained by growing ethical and legal concerns over the risks and complications associated with the learning curve, time constraints in the operating room, and changes in resident work hours.⁴⁷ Learning can be especially daunting when an unfamiliar technology is introduced, such as robotic surgery, where the trainee needs to understand how to manipulate complex machinery while learning to operate. Wet laboratory sessions using animal organs offer essential training and practice outside the operating room. It is an important way to teach residents operative anatomy, instrumentation, tissue handling, and operative skills without the pressure of making mistakes and time constraints. Extensive studies demonstrate that wet laboratory sessions effectively empower trainee surgeons to safely perform complex procedures with lower complication rates and reduce their learning curve.⁴⁸ Simulation and animal laboratory experience have been used extensively in cardiothoracic surgery research and training. For example, Divisi and colleagues⁴⁹ used a swine model in wet laboratory sessions for VATS lobectomy, and the simulation-based learning decreased the resident’s learning curve during the training course.

The STS and the AATS have endorsed the importance of incorporating a wet laboratory experience in resident training and currently offer robotic wet laboratory courses for thoracic surgery residents. For example, the STS Boot Camp⁵⁰ and

AATS Robotic Fellowships⁵¹ provide participating residents with multiday courses filled with hands-on instruction and use high-fidelity robotic simulators to create a real operative surgical experience and enhance robotic operating skills. Both programs have been successful. More than 200 residents have completed the AATS Robotic Fellowships since its inception in 2014, and ~60 cardiothoracic trainees participate in the STS Boot Camp every year. The costs to the participating residency programs are minimal due to grants and sponsorships; however, clinical coverage problems can arise if there are too frequent multiday travel courses in a clinical year, especially for small training programs. Therefore, incorporating the wet laboratory course into a national standardized robotic curriculum once a year is a reasonable balance of providing educational opportunities that reduce the learning curve and promote patient safety while minimizing disruptions to patient care.

7. Emergency conversion simulation must be part of the curriculum and should be performed with the trainees and operating room team at least once a year.

Intraoperative complications are possible in any surgery; however, the stakes are elevated during robotic thoracic operations, where the surgeon sits at the console several feet away from the bedside and has to coordinate with the bedside assistants to manage a potentially catastrophic or life-threatening injury. Events such as pulmonary vascular injury, tracheobronchial injury, and great vessel injury are, fortunately, rare but associated with high morbidity and mortality. Cao and colleagues⁵² performed a retrospective, multi-institutional analysis that evaluated 1810 patients who underwent robotic pulmonary resection and found a 1.9% rate of intraoperative catastrophe. A higher perioperative mortality (5.7% vs 0.5%) was associated with those who suffered a catastrophe.⁵²

The surgeon and the operative team must be prepared for any intraoperative emergency, given the complexity of the situation and the multiple team members involved. Strong leadership and effective communication are key to successful management of intraoperative catastrophes. An emergency algorithm or crisis checklist is also critical to improve the safety and management of intraoperative catastrophes.^{53,54} Such algorithms and/or checklists clearly communicate each individual’s role and responsibilities in an emergency. With that in mind, Kenawy and

colleagues⁵⁵ found that the robotic operative staff at a high-volume institution were unclear about their individual roles during an emergency conversion despite having a high perception of emergency conversion preparedness. This finding highlights the importance and necessity of simulation training for robotic thoracic emergencies.

Robotic simulation training curriculums have been developed since the 2010s in response to many adverse robotic-surgical events between 2000 and 2013, with the idea of teaching basic skills that translate into a safe and competent surgeon.⁵⁶ Thus far, little has been published in the literature regarding emergency conversion simulation. Melnyk and colleagues⁵⁷ published their experience with a training curriculum to provide the necessary skills and knowledge to recognize and complete a successful emergency undocking protocol. Five robotic teams completed 2 full-immersion simulations that incorporated a major vascular bleed and non-recoverable robotic fault and an online training module. Their analysis demonstrated significant improvements in knowledge and confidence from baseline and significant decreases in checklist errors, undocking time, and estimated blood loss. Similarly, Ballas and colleagues⁵⁸ demonstrated statistically significant improvement in knowledge, confidence, and undocking times among the entire operating room team using a gynecologic simulator with a major vessel bleed.

To assuage surgeon concerns about intra-operative emergencies, Bludevich and colleagues⁵⁹ published their experience on the completion of an in situ simulation-based clinical systems test among 6 different robotic thoracic operating room teams using pulmonary artery injury scenarios to identify 28 latent safety errors, 9 of which were considered high priority. In postsimulation surveys, 94% of participants agreed that high-fidelity simulation of intra-operative emergencies is helpful and provides an opportunity to practice high-stakes, low-frequency events. The authors stressed the importance of involving the entire operative team, including the attending thoracic surgeon, surgery resident, anesthesia attending, anesthesia resident, circulating nurse, and scrub technician. On the basis of these data, the emergency conversion simulation should be incorporated into the STS Robotic Thoracic Curriculum. It should be performed at least once per year, given ongoing staff and team member turnover, as well as to provide regular repetition and familiarity.

Bedside Assisting

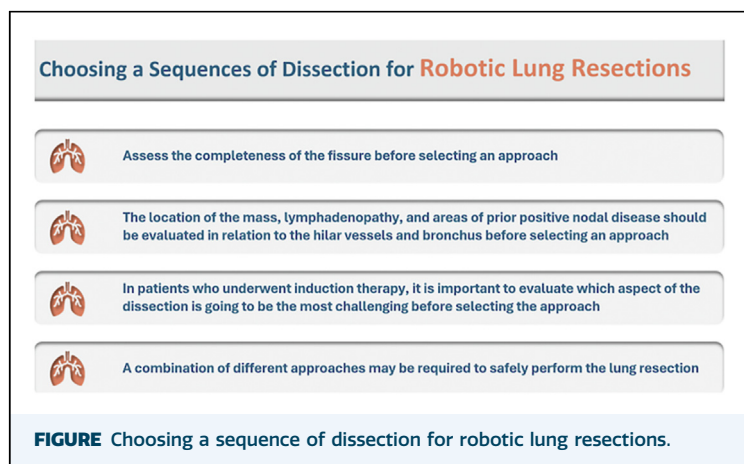
8. The trainee must perform at least 10 bedside robotic assists during the training, 5 of which must be thoracic surgery cases at a minimum. The trainee should be able to demonstrate competency in bedside assisting, which includes docking, arm manipulation, avoiding arm collisions, instrument insertion and withdrawal, and troubleshooting.

This statement is based on the concept that experience serving as a bedside assistant for robotic-assisted operations provides the trainee with valuable skills and an understanding of the robotic platform that will directly translate to improved robotic operative skills and decreased time to proficiency as a robotic thoracic surgeon. Several groups have published general recommendations on the robotic surgery training pathway, highlighting the importance of bedside experience early in trainee progression.^{60,61}

Through dedicated time as a bedside assistant, the trainee learns the nuances of port placement, instrument exchange, mechanics of the robotic arms, the geometry of external collisions, and bedside maneuvers to resolve these collisions. Later, as a console surgeon, this experience allows the surgeon to instruct the bedside team to troubleshoot and better appreciate limitations of the robotic arms. In contrast, because the surgeon is removed from the bedside during robotic-assisted operations and has no view of bedside activity while operating head-in at the console, developing an understanding of the bedside and robotic patient cart dynamics is challenging without having had dedicated bedside assisting experience.

There is a paucity of data to precisely define the impact of bedside assistant experience on surgeon proficiency. However, Cimen and colleagues⁶² suggested in a retrospective cohort study that robotic surgeons with prior bedside assistant experience may have improved outcomes compared with those without this experience. Other investigators have shown that operative case times increase with novice bedside assistants, suggesting a learning curve exists for acquiring proficiency in robotic bedside assisting.³⁰

The number of requisite bedside assistant cases varies across the literature. Consensus recommendations published in 2024 by the Robotic Surgery Education Working Group recommended 10 bedside assistant cases before operating at the surgeon console.⁶⁰ Many groups have considered 10 bedside cases to be an appropriate number,



which should be quickly achievable within the context of a resident or fellow training program and sufficient to acquire the needed bedside skills. This STS expert consensus group has specified that at least 5 of these 10 bedside cases should be thoracic operations. This recommendation is based on recognizing unique skills related to port placement, instrument exchange, and active bedside assisting during thoracic surgery operations. The educational value of bedside assistance cannot be understated, and variability in learners' ability to pick up skill sets exists. Therefore, additional bedside assisting cases are highly encouraged if the trainee fails to demonstrate competency.

The Operation

9. The trainee should review educational videos of anatomic resection before performing a case on the robotic console.

The application of video review in minimally invasive surgery by residents has been extensively studied in the literature. Many studies, regardless of surgical discipline or postgraduate year status, were single-institutional studies that included a limited number of residents. For this reason, the application of the results must be carefully considered. However, several key aspects merit inclusion in a robotic curriculum. In robotic surgery, the critical importance of video may be greatly underappreciated by educators as residents have reported a preference for a video-based curriculum over books for robotic surgery preparation.⁶³ Targeted videos based on the procedure and narrated by the attending, especially for the residents, were significantly associated with increased active time operating on the console. When developing their curriculum, educators should ensure high-quality video development.⁶⁴

Online videos represent a useful and appropriate educational tool but are not sufficiently reviewed to obtain standardization in quality. A concerted effort is necessary to improve the educational value of the uploaded surgical videos through surgical societies based on guidelines or standardized curricula.⁶⁵

Video review before surgery has also been shown to reduce cognitive workload while increasing efficiency, refining technical skills, and for reflective practice. In one study, 19 of the 20 participants felt that the videos helped them with the cognitive aspects of the surgery and played a crucial role in the process of skill acquisition during the 3 stages of motor learning: from cognitive to integrative and then to autonomous.⁶⁶ Self-video review by the resident before the case is an opportunity for self-reflection and self-assessment. Key aspects of the case are (1) critical incidents, (2) unique cases (3) new techniques and procedures, and (4) routine cases. Improving surgical skills requires a growth mindset, especially in the surgical education of novices.⁶⁷

10. The curriculum should have case-specific milestones for robotic anatomic lung resection, with a graduated responsibility given to the resident to operate at the attending surgeon's discretion. Competency should be demonstrated in each milestone. The steps of the operation include but are not limited to:

- Identify appropriate port placement/ placement of the port
- Dissection of mediastinal lymph nodes (levels 9, 8, 7, 4, and 5) and hilar nodes
- Opening mediastinal pleura and exposing the hilar structures.
- Pulmonary vein mobilization/division
- Bronchus mobilization/division
- Fissure dissection/division
- Pulmonary artery mobilization/division

Effective teaching in robotic lung resection involves clear communication between the instructor and the trainee regarding the surgical steps and their complexity. Although a consensus model can guide attending surgeons in structuring their teaching approach, it is essential to recognize individual variations in surgical approaches among surgeons. Residents should understand the specific planned approach (Figure). Several groups have reported on the value of predefining the steps of robotic lobectomy, breaking down the procedure into distinct steps with assigned evaluations. Here, we provide an

TABLE 1 Proposed Approach to Robotic Assisted Right Upper Lobectomy Deconstruction

Steps	Key Points
Ports	Most robotic ports are placed low in the 7th or 8th intercostal spaces, while the assistant port is placed in the 9th or 10th intercostal spaces. When possible, keep ports >8 cm apart. For robotic stapling, the stapling port can be placed for the dominant hand anteriorly on right and posteriorly on left. Consider using 2 stapler ports early in the learning curve. Use a needle for assessing the optimal position before creating the porthole.
Local anesthesia	Infiltrate the intercostal space with local anesthesia before port placement.
Proposed port sites	Port 1 → 8-mm port at the paraspinal and 8th intercostal space Port 2 → 8- or 13-mm port at posterior axillary line and 8th intercostal space Port 3 (Camera) → 8 mm at anterior axillary line and 8th intercostal space Port 4 → 8 or 13 mm at midclavicular line and 8th intercostal space Assistant port → 15 mm at posterior axillary line and 10th intercostal space
Inferior pulmonary ligament	The inferior pulmonary ligament is taken down, and lymph node stations 8 and 9 lymph nodes are removed.
Posterior hilum	The posterior mediastinal pleura is opened in a cephalad direction to the azygous vein. The posterior hilar structures are dissected to define the right upper lobe bronchus and bronchus intermedius.
Subcarinal space	The lymph node station 7 is dissected carefully off the pericardium, membranous airway, and esophagus (using bipolar energy only).
Superior mediastinum	Lymph node station 4 and 2 are dissected between the trachea, superior vena cava and underlying aorta while preserving the vagus nerve.
Sump node of Borrie	Lymph node station 11R is dissected between the right upper lobe bronchus and bronchus intermedius. It overlies A2 and A6.
Truncus arteriosus	The superior mediastinal pleura is divided, exposing the truncus arteriosus (A3–A1). It is carefully mobilized and divided while retracting the lobe inferioposteriorly.
Upper lobe vein	The upper lobe vein is dissected off the station 10R superiorly and the pulmonary artery posteriorly then divided.
Posterior fissure	Carefully identify the main pulmonary artery and fissure. Divide the underlying parenchyma with staples taking care not to injure the previously exposed A2 and A6 arteries.
Posterior ascending artery	The posterior ascending artery (A2) is dissected and ligated or stapled.
Right upper lobe bronchus	The right upper lobe bronchus is dissected back to its segmental branches and staple divided.
Anterior fissure	The anterior fissure is completed after all the structures have been divided.
Survey	Survey of operative bed (including nodal beds, bronchial stumps...) for bleeding and air leaks.
Extraction	Specimen retrieval device is advanced into the assistant port. Ensure the specimen is completely in the bag before retrieval to avoid contamination of the pleural space by the specimen.

example of the deconstruction of robotic-assisted right upper lobectomy (Table 1).

A recent study based on the Delphi process was reported as a “consensus” of experienced surgeons on the essential steps and difficulty levels of multiport VATS of the left upper lobectomy, highlighting key areas suitable for targeted simulation training.⁶⁸ We proffer a similar approach to robotic lobectomy, considering the unique challenges of robotic surgery compared with VATS such as lung retraction, dissection, camera adjustments, and limited tactile feedback.

To prepare for cases, trainees should familiarize themselves with standard anatomy, anatomic variations, and educational videos demonstrating anatomic resection techniques (Table 2). Additionally, they should review the steps involved in the surgery, focus on exposure and executing technical maneuvers, deconstruct

operative steps before the surgery, and analyze the postoperative video for feedback. The deconstruction of the procedure permits residents to gradually assume responsibility for the operation under the supervision of the attending surgeon. Competency should be assessed for each step, and progression to the next step should occur after displaying mastery of the preceding step on several occasions.

C) Assessment and Feedback:

11. Objective-validated assessment tools, such as Global Evaluative Assessment of Robotic Skills (GEARS), should be used to assess the technical competency, and ultimately, Entrusted Professional Activity (EPA) should be developed for pulmonary resection.

Given the rapid increase of robot-assisted operations in thoracic surgery, it is paramount to

TABLE 2 Suggested Steps for Preparing for Robotic Lung Resection Case

- Reviewing standard anatomy and anatomic variations
- Reviewing educational videos to focus on how to expose and technical moves
- Preoperative deconstruction of operative steps (Table 1)
- Postoperative review of the video and feedback

ensure adequate training on this technology. Frequent assessment and evaluation of trainee skills are important to achieving competency in robot-assisted operations. The formal objective evaluation process, along with real-time intra-operative coaching and feedback on technical skills, should be shared regularly at the attending physician's discretion and the institutional policy so the trainees can recognize the areas of deficiencies and practice to improve future performances. As previously described, introduction to robotic surgery typically starts with understanding the system's basic principles, functions, and components, with eventual progression to proficient use of the instruments from the console. To ensure patient safety of practice and the surgeon's proficiency, incorporating objective assessment methods for a defined skill before moving to the next level of instruction is needed.

One way of assessment is the GEARS tool, specifically developed for robot-assisted procedures and consisting of 6 domains: depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy, and robotic control.⁶⁹ The GEARS framework was developed based on the Global Assessment of Laparoscopic Skills (GOALS) in 2005. GEARS has been validated to reliably quantify one's technical proficiency, specifically in robotic skills, with most of the published studies from urologic and gynecologic specialties, including a randomized controlled trial by De Groote and colleagues,⁷⁰ which reported that the proficiency-based progression training led to 42% fewer objectively assessed performance errors compared with the control group without proficiency requirement. Furthermore, GEARS has also recently been adapted and evaluated in cardiac surgery, showing high internal consistency and ability to assess competency in skills such as atrial closure and mitral stitches.⁷¹ GEARS represents only one type of assessment tool. Recent literature offers additional types of assessment tools, including binary metrics, Objective Structured Assessment of Technical Skills (OSATS), Assessment of Robotic Console Skills (ARCS), and others.

A comprehensive comparison of various assessment tools has been described by El-Sayed and colleagues.⁷² Future studies are needed to evaluate the best assessment tool specific to thoracic surgery and pulmonary resections. With the development of new competency-based assessment, the training paradigm is shifting towards EPAs, which is a concept based on assessing the amount of supervision required to perform a particular activity from observation only to supervising others.⁷³ This concept is piloted in general surgery, where evaluators are tasked to rate a trainee on the level of supervision entrusted in 5 cores. Similar EPA programs could be used for thoracic surgery, ensuring trainees can attain adequate supervision before graduation and board certification.

12. Where feasible, objective evaluators should perform a video review and analysis of the trainee's robotic anatomical pulmonary resection at least once a year.

Video reviews can provide detailed information to help evaluate individual performance in areas such as tissue handling, surgical technique, efficiency, decision-making, and kinematic movement. The benefits of video-based coaching for surgical training were described by Daniel and colleagues⁷⁴ in a systematic review and meta-analysis, which revealed significant improvement in posttraining scores and objective surgical skills at different levels of training.

In addition to a positive impact on learning and training, studies from laparoscopic tasks show that video-based assessment can easily be performed using video annotations that involve the definition of surgical gestures, application of Objective Structured Assessment of Technical Skill (OSATS) or GEARS, and free video annotation software.⁷⁵ Such methodology would allow for objective assessment of differences in task performance among trainees, recognition of one's skills, and a user-friendly rapid turnaround platform for surgical skills evaluation by the faculty.

Even though these studies have primarily focused on laparoscopic skills, such as knot tying and peg transfer, the tasks could be easily adapted for robotics and pulmonary resection, including objectives from vessel dissection and handling to efficient lung retraction and exposure, stapler maneuvering, and robotic arm use efficiency. The availability of video recordings to the trainee provides an opportunity to self-analyze any errors and prevent them in the future. Bonrath and colleagues⁷⁶ described the benefit of video review

in identifying “near miss” events and error-event sequences that could be corrected. Moreover, Ketel and colleagues⁷⁷ found that the video-based assessment tool can evaluate competency in minimally invasive esophagectomy and demonstrated that intraoperative technical quality directly correlated with postoperative outcomes. One proposal by Mitzman and colleagues⁷⁸ recommends that the trainee submit an unedited anatomic pulmonary resection video near the end of training and be evaluated by the thoracic surgery faculty to successfully complete the curriculum. A similar review could be instituted annually, or more often if resource is allowed, to assess key components of anatomic pulmonary resections at different stages of training to help guide the degree of graduated autonomy of the trainees as they advance toward proficiency.

COMMENT

The use of robotics in surgery has grown exponentially in the past decade, and the rapid expansion of robotic technology has highlighted current educational challenges and gaps. To keep up with the demand, the surgical workforce’s training has relied heavily on industry-designed curriculums and credentialing processes. Sporadic institutional resident robotic curricula have surfaced in some academic programs. However, building educational programs on the industry’s foundation has generated resident curricula that fail to illustrate the progression of graded autonomy and define intraoperative components clearly. Evaluation and assessment are too often observational, self-reported, or based on resident operative volume. None of these curricula have been validated to improve resident training.

Other challenges to designing a robotic training curriculum in thoracic surgery include the variable recognized training pathways (ie, independent, integrated, and 4+3) that allow for different exposure and robotic operative experience for the trainees before starting the thoracic surgical service and differences in resources and constraints in developing and implementing a comprehensive educational curriculum among programs. These disparities in training and resources can potentially lead to an educational gap affecting thoracic surgical graduates, some of whom may be less prepared to enter the workforce. Furthermore, newly graduated trainees will continue to have to rely on industry-sponsored courses to gain

proficiency and to fulfill hospital credentialing requirements and expose themselves to potential conflict-of-interest implications and the absence of a robotic platform that is independent of any specific vendor.

The call for a standardized robotic surgery curriculum has been steadfast across many specialties and organizations. Unsurprisingly, most thoracic surgery program directors expressed the need for a structured robotic training curriculum in a recent survey.⁷⁹ Therefore, the STS Taskforce on Robotic Surgery, with support from the STS Workforce on E-learning and Educational Innovation and Thoracic Surgery Director’s Association, has drafted these expert consensus statements to lay a foundation for developing a national standardized robotic training curriculum, which is currently underway.

The proposed standardized curriculum should be technology agnostic and teach principles that apply across different platforms, because other robotic surgical systems may be introduced to the market in the near future. As noted in the consensus statement, we recommend that the trainee complete online modules and hands-on in-service before operating as a console surgeon to fully understand all of the robot system components and demonstrate proficiency in bedside assisting and basic robotic skills through VR simulations. A yearly wet laboratory session and emergency conversion scenario should be part of the curriculum to enhance trainees’ preparedness for live operation.

The trainee should be provided graduated responsibility in the operating room based on case-specific milestones for robotic anatomic lung resection, and the technical proficiency should be evaluated using clear objective assessment tools. The trainee should prepare for each console case by watching an educational video of an anatomic pulmonary resection before the operation, and a regular video review and analysis of the trainee’s robotic anatomical pulmonary resection should be performed soon thereafter to reassess and improve performance. Finally, an effective robotic surgery curriculum should have well-articulated, clear objectives and performance metrics that may be used to validate the effectiveness of the curriculum and improve the learning process.

Our intention is that this document serves as an impetus toward developing a standardized national robotic thoracic curriculum validated to improve resident education, abridge educational disparity, and serve as a springboard for future

educational research endeavors. We also hope these recommendations can persuade hospitals and institutions to invest resources in training residents. At the same time, we recognize the disparity among training programs. Therefore, the future national curriculum should be constructed to share resources and platforms among the participating programs to alleviate constraints and improve education across the specialty.

The authors would like to acknowledge Meredith Herzog, Jane Han, and Pallavi Sood of The Society of Thoracic Surgeons for expert coordination.

FUNDING SOURCES

The authors have no funding sources to disclose.

DISCLOSURES

Samuel Kim reports a relationship with Intuitive Surgical, Inc, that includes: funding grants and speaking and lecture fees. Elliot Servais reports a relationship with Intuitive Surgical, Inc, that includes: speaking and lecture fees. Bernard Park reports a relationship with Becton Dickinson and Company that includes: speaking and lecture fees; with Medtronic, Inc, that includes: consulting or advisory; and with Intuitive Surgical, Inc, that includes: speaking and lecture fees. Desmond D'Souza reports a relationship with Intuitive Surgical, Inc, that includes: speaking and lecture fees. Luis Godoy reports a relationship with Intuitive Surgical, Inc, that includes: speaking and lecture fees. Inderpal Sarkaria reports a relationship with Intuitive Surgical, Inc, that includes: consulting or advisory and speaking and lecture fees; with Oncolys BioPharma, Inc, that includes: consulting or advisory; with Medtronic, Inc, that includes: consulting or advisory; with On Target Laboratories, LLC, that includes: consulting or advisory; with Stryker Corporation that includes: consulting or advisory; and with American Medical Solutions, Inc, that includes: consulting or advisory. The other authors have no conflicts of interest to disclose.

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