Transitioning to robotics in a successful thoracoscopic and laparoscopic thoracic program: why do it, and how?

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Abstract: The robotic platform has been successfully embraced within thoracic surgery for over 20 years, with numerous applications in both the thoracoscopic as well as the laparoscopic realms. Despite the success of robotic-assisted surgery in a wide range of operations, from lobectomies to benign foregut surgery to esophagectomies, many centers still face significant barriers to the successful implementation of this platform. In this review, we will briefly discuss the applications of the robotic platform within the field of thoracic surgery. We will highlight the advantages of adopting a robotic practice; namely, improved visualization, wristed instruments, ambidexterity, enhanced trainee education, and the potential for better outcomes, such as reduced length of stay and more effective lymphadenectomy. We will emphasize the importance of embracing the robotic platform in the field of thoracic surgery, and we will also address the obstacles that may hinder the adoption of this platform. Finally, we offer potential methods to enhance the transition to a robotic practice in an academic center, and we share our own experience of transitioning to a robotic thoracic practice at the University of Pittsburgh Medical Center (UPMC). With the right approach, we believe this platform can considerably enhance the practice of minimally invasive thoracic surgeons everywhere in the present day.

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Background: the rise of robotics in thoracic surgery

The robotic surgical platform has been embraced with impressive speed over the past few decades, despite initial skepticism from many surgeons. Computer Motion's initial robot, "Zeus", while a revolution in its time, had many limitations, particularly in articulation. This limited the utility of the robotic platform in complex operations and fueled early skepticism. However, while "Zeus" was approved for a limited number of clinical trials, Computer Motion's competitor, Intuitive Surgical, was soon to release their robotic platform, with several key technologic advances. The two companies merged in 2003 leading to overall improved technology. Intuitive Surgical's "Davinci" system emerged as the clinical forerunner for nearly two decades as more advanced versions of the platform were introduced. The skills required to complete complex cases with the Davinci were soon acquired by an increasing number of surgeons, and, today, robotic-assisted surgery with the Davinci has become the new "norm" in many centers.

The robotic platform has been utilized in thoracic surgery for over 20 years, with one of the first reported robotic lobectomies for lung cancer performed in 2002 (1). From 2002 to 2008, less than one percent of lobectomies were done robotically in the United States. By 2013, this increased to 11% and currently is over 25% (2,3). Outcomes of robotic lobectomy have been promising and comparable to open and video-assisted thoracoscopic surgery (VATS) reports, with 5-year stage specific survival of 83% for stage 1A non-small cell lung cancer (NSCLC), 77% for stage IB, 68% for stage IIA, 70% for stage IIB, 62% for IIIA, and 31% for IIIB (Seventh edition, lung cancer staging), with a 3% local recurrence rate (4). Of course, preceding the pulmonary robotic applications, tremendous strides were made in the minimally invasive thoracoscopic approach to lung cancer.

This early VATS work propelled the popularity of thoracoscopic lobectomy forward, so that VATS lobectomy had already become the standard approach to lung cancer in many major cancer centers long before robotics became available and ultimately popularized (5-7).

The use of robotics in thoracic surgery has expanded significantly, not only in the thoracoscopic realm but also in the laparoscopic realm. The robotic platform has been successfully applied to benign esophageal operations for achalasia, gastroesophageal reflux disease, repair of giant paraesophageal hernias, and in some centers of excellence, robotic-assisted surgery for failed anti-reflux operations. Just as advances in VATS enhanced the subsequent adoption of robotics in pulmonary surgery, advances in minimally invasive foregut surgery by a number of pioneers streamlined the application of robotic surgery to the laparoscopic thoracic realm (8-10). Kernstine *et al.* reported one of the first series of robotic assisted minimally invasive esophagectomy (RAMIE) 15 years ago (11), but few surgeons adopted the robotic platform for esophagectomy initially. With increasing robotic experience, thoracic surgeons have now embraced RAMIE, and it has become increasingly popular in many major medical centers (12-14).

While enthusiasm for the robotic platform has already been embraced by many thoracic surgeons, significant obstacles remain as barriers to its adoption for some. The following article reviews the transition to a successful robotic thoracoscopic and laparoscopic thoracic program.

Transitioning to a robotic thoracic program: why do it?

The motives for adopting a robotic thoracic program are numerous. To some degree, it is no different from "smart" homes, navigation systems, and self-driving cars—the world we live in is changing. Robotic-assisted surgery is, in essence, an extension of existing minimally invasive techniques. The learning curve from laparoscopic and thoracoscopic procedures to robotic-assisted surgery is certainly smaller than the learning curve from open surgery to laparoscopic or thoracoscopic procedures (15), and advancing technology offers several potential benefits.

In addition to providing improved visualization, ambidexterity, and wristed instruments, robotic surgery may offer more favorable ergonomics and increased comfort while operating, thereby reducing surgeon fatigue. Though a bedside assistant is still required, robotic surgery may also lessen the need for a skilled first assist, since the primary surgeon controls most of the needed instruments. Moreover, the robotic platform at most academic centers enhances trainee education, and many surgeons who are still in training or recently graduating are choosing programs that offer significant exposure to robotics and robotic block time. The dual console allows for fluid transition from surgeon to trainee, with the trainee's vantage point and instrument orientation remaining identical to that of the primary surgeon's at all times throughout the operation. Thus, with the robotic platform, residents and fellows no longer have to learn "from the other side of the table". Additionally, with the ability to draw or telestrate directly on the screen, the surgeon can efficiently point out relevant anatomy and redirect a trainee's dissection in real-time without necessarily taking over. Of course, the primary surgeon can resume control from his/her own console at any time if need be. This flexibility can help improve the trainee's confidence and lessen the primary surgeon's concerns or frustrations. Finally, the robotic technology allows for video recordings of the operation to be easily saved, which can enhance teaching through later review and critique of operative conduct (16).

Ultimately, the most important feature of any new technology or surgical approach, is the improvement of outcomes. There is, in fact, an increasing amount of data demonstrating that surgical outcomes are improving with the robotic platform over non-robotic minimally invasive approaches. These improvements are most consistently demonstrated as reduced length of stay and enhanced lymphadenectomy with the robotic approach (17,18).

A recent systematic review comparing robotic and thoracoscopic lung resection demonstrated trends toward decreased mortality, length of stay, and chest tube duration with the robotic approach (17). Utilization of the robot has also demonstrated increased nodal harvest in most studies and has been suggested, though has not been definitively shown, to offer higher rates of nodal upstaging than VATS or open approaches (19). Nodal upstaging enhances the appropriate selection of patients for adjuvant chemotherapy, immunotherapy, and targeted receptor therapy, potentially impacting survival in NSCLC (20). In order to support widespread adoption and investment in robotic surgery, additional data in the form of prospective studies demonstrating the superiority of robotic outcomes are imperative.

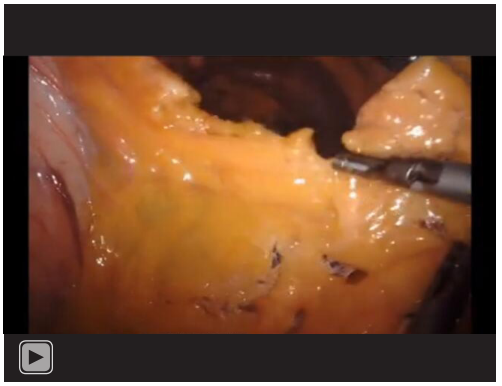
Robotic-assisted foregut surgery has also demonstrated comparable, and in a few studies, better outcomes when compared with the laparoscopic approach. Robotic-assisted Heller myotomy has demonstrated similar relief of dysphagia, operative times, and conversion rates when compared to laparoscopic Heller myotomy, while also demonstrating lower rates of intraoperative esophageal perforations (21). While robotic anti-reflux surgery has demonstrated postoperative outcomes comparable with the laparoscopic approach, some small studies have shown improved outcomes in cases of complex reoperative antireflux surgery with the robotic approach over the laparoscopic approach. Specifically, robotic-assisted reoperative anti-reflux operations have been associated with lower conversion rates, lower perforation and vagal nerve injury rates, lower readmission rates and decreased length of stay, as well as superior symptomatic relief and improved functional outcomes (22-24).

While there are many reasons for adopting a robotic thoracic program, there are a few notable limitations. Perhaps the most important limitation of the robot is the lack of tactile feedback during an operation. While learned assessment of "visual" tension largely obviates this limitation with experience, this is one of the reasons that tissue handling must be practiced on a console prior to using the robot. Additionally, the cost of implementing a robotic platform may be excessive, particularly in low volume centers, as detailed later in the review. Nevertheless, it is not the 'why', but the 'how' that remains an obstacle for many programs.

Transitioning to a robotic thoracic program: how to do it

As with any advancement in medicine, adoption of the robotic platform faces significant barriers which surgeons and institutions alike should be prepared to overcome. Surgeons must be willing to accept the learning curve necessary to be proficient with the robot and must have an adequate volume of cases to do so. Given the advancements in the platform, robotic thoracic surgery can now be offered to even the most complex patients. As surgeons adopt the platform and become more comfortable using the robot for various operations, they can increase their volume of cases by offering robotic surgery to an expanding pool of patients. Of course, there should be buy-in from the institution to allow the operating room time for this platform to grow. All operating room personnel must be trained, must know their roles, and must understand the conduct of robotic-assisted procedures. Communication and trust between the surgeon at the console and the assistant at the bedside are critical. Finally, the institution must be willing to accept increases in operative time and cost, which will likely only be temporary inconveniences. In this review, we will focus on the transition to a robotic thoracic program, specifically in the setting of a large academic center.

The successful transition to a robotic program should begin with the recruitment of a robotic surgeon and the consistent training of one specialized team of surgical technicians, advanced practice providers, and trainees, along with all operating room staff (25). A mock run-through should be performed when the robotic platform is newly being implemented, and this session should include room set-up, patient positioning, and what to do in the case of an emergency. Surgeons adopting the robotic platform must know when to abort and open, and the surgical team must know how to disengage the instruments expeditiously. Simulation training should be required, in addition to experience with bedside assisting, prior to assuming a role at the console. For faculty and trainees who are new to the robotic platform, online modules should be completed for an informational foundation regarding basic set-up, port placement, and instrumentation. Subsequent simulation modules on a robotic console are essential for hands-on training. These simulations are instrument- and technique-specific, so that basic skills such as camera control, switching instruments, suturing, cauterizing, and meticulous tissue handling can be mastered prior to using the robot in the operating room. As suggested in prior reviews, we have found this to be the safest and most efficient way to overcome the learning curve required for individuals to adopt the robotic platform (26). Initial experience at the console should be proctored. Graded privileges may be considered for surgeons as number and skill level of cases increase, and each surgeon must have access to the robot



Video 1 Technique of robotic assisted minimally invasive esophagectomy (RAMIE).

regularly, such as once or twice a week, to develop and maintain their skills. While the same credentialing pathway of online training, simulation modules, and proctored cases applies to all who are adopting the robotic platform, the number of required proctored cases may differ depending on overall surgical experience (e.g., an experienced minimally invasive surgeon versus a graduating fellow).

Ideally, the institution as a whole would embrace the adoption of a robotic platform to support this transition. At the institutional level, a method of credentialing surgeons, trainees, and operating room staff could then be implemented, and institutional monitoring of safety and outcomes could be established. In order to facilitate this, there must be buy in from the leadership, which goes back to the reasons for adopting a robotic program. Surgeons must be convinced of the benefits of the robotic platform to advocate for its support at an institutional level. Thus, surgeon leadership is paramount in this transition.

As an example of how we transitioned to a robotic-assisted thoracic surgery group at the University of Pittsburgh Medical Center (UPMC), let's discuss one of the more complex operations: RAMIE (*Video 1*). Arguably, our group at UPMC, under Dr. Luketich's tenure, has trained more surgeons in laparoscopic/thoracoscopic minimally invasive esophagectomy (MIE) than any other program in the world. We had favorable outcomes, and our operative times and nodal counts were comparable to or better than those achieved with an open approach. How and why did we change to RAMIE? First, the general attitude at UPMC has always been to pursue and achieve the cutting edge in advances in the field of thoracic surgery, including minimally invasive approaches, endoscopic therapies, per oral endoscopic myotomy (POEM), various laser advances and stents, etc. Thus, the desire to implement robotic-assisted surgery into our thoracic program was reflexive. In order to accomplish this, in any institution, we believe you need a clear leader in the robotic platform, one that has dedicated the time and effort to investigate the robotic options, master the robotic approaches, and preferably has previously mastered open and laparoscopic and thoracoscopic techniques.

The initial step in our department was to identify and then recruit who we considered to be one of the leaders in the field of robotic-assisted surgery. As most readers are likely aware, this leader was Inderpal S. Sarkaria. At the time we recruited Dr. Sarkaria, he had already demonstrated his leadership in various robotic societies and meetings and had performed over 100 RAMIEs with outstanding results. After his arrival, he created training programs, and set about training a select few attendings, initially only those with the most advanced minimally invasive techniques. Initially, this was a slow process, but our surgeons (Chairman and Division Chief's as well), recognized the advantages of having an advanced mentored approach by our robotic expert. Now, we have four surgeons credentialed in RAMIE utilizing the same techniques, which have been previously described (27-29).

This mentored approach helped us to avoid the limitations of leaping ahead prematurely and starting a robotic experience after a "weekend course", where unnecessary complications would likely have occurred. We stayed with this approach, and all surgeons in our thoracic department at UPMC who ultimately were credentialed followed the same coordinated approach, which included basic required training on the robotic platform and performing the requisite number of mentored cases on the dual console.

After this, we sought "group consensus" that credentialing was appropriate for various procedures tailored to each attending. With some operations, we were able to see a fairly consistent learning curve which was, to some degree, directly related to the surgeon-in-training's prior laparoscopic/VATS or open experience. We clearly believe this was a successful approach, as we now have over 10 credentialled robotic surgeons with few, if any, true "robotic-related emergencies", no intra-operative deaths, and no compromise in surgical outcomes compared to our standard minimally invasive approaches. Not all thoracic surgeons are credentialed in every robotic operation at our institution. For example, only 4 are RAMIE credentialed, 7 are robotic lobectomy credentialed, and only 2 are credentialed for other less common operations (first rib, etc.). The goal of this mentored, credentialed approach is not to hold surgeons back, but to assure patient safety and excellent outcomes with adoption of robotic techniques.

While beyond the scope of this review, it is worth briefly mentioning the adoption of robotics in a smaller community hospital setting. Following online training and simulation on a robotic console, some hospitals have employed training at an Intuitive Surgical practice facility, where trainees and faculty can practice docking, use the equipment, complete individual tasks such as dissection and knot-tying, and perform operations on cadavers. This would precede proctored use of the robot in the operating room (30).

Lastly, increased costs and operative times are ongoing concerns as the adoption of robotic surgery becomes more widespread. However, our group found that VATS and robotic approaches to lobectomy and segmentectomy actually have comparable direct costs (along with equivalent 30-day mortality, decreased length of stay, and decreased chest tube duration in the robotic group) (31). There is evidence to suggest that costs may actually be reduced with the robotic platform, especially at high volume centers, and operative times will likely decrease as surgeon's gain experience with the robot (24). Indeed, Müller-Stich *et al.* have already reported shorter total operative times with robotic compared to laparoscopic fundoplication (88 *vs.* 102 min), attributable to a single experienced surgeon performing all robotic procedures with a well-trained surgical team (32). A recent nationwide comparative effectiveness analysis utilizing the Premier Healthcare Database performed propensity score matched comparisons of robotic and VATS lobectomy during two different time periods (the 'early period', 2008–2012, and the 'late period', 2013–2015). In the early period, robotic lobectomy had a longer operative time by a median of 30 min. In the late period, operative time was now only longer than VATS by a median of 18 min, and robotic lobectomy now demonstrated a lower in-hospital and 30-day perioperative complication rate than VATS lobectomy. In both time periods, cost comparison demonstrated that robotic lobectomy was more expensive than VATS only in low-volume centers (<25 cases annually); otherwise, total costs with either approach were equivalent (33). Furthermore, while costs of robotic lobectomy have been estimated to outweigh VATS by $3,000–5,000 per case, the robotic approach may actually improve cost effectiveness when also considering indirect costs (34,35).

Conclusions

The reasons to adopt a robotic thoracic program are numerous and include improved visualization, ambidexterity, wristed instruments, surgeon comfort, enhanced education for trainees, and comparable to potentially improved outcomes. The methods of adopting such a program, at least in a large academic medical center, involve protocolized credentialing, training of all operating room staff beginning with a specialized team, and ideally, buy in from the leadership, such that the platform is embraced and implemented at an institutional level.

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Footnote

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References

1. Melfi FM, Menconi GF, Mariani AM, et al. Early experience with robotic technology for thoracoscopic surgery. Eur J Cardiothorac Surg 2002;21:864-8.
2. Park BJ, Melfi F, Mussi A, et al. Robotic lobectomy for non-small cell lung cancer (NSCLC): long-term oncologic results. J Thorac Cardiovasc Surg 2012;143:383-9.
3. Nasir BS, Bryant AS, Minnich DJ, et al. Performing robotic lobectomy and segmentectomy: cost, profitability, and outcomes. Ann Thorac Surg 2014;98:203-8; discussion 208-9.
4. Cerfolio RJ, Ghanim AF, Dylewski M, et al. The long-term survival of robotic lobectomy for non-small cell lung cancer: A multi-institutional study. J Thorac Cardiovasc Surg 2018;155:778-86.
5. Daniels LJ, Balderson SS, Onaitis MW, et al. Thoracoscopic lobectomy: a safe and effective strategy for patients with stage I lung cancer. Ann Thorac Surg 2002;74:860-4.
6. Demmy TL, James TA, Swanson SJ, et al. Troubleshooting video-assisted thoracic surgery lobectomy. Ann Thorac Surg 2005;79:1744-52; discussion 1753.
7. McKenna RJ Jr, Houck W, Fuller CB. Video-assisted thoracic surgery lobectomy: experience with 1,100 cases. Ann Thorac Surg 2006;81:421-5; discussion 425-6.
8. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg 2012;256:95-103.
9. Terry M, Smith CD, Branum GD, et al. Outcomes of laparoscopic fundoplication for gastroesophageal reflux disease and paraesophageal hernia. Surg Endosc 2001;15:691-9.
10. Schuchert MJ, Luketich JD, Landreneau RJ, et al. Minimally-invasive esophagomyotomy in 200 consecutive patients: factors influencing postoperative outcomes. Ann Thorac Surg 2008;85:1729-34.
11. Kernstine KH, DeArmond DT, Shamoun DM, et al. The first series of completely robotic esophagectomies with three-field lymphadenectomy: initial experience. Surg Endosc 2007;21:2285-92.
12. Okusanya OT, Sarkaria IS, Hess NR, et al. Robotic assisted minimally invasive esophagectomy (RAMIE): the University of Pittsburgh Medical Center initial experience. Ann Cardiothorac Surg 2017;6:179-85.
13. van der Sluis PC, van der Horst S, May AM, et al. Robot-assisted Minimally Invasive Thoracolaparoscopic Esophagectomy Versus Open Transthoracic Esophagectomy for Resectable Esophageal Cancer: A Randomized Controlled Trial. Ann Surg 2019;269:621-30.
14. Tong C, Xu Y, Cao H, et al. Short-term outcomes of robot-assisted versus thoracoscopic-assisted minimally invasive esophagectomy. Ann Thorac Surg 2021;S0003-4975(21)01304-7.
15. Sarkaria IS, Latif MJ, Bianco VJ, et al. Early operative outcomes and learning curve of robotic assisted giant paraesophageal hernia repair. Int J Med Robot 2017. doi: 10.1002/rcs.1730.
16. Geraci TC, Sasankan P, Luria B, et al. Intraoperative Anesthetic and Surgical Concerns for Robotic Thoracic Surgery. Thorac Surg Clin 2020;30:293-304.
17. Emmert A, Straube C, Buentzel J, et al. Robotic versus thoracoscopic lung resection: A systematic review and meta-analysis. Medicine (Baltimore) 2017;96:e7633.
18. Yang Y, Li B, Yi J, et al. Robot-assisted Versus Conventional Minimally Invasive Esophagectomy for Resectable Esophageal Squamous Cell Carcinoma: Early Results of a Multicenter Randomized Controlled Trial: the RAMIE Trial. Ann Surg 2022;275:646-53.
19. Okusanya OT, Lutfi W, Baker N, et al. The association of robotic lobectomy volume and nodal upstaging in non-small cell lung cancer. J Robot Surg 2020;14:709-15.
20. Chen Y, Zhang J, Jiang C, et al. The number of lymph nodes examined is associated with survival outcomes and nodal upstaging in patients with stage I small cell lung cancer. Surg Oncol 2021;37:101513.
21. Milone M, Manigrasso M, Vertaldi S, et al. Robotic versus laparoscopic approach to treat symptomatic achalasia: systematic review with meta-analysis. Dis Esophagus 2019;32:1-8.
22. Elmously A, Gray KD, Ullmann TM, et al. Robotic Reoperative Anti-reflux Surgery: Low Perioperative Morbidity and High Symptom Resolution. World J Surg 2018;42:4014-21.
23. Tolboom RC, Draaisma WA, Broeders IA. Evaluation of conventional laparoscopic versus robot-assisted

laparoscopic redo hiatal hernia and antireflux surgery: a cohort study. J Robot Surg 2016;10:33-9.
24. Damani T, Ballantyne G. Robotic Foregut Surgery. Surg Clin North Am 2020;100:249-64.
25. Wrightson W. Robotic thoracic surgery: a support team to replace the bedside surgeon. J Robot Surg 2019;13:511-4.
26. Latif MJ, Park BJ. Robotics in general thoracic surgery procedures. J Vis Surg 2017;3:44.
27. Ekeke CN, Luketich JD, Sarkaria IS. Robotic-assisted minimally invasive esophagectomy. Ann Esophagus 2021;4:7.
28. Okusanya OT, Hess NR, Luketich JD, et al. Technique of robotic assisted minimally invasive esophagectomy (RAMIE). J Vis Surg 2017;3:116.
29. Witek TD, Brady JJ, Sarkaria IS. Technique of robotic esophagectomy. J Thorac Dis 2021;13:6195-204.
30. Spillane J, Brooks P. Developing a robotic program in thoracic surgery at Cape Cod Hospital. J Robot Surg 2014;8:213-20.
31. Coyan GN, Lu M, Ruppert KM, et al. Activity-Based Cost Analysis of Robotic Anatomic Lung Resection During Program Implementation. Ann Thorac Surg 2022;113:244-9.
32. Müller-Stich BP, Reiter MA, Wente MN, et al. Robot-assisted versus conventional laparoscopic fundoplication: short-term outcome of a pilot randomized controlled trial. Surg Endosc 2007;21:1800-5.
33. Nguyen DM, Sarkaria IS, Song C, et al. Clinical and economic comparative effectiveness of robotic-assisted, video-assisted thoracoscopic, and open lobectomy. J Thorac Dis 2020;12:296-306.
34. Marshall MB, Wee JO. Robotic Platform Use in General Thoracic Surgery. JAMA Surg 2019;154:1066-7.
35. Park BJ, Flores RM. Cost comparison of robotic, video-assisted thoracic surgery and thoracotomy approaches to pulmonary lobectomy. Thorac Surg Clin 2008;18:297-300, vii.

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