



Video atlas of each uniportal robotic-assisted thoracic surgery lobectomy and lymphadenectomy

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It is important when evaluating new techniques that a surgeon can see and assess all the differences and similarities between their usual technique and the novel technique. Thus, we have collated a comprehensive atlas of videos of uniportal robotic lobectomies for every lobe. Surgeons who are considering embarking on a program of uniportal robotic lobectomies can accordingly see the different views and techniques that will be required for when they perform their first procedure. We have fully narrated the videos, so that you will be taken through each procedure. Whilst these five videos are fifty-five minutes in total, our intention is not necessarily for you to watch them all from start to finish, but rather, come to this video, select the lobe that you will shortly embark on, and watch it prior to your case so that you can visualise, as closely as possible, the procedure that you will be performing. We recommend that you watch the videos with your bedside assistant as the uniportal robotic lobectomy is a joint procedure between two surgeons, rather than a single surgeon's operation with an assistant. Though we have not provided videos on segmentectomies, the uniportal robotic lobectomy is an advanced technique and we are confident that advanced surgeons will be able to gain key insights with what has been included, even if they are proceeding to a segmentectomy for their first cases. We feel for an advanced surgeon, a segmentectomy will be just as suitable an operation as a lobectomy in the initial learning phase.

Keywords: Uniportal robotic surgery; lobectomy; robotics; video-assisted thoracoscopic surgery (VATS)



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Uniportal robotic left lower lobectomy

The first video is of a left lower lobectomy. We begin with an outside view of the set-up, and have provided more detailed videos of set-up elsewhere for those requiring it. For a left-sided lower lobectomy, we recommend an incision that is more posterior than your usual uniportal video-assisted thoracoscopic surgery (VATS) incision, around the mid-axillary line, with the posterior portion of the incision almost at the highest point of the chest. In this position, the camera port, which is at the back, is only slightly more anterior than a standard 5-port robotic operation. If the incision is too anterior, this can cause clashing of the arms and poor vision of the posterior hilum and subcarinal station. In addition, the incision is one-to-

two rib spaces below a normal uniportal VATS incision. A seventh intercostal space incision is recommended for lower lobes and a sixth intercostal space incision for upper lobes.

The video commences with the development of the anterior oblique fissure and the exposure of the pulmonary artery. It should be noted that the camera view is perfectly in line with the oblique fissure, which is very helpful in the identification of the pulmonary arterial branches of both the upper lobe and lower lobe and is an excellent position for firing a stapler from arm one. The assistant should note here that a long-curved sucker is being used to gently retract at this point without impeding the view of the surgeon, who is using a Maryland bipolar forcep in arm 2 (right hand) and a fenestrated bipolar forcep in arm 1 (left hand).

Stapling is demonstrated using a firing of a blue Sureform 45 curved tip stapler to complete the fissure. We note that the assistant lines up the anterior port with the area of stapling before inserting the stapler, to make the firing as easy as possible for the surgeon. We then dissect under the pulmonary artery with direct vision and subsequently, a white Sureform 45 curved tip stapler is advanced to divide the pulmonary artery. The stapler is hardly articulated using this uniportal technique, demonstrating that the incision was in the perfect position.

We then move to the inferior pulmonary ligament, as the assistant retracts the lower lobe upwards and the inferior ligament is divided, the vein is visualized. We then place a white load to divide the inferior pulmonary vein, with another very straight firing of the stapler. The video catches a glimpse of the subcarinal station, and after the lobectomy it will be very straightforward to come back to that area for the lymphadenectomy, with the assistant providing retraction of the remaining left upper lobe (not shown in this video). Finally, a green Sureform 45 curved tip staple firing is loaded, and the bronchus is divided. An inflation test is not required to check this firing as the 3D vision and perfect positioning of the camera means that the ideal positioning of the stapler can be easily achieved under vision. The lobectomy is then completed. The next steps, not shown in the video, would be that arms 1 and 2 are removed, leaving the camera at the top of the incision and the assistant would place the lobe in a retrieval bag, remove it, and then arm 1 and 2 will be repositioned to complete the lymphadenectomy.

Uniportal robotic left upper lobectomy

We begin the video after the case has been set up and the arms have been inserted. As previously mentioned, the uniportal incision should be more posterior than the usual uniportal incision, close to the highest point of the chest in the mid-axillary line. For an upper lobectomy, the sixth intercostal space is the optimal position for the incision, which is lower than a standard uniportal incision. The fenestrated bipolar forceps are in arm 1 for the left hand and the Maryland bipolar forceps are in arm 2 for the right hand. Of note, is that both instruments are connected to bipolar energy so that the Maryland can be used for more accurate point diathermy. If, however, any larger bronchial arteries are encountered, the fenestrated bipolar can be used to provide a wider field of energy to safely cauterise the vessel.

The view is again along the fissure, and very quickly the

posterior segmental artery is seen and isolated. A Sureform 45 curved tip stapler is brought in with a white load and facilitates division. Some rolled swabs (cigars) are used in the field, which is useful to address small areas of oozing, as well as for safety reasons and usefulness in the gentle retraction of lung tissue without breaching the visceral pleura. The second vessel that is identified is the lingular artery. This time, a sling is placed around this vessel, and held with the bipolar forceps while the stapler is advanced in a straight line. The assistant removes the sling while the stapling is completed. A note is made that the endoscope is placed thirty degrees down. Next, the anterior oblique fissure is completed, and this is stapled after a sling is placed around it in front of the pulmonary artery. A nice technique in the video is shown after one staple firing. The fissure was too long for the 45 mm stapler, and a small area was left behind that would usually require a second staple firing. However, Dr. Gonzalez-Rivas takes a tie and due to the excellent vision and the robotic-wristed dexterity of the instruments, he ties the residual part of the fissure and then diathermies this to divide it, saving the expense of a further staple firing. This is also a good idea to become familiar with, as it can be economical if smaller vessels are tied off and in more advanced cases, this is also good practice for sleeve resections.

We now open the posterior hilum, demonstrating the excellent vision to the back of the hilum, station five and the apical and anterior segmental vessels, which are cleaned up from posteriorly. The lung is then retracted posteriorly, and the superior pulmonary vein is identified. The station five lymph node is identified, and removed with a nice view of the vagus and phrenic nerve. Bipolar energy is used around these nerves with a low level of energy dissipation. The exit point of the dissection around the superior pulmonary vein is identified, and after that the vein is exposed from below and the Maryland passed behind the vein. It is important to note that there is no tactile feedback when passing the Maryland around the back of the vein and the surgeon must use caution and observe closely for movements which might mean that the Maryland is not passing around the vein easily. A sling is then passed around the vein followed by a white Sureform 45 curved tip stapler.

The bronchus is cleaned and L10 lymph nodes are removed in preparation for stapling the final anterior and apical segmental arteries. The lymph nodes are removed by the assistant without any difficulty through narrow ports through the uniportal incision. A sling is placed around the final artery and a white stapler is inserted into arm 2

to perform the last staple firing of the anterior and apical segmental arteries. A green stapler is then immediately brought in to complete the lobectomy, and again no inflation test is needed due to the excellent vision and the fact the lower lobe bronchus has been clearly demonstrated. After the lobectomy has been completed, arm 1 and 2 are removed and the assistant withdraws the lobe either in a retrieval bag or through the single incision with the soft tissue retractor in place. After this, the arms are reintroduced to complete the lymphadenectomy.

Uniportal robotic right lower lobectomy

This video begins with demonstrating a slightly larger tumour. We thought this would be ideal with uniportal robotic surgery as we suspected that there would be some technical difficulties with adhesions, which proved to be correct. A single incision was placed just in front of the mid-axillary line. In this video, this was in the seventh intercostal space with an Alexis atraumatic ring wound protector. Firstly, we used a uniportal VATS approach to sample the effusion and remove some of the adhesions, transferring to the robotic approach once completed. A long line of intercostal blocks, from the first to the tenth intercostal spaces with 60 mL of 0.25% bupivacaine with 1:200,000 adrenaline were undertaken, and then we also performed cryoanalgesia with the Metrum Cryoflex and the long pectus Cryoprobe. We performed cryoanalgesia to the sixth, seventh, and eighth intercostal spaces.

We began in the intercostal space by developing the fissure. We used the fenestrated bipolar in arm 2 for the left hand and the Maryland bipolar forceps in arm 3 for the right hand. We used some rolled swabs, 'cigars', in the operative field as well as suction by the assistant. The outstanding vision provided by the Intuitive system allowed us to quickly dissect down onto the pulmonary artery and identify the basal branches and segment six artery. Large lymph nodes were found around the pulmonary artery, and these were removed *en bloc*. Removal of these lymph nodes also allowed for better visualisation of the anatomy. The adhesions in the posterior oblique fissure were divided and the posterior fissure was developed by electrocautery. A deep lymph node lying under the segment 6 artery was removed. We then moved to the anterior portion of the pulmonary artery where further lymph nodes were removed. Subsequently, we used the Maryland and bipolar forceps to get underneath the pulmonary artery in a safe manner. A sling was then passed under the basal pulmonary

artery, the Maryland was removed, and through arm 3 we introduced a white Sureform 45 staple load and with a very straight firing, we took the pulmonary artery. The posterior oblique fissure was then completed with a blue Sureform 45 staple firing, again using a sling to help. Of note, we needed to use Sureform 45 mm staplers as it is more economical than using both the 45 and 60 Sureform stapler handles. Each stapler handle is a single use device and has 12 charge firings. In addition, the 60 mm stapler is very large and unwieldy and therefore not generally used by us.

The bronchus was then identified after removal of further lymph nodes. With direct vision right down onto the bronchus, we manoeuvre easily around, pass a sling, and then bring in a green Sureform 45 stapler where straight firing is used. Sometimes the port must be withdrawn to complete the firing, but as it is a straight firing this is not an issue. Finally, attention is given to the inferior pulmonary vein which is under the very large tumour. As we left this to last, it was not necessary to retract the lobe and large tumour up into the chest, which would have been difficult. Instead, the vein was easily taken to complete the lobectomy. This is in fact a fast and more cost-effective way to do robotic surgery, using fewer arms, no CO₂ insufflation, and no CO₂ cap seals on the ports. The tumour is then removed in a retrieval bag and the operation is completed.

Uniportal robotic middle lobectomy

We begin this video by showing the position of the single incision that we are going to use for this case. You can clearly see that this is a space lower than a usual uniportal VATS incision and perhaps 2 cm more posterior, so that the camera ends up being close to the highest point in the chest. As we commence the endoscopic view, we can immediately see that we are very well aligned with the oblique fissure and have a great view along its whole course. We are using two transoral robotic surgery (TORS) ports and one conventional 8 mm Intuitive port in between the two TORS ports to optimise the space. The fissure is developed by the surgeon assisted by the long metal sucker from the assistant. The anterior oblique fissure is stapled by removing arm 4, removing the 8 mm port and replacing it with the 12 mm port. Then looking down the port it is positioned to line up exactly with the start of the oblique fissure. A blue Sureform 45 tip-up stapler is advanced to the point where the stapling is to commence, and the port is withdrawn a little to facilitate this firing.

After firing, the pulmonary artery is easily seen with the bronchus below and the middle lobe vein to the right of the middle lobe bronchus. In this operation, Dr. Gonzalez-Rivas has a Cadere forceps in arm 4 for his left hand and a Maryland in arm 3 for his right hand. The middle lobe vein is easily isolated using the Maryland forceps and a sling is brought round it. The Maryland is removed and a white Sureform 45 is introduced, and the vein stapled. The R11 lymph node is then removed from on top of the pulmonary artery. Next the middle lobe bronchus is encircled with the Maryland and a sling is brought around, followed by the green Sureform 45 stapler. Further lymph nodes are removed to fully visualise the pulmonary artery and the two middle lobe arteries. The technique for getting around an artery is slightly different as it is entirely using visual feedback, rather than tactile feedback. Dr. Gonzalez-Rivas changed the Maryland for a bipolar to get around the middle lobe artery safely and the second artery is then stapled. Finally, a line of green Sureform 45 staples are used to complete the horizontal fissure to divide the middle lobe from the upper lobe, completing the lobectomy. The endoscope is left in arm 2 and the other arms are removed for the assistant to remove the lobe. The arms are then repositioned to complete the lymphadenectomy prior to the end of the case.

Uniportal robotic right upper lobectomy with indocyanine green (ICG) labelling of a lower lobe nodule

We begin this case with a view of the operating theatre, demonstrating the positioning of the patient and draping, with the table flexed to open the intercostal space. The uniportal incision was made in the sixth intercostal space just in front of the mid-axillary line. As soon as we entered the chest, we found that there were a considerable number of adhesions and thus we began to divide them initially by uniportal VATS using hook diathermy. Once we had enough space to place the Alexis atraumatic ring wound protector, we were able to introduce the robotic arms to continue division of the adhesions robotically. We place the camera posteriorly in arm 2, but as there were adhesions to divide, we started with the camera in a thirty-degree upwards configuration before changing to thirty-degree downward position. We inserted a bipolar forcep in arm 3 for the left hand and began with a hook diathermy for the sake of speed of division of adhesions in arm 4 for the right hand. The assistant was available to provide suction for the

smoke and to place a rolled swab in the chest. The video demonstrates that we can easily get to every quadrant of the chest with uniportal robotics, and the long metal sucker is shown providing retraction for the surgeon. We then used the Firefly™ (fluorescence imaging) camera to show us the nodule in the lower lobe and mark it for a stapling later.

Further adhesiolysis was performed and the lung was taken off the diaphragm, again using the monopolar diathermy for reasons of speed of cautery for the adhesions. We used two modified TORS ports without the grounding attachments and an 8 mm port in the middle. The hilum is then exposed and an R10 lymph node is taken from under the azygous, which is also exposed through to the posterior portion of the truncal branch of the pulmonary artery. The anterior portion is then exposed, and the Maryland is placed around the truncal branch with a sling brought around it. We show the transition of the 8 mm port to the 12 mm port for the introduction of a stapler. It is quite fast, and we aim the stapler straight at the truncal branch of the upper lobe to complete the stapling with a white load on the Sureform 45 tip up stapler.

After this, we address the upper lobe vein. Having the benefit of the fully articulated instruments translates in an effortless pass of the instrument around the vein, encircling it with a sling. Again, as in uniportal VATS, because we have removed the truncal branch it makes passing the stapler around the vein easier in terms of the angle and the firing is performed with another white load on the Sureform 45 tip up stapler. After this, the posterior ascending artery is seen behind the stump of the upper lobe vein, a sling is placed and a straight white Sureform 45 stapling is performed prior to the bronchial firing. We next retract the upper lobe anteriorly to clean up the posterior hilum so that we can safely staple the bronchus. A green firing is used to staple the bronchus with the Sureform 45 tip up stapler. The fissure is now addressed, and the horizontal fissure is stapled with green and black loads on the Sureform 45 stapler. Of note, we don't use the 60 stapler as it is very long and difficult to handle in the chest. This is an identical issue experienced in multiportal and uniportal robotics.

Once the lobectomy is completed, the lobe is removed by the assistant and the arms repositioned to perform the lymphadenectomy and the wedge resection of the left lower lobe nodule. This was identified by ICG labelling that was performed via CT imaging earlier in the day. The alternative way of doing this would have been by navigational bronchoscopy to inject ICG if you have this available. For the lymphadenectomy, station 10R is cleared

underneath the azygous prior to then going above the azygous vein to complete the 4R lymph node removal. The 4R packet is taken *en bloc*, stripping it first from the superior vena cava, then dissecting across the azygous vein then up the vagus to centralise the lymph node packet and lifting it up, stripping it off the trachea until just before the subclavian artery. The inferior pulmonary ligament is then divided looking for 9R lymph nodes. One is identified and removed. There is a nice view here with the assistant providing retraction of the lower lobe superiorly. Then the subcarinal station is addressed in full, with the lower lobe retracted anteriorly. The thirty-degrees down camera, which is at the highest point of the chest, allows the subcarinal station to be easily removed prior to the end of the case. A line of intercostal blocks was placed at the end of the case as it was not possible to do this at the start due to the adhesions.

Conclusions

Uniportal VATS was first performed over a decade ago by Diego Gonzalez-Rivas, and since then, the field has seen tremendous evolution into robotics (1). We hope this atlas of five uniportal robotic lobectomies is useful to surgeons in helping them consider commencing a programme of uniportal robotic lobectomies (2). We hope that we have demonstrated that this technique is appropriate for all cases, as well as some more advanced ones, including those with larger tumours and with adhesions. We believe that with the correct equipment available (e.g., Intuitive robotic Xi

4th gen) and a two-surgeon approach, this is an excellent option.

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Footnote

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

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