

Subxiphoid-subcostal versus transthoracic thoracoscopic thymectomy: A safe and feasible approach



Madhuri Rao, MD,^a Aitua Salami, MD,^a Alexandria Robbins, MD,^a Jamee Schoepfoerster, BS,^a Amit Bhargava, MD,^a Ilitch Diaz-Gutierrez, MD,^a Qi Wang, MS,^b and Rafael Andrade, MD^a

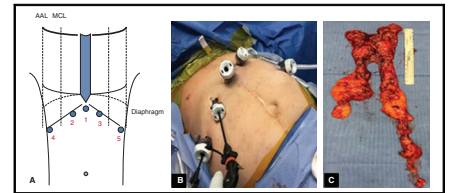
ABSTRACT

Objective: Subxiphoid-subcostal thoracoscopic thymectomy (ST) is an emerging alternative to transthoracic thoracoscopic thymectomy. Potential advantages of ST are the avoidance of intercostal incisions and visualization of both phrenic nerves in their entirety. We describe our experience with ST and compare our results to our previous experience with transthoracic thoracoscopic thymectomy.

Methods: We conducted an institutional review board-exempt retrospective review of all patients who had a minimally invasive thymectomy from August 2008 to October 2021. We excluded patients with a previous sternotomy or radiological evidence of invasion into major vasculature. The ST approach involved 1 subxiphoid port for initial access, 2 subcostal ports on each side, and carbon dioxide insufflation. We used descriptive and comparative statistics on demographic, operative, and postoperative data.

Results: We performed ST in 40 patients and transthoracic thoracoscopic thymectomy in 16 patients. The median age was higher in the ST group (58 years vs 34 years; $P = .02$). Operative data showed no significant differences in operative times, blood loss, or tumor characteristics. In the ST group, we had 2 emergency conversions for bleeding; 1 ministernotomy, and 1 sternotomy. Postoperative data showed that the ST group had fewer days with a chest tube (1 day vs 2.5 days; $P = .02$). There were no differences in median length of stay, tumor characteristics, final margins, major complication rate, and opioid requirements between the groups. There has been no incidence of diaphragmatic hernia and no phrenic nerve injuries or mortality in either group.

Conclusions: ST is safe and has similar outcomes compared with transthoracic thoracoscopic thymectomy. (*JTCVS Techniques* 2022;16:172-81)



Subxiphoid thymectomy: A and B, Port placement. C, Thymectomy specimen.

CENTRAL MESSAGE

Subxiphoid-subcostal thymectomy offers a safe alternative to the transthoracic approach to perform complete thymectomy with excellent visualization and with comparable outcomes.

PERSPECTIVE

Transthoracic thoracoscopic thymectomy is the most widely practiced form of minimally invasive thymectomy. The subxiphoid approach may offer some technical advantages to the transthoracic video-assisted thoracoscopic surgery approach, but it has not yet been widely adopted in many parts of the world. We demonstrate the feasibility of this technique in the largest series in the North American literature.



Video clip is available online.

From the ^aDivision of Thoracic and Foregut Surgery, Department of Surgery, and ^bClinical and Translational Science Institute, University of Minnesota, Minneapolis, Minn.

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Address for reprints: Madhuri Rao, MD, Division of Thoracic and Foregut Surgery, Department of Surgery, University of Minnesota, MMC 207, 420 Delaware St, SE, Minneapolis, MN 55455 (E-mail: mvrhao@umn.edu).

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Subxiphoid-subcostal thoracoscopic thymectomy (ST) is a minimally invasive approach to thymectomy that was first described by Kido and colleagues in 1999.¹ It involves a subxiphoid port with access to both pleural cavities via a retrosternal tunnel. Variations of this technique include additional subcostal ports and the use of carbon dioxide insufflation. The proposed advantages of the ST approach over the transthoracic thoracoscopic thymectomy (TT) are: supine positioning, no need for lung isolation, and visualization of the entire course of both the phrenic nerves. We also hypothesized that avoiding intercostal incisions potentially resulted in better pain control. There have been several reports in Asian and European literature on the safety and feasibility of ST with comparable results to TT.^{2,3} However, experience in North America is very limited.⁴

Abbreviations and Acronyms

BMI	= body mass index
BiPAP	= bilevel positive airway pressure
ST	= subxiphoid-subcostal thoracoscopic thymectomy
TT	= transthoracic thymectomy

We have performed minimally invasive thymectomy since 2008. We started performing ST in 2014 and transitioned to this approach completely in 2016. In this study, we aim to describe our institution's experience with ST and compare those results to our experience with TT.

METHODS

Patient Selection

We conducted a retrospective review of all patients older than age 18 years who underwent minimally invasive thymectomy for any indication. We excluded patients with a previous sternotomy and those with radiological evidence of invasion into major vasculature. The timeline for the TT approach was August 1, 2008, to August 31, 2016, and for the ST approach was August 1, 2014, to October 31, 2021. As of September 1, 2016, we exclusively performed ST. This study was institutional review board exempt (STUDY00014939; January 14, 2022).

Surgical Technique

We position a patient supine with the arms abducted and use a footboard so that the table can be positioned in steep reverse Trendelenburg. We use general anesthesia with a single-lumen tube, and use low tidal volumes, no positive end-expiratory pressure, and carbon dioxide insufflation (8-12 mm Hg) to optimize working space without lung isolation. The subxiphoid-subcostal approach involves the insertion of 1 15-mm subxiphoid port for initial access. We make an incision down to the rectus muscle and dissect bluntly in the retrosternal plane to open up the right pleura. We insert a 15-mm port and 2 5-mm subcostal ports about 5 to 8 cm away on each side of the midline once the retrosternal space is created. Under thoracoscopic visualization, we insert an additional lateral subcostal 5-mm port in the anterior axillary line on each side (Figure 1). We place

the subcostal ports above the insertion of the diaphragm to the costal margin to minimize the risk of diaphragmatic hernia. We begin the dissection at the diaphragm, ensuring complete removal of all fatty tissue between the diaphragm and pericardium. We continue cephalad dissection along the anterior edge of each phrenic nerve using scissors and clips to accomplish a thorough dissection without thermal injury. We move the camera freely between the ports to have complete bilateral visualization of both phrenic nerves (Figure 2). In patients with obesity, this is a key step to completely visualize both nerves. The lateral most ports give a clear view of the cardiophrenic fat. On both sides, but more importantly on the left side, because this fat is dissected and pulled over, the phrenic nerve is well exposed and visualized across the pericardium, and we continue our dissection upward (Video 1). The ST approach also offers a complete view of the cervical horns up to their most cephalad attachment. We remove the specimen using a specimen bag through the 15-mm port. We leave 1 small-bore tube in the mediastinum and close the port sites. The tube is usually removed in the first 24 to 48 hours after surgery.

For the TT, we used a unilateral or bilateral intercostal port approach with a total of 3 to 5 ports with carbon dioxide insufflation. We performed the thymectomy itself using the same principles for both approaches by removing all fatty tissue from phrenic nerve to phrenic nerve and from thoracic inlet to diaphragm; we always remove the cervical horns completely. Most commonly, we started with a 3-port approach through the right chest. After dissecting the thymic tissue off the sternum and pericardium, the gland was separated off the right phrenic nerve with sharp dissection. The horns were dissected mostly from the right side. In the unilateral approach, the left-sided dissection was completed by pulling the thymus over to the right side to expose the nerve. In the bilateral approach, after maximal dissection from the right side along the innominate vein, we inserted 1 or 2 additional left side ports to be able to visualize the left phrenic nerve and complete the dissection from the left side.

Statistical Analysis

We compared our data between the 2 techniques. We used descriptive and comparative statistics on demographic data, operative details (ie, operative time, blood loss, and conversion to sternotomy) and postoperative data (ie, length of stay, chest tube duration, complications, 30-day readmission, opioid requirement, and pathology).

We used the Wilcoxon rank-sum test for continuous variables and Fisher exact test for categorical variables. Histograms and Kolmogorov test for normality were conducted to evaluate if the distribution was normal. Because it was not normally distributed, nonparametric analysis was

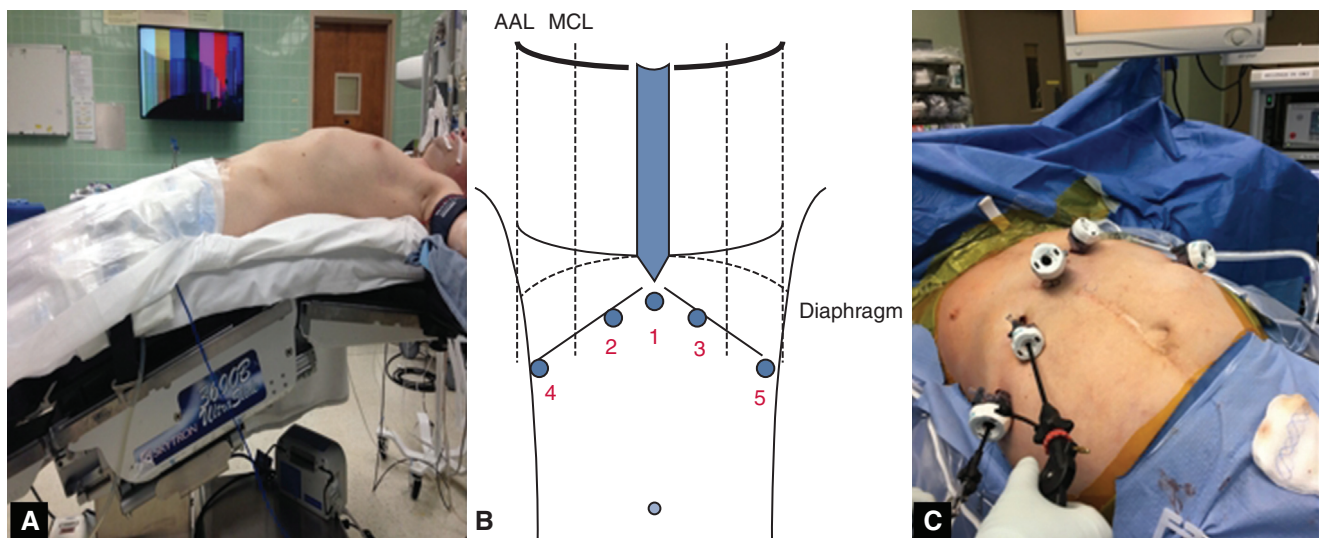


FIGURE 1. Patient positioning and port placement. A, Patient positioning. B and C, Port placement. AAL, Anterior axillary line; MCL, mid clavicular line.

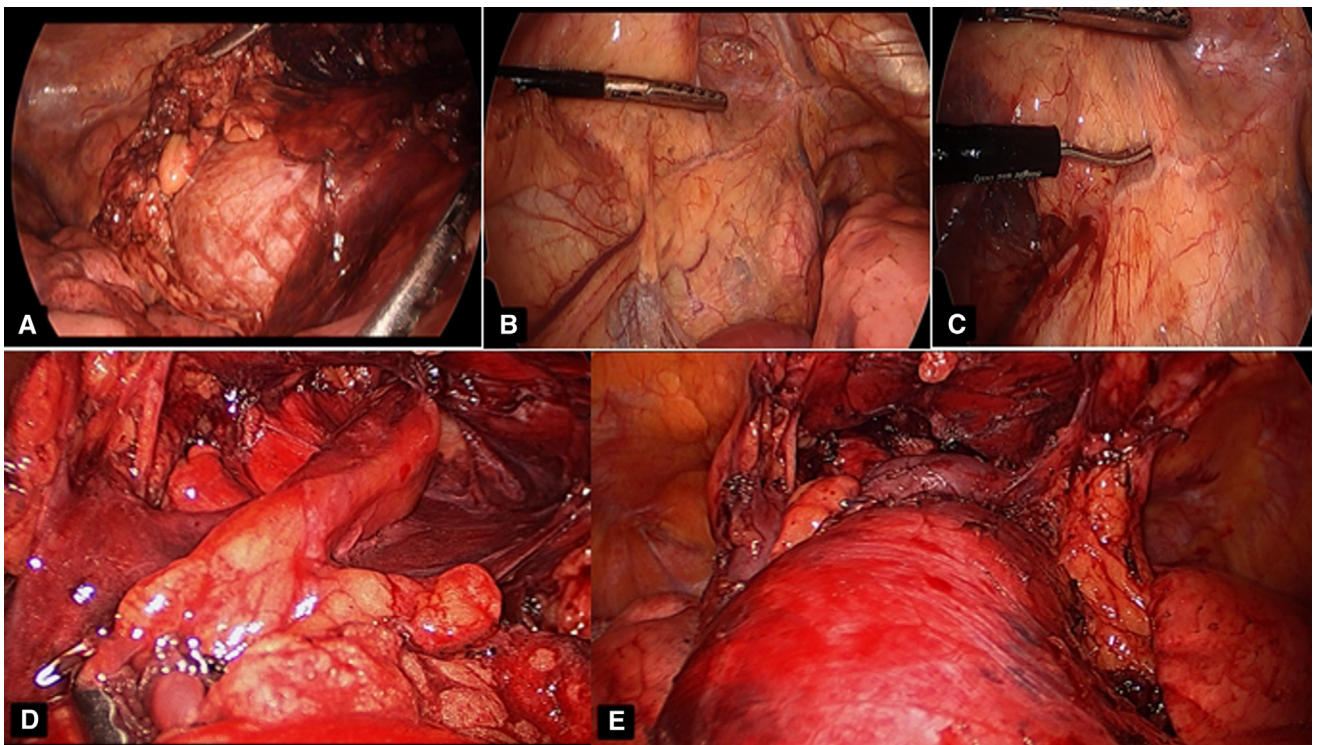


FIGURE 2. Intraoperative views. A, Right phrenic nerve dissection. B and C, Left phrenic nerve dissection. D, Cervical horn. E, Dissection bed after specimen extraction.

performed. Statistical analyses are performed in SAS version 9.4 (SAS Institute).

RESULTS

We identified 56 patients who underwent minimally invasive thymectomy from August 2008 to October 2021. Forty patients underwent a subxiphoid-subcostal thoracoscopic thymectomy and 16 patients underwent TT. Of the TT group, 12 patients had a bilateral thoracoscopic approach and 4 patients underwent a unilateral approach. **Table 1** summarizes patient demographic characteristics and perioperative data for both patient groups.

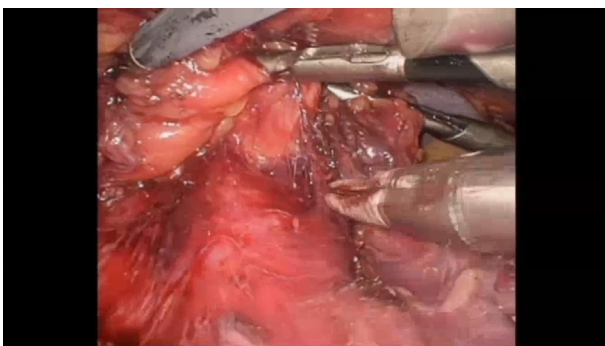
The groups were not significantly different demographically in terms of gender, body mass index (BMI), and

American Society of Anesthesiologists score. However, the median age of the ST group was significantly higher than that of the TT group (58 vs 34 years; $P = .02$). Overall,

TABLE 1. Comparison of demographic and perioperative data

Data point	ST (n = 40)	TT (n = 16)	P value
Demographic characteristic			
Age (y)	58 (36-66)	34 (28-54)	.02
Female sex	20 (50)	12 (75)	.14
Body mass index	30 (26-32)	28 (24-31)	.34
ASA score	3 (2-3)	2.5 (2-3)	.08
Charlson comorbidity index	1 (0-2)	1.5 (1-3)	.1
Operative detail			
Procedure time (min)	206 (168-283)	182 (141-298)	.91
EBL (mL)	30 (30-50)	30 (17.5-40)	.10
Tumor size (cm)	4.4 (3.2-5.3) (n = 24)	5.5 (4.0-7.7) (n = 5)	.18
Postoperative detail			
LOS (d)	3 (2-3)	3 (2-4)	.94
Morphine equivalents	192 (81-246)	358 (92-627)	.12
Chest tube (d)	1 (1-2)	2.5 (1-3)	.02
30-d complication*	5 (12.5)	3 (18.7)	.6
Follow up (mo)	10 (2-24) (n = 23)	36 (19-95) (n = 6)	.05

Values are presented as median (interquartile range) and n (%). Bold indicates significant P values. ST, Subxiphoid-subcostal thoracoscopic thymectomy; TT, transthoracic thoracoscopic thymectomy; ASA, American Society of Anesthesia; EBL, estimated blood loss; LOS, length of stay. *Clavien Dindo III and IV.



VIDEO 1. Subxiphoid-subcostal approach to thymectomy. Video available at: [https://www.jtcvs.org/article/S2666-2507\(22\)00458-8/fulltext](https://www.jtcvs.org/article/S2666-2507(22)00458-8/fulltext).

TABLE 2. Diagnosis distribution by approach

Indication	ST	TT
Myasthenia gravis	18	8
Anterior mediastinal mass/nodule	19	6
Ectopic parathyroid	3	1
Metastatic nodule	0	1

ST, Subxiphoid-subcostal thoroscopic thymectomy; TT, transthoracic thoracic thymectomy.

myasthenia gravis was the most common indication for thymectomy, followed closely by the finding of an anterior mediastinal mass or nodule. Other indications included metastatic nodules from breast cancer and ectopic parathyroid tissue. The indications for thymectomy in the 2 groups are summarized in Table 2. There were no significant differences in intraoperative parameters, including operative times and estimated blood loss. Chest tube duration was shorter in the ST group (1 vs 2.5 days; $P = .02$) (Figure 3).

There was no difference in 30-day complication rate between the two techniques. In the ST group, we had 5 Clavien-Dindo grade III or IV complications (12.5%). One ST patient required video-assisted thoracoscopic surgery drainage of a left hemothorax on postoperative day 1. This patient had bleeding from a small vessel along the

TABLE 3. Outcomes of patients with myasthenia gravis

Outcome	ST (n = 18)	TT (n = 8)	P value
LOS (d)	3 (2-4)	3.5 (2-4)	.83
Chest tube (d)	2 (1-2)	3 (1-3)	.23
30-d complication	3 (16.7)	1 (12.5)	1
Respiratory complications	1 (6.3)	2 (25)	.22

Values are presented as median (interquartile range) or n (%). ST, Subxiphoid thymectomy; TT, thoracoscopic thymectomy; LOS, length of stay.

left phrenic nerve when he returned to the operating room. He did not require a blood transfusion. Three ST patients had respiratory complications needing invasive and noninvasive ventilator support. One of these patients likely had myasthenic crisis; this patient required a prolonged intensive care unit stay complicated by pulmonary emboli and a bleeding duodenal ulcer needing endoscopic intervention. The major complication rate in the TT group was 18% and included 3 patients needing respiratory support and intensive care unit stay. Another TT patient developed postoperative pleural effusions bilaterally and required chest tube placement. Specifically, in patients with myasthenia gravis, there were no significant differences in outcomes between the 2 approaches (Table 3).

In the ST group, we have 3 conversions to sternotomy (7.5%). Two patients had intraoperative bleeding. One patient bled from the left internal thoracic vein and he required

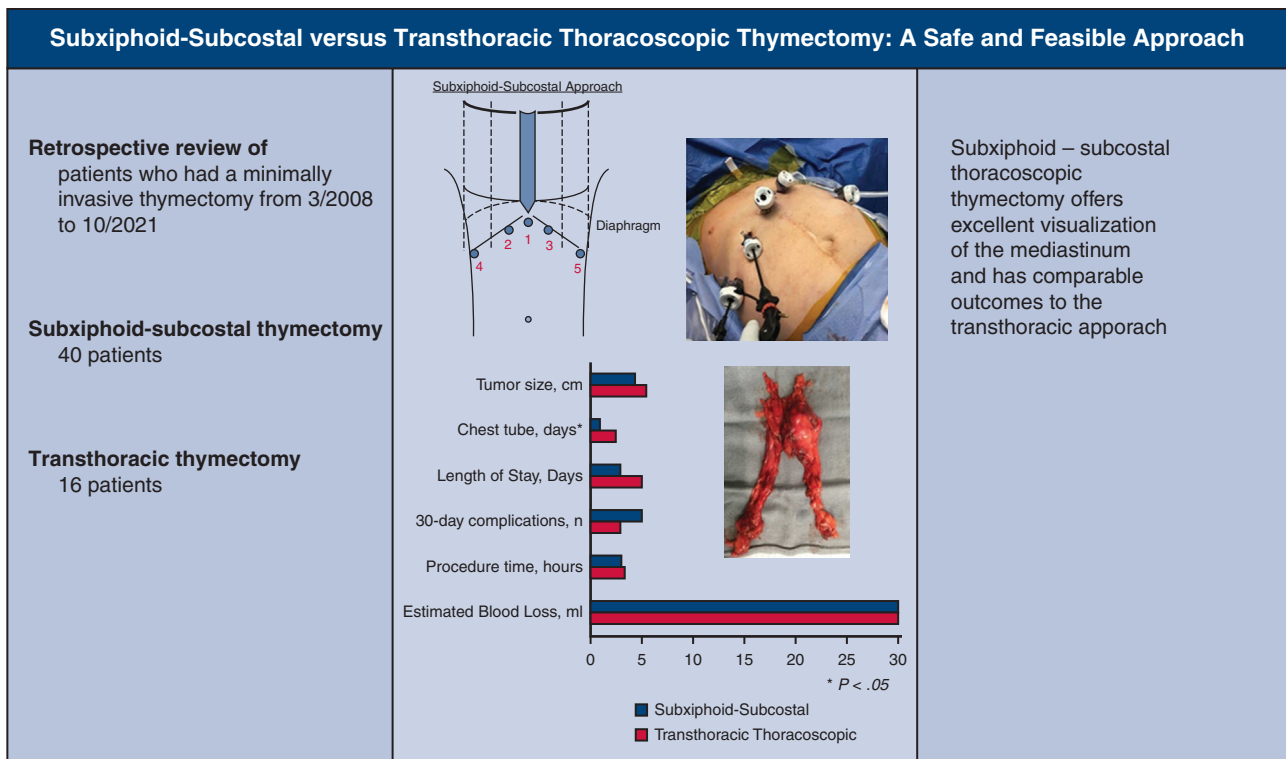


FIGURE 3. Summary of results of the study.

a ministernotomy (manubrial split) to control it. Once it was controlled, we closed the ministernotomy and completed the thymectomy using the ST technique. Another patient had a full-thickness puncture of the right ventricle at the very end of the procedure. We had performed a thymectomy with en bloc anterior pericardiectomy and at the time of chest tube placement we injured the right ventricle. We tamponaded it with a gauze, the patient remained hemodynamically stable, and then we performed a sternotomy to repair it. Neither of these patients required a transfusion. We also had 1 elective conversion to sternotomy due to the location and nature of the nodule. In this patient with myasthenia gravis, the presumed thymic nodule was in fact a densely adherent aortopulmonary window lymph node. Pathology showed a necrotizing granuloma.

The most common pathologies were benign thymic hyperplasia and thymoma. Other diagnoses included ectopic parathyroid, ectopic thyroid, a duplication cyst, and lymph nodes. There was no difference in median tumor size. The largest tumor extracted with the subxiphoid approach was 10.5 cm. We had adequate margins of resection in all cases.

We had no phrenic nerve injuries in either group. Our median follow-up was 10 months for the ST group and 36 months for the TT group. There was no tumor recurrence in either group. There was no incidence of diaphragmatic hernias in the ST group during the follow-up period.

DISCUSSION

In this study, we describe a thymectomy using a minimally invasive subxiphoid-subcostal approach. Our technique is unique in that we have 2 lateral subcostal ports

on each side in addition to the subxiphoid and medial subcostal ports. With camera hopping, we have excellent visualization of both phrenic nerves and the added advantage of angles and maneuverability. Ours is the first report describing a subxiphoid and subcostal approach to thymectomy in North America. Previous publications on minimally invasive subxiphoid thymectomy stem primarily from China, Japan, and Poland.^{2,3,5-7} With our approach, the extent of our thymectomy tends to be closer the maximal thymectomy described by Sonnet and Jaretzki,⁸ although we do not remove the fat lateral to the phrenic nerve or the aortopulmonary window fat (Figure 4).

Access and visualization tends to be more challenging in patients with a higher BMI. Our ST group had a median BMI of 30. Of the 40 patients, 19 patients had a BMI >30, with a maximum BMI of 41. The average BMI in other published studies on subxiphoid thymectomy is 22 or 23.^{3,6,9} Despite this difference, we have been able to replicate the advantages of the subxiphoid approach in our cohort. Most of the literature on the subxiphoid approach to thymectomy describe a 3-port or single-port approach. However, in our patient population we find that the 5-port approach with additional lateral subcostal ports help with retraction and maneuverability. Camera hopping to the lateral most ports on each side gives an excellent view of the phrenic nerve at the cardiophrenic angles. We are then able to safely excise all the thymic tissue and fat inferolaterally. We believe that these ports help us in performing a complete thymectomy. No need for lung isolation, supine positioning, ample working space with carbon dioxide insufflation, and excellent visualization of both phrenic

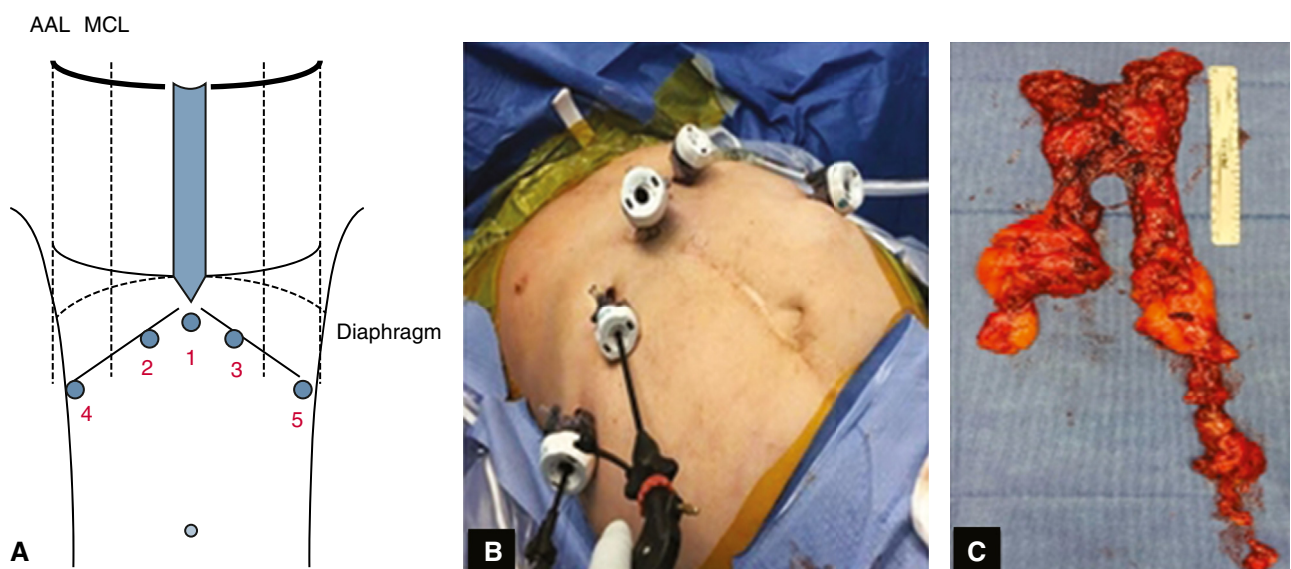


FIGURE 4. A, Diagrammatic representation of port placement. 1 = Subxiphoid port; 2, 3, 4, 5 = Subcostal ports. B, Port placement in a patient. C, Complete thymectomy specimen. AAL, Anterior axillary line; MCL, mid clavicular line.

nerves along their entire course are some of the advantages of the subxiphoid approach.

We did not see a significant difference in median operating times for our ST and TT groups (206 vs 182 minutes; $P = .9$). Several published comparative studies have shown similar results with insignificant operating time differences.^{5,6,10} Other studies have reported shorter operative times in subxiphoid thymectomy when compared with the lateral video-assisted thoracoscopic surgery approach.¹¹⁻¹³ The reported mean operating times for the subxiphoid approaches in various series range from 88 to 150 minutes (Tables E1 and E2). We believe that our longer operative times than those reported are likely a representation of our learning curve as well as the higher BMI in our series. In 1 study, Suda and colleagues³ estimated the learning curve for the subxiphoid approach to be about 30 to 40 cases.

Three of our ST patients had conversions to sternotomy (7.5%). Two of our 3 conversions were due to bleeding, 1 of which was a ministernotomy (manubrial split) and neither patient was hemodynamically unstable nor required a transfusion. One conversion was due to the technical difficulty of removing a scarred lymph node from the aortopulmonary window. In this particular patient, the lymph node was extremely well adhered to the phrenic nerve and to the pulmonary artery. Even after conversion to sternotomy, we were unable to dissect the node safely. At this point, frozen section biopsies revealed benign granulomatous disease and further dissection was aborted. Subxiphoid series in the literature have reported conversion rates of up to 5%.^{7,11,13} Suda and colleagues³ reported 2 conversions in their series of 147 patients (1.3%) and noted that both occurred very early in their learning curve. The reported conversion to sternotomy rate for transthoracic minimally invasive thymectomy ranges from 0% to 13%.¹⁴⁻¹⁸

In our ST cohort, 3 out of 40 patients (7.5%) had respiratory complications, of whom 2 needed invasive ventilation and 1 needed bilevel positive airway pressure (BiPAP). One of these 3 patients had ocular myasthenia gravis and had an extensive evaluation and optimization by the neurologist before surgery. The etiology of his postoperative respiratory failure was unclear and neurology did not attribute it to myasthenic crisis. The other 2 patients did not have a diagnosis of myasthenia gravis; 1 was reintubated in the recovery room because she was oversedated and was extubated on postoperative day 1. The other patient with a background history of chronic obstructive pulmonary disease and significant anxiety disorder needed BiPAP for a few hours postoperatively for hypoxia believed to be due to poor pain control and splinting.

In the TT group, 3 out of 16 patients had respiratory issues (18.7%). Two patients (1 with myasthenia gravis and 1 without) needed BiPAP for hypoxia believed to be due to inadequate pain control and splinting. The third patient with a diagnosis of myasthenia gravis had difficulty with

immediate postoperative extubation and there was concern for myasthenic crisis although she did not meet all criteria for a cholinergic crisis. She was extubated on postoperative day 1.

Of note, we always have patients with myasthenia gravis evaluated and optimized by our neurology team that specializes in myasthenia gravis. In close collaboration with them, we aim to have the patient stabilized on medications with minimal symptoms. The neurologists and surgeons make a joint decision on the need for intravenous immunoglobulin or plasmapheresis preoperatively if indicated.

We had 1 patient who needed a reoperation for bleeding from a small vessel along the phrenic nerve. For dissection along the phrenic nerve, we use sharp dissection with clipping and cutting of the thymic fat and avoid energy devices. In this patient with a BMI of 27 and a fatty thymus, the bleeding was likely from inadequate hemostasis with the clip and cut technique.

Our postoperative complication rate was 12.5%, including respiratory and bleeding complications. The 30-day complication rates for the ST approach in larger series is in the range of 4% to 15% (Tables E1 and E2). In a systematic review, Hess and colleagues¹⁷ found that the complication rates ranged from 0% to 22.7% following TT and 0% to 57% for open thymectomy.¹⁷

Among the major advantages of the subxiphoid approach is the visualization of both the phrenic nerves along their entire course. Comparative studies have demonstrated a higher incidence of phrenic nerve injuries with the lateral approach. Zhang and colleagues⁶ and Lu and colleagues¹¹ report phrenic nerve injuries in their lateral approach group (2.8% and 2.7%, respectively), with no nerve injuries in their corresponding subxiphoid cohorts. Suda and colleagues⁵ had 1 phrenic nerve injury in the subxiphoid group of 46 patients (2.1%) and 2 injuries in the lateral approach group of 35 patients (5.7%). All phrenic nerve injuries via the lateral approach were on the left side and authors state that visualization of the contralateral phrenic nerve was difficult with the traditional right thoracoscopic approach. Some surgeons have adopted a bilateral lateral thoracoscopic approach or a unilateral approach with a subxiphoid port to overcome this visual hurdle.^{19,20} We had no phrenic nerve injuries in either group. It is difficult to draw a definitive conclusion on the safety of the approaches because several studies do not address phrenic nerve injury rates separately.

Another postulated advantage of the subxiphoid/subcostal approach is that there is less incisional pain by avoiding the intercostal space. We did not find a significant difference in opioid requirement between the 2 groups. Qiu and colleagues,¹³ Zhang and colleagues,⁶ and Lu and colleagues¹¹ found that pain control was better in the subxiphoid access patients up to postoperative day 7. Other studies that reported pain scores also showed better pain control in the

subxiphoid group for up to 30 days.^{2,3,9,10} Due to the retrospective nature of the study, we were unable to collect subjective pain scores or perform a more in-depth analysis of pain medication requirements postdischarge.

We found no significant clinical difference between our groups, except for age and duration of chest tubes (1 vs 2.5 days; $P = .02$). We believe the shorter chest tube duration in our ST group is more likely a reflection of our evolving practices than a real clinical difference. In recent years, we have moved toward a more deliberate removal of chest tubes on postoperative day 1 for most of our thoracic operations.

We acknowledge the limitations of our study. Our sample size limits the potential for definitive conclusions. Our TT group is much smaller and over a longer period of time compared with the ST group and this makes the comparison more challenging. The difference in group size and age could be explained by a change in referral patterns after the 2016 publication of the randomized clinical trial showing that thymectomy improved clinical outcomes in patients with nonthymomatous myasthenia gravis.²¹ The TT group is a historical control group in this study. Our evolving practices have affected our length of stay, chest tube duration, and other postoperative parameters and this could have influenced our comparative data to a certain extent. We also believe that our experience reflects our learning curve, which likely explains our operative times and our conversion rates to sternotomy. Specifically, we had 4 surgeons at different points in the learning curve through the study period and do not have surgeon-specific data.

CONCLUSIONS

Our experience with ST suggests that it is a safe and feasible alternative to TT. We find this approach to be advantageous to visualize the entire course of both phrenic nerves and for optimal exposure in patients with obesity.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: thymectomy, minimally invasive surgery, subxiphoid, myasthenia gravis, thymoma

Discussion

Presenter: Madhuri Rao

Unidentified Speaker 1. The discussion will be opened by Dr Joshua Sonett from Columbia University Medical Center.



Dr Joshua Sonett (*New York, NY*). I thank the American Association for Thoracic Surgery for the privilege of discussing this paper. Thank you for an excellent presentation and corresponding so effectively before with videos. There is no 1 best approach to thymectomy, but the tool or technique of any use to produce reliable, safe results must strive to preserve the actual surgical intent of that operation, and your group designed a technique toward that end. Complete extended thymectomy, visualizing the entirety of both phrenic nerves and enabling complete dissection of tissue in the neck as well as both pericardial fat pads bilaterally. So, I congratulate you on being thorough. In particular, this could be a very useful approach for all surgeons to considering borrowing aspects of this approach, in morbidly obese populations that can be a particular challenge in thymic surgery. I appreciate your efforts to objectively compare this to your historical controls, but as you already noted, it is a questionable endeavor to really objectively compare this with stats from 2 disparate populations over a long period of time, and I'd be dubious about using those results.

Four questions. One you've already answered. So really 3 questions. You state that subxiphoid is safe or noninferior. However, you had 3 conversions to sternotomy and 3 significant bleeding events: 1 returned to the operating room for hemothorax in the subxiphoid, and none in the transthoracic. So, do you consider that really noninferior?



Dr Madhuri Rao (*Minneapolis, Minn*). Thank you for the question and the comments. So, I think in terms of the conversions—so 2 of them were for bleeding. The other 1 was a very difficult lymph node dissection, which even after conversion to sternotomy, we were not able to get that granulomatous node off of the pulmonary artery and the phrenic, and so we actually did biopsies and sent it off. And once we knew it was granulomatous we did not actually complete the full nodal dissection. So, it's, of course, surgeon's decision at the point but it's debatable whether a lateral thoracoscopic thymectomy would have offered any better on that. With regard to the bleeding, again, a comparison itself in our group is not—given the population, is not accurate. However, we are pretty early in our learning curve, and there have been studies that show that the learning curve is probably at about 30 to 40 for these subxiphoid thymectomies. And the transthoracic thymectomy conversion rate has been quoted at 8% to 13%. So, taking those into consideration, yes, there is room for improvement. I think it's something that we can work on.

Dr Sonett. And my second question addressed to your adding significance to chest tube duration difference between the 2 subgroups, but I think you answered, basically, that was your practice parameter. We remove our chest tubes in 12 to 24 hours along with discharge, and our length of stay is <1 day for our last 40 patients altogether. So attributing chest tube duration to type of minimally invasive approach is fraught with issues.

Three, a significant number of patients in your group had respiratory complications. In the Randomized Trial of Thymectomy in Myasthenia Gravis (MGTX) trial, which you quoted, there were no exacerbations of myasthenia gravis (MG) in the entire prospective study, if the patient was well taken care of preoperatively. So, 2 questions to this. What is your preoperative stabilization of the patients? Do you ever take patients that are completely are not in remission before doing thymectomy for MG? And, could all those ports across all those diaphragmatic excursions, 5 transgressions, maybe hurt the diaphragm to some extent, at least temporarily?

Dr Rao. Thank you. So, the first question, we do we have 2 dedicated neurologists that work up the patients with MG pretty thoroughly. They need plasmapheresis and medication management. So, we do have a rigorous protocol. Of the 3 respiratory issues, only 1 of them was a patient with MG, actually. And he's also the 1 who had 1 of the bleeding issues. So, it could have been—and I think he was the 1 who also had plasmapheresis and was difficult to manage preoperatively. The other 2 were actually—1 was an obese patient who was hypoventilating after surgery, and 1 was an over-sedation patient who needed bilevel positive airway pressure for a little while. So, there was actually 1 patient with MG who had the respiratory complication. As to the question of the diaphragm, we actually skive above the diaphragm for the lateral ports. The 2 subxiphoid ports that are lateral, we again [inaudible] above the insertion of the diaphragm. So, we do not think that this is the cause for it, but we could look into it further.

Dr Sonett. So, my last question. I really appreciate the subxiphoid approach, and I'm sort of intrigued by the bilateral visualization and am starting to use it some at Columbia. But in Europe and in Asia, where they pioneered this, a true subxiphoid approach is 1 port all subdiaphragmatic/subxyphoid. Do you see yourself going in that direction?

Dr Rao. We would be willing to investigate it as we move along, but I think 1 of the greatest advantages of our port placement is that we can camera hop. we're getting really good views of the phrenic from both of those very lateral ports. So, we don't have any plans to change imminently, but it's something that we could work toward.

Dr Sonett. Yeah, I mean, you should just think of the beautiful views of the phrenic bilaterally.

Unidentified Speaker 2. Dr Sonett, your favorite approach is transthoracic now?

Dr Sonett. Well, I use a combination of 1 5-mm ports in the left chest and a subxiphoid now. Because I've become more familiar with using that subxiphoid to see the right phrenic, and then remove the specimen from the subxiphoid incision. I'm intrigued about transitioning all the way to the subxiphoid but have not made that full transition, in particular at this point I appreciate the left-sided ports enable safe and complete dissection in the neck, and the tissue lateral to the left phrenic nerve.

Unidentified Speaker 2. Okay.

Dr René Peterson (*Copenhagen, Denmark*). Thank you very much. René Peterson, Copenhagen. I enjoyed your presentation.

Dr Rao. Thank you.

Dr Peterson. I use the subxiphoid approach as well, especially for large tumors. I find it very beneficial. You

can bring out quite large tumors from the subxiphoid incision. However, there are some concerns using the subxiphoid incisions, especially in the [inaudible] patients, like you've done in this series, and this is the risk of herniation. The upper midline is known to have a high risk of herniation in abdominal surgery. So, I would just like to hear what were—did you see any herniation in this series, and what are your concerns and thoughts to avoid it? Thank you very much.

Dr Rao. Thank you for your question. We did actually look at that. I didn't put too much into this presentation, but we have it on our manuscript. Our medium follow-up was 17 months, and we did not see any herniations. We try as much to follow our patients. We have had a white referral base, but we try as much to call our patients. And when we do get the scans, we're looking at that, and we haven't seen any.

TABLE E1. Subxiphoid thymectomy studies

First author (y)	Access and No. of ports	n	Operative time (min)	Sternotomy	30-d complication	LOS (d)	Chest tube (d)	Tumor size (cm)
Zelienski (2017)	SX (1) SC (2) Double sternal retraction	147	109.1 (75-150)	0	0	NA	NA	NA
Jiang (2020)	SX (1) SC (2) Midsternal retractor	48	104.5 (59-295)	0	7 (14.6)	4.5	3	5 (2.5-12)
Chen (2020)	SX (1) SC (2)	95	109.4 ± 20	2 (3.2)	4 (4)	2.7 ± 0.6	1.9 ± 0.7	3.5 ± 1.3
Suda (2020)	SX (1)	147	130.1 ± 51.6 (37-415)	2 (1.3)	6 (4)	4.5 ± 5.0	1.2 ± 1.1	3.1 (0.5-17.0)
Rao (2021)*	SX (1) SC (2 + 2)	40	205.5 (168-283)	3 (7)	5 (12.5)	3	1	4.4 (3.2-5.3)

Values are presented as mean and median (range). LOS, Length of stay; SX, subxiphoid; SC, subcostal; NA, not available. *Current study.

TABLE E2. Table of comparative studies (operative data)

First author (y)	N		Operative time (min)			Blood loss (mL)			Conversion to sternotomy	
	SxT	TT	SxT	TT	P value	SxT	TT	P value	SxT	TT
Suda (2016)	46	35	150	139	.08	2	20	<.0001	NA	NA
Lu (2018)	41	36	95 ± 26	120 ± 25	<.001	26 ± 11	55 ± 10	<.001	2 (4.8)	4 (11)
Zhang (2019)	28	70	104 ± 29	96 ± 40	.4	50 (30-70)	50 (30-70)	.12	0	0
Qiu (2020)	68	63	139 ± 35	152 ± 3	.035	74 ± 37	88 ± 52	.07	1 (1.5)	2 (3.1)
Liu (2020)	76	76	88	81	.6	55	46	.7	NA	NA
Xu (2020)	37	70	95.6 ± 31.2	141.5 ± 54.2	.004	58.8 ± 48.7	112.1 ± 117	.003	NA	NA
Rao (2022)*	40	16	206	182	.91	30	30	.1	3 (7.5)	0

Values are presented as n or n (%). Bold indicates significant P values. SxT, Subxiphoid thymectomy; TT, thoracoscopic thymectomy; NA, not available. *Current study.