Review Article

Robotic thymectomy

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Abstract: Thymectomy is performed for malignant tumors and benign tumors of the thymus or for when there is known myasthenia gravis. The traditional approach for thymectomy has been midline sternotomy. Video-assisted thoracoscopic surgery (VATS) has been utilized but with some unique difficulties due to the thymus' location in the anterior midline position. Robotic thymectomy offers a superior approach to VATS and is less invasive compared to sternotomy. We utilize the Da Vinci Surgical System for robotic thymectomy. A right or left sided approach can be utilized. We utilize a left sided double lumen tube for intubation. Three robotic arms are utilized for the operation with a 30-degree scope. For invasive tumors, pericardiectomy and innominate vein resection can be utilized with the robot. Robotic thymectomy achieves excellent perioperative and long term outcomes. Typical postoperative stay is 1–2 days. Robotic thymectomy results in less blood loss in the OR, less drainage output, and shorter hospital length with shorter duration of chest tubes compared to sternotomy. Compared to VATS thymectomy, robotic thymectomy provides high definition 3D views, improved dexterity and precision of movement with rotating wrists. We demonstrate our technique of robotic thymectomy in written and video format. This technique permits a safe operation with minimal perioperative morbidity.

Keywords: Robotic thymectomy; minimally invasive thymectomy; da Vinci robot

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Introduction

Since the first robotic thymectomy in 2003 (1), robotic assistance has been increasingly used, including for radical thymectomy. The traditional approach for thymectomy has been median sternotomy. Video-assisted thoracoscopic surgery (VATS) has been utilized, but with some difficulty even among experienced practitioners due to the midline location of the thymus. Compared to sternotomy, robotic thymectomy achieves greater safety with an excellent profile of intraoperative, perioperative and long term results. Hospital length of stay typically is 1–2 days and patients return to work or pre-operative activities within 2 weeks which is shorter compared to sternotomy (2). Additionally, there is less intraoperative blood loss and lower quantity chest tube output leading to earlier chest tube removal (3). Overall quality of life, with less pain and earlier return of function are also improved compared to sternotomy (4).

There is a paucity of published literature with direct comparisons between VATS and robotic thymectomy. Rückert *et al.* compared 74 robotic thymectomies with 79 VATS demonstrating similar operative time, similar conversion rates to sternotomy (1.2% robotic *vs.* 1.3% VATS), and similar perioperative morbidity (5). The authors demonstrated that the robotic group had increased rates of complete remission of myasthenia gravis (39.2% *vs.* 20.3%, P=0.01). Other retrospective comparisons suggest decreased chest tube duration and hospital stay after robotic thymectomy compared to VATS thymectomy (1.1 *vs.* 3.6 days and 3.7 *vs.* 6.7 days respectively, P<0.01

Figure 1 Video of the approach: how we position the patient, drape, and place robotic ports (11).
Available online: http://www.asvide.com/articles/1844

for both) (6).

Robotic thymectomy for neurologic relief of myasthenia gravis demonstrates a 5-year rate of complete remission and overall improvement of 28.5% and 87.5% respectively, results which are similar for open and VATS series (7). For early-stage thymoma, robotic thymectomy results are excellent, with a 5-year survival rate of 90% (8). Robotic thymectomy has also been successful in the pediatric population as well as patients with large tumors and invasive tumors involving lung, pericardium, and phrenic nerve (9,10).

Patient selection and workup

The disease process determines how we approach preoperative evaluation. We take a complete history and physical, with questions that elicit neurological symptoms of myasthenia gravis (diplopia, ptosis, fatigable chewing dysarthria, general fatigability, and dysphagia). Stress testing and/or pulmonary function testing is performed based on risk assessment via history and physical.

If we suspect myasthenia gravis, we strongly believe that preoperative evaluation and treatment including appropriate serologic and electrophysiologic evaluation must be undertaken to avoid perioperative complications. For example, a myasthenia crisis is a contra-indication for urgent or emergent thymectomy. Medical management precedes operation with anticholinesterase inhibitors, intravenous immunoglobulin, and/or plasmapheresis. Once the disease is stabilized, elective thymectomy can then be performed.

Preoperative workup typically includes CT scan of the chest alone. Intravenous contrast is used when possible to assess the tumor location relative to the superior vena cava and innominate vein. We also examine for a fat plane between the mass and the vessels. Except in the most experienced hands, tumor involvement of the great vessels should be approached with median sternotomy, although robotic exploration can be considered. Extensive great vessel involvement is a relative contraindication for robotic thymectomy. However, robotic thymectomy can still be performed if the lung is involved utilizing wedge resection. We have demonstrated successful robotic thymectomy with large tumors as well.

There are relatively few absolute contraindications to robotic thymectomy other than medically unfit patients or patients in myasthenic crisis.

Either a left or right robotic thymectomy can be performed. While we previously have recommended a right approach, we now feel that a majority of cases should be performed on the left to allow for more direct visualization of the aortopulmonary window and avoidance of accidental injury to the superior vena cava.

Description of the approach

Robotic thymectomy can be performed through either chest, depending on its location. An experienced anesthesiologist places a left-sided double lumen endotracheal tube. The tube is checked from the tracheal lumen with a pediatric bronchoscope with a sliver of visible cuff for the left side and visualization of the right upper lobe bronchus to confirm correct placement. The endotracheal tube is positioned away from the robotic arms. At our institution, we do not place epidurals, foley catheters, and arterial lines.

Figure 1 demonstrates how we position the patient (11): the patient is supine on the operating table with the operative side of the body moved close to the edge of the bed and elevated slightly with pads or blankets. The corresponding arm hangs low on an attached arm board to expose the axilla. While draping the patient, we expose the entire sternum (for possible conversion to sternotomy) and the right chest just to the bed. The superior robotic arm is placed high in the axilla. We sometimes place an extra-long robotic port at the axilla to avoid collisions between the patient's shoulder and the robotic arm. The camera port is placed halfway between the sternal notch and the xiphoid process. The inferior robotic arm port is placed close to the diaphragm and slightly more medial than the other ports, though not too close to the inferior horn of the thymus. We do not use a fourth arm. The robotic arm

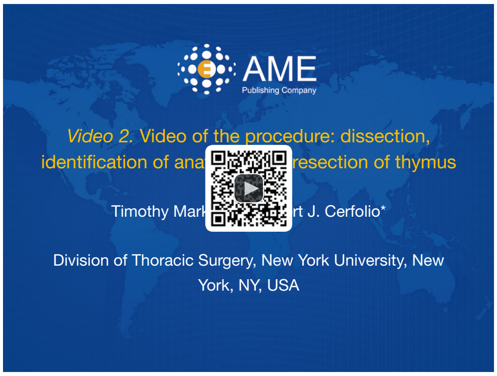

Figure 2 Video of the procedure: dissection, identification of anatomy, and resection of thymus (12).
Available online: http://www.asvide.com/articles/1845

Figure 3 Video of tips and tricks: illustration of key anatomy and key retraction (13).
Available online: http://www.asvide.com/articles/1846

ports for the DaVinci Xi system are 8 mm in diameter. For the Si system, the camera port is a 12-mm port and the arm ports are 8 mm. There should be at least 8–9 cm between each of the robotic ports. We utilize a 12-mm assistant port that is triangulated behind the camera and right robotic arm ports. We typically insufflate with carbon dioxide to 12 cm H20 through any port except the robotic camera port which tends to cause misting of the camera lens and occasionally becomes kinked with movement. The robot is then docked opposite the side of the approach.

Procedure

Figure 2 demonstrates the procedure (12). The pleura, lung and chest wall are inspected for abnormalities. Any suspicious lesions are biopsied or addressed. Lysis of adhesions can be performed with either robotic bipolar cautery or thoracoscopically prior to docking. The 8 mm robotic ports in the Si can be sized down with the rubber introducer cap to avoid losing the capnothorax when inserting 5 mm VATS instruments. The 8 mm robotic ports in the Xi have the 5 mm compatible valve built in.

A cadiere grasper is used in the left hand, and a thoracic bipolar dissector is used in the right.

Dissection begins at the diaphragm, and continued anteriorly near the sternal edge with careful identification and avoidance of the internal mammary vessels. This dissection is continued towards the junction of the mammary and the innominate vein. The thymus is then dissected laterally (or towards the bottom of the screen) off the pericardium, avoiding the phrenic nerve.

The innominate vein is visualized and the closest superior horn of the thymus is dissected off the vein, taking care to cauterize the small veins entering the thymus. A rolled up gauze sponge is at the ready for any bleeding from these vessels. The superior horn needs to be followed towards the thoracic inlet and brought down into the chest. The superior vena cava is identified and avoided taking special care that the left robotic arm does not injure it inadvertently.

Following dissection of the superior horn, the lateral side of the thymus inferiorly (toward the diaphragm) is performed. The opposite pleural space is opened and the thymus is then retracted medially in the chest and towards the patient's shoulder. The opposite phrenic nerve can generally be seen if retraction is appropriate. Next, the remaining superior thymic horn is dissected off the innominate vein, which is below it. The left internal mammary vein will enter the innominate vein near the apex of the left chest and should be avoided. The remainder of the dissection is then performed and the specimen removed with a laparoscopic bag via the assistant port. We then place a flexible blake that spans across both pleural spaces. The gas insufflation is discontinued and each of the ports is removed to check for bleeding. The lung is reinsufflated under direct vision via the camera and the camera port is finally removed.

Tips/tricks/downfalls

(I) *Figure 3* illustrates key anatomy and tips (13);
(II) Retraction is key for dissection of the superior horns. A complete thymectomy requires complete extraction of the horn tissue. The innominate vein is visualized

and the superior horns freed above and below it;

(III) An innominate vein injury is the most common and most feared complication. If the injury is small, application of topical hemostatics and pressure is applied. If the injury is larger, then the area is packed and direct pressure is applied with a sponge. The robot is then undocked and sternotomy is performed;

(IV) To avoid conflict of the patient's shoulder with the superior arm, the shoulder is brought as low as possible. The superior port is placed as far anterior to provide clearance from the shoulder. Additionally, a longer robotic trocar can be placed to help with further clearance of the robotic arm;

(V) The opposite phrenic nerve can typically be visualized with a 0-degree scope if the 30-degree down scope cannot visualize it. Occasionally, a large tumor can obscure the nerve and a separate VATS port on the opposite side can be used to visualize the nerve. Some investigators have reported using the intravenous injection of indocyanine green and near-infrared fluorescent imaging to identify the phrenic nerve (14).

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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