A video atlas for robotic lingulectomy

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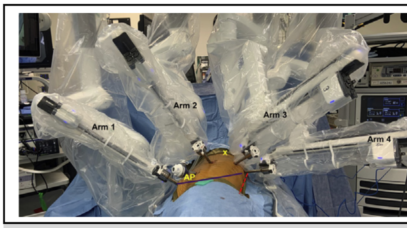


Robotic-assisted thoracic surgery is a valuable tool for pulmonary segmentectomy.

CENTRAL MESSAGE

Robotic segmentectomy offers theoretical advantages during segmentectomy and may be performed with excellent technical and postoperative outcomes.

▶ Video clip is available online.

Since the first descriptions of robotic-assisted thoracoscopic surgery (RATS) for lobectomy in the early 2000s,[1,2] robotics has been used for an increasing array of thoracic disease processes. Among the most common applications of RATS is pulmonary segmentectomy.[3] The safety and feasibility of RATS segmentectomy have been well-documented.[4]

Similar to traditional video-assisted thoracic surgery (VATS) segmentectomy, robotic segmentectomy is commonly used as an approach for patients presenting with early-stage lung cancers, low-grade infectious processes, or borderline pulmonary function tests. For patients presenting with lesions suspicious for or proven to be non–small cell lung cancer, the preoperative work-up includes high-resolution computed tomography of the chest, positron emission tomography–computed tomography, and pulmonary function testing. Axial imaging allows for a careful assessment of disease burden but also provides an important roadmap for understanding segmental anatomy, lymph node location, and fissure status. At our institution, preoperative invasive mediastinal staging for early-stage non–small cell lung cancer is not typical for patients undergoing segmentectomy but may be used if clinically indicated. Absolute and relative contraindications are not well defined for robotic segmentectomy; however, robotic pulmonary resection in general has been used in scenarios involving previous thoracic surgery, neoadjuvant chemoradiation, chest wall invasion, and hilar lymphadenopathy.

Compared with traditional open and thoracoscopic methods, our opinion is that RATS provides a combination of outstanding exposure, enhanced optics, and unparalleled dexterity. These advances make RATS an ideal tool that can facilitate the precision necessary for isolation and division of segmental anatomy. Although there is a learning curve, we believe that with mastery of basic robotic techniques and a thorough understanding of 3-dimensional thoracic anatomy, robotic segmentectomy is feasible for most, if not all, thoracic surgeons. With these considerations in mind, the goal of this Video Atlas is to provide a comprehensive, step-by-step description of our approach to robotic lingulectomy that can serve as a useful reference for both novice and experienced thoracic surgeons using RATS.

METHODS

This approach to robotic lingulectomy is described in 8 distinct steps. The described approach uses the da Vinci Xi System (Intuitive Surgical). Instrumentation descriptions are provided within the text. We acknowledge that there are other reproducible approaches to robotic lingulectomy.

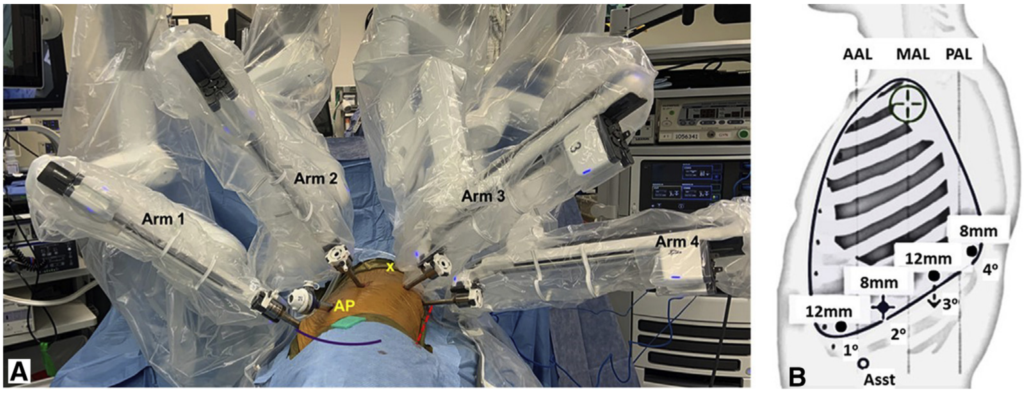


FIGURE 1. Port positions for robotic lingulectomy (after docking). A, As described within the text, 4 robotic ports (labeled arms 1-4) are placed in the eighth or ninth interspace and an assistant port (AP) triangulated between arm 1 and arm 2. Proper spacing is critical to maximize mobility and minimize collision of robotic arms. B, Illustration of port placement for lingulectomy. The scapular tip is marked with a yellow "X," the spine is marked with *a red dashed line*, and costal margin is marked with a *purple solid line*. *AAL*, Anterior axillary line; *MAL*, mid-axillary line; *PAL*, posterior axillary line; *Asst*, Assistant Port.

OPERATION

Step 1: Patient Positioning, Port Placement

After placement of a double-lumen endotracheal tube, the patient should be positioned in the right lateral decubitus position. After generous flexing of the bed, the hips should fall below the level of costal margin and left arm should be extended with minimal abduction of the shoulder; these considerations allow for maximum mobility of robot arms after docking.

We place 5 ports in a fairly standardized manner and in a method similar to Cerfolio and colleagues.[5] To summarize, we use 4 robotic arms which are placed in the 8th or 9th intercostal space and an assistant port which is placed 1 to 2 spaces below (Figure 1). The robotic ports are as follows: port 1 is a 12-mm port and is placed anteriorly so that port enters the chest at the cardiophrenic recess, port 2 is an 8-mm port that is placed 1 to 2 interspaces below and just anterior to the scapular tip and will serve as the camera port, port 3 is a 12-mm port that is positioned midway between scapular tip and the spine, and port 4 is an 8-mm port that is placed fairly posteriorly and approximately 3 to 4 cm anterior to the spine. The assistant port is a 15-mm port and is triangulated with ports 1 and 2. We use a 15-mm port to accommodate a large specimen collection bag and for the Endo GIA stapler (Medtronic), which may be used for challenging stapler angles. It is helpful that ports be spaced at least 8 to 10 cm apart to maximize workspace and minimize collision of robotic arms. In smaller patients, ports can be positioned a bit closer, with as little as 6 to 7 cm of distance between them. After the ports have been placed, the robot is docked at the patient's bedside with arm 1 initially using the Cadiere forceps (Intuitive Surgical; will later serve as a stapler port), arm 2 using the 30° camera, arm 3 using a Maryland Bipolar grasper (will also serve as a stapler port), and arm 4 using a Tip-Up Fenestrated Grasper (Intuitive Surgical). We use CO_2 insufflation set to 5 to 8 mm Hg to improve exposure as it pushes the diaphragm inferiorly and displaces the mediastinum toward the contralateral hemithorax.

Step 2: Division of Inferior Pulmonary Ligament and Dissection of Stations 8 and 9

We begin with an inspection of the hemithorax to rule out advanced disease (Video 1, Figure 2). After metastatic disease has been ruled out, the Tip-Up Fenestrated Grasper is used to gently retract the lung in a medial/cephalad direction and place traction on the inferior pulmonary ligament. The inferior pulmonary ligament is released using a bipolar cautery. Any level 9 lymph nodes encountered are dissected and sent for a permanent pathology. At this time, we also take level 8 lymph nodes, which are within view. The lung is then repositioned and retracted anteriorly; this redistributes tension, thus allowing for continued cephalad

VIDEO 1. Division of inferior pulmonary ligament and dissection of stations 7, 8, and 9. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.

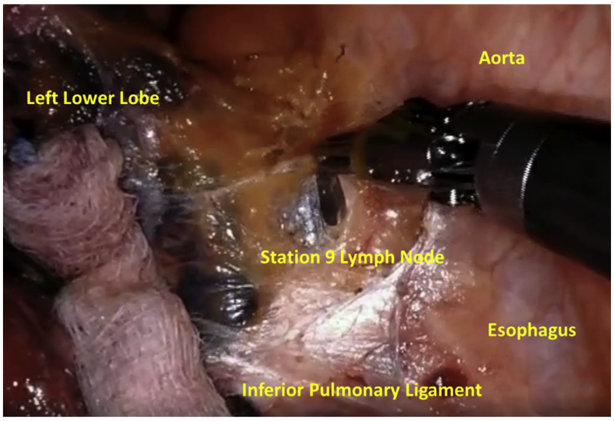


FIGURE 2. Division of the inferior pulmonary ligament.

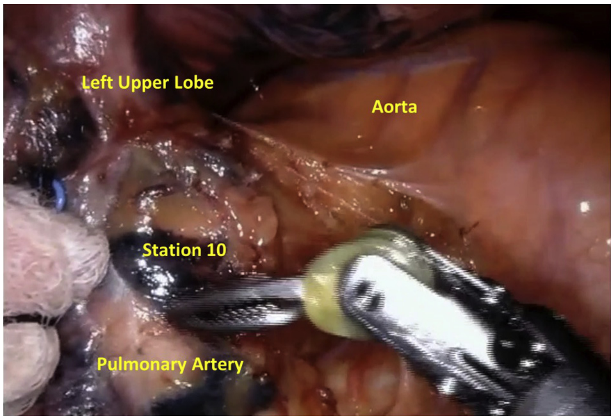


FIGURE 3. Identification of pulmonary artery in posterior hilum.

dissection along the posterior hilum. To maintain hemostasis and minimize distortion of tissue planes, the pleura should be incised immediately posterior to the lung parenchyma.

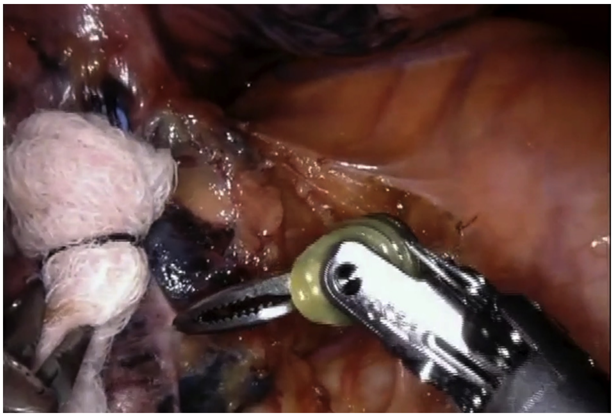
This dissection is continued until station 7 is encountered between the inferior vein, left mainstem bronchus, and the esophagus. We routinely perform a complete level 7 nodal dissection. We begin by carefully clearing the most superficial tissue off the node. Once approximately 50% of the node is clear, we grasp the node with the Cadiere forceps and gently retract the node. This retraction nicely exposes bronchial vessels and lymphatics which can be ligated with the Maryland bipolar. Residual oozing is typically controlled with Surgicel (Ethicon).

Step 3: Identification of the Pulmonary Artery in the Posterior Hilum, Dissection of Stations 5 and 6

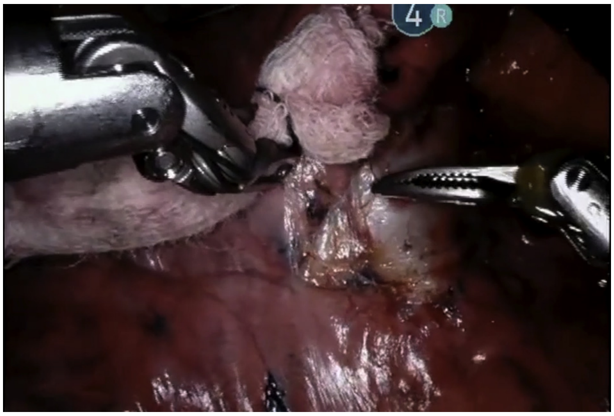
Releasing the posterior hilum continues in a cephalad direction, heading toward the left pulmonary artery and then the aorticopulmonary window (Video 2, Figure 3). We point out that one can almost always identify the interlobar pulmonary artery posteriorly, even in circumstances of an incomplete fissure. Identifying the pulmonary artery in this location provides a useful landmark to begin the fissure dissection. After identification of the pulmonary artery and before beginning our fissure work, we complete the posterior hilum and take station 10 lymph nodes. We then continue to mobilize in a cephalad direction and free superior hilum by retracting the upper lobe inferiorly and taking nodal stations 5 and 6. We are careful to avoid injury to the recurrent nerve with traction and dissection in the aorticopulmonary window.

Step 4: Unroofing the Pulmonary Artery and Identification of Lingular Branches

With the posterior hilum released, we move our dissection to the fissure where we unroof the interlobar pulmonary artery (Video 3, Figure 4). Beginning posteriorly at the already identified pulmonary artery, we arrive at the subadventitial plane and proceed with



VIDEO 2. Identification of the pulmonary artery in the posterior hilum. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.



VIDEO 3. Initial unroofing the pulmonary artery within fissure. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.

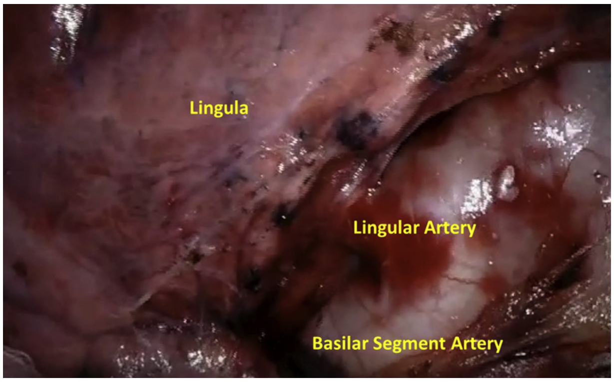
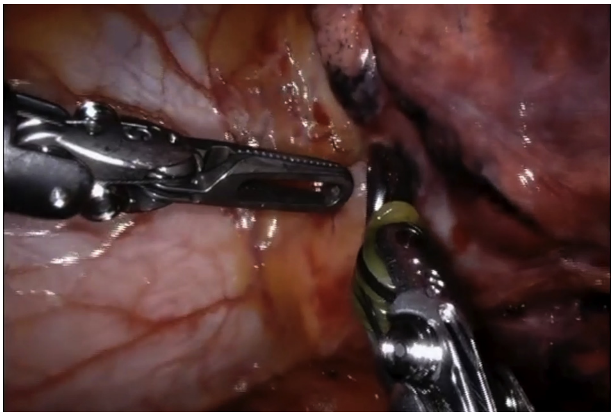


FIGURE 4. Identification of the lingular artery within major fissure.

unroofing the pulmonary artery in anterior direction with use of the bipolar cautery or stapler (blue loads of the SureForm stapler; Intuitive Surgical). To maximize exposure in the fissure, the Tip-Up Fenestrated Grasper (arm 4) is used to retract the upper lobe superiorly while the assistant provides gentle traction inferiorly using a rolled sponge. It is common to identify level 11 lymph nodes along the interlobar pulmonary artery and 12 lymph nodes at branch points. When encountered, these are carefully dissected for 2 primary reasons: (1) removal enhances exposure of the pulmonary artery and branches and (2) involved lymphadenopathy on frozen section analysis suggests the need for lobectomy. The lingular artery branches are typically isolated and divided using a white load of the SureForm stapler (brought in through arm 1). Although there is typically a singular lingular artery, some patients may have multiple branches, some of which may arise from the locations other than interlobar pulmonary artery. In the circumstances of an incomplete fissure, it is common to identify small crossing veins, which can be controlled with a bipolar cautery. Infrequently, we turn our attention to the anterior hilum when dissection in the fissure becomes cumbersome, as noted in this example.

Step 5: Division of the Lingular Vein

We typically move to the anterior hilum and focus on the lingular vein after completing the fissure dissection and dividing the lingular arteries (Video 4, Figure 5). As previously noted, we will occasionally need to turn our attention to the anterior hilum before completing our fissure dissection in cases an incomplete fissure (as demonstrated in this video). After confirming the origin of the lingular vein from the superior pulmonary vein, the lingular vein is dissected circumferentially and taken with White load of the SureForm stapler (brought in with arm 3). Any level 10 nodes encountered in the hilum are again taken and sent for frozen section analysis as nodal disease may suggest the need for lobectomy.



VIDEO 4. Identification of the lingular vein. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.

Step 6: Completion of the Anterior Fissure

In cases of an incomplete fissure, we return focus to the fissure after freeing the anterior hilum and dividing the lingular vein, which is typically the most inferior branch of the superior pulmonary vein (Video 5, Figure 6). Common variations include circumstances of more than lingular vein or an origin off the inferior pulmonary vein. Identification of the characteristic level 11 lymph node packet at the secondary carina is important as dissection of this nodal tissue provides a safe window to divide the anterior fissure. Once this window is cleared, a vessel loop can be passed that allows for gentle retraction and positioning of a blue load of the SureForm stapler (brought in brought in with arm 1). Dividing the anterior fissure improves the mobility of the upper and lower lobes, and therefore allows for improved exposure of the interlobar pulmonary artery and lingular branches. Lingular artery branches can be readily skeletonized and freed circumferentially using the bipolar cautery and then isolated with vessel loops. In general, there is a single lingular artery; however, approximately 25% of patients will have multiple branches.[6] After carefully isolating the arterial blood supply to the lingula, vessels may be taken with a White load of the Surefire stapler (brought in through arm 1).

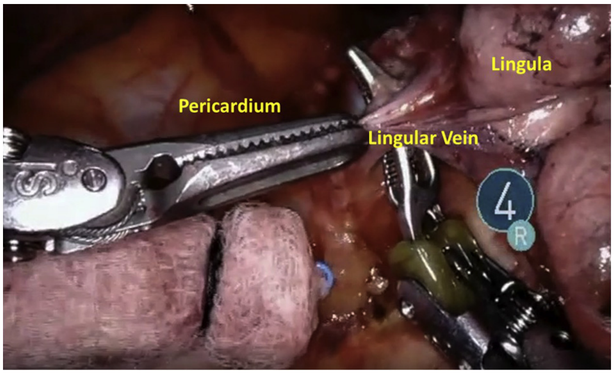
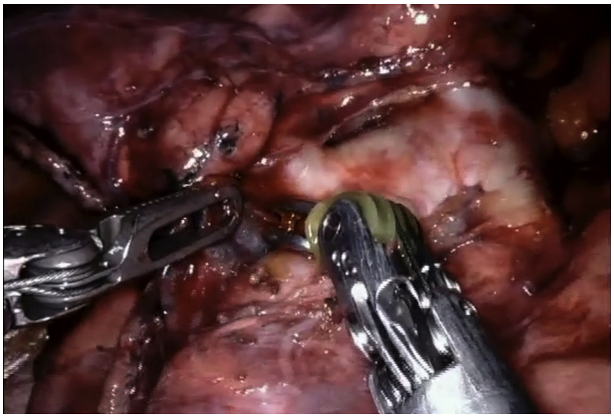
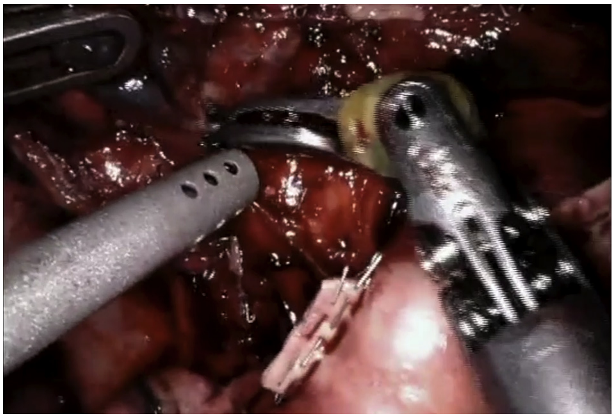


FIGURE 5. Identification of the lingular vein.



VIDEO 5. Completion of the anterior fissure, division of lingular artery branches. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.



VIDEO 6. Isolation and division of the lingular bronchus. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.

Step 7: Division of the Lingular Bronchus

With the vascular supply divided and fissure released, attention is turned to the lingular airway which typically lies below the venous staple line and anterior to the lingular artery staple line(s) (Video 6, Figure 7). One should expect to encounter a station 12 lymph nodal packet at the tertiary carina between the airways to the superior division and lingula. If frozen section demonstrates station 12 nodal involvement, we advocate for formal lobectomy if the patient can tolerate. Removal of these tissues greatly enhances the view of the lingular airway. After the nodal dissection has been completed, remaining peribronchial tissue is carefully dissected distally (so that it is included within the specimen). Once adequate dissection of the airway is achieved, the airway is transected with a blue load of the SureForm stapler (brought in through Arm 3).

Step 8: Parenchymal Division Along the Intersegmental Plane

With the lingula artery, vein, and airway dissected, the final step remaining involves division of parenchyma at the intersegmental plane (Video 7, Figure 8). To identify this line, we use intravenous indocyanine green (ICG) and near-infrared imaging using the Firefly system in the Xi Robot as previously described.[7] To summarize, 5 mg of ICG is delivered as an intravenous push by the anesthesia team. Within 1 to 2 minutes, the camera is switched to the Firefly mode, which allows the surgeon to identify the well-perfused superior division (displays green near-infrared signal from circulating ICG) and the ischemic lingular specimen (does not illuminate). The plane between these areas is scored using a bipolar cautery, and then divided from posterior to anterior using the several blue loads of the SureForm stapler (brought in through arm 3). With the lingula now fully freed, the specimen is placed in a specimen bag and removed through the assistant port.

DISCUSSION

Although RATS segmentectomy is viewed as technically challenging, after overcoming learning curves excellent results are achievable. Data suggest that outcomes are comparable with traditional VATS segmentectomy, with complication rates less than 10% and a negligible risk for perioperative mortality. In general, we find that most

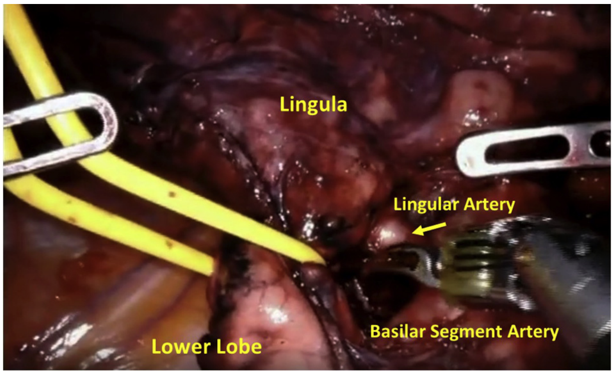


FIGURE 6. Completion of the anterior fissure

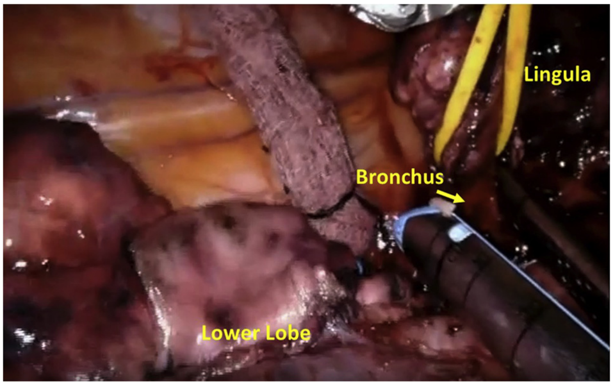
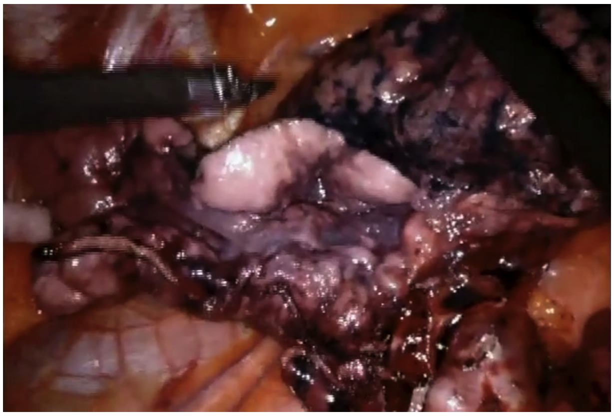


FIGURE 7. Isolation and division of the lingular bronchus.



VIDEO 7. Parenchymal division along the intersegmental plane using indocyanine green. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00371-6/fulltext.

patients are discharged on postoperative day 1 or 2 in good condition and with minimal narcotic needs. Chest tubes are removed when the air leak has resolved. A full review of postoperative outcomes is beyond the scope of this technical piece, and has been comprehensively reviewed elsewhere.[3] In addition to safety and feasibility, there are theoretical oncologic advantages with data suggesting a more complete lymphadenectomy with RATS anatomic lung resection.[8] As compared with traditional thoracoscopic segmentectomy, RATS offers subjective advantages including improved visualization, dexterity, and exposure We acknowledge that despite previously noted advantages, there remains no clear outcome data suggesting superiority of RATS over VATS segmentectomy.

CONCLUSIONS

Lingulectomy is a common application for RATS. Safety, feasibility, and outcomes are comparable with more traditional open and VATS approaches. Subjective advantages

FIGURE 8. Parenchymal division along the intersegmental plane using indocyanine green.

include improved optics, enhanced dexterity, and better ergonomics for the surgeon. We believe that with proper training and experience, robotic segmentectomy can become a useful tool for the current generation of thoracic surgeons.

References

1. Ashton RC Jr, Connery CP, Swistel DG, DeRose JJ Jr. Robot-assisted lobectomy. *J Thorac Cardiovasc Surg*. 2003;126:292-3.
2. Morgan JA, Ginsburg ME, Sonett JR, Morales DL, Kohmoto T, Gorenstein LA, et al. Advanced thoracoscopic procedures are facilitated by computer-aided robotic technology. *Eur J Cardiothorac Surg*. 2003;23:883-7; discussion 7.
3. Wei B, Cerfolio RJ. Robotic lobectomy and segmentectomy: technical details and results. *Surg Clin North Am*. 2017;97:771-82.
4. White PT, Antonoff MB, Rajaram R. Robotic surgical techniques for standard segmentectomies. *Video-Assist Thorac Surg*. 2020;5:1-8.
5. Cerfolio RJ, Watson C, Minnich DJ, Calloway S, Wei B. One hundred planned robotic segmentectomies: early results, technical details, and preferred port placement. *Ann Thorac Surg*. 2016;101:1089-95; discussion 95-6.
6. Gossot D, Seguin-Givelet A. Anatomical variations and pitfalls to know during thoracoscopic segmentectomies. *J Thorac Dis*. 2018;10(suppl 10):S1134-44.
7. Newton AD, Predina JD, Nie S, Low PS, Singhal S. Intraoperative fluorescence imaging in thoracic surgery. *J Surg Oncol*. 2018;118:344-55.
8. Pardolesi A, Park B, Petrella F, Borri A, Gasparri R, Veronesi G. Robotic anatomic segmentectomy of the lung: technical aspects and initial results. *Ann Thorac Surg*. 2012;94:929-34.