Review Article

Suggested robotic-assisted thoracic surgery training curriculum

Muteb Al Zaidi[1,2], Gavin M. Wright[3,4,5], Kazuhiro Yasufuku[1,6]

[1]Division of Thoracic Surgery, University Health Network, Toronto General Hospital, Toronto, ON, Canada; [2]Division of Thoracic Surgery, King Abdullah Medical City, Makkah, Saudi Arabia; [3]St. Vincent's Hospital Melbourne, Melbourne, VIC, Australia; [4]Department of Surgery, University of Melbourne, Melbourne, VIC, Australia; [5]Victorian Comprehensive Cancer Centre, Melbourne, VIC, Australia; [6]Division of Thoracic Surgery, University of Toronto, Toronto, ON, Canada

Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: M Al Zaidi, GM Wright; (IV) Collection and assembly of data: M Al Zaidi; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Muteb Al Zaidi, MD, SBGS. Division of Thoracic Surgery, University Health Network, Toronto General Hospital 200 Elizabeth St. 9N-957, Toronto, ON M5G 2C4, Canada. Email: mutebzaidi@gmail.com.

Abstract: Robotic-assisted surgery, a technological advancement in the field of surgery, has become increasingly popular among surgeons of many specialties over time. Robotic-assisted thoracic surgery (RATS) is comparable to video-assisted thoracic surgery (VATS) in terms of patient care outcomes; however, the perception of increased operative time and a lack of cost-effectiveness have led to controversy regarding its alleged benefits. Nevertheless, robotic surgery is one of the preferred options for minimally invasive surgery by some thoracic surgeon over VATS, due to its ability to provide 3-D vision, precise wrist movements, enhanced magnification, and instrument stability and articulation. Notably, trainees in the field of thoracic surgery experience difficulty gaining knowledge and learning skills associated with RATS due to its complexity, limited access to robotic instruments, the lack of a standardized curriculum for trainees, and lack of mentorship or proctorship, thus leading to a steeper learning curve compared to laparoscopic or VATS procedures that are cost-friendly, easy to learn, and feasible to practice. Nevertheless, focusing on RATS training for thoracic surgeons will keep them familiar with robotic techniques, including the pre-operative setup and intra-operative process, which will ultimately decrease operative times. In this paper, we will review the literature, express and discuss the most viable training curriculum from authors' point of view to help achieve this goal.

Keywords: Robotic-assisted thoracic surgery (RATS); robotic thoracic surgery training program; robotic surgery training curriculum

Submitted May 02, 2022. Accepted for publication Dec 05, 2022. Published online Feb 16, 2023.
doi: 10.21037/jtd-22-598
View this article at: https://dx.doi.org/10.21037/jtd-22-598

Introduction

Robotic-assisted surgery training is a new modality in the surgery field that has produced improvements in patient care by enhancing patient recoveries with minimal complications (1). After a struggle of approximately sixty years since 1920, the first robotic surgery was performed by Czech and Capek (2). Initially, robots were designed to work autonomously according to the installed program, such as ROBODOC used in orthopedic surgeries, and PROBOT used in urological purposes (3). After 1990, however, robotic technology was changed from autonomous to a master-slave system rendering them dependent on surgeons. Further advancements were made through the introduction of the Zeus system designed especially for cardiac surgery. In 2003, the Da Vinci system was introduced, which consists of three essential components including a vision cart, master console cart, and surgical cart. The technique attained significant precision over years by combining tri-dimensional high-quality vision and improved magnification up to a multiple of 10 (4). Most recently, the Da Vinci Xi was introduced, which permits rapid docking and undocking, thus leading to decreased operative times. Additionally, a smaller trocar diameter and improved overhead architecture lead to reduced arm collision and less port trauma for patients. These advancements have led to increased applications of robotic surgery in the thoracic field (5).

Now, robotic surgery in the field of thoracic surgery is one of the preferred options for minimally invasive surgery, over video-assisted thoracoscopic surgery (VATS), due to its ability to provide 3-D vision, precise wrist movements, enhanced magnification, and instrument stability and articulation (6). However, studies have highlighted the significant cost of robotic lobectomies as an obstacle to adopting robotic lobectomies over video-assisted thoracoscopic lobectomies (7,8). Additionally, a comparison of robotic-assisted thoracic surgery (RATS) with VATS by Louie *et al.* showed no difference in terms of perioperative outcomes and nodal staging (6). Similarly, other single-center studies compared RATS to VATS and showed no difference in outcomes of VATS over RATS (9,10). Other multi-institutional studies reported similar perioperative outcomes (11,12). Apart from perioperative outcomes, long operative times were observed in robotic lobectomies compared to VATS lobectomies (10,12). This might be due to a lack of familiarity with docking, troubleshooting, and placement of ports. Therefore, increased experience with the technique has been suggested to result in decreased operative times (13-15).

Resident and fellow training

The application of robotic surgery in the field of thoracic surgery requires resident/fellow surgeons to be trained sufficiently in the field of robotic surgery by ensuring ample hands-on experience using robotic instruments through simulators (16). A proposal for a robotic thoracic surgery training program was presented by Shahin *et al.* (17). The essential components of this proposal included ascertaining plans for implementation of robotic thoracic surgery in real life, providing trainees with a training plan in accordance with the specific period, providing trainees with a mentor, certifying the knowledge and skills gained while completing their training, designing and performing an evaluation program to assess the competency of trainees in robotic thoracic surgery after the completion of their training period, and developing a process of bilateral feedback. Additionally, the registration of data for research purposes and patient follow-ups (i.e., for purposes of determining surgery outcomes in terms of patient wellbeing) is a mandatory part of this training program (18). Generally, training thoracic surgeons on the RATS technique is suggested to include multiple phases: pre-clinical, clinical, and continuous monitoring phase.

Pre-clinical training

Pre-clinical training is the initial phase of the RATS training program described by Guzzo *et al.* (19). It refers to robotic surgery trainees developing familiarity with the robotic surgery system and enabling them to learn basic robotic surgery techniques using simulators. This is achieved by developing a well-oriented course designed to deliver skill-based training that is organized in a structured manner. Every trainee should initially gain deep insights regarding general robotic surgery including basic functioning of the device model, parameters of the device used for troubleshooting, basic principles of device functioning, and device limitations. Therefore, thoracic trainees should learn basic robotic surgical knowledge before being trained in RATS-specific procedures. Schreuder *et al.* stated that like laparoscopies, robotic surgery training should be arranged in skill labs to help trainees develop hands-on experiences in their specialty-specific procedures. This requires a significant number of robots for various skill labs, thus raising concerns about cost-effectiveness (16). Therefore, it is recommended to utilize robots available in hospital operating rooms for training purposes when this system is not being used for real-life procedures. Apart from the availability of robotic devices, patient safety is also a matter of concern, as the chances of committing mistakes during the initial phase of the learning process are greater than in laparoscopic surgery (19).

Several researchers have highlighted the steep learning curve associated with thoracic robotic surgery in existing literature (15,20,21). One paper described most of the difficulty occurring during the first twenty procedures of every trainee (21). According to Melfi *et al.*, after training, the operative time of the thoracic robotic team was reduced to 2.5 hours from 5 hours (20). This has led to the introduction of simulators in robotic surgery training programs, which has enabled trainees to bypass the error-prone phase of the robotic surgery learning curve and practice thoracic procedures. This necessitates less early learning time in the operating room (19). Multiple

Table 1 Stages of RATS procedures according to its complexity

Standard level	Complex level	Expert level
• Pleural biopsy	• Lobectomies	• Pneumonectomy
• Peripheral wedge resection	• Segmentectomies	• Sleeve resections
• Mediastinal lymph node dissection	• Complex/deep wedge resection	• Tracheobronchoplasty
• Small hiatal hernia repair	• Thymectomy for myasthenia gravis	• Redo hiatal hernia repair
• Heller myotomy	• Giant hiatal hernia repair	• Esophagectomy
• Thoracic duct ligation	• Gastrectomy	
• Stage I–II thymic tumor		
• Small posterior mediastinal tumor		
• Thoracic sympathectomy		

RATS, robotic-assisted thoracic surgery.

thoracic surgery simulators are being used currently, including several animal and cadaveric models. Studies have demonstrated the effectiveness of animal and cadaveric models in robotic surgery training programs owing to their similarity to live human anatomy (22-25).

Clinical training

The clinical phase of RATS would necessitate practicing robotic surgery under the guidance of either a mentor or proctor. The concept of mutual mentoring is essential to developing skills and expertise associated with robotic surgery in trainees (26). The benefit of practicing robotic surgery under the guidance of a mentor is that it establishes quality surgical outcomes without sacrificing patient safety. Another mode of clinical training that is thought to decrease the steepness of the trainee learning curve in robotic thoracic surgery is proctorship. According to Kwon *et al.*, proctorship provides trainees with a rapid learning curve and greater efficiency (27). Proctorship is described as a rotational, turn-based form of surgical clinical training during which one trainee practices as a console surgeon and the other as a proctor. This mode of clinical training is acceptable, as the complication rate in this type of clinical training is far lower at only 8%, and operative time was also reduced (28,29). Furthermore, our use of the term "proctorship" is that an accredited expert who is employed to do a combination of advices, hands-on demonstration, assessment and take-over a procedure if necessary.

This phase can be broken down into three tiers of difficulty according to the complexity of RATS procedures (*Table 1*). It is mandatory for trainees to master simple techniques before progressing to more complex procedures.

Continuous monitoring and learning curve

The surgical learning curve refers to the number of surgical procedures that a surgeon performs to become an expert who is capable of consistently achieving good surgical outcomes, low incidence of perioperative complications, and acceptable operative times. The duration of the learning curve depends on multiple factors including those related to surgeons and those related to the hospital setting in which surgery is performed (16). The operative time required for robotic surgery is a component of the learning curve and is classified as setup time, docking time, console time, and theatre time. Setup time refers to the time required by the operating team to prepare the robot, and docking time refers to the time required for positioning and connecting the robot to the patient ports. Console time refers to the time required by the surgeon to complete a specific surgical procedure, and theatre time refers to the entire period in which the patient is kept in theatre for surgery. A highly trained operating team working in a good-quality healthcare setup is capable of reducing the setup and docking time of the procedure, whereas the console time is largely dependent on the surgeons' skills (30,31). The average thoracic surgeon needs to perform approximately 20 robotic lobectomies to develop the technical skills of a skilled robotic thoracic surgeon (15).

A study conducted by Hernandez *et al.* has described the learning curve of Ivor-Lewis esophagectomy as requiring

20 operations to attain robotic surgery proficiency for that procedure (32). The operative time of robotic esophagectomy was reduced after 20 cases, whereas overall morbidity due to surgery was reduced after 29 cases (33). In another study conducted by Sarkaria *et al.*, there was a reduction in median operative time from approximately 430 minutes to just over 370 minutes after performing of 30 to 45 cases (34). According to Tchouta *et al.*, the learning curve for RATS is far shorter than VATS (35). Furthermore, the standardization of techniques is an essential component of the learning curve, which helps the surgeon decrease the time required to learn a procedure by learning the basic heuristics of robotic procedures (36).

Team-based approach

The well-known adage, "Surgery is a team sport", is highly applicable to the field of robotic surgery, for it requires the applicability of a multi-disciplinary approach for surgery training and preparation. Accordingly, a dedicated team of surgeons, anesthetists, nurses, technicians, and bedside assistants is required to perform successful robotic thoracic surgeries. Technicians and nurses involved in robotic thoracic surgery should be competent in arranging robotic systems and its elements in the operating room, assembling all essential components of robotic instruments, turning the system on and off, positioning the patient cart, setting up the surgeon's console, and ensuring the safety features of the robotic instruments during the operative time (37). However, a major issue in team-based work in robotic surgery is a lack of effective communication among team members due to visual, auditory, and physical obstacles (38). Nevertheless, effective communication between console surgeons and bedside assistants and nurses should be part of the training process to enhance communication and to overcome critical situation, such as massive bleeding. It is recommended that the console surgeons should provide clear instructions to the team, and for the bedside assistant to repeat the instructions given by the console surgeon for confirmatory purposes. Intraoperatively, another possible solution is to reduce the ambient noise and use additive systems other than the Da Vinci audio system, such as headsets, to enhance communication among team members. Despite the additional training and time burden of the team-based approach in robotic thoracic surgery, a well-managed robotic surgery team is essential for decreasing the learning curve of the console surgeon and maintaining optimized learning circumstances for RATS program trainees (39).

Suggested curriculum

The safety of RATS procedures is largely dependent on the knowledge and skills of operators. It is therefore of prime importance to develop a standardized curriculum for RATS trainees in the form of an integrated RATS module to obtain relevant knowledge and skills. The thoracic trainee's module is designed according to several milestones; these milestones are structured based on competency levels required at various stages of training during graduation. In this milestone-based curriculum of thoracic surgery training, robotics training is set as a "level five" milestone in which trainees are trained in the care of patients' lungs and airways by acquiring technical skills (40). This milestone is considered to be an extraordinary milestone for thoracic surgery trainees and is not mandatory for everyone to reach (41).

A new curriculum was suggested by Raad *et al.* in which post-graduate robotic surgery training is categorized into two stages. Stage I refers to a preclinical stage lasting from the second year to the third year [postgraduate year (PGY) 2–3] and stage II from the fourth year through the sixth year. In PGY 2–3, trainees complete their learning from online modules, virtual reality, simulator training, and workshops. Conversely, the trainee in PGY 4–6 should be involved in more structural clinical learning, including docking, instrument insertion and exchange, and assisting console surgeons to achieve tissue retraction and hemostasis (41). Thus, this newly proposed curriculum can be incorporated into the previous milestone-based curriculum to ensure the production of competent robotic thoracic surgeons after graduation (41,42). A survey of program directors showed that most support the introduction of thoracic robotic surgery training in thoracic residency programs, and several of these program directors suggested robotic surgery training as a mandatory aspect of thoracic surgery training. This is further supported in the same survey by the opinions of some freshly graduated thoracic trainees who consider themselves to be less competent in performing minimally invasive robotic thoracic procedures. Considering the issues of cost and timing of practice in implementing robotic surgery training, didactic learning is maintained as an initial part of the newly suggested curriculum. It includes providing free access to robotic surgery knowledge to trainees through an online module. It also enables trainees to acquire the basic knowledge required to initiate robotic surgical practices. After these didactic modules, they are directed to practical training using simulators (42). Nevertheless, formal RATS training (fellowship training) is considered as one of the well-structured training programs. Hence, the trainees during their residency program may not be sufficiently exposed to RATS training as its usually interrupted by their other program agendas. A formal RATS rotation during residency training program or formal RATS fellowship training may be necessary to achieve a beneficial educational effect.

The senior authors are from different schools; however, their trainees follow this integrated curriculum which begins with online modules and simulator training, and escalates to more clinical practice and bedside care. Trainees then become assistants, and once the trainees master console handling, they will step up to practice simple RATS procedures (e.g., pleural biopsies and lymph node dissections). Then, they will begin more complex procedures under continuous direct supervision.

Assessment of trainees

After adequate training of residents and fellows, it is customary to evaluate trainees with formative and/or summative assessments. Thus, the establishment of a successful RATS training program requires a well-structured training module and systematic trainee evaluation plan. Trainees of robotic thoracic surgeons are assessed for the placement and positioning of patients, ports, and patient carts (43). Trainees are mostly evaluated after their training by assessing their ability to assist at the table side, use cameras and master manipulators, and handle tissues. Further evaluations include the use of clutches, EndoWrist®, stapling, suturing, and specimen retrieval. Moreover, the experience of trainees in troubleshooting and providing feedback to the proctor is essential. After evaluation, trainees should receive certification for their training by a thoracic surgery society or certification body (43). One of the suggested certification methods is to submit videos of procedures done by the trainee to the certifying body for evaluation and certification, and it is preferred to repeat certifications at regular intervals to maintain robotic thoracic surgery quality (41).

Limitation of RATS training development

Training in the field of robotic surgery is complex, and it has only been made more complicated due to the lack of a standardized program for thoracic surgery trainees. However, there are multiple limitations to the development of resident training programs in the field of robotic surgery. The most highlighted reason is the lack of cost-effectiveness. Hands-on training for robotic surgery requires residents to receive hands-on experience with the robotic instruments. This demands the availability of an adequate number of robotic instruments according to the resident load available in the hospital (44). Furthermore, transitioning thoracic surgeons are still on their own robotic learning curve. This results in competition for trainees' exposure time. Well-structured training will produce more expert surgeons, who are unencumbered by their own learning curve. Therefore, hands-on courses and using simulator are now considered to be an important component of the robotic thoracic resident training program. According to one study, approximately 80% of robotic surgery program directors rely on the robotic industry for assistance in acquiring robotic instruments for resident training, as the cost and availability of simulators are major barriers in the development of training programs of robotics surgeries (45). Another study reported the importance of sponsored cadaveric or animal labs in the development of hands-on robotics training labs for trainees of robotic thoracic surgery (46). It is, therefore, necessary to optimize the availability and accessibility of simulators for trainees who are future surgeons. An ideal simulator should be available 24 hours per day to all trainees, with a vision monitor to allow the tutor to provide the trainee with feedback. According to Rehman *et al.*, the Da Vinci skills simulator (dVSS) costs approximately $85,000 without an annual maintenance fund and, given that the dVSS cannot function without a console system, additional costs of the Da Vinci surgical system console are incurred through ongoing use (47). One of the suggested solutions to this problem is the availability of shared simulators across various departments.

Conclusions

Focused and well-structured RATS training program for trainee surgeons will ensure competence in robotic troubleshooting and techniques. Our recommendation is for future studies to focus on the qualitative assessment of these curricula, which would enhance global RATS training and may decrease the operative times which are widely considered to be a primary drawback of RATS compared to VATS.

Acknowledgments

Funding: None.

Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-598/coif). GMW reports non-financial support from Device Technologies, personal fees from Device Technologies, during the conduct of the study; personal fees from Medtronic, grants from Johnson & Johnson, outside the submitted work. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Hussain A, Malik A, Halim MU, et al. The use of robotics in surgery: a review. Int J Clin Pract 2014;68:1376-82.
2. Marino MV, Shabat G, Gulotta G, et al. From Illusion to Reality: A Brief History of Robotic Surgery. Surg Innov 2018;25:291-6.
3. Kalan S, Chauhan S, Coelho RF, et al. History of robotic surgery. J Robot Surg 2010;4:141-7.
4. Ashrafian H, Clancy O, Grover V, et al. The evolution of robotic surgery: surgical and anaesthetic aspects. Br J Anaesth 2017;119:i72-84.
5. Zirafa CC, Romano G, Key TH, et al. The evolution of robotic thoracic surgery. Ann Cardiothorac Surg 2019;8:210-7.
6. Louie BE, Wilson JL, Kim S, et al. Comparison of Video-Assisted Thoracoscopic Surgery and Robotic Approaches for Clinical Stage I and Stage II Non-Small Cell Lung Cancer Using The Society of Thoracic Surgeons Database. Ann Thorac Surg 2016;102:917-24.
7. Deen SA, Wilson JL, Wilshire CL, et al. Defining the cost of care for lobectomy and segmentectomy: a comparison of open, video-assisted thoracoscopic, and robotic approaches. Ann Thorac Surg 2014;97:1000-7.
8. Swanson SJ, Miller DL, McKenna RJ Jr, et al. Comparing robot-assisted thoracic surgical lobectomy with conventional video-assisted thoracic surgical lobectomy and wedge resection: results from a multihospital database (Premier). J Thorac Cardiovasc Surg 2014;147:929-37.
9. Louie BE, Farivar AS, Aye RW, et al. Early experience with robotic lung resection results in similar operative outcomes and morbidity when compared with matched video-assisted thoracoscopic surgery cases. Ann Thorac Surg 2012;93:1598-605.
10. Jang HJ, Lee HS, Park SY, et al. Comparison of the early robot-assisted lobectomy experience to video-assisted thoracic surgery lobectomy for lung cancer: a single-institution case series matching study. Innovations (Phila) 2011;6:305-10.
11. Farivar AS, Cerfolio RJ, Vallières E, et al. Comparing robotic lung resection with thoracotomy and video-assisted thoracoscopic surgery cases entered into the Society of Thoracic Surgeons database. Innovations (Phila) 2014;9:10-5.
12. Adams RD, Bolton WD, Stephenson JE, et al. Initial multicenter community robotic lobectomy experience: comparisons to a national database. Ann Thorac Surg 2014;97:1893-8; discussion 1899-900.
13. Veronesi G, Galetta D, Maisonneuve P, et al. Four-arm robotic lobectomy for the treatment of early-stage lung cancer. J Thorac Cardiovasc Surg 2010;140:19-25.
14. Cerfolio RJ, Bryant AS, Skylizard L, et al. Initial consecutive experience of completely portal robotic pulmonary resection with 4 arms. J Thorac Cardiovasc Surg 2011;142:740-6.
15. Veronesi G, Agoglia BG, Melfi F, et al. Experience with robotic lobectomy for lung cancer. Innovations (Phila) 2011;6:355-60.
16. Schreuder HW, Wolswijk R, Zweemer RP, et al. Training and learning robotic surgery, time for a more structured approach: a systematic review. BJOG 2012;119:137-49.
17. Shahin GMM, Brandon Bravo Bruinsma GJ, Stamenkovic S, et al. Training in robotic thoracic surgery-the European way. Ann Cardiothorac Surg 2019;8:202-9.
18. Nashaat A, Sidhu HS, Yatham S, et al. Simulation training for lobectomy: a review of current literature and future directions. Eur J Cardiothorac Surg 2019;55:386-94.

19. Guzzo TJ, Gonzalgo ML. Robotic surgical training of the urologic oncologist. Urol Oncol 2009;27:214-7.
20. Melfi FM, Menconi GF, Mariani AM, et al. Early experience with robotic technology for thoracoscopic surgery. Eur J Cardiothorac Surg 2002;21:864-8.
21. Gharagozloo F, Margolis M, Tempesta B, et al. Robot-assisted lobectomy for early-stage lung cancer: report of 100 consecutive cases. Ann Thorac Surg 2009;88:380-4.
22. Kajiwara N, Kakihana M, Usuda J, et al. Training in robotic surgery using the da Vinci® surgical system for left pneumonectomy and lymph node dissection in an animal model. Ann Thorac Cardiovasc Surg 2011;17:446-53.
23. McDougall EM, Corica FA, Chou DS, et al. Short-term impact of a robot-assisted laparoscopic prostatectomy 'mini-residency' experience on postgraduate urologists' practice patterns. Int J Med Robot 2006;2:70-4.
24. Vlaovic PD, Sargent ER, Boker JR, et al. Immediate impact of an intensive one-week laparoscopy training program on laparoscopic skills among postgraduate urologists. JSLS 2008;12:1-8.
25. Gamboa AJ, Santos RT, Sargent ER, et al. Long-term impact of a robot assisted laparoscopic prostatectomy mini fellowship training program on postgraduate urological practice patterns. J Urol 2009;181:778-82.
26. Jones A, Eden C, Sullivan ME. Mutual mentoring in laparoscopic urology – a natural progression from laparoscopic fellowship. Ann R Coll Surg Engl 2007;89:422-5.
27. Kwon EO, Bautista TC, Blumberg JM, et al. Rapid implementation of a robot-assisted prostatectomy program in a large health maintenance organization setting. J Endourol 2010;24:461-5.
28. Mirheydar H, Jones M, Koeneman KS, et al. Robotic surgical education: a collaborative approach to training postgraduate urologists and endourology fellows. JSLS 2009;13:287-92.
29. Santok GD, Raheem AA, Kim LH, et al. Proctorship and mentoring: Its backbone and application in robotic surgery. Investig Clin Urol 2016;57:S114-20.
30. Sammon J, Perry A, Beaule L, et al. Robot-assisted radical prostatectomy: learning rate analysis as an objective measure of the acquisition of surgical skill. BJU Int 2010;106:855-60.
31. Seamon LG, Fowler JM, Richardson DL, et al. A detailed analysis of the learning curve: robotic hysterectomy and pelvic-aortic lymphadenectomy for endometrial cancer. Gynecol Oncol 2009;114:162-7.
32. Hernandez JM, Dimou F, Weber J, et al. Defining the learning curve for robotic-assisted esophagogastrectomy. J Gastrointest Surg 2013;17:1346-51.
33. Abbott A, Shridhar R, Hoffe S, et al. Robotic assisted Ivor Lewis esophagectomy in the elderly patient. J Gastrointest Oncol 2015;6:31-8.
34. Sarkaria IS, Rizk NP, Grosser R, et al. Attaining Proficiency in Robotic-Assisted Minimally Invasive Esophagectomy While Maximizing Safety During Procedure Development. Innovations (Phila) 2016;11:268-73.
35. Tchouta LN, Park HS, Boffa DJ, et al. Hospital Volume and Outcomes of Robot-Assisted Lobectomies. Chest 2017;151:329-39.
36. Ricciardi S, Zirafa CC, Davini F, et al. How to get the best from robotic thoracic surgery. J Thorac Dis 2018;10:S947-50.
37. Zender J, Thell C. Developing a successful robotic surgery program in a rural hospital. AORN J 2010;92:72-83; quiz 84-6.
38. Schiff L, Tsafrir Z, Aoun J, et al. Quality of Communication in Robotic Surgery and Surgical Outcomes. JSLS 2016;20:e2016.00026.
39. Sim HG, Yip SK, Lau WK, et al. Team-based approach reduces learning curve in robot-assisted laparoscopic radical prostatectomy. Int J Urol 2006;13:560-4.
40. Vaporciyan AA, Yang SC, Baker CJ, et al. Cardiothoracic surgery residency training: past, present, and future. J Thorac Cardiovasc Surg 2013;146:759-67.
41. Raad WN, Ayub A, Huang CY, et al. Robotic Thoracic Surgery Training for Residency Programs: A Position Paper for an Educational Curriculum. Innovations (Phila) 2018;13:417-22.
42. Raad W. Approaches to maintaining high-quality surgery training in the twenty-first century. Bull Am Coll Surg 2011;96:45-7.
43. Sridhar AN, Briggs TP, Kelly JD, et al. Training in Robotic Surgery-an Overview. Curr Urol Rep 2017;18:58.
44. Chen R, Rodrigues Armijo P, Krause C, et al. A comprehensive review of robotic surgery curriculum and training for residents, fellows, and postgraduate surgical education. Surg Endosc 2020;34:361-7.
45. Kempenich JW, Willis RE, Campi HD, et al. The Cost of Compliance: The Financial Burden of Fulfilling Accreditation Council for Graduate Medical Education

and American Board of Surgery Requirements. J Surg Educ 2018;75:e47-53.
46. Alicuben ET, Wightman SC, Shemanski KA, et al. Training residents in robotic thoracic surgery. J Thorac Dis 2021;13:6169-78.
47. Rehman S, Raza SJ, Stegemann AP, et al. Simulation-based robot-assisted surgical training: a health economic evaluation. Int J Surg 2013;11:841-6.

Cite this article as: Al Zaidi M, Wright GM, Yasufuku K. Suggested robotic-assisted thoracic surgery training curriculum. J Thorac Dis 2023;15(2):791-798. doi: 10.21037/jtd-22-598

