10 Difficult Mediastinal Mass Resections: Robotic Approach and Solutions—Austria

Johannes Bodner, Florian Augustin, and Thomas Schmid

Abstract

Approaching the narrow mediastinum with its various vulnerable structures by conventional Video Assisted Thoracoscopic Surgery (VATS) is technically challenging. The daVinci robotic system was developed to overcome the limitations of VATS by providing a 3-dimensional vision of the operating field, an intuitive and extended manoeuvrability of the instruments as well as motion scaling with tremor filtering. These features come to advantage particularly in difficult to reach anatomical regions like the mediastinum. Both, the anterior and the posterior mediastinum are easily accessible by a robotic approach allowing to perform all common procedures of the thymus, the thoracic esophagus, (para-) thyroids and tumors of lymphatic or neurogenic origin. The anaesthetic management as well as surgical-technical aspects of robotic procedures within the mediastinum are discussed in detail, potential pitfalls are elaborated and tips to prevent complications are given.

Keywords

Robotic assisted thoracoscopic surgery • daVinci • Mediastinum • Thymectomy • Myasthenia gravis • Ectopic (para)thyroid adenoma • Neurinoma

10.1 Background and Specific Indications

Video-assisted thoracoscopic surgery (VATS) has been performed for more than 25 years. Starting with technically rather simple procedures like pleural biopsies, increasing experience and evolution of minimally invasive instruments led to a broader application of the technique [1]. However, when facing the narrow and difficult to reach area of the mediastinum, a minimally invasive approach using conventional instruments with limited manoeuvrability is still challenging for many surgeons [2].

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To overcome limitations of the conventional minimally approach, micromechanic robotic systems have been introduced in the late 1990s. The da Vinci system offers 3-dimensional vision, improved manoeuvrability with 7 degrees of freedom (Endowrist® Technology) as well as motion scaling and tremor filtering. All of these advances improve surgical dexterity within the mediastinum [3]. Thoracic surgeons, therefore, soon focused their interest in robotic applications on the diagnostic and therapeutic approach to mediastinal masses [4, 5].

Robotic applications for diagnostic and therapeutic procedures for mediastinal masses are described in this chapter, reviewing the recent literature.

The mediastinum is the central department of the thoracic cavity, extending from the sternum in front to the vertebral column behind; it contains all the thoracic viscera except the lungs.

For the purpose of description, the mediastinum is divided into two parts (Fig. 10.1):

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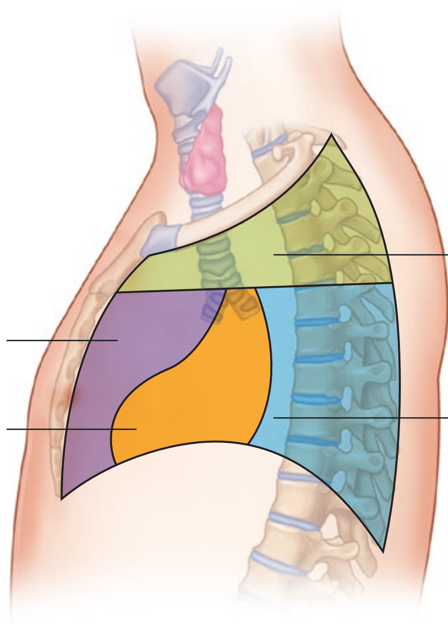

Fig. 10.1 Anatomic location of the four compartments of the mediastinum

- The upper mediastinum is bounded by the thoracic inlet and the plane from the sternal angle to the disc of T4–T5
- The lower mediastinum can be subdivided into three parts
  - anterior mediastinum in front of the pericardium
  - middle mediastinum containing the pericardium and its contents
  - posterior mediastinum behind the pericardium

10.2 Surgery of the Mediastinum

Diseases of the thymus, the esophagus, and the lymphatic tissue are the main indications for surgery of the mediastinum, more rarely, ectopic thyroid and parathyroid glands. A variety of benign as well as primary and secondary (metastatic) malignant lesions indicates surgical biopsy or resection (Table 10.1). While in open surgery the mediastinum is approached either transcervically or via a sternotomy, for most minimally invasive video-assisted procedures the approach is transthoracic with incision of the mediastinal pleura.

It has turned out that both, the anterior and the posterior mediastinum are accessible by a robotic approach. It is, thus, not the anatomic location, but the underlying disease that determines whether a robotic approach is indicated or not. Lesions larger than 5–7 cm in diameter are difficult to grasp and handle with the robotic instruments and the vision might be impaired. Potential infiltration of surrounding tissue has still been considered a contraindication for any minimally invasive approach, though the robot specific technical advances (3-D imaging, multi-articulating instruments) allow for meticulous dissection.

Table 10.1 Surgically relevant diseases of the mediastinum and corresponding (minimally invasive) procedures

Disease	Procedure
Thymoma, thymic cyst, myasthenia gravis	(Extended) thymectomy
(paravertebral) neurinoma	Extirpation
Lymph node metastasis	Biopsy, sampling, oncologic dissection
Foregut cyst	Extirpation
Esophageal leiomyoma	Extirpation
Esophageal cancer	Dissection, resection, reconstruction
(Ectopic) parathyroid tissue	Extirpation
(Ectopic) thyroid tissue	Extirpation
Lymphoma	Biopsy, (extirpation)
Germ cell tumors including teratoma	Extirpation

10.3 Anesthetic Management

The anesthetic management does not significantly differ from a conventional video-assisted thoracoscopic approach. Since all procedures are trans-thoracic through one pleural cavity, single lung ventilation achieved by a double lumen tube is standard. The earlier the single lung ventilation is set, the faster the excluded lung collapses, thus opening space for the robotic instruments and videoscope. Intense collaboration and communication with the anesthesiologists are of utmost importance since their working space is significantly limited by the robotic arm cart which is positioned cephalad in most thoracic robotic procedures. An arterial as well as a central venous line are recommended.

10.4 Operative Set-Up

The procedures are performed with a limited range of robotic instruments: DeBakey® and Cadiere® forceps, needle holder, scissors, cautery hook and robotic clip applier are used. Dissection is mainly performed with electrocautery, alternatively with scissors or ultrasonic energy instruments (harmonic curved shears). Robotic clips are used for small vascular structures (e.g. thymic veins) while larger structures may alternatively be controlled by conventional stapler devices introduced through an auxiliary port by the table-site assistant.

We have the scrub nurse warming the binocular robotic scope in a sterilized thermos bottle to prevent it from recurrent fogging during the initial phase. Both, surgeons and scrub nurses should be well-prepared for immediate conversion to an emergency thoracotomy in case of a major bleeding. Therefore, a set of instruments for thoracotomy is always prepared in our operating room. It is highly advisable to establish a dedicated team for robotic surgery.

Patient positioning is procedure specific:

- Posterior mediastinal interventions (paravertebral neurinoma, cyst, esophageal dissection, lymph node dissection) positioning is extreme lateral decubitus;
- Anterior mediastinal lesions standard lateral decubitus position is applied;
- Thymectomies, incomplete lateral decubitus (30°–45°) position is of advantage.

The site of incision might differ from the ones listed below based on tumor location.

Padding and taping do not differ from those for conventional thoracoscopic procedures. Specific attention must be paid by the bedside-assistant surgeon to avoid injuries to the patient from movements of the robotic arms. The primary surgeon on the console is not aware of range and power of motions that are transmitted from the handles of his console to the robotic arm cart.

At the end of a procedure a chest tube is placed in the pleural cavity.

10.5 Stepwise Conduct of the Operation

10.5.1 Extended Thymectomy

Extended thymectomy is performed with en bloc resection of the anterior mediastinal fat tissue including the thymus as described by Masaoka et al. [6]. All adipose tissue around the upper poles of the thymus, around both brachiocephalic veins and on the pericardium is dissected meticulously. Borders of dissection are the diaphragm caudally, the thyroid gland cranially, and the phrenic nerves laterally.

In our setting, which is a right-sided approach (unless there is a far left sided thymoma), the patient's right arm is positioned at the side as far back as possible to gain enough space for the robotic arms (Fig. 10.2). The port for the robotic endoscope is positioned in the fifth to sixth intercostal space in the mid-axillary line. A more ventral position would facilitate contralateral preparation but hamper ipsilateral dissection. The camera is inserted and under vision control the two robotic instrument ports are placed in the third and sixth intercostal spaces, one hand's breadth left and right of the camera trocar, respectively, in the submammary fold. (Fig. 10.3). The three ports enclose an angle of 70°–90° to

Fig. 10.2 Patient positioning for a robotic thymectomy

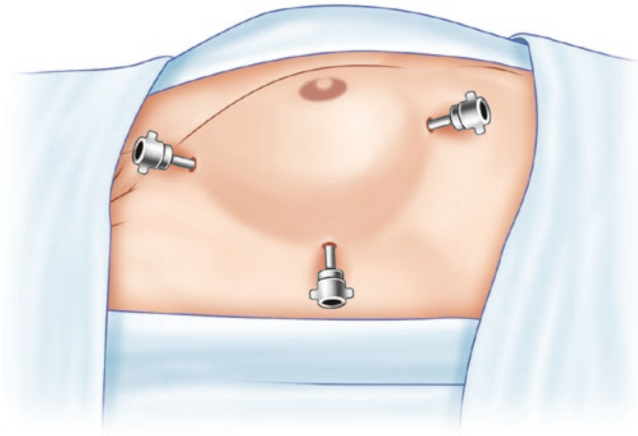

Fig. 10.3 Incisions for robotic thymectomy in a right sided approach

prevent extra-corporal collision of the robotic arms. An auxiliary port is inserted latero-dorsal to the camera trocar one intercostal space cranially, if needed. The robotic arm cart is moved towards the patient's ventral side (Fig. 10.4). Dissection starts ventral to the right phrenic nerve from cranial to caudal and is performed with the robotic cautery hook in the right and the Cadiere forceps in the left robotic instrument arm (Fig. 10.5). En-bloc extirpation of fat tissue in the lower anterior mediastinum may be hindered by collision of the left robotic arm with the patient's shoulder. In this situation a curved thoracoscopic grasper is inserted via the auxiliary port to achieve better exposure. Dissection continues to the substernal region where the left parietal pleural is incised along, but medially to the intrathoracic (mammaric) bundle. The thymus is dissected free from the pericardium and preparation proceeds cranially up to the thymic and innominate veins. Before the thymic veins are controlled, the right and left upper horns are freed. This allows for better mobility of the specimen and thus for better dissection of the (usually one to three) thymic veins. The vessels are clipped; however, very smaller ones are controlled by electrocautery. The da Vinci system enables the surgeon to also dissect the left thymic lobe accurately from a right-sided access in most patients. This is facilitated by the thoraco-lift, meaning that the chest wall is actively lifted by the robotic arms along the three trocars. This allows in addition with the multi-articulation of the robotic instruments for a dissection along the curved shape of the heart and the great vessels over to the left phrenic nerve. Once the specimen is completely freed, it is removed in an endobag that is either inserted via one of the robotic ports or an auxiliary port. A specimen of a robotic assisted thymectomy is shown in Fig. 10.6**.**

When looking at the current literature, right- and left-sided approaches have been used. According to the authors, a left-sided approach facilitates the accurate dissection at the level of the left phrenic nerve and the aorto-pulmonary window as a frequent site of ectopic thymic tissue is easier to reach [7, 8]. Savitt et al. favor a right-side approach, because the heart impairs the reach of the lower robotic arm into the superior mediastinum [9]. This might be one reason why this right-sided approach is described one intercostal space lower than the left-sided approach. A bilateral approach may be even more accurate. However, it is more time consuming and should only be used when exposure of the contralateral phrenic nerve is insufficient and appropriate dissection is not possible, especially in myasthenia gravis patients. Also, a subxiphoid robotic approach for thymic resection in a cadaver was described. However, no application of this approach in a clinical setting was reported.

In patients with thymoma, the dissection does not differ from thymus resection for myasthenia gravis. However, based on our experience, the robotic approach is not recommended in thymic tumors larger than 5 cm in diameter. Handling of the specimen with small robotic instruments is impaired, removal of the usually hard lesions through the small incisions bears the risk of harm to the lesion and affects pathological examination negatively; finally, oncologic concerns exist [5].

10.5.2 Extirpation of a Posterior Mediastinal Paravertebral Tumor (Neurinoma, Cyst, Sympathetic Chain Lesion)

For posteriorly located masses, the camera port is positioned in the anterior axillary line. Locations of the incisions are highly dependable on tumor location. The ports for the two working arms are placed symmetrically one hand's breadth right and left of the camera trocar. The cart is then approached from dorso-cranial (Fig. 10.7). An auxiliary port is usually not needed in these procedures. Dissection is carried out using a Cadiere forceps in one and the cautery hook in the other hand. The tumor is excised en bloc with the covering parietal pleura. It is removed in an endobag through the most anterior port site where the intercostal space is wider.

10.5.3 Resection of a Benign Esophageal Tumor (Leiomyoma, Foregut Cyst, Esophageal Diverticulum)

The robotic cart is situated at the right upper side of the patient. The trocars are placed far caudally (camera trocar in the ninth intercostal space in the mid-axillary line, left robotic arm in the ninth intercostal space in the posterior-axillary line, right robotic arm in the eighth intercostal space in the anterior-axillary line). One auxiliary port for suction and retraction of the deflated lung is positioned between the left robotic arm and the camera arm. Dissection starts with

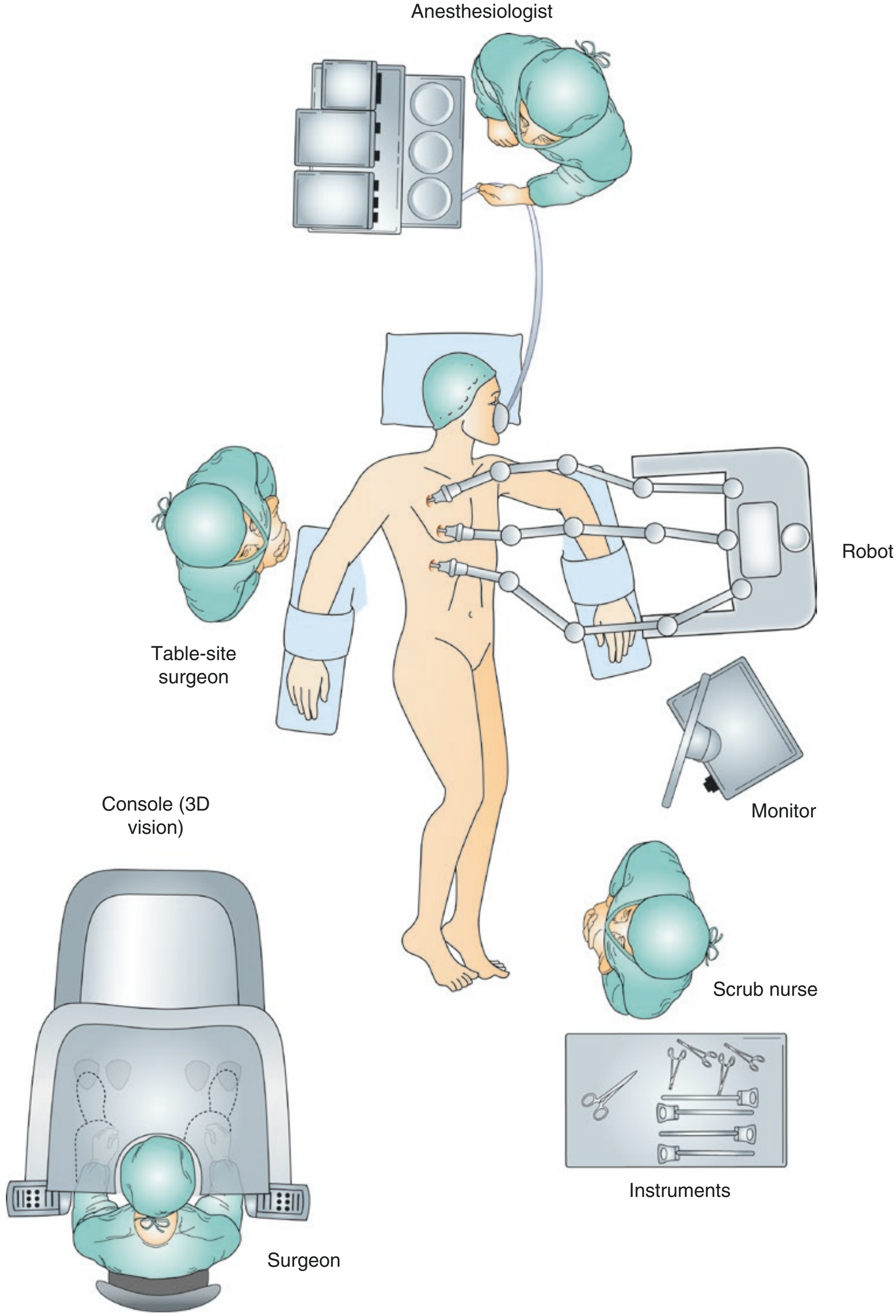

Fig. 10.4 OR setting for a robotic thymectomy

the incision of the parietal pleura to expose the esophagus. If the tumor is located deep to the azygos vein, the azygos vein is divided using a vascular endostapler introduced through the auxiliary port. A 270°–360° mobilisation of the esophagus over a distance of at least 10 cm (corresponding to the location of the tumor) is performed using the robotic hook cautery. An esophageal myotomy for resection of an intramural tumor of approximately 6 cm (depending of the size of the lesion) is performed. The tumor is dissected with the hook cautery including control of small feeding vessels. After complete resection, the integrity of the mucosa is confirmed by intraoperative upper endoscopy with gas insufflation. The tumor is removed in an endobag and the esophageal myotomy is closed using interrupted sutures. If the lesion is located in the lower esophagus in the posterior phrenicocostal sinus, the diaphragm gets intermittently fixed to the

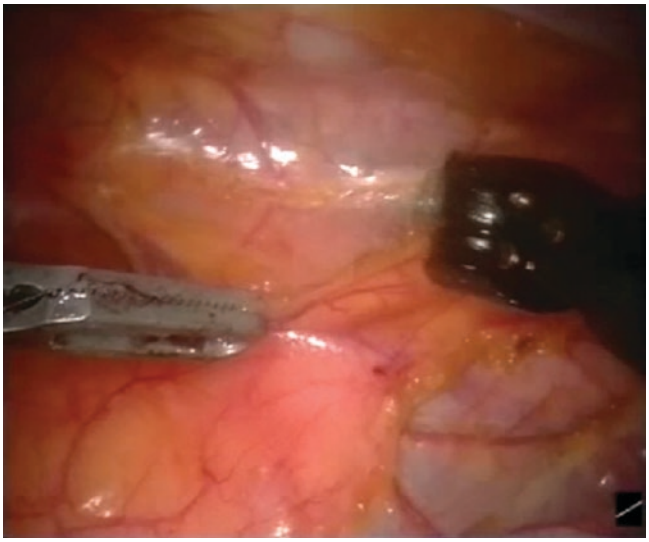

Fig. 10.5 Intraoperative view during robotic thymectomy

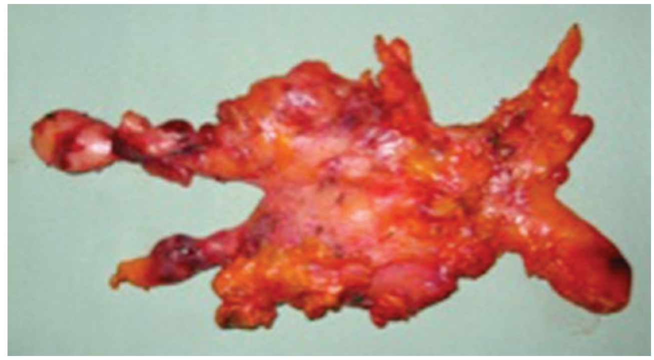

Fig. 10.6 Specimen of robotic assisted thymectomy

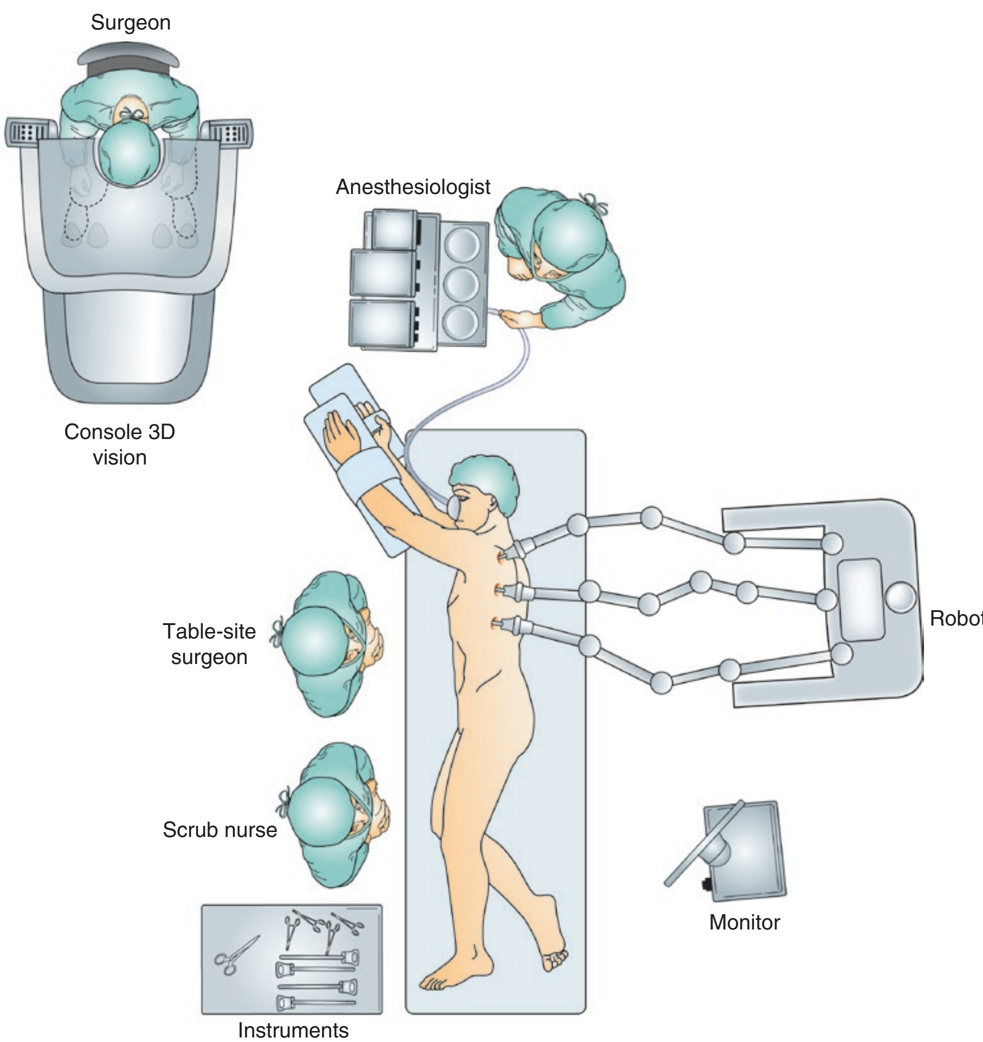

Fig. 10.7 OR setting for a robotic dorso-cranial approach

thoracic wall and the pulmonary ligament is divided with the cautery hook, both for better exposure. Again, the lesion is enucleated and the esophageal muscular layer is repaired in an interrupted stitch fashion. An esophageal diverticulum is excised followed by the closure of the esophageal defect in a two layer single stitch fashion.

10.5.4 Extirpation of Masses in the Aortopulmonary Window (Ectopic Parathyroids, Lymph Nodes)

The camera port is inserted in the sixth intercostal space in the anterior axillary line and the two instrument ports are both placed in the fourth intercostal space one hand's breadth right and left, respectively [10]. A first auxiliary port flexible is placed in the medio-clavicular line of the sixth intercostal space and the upper lobe of the left lung is pushed caudally with a retractor by the table site assistant. Suction is provided via a second auxiliary port, positioned in the posterior axillary line of the sixth intercostal space. Dissection starts by incising the parietal pleura covering the aortopulmonary window. Care must be taken not to injure the left vagal and recurrent laryngeal nerves. The mass is carefully dissected from the aortic arch, the trunk of the pulmonary artery, and the trachea with the hook cautery. If present, vascular pedicles are controlled with clips.

10.5.5 Resection of an Ectopic Mediastinal Goiter

The trocar for the robotic endoscope is positioned in the eighth intercostal space in the posterior axillary line and the two 8-mm robotic operating trocars are placed one hand-breadth to the right and left of the first incision, respectively. Lung retraction is performed by the bedside assistant with a flexible retractor inserted via an auxiliary port in the anterior axillary line of the sixth intercostal space. Resection is performed using the robotic Cadiere forceps and the robotic cautery hook. Dissection starts with incision of the parietal pleura at the upper margin of the azygos vein. The tumor is freed beginning from caudally and dissection proceeds upwards along but lateral to the superior vena cava. When dissection posterior to the superior vena cava is necessary, care must be taken not to injure the phrenic nerve. In ectopic goiters, the blood supply derives from cephalad from one or more arteries and several small veins draining into the innominate veins. Control of these structures is achieved using robotic clips or coagulation.

10.6 Tips and Pitfalls

These have been mentioned in the previous chapter when the different procedures were described and are here listed in a summary fashion:

- place the three robotic ports in a way that they enclose an angle of at least 70°–90° to prevent extra-corporal collision of the robotic arms
- in robotic thymectomy, position the patient's right arm at the side as far back as possible to gain enough space for the robotic arms
- in robotic thymectomy, dissection in the far low anterior mediastinum may be hindered by collision of the left robotic arm with the patient's shoulder. If experiencing this situation insert a curved thoracoscopic grasper via the auxiliary port to achieve better exposure
- prior dissection of the upper thymic horns allows for better mobility of the specimen and thus for safer dissection of the thymic veins
- the thoraco-lift (the active lifting of the chest wall by the robotic arms along the three trocars) provides more space and allows for dissection of the left thymic lobes from a single right sided approach (and vice versa)
- do not approach thymic tumors larger than 5 cm in diameter robotically for safety and oncologic reasons
- remove the mass always through the most anterior port site where the intercostal spaces are wider.
- fix the diaphragm intermittently to the thoracic wall and divide the pulmonary ligament if a mass is located in the posterior phrenico-costal sinus
- the console surgeon should be aware of range and power of motions which are transmitted from the handles of his console to the robotic arm cart

10.7 Postoperative Management Issues

Once the procedure has been completed and hemostasis has been controlled, the robotic instruments are removed and the robotic arms are detached from the ports. Usually one chest drain is inserted under vision but with manual control of the robotic camera. After the lung is reinflated, the camera is removed. Extubation in the operating room is routinely performed unless specific contraindications exist.

Postoperative management is not robotic-specific and does not differ from the conventional VATS regime. Patients start drinking when fully awake and get mobilized the evening of the procedure. Drains are removed when no air-leak is present and output is less 300 cm^3. Chest x-rays are performed in the recovery room and after chest tube removal.

10.8 Outcomes

Favorable outcomes for robotic resections of mediastinal masses were reported by different groups [3, 8, 11–13]. The robot facilitates and enables more technically advanced surgical procedures by means of a minimally invasive approach. The main concern of robotic surgery—when starting a program—is operative time which has a proven negative impact on patient outcome if excessively prolonged. Thus, surgeons are encouraged to work with a dedicated team specially trained in robotic set up and to convert to an open approach if no surgical progress has been made over a period of time.

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