Review Article

Surgical access to the mediastinum—*all roads lead to Rome*: a literature review

Nora Mayer^, Peter Kestenholz^, Fabrizio Minervini^

Division of Thoracic Surgery, Lucerne Cantonal Hospital, Luzern, Switzerland

Contributions: (I) Conception and design: F Minervini, N Mayer; (II) Administrative support: P Kestenholz; (III) Provision of study materials or patients: N Mayer; (IV) Collection and assembly of data: N Mayer, F Minervini; (V) Data analysis and interpretation: N Mayer, F Minervini; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Fabrizio Minervini, MD, PhD, FEBTS, MBA. Division of Thoracic Surgery, Lucerne Cantonal Hospital, Spitalstrasse 16, 6000 Luzern, Switzerland. Email: fabrizio minervini@hotmail.com.

Background and Objective: The mediastinum is a complex, heterogeneous area, which leads vertically across the thoracic cavity between the bilateral mediastinal pleurae, connecting the head and neck region with the thoracic cavity. Different classifications have been published to differentiate between the so-called mediastinal compartments while the most used classification surely is the 4-compartments Gray`s classification, dividing it into the superior, anterior, middle and posterior mediastinum. Mediastinal abnormalities include infections (mediastinitis) and solid or cystic mediastinal masses. These masses can be divided into benign and malignant lesions originating from mediastinal structures/organs or represent manifestations of metastatic disease, often metastatic non-small cell lung cancer (NSCLC). This review aims to explore the different mediastinal pathologies along with indications and surgical approaches.

Methods: We performed literature research in PubMed, MEDLINE, Embase, CENTRAL, and CINAHL databases. Only papers written in English were included.

Key Content and Findings: Depending on the indication for surgical intervention and the localization of the pathology, surgical approach may differ immensely. Mediastinal staging of lung cancer, primary lesions of the mediastinum, mediastinitis and traumatic mediastinal injuries display the most frequent indications for mediastinal surgery. Surgical approaches trend towards minimally invasive, video- or robotic-assisted techniques and are becoming increasingly refined to adapt to the special characteristics of the mediastinum. However, certain indications still require open access for best possible mediastinal exposure or oncological reasons.

Conclusions: To guide optimal surgical approach selection to the mediastinum, the following overview will present all published surgical approaches to the mediastinum and discuss their practical relevance and indications aiming to help surgeons in the management of patients with mediastinal pathologies who should undergo surgery.

Keywords: Mediastinum; mediastinal pathologies; surgical access; minimally invasive; mediastinal staging

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^ ORCID: Nora Mayer, 0000-0001-7412-8224; Peter Kestenholz, 0000-0002-0419-3685; Fabrizio Minervini, 0000-0003-3595-7307.

Introduction

The mediastinum is divided into specific compartments, most commonly referred to as the superior, anterior, middle and posterior mediastinum (1-3). It contains fundamentally important vascular and non-vascular structures as well as organs and furthermore, it connects the head and neck region with the thoracic cavity. The currently accepted radiological standard of mediastinal compartments was developed by the International Thymic Malignancy Interest Group (ITMIG) based on computed tomography (CT)-images. It defines the different compartments bordered by specific anatomic structures (4) (*Table 1*).

Mediastinal lesions can be of benign or malignant nature originating from the respective mediastinal structures or be metastatic manifestations of distant disease.

Primary tumours in the anterior mediastinum account for more than half of all mediastinal masses in adults comprising malignant and benign lesions (5). Malignant lesions consist of thymoma, lymphoma and teratoma whilst benign lesions include thymic cysts, lymphangioma and intrathoracic goitre (6). A further quarter of the mediastinal abnormalities can be found in either the middle or the posterior mediastinum respectively (7). There, the lesions comprise neurogenic tumours lymphoma and mediastinal cysts (8,9).

Clinical characterization plus radiological findings in CT may be sufficient for definitive diagnosis, however, in other cases, further imaging like magnetic resonance imaging (MRI), fluorodeoxyglucose-positron emission tomography-CT (FDG-PET-CT) or histological confirmation (often immunohistochemistry) may become necessary to delineate the origin of mediastinal abnormalities (7). To choose the optimal treatment, histological diagnosis sometimes is mandatory if the imaging cannot predict a diagnosis with a high degree of certainty. A biopsy indication however has to be evaluated carefully and the biopsy technique highly depends on the localization of the lesion and surrounding structures, the experience of the respective physician as well as the most expected nature of the lesion. Metastatic seeding of the lesion through biopsy procedures needs to be avoided.

Various interventional biopsy options including CT-guided percutaneous biopsy, endobronchial ultrasound-guided transbronchial fine needle aspiration (EBUS-TBNA) and endoscopic ultrasound fine-needle aspiration (EUS-FNA) exist. For the posterior mediastinum, EUS-FNA is safe and provides an excellent diagnostic yield with a sensitivity of more than 90% and a specificity of 100% (10,11). Concerning mediastinal staging in lung cancer patients, EBUS-TBNA and EUS-FNA are currently playing an increasing role as a minimally invasive alternative, reducing the need for mediastinoscopy (12). However, if clinical suspicion of mediastinal lymph node (LN) metastases remains, cervical mediastinoscopy in the experienced hand is still recommended (13).

Surgery, like cervical mediastinoscopy mentioned above, may be required in cases of failed interventional mediastinal staging (technical, localization, insufficient tissue amount for molecular analysis, inconclusive histopathological result). The chosen surgical approach depends on different factors including the localisation of the pathology as well as the surgical indication. Biopsy/staging techniques include mediastinoscopy, Chamberlain/McNeill procedure, video-assisted mediastinoscopic lymphadenectomy (VAMLA) and transcervical extended mediastinal lymphadenectomy (TEMLA).

Furthermore, surgery remains the standard for removal of mediastinal masses, with transsternal open resection having been the gold standard for many years. However, minimally invasive surgical techniques such as video- and robotic-assisted thoracic surgery (VATS/RATS) are gaining ground if not already longing to replace open surgery in certain fields (8,14).

The aim of our publication was to describe all the available surgical accesses and emphasize their indications

Table 1 Boundaries and contents of the 4-compartment mediastinal scheme

Mediastinal compartment	Boundaries	Content
Superior	Thoracic inlet to a line from the sternal angle to T4	Aorta, great vessels, trachea, upper 3rd of the oesophagus, upper thymus
Anterior	Pericardium, sternal body	Mediastinal fat and thymus
Middle	Pericardium to pericardium	Pericardium, heart, carina, lymph nodes
Posterior	Dorsal pericardium to anterior surface of T4–T12	Oesophagus, thoracic aorta, azygos vein, thoracic duct

Table 2 Methods and specification of underlying database research

Items	Specification
Date of search	Search performed between 19th of November and 6th of December 2023
Databases searched	PubMed/MEDLINE/Embase/CENTRAL/CINAHL
Search terms used	(mediastinum OR mediastinal) AND (access OR approach OR surgery OR resection OR "surgical resection" OR "tumour resection") OR (mediastinoscopy)
	(mediastinal OR mediastinum) AND (tumour OR pathology OR mass OR "tumour mass" OR neoplasia)
	(RATS OR "robotic-assisted" OR robotic OR "video-assisted" OR VATS OR "minimally invasive" AND surgery) AND (thymectomy OR "resection of thymus" OR thymoma)
Timeframe	Not specified
Inclusion and exclusion criteria	Inclusion criteria:
	❖ Studies including mediastinal tumor resection were included
	❖ All surgical approaches (open/video/robotic-assisted thoracoscopic surgery)
	Exclusion criteria:
	❖ Commentaries and case reports
	❖ Language other than English
	❖ Full text unavailable
Selection process	Initially, records were screened by title and abstract and then duplicate studies were identified and removed using ZOTERO
	For the second stage of screening, we performed full text review of all eligible studies from the title and abstract screening. Both stages were performed by two authors (F.M., N.M.)

RATS, robotic-assisted thoracic surgery; VATS, video-assisted thoracic surgery.

and practical implementation as well as informing about current evolutions to provide guidance for decision-making in choosing the most appropriate surgical approach to the mediastinum. We present this article in accordance with the Narrative Review reporting checklist (available at https://med.amegroups.com/article/view/10.21037/med-23-71/rc).

Methods

We performed a literature search in PubMed, MEDLINE, Embase, CENTRAL, and CINAHL databases to identify relevant publications for the assessed topic of accesses/approaches to the mediastinum for mediastinal pathologies (*Table 2*).

The searches for the main review were conducted as: (mediastinum OR mediastinal) AND (access OR approach OR surgery OR resection OR "surgical resection" OR "tumour resection") OR (mediastinoscopy).

The more specific research for certain sections of the review was done with the following additions: (mediastinal OR mediastinum) AND (tumour OR pathology OR mass OR "tumour mass" OR neoplasia).

(RATS OR "robotic-assisted" OR robotic OR "video-assisted" OR VATS OR "minimally invasive" AND surgery) AND (thymectomy OR "resection of thymus" OR thymoma).

All citations returned from the above searches were exported into a ZOTERO library. Duplications were removed and abstracts were reviewed by two authors (N.M., F.M.) for potential inclusion in the manuscript.

Further searches were conducted without using Boolean operators.

We included all the studies where surgery-related mediastinal pathologies were reported. Only publications in English language were included. We were focussing on the most recent publications to enhance the importance of our review, however, publications including first descriptions of rare access techniques were included.

Due to the narrative design of the review, a certain

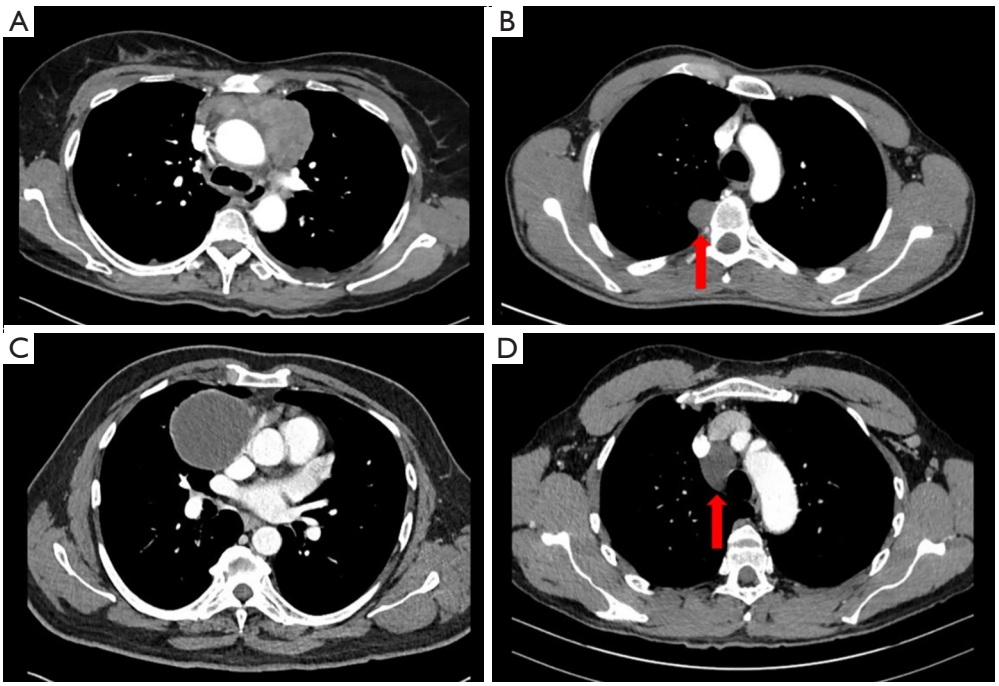

Figure 1 Pathologies of the mediastinum. (A) Thoracic CT showing a thymoma type B3 in the anterior mediastinal compartment, (B) CT showing a neurogenic tumor in the posterior mediastinum (arrow), (C) CT-scan showing a pericardial cyst in the antero-medial compartment of the mediastinum as well as (D) showing at CT-scan with a bronchogenic cyst (arrow) in the middle compartment of the mediastinum. CT, computed tomography.

subjectivity in choice of studies included is likely. Patients' consents were obtained for publication of the images and saved in their electronic charts.

Pathologies of the mediastinum

Mediastinal lesions/tumours

Anterior mediastinum

Thymoma is by far the most common tumour of the anterior mediastinum (9). Open extended thymectomy via sternotomy remains the gold standard, particularly for advanced-stage tumours. There is however significant evidence now available for the use of minimally invasive approaches for early-stage thymomas (15). Teratoma, lymphoma and thyroid or other endocrine masses are less common differential diagnoses of anterior mediastinal masses (5,16). Growth of lymphoma or lymphadenopathy may occur in all three compartments of the mediastinum (17) (*Figure 1A*).

Posterior mediastinum

Neurogenic tumours (mainly benign peripheral nerve sheath neoplasms like schwannoma and neurofibroma) most commonly occur in the posterior mediastinum (17) (*Figure 1B*).

Middle mediastinum

Lymphoma and mediastinal cysts (predominantly bronchogenic and enteric as well as pericardial cysts) are the most common tumours of the middle mediastinum (17) (*Figure 1C,1D*).

Mediastinitis

Mediastinitis is a life-threatening condition mainly secondary to oropharyngeal abscesses, neck infections or oesophageal leak either descending into the mediastinum via the cervical fascial planes or directly penetrating the intrathoracic mediastinum with a mortality of up to 40%. Early diagnosis and optimal immediate therapeutic approach, often including surgical drainage of the mediastinum, are crucial for patient survival (18).

Traumatic mediastinal injuries

Traumatic mediastinal injuries must be divided into blunt

and penetrating injuries according to their injury mechanism. Blunt thoracic trauma occurs in up to 60% of polytraumatized patients and results in about 25% mortality (19). Due to the suspected high mortality caused by injury of major mediastinal structures in blunt thoracic trauma in the preclinical setting as well, the exact incidence of mediastinal injuries remains uncertain (20,21).

Indications for mediastinal surgery

Indications for mediastinal surgery include (I) tissue sampling and staging, (II) surgical drainage of mediastinal infection/abscess (mediastinitis), (III) resection of mediastinal pathologies for diagnostic and therapeutic reasons, especially when they are symptomatic, and traumatic mediastinal injuries (20,22).

Sampling and staging

Surgical access to the mediastinum may be necessary for tissue sampling or mediastinal staging. Open and/or video-assisted surgical access is available. Mediastinoscopy, one of the most common approaches is often indicated in mediastinal LN staging in non-small cell lung cancer (NSCLC) patients.

Surgical resection

Several surgical approaches to the mediastinum with a tendency towards minimally invasive techniques, currently favouring robotic-assisted techniques, have been described before (23). Minimally invasive approach for surgical resection of mediastinal masses, for example the well-studied minimally-invasive thymectomy is associated with improved surgical results and fewer complications compared to transsternal open thymectomy, without any substantial changes in myasthenia gravis (MG) complete rates of remission (8).

Surgical drainage of mediastinal infection/mediastinitis

Necrotizing mediastinitis has high mortality rates of around 25% to 40% and mainly arises from head-and-neck abscesses (descending necrotizing mediastinitis) or develops after oesophageal perforation (iatrogenic, spontaneous) (24,25). Aggressive surgical drainage and debridement of the mediastinum as well as of accompanying pleural effusion and empyema in combination with broad-spectrum or targeted antibiotic treatment and elimination of the primary source has shown to drastically reduce mortality (26). Both open and minimally invasive approaches of all kinds have been described (26-29). As published series are rather small and surgical accesses are very heterogenous, there are no clear guidelines as to which access can be considered superior but there is still a tendency to open approach due to the aggressivity and fatality of the disease (30).

Traumatic mediastinal injuries

Due to suspected high mortality of traumatic injuries of major structures of the mediastinum in blunt thoracic trauma, the exact incidence of mediastinal injuries remains uncertain (20,21). Mortality rates after resuscitation thoracotomy for penetrating trauma are reported from 15% to 35%, while those with blunt thoracic trauma only yielded in successful resuscitation in about 2% (31,32).

A left anterolateral thoracotomy is recommended in hemodynamically instable patients with blunt chest trauma aiming to control avoidable causes of death (haemothorax, pneumothorax, hemopericardium) and providing access to mediastinal structures (33,34). To gain access to the contralateral hemithorax if necessary, a right-sided thoracotomy and/or extension to a clamshell incision may follow (34,35).

In hemodynamically stable individuals with suspicion of cardiac injury, median sternotomy is the most suitable approach to expose the heart and thoracic cavity bilaterally (36). VATS may provide diagnostic and therapeutic value in hemodynamically stable patients with localized, penetrating thoracic trauma (21,37).

Surgical access to the mediastinum

The various surgical accesses to the mediastinum can be divided into open and minimally invasive approaches and further categorized in accordance with the respective targeted compartment of the mediastinum, the size of the targeted mass and the relation to adjacent structures. As surgery of mediastinal pathologies can be very challenging, open surgical techniques may be combined with minimally invasive ones to improve the effectiveness and outcome. To help understand the various access modalities, we have either added an illustration taken in our institution or for less commonly applied techniques have highlighted significant illustrated reference.

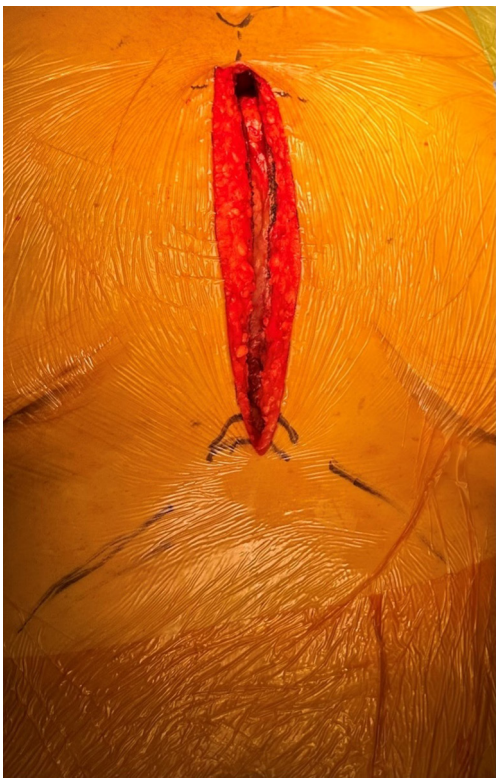

Figure 2 Median sternotomy incision in a 57-year-old female. The sternal notch and xiphoid process as well as the ventral rib cage are inked to the skin foil as landmarks.

Open accesses

Median sternotomy

Median sternotomy is the most common access for cardiac bypass surgery and remains a very common open thoracic approach for mediastinal, bilateral pulmonary or lower trachea and main stem bronchus surgery (38). The sternotomy technique is well established, and the technical details were presented many times before (*Figure 2*). Crucial steps are the strict sternal midline preparation and performing the osteotomy during apnoea in order to avoid injuries of the underlying structures like pericardium, pleura, innominate vein and brachiocephalic artery. A proper sternal closure to prevent instability and infection is as important as performing a proper sternotomy to reduce morbidity (39). Because of its midline location, the postoperative pain associated with sternotomy is less than for intercostal incisions like performed in thoracotomy.

Partial upper sternotomy

Partial sternotomy is an appropriate approach for thyroid surgery with reachable retrosternal extension and for limited additional access to the anterosuperior mediastinum (40,41). However, a full median sternotomy as described above should be performed in cases of proven or expected malignancy, extension into the posterior mediastinum and extension to the aortic arch. For the partial upper sternotomy, a 10–12 cm mid-sternal incision is followed by a division of the sternum in a J-form manner from the sternal notch to the right 4th intercostal space. A spreader is inserted to grant access. A valuable illustration of a partial upper sternotomy (in aortic valve surgery) can be found in the publication of Gillinov *et al.* (42). As for full median sternotomy, cautious closure of the partial sternotomy is crucial to avoid long-term morbidity. In addition to a cosmetic benefit, the incidence of sternal wound infection can be reduced by helping maintain part of the sternum, hence keeping the rigidity of the chest wall.

Trapdoor incision (anterior cervico-sterno-thoracotomy)

The trapdoor incision gives access to the superior mediastinum and thoracic inlet. A partial J-type sternotomy in the 2nd or 3rd intercostal space is combined with the supraclavicular extension of a standard sternotomy. The major necessary addition to complete the trapdoor incision is the extension of the inferior lateral arm of the incision through the pectoralis major muscle. The internal mammary vessels need to be ligated when entering the chest. A rib-spreading retractor is elevating the "trapdoor". Large anterior mediastinal masses, such as thymomas and germ cell tumours can be accessed through the trapdoor, hence this approach is often used in paediatrics (43,44). Christison-Lagay *et al.* showed a clear illustration of the trapdoor-incision and the respective surrounding anatomical structures in their work from 2014 (43).

(Hemi-) Clamshell

The Hemi-clamshell incision is defined as a partial sternotomy with antero-lateral thoracotomy. As compared to the afore-mentioned, seldom used trapdoor incision, it provides additional exposure of the mediastinum in its middle and lower compartments. The transverse intercostal incision connecting to the sternal incision is positioned in the 4th or 5th intercostal space. Postoperative analgetic requirements have shown to be similar to those after different approaches (45). The patient is positioned supine. An L-shaped skin incision is done, followed by entering the chest through the intercostal space after ligating the internal mammary pedicle. Afterwards, median sternal

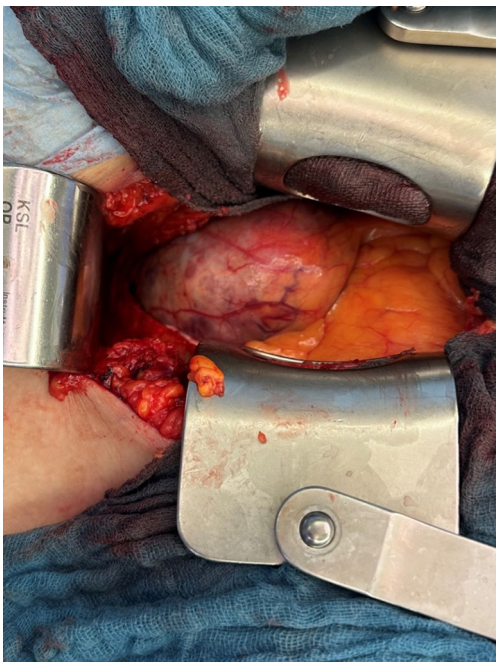

Figure 3 Right antero-lateral thoracotomy in a 60-year-old female with visible biopsy proven large type B1 thymoma surrounded by pericardial fatty tissue in the anterior mediastinum.

incision followed by the J-formed incision of the respective half of the sternum is done. Sternal wires and pericostal non-resorbable sutures serve for closure. Bains *et al.* nicely demonstrate sketches of both the hemi-clamshell and clamshell incision as well as the exposure of relevant structures with these two approaches in their publication from 1994 (46).

Thoracotomy (postero-lateral, antero-lateral)

Postero-lateral

The postero-lateral thoracotomy is one of the most used incisions in thoracic surgery providing access to the lung, hilum, middle and posterior mediastinum, endothoracic trachea and oesophagus. The patient is positioned in lateral decubitus position. The skin incision runs along the fifth or sixth intercostal space starting from the anterior axillary line (AAL) with a slight curve around the tip of the scapula. The M. latissimus dorsi is opened with electrocautery. the anterior portion of the M. trapezius and rhomboid muscles can be divided posteriorly. The M. serratus anterior muscle is usually spared and retracted. To identify the appropriate intercostal space, the hand is passed towards the first rib by developing a plane beneath the scapula. To make access to the chest cavity easier, a rib resection or partial rib resection can be done according to the surgeon's preference followed by the opening of the endothoracic fascia and parietal pleura along the upper border of the rib to avoid injury of the neurovascular bundle. A retractor is then placed and opened gently to avoid rib fractures. For closure of the intercostal spaces after the procedure, a loop or interrupted stitches can be applied. Standard wound closure of all layers is performed (47). Muscle-sparing postero-lateral thoracotomy has been described as well, but has not prevailed (48).

Antero-lateral

The antero-lateral thoracotomy provides good access to the anterior mediastinum (*Figure 3*). The skin incision runs from the 4th or 5th intercostal space from parasternal until the AAL. It can be easily extended to become a Hemi-Clamshell incision. The pectoral muscle in direction of the fibres followed by division of the intercostal muscles and parietal pleura to enter the chest (49,50).

Anterior mediastinotomy

Anterior mediastinotomy, also known as Chamberlain- or McNeill-procedure, is an open procedure done under general anesthesia that allows for dissection of the aortopulmonary LNs (51,52). This technique is very effective in biopsying the anterior mediastinal, the periaortic, the aortopulmonary LNs, or the lung. The chest is entered via a restrictive incision in the 2nd parasternal intercostal space on the left. The Chamberlain-procedure has mainly been abandoned nowadays but has its main indication in aorto-pulmonary (AP)-window (paraaortic/subaortic LN station 5/6) involvement in NSCLC, unreachable in mediastinoscopy and EBUS-TBNA (53). Ginsberg showed a recommendable sketch of the access in their publication of mediastinal accesses from 1987 (54).

Mediastinoscopy

Mediastinoscopy through a 2–3 cm transverse cervical incision (Kocher-incision) provides access to the pre-tracheal, paratracheal, and anterior sub-carinal LNs (55-57). One has to differentiate between video-assisted (VAM) and conventional mediastinoscopy (CM) without video-support (58). The VAM is considered the standard as compared to CM nowadays. After the Kocher-incision, the video-mediastinoscope is inserted (with closed spatula) after opening of the pretracheal fascia, identification of the anatomical landmarks (bifurcation, both main bronchi and the left recurrent nerve) is necessary to avoid injuries.

Mediastinal dissection continues with spatulas open. LN-stations 2, 3, 4, 7, 10 and 11 can be accessed bilaterally. Of note, mediastinoscopy has a high sensitivity (>80%) and specificity (100%) in the staging of lung cancer (55). One rare but potentially fatal complication of mediastinoscopy is bleeding from one of the great vessels in close proximity to the operating field. However, even when Eric Carlens published his experience on his first 100 cases back in 1959, no bleeding complication occurred (59). As of today, the rate of complications and mortality remains minimal (56,60).

Extended cervical mediastinoscopy

This extended cervical mediastinoscopy approach published and apparently to our knowledge best visualized by Ginsberg in 1987 helps to reach the subaortic and preaortic station 5 and 6 LNs through a conventional Kocher-incision in addition to the aforementioned investigated pre-tracheal, paratracheal, and anterior sub-carinal LNs. The video-mediastinoscope is advanced over the aortic arch between the innominate artery and the left common carotid artery. In case of failure of this approach in staging of left upper lobe tumours, an additional anterior mediastinotomy through a second incision can follow to complete staging (54). Ginsberg concluded in their original work, that "In expert hands, invasive mediastinal exploration has very low morbidity and mortality". Nevertheless, we advocate for critically evaluating any other less invasive modality to reduce potentially fatal injury of neighbouring arteries along the way of this access.

Video-assisted, mediastinoscopic lymphadenectomy (VAMLA)

VAMLA has shown to be safe and represents one of the two best staging methods in terms of accuracy in mediastinal staging of NSCLC. Like TEMLA, it can serve as preresectional lymphadenectomy prior to VATS (61,62). After starting VAMLA like a mediastinoscopy described above, the subcarinal nodes are extracted *en bloc*. In this way, the oesophagus and the mediastinal pleura can be exposed and right para-oesophageal nodes as well as hilar N1-nodes can be carefully harvested. *En bloc* resection of the pre-tracheal, right paratracheal and right tracheobronchial compartments is done afterwards.

TEMLA

TEMLA, developed by Zieliński *et al.*, is performed through a 5–8-cm transverse cervical incision in the neck and enables the complete removal of all mediastinal nodal stations except for station 9 and station 4L nodes (63). TEMLA is an open procedure performed partly with mediastinoscopy-assisted and video-assisted techniques and includes elevation of the sternal manubrium with a retractor as well as bilateral visualization of the laryngeal recurrent and vagus nerves. It can serve as a preresectional lymphadenectomy in VATS cases like the before described VAMLA.

Minimally invasive video-assisted techniques

VATS

VATS is a suitable access for both mediastinal staging and resection of mediastinal masses mainly in the middle and posterior, as well as accessible lesions in the anterior mediastinum. Right VATS provides access to LN stations 10R, 4R, 7, 8R and 9R. On the left side, LN station 10L, 4L, 5, 6, 7, 8L and 9L can be reached. Station 4L cannot be explored in right VATS due to its difficult access. VATS can be performed uniportally or with a multi-port-approach, while the single port technique is increasing worldwide. Double lumen endobronchial tube insertion for selective ventilation is done before placing the patient in a lateral decubitus position or slightly one side lifted supine position, is recommended. In addition to selective ventilation, CO_2 gas insufflation for further collapsing the lung can be applied in selected patients. A 0° or 30° video-telescopic camera via a two-to-three port access plus a potential subxyphoideal access for better visualization and retrieval of the specimen have shown to be successfully used in thoracic surgery practice.

Subxiphoid

For a uniportal subxiphoid approach, the patients can be positioned supine or in slightly half sided 45° lifted supine position. A 2–3 cm transverse or vertical skin incision is made 1–2 cm below the xiphoid. A vacuum multi-port system with the possibility of CO_2 insufflation with two to three ports is inserted. In a multiport approach, a second or third intercostal 5 mm incision can be added (64).

RATS

Since the first RATS thymectomy reported by Yoshino *et al.* in 2001, RATS has shown to have clear benefits in technically demanding anatomical regions like the mediastinum whilst in addition showing better outcomes in postoperative quality of life (QoL), pain, length of stay (LOS) with equal results regarding MG compared to open approach (65,66). RATS can be performed through

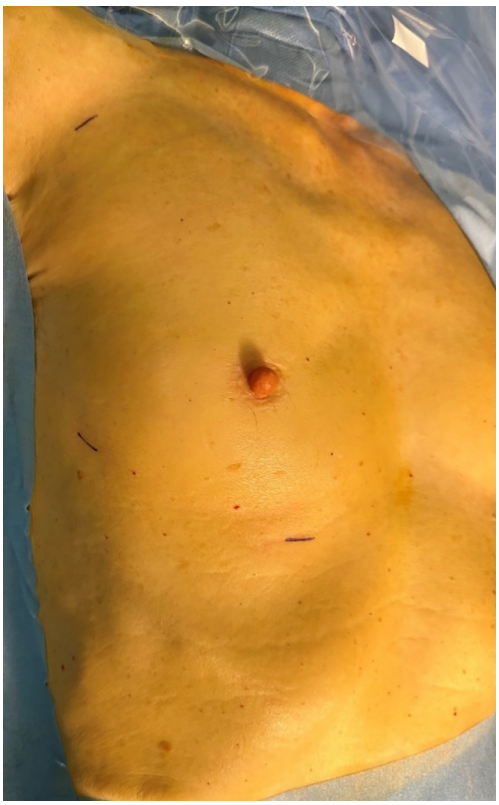

Figure 4 Three-port right sided RATS access for thymectomy in a 57-year-old female patient with thymoma. RATS, robotic-assisted thoracic surgery.

three port incisions (thoracoscope, two robotic arms) under CO_2 insufflation, double lumen intubation and intercostal blockades (*Figure 4*). The phrenic nerves can be visualized on both sides and spared. Being provided with a robotic surgery console,-technical benefits like an increased range of motion in a stable operation field with excellent camera stability and improved 3D-visualization, a superior mediastinal dissection can be achieved (67). Advanced thoracic surgeons in this rapidly evolving robotic field like Diego Gonzalez-Rivas have started doing RATS thymectomies through a 4 cm uniportal subxiphoideal longitudinal incision (with the cartilaginous xiphoid process excised), initially on cadavers in 2018 followed by Park *et al.* in the clinical setting (performed in 2018/2019) and published in 2020 (68,69). A single, 2.5 cm cannula accessible for an articulating 3D camera and three fully articulating instruments with seven degrees of freedom were used (70). A hybrid subxiphoid VATS/RATS approach (3-ports in total) described as trans-subxiphoid robotic thymectomy was found equally minimal-invasive as single-port VATS thymectomy by Suda *et al.* in 2016 (71).

Combination of minimally invasive and open access

VATS-assisted anterior mediastinotomy

VATS-supported anterior mediastinotomy has shown to be another upcoming technique for removal of anterior mediastinal masses (72). Under general anaesthesia, a single port is inserted in the AAL in the 5th intercostal space, and a 0°–30°-degree thoracoscope is introduced into the chest. A parasternal 2–3 cm transverse incision is made over the second or third intercostal space under thoracoscopic guidance. The surgeon may benefit from dual visual control through a spreader directly and indirectly from below using the thoracoscope (73,74). A clear self-made illustration of this technique is available in the publication of Hunt *et al.* (73).

Transcervical VATS procedure

A transcervical approach with a silicon rubber cup to apply pneumomediastinum and the insertion of multiple ports for thoracoscopic instruments was used in the series of Tsuboi *et al.* in 2018 for resecting a parathyroid adenoma in the superior mediastinum (75). This access can rather be considered experimental than being an established access and is best illustrated in the original publication mentioned above.

Discussion

Fortunately, an already comfortably wide range of surgical approaches to the mediastinum, which is still further developing and evolving, is available at our disposal. While there are well established guidelines for common pathologies (e.g., median sternotomy as the gold standard in malign/suspected malignant tumours, thymomas of certain size and tumours invading surrounding anterior mediastinal structures), it requires certain experience to choose the most appropriate mediastinal access for more complex cases, to successfully achieve the desired outcome. The choice of access primarily depends on the indication, which may either be sampling/biopsy or surgical resection as well as the localization and extent of the anomaly.

In our opinion, patient selection criteria tend to take a back seat in connection with mediastinal pathologies, apart from exceptions such as geriatric patients, who should preferably be treated as minimally invasive as possible where indication allows, to minimize morbidity and

mortality. To mention in addition, obesity has shown to be a contraindication for subxiphoid accesses due to difficult subcutaneous tunnel creation and instrument angulation (69). Selection criteria such as (I) sepsis, hemodynamics, and onset of infection in mediastinitis, (II) trauma mechanism (blunt *vs.* penetrating) and hemodynamics in thoracic trauma or (III) the expertise of the surgical team should be prioritized and outweigh patient selection criteria by far. Oncological indications should be mandatorily discussed in a multidisciplinary team (MDT) meeting prior to surgical intervention.

The aim of our publication was to describe all the available surgical accesses and emphasize their indications as well as their practical implementation to inform about current clinical practice in this rapidly evolving field trending towards minimally invasive approaches and ultimately help to guide decision-making in finding the most appropriate access to mediastinal abnormalities. In general, we ought to take into consideration, that the best compromise between the least invasive method and maximal benefit should guide our decision on which access to choose. However, as certain minimally invasive methods are not suitable for being extended, e.g., in the event of bleeding in subxiphoid or mediastinoscopy approach, the surgeon should always have an alternative emergency access in mind and drape the patient accordingly in theatres (69,76).

In terms of sampling and staging procedures, one should appreciate that interventional access like EBUS- and EUS-TBNA have become a valuable alternative to video-mediastinoscopy for diagnosing and staging the mediastinum (77). However, in times of immunohistochemistry, thorough molecular analysis requires more tissue than often provided by the aforementioned, especially in suspected lymphatic disease. In these cases, surgical biopsy is of high importance to achieve tissue diagnosis. In the special field of mediastinal staging in NSCLC, the combination of EBUS-TBNA and mediastinoscopy has proven to be more accurate in mediastinal staging than just one option alone and video-mediastinoscopy shall not be omitted in persistent clinical suspicion of mediastinal metastatic spread. For sampling reasons, mediastinoscopy represents a recommendable option for anterior mediastinal masses, while VATS has been suitable for middle and posterior mediastinal biopsies with beneficial perioperative outcomes (78).

If surgical R0-resection of a mediastinal mass is required, nowadays, most pathologies allow minimally invasive approach (VATS/RATS). The personal surgeon's preference and availability of equipment play a major role in decision-making. The minimally invasive accesses to the mediastinum have shown to lead to less blood loss, post-operative pain and reduced need for analgesia, allow quicker recovery, shorter LOS in hospital and intensive care unit, and lower perioperative morbidity (9,79). Equivalence in oncologic outcome as compared to open approach (e.g., in terms of minimally invasive thymectomy) has recently been published (80). Comparing outcomes between RATS and VATS, Haruki *et al.* could retrospectively show in 2021 that more LNs could be dissected with RATS compared to VATS, especially in bilateral hilar and superior mediastinal regions in lymphadenectomy in NSCLC surgery (81). RATS was described to provide better visualization, manoeuvrability, deep perception and lower risk of bleeding complications, yet being technically superior to VATS and safe (82-84). However, some known disadvantages of RATS are the lack of tactile feedback for the surgeon as well as the acquisition and maintenance cost (84).

A major limitation of minimally invasive accesses for resection of mediastinal masses is the technical restriction when invasion of relevant surrounding anatomic structures by large tumours is present. To avoid incomplete resection, open access remains the recommended approach. Removal of even average size mediastinal lesions through small keyhole access may be challenging too. Overcoming this challenge, either an additional incision (like a minimal cervicotomy or an inframammary incision) or the extension of one of the existing incisions were proposed (82,84). Median sternotomy remains the gold standard in malign as well as suspected malignant tumours as well as thymomas of certain size and tumours invading surrounding structures in the anterior mediastinum, while antero-lateral thoracotomy is superior for resection of lesions in the middle and posterior mediastinum (85,86). Again, there is no standard open access carved in stone for any known mediastinal pathology and anatomical relations of the lesion and related important structures and their best visualization should be taken into consideration. Benign mediastinal tumours, however, can primarily be approached via VATS or RATS access (78). Tumours in the middle compartment of the mediastinum or tumours of exceptional great extend benefit from exposure via hemi-clamshell approach. When compared to minimally invasive techniques, open accesses are associated with more postoperative pain, higher morbidity and longer LOS with slower return to active life (78,87). Partial and full median sternotomy, however, showed less postoperative pain and quicker recovery than thoracotomy.

Concerning mediastinitis, overall patient perioperative outcome mainly depends on rapid diagnosis and immediate targeted treatment as well as on the underlying pathology. Nevertheless, the outcome associated with the respective surgical modality should as well be taken into consideration. In lack of consensus regarding modality-comparing studies, individual experience and knowledge about approach-associated outcomes shall guide decision-making (28). VATS has been leading to lower morbidity (29), however, the risk of undertreatment, resulting in poor outcomes, should prevent us from choosing minimal-invasive access in mediastinitis, especially as the morbidity caused by thoracotomy is usually minimal. Minimally invasive techniques should certainly be avoided in advanced stages of the disease and unstable/septic patients.

Critically reviewing rarely applied open accesses (e.g., parasternal/anterior mediastinotomy or the Chamberlain-procedure), which have basically vanished from everyday surgical practice being replaced by VATS/RATS, we must reflect on whether these accesses shall still be considered mandatory in surgical training logbooks. As already done by some colleagues in case series, it might be worth combining a minimally invasive approach with an open approach to improve accessibility, the field of vision and the removability of the resected lesion (73,75).

There is a noticeable trend to reduce invasiveness of mediastinal approaches even further to e.g., subcostal or subxiphoid uniportal VATS/RATS (68,70,88,89) almost certainly being followed by a race for more appealing economics, reduction in operating time and postoperative pain, increase in non-intubated cases with shorter LOS and ultimately, at least in terms of elective surgery, a potential complete displacement of open accesses (90). For now, further economic analysis comparing VATS/RATS is still wanted e.g., as claimed by O'sullivan *et al.* in 2019. Non-debatable, however, is that minimally invasive accesses are clearly superior in blood loss, LOS and postoperative pain (14,91). Even more crucial is a thorough decision-making in selecting the most appropriate approach to the mediastinum.

Limitations

Our review has certain limitations. To start with, even though our aim was to give a detailed overview on accesses to the mediastinum, the accesses are described in detail but not displayed in step-by-step graphics with the intention not to turn this review in a book chapter. As some of the described accesses are rather rare and not applied regularly (e.g., the Chamberlain or the Ginsberg procedure), imagination of these approaches without precise visualization for the unexperienced (thoracic) surgeon may be difficult. Furthermore, our review fails to provide structured indication guidelines for certain accesses as per lack of significant evidence due to only rare cases being published or due to more recent advantages in accesses which need further prospective trials to prove superiority to established accesses (e.g., in comparing RATS and VATS for early-stage thymoma) (14).

Conclusions

The complex mediastinal anatomy and the variety of mediastinal pathologies require different surgical approaches to the respective mediastinal compartment. While there is a wide selection of surgical accesses and certain guidelines available, often, individual choice of access depends on surgical expertise and available equipment.

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Footnote

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References

1. Liu W, Deslauriers J. Mediastinal divisions and compartments. Thorac Surg Clin 2011;21:183-90, viii.
2. Fujimoto K, Hara M, Tomiyama N, et al. Proposal for a new mediastinal compartment classification of transverse plane images according to the Japanese Association for Research on the Thymus (JART) General Rules for the Study of Mediastinal Tumors. Oncol Rep 2014;31:565-72.
3. Gray's Anatomy, 39th Edition: The Anatomical Basis of Clinical Practice. AJNR Am J Neuroradiol 2005;26:2703-4.
4. Carter BW, Benveniste MF, Madan R, et al. ITMIG Classification of Mediastinal Compartments and Multidisciplinary Approach to Mediastinal Masses. Radiographics 2017;37:413-36.
5. Carter BW, Okumura M, Detterbeck FC, et al. Approaching the patient with an anterior mediastinal mass: a guide for radiologists. J Thorac Oncol 2014;9:S110-8.
6. Priola AM, Priola SM, Cardinale L, et al. The anterior mediastinum: diseases. Radiol Med 2006;111:312-42.
7. Takeda S, Miyoshi S, Akashi A, et al. Clinical spectrum of primary mediastinal tumors: a comparison of adult and pediatric populations at a single Japanese institution. J Surg Oncol 2003;83:24-30.
8. Coco D, Leanza S. Robotic thymectomy: a review of techniques and results. Kardiochir Torakochirurgia Pol 2023;20:36-44.
9. Cohen AJ, Thompson L, Edwards FH, et al. Primary cysts and tumors of the mediastinum. Ann Thorac Surg 1991;51:378-84; discussion 385-6.
10. Vilmann P, Puri R. The complete "medical" mediastinoscopy (EUS-FNA + EBUS-TBNA). Minerva Med 2007;98:331-8.
11. Vilmann P, Clementsen PF, Colella S, et al. Combined endobronchial and oesophageal endosonography for the diagnosis and staging of lung cancer. European Society of Gastrointestinal Endoscopy (ESGE) Guideline, in cooperation with the European Respiratory Society (ERS) and the European Society of Thoracic Surgeons (ESTS). Eur Respir J 2015;46:40-60.
12. Guerra M. Video-mediastinoscopy is still the gold standard. Rev Port Pneumol 2014;20:52.
13. Herth FJ. Access to the mediastinum--the standard has changed. Rev Port Pneumol 2013;19:190-1.
14. O'Sullivan KE, Kreaden US, Hebert AE, et al. A systematic review of robotic versus open and video assisted thoracoscopic surgery (VATS) approaches for thymectomy. Ann Cardiothorac Surg 2019;8:174-93.
15. Kumar A, Asaf BB, Pulle MV, et al. Minimal Access Surgery for Thymoma. Indian J Surg Oncol 2020;11:625-32.
16. Duwe BV, Sterman DH, Musani AI. Tumors of the mediastinum. Chest 2005;128:2893-909.
17. Strollo DC, Rosado-de-Christenson ML, Jett JR. Primary mediastinal tumors: part II. Tumors of the middle and posterior mediastinum. Chest 1997;112:1344-57.
18. Vodička J, Geiger J, Židková A, et al. Acute Mediastinitis - Outcomes and Prognostic Factors of Surgical Therapy (A Single-Center Experience). Ann Thorac Cardiovasc Surg 2022;28:171-9.
19. Dogrul BN, Kiliccalan I, Asci ES, et al. Blunt trauma related chest wall and pulmonary injuries: An overview. Chin J Traumatol 2020;23:125-38.
20. Williams E, Agzarian J. A narrative review of traumatic mediastinal injuries and their management: the thoracic surgeon perspective. Mediastinum 2021;5:33.
21. Reddy VS. Minimally invasive techniques in thoracic trauma. Semin Thorac Cardiovasc Surg 2008;20:72-7.
22. Barrios P, Avella Patino D. Surgical indications for mediastinal cysts-a narrative review. Mediastinum 2022;6:31.
23. Magee MJ, Mack MJ. Surgical approaches to the thymus in patients with myasthenia gravis. Thorac Surg Clin 2009;19:83-9, vii.
24. Freeman RK, Vallières E, Verrier ED, et al. Descending necrotizing mediastinitis: An analysis of the effects of serial surgical debridement on patient mortality. J Thorac Cardiovasc Surg 2000;119:260-7.
25. Divisi D, Di Tommaso S, Garramone M, et al. Necrotizing mediastinitis linked to Boerhaave's syndrome: a surgical approach. Thorac Cardiovasc Surg 2009;57:57-8.
26. Mihos P, Potaris K, Gakidis I, et al. Management of descending necrotizing mediastinitis. J Oral Maxillofac Surg 2004;62:966-72.
27. Sancho LM, Minamoto H, Fernandez A, et al. Descending necrotizing mediastinitis: a retrospective surgical experience. Eur J Cardiothorac Surg 1999;16:200-5.

28. Nhat LX, Vinh VH, Thi CP, et al. Surgical management of descending necrotizing mediastinitis: strategy for thoracic interference. J Cardiothorac Surg 2023;18:229.
29. Min HK, Choi YS, Shim YM, et al. Descending necrotizing mediastinitis: a minimally invasive approach using video-assisted thoracoscopic surgery. Ann Thorac Surg 2004;77:306-10.
30. Singhal P, Kejriwal N, Lin Z, et al. Optimal surgical management of descending necrotising mediastinitis: our experience and review of literature. Heart Lung Circ 2008;17:124-8.
31. Burlew CC, Moore EE, Moore FA, et al. Western Trauma Association critical decisions in trauma: resuscitative thoracotomy. J Trauma Acute Care Surg 2012;73:1359-63.
32. Rhee PM, Acosta J, Bridgeman A, et al. Survival after emergency department thoracotomy: review of published data from the past 25 years. J Am Coll Surg 2000;190:288-98.
33. Gao JM, Du DY, Kong LW, et al. Emergency Surgery for Blunt Cardiac Injury: Experience in 43 Cases. World J Surg 2020;44:1666-72.
34. De Lesquen H, Beranger F, Natale C, et al. Resuscitation thoracotomy-technical aspects. J Visc Surg 2017;154 Suppl 1:S61-7.
35. Boddaert G, Hornez E, De Lesquen H, et al. Resuscitation thoracotomy. J Visc Surg 2017;154 Suppl 1:S35-41.
36. Kong VY, Oosthuizen G, Sartorius B, et al. Penetrating cardiac injuries and the evolving management algorithm in the current era. J Surg Res 2015;193:926-32.
37. Carpenter AJ. Diagnostic techniques in thoracic trauma. Semin Thorac Cardiovasc Surg 2008;20:2-5.
38. Tribble C, Merrill W, Derryberry S, et al. The Median Sternotomy: The Unkindest Cut of All? Pearls, Pitfalls, Aphorisms, & Myths. Heart Surg Forum 2021;24:E267-77.
39. Reser D, Caliskan E, Tolboom H, et al. Median sternotomy. Multimed Man Cardiothorac Surg 2015;2015:mmv017.
40. Šafránek J, Třeška V, Soukupová V, et al. Sternotomy in thyroid surgery. Rozhl Chir 2022;101:536-9.
41. Paul S, Lee PC, Altorki NK, et al. Partial upper sternotomy for anterosuperior mediastinal surgery: an institutional experience. Ann Surg Oncol 2009;16:1039-42.
42. Gillinov AM, Cosgrove DM. Partial Sternotomy for Aortic Valve Operations. Oper Tech Thorac Cardiovasc Surg 2000;5:203-11.
43. Christison-Lagay ER, Darcy DG, Stanelle EJ, et al. "Trap-door" and "clamshell" surgical approaches for the management of pediatric tumors of the cervicothoracic junction and mediastinum. J Pediatr Surg 2014;49:172-7.
44. Ge PS, Imai TA, Van Natta TL. Versatility of a mini-trapdoor incision in upper mediastinal exposure. Ann Thorac Surg 2011;91:938-40.
45. Lebreton G, Baste JM, Thumerel M, et al. The hemiclamshell approach in thoracic surgery: indications and associated morbidity in 50 patients. Interact Cardiovasc Thorac Surg 2009;9:965-9.
46. Bains MS, Ginsberg RJ, Jones WG 2nd, et al. The clamshell incision: an improved approach to bilateral pulmonary and mediastinal tumor. Ann Thorac Surg 1994;58:30-2; discussion 33.
47. Deslauriers J, Mehran RJ. Posterolateral thoracotomy. Oper Tech Thorac Cardiovasc Surg 2003;8:51-7.
48. Bethencourt DM, Holmes EC. Muscle-sparing posterolateral thoracotomy. Ann Thorac Surg 1988;45:337-9.
49. Dürrleman N, Massard G. Antero-lateral thoracotomy. Multimed Man Cardiothorac Surg 2006;2006:mmcts.2006.001859.
50. Force S, Patterson GA. Anterolateral thoracotomy. Oper Tech Thorac Cardiovasc Surg 2003;8:104-9.
51. Nottingham JM, Kyriakopoulos C. Parasternal Mediastinotomy. Treasure Island (FL): StatPearls Publishing; 2024.
52. McNeill TM, Chamberlain JM. Diagnostic anterior mediastinotomy. Ann Thorac Surg 1966;2:532-9.
53. Call S, Obiols C, Rami-Porta R. Present indications of surgical exploration of the mediastinum. J Thorac Dis 2018;10:S2601-10.
54. Ginsberg RJ. Evaluation of the mediastinum by invasive techniques. Surg Clin North Am 1987;67:1025-35.
55. McNally PA, Arthur ME. Mediastinoscopy. Treasure Island (FL): StatPearls Publishing; 2023.
56. Ghosh S, Nanjiah P, Dunning J. Should all patients with non-small cell lung cancer who are surgical candidates have cervical mediastinoscopy preoperatively? Interact Cardiovasc Thorac Surg 2006;5:20-4.
57. De Leyn P, Lardinois D, Van Schil PE, et al. ESTS guidelines for preoperative lymph node staging for non-small cell lung cancer. Eur J Cardiothorac Surg 2007;32:1-8.
58. Cho JH, Kim J, Kim K, et al. A comparative analysis of video-assisted mediastinoscopy and conventional mediastinoscopy. Ann Thorac Surg 2011;92:1007-11.
59. Carlens E. Mediastinoscopy: a method for inspection and tissue biopsy in the superior mediastinum. Dis Chest 1959;36:343-52.

60. Onat S, Ates G, Avcı A, et al. The role of mediastinoscopy in the diagnosis of non-lung cancer diseases. Ther Clin Risk Manag 2017;13:939-43.
61. Hürtgen M, Friedel G, Toomes H, et al. Radical video-assisted mediastinoscopic lymphadenectomy (VAMLA)--technique and first results. Eur J Cardiothorac Surg 2002;21:348-51.
62. Hürtgen M, Friedel G, Witte B, et al. Systematic Video-Assisted Mediastinoscopic Lymphadenectomy (VAMLA). Thorac Surg Sci 2005;2:Doc02.
63. Zieliński M. Transcervical extended mediastinal lymphadenectomy: results of staging in two hundred fifty-six patients with non-small cell lung cancer. J Thorac Oncol 2007;2:370-2.
64. Yano M, Moriyama S, Haneda H, et al. Thymectomy using the subxiphoid approach. J Thorac Cardiovasc Surg 2016;152:278-9.
65. Balduyck B, Hendriks JM, Lauwers P, et al. Quality of life after anterior mediastinal mass resection: a prospective study comparing open with robotic-assisted thoracoscopic resection. Eur J Cardiothorac Surg 2011;39:543-8.
66. Yoshino I, Hashizume M, Shimada M, et al. Thoracoscopic thymomectomy with the da Vinci computer-enhanced surgical system. J Thorac Cardiovasc Surg 2001;122:783-5.
67. Rückert JC, Swierzy M, Ismail M. Comparison of robotic and nonrobotic thoracoscopic thymectomy: a cohort study. J Thorac Cardiovasc Surg 2011;141:673-7.
68. Manolache V, Gonzalez-Rivas D, Bosinceanu ML, et al. Uniportal robotic-assisted thoracic surgery for mediastinal tumors. Ann Cardiothorac Surg 2023;12:139-41.
69. Park SY, Han KN, Hong JI, et al. Subxiphoid approach for robotic single-site-assisted thymectomy. Eur J Cardiothorac Surg 2020;58:i34-8.
70. Gonzalez-Rivas D, Ismail M. Subxiphoid or subcostal uniportal robotic-assisted surgery: early experimental experience. J Thorac Dis 2019;11:231-9.
71. Suda T, Kaneda S, Hachimaru A, et al. Thymectomy via a subxiphoid approach: single-port and robot-assisted. J Thorac Dis 2016;8:S265-71.
72. Cheng YJ, Wu HH, Chou SH, et al. Video-assisted thoracoscopic management of mediastinal tumors. JSLS 2001;5:241-4.
73. Hunt I, Alwahab Y, Treasure T. Using video-assisted thorascoscopy (VATS) to aid the anterior mediastinotomy approach to mediastinal masses. Ann R Coll Surg Engl 2007;89:435-6.
74. Migliore M, Criscione A, Calvo D, et al. Minimal access anterior mediastinotomy. Updates Surg 2013;65:59-61.
75. Tsuboi M, Takizawa H, Yoshida T, et al. Mediastinal Parathyroidectomy Using a Cervical Approach Under a Pneumomediastinum. Semin Thorac Cardiovasc Surg 2018;30:472-4.
76. Puhakka HJ. Complications of mediastinoscopy. J Laryngol Otol 1989;103:312-5.
77. Pillai A, Medford AR. Greater physician involvement improves coding outcomes in endobronchial ultrasound-guided transbronchial needle aspiration procedures. Respiration 2013;85:417-21.
78. Demmy TL, Krasna MJ, Detterbeck FC, et al. Multicenter VATS experience with mediastinal tumors. Ann Thorac Surg 1998;66:187-92.
79. El-Akkawi AI, Eckardt J. Comparison of surgical outcomes after robotic assisted thoracic surgery, video-assisted thoracic surgery and open resection of thymoma. Mediastinum 2021;5:11.
80. Agatsuma H, Yoshida K, Yoshino I, et al. Video-Assisted Thoracic Surgery Thymectomy Versus Sternotomy Thymectomy in Patients With Thymoma. Ann Thorac Surg 2017;104:1047-53.
81. Haruki T, Takagi Y, Kubouchi Y, et al. Comparison between robot-assisted thoracoscopic surgery and video-assisted thoracoscopic surgery for mediastinal and hilar lymph node dissection in lung cancer surgery. Interact Cardiovasc Thorac Surg 2021;33:409-17.
82. Melinte A, Saftoiu A, Vlaicu-Melinte A, et al. Robotic Resection of Ectopic Thyroid Tissue of the Mediastinum - Case Report and Literature Review. Chirurgia (Bucur) 2023;118:96-102.
83. Bodner J, Wykypiel H, Greiner A, et al. Early experience with robot-assisted surgery for mediastinal masses. Ann Thorac Surg 2004;78:259-65; discussion 265-6.
84. Ferreira R, Junqueira N, Rodrigues M, et al. Inframammary approach for addressing anterior mediastinal tumours: initial experience. J Thorac Dis 2020;12:2077-81.
85. Burt BM, Yao X, Shrager J, et al. Determinants of Complete Resection of Thymoma by Minimally Invasive and Open Thymectomy: Analysis of an International Registry. J Thorac Oncol 2017;12:129-36.
86. Kaufman AJ, Flores RM. Minimally invasive thymectomy for thymoma: does surgical approach matter or is it a question of stage? J Thorac Dis 2016;8:E1711-4.
87. Melfi FM, Fanucchi O, Mussi A. Minimally invasive mediastinal surgery. Ann Cardiothorac Surg 2016;5:10-7.
88. Guido Guerrero W, Hernandez Arenas LA, Jiang G, et

al. Subxiphoid mediastinal lymphadenectomy. J Vis Surg 2016;2:105.
89. Suda T. Uniportal subxiphoid video-assisted thoracoscopic thymectomy. J Vis Surg 2016;2:123.
90. Liu Z, Yang R, Sun Y. Non-intubated subxiphoid uniportal video-assisted thoracoscopic thymectomy. Interact Cardiovasc Thorac Surg 2019;29:742-5.
91. Wu L, Lin L, Liu M, et al. Subxiphoid uniportal thoracoscopic extended thymectomy. J Thorac Dis 2015;7:1658-60.

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