Review Article

Robotic thoracic surgery: The state of the art

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Abstract

Minimally invasive thoracic surgery has come a long way. It has rapidly progressed to complex procedures such as lobectomy, pneumonectomy, esophagectomy, and resection of mediastinal tumors. Video-assisted thoracic surgery (VATS) offered perceptible benefits over thoracotomy in terms of less postoperative pain and narcotic utilization, shorter ICU and hospital stay, decreased incidence of postoperative complications combined with quicker return to work, and better cosmesis. However, despite its obvious advantages, the General Thoracic Surgical Community has been relatively slow in adapting VATS more widely.

The introduction of da Vinci surgical system has helped overcome certain inherent limitations of VATS such as two-dimensional (2D) vision and counter intuitive movement using long rigid instruments allowing thoracic surgeons to perform a plethora of minimally invasive thoracic procedures more efficiently.

Although the cumulative experience worldwide is still limited and evolving, Robotic Thoracic Surgery is an evolution over VATS. There is however a lot of concern among established high-volume VATS centers regarding the superiority of the robotic technique. We have over 7 years experience and believe that any new technology designed to make minimal invasive surgery easier and more comfortable for the surgeon is most likely to have better and safer outcomes in the long run. Our only concern is its cost effectiveness and we believe that if the cost factor is removed more and more surgeons will use the technology and it will increase the spectrum and the reach of minimally invasive thoracic surgery.

This article reviews worldwide experience with robotic thoracic surgery and addresses the potential benefits and limitations of using the robotic platform for the performance of thoracic surgical procedures.

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INTRODUCTION

Since its inception in early twentieth century, minimally invasive thoracic surgery has come a long way. Described first by a Swedish Physician, Dr. Hans Christian Jacobaeus in 1903, Thoracoscopy started off as pleural adhesiolysis and remained mainly in diagnostic arena for many decades. In early 1990s, with the incorporation of video technology, video-assisted thoracoscopic surgery (VATS) came into being and rapidly progressed to complex procedures such as lobectomy, pneumonectomy, Esophagectomy and resection of mediastinal tumors. VATS offered perceptible benefits over thoracotomy in terms of less postoperative pain and narcotic utilization, shorter ICU and hospital stay, decreased incidence of postoperative complications, quicker return to work, and better cosmesis. However, despite its obvious advantages, the general thoracic surgical community has been relatively slow in adapting VATS more widely. Recent reviews have shown that over 70% of stage I lung cancers are still being performed by open technique.[1] Even in the United States, Society of Thoracic Surgeon's database shows that only 45% of lobectomies are being performed by VATS.[2] The reasons for this slow adaptation of VATS include 2D vision with lack of depth perception and the use of long rigid instruments in a counter intuitive manner. The lack of maneuverability, with ribs acting as fulcrum points, limiting accessibility and ease of movement in inaccessible areas prevents fine dissection and makes dealing with large and fragile pulmonary vessels really demanding. These concerns about the VATS approach make it difficult to adopt. These findings suggest that surgeons are still struggling with the VATS platform and the outcomes claimed by expert VATS groups may not be replicated uniformly across the general thoracic surgical community.

The introduction of da Vinci surgical system with three-dimensional (3D) vision and the endo-wrist technology leading to intuitive instrument movements has helped overcome these limitations and allowed the surgeon to virtually perform the lobectomy with his hands without the morbidity of a thoracotomy. It provides excellent 3D vision with magnification (a view even better than open surgery) and precise dissection with much improved surgeon ergonomics. Although the cumulative experience worldwide is still limited and evolving, robotic thoracic surgery is an evolution over VATS.

This article reviews worldwide experience with robotic thoracic surgery and addresses the potential benefits and limitations of using the robotic platform for the performance of thoracic operations.

Robotic Lung Resection

The first report of the use of Robotic System for primary lung cancer came from Melfi *et al*.,[3] in 2002. Due to safety concerns, the surgery was converted to thoracotomy in two of five patients. Nevertheless, the report demonstrated the feasibility of the procedure. Since then numerous reports have been published. Most of the authors have reported the use of three robotic arms with the four-arm technique being reported only by Veronesi *et al*, Cerfolio *et al*, and Park *et al*.[4-6] We believe it is much simpler and more standardized and can be adapted for all the lobes. It also allows for a relatively more efficient use of assistant port by the bedside surgeon. Reported complications range from 10.5% to 43.5% across various case series. The most commonly reported complications were prolonged air leak and arrhythmia. None of the reports have attributed any complication specific to the use of robotic system. The operative time shortens along the learning curve, and this shortening is evident after doing 20-30 cases in many reports.[7,8] The mortality is 0-3%, which is similar to that after conventional lung cancer surgery. Park *et al*.[6] recently reported a multicenter study involving 325 patients, in which the 5-year survival rate in all patients was 80% (stage IA, 91%, stage IB 88%, stage II 49%), showing a favorable outcome.

Robotic lobectomy is an extension of the minimally invasive lobectomy spectrum and is therefore naturally expected to have all the advantages of VATS lobectomy when compared with conventional open technique. But whether it is better than VATS lobectomy remains to be seen. There are very few reports comparing robotic lobectomy with conventional VATS lobectomy.[9-12] At present, only data on short-term results can be compared. Paul *et al*.[13] compared in-hospital mortality, complications, length of stay, and cost for patients undergoing robotic-assisted lobectomy and those undergoing thoracoscopic lobectomy. A 2498 robotic-assisted and 37,595 thoracoscopic lobectomies performed from 2008 to 2011 were analyzed. In this early experience with robotic surgery, robotic-assisted lobectomy was found to be associated with a higher rate of intraoperative injury and bleeding than thoracoscopic lobectomy at a significantly higher cost. Swanson *et al*.[14] compared hospital costs and clinical outcomes for VATS lobectomies and wedge resections versus robotic-assisted thoracoscopic surgery using the Premier hospital database. The association between VATS or robotic approach and adverse events, hospital costs, surgery time, and length of stay was examined. Robotic lobectomy and wedge resection were found to have higher hospital costs and longer operating times, without any differences in adverse events. Jang *et al*.[9] compared 40 patients treated with robot-assisted lobectomy for lung cancer and 40 treated with thoracoscopic surgery. Postoperative complications occurred in 4 (10%) and 13 (32.5%) patients, respectively, the intraoperative blood losses were 219 and 374 mL, respectively, and the postoperative length of hospital stay were 6 and 9 days, respectively. They showed that the outcome of robot-assisted surgery was significantly more favorable than that of thoracoscopic surgery. In a case-controlled analysis by Louie *et al*.,[10] patients treated with robot-assisted surgery used fewer analgesics and returned to daily activities earlier when compared with VATS, although there was no marked difference in the perioperative results between the surgical procedures. On the other hand, Augustin *et al*.[11] reported that the operative time, postoperative hemoglobin level, and cost of surgery were superior in thoracoscopic surgery. Veronesi *et al*.[15] summarized that the curability and safety of robot-assisted surgery for lung cancer are equivalent and the operability and length of the learning curve are superior to thoracoscopic surgery, but a high cost, limited devices, and a long operative time are disadvantageous. Therefore, at present, the merits of robot-assisted surgery have not been verified.

In conclusion, robotic surgery for pulmonary resections is safe and efficient and has similar survival rates compared with the open and VATS approaches. Based on our experience, we believe that the robotic platform helps in achieving, with far more finesse, an outstanding lymph node dissection. The other advantages offered by robotics in lung resectional surgery is debatable, but there is more or less a consensus on some of its obvious disadvantages so very rightly pointed out by Cerfolio, namely, the cost and lack of consistent platform availability, the lack of tactile feedback.[16,17]

Robotic Surgery in Anterior Mediastinum

There have been many reports on the efficacy of robotic surgery for mediastinal diseases.[18-25] The robotic system appears to be ideally suited for the surgery on anterior mediastinal lesions. The robotic approach saves the patient from the morbidity of sternotomy. We review the use of the surgical robot in diseases of the mediastinum with emphasis on thymic disorders, which comprise the majority of the surgical indications in anterior mediastinum.

Myasthenia gravis (MG) is an autoimmune neuromuscular disease leading to fluctuating weakness and fatigue of different muscle groups. Fifteen percent of MG patients have Thymoma.[26] The thymus gland is located in the anterior mediastinum between right and left phrenic nerves. Ectopic thymic tissue can be located at various locations throughout the anterior mediastinum.[27] The radicality of thymectomy therefore is crucial both for tumor resection and achieving complete stable remission (CSR) of MG.[28] Robotic approach allows for a radical thymectomy, thereby improving the complete remission rate for MG when compared with the conventional thoracoscopic technique.[29] For patients with thymoma, the oncologic outcome in terms of overall survival and thymoma-related survival is promising, but a longer follow-up is needed to consider robotic thymectomy a standard approach.[30]

Thymectomy can be done from either the right side or left side or bilaterally. With the use of robotic system a radical thymectomy is achievable from one side only. Choice of the side is a point of debate. The major points that guide the choice of the side include safety of trocar placement, mediastinal dissection, anatomic considerations for the distribution of thymic tissue, and surgeon's preference.[31-35] Ismail *et al*. have pointed out that surgical manipulation of the right phrenic nerve is rarely necessary, because there is little if any thymic tissue lateral to or beneath the nerve and preservation of the right phrenic nerve is easier than on the left.[36] Proponent of left-sided approach site the following reasons for choosing the left side:

1. Thymic tissue may extend lateral to or under the left phrenic nerve.[36]
2. Occasionally the thymic gland descends totally or partially posterior rather than anterior to the innominate vein.
3. The left thymic portion is usually larger and extends up to the cardiophrenic area thereby needing more dissection on left side.
4. The aortopulmonary window is a frequent site of ectopic thymic tissue and can be accessed better or exclusively from the left side.[35]

The points put in favor of a right-sided approach include better visualization of the venous confluence from the right side by following the superior vena cava, the visualization and dissection of the aortocaval groove, and better ergonomic position to accomplish dissection in caudal to cephalad direction from the right side. Cerfolio and colleagues also suggested that a right-sided approach may be easier and safer during the early part of the surgeon's learning curve.[32] Regardless of the preference, it is important to use a tailor-made approach for each patient based on the individual anatomy with the aim to achieve a radical dissection of all thymic tissue and anterior mediastinal and pericardial fat from one phrenic nerve to the other and from thyrothymic ligaments to bilateral pericardiophrenic recess.

Between 2001 and 2012, there were approximately 3500 robotic thymectomies[36] registered by Intuitive Surgical, Sunny Vale, CA, USA. Table 1 lists the major published articles on robotic thymectomy. Ismail and colleagues[36] reported

Table 1: Summary of major series on robotic thymectomy

Authors	Year	Country	Number of cases	MG	Thymoma	Approach	Complete remission rate (%)	Thymoma recurrence rate (%)
Augustin *et al*[37]	2008	Austria	32	32	9	Right	NA	0
Castle and Kernstine[38]	2008	USA	26	18	1	Right	NA	NA
Tomulescu *et al*[39]	2009	Romania	22	22	Excluded	Left	NA	NA
Goldstein *et al*[40]	2010	USA	26	26	5	Right	NA	NA
Cerfolio *et al*[32]	2011	USA	30	30	NA	Right	NA	NA
Freeman *et al*[41]	2011	USA	75	75	Excluded	Left	28	NA
Melfi *et al*[25]	2012	Italy	39	19	13	Left	NA	0
Keijzers *et al*[42]	2013	The Netherlands	138	NA	37	Right	NA	2.7
Marulli *et al*[30]	2013	Italy	100	100	8	Left	28.5	0
Ismail *et al*[31]	2013	Germany	317	273	56	Left	57	0
Schneiter *et al*[43]	2013	Switzerland	58	25	20	Left	NA	11.1
Ye *et al*[44]	2013	China	21	0	21	Right	NA	

the largest series, containing 317 patients who underwent robotic thymectomy in a span of 9 years. The indications were MG in 273 cases and thymoma in 56 patients. They accessed the thymus via a three-trocar left-sided approach in all the patients except for patients with thymoma on the right side. The cumulative complete stable remission rate after robotic thymectomy for MG patients, according to the MGFA postinterventional status was observed in 57% of the cases. There were no recurrences in patients with thymoma.

Another large series was published by Marulli *et al*. consisting of 100 robotic thymectomies. The complete stable remission rate for patients with MG was 28.5%. There were no conversions but in one patient a cervicotomy was required to complete dissection of the thymic upper horns. They concluded that robotic thymectomy is a technically sound operation, with low morbidity, short hospitalization, and good neurologic long-term results.[30]

We ourselves have performed over 100 robotic thymectomies for MG and early-stage thymoma. Seventy-two of these patients had MG. Fifty-one of these 72 had myasthenia gravis without thymoma, whereas 21 patients had myasthenia gravis with thymoma. We used the unilateral left-sided 3- to 4-port approach. In patients without thymoma, all procedures were completed robotically with no conversion to median sternotomy or thoracotomy. A fourth access port was used in 10 patients to provide assistance in cases with excessive pericardial fat. There were no deaths or intraoperative complications. No evidence of tumor recurrence was found in patients with thymoma on a mean follow up of 3 years. The overall CSR rate was 31%. In all a total of 58 (81%) patients including those who achieved CSR status and those who showed improvement in their MGFA class, benefitted from robotic thymectomy.

Single-center comparisons of transsternal, VATS, and robotic thymectomy have also been reported. Generally, no significant difference in clinical outcome has been observed, but a shorter length of stay and perhaps a more rapidly improved quality of life has been associated with the robotic approach.[29] The cost differential is institution-dependent, but the robotic approach can cost as much as 91% more than a VATS approach because of instrument costs and operating room expenses.[37]

Reported complication rates after robotic thymectomy were comparable to those associated with a VATS approach. The most commonly reported complications were vascular injury and incomplete resection requiring reoperation.[23,37,40,41,45] However, the rates of these complications are significantly lower than with the transsternal approach. Intercostal neuralgia and brachial plexus injury are certain additional complications associated with the robotic approach.[46]

After having performed a significant number of thymectomies with robotic assistance, we believe that the extended intuitive dexterity offered by the endo-wristed robotic instruments complemented by excellent magnified stereoscopic view, allows one to perform a radical dissection of all thymic tissue with relative ease. On occasions we have completely bared the left brachiocephalic vein of all thymic tissue and fat from all around, a task which would be significantly difficult using conventional VATS. The robotic approach is growing and seems to have a great potential in the management of anterior mediastinal pathology.

Robotic Surgery for Posterior Mediastinal Tumors

Most common posterior mediastinal tumor are typically neurogenic tumors, but lymphatic system tumors and esophageal cysts are also encountered. Minimally invasive surgery for posterior mediastinal tumors has been reported to be comparable to conventional thoracotomy in terms of improvement of symptoms, recurrence, and the survival rate,[47,48] and is considered to be the gold standard for neurogenic tumors.[47,48] Only a few reports of experiences of robotic surgery for posterior mediastinal tumors are available. But the morbidity, conversion rate, and hospital stay appear to be comparable to thoracoscopic surgery.[49] Particular advantage of the robot is evident for the treatment of tumors arising near the diaphragm at a low position and those located at the thoracic apex. Important consideration in managing posterior mediastinal pathologies is the port placement and set up of the patient cart.[50,51] There are no published randomized trials comparing robotic surgery with either thoracoscopic surgery or an open approach for posterior mediastinal surgery, and further studies are required to prove its benefits over VATS. But we believe that robotic assistance simplifies surgical management of posterior mediastinal pathology, particularly those in the apex and toward the inferior most areas of the thoracic cavity.

Robotic Esophageal Surgery

The first *robotic-assisted esophagectomy* was reported in 2003.[52] The esophagus was resected using the transhiatal route with the da Vinci robot. Foregut continuity was re-established by a gastric pull-up with cervical anastomosis. Till date there are 26 articles in the literature on this topic reporting experience with 295 robotic esophagectomies in the management of malignant and benign esophageal diseases, including transthoracic esophagectomy with lymphadenectomy and transhiatal esophagectomy.

Most reports have described transthoracic esophagectomy and have demonstrated the feasibility and safety of esophagectomy using the surgical robot. Few of the largest reported series are described in this section.

The first report of completely robotic esophagectomy was by Kernstine *et al*,[53] in 2007, who reported the use of surgical robot in 14 patients undergoing esophagectomy. Eight of the 14 patients underwent completely robotic esophagectomy with operating room time of 11.1 ± 0.8 h and estimated blood loss was 400 ± 300 mL.

Boon *et al*[54] reported their experience of 47 transthoracic robotic esophagectomy (TRE). They reported a 14.9% conversion rate. The median operating time was 450 min and median blood loss of 625 mL with a mean hospital stay of 18 days. Twenty-one of 47 patients had pulmonary complications with three in-patient mortalities. A median of 29 (range 8-68) lymph nodes were dissected and R0 resection was achieved in 76.6% patients.

From India, Puntambekar *et al*[55] have reported a series of 32 cases. The mean total operative time was 210 min with an average blood loss of 80 mL. They reported no conversions and concluded that TRE is a better alternative than thoracoscopic esophagectomy in view of the reduced stress to surgeon. Cerfolio *et al*[56] reported first series of successful Robotic Ivor Lewis with chest anastomosis in 22 patients. The initial six patients underwent a posterior stapled and anterior hand-sewn anastomosis; however, the investigators noted significant morbidity, with anastomotic leak, gastric conduit leak, and five reoperations during the hospital stay. The later 16 patients underwent robotically hand-sewn two-layer anastomosis. The authors reported that there was a significant decrease in morbidity, which led them to advocate this anastomosis for intrathoracic robotic approaches.

Dunn *et al*[57] presented their 3-year single center experience with transhiatal robotic esophagectomy (THRE) for dissection of thoracic esophagus. Forty patients with resectable esophageal carcinoma underwent THRE at their institute. Five patients were converted from robotic to open. Median operative time and estimated blood loss were 311 min and 97.2 mL, respectively. Postoperative complications frequently observed were anastomotic stricture, recurrent laryngeal nerve paresis, anastomotic leak, pneumonia, and pleural effusion. Incidence of laryngeal nerve paresis (35%) and leak rate (25%) were somewhat higher in comparison with that reported in the literature. They reported no in-hospital mortality with a 30-day mortality of 2.5% (1/40). R0 resection was achieved in 94.7% of patients.

The feasibility and safety of robot-assisted thoracoscopic esophagectomy for esophageal cancer in the prone position was assessed by Kim *et al*.[58] The principal finding of this study was the potential role of a robotic system to achieve an adequate learning curve by a low-volume surgeon who had no prior experience with thoracoscopic esophagectomy.

De la Fuente and colleagues[59] have also reported a series of 50 robotic esophagectomies with intrathoracic anastomosis, approximately half of which underwent total robotic Ivor Lewis procedures. Reported operative outcomes were excellent, with no mortality, 1 anastomotic leak, and a median lymph node retrieval of 19 (range, 8-63).

Clark and colleagues[60] conducted a systematic review of all published literature prior to April 2010. The review revealed that the mean lymph node yield was from 12 to 38; the R0 resection rate was from 76% to 100%. Three of the five series reported R0 resection rate greater than or equal to 95%. Transthoracic approach was employed in seven case series with a conversion rate of 0%-14%. Two of the series reported major complication rates of approximately 30%, and another trial reported an overall rate of complications of 64%. The 30-day mortality was 0% in 5 of the 8 case series, whereas the remaining three reported a single death in each.

At present, no prospective data comparing robotic esophagectomy with standard laparoscopic or open procedures exists. At the Memorial Sloan-Kettering Cancer Center, Sarkaria and Rizk[61] are actively accruing a prospective quality-of-life and outcomes trial comparing Robotic Assisted Minimal Invasive Esophagectomy (RAMIE) with open esophagectomy (ClinicalTrials.gov: NCT01558648). In addition, a prospective, randomized controlled trial comparing complications and outcomes in robotic esophagectomy versus open transthoracic esophagectomy (also known as the ROBOT trial) is under way in the Netherlands, with an expected completion in 2015.

Robotic Surgical System has also been used for *Heller's myotomy*. Robotic Heller's myotomy has gained popularity and has emerged as a safe and effective alternative. Reports suggest that robotic system allows for more precise dissection, especially during the myotomy itself, due to better visualization and increased maneuverability related to enhanced instrument articulation. Mucosal perforations during the myotomy seem to occur less often with robotic assistance when compared with traditional laparoscopy. But the actual clinical benefits need to be established further. In a prospective, multi-institution study, Melvin *et al*[62] evaluated the outcomes of 104 patients who underwent robotic Heller myotomy with partial fundoplication for achalasia using the da Vinci system. There were no mucosal perforations in the 104 cases. The average hospital stay was 1.5 days. All of the 76% patients, who completed a postoperative symptom survey, reported a significant improvement of symptoms. The average follow-up was 16 months. One patient required endoscopic esophageal balloon dilation, whereas none required reoperation.

Horgan *et al*. performed a retrospective review of prospectively collected data comparing the robotic-assisted Heller myotomy with the laparoscopic Heller myotomy.[63] A total of 121 patients underwent operative intervention with 59 cases done robotically and 62 by laparoscopic approach. The average operative time for the robotic-assisted approach was 141 min compared with 122 min for the laparoscopic approach. The rate of mucosal perforation was found to be higher in the laparoscopic group compared with the robotic-assisted group with the degree of symptom improvement and incidence of postoperative reflux being similar between the two groups. Huffmann *et al*[64] reported that patients who underwent robotic Heller's myotomy experienced better quality-of-life indices than patients who had the laparoscopic Heller's myotomy. A recently published retrospective review by Shaligram *et al*[65] used a large administrative database to compare perioperative outcomes for open, laparoscopic, and robotic Heller myotomy for achalasia. Outcomes for both the laparoscopic approach and the robotic approach were superior to those of the open approach. Only the robotic surgery group, however, had statistically significant reductions in postoperative morbidity, need for intensive care unit (ICU) admission, and length of stay when compared with open surgery. There was no statistical difference in mortality and morbidity need for ICU admission, length of stay, or 30-day readmissions between the laparoscopic group and the robotic group.

Heller's myotomy using robotic assistance appears to be at least as safe and efficacious as laparoscopic Heller's myotomy on the basis of whatever limited data that are available. Mucosal perforation rates during myotomy may be lower with the use of robotic technologies, although the clinical significance of this finding is uncertain.

Esophageal Leimyoma enucleation is another important indication for the use of robotic system. Open surgical approaches are associated with a higher morbidity. Surgical enucleation of esophageal leiomyomas by video-assisted thoracoscopic surgery (VATS) has also been reported since 1992 and is the preferred minimally invasive approach for enucleation of upper two-third leiomyomas of the esophagus. Laparoscopic approach can be an alternative to VATS for tumors of the lower third of esophagus. There are reports to suggest that thoracoscopic and laparoscopic enucleation of esophageal leiomyomas and other benign esophageal tumors is associated with a lower incidence of mucosal injury and reduced hospital stay. The use of robotic-assisted thoracoscopy particularly in enucleation of benign esophageal tumor may provide a clearer distinction between anatomic layers due to superior magnified stereoscopic view, thus minimizing the chances of a mucosal perforation, when compared with VATS.[66] The advantages become more pronounced when the lesion is toward the either end of the thoracic esophagus, that is upper thoracic esophagus and toward the hiatus.

Robotic-assisted esophageal surgery is an evolving field. However, Level 1 evidence supporting a robotic approach when compared with other approaches is lacking. The benefits are not very clear when compared with a conventional laparoscopic or thoracoscopic approach. Prolonged operative times together with high costs are obstacles to wide acceptance of these techniques. Further research in the field of robotic surgery leading to better technology and reduced costs will likely generate more interest and acceptance increasing its role in esophageal surgery in the near future.

Summary

From the era of thoracoscopic adhesiolysis attempted by Hans Christian Jacobeaus, the minimally invasive thoracic surgery has come a long way. Complex thoracoscopic procedures are being performed robotically and have been shown to be safe and feasible. Although the conclusive answer to its benefits in terms of patient outcome is yet not clear, we strongly believe that robotic assistance greatly simplifies the thoracoscopic approach for various thoracic surgical pathologies. The most important concerns regarding the use of the robotic platform, namely, feasibility and safety, have been adequately addressed in a number of publications. We believe that any thing that can be done by VATS can be better done by robotic assistance. What concerns us is the cost effectiveness of the procedure particularly in terms of patient outcome. Therefore, given the current cost status, we do not promote the use of robotic system for procedures such as sympathectomy, simple wedge resections, or bullectomy, which can be very conveniently handled by VATS. But having used the robot extensively in operations on the thymus and other anterior mediastinal masses, it is extremely difficult for us to even contemplate going back to conventional thoracoscopy for these indications, simply because we are convinced about the quality of surgery and the radicality of resection it offers particularly in cases of thymectomy for myasthenia gravis where the extent of resection correlates with the chances of stable remission. In case of lobectomy, we believe that utilizing the robot can increase the percentage of resection for lung cancer being performed in a minimally invasive manner, thereby extending the benefit to a larger group of patients. It also allows for a better lymph nodal clearance.

In conclusion, we can say that robotic thoracic surgery is here to stay, but long-term survival studies particularly in cancer patients have to be carried out to prove the perceived benefits. It is important to realize that the enthusiasm to adopt the surgical robot into one's thoracic surgical practice should be adequately backed up by proper training, careful patient selection, and a team-based robotic program development.

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