Surgical Technique on Robotic Surgery

Robotic lobectomy

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Abstract: Lobectomy is still currently the gold standard for treatment of lung cancer. With the great advancement of robotic surgery, robotic lobectomy has been demonstrated to be an operation that is safe and can be done in a timely manner, similar to video-assisted thoracoscopic surgery (VATS). Additionally, reports show that long-term oncologic outcomes for robotic lobectomy are consistent with those reported for VATS and open lobectomy. Patients are selected in the same manner as those for VATS. Improved optics, increased dexterity of the instruments, and better ergonomics can yield subjective advantages to the surgeon. The techniques of port placement, mediastinal lymph node dissection and the steps of each of the five lobectomies are important and described in the chapter, for both the da Vinci Si and da Vinci Xi platforms. The subtle differences are highlighted. Additionally, advantages of the platforms are discussed.

Keywords: Robotic; lobectomy; lung cancer; minimally invasive; lung resection

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Introduction

One of the first published reports of pulmonary lobectomy was by Drs. Norman Shenstone and Robert Janes from the Toronto General Hospital in 1932 (1). In their report, they described an open technique as "a long incision in the general direction of the ribs, passing just below the scapula," or via a thoracotomy. With modern advances in technology, surgeons have found techniques that decrease the size of incisions. Minimizing the invasiveness of pulmonary lobectomy has decreased postoperative morbidity, recovery time, and pain. Initially, minimally invasive lobectomy was performed using video-assisted thoracoscopic surgery (VATS) techniques. However, with the advent of the surgical robot-assisted techniques, the first robotic lobectomies were reported in 2003 by Morgan *et al.* and Ashton et al (2,3). Since then, the use of robotic technology for lobectomy has only grown. In 2015, over 6,000 robotic lobectomies were performed in the United States, and over 8600 done worldwide.

Initial evaluation

The evaluation of candidates for robotic lobectomy is similar to the evaluation of a patient for VATS or open. The same standard preoperative studies for any patient undergoing pulmonary resection are required. All patients require pulmonary function testing including measurement of diffusion capacity (DLCO) and spirometry. Patients with history of cardiac disease or have highs suspicion for cardiac disease should undergo a cardiac stress test.

If the resection is for suspected or biopsy-proven lung cancer, an oncological work up must be performed. Whole-body PET-CT scan is currently the standard of care. Mediastinal staging can consist of either endobronchial ultrasound guided fine-needle aspiration biopsy (EBUS-FNA) or mediastinoscopy, depending on expertise of the physician performing the procedure. A brain MRI may be ordered if concern exists for metastatic disease. Dedicated computed tomography scan with intravenous contrast or MRI can be performed if concern exists for vascular or vertebral/nerve invasion, respectively.

When it comes to assessing the ability of a patient to tolerate lobectomy from a respiratory point of view, the same criteria for VATS are used. It has been shown that VATS is safe in patients with a predicted postoperative forced expiratory volume (FEV1) or DLCO <40% of predicted (4). Currently the only absolute contraindications are our institution are vascular invasion, locally invasive T4 lesions, Pancoast tumors, and massive tumor (>10 cm). Other relative contraindications, such the need for reconstruction of the airway, chest wall invasion, presence of induction chemotherapy and/or radiation, prior thoracic surgery, and hilar nodal disease may not be absolute contraindications for robotic-assisted lobectomy for experienced surgeons.

Relevant anatomy/physiology

An intimate knowledge of the pulmonary anatomy and specifically, the relationship between hilar structures and their potential variations is needed to perform any lobectomy regardless of approach. Some discussion of the viewing angle does warrant discussion. In an open technique, the surgeon basically has two views of the hilum, the anterior or posterior direction. In VATS or robotic lobectomy, the camera approaches the hilum from an inferior direction. Retraction of the lung cam affect interpretation of the anatomy. Obviously, the spatial relationships between structures do not change, only the perception and visibility are adjusted. The surgeon must have a strong knowledge of what structures are at risk while performing each step and maneuver during the operation. This is the key to avoiding excessive blood loss, serious injury to structures and bad outcomes for the patient. Even more important, avoiding misidentification of structures and attention to aberrant or variable anatomy are also of paramount importance during robotic lobectomy. An injury to the wrong structure can force conversion to an open operation and negate the benefit of attempting minimally invasive surgery.

Conduct of operation

Patient positioning/port placement

Single lung ventilation is accomplished by placement of the double lumen endotracheal tube prior to positioning the patient. It is important check the ability to tolerate single lung ventilation prior to draping the patient, as repositioning the tube will be virtually impossible once the robot is docked. As with all lobectomies, positioning is in lateral decubitus position. Despite most surgeons' and anesthesiologists' beliefs, there is no need for axillary rolls and arm boards.

The robotic ports are inserted in differently depending on which model da Vinci robot being used. When using either robot, we mark the location of scapula, the spinous processes the entire length of the patients back and number the intercostal spaces. Port placement is dependent on system being used. Typically, for most resections, we place the ports in the 8th intercostal space. However, some surgeons may choose to place their ports in the 7th intercostal space for upper and middle lobectomies.

With the SI system, typical port placement for a right robotic lobectomy is as follows: robotic arm 3 is located two cm lateral from the spinous process of the vertebral body, robotic arm 2 is 10 cm medial to robotic arm 3, the camera port (we prefer the 12 mm camera) is 9 cm medial to robotic arm 2, and robotic arm 1 is placed right above the diaphragm anteriorly. All of these ports are typically placed in the same intercostal space. The assistant port is triangulated behind the camera port and the most anterior robotic port, and as inferior as possible without disrupting the diaphragm. The goal is to form the largest triangle possible to allow the assistant the most room to work. Transillumination of the ribs is helpful guide to finding the most ideal location for the assistant port and port 1. The robotic port 3 is a 5 mm port; port 2 is an 8 mm; camera port is a 12 mm; port 1 is a 12 mm; and the assistant port is a 12 mm.

For the Xi system, the ports are placed in slightly different locations. They are also numbered differently due to the system. Depending on the side of the operation, the ports are numbered differently. The following nomenclature applies for a right-sided lobectomy. Robotic port 1 is placed 4 cm away from the spinous process. Robotic port 2 is placed 8 cm from arm 1 and robotic port 3 is placed 8 cm from port 2. Robotic port 4 is placed right above the diaphragm anteriorly. The assistant port is triangulated behind the camera port and robotic arm 4 in a similar fashion. The camera is inserted into port 3. Ports 1 through 4 are all in the 8th intercostal space. The numbering of the ports is reversed for a left-sided lobectomy.

Exceptions to these arrangements are middle lobectomies, upper lobectomies with surgeon preference, and larger patients. Middle lobectomy ports differ in that the assistant port is placed more posteriorly, between the camera port and the left robotic arm. Additionally, the camera port may be better situated in some patients if it is located in the 7th intercostal space for upper lobectomies. In larger patients, the spacing between ports may be increased, but the placement of the most posterior port must remain the same.

A zero degree camera is used for all lobectomies. Insufflation of the camera or assistant port with carbon dioxide is used to depress the diaphragm, decrease bleeding, and compress the lung.

Mediastinal lymph node dissection

After examining the pleura to confirm the absence of metastases, the next step during our performance of robotic lobectomy is removal of the mediastinal lymph nodes, for staging and also to help expose the structures of the hilum.

- ❖ Right side: the inferior pulmonary ligament is divided. Lymph nodes at stations 9 and 8 are removed. The most posterior arm is used to retract the lower lobe medially and anteriorly in order to remove lymph nodes from station 7. Then, the most posterior arm is used to retract the upper lobe inferiorly during dissection of stations 2R and 4R, clearing the space between the SVC anteriorly, the trachea posteriorly, and the azygos vein inferiorly. Avoiding dissection too far superiorly can prevent injury to the right recurrent laryngeal nerve that wraps around the subclavian artery.
- ❖ Left side: the accessory arm (most posterior arm) is used the retract the lung anteriorly. The inferior pulmonary ligament is divided to facilitate the removal of lymph node station 9. The nodes in station 8 are then removed. Station 7 is accessed in the space between the inferior pulmonary vein and lower lobe bronchus, lateral to the esophagus. It is essential to dissect in plane anterior to the vagus nerve, so that the vagus is retracted toward the esophagus and the aorta. Finally, the accessory arm is used to wrap around the left upper lobe and pressed it inferior to allow dissection of stations 5 and 6. Care should be taken while working in the aorto-pulmonary window to avoid injury to the left recurrent laryngeal nerve. Station 2L cannot typically be accessed during left sided mediastinal lymph node dissection due to the presence of the aortic arch but the 4L node is commonly removed.

The five lobectomies

A key advantage of the robot is that the camera gives the surgeon the ability to change the view for greater than either VATS or open surgery can achieve. Due to this, structures may be isolated and divided in the order that the patient's individual anatomy permits and aids in a shorter operation. Below are descriptions of an outline of the typical conduct of each lobectomy.

Right upper lobectomy

- ❖ What is described below is a posterior technique starting with completion of the posterior fissure.
- ❖ Upon completion of the lymph node dissection, the 10R lymph node between the truncus branch and the superior pulmonary vein should be removed or swept up towards the lung, which exposes the truncus branch. During the lymph node dissection the arteries and veins should be dissected of off each other to facilitate safe encircling during the resection.
- ❖ The right upper lobe is then reflected anteriorly to expose the bifurcation of the right main stem bronchus. There is usually a lymph node here that should be dissected out to expose the bifurcation. This is key to both performing a right upper lobectomy or right lower lobectomy.
- ❖ The posterior fissure can be completed by identifying the main pulmonary artery and dissecting directly on its surface. Two key vascular structures should be identified at this step: the posterior segmental artery and the crossing vein that drains the posterior segment. Once identified, the path to completing the fissure can be found and performed with a stapler.
- ❖ The posterior segmental artery to the right upper lobe is exposed, the surrounding N1 nodes removed, and the artery encircled and divided.
- ❖ The right upper lobe bronchus is then encircled and divided. Care must be taken to apply only minimal retraction on the specimen in order to avoid tearing the pulmonary artery branches.
- ❖ Using the divided bronchus for retraction, the remaining arterial vessels should be exposed and can be divided individually or simultaneously, depending on the anatomy.
- ❖ With the completion of the arteries being divided, all that should be remaining is pulmonary veins. The bifurcation between the right upper and middle lobar veins is developed by dissecting it. The vein to the upper lobe can be divided.
- ❖ The anterior fissure can be completed with a stapler.

Right middle lobectomy

- ❖ Retraction of the right middle lobe laterally and posteriorly with the most posterior robot arm helps expose the hilum.

- ❖ The bifurcation between the right upper and middle lobar veins is developed by dissecting it off the underlying pulmonary artery. The right middle lobe vein is encircled and divided.
- ❖ The fissure between the right middle and lower lobes, if not complete, is divided from anterior to posterior. Care should be taken to avoid transecting segmental arteries to the right lower lobe.
- ❖ The right middle lobe bronchus is then isolated. It will be running from left to right in the fissure. Level 11 lymph nodes are dissected from around it. It is encircled and divided, taking care to avoid injuring the right middle lobar artery that is located directly behind it.
- ❖ Dissection of the fissure should continue posteriorly until the branches to the superior segment are identified. Then the one or two right middle lobar segmental arteries are isolated and divided.
- ❖ Stapling of middle lobar structures may be facilitated by passing the stapler from posterior to anterior, to have a greater working distance.
- ❖ The fissure between right middle and upper lobes is then divided.

Right lower lobectomy

- ❖ The inferior pulmonary ligament should be divided to the level of the inferior pulmonary vein.
- ❖ The bifurcation of the right superior and inferior pulmonary veins should be dissected out. The location of the right middle lobar vein should be positively identified to avoid inadvertent transection.
- ❖ A sub-adventitial plane on the ongoing pulmonary artery should be established. If the major fissure is not complete then it should be divided.
- ❖ The right upper lobe is then reflected anteriorly to expose the bifurcation of the right main stem bronchus. There is usually a lymph node here that should be dissected out to expose the bifurcation. This is key to both performing a right upper lobectomy or right lower lobectomy.
- ❖ The superior segmental artery and the right middle lobe arterial branches are identified. If the superior segmental comes off early from the main pulmonary artery, it is isolated and divided, followed by the common trunk to right lower lobe basilar segments. It may arise more distally so that the right lower lobe artery may be taken with one staple. This can be done as long as this does not compromise the middle lobar segmental artery/arteries; otherwise, dissection may have to extend further distally to ensure safe division. Arterial division must preceded by proper identification of the middle lobe arteries and posterior segment of the upper lobe.
- ❖ The inferior pulmonary vein is divided.
- ❖ The right lower lobe bronchus is isolated, taking care to visualize the right middle lobar bronchus crossing from left to right. The surrounding lymph nodes, as usual, are dissected and the bronchus divided. As with the arteries, care to not compromise the middle lobe bronchus must be made.

Left upper lobectomy

- ❖ The presence of both superior and inferior pulmonary veins is confirmed, and the bifurcation dissected.
- ❖ As with the right sided resections, a thorough lymph node dissection opens up the posterior aspects of the dissection planes. Especially crucial is the removal of the level 10 lymph node that sits on the posterior aspect of the main pulmonary artery. This is accomplished by retraction of the left upper lobe anteriorly with most posterior robot arm helps expose the posterior hilum.
- ❖ Interlobar dissection is started, going from posterior to anterior.
- ❖ If the fissure is not complete then it will need to be divided. Reflecting the lung posteriorly again and establishing a sub-adventitial plane will be helpful. The branches to the lingula are encountered and divided in the fissure during this process. The posterior segmental artery is also isolated and divided. Division of the lingular artery or arteries can be done before or after division of the posterior segmental artery.
- ❖ The superior pulmonary vein is isolated then divided. Because the superior pulmonary vein can be fairly wide, it may require that the lingular and upper division branches be transected separately.
- ❖ Often the next structure that can be divided readily will be the left upper lobar bronchus, as opposed to the anterior and apical arterial branches to the left upper lobe. The upper lobe bronchus should be encircled and divided. Care is taken to avoid injuring the main pulmonary artery.
- ❖ Finally, the remaining arterial branches are encircled and divided.

Left lower lobectomy

- ❖ The inferior pulmonary ligament should be divided to the level of the inferior pulmonary vein. The lower

lobe is then reflected posteriorly by the most posterior robotic arm.
- ❖ The bifurcation of the left superior and inferior pulmonary veins should be dissected out.
- ❖ The lung is reflected anteriorly by most posterior robotic arm. The superior segmental artery is identified. The posterior ascending arteries to the left upper lobe are frequently visible from this view also. The superior segmental artery is isolated and divided. The common trunk to left lower lobe basilar segments may be taken as long as this does not compromise the middle lobar segmental artery/arteries; otherwise, dissection may have to extend further distally to ensure safe division. If the fissure is not complete, this will need to be divided to expose the ongoing pulmonary artery to the lower lobe.
- ❖ After division of the arterial branches, the lung is reflected again posteriorly. The inferior pulmonary vein is divided.
- ❖ The left lower lobe bronchus is isolated. The surrounding lymph nodes, as usual, are dissected and the bronchus divided.
- ❖ For left lower lobectomy, it may be simpler to wait until after resection is performed before targeting the subcarinal space for removal of level 7 lymph nodes.

Results

Robotic lobectomy can be performed with both excellent perioperative and long-term outcomes. At our center, we have a 30-day mortality rate of 0.25%, 90-day mortality rate of 0.5%, and major morbidity rate of 9.6% in patients undergoing robotic lobectomy and segmentectomy (5). Additionally, our median length of stay following robotic lobectomy is 3 days (6). Robotic lobectomy is equivocal to VATS in regards to blood loss, blood transfusion, air leak, chest tube duration, length of stay, and mortality when compared to traditional open technique (7-9). We have a <1% conversion rates to thoracotomy at our institution, but 3-5% is more typically reported[1]. Vascular injury is rare, and when it does occur, can occasionally be repaired without converting to a thoracotomy (10). Lymph node upstaging rates and 5-year survival for robotic lobectomy are comparable to lobectomy via thoracotomy and possibly improved versus VATS (11,12).

The one obvious disadvantage of the robotic approach when compared to VATS is cost. A robotic lobectomy can cost an additional $3,000–5,000 per case (13,14). This is due to multiple factors. First, the use of disposable instruments adds to the cost. Secondly, the sunk cost of the robot itself increases cost. Finally, there is a price for the maintenance plans required for employing the robot. Even with this additional cost, however, each robotic lobectomy yields an estimated median profit margin of around $3,500 per patient (15).

Conclusions

Robotic lobectomy has demonstrated as an operation that is safe and can be done in a timely manner. It can be done with superior perioperative morbidity and mortality outcomes compared to thoracotomy and similar to VATS. Additionally, reports show that long-term oncologic outcomes for robotic lobectomy are consistent with those reported for VATS and open lobectomy. Improved optics, increased dexterity of the instruments, and better ergonomics can yield subjective advantages to the surgeon.

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Footnote

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

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