The resident's point of view in the learning curve of thymic MIS: why should I learn it?

Anna E. Frick, Hans Van Veer, Herbert Decaluwé, Willy Coosemans, Dirk Van Raemdonck

Department of Thoracic Surgery, University Hospitals Leuven, Leuven, Belgium

Contributions: (I) Conception and design: AE Frick, D Van Raemdonck; (II) Administrative support: None; (III) Provision of study materials or patients: H Van Veer, H Decaluwé, W Coosemans, D Van Raemdonck; (IV) Collection and assembly of data: AE Frick; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Anna E. Frick. Department of Thoracic Surgery, University Hospital Leuven, Herestraat 49, 3000 Leuven, Belgium. Email: annaelisabeth.frick@uzleuven.be.

Abstract: Minimally invasive surgery (MIS) in thoracic surgery became quite popular during the last years. The aim of introducing and performing more MIS is to reduce surgical trauma, pain and complications in patients. Training in MIS increases operative time and thus cost in theatre but thus improves with experience. For a resident, the cases should be well selected with experienced supervision in a suitable setting with supporting staff and optimal instruments. Understanding the anatomy of the lung, using simulators, and attending workshops makes the learning curve shorter.

Keywords: Minimally invasive surgery (MIS); thymectomy; surgical learning curve

Received: 16 March 2018; Accepted: 17 April 2018; Published: 27 April 2018.
doi: 10.21037/jovs.2018.04.15
View this article at: http://dx.doi.org/10.21037/jovs.2018.04.15

Introduction

In this article, we describe why a resident should learn thymic minimally invasive surgery (MIS) and its learning curve.

To describe mediastinal abnormalities and evaluate differential diagnoses it is essential to understand the different compartments for treatment algorithm in further strategies for diagnosis and therapy. Furthermore, the knowledge in variety of histologies and pathologies in thymic abnormalities provides the optimal strategy for the best surgical approach with assessing the risks.

Mediastinal comprehension

Understanding mediastinal anatomy and pathology the anatomic information that every thoracic surgical resident must know and understand about the mediastinum is the anatomical complex regions. Surgical access without a complete understanding of the mediastinum may result in incomplete operations or technical mishaps.

The mediastinum, extending from the thoracic inlet superiorly to the diaphragm inferiorly, is the central compartment of the chest and contains a group of intrathoracic structures such as the heart and its vessels, the esophagus, trachea and main bronchi, thymus, lymphatic structures (thoracic duct and lymph nodes) and phrenic nerve (1,2).

Dividing the mediastinum into different compartments was proposed by anatomists, clinicians, and radiologists to establish differential diagnosis and selecting the best surgical approach for mediastinal abnormalities (3).

Over the years several mediastinal divisions have been advocated and the most frequent used for surgical approach was the classic 4-compartment by Gray's classification.

Also, frequently used by thoracic surgeons is the 3-compartment model and Shields' 3-classification scheme, also known as Felson's classification. Each compartment of the mediastinum has its own most common pathology and clinical presentation and narrows the possible diagnoses (4).

Another classification and rarely used by thoracic surgeons is the Heitzman classification. Heitzman divided the mediastinum into the following anatomic regions: the thoracic inlet, the supra-aortic area (above the aortic arch), the infra-aortic area (below the aortic arch), the supra-azygos area (above the azygos arch), and the infra-azygos area (below the azygos arch) (5).

Computed tomography (CT) scan, especially multiple detector computed tomography (MDCT) scan, and magnetic resonance imaging (MRI) provides the optimal imaging to evaluate a mediastinal mass and its extension, size and adjacent organ involvement of the lesion (6,7).

Disadvantage of a CT scan includes relatively high radiation dose (8).

For mediastinal mass evaluation, the use of MRI has been increased as it provides both physiological and anatomic data unlike other imaging modalities. To differentiate cystic from solid mass, MRI provides the ideal tool.

In 2014, the Japanese Association of Research of the Thymus (JART) was the first group to propose a CT-based mediastinal classification system into four compartments to classify mediastinal lesions. The authors analyzed in a retrospective study 445 pathologically proven mediastinal mass lesions, and categorized these into the proposed four compartments: superior portion of mediastinum, anterior mediastinum (prevascular zone), middle mediastinum (peri-tracheoesophageal zone), and posterior mediastinum (paravertebral zone) (9). Advantage of this 4-CT based compartment division is its efficacy and its recognition that thyroid goiters primarily remain confined within the superior mediastinum. Disadvantage of this model includes the complexity of existence of a fourth compartment, nonanatomic features of the 4-compartment scheme, and the overall perception that most clinicians and radiologists do not use the existing 4-compartment schemes (3,10,11).

The International Thymic Malignancy Interest Group (ITMIG) published a CT-based 3-compartment mediastinal classification system. ITMIG proposed mediastinal division into prevascular (anterior), visceral (middle), and paravertebral (posterior) compartments (3,12).

The major contents of the prevascular compartment are: thymus, fat, lymph nodes and left brachiocephalic vein. The vascular compartment includes: nonvascular contents like trachea, carina, esophagus, lymph nodes and vascular contents like heart, ascending thoracic aorta, aortic arch, descending thoracic aorta, superior vena cava, intrapericardial pulmonary arteries, thoracic duct. The paravertebral compartment includes the thoracic spine and paravertebral soft tissues.

According to the CT-based classification system the most common pathologies and differential diagnostic possibilities are provided.

Anatomical and histological knowledge of mediastinal diseases and the stage at diagnosis of thymic mass are necessary to choose the optimal treatment as prognostic assessment can be challenging. To classify thymic epithelial tumors the World Health Organization (WHO) has developed a classification (12).

Masaoka and colleagues described the mostly used staging system for thymoma in 1981 (13).

The TNM classification describes the stage of cancer which T standing for tumor descriptor, N describes nearby (regional) involved lymph nodes that are involved and M describes distant metastases.

The European Society for Medical Oncology (ESMO) guidelines for thymic epithelial tumors provide clinical practice on current management of thymic epithelial tumors including recommendations for diagnosis, staging and risk assessment and management of resectable and advanced disease (14).

Different approaches in MIS

Over the last years the focus in surgery was to improve MIS techniques with research to proceed in developing new technologies, devices, staplers, instruments, 3D systems or wireless cameras, and robotic surgery (15).

One of the main questions in MIS remains which and how a surgical approach for thymectomy should be chosen.

MIS, including transcervical, extended transcervical, video-assisted thoracoscopic surgery (VATS), bilateral and unilateral VATS (either left or right), and robotic-assisted thoracoscopy surgery (RATS) (right or left, right and left, right and cervical, left and cervical, subxiphoid and right and left, cervical and subxiphoid), is an option in the treatment strategy of thymic abnormalities if this surgical approach is feasible. MIS is an alternative approach to open approach such as median sternotomy, posterolateral thoracotomy, unilateral anterior thoracotomy with partial sternotomy (hemi-clamshell), and bilateral anterior thoracotomy with transverse sternotomy (clamshell) and became the default approach for many thoracic surgeons. The open approach has the major advantage of providing a large surgical field to all structures surrounding the thymus gland at accost of more surgical trauma and risk for bleeding and infection.

VATS

The advantages of VATS over open approach are such as less trauma, shorter hospital stay, increased cosmetic results, and better preservation and faster recovery of pulmonary function (14,16). VATS provide an exceptional intraoperative accurate overview and reduces operative risks for injury to fine structures. It is a safe technique for mediastinal well circumscribed or encapsulated tumors (17).

Nevertheless, VATS is associated with disadvantages especially with the location of the mediastinal mass in the anterior mediastinum. There are also disadvantages for the surgeon such as long instruments placed through fixed entry points. This creates a fulcrum effect and limits maneuverability and bi-dimensional screen vision of the surgical field.

RATS

In 1994 VATS thymectomy was first performed as a minimally invasive alternative approach to open procedures and some years later thymectomy was performed by a robotic system to overcome the disadvantages of VATS (18).

Performing a thymectomy with limited or difficult access, RATS offers an adequate approach especially for the cervical and contralateral parts of the dissection.

Disadvantages in RATS procedures are replacing the ports intraoperatively and changing the position of the installed patient.

In 2012, collected data by four European centers on robotic thymoma resections was published. In total 79 patients with early stage thymoma who underwent surgery were analyzed. The authors concluded that robot-enhanced thoracoscopic thymectomy for early-stage thymoma is a technically sound and safe procedure with a low complication rate, a short hospital stay and a good oncological outcome (19).

Subxiphoid VATS

A subxiphoid VATS approach for mediastinum was described by Zielinski *et al.* as an alternative approach to sternotomy for patients presenting with Masaoka stages I–III thymoma. Advantages of a subxiphoid VATS approach are: relatively non-painful, total avoidance of the risk of disruption or infection of the sternotomy wound, visualization and dissection up to the thyroid possible, which enables complete removal of the thymus, access to the chest wider than for intercostal utility thoracotomy and perfect cosmetic results. For advanced thymomas the subxiphoid approach is a disadvantage also it provides a limited possibility of visualization and dissection of the laryngeal recurrent nerves and the fatty tissue in the lower neck (20).

Bilateral approach

The bilateral approach advocates a better visualization of anatomical structures and the complete excision (21).

To compare the feasibility of performing a bilateral video-assisted thoracoscopic extended thymectomy with sternotomy, Fiorelli *et al.* divided 43 patients into two groups (one group underwent minimally invasive approach and 20 underwent thymectomy by sternotomy). In this study, there was no significant difference between the two groups though the video-assisted thoracoscopic thymectomy group had lower pain scores and morphine consumption, significantly less operative blood loss and chest drainage volume, and shorter hospital stay. A bilateral video-assisted thoracoscopic approach with extended thymectomy had the advantage of amplifying the view of both cardiophrenic regions (22).

MIS versus open approach

In the literature, the main controversy between MIS and open approach refers to incomplete resections.

From 1995 to 2014 Friedant *et al.* identified studies that compared minimally invasive to open thymectomy for thymic malignancies in a systematic review and meta-analysis. All together 516 studies, 30 with a total of 2,038 patients were included and 94.89% of patients in the MIS group had Masaoka stage I or II thymic malignancy and 78.62% of those in open thymectomy (open) group. The MIS group had significantly less blood loss; no significant differences in operating time, respiratory complications, cardiac complications, or overall complications were identified. In the MIS group length of stay was shorter. This meta-analysis shows that invasive thymectomy is safe and can achieve oncologic outcomes similar to those of open thymectomy. In this analysis, the authors could not point out any supporting factors for a surgeon in selecting appropriate patients for minimally invasive as opposed to open thymectomy approaches (23).

MIS may be as effective and have more advantages as open approach in treating small, early-stage thymic malignancies, but there is still a debate over the exact technique of the approach by MIS.

Capsular rupture and risk of pleural spread with an MIS approach is another apprehension though there is no convincing evidence for a higher rate of recurrence and other complications in MIS than open approaches (24).

Ye *et al.* compared 262 patients without myasthenia gravis who had undergone surgery (unilateral VATS thymectomy and open procedure by sternotomy) for Masaoka stages I and II thymoma. The VATS group showed shorter operative time than the open approach group, smaller intraoperative blood loss, smaller pleural drainage volume in the first 24 hours postoperatively, shorter postoperative pleural drainage duration, shorter postoperative hospital stays (25).

According to Mineo *et al.* dissections are safer from a left sided approach because the superior vena cava lies outside the surgical field furthermore dissection of the peri-thymic fatty tissue around the left peri-cardiophrenic angle is removed easier from the left side (26). A right sided approach provides the identification of the superior vena cava and can be used as a landmark to dissect around the innominate veins. Another advantage of a right-side approach is that it is also more comfortable for right-handed surgeons (27).

Learning curve for a resident—what should I be aware of?

Why is it necessary to get trained and to develop a thoracic technique to master and perform MIS in thymic surgery?

The thoracic training is widely divergent, especially in Europe (28).

One of the remaining problems in training is: specifications and trainings, economic cost, conservation and innovation (29).

The learning curve in MIS procedures is associated with increasing time and costs in the operative room.

The difficulties in MIS start with the port placement in obese patients, perioperative risks during single-lung ventilation, pathology of the tumor and the surgical technique for the dissection of the thymus (dissection along the innominate vein as the most important and accident inviting part) and complications like hemorrhage (30).

For dissecting various tissues and vessels, useful tools in MIS are electrocautery and harmonic scalpel. The harmonic scalpel allows cutting and coagulating precisely at a lower temperature than an electrocautery, especially in the surrounding area of the phrenic nerve this can be beneficial. Soon *et al.* described the use of the harmonic scalpel in video-assisted thoracoscopic thymic resection as a safe procedure and confers some advantages over conventional methods of dissection (31).

Other helpful factors in a learning curve for a resident in MIS is to use carbon dioxide (CO_2), insufflation at 10 to 12 mmHg, insufflation to collapse the lung and to aid in dissection of areolar tissues. The insufflation improves visualization and the carbon dioxide is harmless und fast absorbed postoperatively (32). Though CO_2 insufflation can create right atrial and right ventricular compression with obstructive shock resulting in hemodynamic instability (33).

In our center, we prefer to perform a right- or left-sided three-port technique thoracoscopic thymectomy with surgeon and assistant standing dorsally to the patient and the scrubbed nurse on the opposite side. The patient is intubated with a double lumen endotracheal tube and is installed in a partial lateral decubitus position on a vacuum mattress. The ipsilateral arm is wrapped in cotton wool to avoid ulnar nerve palsy and is fixed abducted overhead on a bar. Under the chest we place a bump to provide access to the axilla. With a band over the pelvis the patient is secured to the table.

We place two 5-mm and one 10-mm ports in the retropectoral position. A 30-degree angled camera is used and the others are working ports. To obtain an isolation of the lung we use CO_2 insufflation additionally to the double lumen endobronchial tube. We achieve a complete radical thymectomy by *en bloc* removal of the thymus, perithymic fat and tissue from the thoracic inlet to the diaphragm, and from the phrenic nerve to phrenic nerve.

The presentation of the phrenic nerve begins by mobilization of the thymus with incising the mediastinal pleura on the left lateral side of the thymus taking in account the alongside running phrenic nerve. Prepare the pericardial space freeing the back of the thymus (attack the right side of the thymus). Furthermore, mobilization of the body of the thymus is done by dissection of the retrosternal plane. The next challenging part is to free up the horns by dissecting with clips or harmonic scalpel (*Figure 1*).

Also, be aware of vascular branches from the innominate vein and from the internal mammary vessel. Residents and their mentors should always be prepared for complications and conversion.

Learning curve for a resident—how can I improve my surgical skills?

The learning curve differs in MIS individually and depends on case volume, supervision, mentoring, experience, and surgical talent. Petersen *et al.* analyzed the learning

Figure 1 Left VATS thymectomy (34).
Available online: http://www.asvide.com/article/view/24427

curve associated with VATS lobectomy and suggested recommendations for the introduction of a VATS lobectomy program. The recommendations for the introduction of a VATS lobectomy program are: perform open lobectomy by an anterior thoracotomy, perform >100 minor VATS procedures, attend formal courses in VATS lobectomy, visit clinic with experience in VATS lobectomy, training on simulators, chose one approach, consider volume/clinic/surgeon, select patients, stepwise introduction to surgical procedures, prospective data collection (35).

Similar programs or recommendations for a MIS thymectomy do not exist, but many points could be adopted how to perform a thymectomy.

Starting with thymectomy to learn in thoracic surgery might not be the first experience in thoracic surgery. Experience should be gained with other MIS procedures such as wedge resections and pleural biopsies. For a faster learning curve and improving surgical skills, simulators for VATS procedures in an animal model may help. In Europe, there are many courses offered to learn more about VATS mainly for lobectomy. Our generation is confronted with training on simulators, learning through simulation rather than on patients.

The European Society of Thoracic Surgeons (ESTS) offers an itinerant expert course on robotic thymectomy and lobectomy. In this course, the participants are attending operative sessions (36). Another possibility to gain surgical skills in RATS techniques is an inter-university diploma in robotic surgery from the cooperation of: University of Lorraine, Faculty of Medicine Nancy and Surgery School Nancy-Lorraine. It is a 5-day course and provides a basis of technical competence of robotic surgery. The program includes an E-learning part, simulation part, technical practice in the dry-lab and a clinical practice in the wet lab and case observations in the operating room. This course is accredited by the European Accreditation Council for Continuing Medical Education (EACCME) (37).

Toker *et al.* in 90 patients undergoing videothoracoscopic thymic surgery analyzed the learning curve of a surgeon. VATS thymectomy surgery has a learning curve and surgeon gets faster and safer with their practice (38).

Why should a resident learn MIS in thymic surgery because it is the future approach for surgical resection of thymic pathologies. Nevertheless, the resident and the mentor should be skilled in all techniques and all approaches should be performed with the same competence including safety, efficacy and precision.

Conclusions

Understanding the anatomy and the pathology in thymic diseases are prerequisites to perform MIS. The approach is an individual choice, but it requires a decision for the best benefit, safety and efficiency for the patient. Only through practice, expertise in MIS can be achieved.

Acknowledgements

None.

Footnote:

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2018.04.15
Cite this article as: Frick AE, Van Veer H, Decaluwé H, Coosemans W, Van Raemdonck D. The resident's point of view in the learning curve of thymic MIS: why should I learn it? J Vis Surg 2018;4:85.