# Robotic Anterior Mediastinal Mass/Cyst and Thymectomy

# 6

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**Abstract**

Thymectomy is necessary for thymic tumors and an essential part of the therapeutic strategy for myasthenia gravis. Within a century, the history of thymectomy has been characterized by the development of minimally-invasive surgical techniques. The latest refinement is robotic-assisted thymectomy. The perioperative management including anesthesia is described. The stepwise operative technique starts with special positioning of the patient. The preferred conduct of the operation is provided. For anatomical reasons the left side is preferred for the unilateral approach. The extended thymectomy is necessary to achieve the best outcome. This includes resection of the contralateral cardiophrenic tissue. Tips for performing the operation are included and pitfalls are described. All essential steps of the operation are illustrated. The advantages of robotic technology optimized by the described approach and consist of surgeon-directed 3-D vision, magnification, multiple arcs of instrument movement, tremorless precision, and potentially the most thorough mediastinal dissection of all minimally invasive surgical options. The review of the supportive literature for thymectomy in the treatment of myasthenia gravis is described; especially the recently published prospective randomized trial comparing medical therapy to thymectomy, showing superiority of thymectomy. It is likely that the impact will increase the number of patients seeking thymectomy.

**Keywords**

Thymectomy • da Vinci • Robotic surgery • Myasthenia gravis

## 6.1 Background/Specific Indications

Historically, surgery was found to be the first means to improve myasthenia gravis (MG) symptoms. At that time, MG was thought to be connected with thymic tumors given the association of MG symptoms and thymic pathology, tumors and hyperplasia [1]. The first reported operation was performed by Sauerbruch in an 18-year-old women in Zurich in 1911 [2]. The patient was suffering from a combination of Grave´s disease and MG. At the time there was a certain notion of a possible connection between thyroid diseases and the appearance of muscular weakening MG. In a two stage procedure Sauerbruch went through the neck for the thymectomy and partial thyroid vessel ligation first and a second intervention for the thyroid resection. Because the operation technique was a transcervical approach, it might be seen as a minimally invasive operation; not only the first thymectomy, but the first minimally invasive approach as well. The patient reportedly significantly improved. The discovery of symptomatic treatment for MG was, yet, 23 years away [3]. In 1944 Blalock published the first series of 20 patients with

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thymectomy for MG based on his own successful case history of a 19-years-old patient in 1939 [4, 5]. Though symptomatic treatment for MG was available, a 25% mortality rate for his transsternal technique was reported [5]. Blalock pointed out that there should always be a comprehensive view of the anterior mediastinal compartment, necessitating a sternotomy.

In 1950, thymectomy was most comprehensively analyzed by the British surgeon Keynes. He reported on a personal experience of 250 cases [6, 7]. He was the first to postulate not only the significant importance of thymectomy to improve MG, but also the significance of the prognostic factors such as the interval between the diagnosis and thymectomy and the special role of thymoma. This period of our understanding of the pathophysiology and treatment of MG and the role of thymectomy was largely via median sternotomy. By elucidating the outcome difference of thymoma and non-thymomatous MG, Keynes correctly elucidated the difference and the contribution of thymectomy to the therapeutic success [6, 7].

The next stage in the evolution of MG treatment and, historically, the last debate before the age of surgical thoracoscopy began was around 1970. A renewed interest in refinement of the transcervical thymectomy was accompanied by the findings of potential ectopic thymic tissue in the anterior mediastinal area [8–11]. Even today, it seems most instructive to compare the arguments for either transcervical approach or most extensive forms of median sternotomy [12, 13]. Basic and clinical research during the 1970s discovered the autoimmune nature of MG; yet, there was no randomized trial support for thymectomy for MG. The diversity of MG patients in the degree of severity and presence or absence of anti-acetylcholine-receptor-antibodies resulted in a relative indication for non-thymomatous MG; whereas, there was a clear indication for the treatment of thymoma or suspected thymoma without MG [14, 15].

Around 1990 the technical development of surgical thoracoscopy significantly influenced the performance of thymectomy. The first thoracoscopic approach was published by Landreneau in 1992 who excised a small thymoma from the thymic gland [16]. During the next decade, various thoracoscopic operative techniques for thymectomy have been developed and performed [17–20]. As a result, there were 14 different minimally invasive techniques for thymectomy all claiming radicality. The results of MG improvement were reported with limited direct comparisons. Therefore, with the intention to better analyze the role of thymectomy, Jaretzki suggested and introduced a MG task force in 1997 [21]. Comprehensive decision making included the neurological societies and led, again, to the role of thymectomy for the treatment of MG [22].

At the same time, surgical innovation opened quite a new era with the development of robotic surgical platforms. In contrast to other minimally invasive approaches, robotics offers greater precision, potentially providing the most radical thoracoscopic thymectomy. Interestingly enough, as with the thoracoscopic approach, the first description was a non-radical simple excision of a thymoma in 2001 [23]. Many surgeons adopted robotic thymectomy [24–26]. This latest step in the development of thymectomy was followed be worldwide acceptance of minimally-invasive thymectomy not only for non-thymoma MG, but also for anterior mediastinal tumors, namely thymoma [27, 28]. While there were already more than 1000 robotic thymectomies that had been performed worldwide in 2012 [27], the low level of evidence to support the role of thymectomy for the treatment of MG was analyzed and provided confirmation that thymectomy is beneficial to patients with nonthymomatous MG [29].

## 6.2 Operative Set-Up

Removal of the thymus is warranted in patients with myasthenia gravis and those suspicious of malignancy. Specifically, we resect patients with a diagnosis of stages I–IIb MG (Ossermann Classification) and those with confirmed or suspicious for thymoma that is less than 2 cm. All patients undergo a preoperative chest radiograph, a recent chest computed tomogram (Fig. 6.1), baseline pulmonary function testing, and a thorough neurological examination, inclusive of serological testing.

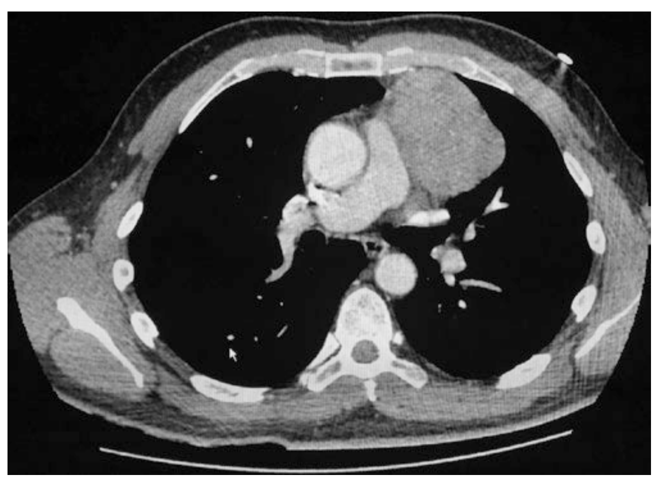

**Fig. 6.1** Contrast-enhanced chest computed tomogram of a large left-sided thymoma on axial image

## 6.3 Anesthetic Management

### 6.3.1 Preoperative Preparation

The preoperative optimization of therapy should be done by neurologists. The medication for most stable situation as to MG symptoms should be maintained and represents a major factor for perioperative risk reduction. Any form of immunosuppressive therapy has not to be changed. Possibly a premedication with promethazine of 1 mg/kg is given.

### 6.3.2 Operative Phase

An intra-arterial blood pressure monitoring catheter, two peripheral intravenous infusion catheters, and a bladder catheter are all placed. A perioperative single shot antibiotic prophylaxis is given and we choose a second generation cephalosporin (we commonly choose cefuroxime). Total intravenous anesthesia is conducted with continuous application of propofol and remifentanil. For intubation, a left-sided double-lumen tube for right single lung ventilation is used after relaxation with cis-atracurium (0.1 mg/kg). During the surgery, pressure-controlled ventilation is used. To accommodate for the hemodynamic interference of $CO_2$-insufflation or intermittent arrhythmia due to direct pericardial dissection a close contact between surgeons at the console and at the table and anesthesiology is essential. At the end of the operation, metimazole and piritramide are given before primary extubation of the wake patient on the operation table.

## 6.4 Stepwise Conduct of the Operation

Mainly for anatomical reasons, we prefer and recommend to approach the thymus from the left thorax. Our operation technique is a unilateral left-sided three trocar approach.

The patient is brought into a special position on the operating table; we call it the semilateral right-sided position. It is created from a supine position with the patient on a vacuum mattress with elevated left shoulder. The left arm is positioned as low as possible, for that purpose the patient is positioned slightly over the left edge of the operation table (Fig. 6.2). The patient is always prepared for a conversion to median sternotomy. The trocar positions are as follows: the camera trocar is placed first in the fourth intercostal space. The criterion for correct placement is the direct view at the left phrenic nerve with the 30° optic looking down. The two

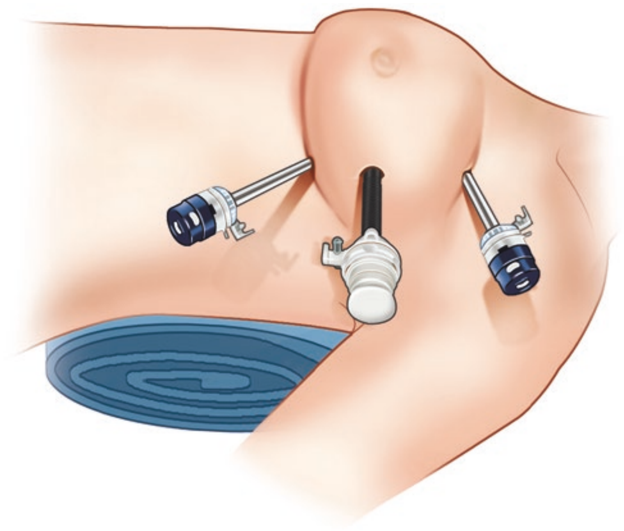

**Fig. 6.2** Left-sided approach for a robotic thymectomy. The patient is placed on the edge of the operating table with arm below the table. The patient is positioned and prepared for a potential sternotomy and for the potential placment of an extra trocar from the right side in case of necessity to check the radicality to make certain that the entire thymus is being removed.. The bedside cart is brought from the patient's right side. A roll is placed under the mid upper chest allowing the left shoulder to fall down toward the floor. The patient's left side is rotated approximately 10–15° up. All three trocars are placed along the mammary fold forming a triangle. The trocars are initially inserted with the help of a conventional thoracoscope. For obese patients, we prefer the use of the extra-long trocars

working trocars are placed in the third and fifth intercostal space and in the midclavicular and anterior to midaxillary line, respectively, under direct vision using a simple thoracoscopic camera. The three trocars should form a symmetric triangle with the connection between both working trocars just parallel to the sternum. Our preferred instruments are the Bipolar Maryland® for the left hand and Ultracision™ Harmonic Scalpel for the right hand. In our opinion, two grasping instruments are necessary. The dissection starts in the middle part of the pericardial area adjacent to the phrenic nerve (Fig. 6.3). We incise the pleura anterior to the left phrenic nerve and continue the dissection cranially until the pleural fold where the pleural incision turns left and proceeds to the right pleural space (Fig. 6.4). At this point in the dissection, it is important to dissect directly left from the left phrenic inside the neck to identify and free the innominate vein. Clearing the innominate vein is the landmark prior to entering the neck and completely mobilizing the left (Fig. 6.5) and afterwards the right upper thymic poles (Fig. 6.6). Gentle traction and meticulous dissection of the capsule is essential (Fig. 6.7). Here, both grasping instruments

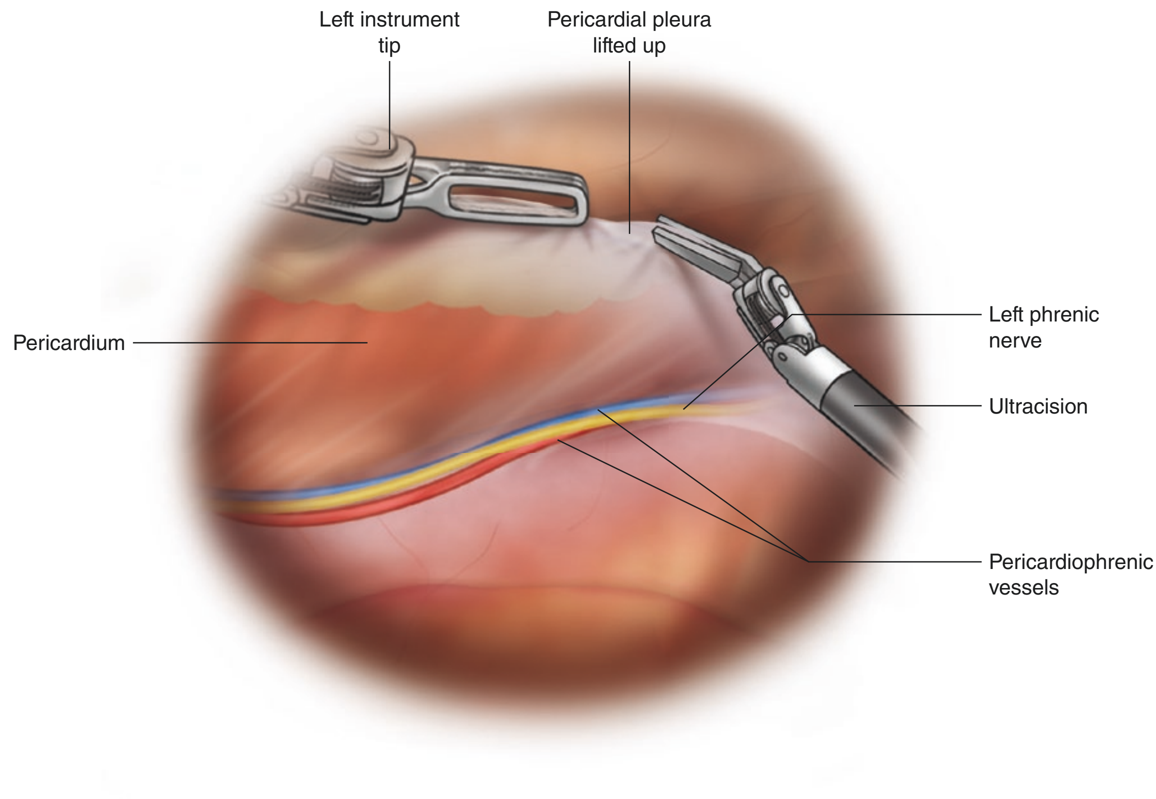


**Fig. 6.3** Initiation of the left-sided approach to a thymoma. The dissection is started directly above the phrenic nerve in an area free of fatty tissue. This area is seen in almost all patients

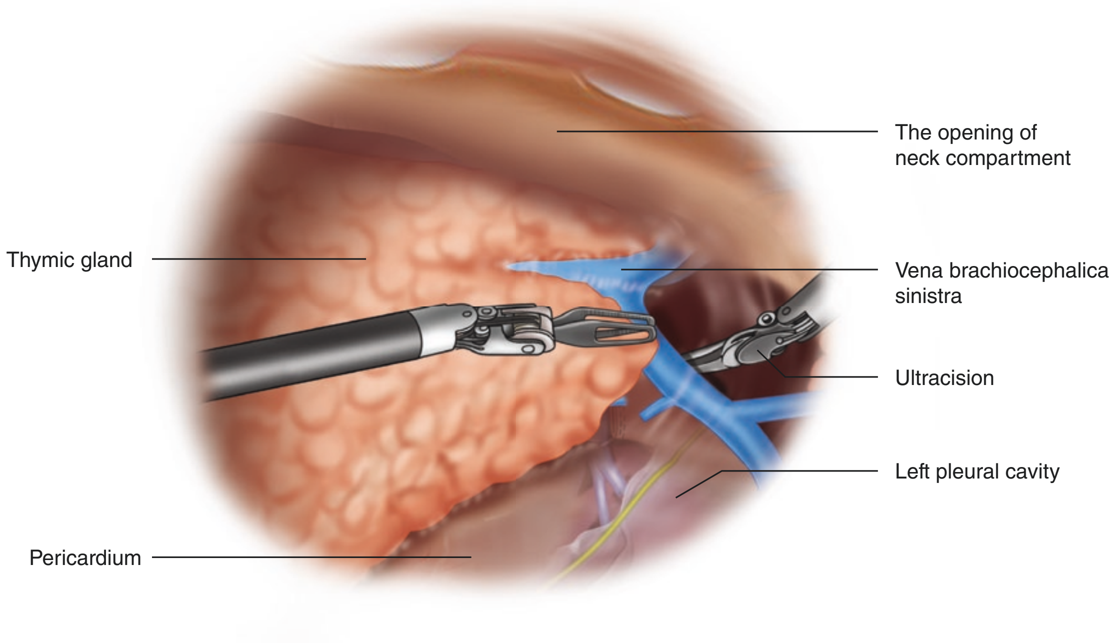


**Fig. 6.4** Dissection of the thymus from the phrenic nerve to the upper aspect of the mediastinum. The dissection is continued along the left phrenic nerve. After dissection of the tissue in the aortopulmonary window, the left innominate vein is shown

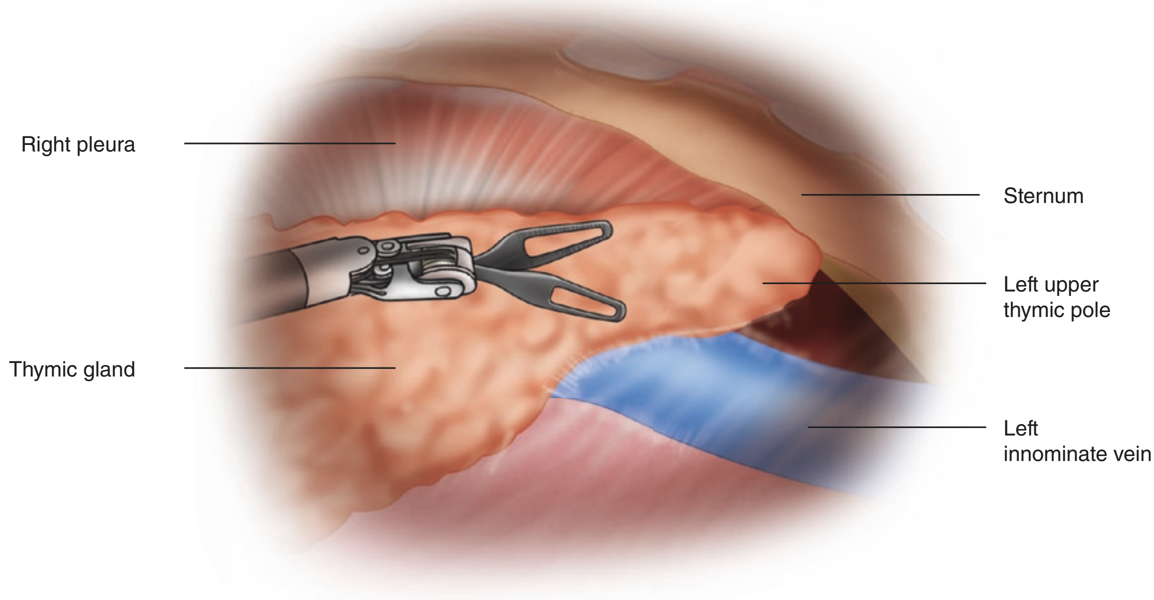


**Fig. 6.5** Dissection of the left upper thymic pole away from the left innominate vein. The fascial planes of the neck are entered and the upper thymic poles are completely removed after dissection of the thymo-thyroid ligament

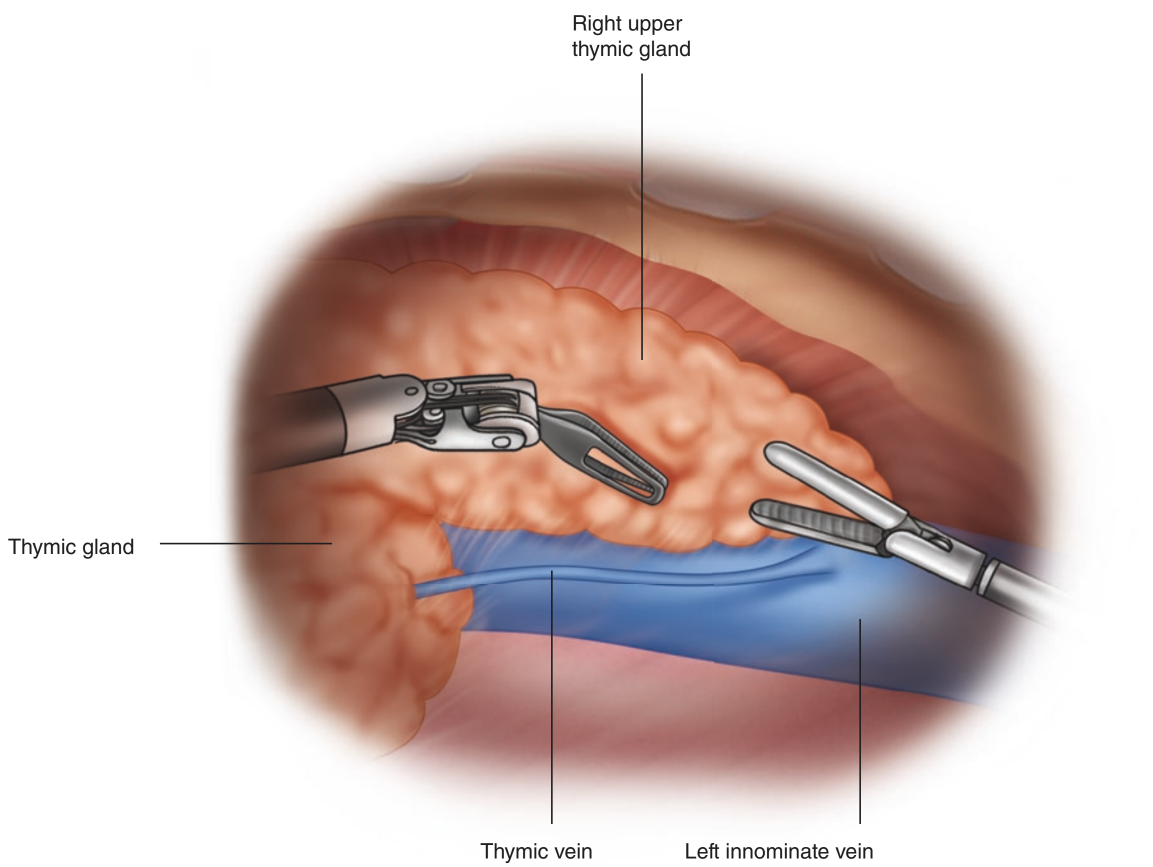


**Fig. 6.6** Dissection of the right upper thymic pole away from the attachments in the neck and upper mediastinum. The right upper thymic pole is dissected in a similar way as the left upper pole. The thymic vein is dissected with the Ultracision, but in some cases where the vein is more than 2–3 mm in size, we prefer the use of endoclips

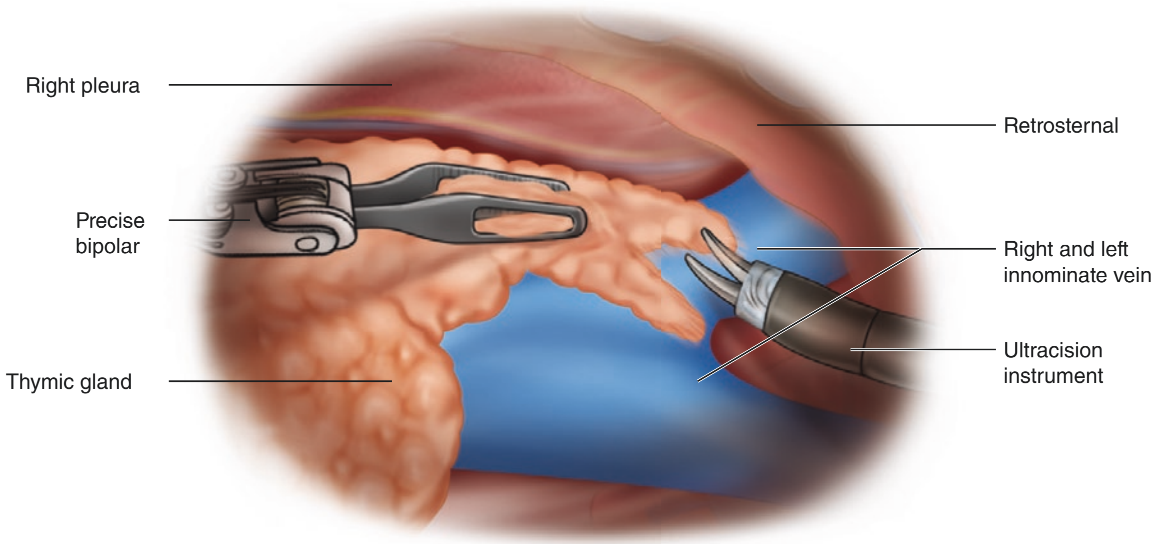


**Fig. 6.7** Dissection of the thymus away from the pericardium to expose the right mediastinal pleura. The tissue above the right innominate vein is dissected. This allows a better view of the right mammary vein and right phrenic nerve

are used to identify vascular supply for ligation most effectively. The thymic veins can be expected to be variable from one large sampling vessel (vein of Keynes) to more than four smaller vessels distributed between left area of the phrenic nerve and even SVC on the right side. The dissection does not require clips or ligation, but can always be done by Ultracision. We try to preserve the left mediastinal pleura as much as possible to allow for effective $CO_2$ insufflation. It is at this point that the $CO_2$ insufflation is started. After isolation of the left phrenic bundle and dissection of the tissue portion in the aortopulmonary window, the main thymic lobes are mobilized on the pericardium. We dissect until the right pleura is shown. The venous confluence is completely dissected free. The right brachiocephalic vein as well as the right mammary vein must be demonstrated. The entrance of the right mammary vein into the venous confluence is the anatomical landmark for searching for the right phrenic nerve (Fig. 6.8). It can always be found here at the lateral side of the superior vena cava. Then, the right phrenic verve is completely dissected free; thus, enabling complete mobilization of the tissue portion in the aorto-caval groove down to the entrance of the SVC into the right atrium. We then turn the camera down to the left side to mobilize the whole tissue of the left cardiophrenic area (Fig. 6.9). If completed, one of the most important steps is the final portion of *en bloc*-thymic dissection; at the subxiphoid location, we open-up the right pleural mediastinal pleura and dissect the right cardio-phrenic fat pad (Fig. 6.10). This dissection is performed from caudal to cranial position without danger for the right phrenic nerve being under vision until its turn down away from dissection line at the right diaphragm. For all unilateral thoracoscopic operation techniques for thymectomy this dissection of the contralateral cardiophrenic fatty tissue is a key step to confirm anatomical radicality (Fig. 6.11).

After *en bloc* resection the specimen is brought into a retrieval bag and removed through the middle incision after changing the camera for the lower trocar. The specimen is always measured for size and weight and will be placed on the International Thymic Malignancy Interest Group (ITMIG) scaffold after photo-documentation to the pathologist for review (Fig. 6.12). After inspection of the operative field, a chest tube is placed in the left pleural cavity. After reinflation of both lungs, all trocars are removed and the incisions closed.

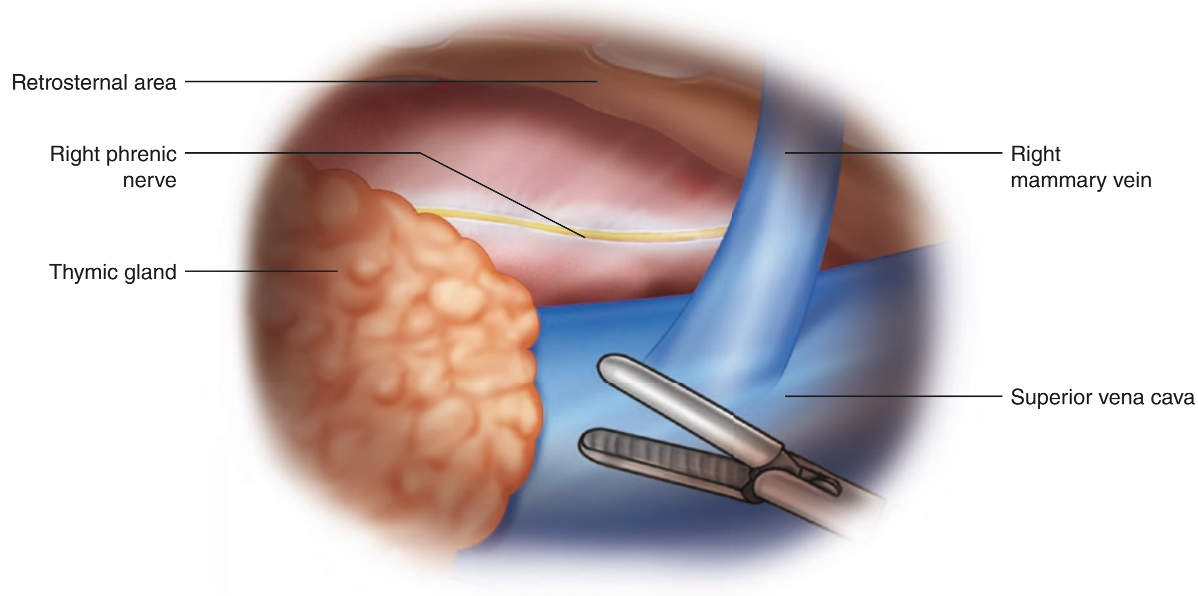


**Fig. 6.8** Exposure of the right mediastinal pleura with exposure of the right phrenic nerve. The right pleura is kept intact at the beginning this can help demonstrating the right phrenic nerve

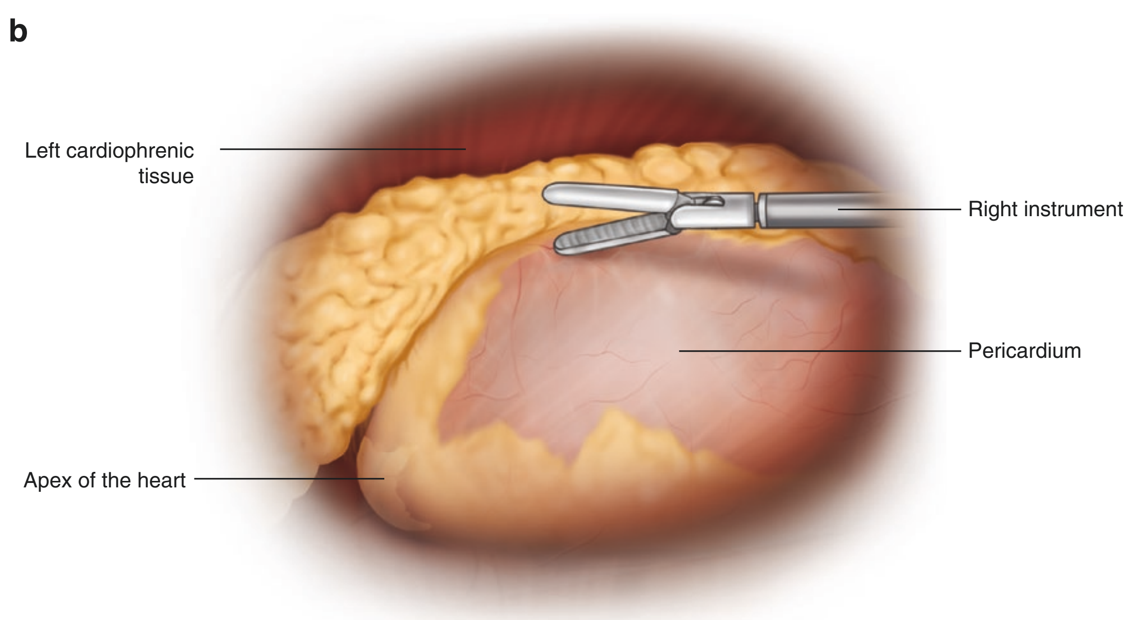


**Fig. 6.9** *En Bloc* dissection of the left lower anterior mediastinal perithymic tissue away from the phrenic nerve, pericardium, and the subxiphoid diaphragm. The left pericardial fatty tissue in the left cardiophrenic region is dissected. At this point attention should be given to left phrenic nerve and it's branches

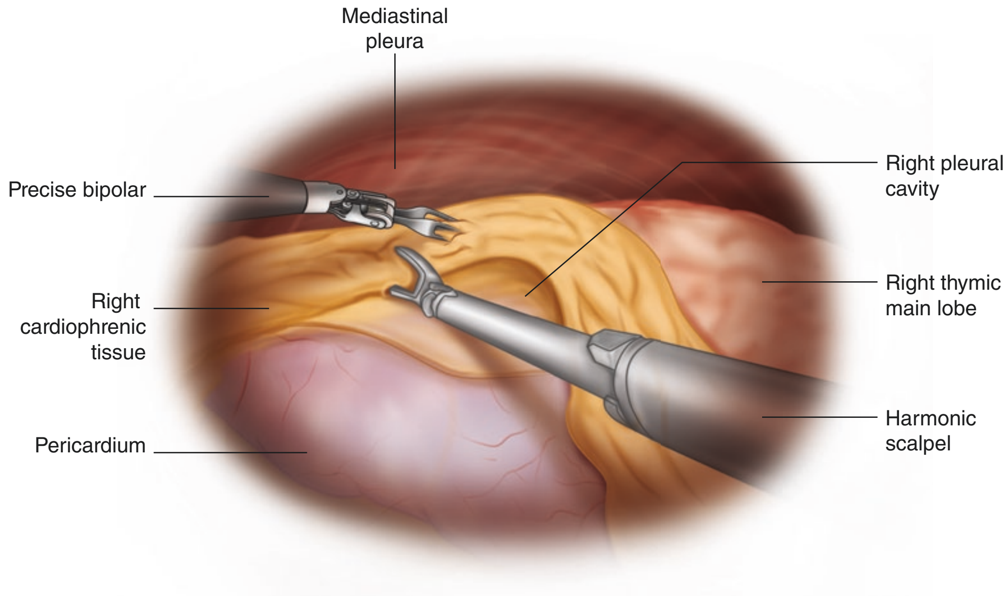


**Fig. 6.10** En Bloc dissection of the right lower anterior mediastinal peri-thymic tissue away from the right lower inferior mediastinum. The retrosternal pleura is opened and the right cardiophrenic fatty tissue is completely dissected en bloc with the rest of the thymus and perithymic tissue

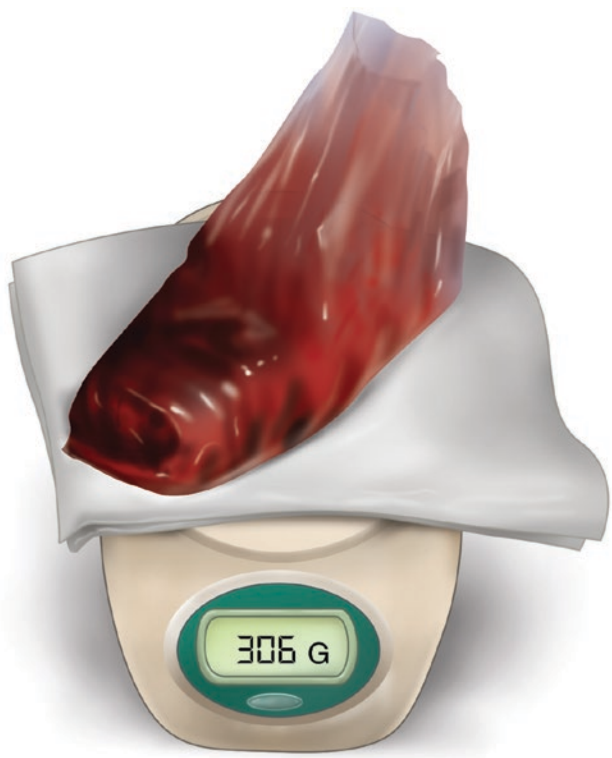


**Fig. 6.11** Dissection of the right lower cardiophrenic area. After dissection of the right cardiophrenic tissue the right phrenic nerve is demonstrated. During this step is the right pleural cavity opened

## 6.5 Postoperative Phase

The preoperative myasthenia gravis medication is continued. Patients are most frequently sent to the ward, but always consider ICU/IMCU or PACU for the exceptional case where the preoperative MG is unstable. There is a range as to pleural drainage from no drainage at all to one large tube. We recommend 18–20 Fr. single left-sided drainage for approximately 24 h.

## 6.6 Tips and Pitfalls

- The table position is important for an efficient procedure. Turning and tilting the operating table approximately 15° left side up to improve the positioning of the table cart and the three robotic arms.
- Use a simple thoracoscopic camera and optic instead of the robotic camera for placing the three special trocars.
- If the intrapleural space is insufficient, such as with higher body mass index, use $CO_2$ insufflation from the beginning.

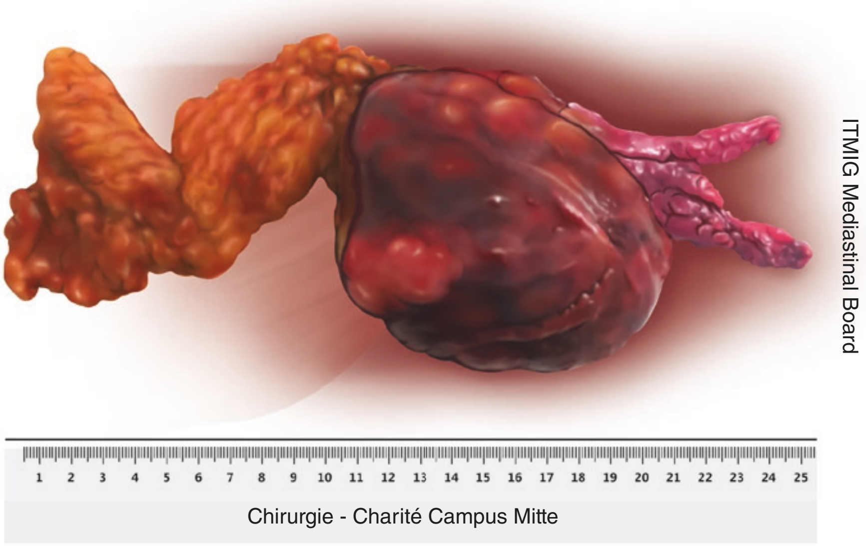


**Fig. 6.12** Specimen weighing after removal in an endobag and preparation of the specimen prior to histological evaluation using the International Thymic Malignancy Interest Group (ITMIG) Anatomical Map. The specimen is always measured for size and weight and is placed on the ITMIG-scaffold after photo documentation

- The use of two grasping instruments is essential for an efficient dissection, especially in the anatomical regions of aortopulmonary window, both upper thymic poles, and the contralateral cardiophrenic fat pad.
- If the lower mediastinal area at the cardiophrenic location cannot be addressed without instrument interference, take out all the instruments and the camera, disconnect the robotic arms and reposition the bedside cart. After reconnection the dissection of the lower mediastinal tissue will be much more easily performed.

## 6.7 Brief Outcome Analysis

The performance of this technique of robotic thymectomy, we believe is one of the most radical minimally-invasive techniques. The three-trocar unilateral robotic approach leads to one of the most acceptable cosmetic results with minimal pain. Patients usually recover quickly. Due to different national health care systems and depending on the individual severity of MG and the co-morbidity most patients are treated in the hospital between 0 and 2 days after the operation. The procedure may be more radical than non-robotic median sternotomy thymectomy translating into better outcome for MG [30]. The procedure has become the most frequent indication for robotic thoracic surgery; worldwide there have been more than 3500 robotic thymectomies performed (Intuitive Surgical, Sunny Vale, CA). By 2012 over 100 institutions had performed robotic thymectomy [27]. By 2014, there were 13 publications each reporting on at least 20 robotic thymectomies per publication. The largest single-center series comprises 650 robotic thymectomies. It is anticipated that there will be further adoption of robotic thymectomy as a result of the recent publication of the prospective randomized trial demonstrating superior outcomes of complete thymectomy for MG compared to medical therapy alone [29]. This information should encourage others to evaluate the result of thymectomy in MG, as few adequately assess the postoperative improvement of MG post-thymectomy [26]. For thymoma, the robotic technique appears to be sufficient when compared to sternotomy (Table 6.1) [27, 30–39].

**Table 6.1** Literature summary of robotic thymectomy series including 30+ cases

| Author year | Country | Study interval | Total | MG | Thymoma | Approach | Ports | Complete remission rate (%) | Thymoma remission rate (%) |
|---|---|---|---|---|---|---|---|---|---|
| Ismail 2013 [27] | Germany | 2003–2012 | 317 | 273 | 56 | Left | 3 | 57 | 0 |
| Keijzers 2013 [31] | Netherlands | 2004–2012 | 138 | NA | 37 | Right | 3 | NA | 2.7 |
| Marulli 2013 [32] | Italy | 2002–2010 | 100 | 100 | 8 | Left | 3 | 28.5 | 0 |
| Freeman 2011 [33] | USA | 6-years | 75 | 75 | Excluded | Left | 3 | 28 | NA |
| Schneiter 2013 [34] | Switzerland | 2004–2011 | 58 | 25 | 20 | Left | 3 | NA | 11.1 |
| Jun 2014 [35] | China | 2010–2012 | 55 | NA | 21 | Left + right | 3–4 | NA | NA |
| Melfi 2012 [36] | Italy | 2001–2010 | 39 | 19 | 13 | Left | 3 | NA | 0 |
| Seong 2014 [37] | Korea | 2008–2012 | 37 | NA | 11 | NA | NA | NA | NA |
| Augustin 2008 [38] | Austria | 2001–2007 | 32 | 32 | 9 | Right | 3 | NA | 0 |
| Cerfolio 2011 [39] | USA | 2009–2010 | 30 | 30 | NA | Right | 3 | NA | NA |

*NA* not announced

## References


1. Lacquer L, Weigert C. Beitrage zur Lehre von der Erb'schen krankheit ueber die Erb-sche krankheit (myasthenia gravis). Neurol Zentralblatt. 1901;20:594–601.
2. Schumachter E, Roth J. Thymektomie bei einem Fall von Morbus Basedowi mit Myasthnie. Grenzgeb d Med u Chir. 1912;25:746–65.
3. Walker MB. Treatment of myasthenia gravis with physostigmine. Lancet. 1934;223(5779):1200–1.
4. Blalock A, Mason MF, Morgan HJ, Riven SS. Myasthenia gravis and tumors of the thymic region: report of a case in which the tumor was removed. Ann Surg. 1939;110(4):544–61.
5. Blalock A. Thymectomy in the treatment of myasthenia gravis. Report of twenty cases. J Thorac Surg. 1944;13:316–39.
6. Keynes G. The results of thymectomy in myasthenia gravis. Br Med J. 1949;2(4628):611–6.
7. Keynes G. Surgery of the thymus gland: second (and third) thoughts. Lancet. 1954;263(6824):1197–202.
8. Kark AE, Kirschner PA. Total thymectomy by the transcervical approach. Br J Surg. 1971;58(5):321–6.
9. Kark A, Papatestas A. Some anatomic features of the transcervical approach for thymectomy. Mt Sinai J Med. 1971;38(6):580–5.
10. Masaoka A, Nagaoka Y, Kotake Y. Distribution of thymic tissue at the anterior mediastinum. Current procedures in thymectomy. J Thorac Cardiovasc Surg. 1975;70(4):747–54.
11. Jaretzki A 3rd, Penn A, Younger D, Wolff M, Olarte M, Lovelace R, Rowland L. "Maximal" thymectomy for myasthenia gravis. Results. J Thorac Cardiovasc Surg. 1988;95(5):747–57.
12. Jaretzki A III, Wolff M. "Maximal" thymectomy for myasthenia gravis. Surgical anatomy and operative technique. J Thorac Cardiovasc Surg. 1988;96(5):711–6.
13. Cooper JD, Al-Jilaihawa AN, Pearson FG, Humphrey JG, Humphrey HE. An improved technique to facilitate transcervical thymectomy for myasthenia gravis. Ann Thorac Surg. 1988;45(3):242–7.
14. Rückert JC, Ismail M, Badakhshi H, Meisel A, Swierzy M. Thymektomie bei Myasthenie und/oder Thymom. Zentralblatt für Chirurgie-Zeitschrift für Allgemeine, Viszeral-, Thorax-und Gefäßchirurgie. 2014;139(01):121–34.
15. Gronseth GS, Barohn RJ. Thymectomy for Myasthenia gravis. Curr Treat Options Neurol. 2002;4(3):203–9.
16. Landreneau RJ, Dowling RD, Castillo WM, Ferson PF. Thoracoscopic resection of an anterior mediastinal tumor. Ann Thorac Surg. 1992;54(1):142–4.
17. Mack MJ, Landreneau RJ, Yim AP, Hazelrigg SR, Scruggs GR. Results of video-assisted thymectomy in patients with myasthenia gravis. J Thorac Cardiovasc Surg. 1996;112(5):1352–9; discussion 1359–60
18. Mineo TC, Pompeo E, Ambrogi V, Bernardi G, Iani C, Sabato AF. Video-assisted completion thymectomy in refractory myasthenia gravis. J Thorac Cardiovasc Surg. 1998;115(1):252–4.
19. Novellino L, Longoni M, Spinelli L, Andretta M, Cozzi M, Faillace G, et al. "Extended" thymectomy, without sternotomy, performed by cervicotomy and thoracoscopic technique in the treatment of myasthenia gravis. Int Surg. 1994;79(4):378–81.
20. Rückert J, Gellert K, Einhäupl K, Müller J. Thoracoscopic thymectomy for treatment of myasthenia gravis. Zentralbl Chir. 1997;123(5):506–11.
21. Jaretzki A III. Thymectomy for myasthenia gravis: analysis of the controversies regarding technique and results. Neurology. 1997;48(Suppl 5):S52–63.
22. Gronseth GS, Barohn RJ. Practice parameter: thymectomy for autoimmune myasthenia gravis (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology. 2000;55(1):7–15.
23. Yoshino I, Hashizume M, Shimada M, Tomikawa M, Tomiyasu M, Suemitsu R, Sugimachi K. Thoracoscopic thymomectomy with the da Vinci computer-enhanced surgical system. J Thorac Cardiovasc Surg. 2001;122(4):783–5. https://doi.org/10.1067/mtc.2001.115231.
24. Ruckert JC, Ismail M, Swierzy M, Sobel H, Rogalla P, Meisel A, et al. Thoracoscopic thymectomy with the da Vinci robotic system for Myasthenia gravis. Ann N Y Acad Sci. 2008;1132:329–35.
25. Rea F, Marulli G, Bortolotti L, Feltracco P, Zuin A, Sartori F. Experience with the "da Vinci" robotic system for thymectomy in patients with myasthenia gravis: report of 33 cases. Ann Thorac Surg. 2006;81(2):455–9.
26. Castle SL, Kernstine KH. Robotic-assisted thymectomy. Semin Thorac Cardiovasc Surg. 2008;20(4):326–31.
27. Ismail M, Swierzy M, Ruckert JC. State of the art of robotic thymectomy. World J Surg. 2013;37(12):2740–6. https://doi.org/10.1007/s00268–013–2250-z.
28. Marulli G, Maessen J, Melfi F, Schmid TA, Keijzers M, Fanucchi O, et al. Multi-institutional European experience of robotic thymectomy for thymoma. Ann Cardiothorac Surg. 2016;5(1):18–25. https://doi.org/10.3978/j.issn.2225-319X.2015.08.13.
29. Wolfe GI, Kaminski HJ, Aban IB, Minisman G, Kuo HC, Marx A, et al., MGTX Study Group. Randomized trial of thymectomy in Myasthenia gravis. N Engl J Med. 2016;375(6):511–22. doi:https://doi.org/10.1056/NEJMoa1602489.

30. Rückert JC, Swierzy M, Ismail M. Comparison of robotic and nonrobotic thoracoscopic thymectomy: a cohort study. J Thorac Cardiovasc Surg. 2011;141(3):673–7.
31. Keijzers M, Dingemans AM, Blaauwgeers H, van Suylen RJ, Hochstenbag M, van Garsse L, et al. 8 years' experience with robotic thymectomy for thymomas. Surg Endosc. 2014;28(4):1202–8. https://doi.org/10.1007/s00464–013–3309–5.
32. Marulli G, Schiavon M, Perissinotto E, Bugana A, Di Chiara F, Rebusso A, Rea F. Surgical and neurologic outcomes after robotic thymectomy in 100 consecutive patients with myasthenia gravis. J Thorac Cardiovasc Surg. 2013;145(3):730–5; discussion 735–6. doi:https://doi.org/10.1016/j.jtcvs.2012.12.031.
33. Freeman RK, Ascioti AJ, Van Woerkom JM, Vyverberg A, Robison RJ. Long-term follow-up after robotic thymectomy for nonthymomatous myasthenia gravis. Ann Thorac Surg. 2011;92(3):1018–22; discussion 1022–3. doi:https://doi.org/10.1016/j.athoracsur.2011.04.054.
34. Schneiter D, Tomaszek S, Kestenholz P, Hillinger S, Opitz I, Inci I, Weder W. Minimally invasive resection of thymomas with the da Vinci(R) Surgical System. Eur J Cardiothorac Surg. 2013;43(2):288–92. https://doi.org/10.1093/ejcts/ezs247.
35. Jun Y, Hao L, Demin L, Guohua D, Hua J, Yi S. Da Vinci robot-assisted system for thymectomy: experience of 55 patients in China. Int J Med Robot. 2014;10(3):294–9. https://doi.org/10.1002/rcs.1577.
36. Melfi F, Fanucchi O, Davini F, Viti A, Lucchi M, Ambrogi MC, Mussi A. Ten-year experience of mediastinal robotic surgery in a single referral centre. Eur J Cardiothorac Surg. 2012;41(4):847–51. https://doi.org/10.1093/ejcts/ezr112.
37. Seong YW, Kang CH, Choi JW, Kim HS, Jeon JH, Park IK, Kim YT. Early clinical outcomes of robot-assisted surgery for anterior mediastinal mass: its superiority over a conventional sternotomy approach evaluated by propensity score matching. Eur J Cardiothorac Surg. 2014;45(3):e68–e73; discussion e73. https://doi.org/10.1093/ejcts/ezt557.
38. Augustin F, Schmid T, Sieb M, Lucciarini P, Bodner J. Video-assisted thoracoscopic surgery versus robotic-assisted thoracoscopic surgery thymectomy. Ann Thorac Surg. 2008;85(2):S768–71. https://doi.org/10.1016/j.athoracsur.2007.11.079.
39. Cerfolio RJ, Bryant AS, Minnich DJ. Starting a robotic program in general thoracic surgery: why, how, and lessons learned. Ann Thorac Surg. 2011;91(6):1729–1736; discussion 1736–7. doi:https://doi.org/10.1016/j.athoracsur.2011.01.104.

## Further Reading

Sonett JR, Jaretzki A III. Thymectomy for nonthymomatous myasthenia gravis: a critical analysis. Ann N Y Acad Sci. 2008;1132(1):315–28. https://doi.org/10.1196/annals.1405.004.

Park BJ, Yang HX, Woo KM, Sima CS. Minimally invasive (robotic assisted thoracic surgery and video-assisted thoracic surgery) lobectomy for the treatment of locally advanced non-small cell lung cancer. J Thorac Dis. 2016;8(Suppl 4):S406–13. https://doi.org/10.21037/jtd.2016.04.56.