4 Robotic Lobectomy: Hilum First Technique

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Abstract

Lobectomy of the lung is performed for primary lung cancer with individual ligation of the pulmonary vasculature and bronchus along with division of the fissures. Recent estimates claim nearly 30% of lobectomy cases are performed in a minimally invasive fashion, the robotic approach of the nonrobotic minimally invasive option may have some advantages that includes a potentially more oncologic resection, less instrument movement at the chest wall that may result in less trauma to nerves and, thus, potentially less postoperative discomfort, and a simpler technique to learn and teach, more closely approximating the moves of surgery by thoracotomy. The operative setup and surgical details for each of the five lobes is described and illustrated, outlining the technique to divide the hilar structures first and then to divide the fissures. Over the 15 years of performing the technique, particular learning points are described.

Keywords

Video-assisted thoracoscopic surgery · Robotic · Computer-assisted surgery · Anatomic resection · Thoracotomy · Thoracoscopy · Lung cancer · Neoplasms · Squamous cell Adenocarcinoma · Treatment · Surgical technique · Lobectomy · Segmentectomy Pneumonectomy · Minimally invasive surgery · Pulmonary · Thoracic surgery · VATS NSCLC · Sleeve lobectomy · Lymphadenectomy · Lymph node dissection · Surgical methods

4.1 Background, Specific Indications

Lobectomy is the standard-of-care for the treatment of early stage lung cancer and is defined as an anatomic resection of the lobe with the individual ligation of the artery, vein, and bronchus. Hilar and mediastinal lymph nodes are resected, as well, with sufficient lymphadenectomy to provide at least 2–3 mediastinal lymph node stations and total lymph node count of more than 10 nodes; potentially more than 20 is necessary to provide sufficient staging information.

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Since the early 1990s, the video-assisted thoracic surgery (VATS) lobectomy has evolved into an efficient oncologic procedure that has been found to have less blood loss, less surgery-related disability, less pain, and reduced hospital length-of-stay/cost compared to the open thoracotomy lobectomy. Robotic technology was introduced in the early 2000 and the first series of robotic lobectomies were reported. The initial equipment was somewhat cumbersome and the techniques used with VATS and the open thoracotomy did not lend themselves to a robotic approach. The length of time for the robotic procedure was long and surgical bleeding obstructed the view. As the technology evolved and with the introduction of robotics into more surgical training programs, greater opportunities were realized with robotic technology in the performance of the anatomic lobectomy.

Lobectomy is particularly suited for robotics; there are restrictive areas within the hilum and mediastinum that are

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difficult to manage with VATS or even open thoracotomy. The degrees of freedom of the instruments and the surgeon-directed magnified view provide a platform to perform intricate maneuvers to resect and, if necessary, repair or reconstruct defects. For the first 10 years after robotic technology was introduced, fewer than 15% of lobectomies were performed in a minimally invasive fashion. In spite of the lack of tactile feedback, the lack of which does not appear to be a major obstacle, there are likely some unproven additional benefits: reduced trocar movement at the chest wall may reduce postoperative pain and improved instrument dexterity may improve the quality of the cancer resection and reduce the likelihood for conversion to open thoracotomy. An additional benefit may be the ability to perform a lobectomy without single lung ventilation. Many other opportunities may be afforded by the surgeon-controlled view and greater dexterity, obstacles such as the shape of the thorax and the presence of the great vessels and the small spaces that would historically prevent resection and reconstructive efforts would now become surgically-capable.

4.2 Operative Setup

The currently available Food and Drug Administration-approved robotic system has three components, (1) the surgeon console; (2) the "praying mantis-like" robotic arms chassis or "bedside cart;" and (3) the electronic communications tower system between the console and the chassis. These components must be considered prior to bringing the patient into the room, operating rooms often small and unaccustomed to already limited space. The recommendation of the room setup is noted for the right upper lobectomy in Fig. 4.1.

In light of the extra equipment, the following are the steps for the robotic lobectomy: room setup (Fig. 4.1), patient positioning (Fig. 4.3), thoracoport placement marking, port placement (Figs. 4.4, 4.5, 4.6, 4.7, and 4.8), robotic docking and performance of the procedure; hilum-first approach. For the novice team and surgeon, it is recommended that extra time be committed for treatment planning and discussion with the team; surgeon team, anesthesia and nursing. There should be robotic technology knowledgeable individuals on the team. A thoracotomy surgical equipment tray and a sterile sponge-stick with a folded piece of hemostatic collagen-based fabric, such as Surgicel® (Johnson & Johnson) (Fig. 4.2), to serve as a means to compress and hold any possible major bleeding within the mediastinum or hilum.

4.3 Anesthetic Management

The anesthetic management for the robotic lobectomy is not significantly different than the management of the open thoracotomy or VATS lobectomy. Consideration should be

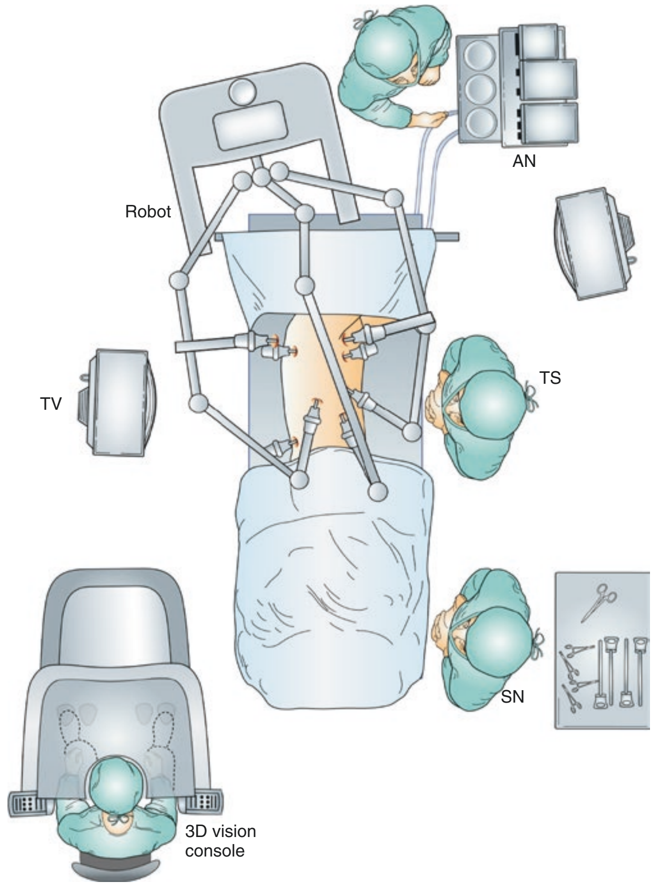


Fig. 4.1 This is an example of an **operating room setup for a robotic case, a robotic right upper lobectomy**. The head of the bed is toward the anesthesiologist (AN) and the bedside cart (Robot) is brought obliquely over the patient's head. The operating console is toward the bottom right of the diagram and the bedside surgeon (TS) and scrub nurse (SN) are toward the front of the patient. Two monitors (TV) or are more often used for viewing the procedure by the team

given to the patient's co-morbidities and prepare the patient for single lung ventilation whether by double-lumen intubation or bronchial blocker. Fluids should be minimized. Colloid is preferred over crystalloid. Volumes of greater than 1.5 L should be avoided. Transfusions should be avoided, if possible. Once positioned under the robot and the robot docked to the patient's previously placed trocars, the bed cannot be moved. To avoid hemodynamic compromise, sufficient time should be allowed for the patient positioning and the introduction of the intrapleural carbon dioxide (CO_2) that can result in hypotension and hemodynamic instability. Any movement of the bed after the robot is docked could injure the patient. To maintain adequate oxygen saturation, positive end expiratory pressure (PEEP) can be added to the ventilated or dependent lung and the tidal volume adjusted. The anesthesiologist must realize that for an efficient surgical procedure to be performed safety and hemodynamic stability must be the goal of the patient management. The arterial partial pressure of carbon dioxide ($PaCO_2$) is often elevated during the course of the procedure and we attempt to keep it less than 70 mmHg and avoid acidosis by adjusting the minute ventilation and the insufflation CO_2 pressure. The robotic technique may need to be aborted if the patient is unable to tolerate it.

At case completion, we typically provide intravenous ketorolac and/or acetaminophen and provide intercostal bupivacaine blocks to cover the appropriate dermatomes. We have attempted to provide further pain control with extrapleurally and paravertebrally placed catheters infusing bupivacaine. We have found no improvement in postoperative pain by using continuous bupivacaine infusion. Given the fact that the pain management is good to excellent in the vast majority of the patients, epidural catheters are utilized only in those patients that the typical plan for pain management will be compromised, such as those patients that have previously demonstrated in other surgical procedures to be under-treated for pain or those that might have more-than-usual pain, such as with an additional chest wall resection, intercostal muscle flap or particularly large tumors that would be difficult to extract between the ribs, larger than 4–5 cm.

4.4 Stepwise Conduct of the Operation

In preparation for a robotic lobectomy, adequate time should be given for procedure planning, accurate port placement and patient positioning. Failure to address these aspects can result in an inefficient and frustrating case. The chest computed tomogram and the topographical anatomy are used for port position planning. The novice robotic surgical team should make a point to select patients with peripheral lung lesions that are less than 2–3 cm in size and who have had no prior thoracic surgical procedures and no evidence on chest tomogram evidence of pleural symphysis. It is recommended that for the early series of robotic cases, the surgeon should have the same anesthesiologist and scrub/circulator nursing team; the team learns as a group. Prior to the case beginning, there should be a clear plan amongst the team concerning the potential disaster scenario where conversion to open thoracotomy may be necessary. A ring clamp with 2–4 pieces of collagen fabric (Surgicel® is an example) (Fig. 4.2) and a thoracotomy tray should be available should there be an emergency.

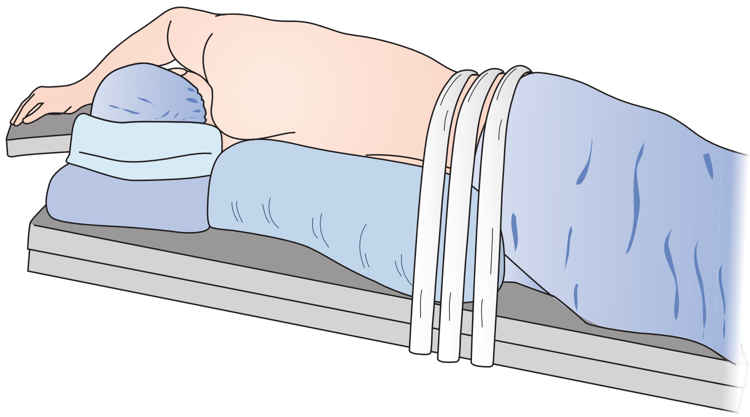
We start our cases with flexible bronchoscopy either through a single-lumen endotracheal tube or prior to intubation under conscious sedation prior to the placement of the endotracheal tube. Once we verify that the patient has no untoward finding that would prevent us from performing a minimally invasive lung resection, the patient is prepared for single lung ventilation with an appropriate endotracheal tube. Cervical mediastinoscopy is not uncommonly performed prior to the initiation of the robotic procedure; we have found that robotic upper lobe dissection may be enhanced by mediastinoscopy-directed dissection. After the mediastinoscopy is completed and it is confirmed that there is no significant mediastinal pathology that would prevent the patient from having a beneficial anatomical lung resection, the patient is placed in the lateral decubitus position (Fig. 4.3). As tolerated, all the patients will be positioned in a reverse Trendelenburg fashion allowing for the diaphragm and the intra-abdominal contents to drop away from the operative field, allowing improved exposure, and allowing for any bleeding that might occur to collect away from the operative filed in the lower aspect of the thorax. For upper and middle lobectomies, the patient position is rotated approximately 30° posteriorly, allowing the lung to fall away from the hilum. For lower lobectomies, rotation is approximately 30° anteriorly to allow the lung to fall anteriorly, exposing the posterior hilum.

Fig. 4.2 Prior to the case initiation, **2–4 Surgicel® pieces are fixed in a surgical ring clamp** in preparation for any bleeding. There should be discussion amongst the team about the worst case scenario, how potential bleeding might be controlled, the robot undocking, and the moving the robot out of the way, the location of the equipment for emergency thoracotomy and who will be the individual to maintain pressure on the bleeding while the thoracotomy is being performed. Should surgical bleeding occur, the robotic surgeon can grasp adjacent lung and compress it over the bleeding site while the bedside surgeon places the ring clamp-Surgicel into the chest for compression of the bleeding. We recommend that the axillary port be the portal of entry for compression, the thoracoport is removed prior to enlarging the incision with Mayo surgical scissors and inserting the ring clamp-Surgicel

The preoperative chest tomogram and the topographical anatomy of the chest wall, the accurate location of the hilum in relation to the sternal angle and the tip of the scapula are identified and marked with indelible ink on the chest wall prior to sterile prepping of the chest. For this robotic lung lobectomy, the target of which the robotic instrumentation is focused is the hilum, typically, a 4 cm circle that covers the distal tip of the scapula. Then, six other marks are made on the chest wall to estimate the location of the thoracoports to be placed (Figs. 4.4, 4.5, 4.6, 4.7, and 4.8).

As described previously, the chest wall is marked prior to prepping the chest and placing the surgical drapes to create the surgical field. Then, after placing the drapes, the ports are placed, the robot is brought into position and the bed position is adjusted as described. For chest wall marking of the upper and middle lobes, see Figs. 4.4 and 4.5 for a diagram and explanation of placement, one for the right and Fig. 4.7 for the left side. For the lower lobes, see Figs. 4.6 (right side) and Fig. 4.8 (left side).

Once the ports are marked with an indelible marking pen, the chest is prepped and draped in the usual sterile surgical fashion. We then place the thoracoports. Prior to placing



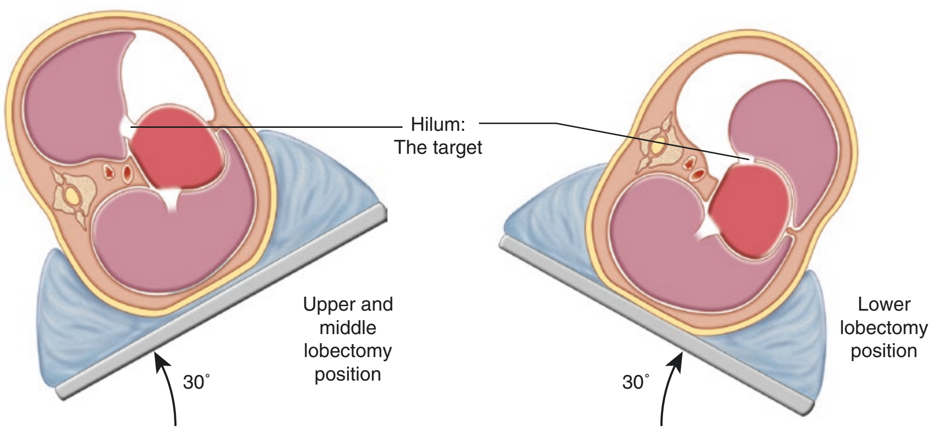


Fig. 4.3 **Patient position for a robotic lobectomy**. For the robotic lobectomy, we place the patients in the lateral decubitus position and strap them to the bed with 3–6 in. adhesive tape wrapped around the table and the patient's greater trochanter to prevent the patient from falling off the bed and maintaining position throughout the case, and, then, in reverse Trendelenburg; for upper and middle lobes, the patient is rotated 30° toward posterior and for the lower lobes, they are rotated 30° anterior. This bed position is often made after the robot chassis or bed side cart is brought over the patient in position, as it may be difficult to bring the robot into position once the patient is in Trendelenburg. For patients with particularly large hips, more Trendelenburg or breaking the table at the waist may help optimize exposure

each of the thoracoports, we inject 0.125% bupivacaine with epinephrine at each site; we believe that it helps to reduce postoperative pain and appears to reduce the local bleeding associated with port placement. We refrain from using electrocautery in these locations as it appears to increase pain and scarring. Among the six port sites marked, the first port to be placed is usually the camera port or **Port A**. However, in the obese patient the diaphragm may be quite high, minimizing the distance between the chest wall and the diaphragm and increasing the likelihood for diaphragm injury during port placement; in which case, we recommend using **Port F** or the axillary port as the first port to be placed. The pathology or CT-guided anatomy may also dictate the first port placement; large anterior tumors may require that the first port to be placed might be posterior port or that instead, a 5-mm thoracoport and thoracoscope might be used to assess the intrathoracic anatomy and guide port placement. After injecting the local anesthetic, as described, we then make an incision typically transversely or within Langer's Lines in the area around the patient's breast. We then use a Tonsil clamp and a very carefully insert the tip of the clamp just over the most cephalad aspect of the adjacent rib while the ventilator has been completely turned off. Wide spreading of the clamp should not be performed reducing the likelihood for intercostal injury and potential bleeding and nerve injury. The thoracoport is then carefully placed into the incision. Before introducing carbon dioxide, the intrathoracic location of the port should be confirmed; there have been reports of inadvertent carbon dioxide insufflation into vascular structures. Once carbon dioxide is insufflated into the pleural space, the videoscope is inserted into the scope and is used to guide further port placement. The remaining ports are placed in a similar fashion with injec-

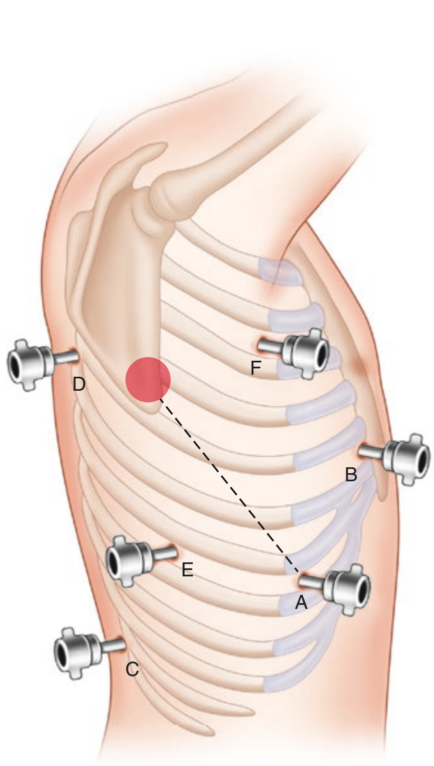


Fig. 4.4 **Port placement for the right upper and middle lobectomy**. Four 12-mm thoracoports are placed in the following fashion (**ports A, C, D, and F**). The Target for the routine lobectomy is the hilum. The topographical approximate location is drawn in the patient's chest wall and is approximately a 4 cm circle is approximately 2 cm cephalad the tip of the scapula. First the camera or video port, port A is in the seventh intercostal space, just cephalad to the eighth rib in the anterior axillary line. We marked a 12 mm indelible mark at this location. A faint indelible line is drawn between the target and this port site. **Port B** is placed in a submammary location just cephalad to the sixth rib, the fifth intercostal space. **Port C** is placed in the seventh intercostal space, just cephalad to the eighth rib in the posterior axillary line to just anterior to the anterior line of the scapula. **Ports B and C**, both 8 mm robotic ports, should be approximately 10–14 cm away from the line between port A and the Target. The second 12 mm port, **port F**, is placed in the second intercostal space, just cephalad of the third rib and in the anterior axillary line, in the same line as **port A**. The third 12 mm port, **port C**, is placed in the ninth intercostal space, just cephalad to the tenth rib and at the most anterior border of the posterior longitudinal muscle of the spine. The final port and the last 12 mm port, **port D**, is located approximately 3–4 cm posterior to the edge of the scapula and at the upper most portion of the level **of the target**. **Port A—Camera Port**, a 12-mm port. **Port B and E**—both 8-mm port, ProGrasp, Cadiere, Bipolar Maryland, Harmonic, Needle holders, Clip Appliers, Hem-o-Loc, hook cautery. **Port D**—a 12-mm port, Forrester Ring Clamp to serve as an atraumatic clamp that can gently and in an atraumatic manner grasp the lung and expose the hilum, otherwise same as **Port F**. **Port C**—12-mm port, 5- and 10-mm minimally invasive Endograspers, Needle Holders for grasping and delivering sutures up to an SH and CT-1 size needles, Endopeanuts, Endosuctioning, endostaplers. **Port F**—The Axillary Port, a 12-mm port, same as Ports C and D, but is chosen because of the particularly wide intercostal space and at the end of the procedure, the interspace pleura is incised with cautery to pull the bagged specimen out of the chest

tion of bupivacaine with epinephrine, an incision and then directly placing the ports under thoracoscopic view to avoid injury the intercostal bundle. Once the ports are placed, the patient is positioned; all patients are positioned in a reverse Trendelenburg fashion and for the upper lobes are rotated towards her back approximately 30° and for lower lobes are rotated towards the front approximately 30° (Fig. 4.3). The robot is then brought in over the head for the lower lobes and for the upper lobe patients approximately 30–40° off center over the head and towards the patients back as noted in Figs. 4.5, 4.6, 4.7, and 4.8. For the S and Si Intuitive Surgical Systems (ISI), the view is between the camera and the base of the robot; the Xi ISI is not as restrictive. The robotic arms should be set to minimize instrument conflict.

Instrument choice is surgeon dependent. For the novice robotic surgeon, it might be helpful to place the ProGrasp or the Cadiere grasper in the leftward or #2 arm and the Harmonic Scalpel or Hooked Cautery in the rightward or #1 arm. We use a Forrester ring clamp or, alternatively a Landreneau ring grasper (Teleflex Medical; Weck Corporation., Triangle Park, NC) to grasp the lobe just laterally to the hilar location where the surgery is to begin, 3–4 cm away from the hilar structures into the pulmonary parenchyma. Once set to the ideal location to provide the best visibility is rarely moved during the case. The weight of the instrument typically provides sufficient traction and is usually unnecessary to provide any additional retraction during the procedure; the assistant should let the clamp sit at rest. For the upper and middle lobes, the grasper is brought through the posterior-superior port or **port D** and, for lower lobes is brought through the upper anterior-superior port or **port F**. The goal is to provide exposure and counter-tension for dissection. Even friable lung can be grasped with the atraumatic graspers with little, if any, damage to the lung.

Once the instrumentation has been placed into the robotic arms, the procedure is ready to be performed. Grasping the lung or hilar structures that are friable with any of the robotic grasping instruments such as the ProGrasp or the Cadiere should be avoided or at least minimized to reduce the risk of injury or bleeding. For the upper lobes, the pulmonary veins are typically taken first. For the right upper lobe the pulmonary artery blood supply branches are taken next, exposing the right upper lobe bronchus. For the lower and middle lobes, the bronchus is taken after the vein is taken. For the left upper lobe, the first main pulmonary artery branch to the upper lobe is taken after the vein that allows exposure of the left upper lobe bronchus; the remaining pulmonary artery branches to the left upper lobe are then taken. Taking the vein first may have some oncologic benefit, reducing the likelihood for pulmonary venous metastasis during lung/tumor manipulation. There is no credible evidence that it results in the pulmonary edema by preventing venous outflow during the course of a lobectomy.

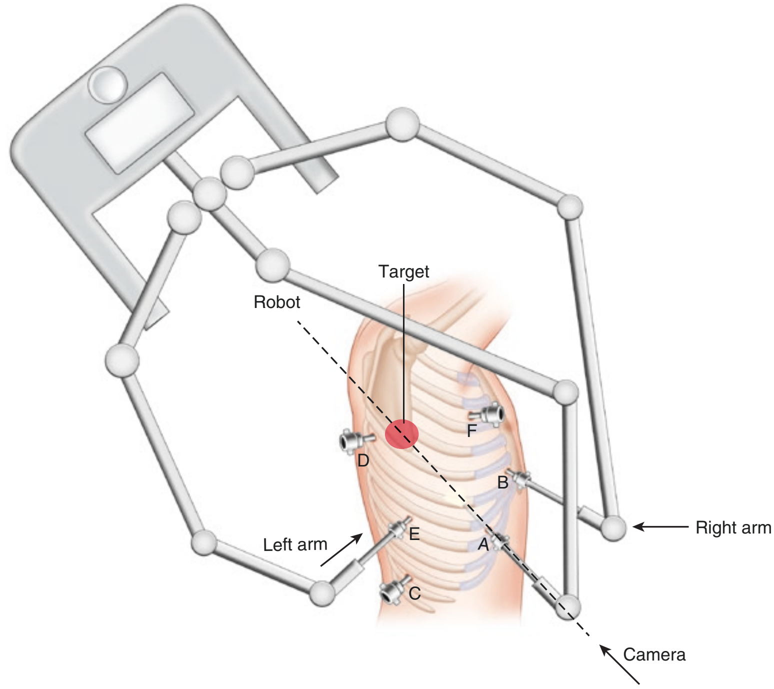


Fig. 4.5 Right upper and middle lobectomy port site setup with the bedside cart in place

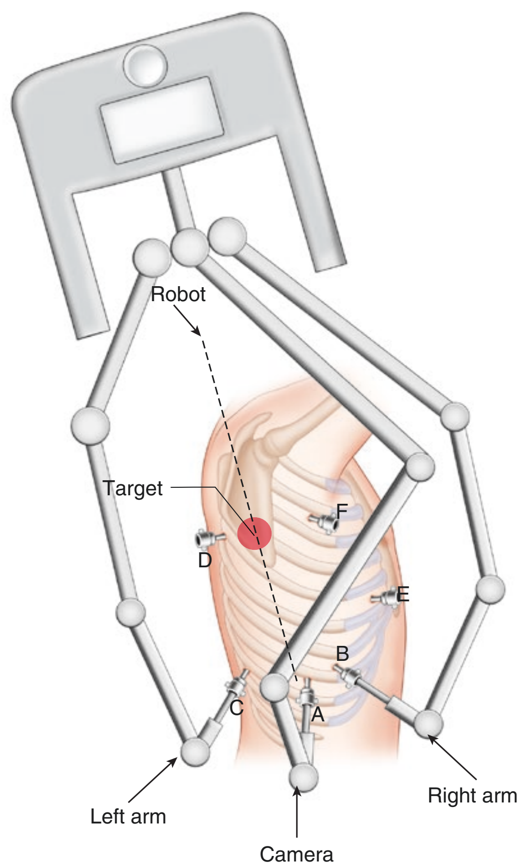
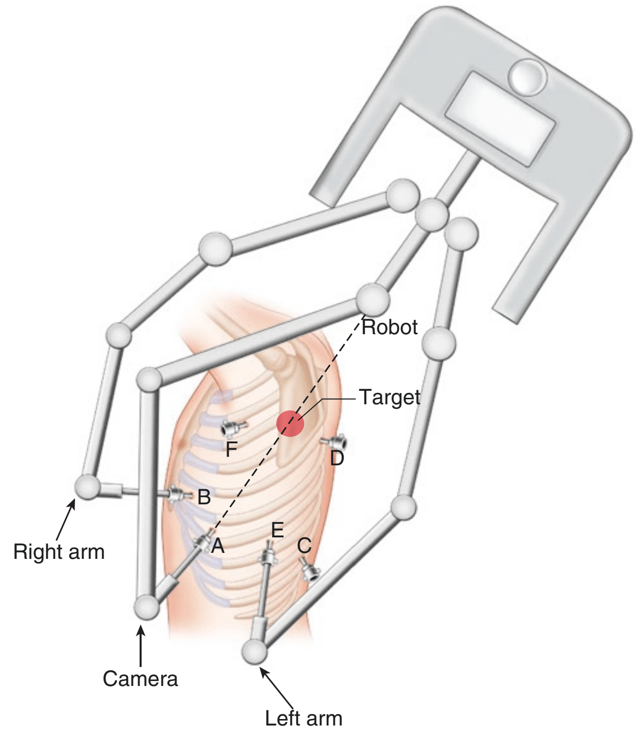


Fig. 4.6 Right lower lobectomy port site setup

Fig. 4.7 Left upper lobectomy port site setup



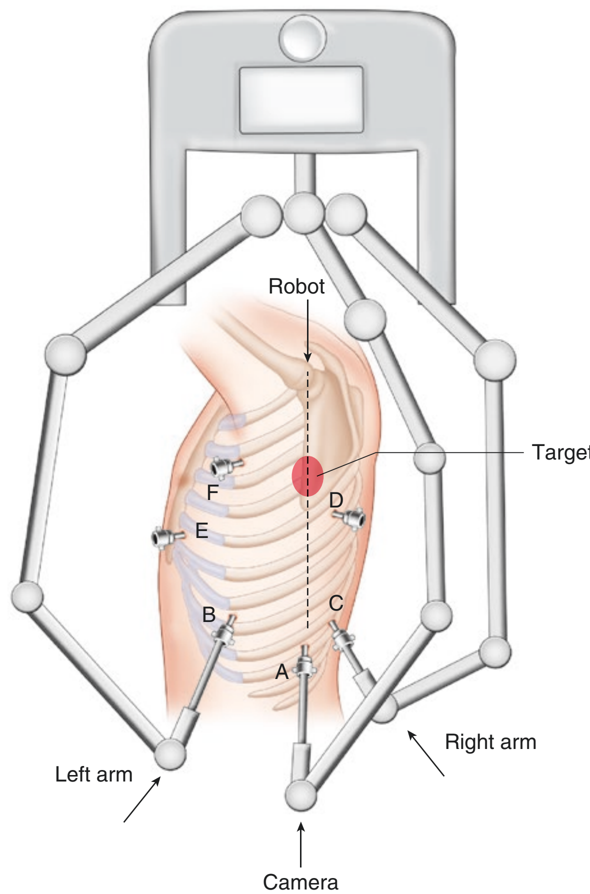


Fig. 4.8 Left lower lobectomy port site setup

4.4.1 Right Upper Lobectomy (Figs. 4.9, 4.10, 4.11, 4.12, and 4.13)

We prefer a 0° scope that allows for a much wider view than the 30° scope. Dependent upon the robot used, the surgeon should set the operating console to a normal view and movement and turned off the "fourth arm" and make certain that the video view is set appropriately to either 0° or 30° down, whichever has been chosen. As stated, in the left arm, the ProGrasp is placed and in the right arm, the Harmonic Scalpel. A general examination of the mediastinum and chest is performed, in addition to what was seen during the placement of the ports and initiation of the procedure. The operative view is then focused on the upper hilum. Once sufficient exposure has been achieved the focus is on the upper mediastinum, avoiding injury to the phrenic nerve and superior vena cava, the harmonic scalpel is used to divide the mediastinal pleura maintaining a distance of approximately 1 cm away from the phrenic nerve and only brief pulses of the harmonic scalpel to avoid lateral heat injury to the nerve. The dissection is continued superiorly along the superior vena cava and azygous vein. A ProGrasp is used to sweep the tissue cleanly away from the proximal pulmonary vein. Effort is made to identify the bifurcation between the right middle and right

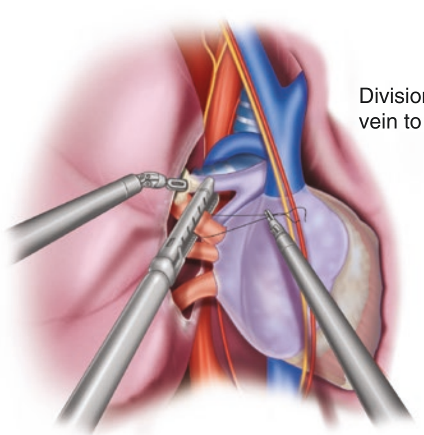


Fig. 4.9 At the start of the upper lobectomy**, the superior pulmonary vein to the right upper lobe is divided** by passing a stapler through **port C** and the adjacent nodal tissue is taken *en bloc* with the lobe. Care should be taken to avoid injury to the middle lobe vein, immediately adjacent to the superior pulmonary vein

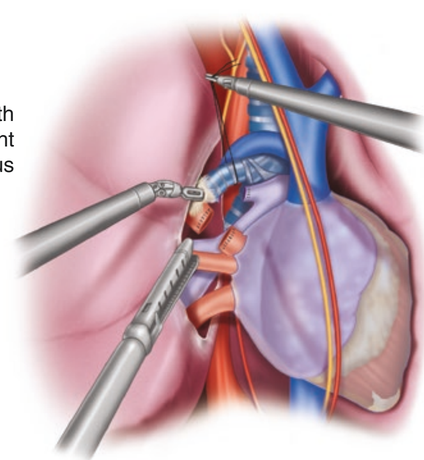


Fig. 4.11 After **division of the recurrent branch of the pulmonary artery to the right upper lobe** and clearing of the hilar tissue between the right upper lobe and the bronchus intermedius, the right upper lobe bronchus is divided with a tissue endostapler flush with the right main stem bronchus and passed through **port C**

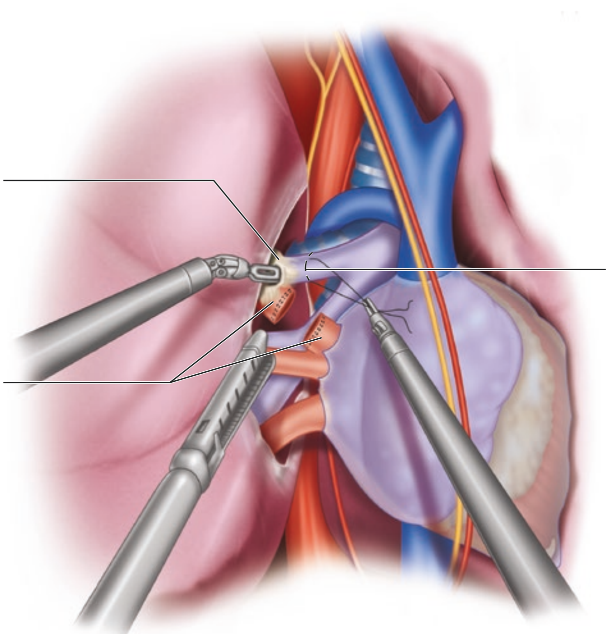


Fig. 4.10 After the lymphatic tissue is dissected away from the pulmonary vasculature, **the pulmonary arteries to the upper lobe are divided with a vascular stapler passed through port C**

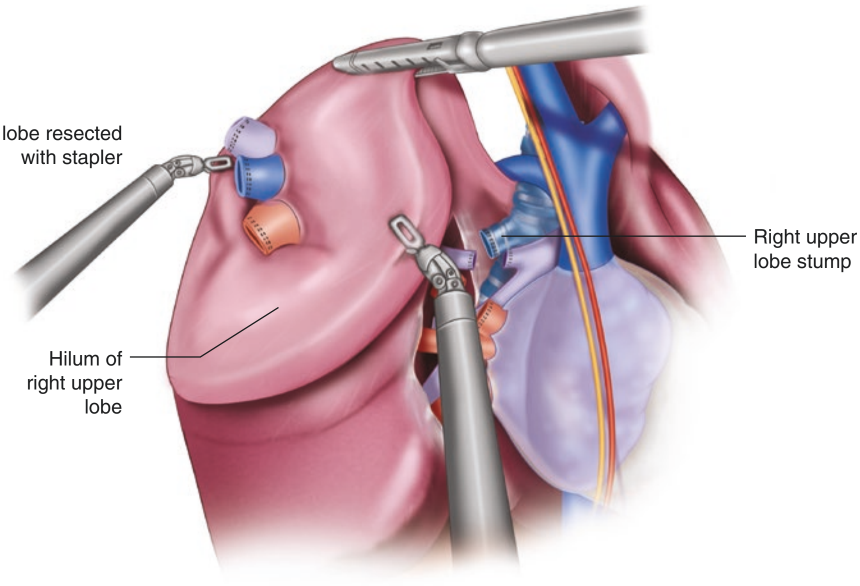


Fig. 4.12 The **minor fissure is divided** between the upper and middle lobe by passing a tissue stapler through **port D** to divide the posterior aspect of the fissure and, if necessary, through **port F** or **port C** to divide the anterior aspect of the fissure. Make certain that the fissure is taken flush with the vasculature in the hilum and the bronchus and any malignant pathology are sufficiently away from the staple line

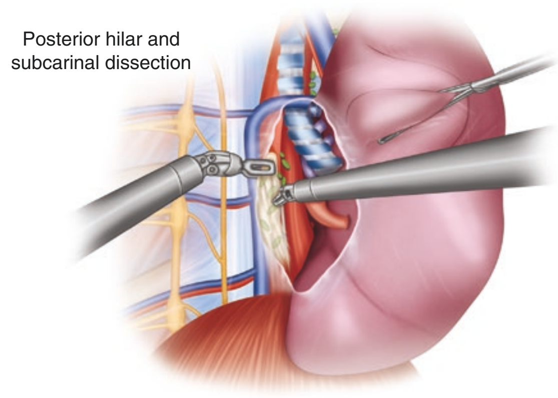


Fig. 4.13 For the lower lobectomy, the **subcarinal tissue is resected** at the start of the case to provide exposure to the main stem bronchus and the pericardium. The lung is retracted anteriorly and the Harmonic scalpel or hook cautery is used. The right paratracheal lymphatic tissue is resected in a similar fashion cleanly from the trachea and the superior vena cava

upper lobe veins within the superior pulmonary vein complex. Using the ProGrasp and harmonic scalpel, hilar tissue is dissected away from the upper lobe vein preserving the middle lobe vein and lifting the vein away from the intermedius and middle lobe pulmonary arteries, grasping the vessels should be avoided. The hilar tissue is bluntly swept toward the resection specimen, clearing the pulmonary artery and the under-aspect of the right upper lobe vein. We strongly encourage that time should be taken to visualize the vein as this is a common site of vascular injury and taking time to perform a thorough posterior dissection will avoid injury and bleeding. Further dissection is performed along the inferior and under aspect of the azygous vein cleaning the adjacent pulmonary arteries and exposing them. The ProGrasp is used like a spatula to push the tissue toward the resection specimen. There are times when the lymphatic tissue is so prominent that it requires complete resection of the lymphatic tissue at those locations to provide better exposure. In that case the completely resected tissue can be removed through **ports D, E, and F**. With the harmonic scalpel the lack of articulations may make it difficult for the novice robotic surgeon to perform the dissection around the pulmonary arteries. Instead, a hook cautery may be used, using it like a right angle to lift the tissue away from the pulmonary artery making certain that it does not injure the pulmonary artery with this maneuver potentially resulting in damage to the pulmonary artery. Then, an 8 cm 0 silk tie is passed into the operative field and placed around the right upper lobe pulmonary vein using it to lift the vessel away from the underlying pulmonary artery. From **port C** a vascular load endostapler is then used to transect the pulmonary vein (Fig. 4.9), one should be especially careful with this maneuver to not partially or completely transect, or narrow the right middle lobe vein. After the pulmonary vein has been ligated, it is not uncommon to need to adjust the upper lobe retracting lung grasper, be it a Landreneau or Forrester clamp. Once this has been completed, the next step is to identify and clean the main pulmonary artery trunk and the right upper lobe branches to expose them for transection. The cephalad aspect of the pulmonary arteries is cleared of hilar tissue and, using the ProGrasp to sweep and grasp non-vascular tissue, the truncus branch pulmonary artery and the recurrent branch are taken back to its junction with the main pulmonary artery, both being cleanly exposed (Fig. 4.10). Each should be identified at its origin and ligated the vascular endostapler (Fig. 4.11), exposing the lymphatic tissue just anterior to the main stem bronchus. In this location it is not uncommon that small tributary pulmonary artery branches may be encountered here; the harmonic scalpel on slow speed may be used to take these vessels. More than one recurrent branch pulmonary artery to the right upper lobe may be encountered as well. The main recurrent branch is located at the inferior aspect of the right upper lobe bronchus and bronchus intermedius junction. Once this vessel is taken, it provides exposure of the right upper lobe and bronchus intermedius junction; cleaning this very well will allow the eventual encircling the proximal right upper lobe bronchus using the ProGrasp. In the rare case that the ProGrasp is not easily passed around the bronchus, the Landreneau or Forrester lung grasper is released and through **port F**, the lung is grasped and retracted anteriorly to expose the posterior aspect of the right upper lobe bronchus. The ProGrasp and the harmonic scalpel are used to identify the posterior pleural and lymphatic tissue, and are taken; bronchial arteries discovered in this location and the blood supply and membranous airway should be preserved if there is no malignancy here. To expose this area, it is sometimes necessary to divide the upper aspect of the major fissure with a tissue endostapler through **port D**. Also in this location, the subcarinal lymph nodes can be identified and cleared from the subcarinal. When taking these nodes, care should be taken to preserve the blood supply to the posterior right main stem and right upper lobe bronchi. Once the airway has been sufficiently cleared, the 8 cm 0 silk is passed around the bronchus as it was for the vessels and clamped at the base of the bronchus with a tissue stapler. It is important not to fire the tissue stapler right away; first, the bronchus intermedius should be examined and if it is not clearly seen, then the right main stem bronchus and bronchus intermedius should be sufficiently exposed to demonstrate that the bronchi are not kinked or narrowed and to make sure that the stapler around the right upper lobe bronchus is flush with the main stem bronchus. The lung can be inflated at this point to demonstrate that the lower and middle lobes are not obstructed. Once divided, the bronchus or adjacent peribronchial tissue is grasped with the ProGrasp and is retracted inferiorly exposing more lymphatic tissue along bronchus intermedius; clearing the tissue from the bronchus to the major fissure. At this location, the major fissure can be hard to discern, the parenchyma of the right upper lobe and the superior segment can seem continuous.

Once the hilar structures are taken and the hilum is thoroughly cleared of lymphatic tissue, the fissure is divided with tissue staplers Fig. 4.12 passed along the angles of presentation through **ports C, D and F**; for patients with friable and/or emphysematous lung tissue, a covered biocompatible mesh endostapler is used to reduce postoperative air leak. Once completely separated, the lobe is placed away from the operative field and remains in the chest until case completion.

Next, further lymph node resection is performed. First, the anterior aspect of the bronchus intermedius and right main stem airway are examined for additional lymphatic tissue. The ProGrasp is used as a spatula to gently retract the pulmonary artery form the main stem bronchus, creating a plane along the pulmonary artery into the mediastinum. Then through the assistant port, a soft endopeanut is inserted through **port C or port F** to retract the pulmonary artery anteriorly. The ProGrasp and the Harmonic are then used to grasp and resect the lymphatic tissue from the anterior aspect of the airway. Once the airway is completely cleaned of lymphatic tissue, the packet of lymphatic tissue is removed. The subcarinal lymphatic tissue can be resected deep in this location, anterior and inferior to the carina. Then, the dissection can be performed in the subazygous location, removing the 10R lymph node packet; beneath the azygous and posterior to the superior vena cava, the lymphatic tissue is grasped and retracted posteriorly, exposing the posterior wall of the superior vena cava. The Harmonic scalpel is used to create a plane along the vena cava well into the mediastinum. Once this is completed, the deep aspect of the dissection along the superior aspect of the right main pulmonary artery and to the leftward side of the mediastinum and then along the anterior and rightward aspect of the trachea. This last maneuver may require switching the ProGrasp and the Harmonic scalpels to achieve the necessary angles of dissection. Complete resection of 4R is accomplished and may be performed with or without division of the azygous vein and the mediastinal pleura. Level 2R or the upper paratracheal lymphatic tissue may be additionally resected, but this should be done with great care to avoid injury of the right recurrent laryngeal nerve where the nerve crosses the origin of the subclavian artery with the innominate artery.

For patients with a nearly complete fissure between the middle and lower lobe and to prevent middle lobe torsion, we perform a pexy using a knifeless tissue stapler through port C stapling together in 1–2 peripheral locations between the peripheral aspect of the inferior aspect of the middle lobe to the periphery of the inferior and lateral aspect of the lower lobe. Too, we do not routinely divide the inferior pulmonary ligament, but do take the pulmonary lymphatic tissue in this location. However, in patients with particularly large right upper lobe tumors, the space left behind may be quite large and result in a persistent pleural space. In those situations taking the inferior pulmonary ligament may allow sufficient mobilization of the lung to fill the apical space avoiding space problems later.

Once all of the lymphatic tissue stations are removed and the lobe completely resected, we place a hook cautery into the left or #2 arm, **port E,** and divide the intercostal pleura and adjacent muscle for an 8–10 cm area along the superior aspect of the rib adjacent to **port F**, the port site planned to remove the lobe; avoid injuring the intercostal bundle and the adjacent periosteum. Once a sufficient intercostal incision has been made, a retrieval bag is passed into the chest through **port F**, there are two of which that we have had significant experience, the Anchor Bag (http://dev.thethreelionsden.com/tissue-retrieval-system/) and the Espiner Bag (http://www.espinermedical.com/). Both bags are made of particularly strong material that does not break or tear and are air and water tight and have a system to completely cover the mouth of the bag for easy removal minimizing the likelihood of spillage. The specimen is placed into the endobag and pulled up into **port F** incision site; the port is often removed prior to this point to allow placement of the endobag. Prior to removal, we suction all debris from the hilum and pleural space and examine for any evidence of bleeding. Once we are satisfied with hemostasis, we fill the pleural space hilum with body temperature saline and ventilate, the bronchial stump is examined for air leak. If there is an air leak, which there rarely is, then we use needle holders in the two robotic arms and place 1–2 simple sutures of 4–0 Prolene on an SH needle or 5–0 Prolene on an RB-1 needle; before passing it into the chest through a port, the suture is cut to 6 cm in length. We recheck the stump for air leak again after performing the repair. The saline is suctioned into a new canister into which 5000 units of heparin has been placed. The canister is sent for post-resection pleural lavage cytology.

In patients in whom we are concerned about the healing and/or blood supply of the bronchial stump or who are likely to receive adjuvant radiation therapy, the stump and adjacent airway is covered with a vascularized pedicle of tissue; our preference is the thymus. Low on the inferior pericardium near the diaphragm using the ProGrasp and the Harmonic scalpel, we clean a wide swath of thymic/anterior mediastinal tissue off of the pericardium and up to the level of the innominate vein. This wide fatty tissue is then used to completely cover the stump and is sewn into place with numerous peribronchially and perihilarly placed 3–0 Vicryl sutures on SH needles in 6–8 cm lengths. As an alternative, we have also performed a wide resection of intercostal muscle and intermammary tissue to provide coverage and extra blood supply to cover the bronchial stump.

The endobags suggested are tough allowing us to remove fairly large tumors. To optimize cosmesis, we attempt to keep the skin incision fairly small, usually 3–5 cm in size, and allow the skin and incision to stretch when removing the bag containing the large specimen. During this time a fair amount of effort is necessary to withdraw the bag, so much so that the anesthesiologist and circulator nurse must hold the patient down onto the operating room table and to prevent dislodging the endotracheal tube. Once removed, the axillary port is packed with a saline soaked laparotomy pad to maintain CO_2 pressure for the remainder of the case.

The robot is undocked at this point. Do not yet remove the sterile covering from the bedside cart. The lung and hilum are again examined for any damage or areas of concern. Once satisfied with the completion of the case, we then inject bupivacaine 0.125% with epinephrine from approximately T2-T10 2–4 cm from the spine using a mediastinoscopy 21 gauge aspirating needle, 5–10 mL into each intercostal space. Then, through two of the port sites, we place a 24 or 28 Fr. French Argyle chest tube to the apex of the chest, accounting for the lung expansion and the curvature of the chest wall, and then through the other chosen port site we place a 19 Fr. round Blake drain, also to the apex of the chest cavity. Both are sutured into place at the skin with 2–0 long nylon that is placed into the port site incision in a vertical mattress fashion, so that when the drain is eventually removed that it pulls the port site incision closed and prevents the egress of pleural effusion and/or entry of air into the chest and provides a good cosmetic approximation of the port site incision. The remaining wounds are closed with 1–2 simple inverting 3–0 Vicryl sutures on SH needles. The port F site or wound where the lobe was removed is closed in 1–2 layers with interrupted and running absorbable sutures. Tegaderm® or Dermabond® dressings are applied to all wounds and Tegaderm® sandwiched around the two drains.

Key features for the immediate postoperative care include keeping the head of the bed elevated at all times. Patients do not eat or drink until the next morning and only when they are able to sit up in a chair and eat under their own volition. There is no drinking or eating in bed to minimize the risk of aspiration. Intravenous and oral fluids are restricted to less than 1.5 L/day for a 70 kg person. Ambulation is initiated early, best on the same day. We give the patient a dose of ketorolac 30–60 mg IV at completion of the case and then 30 mg IV every 6 h. Incentive spirometry is performed every 1–2 h while awake 10–20 times to a target of 1–1.5 L. For patients at risk for bronchospasm, we give them 100 mg of solumedrol at the beginning of the case and routine nebulized bronchodilators afterwards. For patients considered high risk for postoperative supraventricular tachycardia and atrial fibrillation, we give them amiodarone on induction according to the protocol of Tisdale et al. (2009). From the 20 cm H_2O suction the Argyle is placed on water seal at 4 AM and if by 8 AM, there is no dyspnea, no requirement of supplemental oxygen, no enlarging pneumothorax or subcutaneous emphysema on chest x-ray, and if the Blake bulb is holding suction, then the Argyle is removed and the patient is prepared for discharge home that afternoon. If not, the same process is repeated on the second day. If the Argyle is not removed by the third day and the patient is not dyspneic and there is no enlarging pneumothorax or subcutaneous emphysema and the Blake bulb holds suction, then a Heimlich valve is placed on the Argyle and the patient is discharged home. We see our patients in clinic in 5–7 days.

4.4.2 Right Middle Lobectomy (Figs. 4.14 and 4.15)

The patient, table position, ports and instrumentation are all the same as for the upper lobectomy. The Landreneau or Forrester ring clamp is brought through **port D** as for the

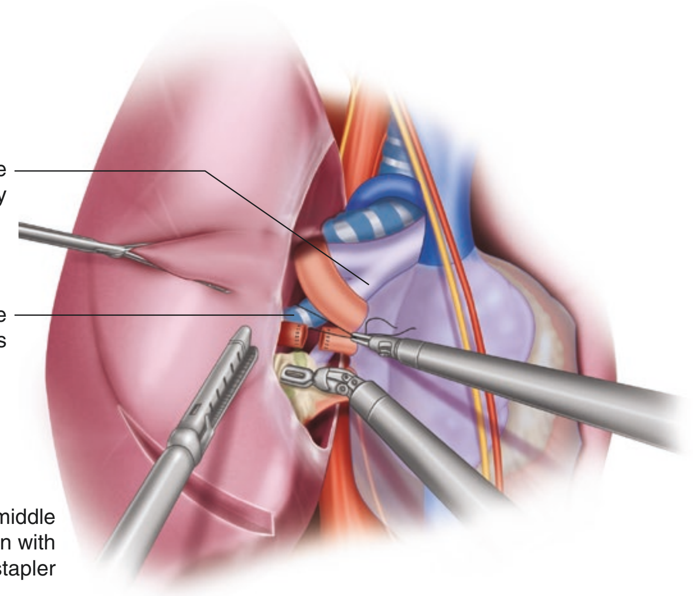


Fig. 4.14 At the beginning of the **right middle lobectomy**, the right middle lobe vein (RMLV) is identified and the lymphatic tissue is dissected away toward the middle lobe to be resected. A vascular endostapler is passed through **port C** to divide the vein. The right middle lobe bronchus (RMLB) and right middle lobe pulmonary artery (RMLA) can be seen deep to the divided vein

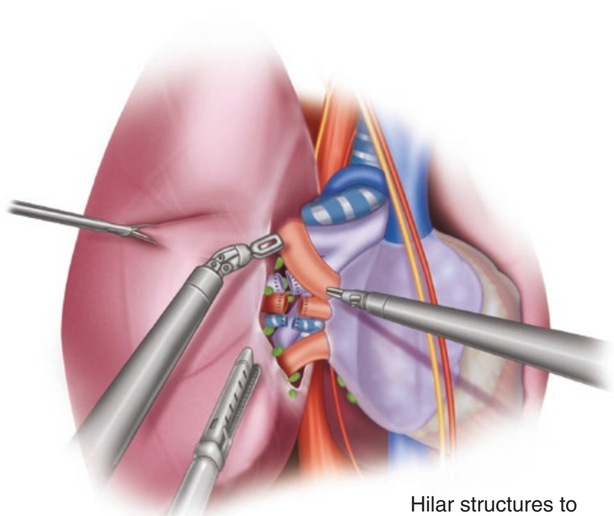


Fig. 4.15 The **right middle lobe vein is divided** first, then the bronchus and then, the pulmonary artery. All staplers for this resection is passed through **port C**. The fissure is divided by passing tissue staplers through **ports C and D**

right upper lobe and the lung parenchyma of the middle lobe is grasped to retract the lung away from the hilum and mediastinum, exposing the right middle lobe hilar structures. The phrenic nerve is identified and the hilar mediastinal pleura is incised with the Harmonic scalpel and then using sharp and blunt dissection the middle lobe vein is identified, it is usually the lowest aspect of the superior venous drainage complex. For the middle lobe, there is a single vein in almost all cases, but in patients with particularly large middle tumors there may be more veins, some draining to the upper lobe vein which should be carefully examined before division to avoid damaging the upper lobe venous drainage. The lymphatic tissue between the middle lobe and upper lobe veins is carefully dissected away to expose the veins. During the dissection of the lymphatic tissue in the hilum, the tissue is dissected toward the pulmonary parenchyma with great care taken to avoid injury to the middle lobe pulmonary artery traversing along the superior aspect of the pulmonary artery to the lower lobe. The dissection is continued into the hilum encircling the middle lobe vein. Hilar tissue from the middle lobe vein is cleaned from the pericardium. Once the middle lobe vein has been completely dissected away from surrounding structures, an 8 cm piece of 0 silk suture is passed around the vein and the vein divided with a vascular endostapler passed through **port C** (Fig. 4.14). Division of the vein exposes the middle lobe bronchus which is directly behind it and is orientated in the same direction as the vein. Resection of the hilar lymphatic tissue adjacent to the middle lobe bronchus and the adjacent lower lobe pulmonary artery exposes distal bronchus intermedius. At the upper rightward aspect of the exposure and coming from the main pulmonary artery is the middle lobe pulmonary artery obliquely heading into the parenchyma from that location. The ProGrasp and the Harmonic scalpel are used to dissect out the vessels and the bronchus and encircle the bronchus with the 0 silk suture. The middle lobe bronchus is then transected with a tissue endostapler passed through **port C (**Fig. 4.15). In some patients exposure to the bronchus may be difficult through **port C** and it may be necessary to divide with a tissue endostapler the most inferior aspect of the major fissure. At this point it may be necessary to adjust the Landreneau or Forrester ring clamp passed through **port D** to provide sufficient retraction to assess the remaining structures in the hilum. Lymphatic and areolar tissue is then dissected away from the pulmonary artery to the lower lobe potentially exposing 1–3 more pulmonary artery branches to the middle lobe, most major one that had been previously identified just posterior and inferior to the remaining upper lobe pulmonary vein. Each of these arteries is then ligated in the same fashion with a vascular endostapler, resecting the hilar tissue cleanly from the lower lobe/intermedius pulmonary artery. Once the pulmonary vasculature has been completely taken, the fissure is then completed as is described for the right upper lobe. Once the specimen has been completely separated, it is placed away from the operative area. As with the right upper lobe, the hilum and mediastinum are then examined and further lymphatic tissue is resected. Once an adequate lymphadenectomy has been performed, a bronchial leak test is then performed, as previously described. The mediastinum is covered with saline and the lung inflated. If any bronchial stump leak is found a 6 cm length stitch of 4–0 Prolene sutures on an SH needle or a 5–0 Prolene on an RB-1 needle is used to provide further support to the bronchial stump recheck for air leak and add more sutures as necessarily. The specimen is brought out through an endobag in the same fashion as with the right upper lobe.

4.4.3 Right Lower Lobectomy

Using the body position in Fig. 4.3, port placement is performed for the lower lobe as described in Fig. 4.6. In contrast to the upper lobe, the Landreneau ring clamp or the Forrester ring clamp is passed through **port F** rather than **port D**. The most inferior lateral aspect of the lower lobe is then grasped with the ring clamp pulling the lower lobe up exposing the inferior pulmonary ligament and keeping it on tension (Fig. 4.16). In the rightward arm of the robot, the harmonic scalpel is passed and in the leftward arm a ProGrasp, as it is for the upper lobe. The inferior pulmonary ligament is divided with all of the adjacent nodal tissue, completely cleaning the pericardium at this location and avoiding injury to the esophagus and the Vagus and phrenic nerves. The lung is then retracted anteriorly to expose the posterior aspect of the right lower lobe and its adjacent mediastinal and hilar lymphatic tissue and pleural reflection (Fig. 4.17). The tissue along the esophagus and the Vagus nerve is resected taking the hilar/mediastinal tissue with the intended specimen and exposing the inferior pulmonary vein along its posterior aspect. Some of the dissection is then performed anteriorly avoiding injury to the phrenic nerve. Once the inferior vein is encircled by an 8 cm 0 silk suture and the

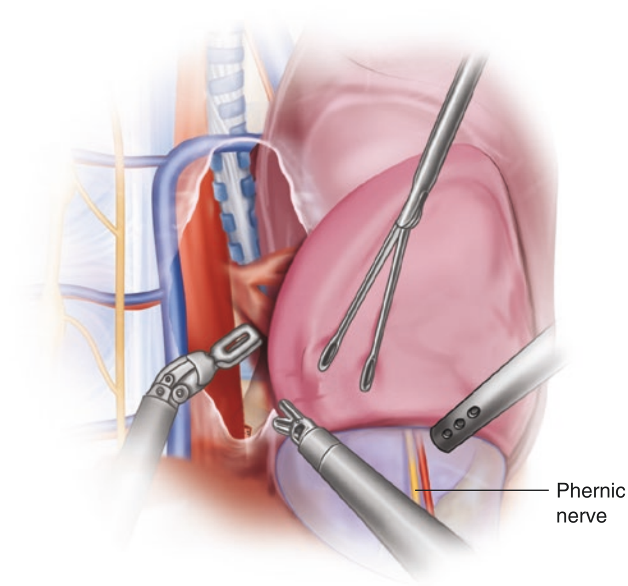


Fig. 4.16 **Right lower lobectomy**. Grasping with ring clamp through **port F** (from Fig. 4.6) of the lateral aspect of the lower lobe and exposing, on tension, the inferior pulmonary ligament. The Harmonic in the R arm (**port B**) is taking the inferior pulmonary ligament close and flush with the esophagus and the pericardium and the ProGrasp in the L arm (**port C**) pushing the tissue up toward the specimen to be removed

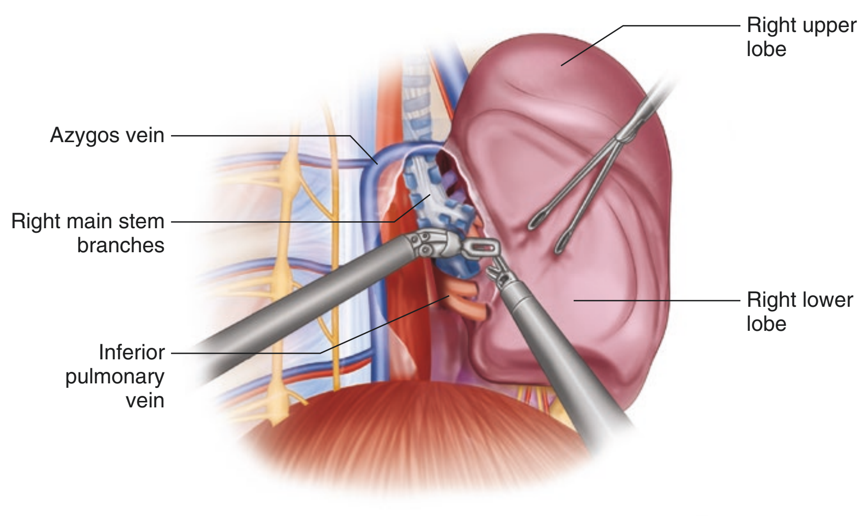
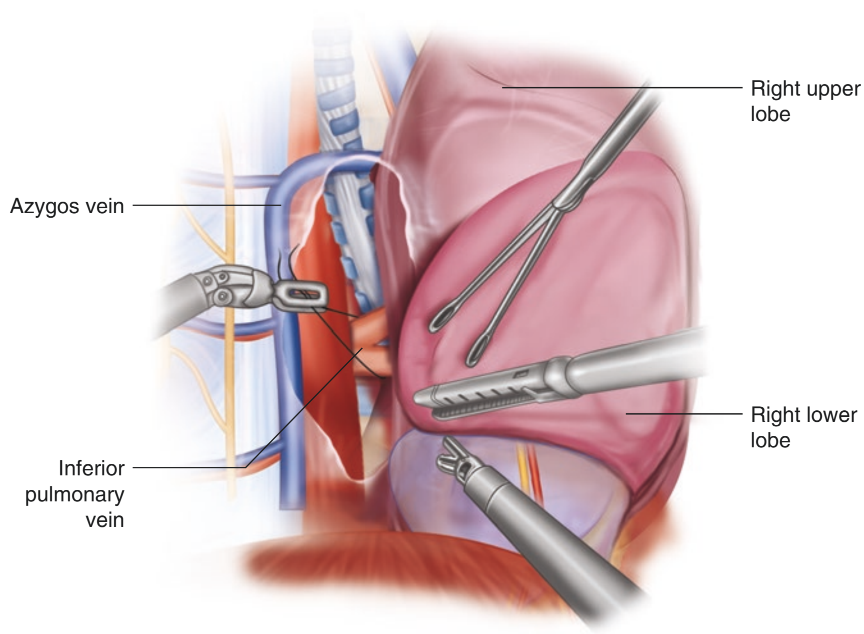


Fig. 4.17 **Right lower lobectomy. Exposure of the posterior hilum of the lower lobe**. The left arm is pushing the pleural reflection away from the bronchus, exposing the pulmonary parenchymal aspect of the lower lobe bronchus and a Harmonic being used to incise and create this plane separating the edge of the pulmonary artery just in the view from the airway

Fig. 4.18 **Right lower lobectomy**. **Division the inferior pulmonary vein** by passing a vascular stapler from **port E**. Both robotic arms working to lift the lung away from the pericardium assisting the passage of the stapler



right middle lobe vein confirmed, a vascular endostapler is passed through **port E** to divide the inferior vein (Fig. 4.18). Then, the subcarinal lymph nodes are resected by dissecting along the inferior aspect of the right bronchus intermedius up to the carina and deep along the pericardium, avoiding injury to the esophagus and the left main stem bronchus. Once resected, the subcarinal tissue is removed from the pleural space through one of the available thoracoports. The parenchymal envelope that covers the distal bronchus intermedius, superior segment and basilar segment bronchus is then dissected off the airway, exposing the medial aspect of the airway just cephalad to the superior segment bronchus. This dissection is continued well into the hilum so that the parenchyma and lymphatic tissue are off the bronchus. The degree of this dissection will set up the next maneuver, encircling the right lower lobe bronchus.

The ring clamp through **port F** is used to retract the lung posteriorly exposing the anterior hilum to allow complete resection of all of the lower anterior hilar tissue toward the lower lobe and to correctly identify the inferior aspect of the major fissure. This further releases the lower lobe from the pericardium. The lung is then retracted laterally and superiorly, toward the apex of the chest. This often exposes significant lymphatic tissue between the most cephalad aspect of the inferior pulmonary vein and the airways. This lymphatic tissue is then dissected off the airways exposing the bifurcation between the basilar segment airways of the lower lobe which in this location to straight up with the middle lobe bronchus is now to the right of the operative field at a right angle. There is often an enlarged lymph node (s) just at the bifurcation between the basilar segment bronchus and the middle lobe bronchus. Using the ProGrasp and the Harmonic scalpel the node is dissected off; inferiorly clearing and exposing the bifurcation between the two airways (Fig. 4.19). Once completely cleared it exposes the pulmonary artery to the lower lobe. Then, the dissection is performed between the basilar segment lower lobe airway and the lower lobe pulmonary artery carefully separating the two under direct vision with the Harmonic scalpel. After this is then completed, a ProGrasp is replaced in the location where the Harmonic scalpel had been, the rightward arm. The two ProGrasps are used to carefully pass along the plane between the bronchus and the pulmonary artery. A slow rocking motion will assist in this maneuver and avoid any injury. It is also possible to use the ProGrasp to retract the bronchus into position so as to see the plane that is being developed. A slow and continued movement will allow the passage of the rightward arm ProGrasp to pass around the bronchus and a silk suture is placed around it encircling the distal bronchus intermedius (Fig. 4.20). Once completed a tissue endostapler is then passed from **port E** to transect the right lower lobe bronchus, both the superior segment and the basilar segment bronchi. Once this is completed, it is often necessary to replace the ring clamp in **port F** so as to expose the right lower lobe pulmonary artery. The Harmonic scalpel is placed in the right arm again and any lymphatic tissue is dissected away from the pulmonary artery to expose it. Once the remaining pulmonary arteries are sufficiently exposed and encircled with the 0 silk, 1–2 vascular endostapler firings are necessary to resect these vessels (Fig. 4.21). The remaining major fissure is then completed in the same fashion as with the right upper lobectomy (Fig. 4.22). Again as with the right upper lobectomy the bronchial stump is covered with irrigant and

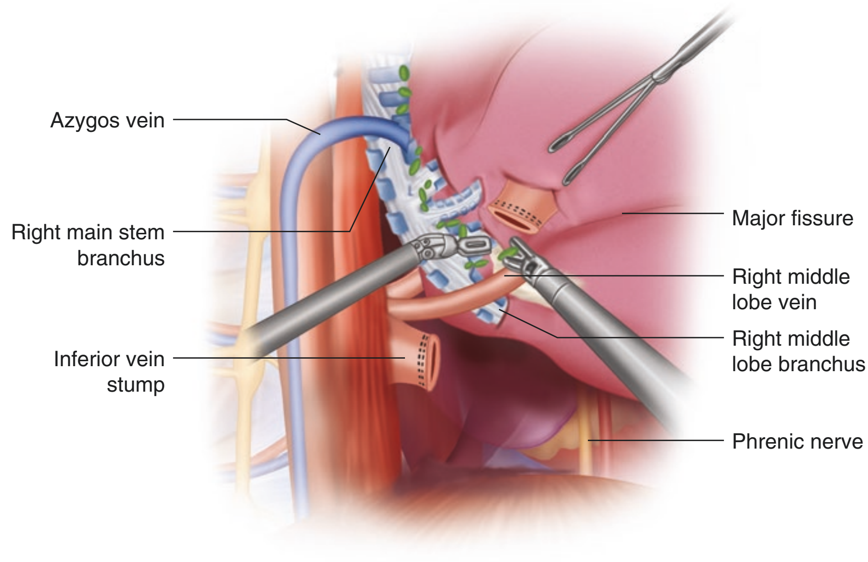


Fig. 4.19 Right lower lobectomy. Shows the under aspect of the lobe after the vein had been divided showing lymphatic tissue under the inferior pulmonary vein stump, exposure of the basilar bronchus coming to a right angle with the middle lobe bronchus. There is a lymph node station at the bifurcation of the lower lobe basilar segment and middle lobe bronchi covering the pulmonary artery. The lung grasper is used to expose this area. The ProGrasp in the left arm is used to grasp the lymph tissue covering the bronchi and the Harmonic scalpel in the right arm is used to tease the lymph tissue away from the bronchi and pulmonary artery beneath the covering lymph tissue avoiding heat or mechanical injury to the bronchi or the pulmonary artery

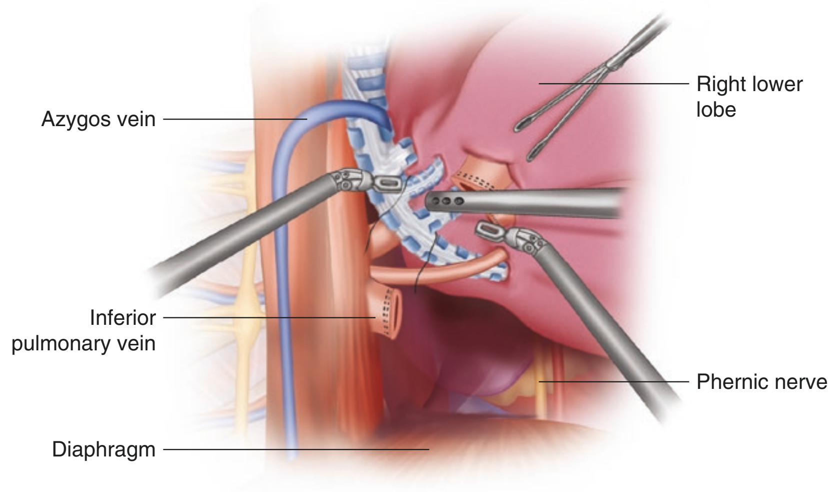


Fig. 4.20 Right lower lobectomy. **Isolation of the basilar and superior segment bronchi for division**. The right robotic arm is exchanged for a ProGrasp replacing the Harmonic that was there and under direct vision the blunt tip of the ProGrasp is used to tease the basilar and superior segment bronchi away from the pulmonary artery. A 0-silk suture is passed around the superior segment and basilar segment bronchus for division

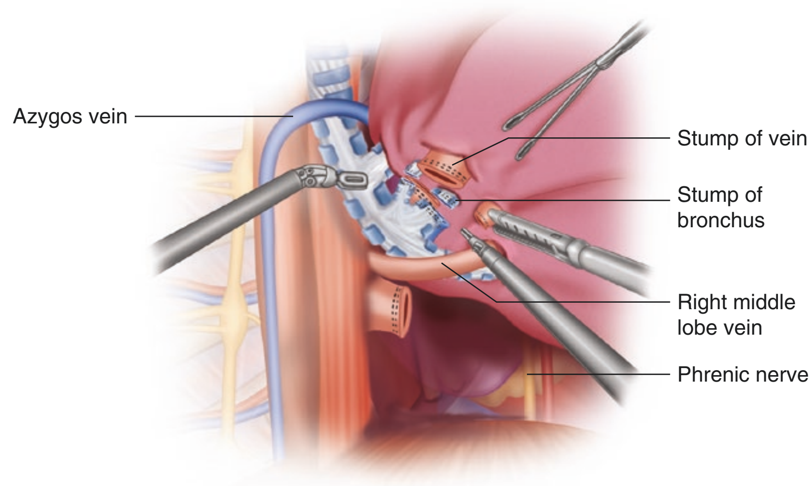


Fig. 4.21 Right lower lobectomy. A silk stitch around the two arteries to the lower lobe, the basilar segment and superior segment pulmonary artery branches taken with an endostapler from **port E**

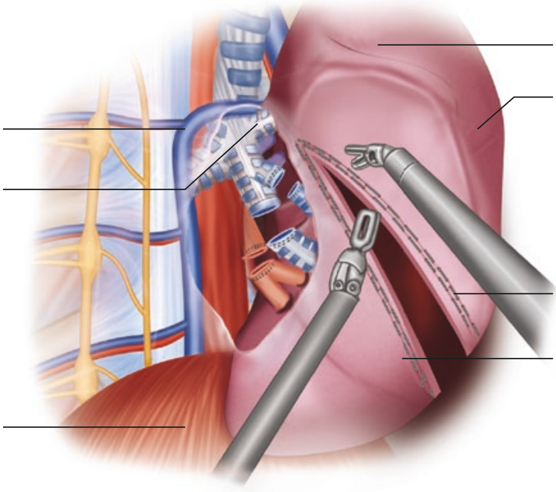


Fig. 4.22 **Right lower lobectomy**. **Fissure being completed** by a stapler being passed from **port E**

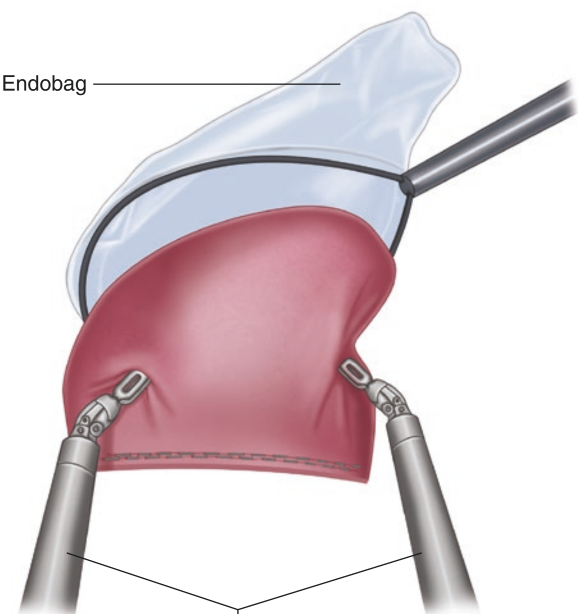


Fig. 4.23 **Right lower lobectomy**. The bag is closed and is pulled partially up into the **port F** incision and the mediastinum is covered in saline looking for an air leak in the bronchial stump

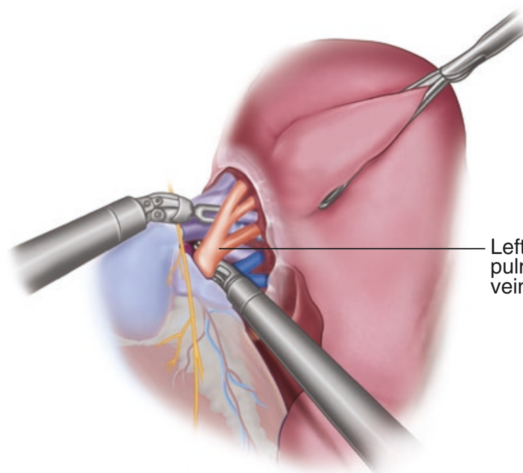


Fig. 4.24 **Initiation of the left upper lobectomy**. After resection of the aortopulmonary window lymphatic tissue avoiding injury to the phrenic and recurrent laryngeal nerves (being aware that the recurrent laryngeal nerve may not be intimately associated with the under aspect of the aortic arch and the nerve can come very close to the upper aspect of the pulmonary artery), the left upper lobe pulmonary vein is isolated by dissecting the circumference with a Harmonic scalpel. Before taking the upper lobe vein, confirm that there is a lower lobe vein by dissecting the lower lobe vein from surrounding tissue

managed in the same fashion as with the right upper lobectomy. Further lymphatic resection is performed as with the upper lobectomy (Fig. 4.23).

4.4.4 Left Upper Lobectomy (Figs. 4.24 and 4.25)

Using the left upper chest port placement as outlined in Fig. 4.7 and with the ProGrasp in the left robotic arm and a Harmonic scalpel in the right, the dissection is initiated along and 1 cm posterior to the phrenic nerve and the incision is continued to the aorta pulmonary window exposing the under aspect of the aortic arch. A Landreneau ring clamp or Forrester ring clamp is brought through the posterior-superior thoracoport or **port D** to grasp the pulmonary parenchyma just adjacent and lateral to the hilum placing the hilar tissue on some tension. Then, the tissue in the aorta pulmonary window is completely resected, avoiding injury to the phrenic nerve and the recurrent laryngeal nerves. There is often so much tissue resected that it is necessary to remove the tissue in a small endobag.

Using blunt dissection, the origin of the superior pulmonary vein is dissected cleanly, identifying the bifurca-

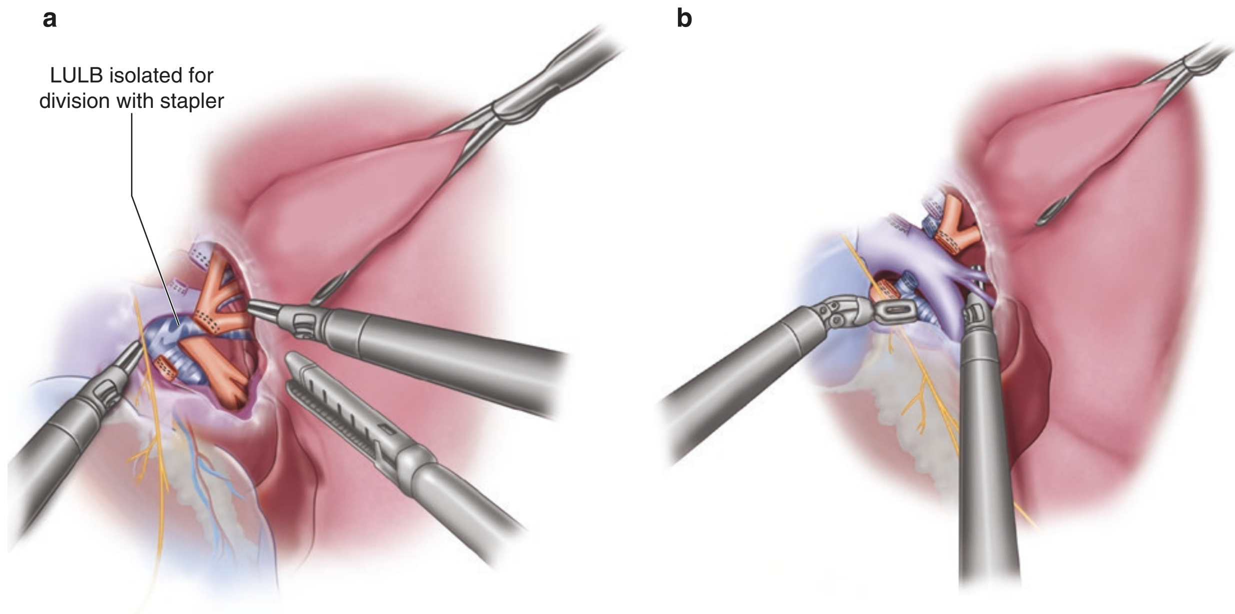


Fig. 4.25 After division of the first branch of the pulmonary artery, the left upper lobe bronchus (LULB) is identified by dissecting away areolar and lymphatic tissue beneath the divided pulmonary vein. The cartilaginous portion of the bronchus, should be readily visible. At the bifurcation of the left upper and lower lobe bronchi, there is lymphatic tissue present that is removed to expose the pulmonary artery beneath it. Once the nodal tissue is removed, the left upper lobe bronchus is dissected away from the pulmonary artery behind it using the ProGrasp from the leftward arm and a Harmonic from the right arm. The Forrester ring clamp can be used to exert tension on the bronchus by grasping the lung and holding the bronchus away from the pulmonary artery. Once the left upper lobe bronchus is sufficiently teased away from the pulmonary artery, the Harmonic scalpel in the right arm is exchanged for a ProGrasp and the right or left arm ProGrasp is carefully passed behind the left upper lobe bronchus to place a 0-silk suture, 8 cm in length. Once completed a tissue endostapler is passed through **port C** and clamped down on the upper lobe bronchus. Then a test inflation of the left lower lobe is performed and once confirmed that the left lower lobe inflates and deflates, the bronchus is divided. To complete the left upper lobectomy, the Forrester retracting grasper exposes the pulmonary artery to the lower lobe and the remaining pulmonary artery branches to the upper lobe it and the areolar tissue is divided with the Harmonic scalpel in the right arm. This exposes the remaining left upper lobe and lingular pulmonary artery branches which are divided with a vascular endostapler passed through **port C**. The fissure is divided with an endostapler and the lobe is placed in an endobag brought through **port F** after the intercostal space has been widened with the Hook cautery in the right arm. The stump is submerged in saline to make certain that there is no bronchial stump leak. If there is a leak, it may be repaired as described for the right upper lobectomy

tion between the upper and lower lobe pulmonary veins and dissecting tissue from the posterior and anterior aspect of the main pulmonary artery at the upper most aspect of the hilum (Fig. 4.24). Time and effort should be taken to be absolutely certain that the inferior pulmonary vein has been identified; it may require division of the anterior and posterior hilar pleura. Then, the superior pulmonary vein is carefully lifted away to expose structures posterior to the vein, not grasping the superior vein by the ProGrasp, but using it like a spatula to expose the underlying left upper lobe bronchus and pulmonary artery. The Harmonic scalpel is used for this posterior dissection of the lymphatic tissue that is often encountered. Once the superior pulmonary vein is completely encircled, a 0 silk suture is passed around it and the vein is divided with a vascular endostapler passed through **port C**. Once transected, the ring clamp in **port D** is repositioned on the anterior aspect of the left upper lobe to a closer location to the hilum to expose the bronchus. Often significant lymphatic tissue is encountered and is resected with the specimen. Since the most cephalad aspect of the bronchus is difficult to identify as it is often partially covered by the first major pulmonary artery branch, it is best to divide the pulmonary artery branch first. Adjacent lymphatic tissue is dissected off of the origin of this branch and the adjacent main pulmonary artery. Once this has been completed, a 0 silk is placed around the pulmonary artery and a vascular endostapler brought in through **port C** can be used to transect the pulmonary artery. Once this has been completed, the lymphatic tissue from the anterior aspect of the distal left main bronchus and the upper and lower lobe bronchi is resected. This is a very important maneuver as it will help to identify the left lower lobe bronchus. There is significant lymphatic tissue just at the bifurcation between the upper lobe and lower lobe bronchi. Once this is then resected the main pulmonary artery to the lower lobe becomes visible. This then allows the plane to be developed along the posterior aspect of the upper lobe bronchus. Then under direct vision and using a Harmonic scalpel the plane is created between the pulmonary artery and the upper lobe bronchus. The silk is passed around the airway and the bronchus divided with a tissue endostapler (Fig. 4.25). The ring clamp through **port D** is reattached closer on the hilum, in some cases grasping the specimen side bronchus, to expose the main pulmonary artery to the lower lobe and the remaining pulmonary artery branches to the upper lobe. The adjacent lymphatic and areolar tissue are taken with a Harmonic scalpel and the remaining pulmonary artery branches taken with vascular endostapler. The fissure is then completed as it is for the right upper lobe bronchus. The specimen is placed away from the area of dissection and further lymphatic tissue is then resected as necessary as described in the sections on the other lobes. In the same fashion as with the other lobes, **port F** is then prepared and an endobag is placed through that site and into which the upper lobe is placed. The upper lobe is removed in the same fashion as described in the right upper lobectomy in the case completed in the same fashion.

4.4.5 Left Lower Lobectomy (Figs. 4.8, 4.26, 4.27, 4.28, 4.29, 4.30, 4.31, and 4.32)

The patient, table position, and the thoracoport sites are as shown in Fig. 4.8. As with the other robotic lobectomies, a 0° scope is used. The dissection is initiated after the Landreneau ring clamp or Forrester ring clamp is passed through the anterior-superior thoracoport site or **port F** and grasped on the lower most lateral portion of the left lower lobe. This exposes and places on tension the inferior pulmonary ligament (Fig. 4.26). In the left robotic arm is the ProGrasp and in the right robotic arm the Harmonic scalpel. The inferior pulmonary ligament is taken cleanly from the pericardium avoiding injury to the esophagus, the Vagus and phrenic nerves. The dissection is continued to the inferior pulmonary vein at its origin. The lung is retracted anteriorly to expose the posterior hilum and the region of the subcarina (Fig. 4.27). This dissection is continued into the subcarina and all of the adjacent lymphatic tissue is resected preserving, if possible, the adjacent bronchial artery blood supply (Fig. 4.28).

Then, the parenchymal envelope is dissected off of the distal airway up to the takeoff of the superior segment bronchus exposing the distal main stem bronchus at this location so that the most superior aspect of the lobe has been detached from the bronchus, exposing the pulmonary artery to the lower lobe. The lobe is then retracted posteriorly and the dissection is continued to along the pericardium up to the superior pulmonary vein, identifying the superior pulmonary vein before any resection of the inferior vein is performed. Adjacent lymphatic tissue is taken with the specimen. The inferior pulmonary vein is then encircled with a 0 silk suture (Fig. 4.29). The inferior or lower lobe vein is then divided with a vascular endostapler passed through **port E**. This exposes the left lower lobe bronchus at the bifurcation with the lower lobe bronchus. Adjacent lymphatic tissue is taken off the bronchus and along the leftward aspect of the bronchus the bifurcation between the upper lobe and lower lobe bronchus can be identified at this location (Fig. 4.30). This lymphatic tis-

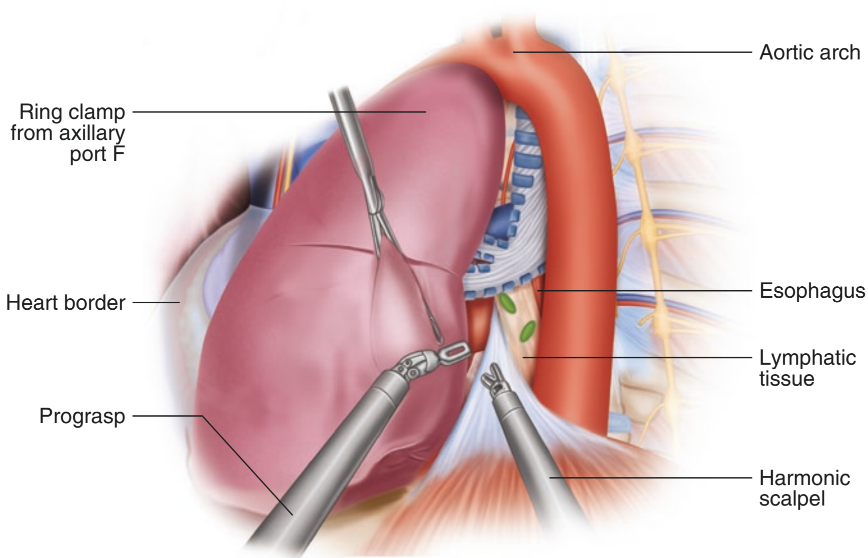


Fig. 4.26 Robotic left lower lobectomy. Dissection of the inferior pulmonary ligament of the left lower lobe. Through **port F** grasp the lateral or basilar aspect of the left lower lobe resulting in exposure and tension of the inferior pulmonary ligament. In the right arm the Harmonic scalpel is used to incise the ligament with lymphatic tissue at the base, adjacent to the pericardium and the esophagus; yet, avoiding injury to the esophagus and the Vagus nerve, taking a wide section of tissue with the specimen

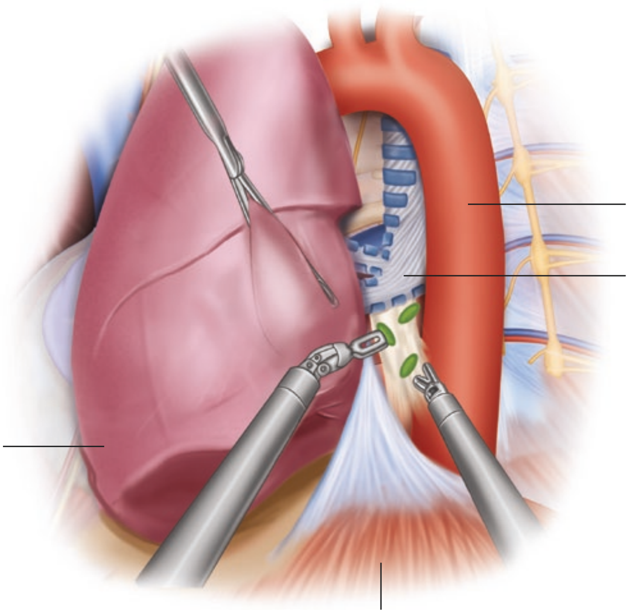


Fig. 4.27 **Robotic left lower lobectomy**. Retract the lobe anteriorly **exposing the posterior aspect of the lobe and hilum**. The ProGrasp in the left arm and the Harmonic in the right arm are used to remove the subcarinal tissue and clearing of the under aspect of the left main stem bronchus

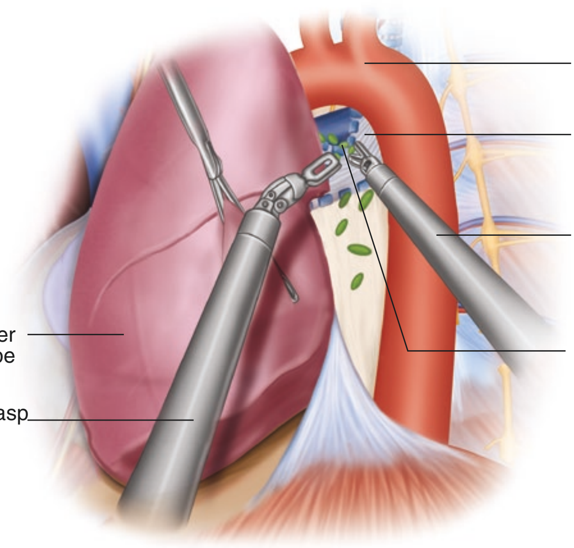


Fig. 4.28 **Robotic left lower lobectomy**. **Clearing of the upper aspect of the left mainstem bronchus** exposes the main pulmonary artery just cephalad to the superior segment bronchus and allows development of a plane between the pulmonary artery and the bronchus at this location. Avoid taking any bronchial arterial branches that will be important in blood supply to the healing bronchial stump

sue is carefully teased away from the bifurcation and once achieved the ProGrasp in the leftward arm is then used to carefully pass around the origin of the lower lobe bronchus. A 0 silk is then passed around it and a tissue endostapler is used to divide it. The ring clamp through **port F** is then adjusted so as to expose the pulmonary arteries beneath it (Fig. 4.31). There are at least two pulmonary arteries present, the basilar segment and the superior segment arteries and others identified are divided separately or together with a vascular endostapler through **port E**. The fissure is then completed in the same fashion as with the right upper lobe (Fig. 4.32). The course of the remaining case is then completed in the same fashion as with the right upper lobe.

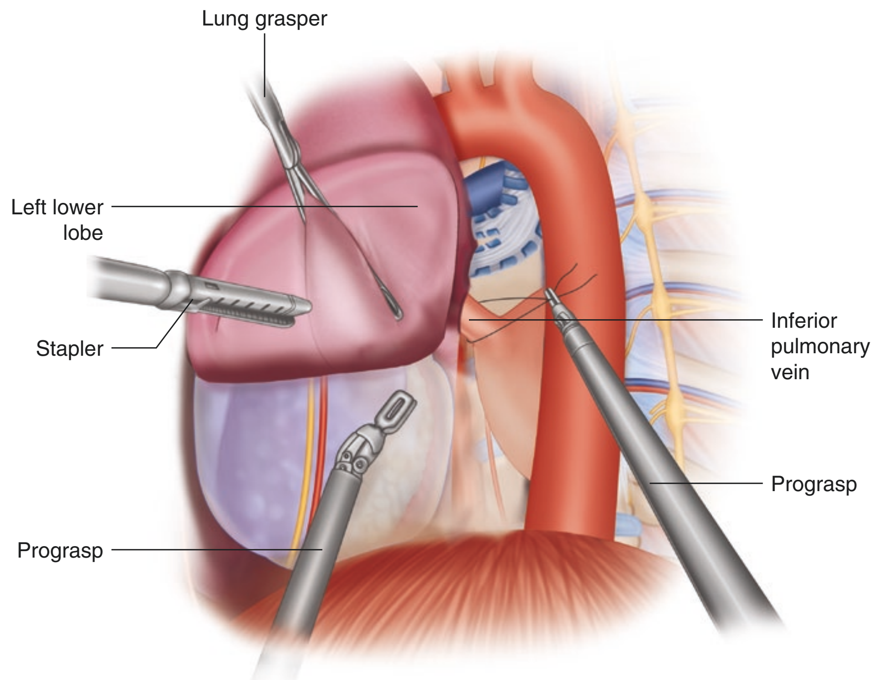


Fig. 4.29 **Robotic left lower lobectomy**. **Division of the inferior pulmonary vein** by passing a stapler from **port E** with ProGrasps used to expose the area and lift the 0-silk suture around it

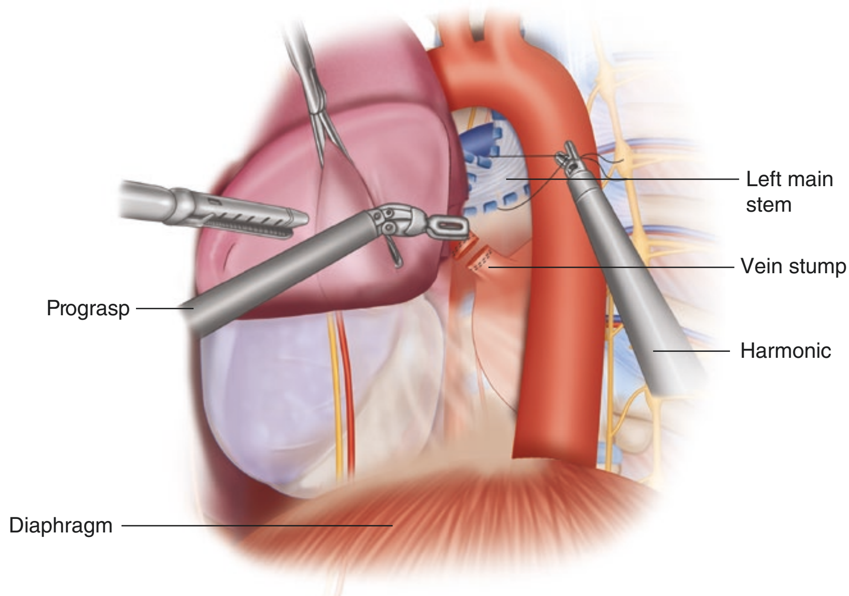


Fig. 4.30 **Robotic left lower lobectomy**. **Exposure and Division of the Left Lower Lobe Bronchus**. The left arm ProGrasp is used to identify the lymphatic tissue around the bifurcation of the left lower lobe and the upper lobe bronchi. The Forrester ring clamp is positioned to allow optimal exposure of this portion of the hilum. Once achieved, the lymphatic tissue is dissected away from the bifurcation to expose the pulmonary artery beneath it and then the ProGrasp is carefully passed behind the lower lobe bronchus to the posterior hilum, a silk suture is passed around the bronchus for retraction purposes. The stapler is passed from **port E** and in the same fashion with the left upper lobe, a test clamp is performed making certain that the left upper lobe inflates and deflates. Once confirmed the bronchus is divided

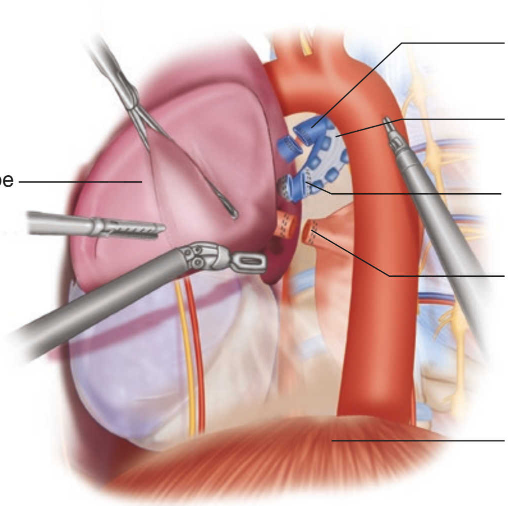


Fig. 4.31 **Robotic left lower lobectomy**. **Division of the left lower lobe pulmonary artery branches**. Shown are the divided stumps of the bronchus and pulmonary vein and the unresected pulmonary arteries, the left arm ProGrasp is shown passing around the pulmonary arteries. A 6–8 cm 0-silk is passed around the pulmonary artery and the arteries are divided with a vascular load stapler from **port E**

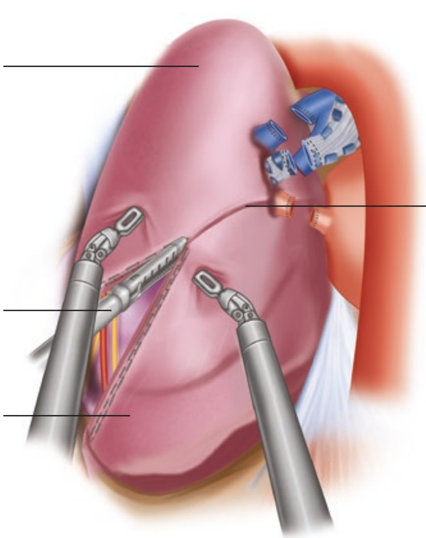


Fig. 4.32 **Robotic left lower lobectomy**. **Division of the Fissure** ProGrasps in both arms expose the major fissure and the stapler being passed through **port E**

4.5 Tips and Pitfalls

- Continuous carbon dioxide insufflation (CO_2) should be kept at a pressure of less than 10–15 mmHg. It is used to assist in compressing the lung and pushing the mediastinum away from the operative area and assisting in clearing any surgical smoke or vapor. We recommend a gradual increase rather than sudden increase in intrapleural CO_2 pressure to allow the patient to hemodynamically adjust to the increased intrapleural pressure.
- With the currently available robotic equipment, it is recommended that grasping the lung, any hilar structures, or the airway with the robotic instrumentation should be avoided to minimize the risk of injury and/or bleeding. Robotic instrumentation is better used for sweeping and very precise grasping of areolar tissue adjacent to the major structures. We recommend using instead instruments used in video-assisted thoracoscopic surgery as these are less traumatic to these structures than the robotic instrumentation.
- Avoid using in the chest cavity any operating sponges. Instead, we use tightly rolled swathes of Surgicel® 3-0 Vicryl sutures to mop or pack bleeding areas. Free operating sponges can be lost, even when the sponge count is correct at the end of the case. Making a habit of not having them on the table eliminates a potential complication and although, uses material that might be expensive, provides hemostasis and will dissolve if lost within a couple of weeks.
- It is critical to identify anomalous bronchial, pulmonary vascular, and azygous vein anatomy prior to dividing any structures. Often, these anomalies can be inferred by the appearance on the computed tomogram, but tumor and disease may alter the operative anatomy so much so that it may be difficult to clearly identify the anomalies. Commonly encountered anomalous structures:

- Common pulmonary vein, rather than a superior and inferior pulmonary vein
- Right middle lobe vein that comes off the upper lobe vein complex late
- High riding main pulmonary artery potentially confused with the pulmonary artery blood supply to the upper lobe.
- Replacement of the inferior vena cava with the azygous vein, all inferior venous return comes through the azygous vein
- Right upper lobe take off from the distal trachea rather than the right main stem bronchus
- Azygous lobe
- Left lower lobe take off is more distal than expected, taking what is presumed to be the upper lobe bronchus can potentially injure the distal main stem bronchus

- Vascular staplers, rather than tissue staplers, should be used for the pulmonary vasculature. When taking the bronchus and normal appearing airways, tissue staplers should be used. Inexperienced teams can sometimes mistake tissue staplers for vascular staplers and vice versa.
- In the emphysematous and/or friable lung tissue, we recommend using covered staplers; examples include Surgisis® (Cook Medical)
- Thick tissue staplers may be necessary in the particularly thick and often incomplete fissures. Be prepared to use them.
- After using stitches with swedged-on needles, cut the suture to leave at least a 1–2 cm segment of suture on the needle for suture/needle removal and use a nonrobotic minimally invasive needle holder to grasp the suture rather than the needle for removal of the needle.
- In patients that have had or are likely to have hilar or mediastinal irradiation or in those where the blood supply to the stump is of concern, perform a vascular pedicled tissue coverage of the bronchial stump with either thymic tissue, adjacent mediastinal tissue, intercostal muscle or internal mammary blood supply-tissue.
- Always keep your eye on the phrenic nerve. Carbon dioxide pressure in the pleural space can distend the diaphragm and raise the phrenic nerve from the normal location along the mediastinum and like a violin string can be quite taut and raised off the mediastinum sufficiently that it can be injured during the dissection and/or passage of the stapler.
- In patients with fairly brittle ribs or in patients with particularly large tumors, it is often better to "shingle" or resect a 1–2 cm segment of the rib or ribs adjacent to the planned removal of the endobag.

4.6 Outcomes in Brief

We have performed over 600 robotic lung lobectomies since 2002, the majority of which were performed using the hilum-first technique as outlined in this chapter. We have learned that both the fissure-first and the hilum-first techniques may be used dependent on the pathology and the anatomy of the given situation. Dependent upon the anesthesia and surgical team's experience, the procedure rarely takes longer than 3 h, even when cardiothoracic surgery trainees are the console surgeon. Conversion rates are less than 1%. Blood loss is rarely more than 100 mL. The rate of positive surgical margins of malignancy is less than 3%. Fewer than 5% of patients with cancer have less than 20 lymph nodes counted by our pathology team. The average size of the primary tumor is approximately 4.3 cm with the largest being 21 cm. Median length of stay in the hospital is 2 days with 20% being discharged on day 1. Unless chest wall resection is performed, we do not use epidural anesthesia. Although we discharge patients with narcotics, nearly a third are off the narcotics by the first postoperative visit and over half are off narcotics by the end of 2 weeks. Less than 1% of patients had any pain from the procedure beyond 1 month and if working nearly all returned to work within the month. Overall complication rate is less than 8%. Persistent air leak beyond 3 days occurs in fewer than 5%. In a propensity-matched analysis of 65 robotic lobectomies with the SEER database, there appeared to be at least an equivalent long term survival and potentially superior survival for the robotic lobectomy patients; 80% at 3 years with 15% of the patients having stage IIB or greater.

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