Video-assisted thoracic surgery tunnel technique: an alternative fissureless approach for anatomical lung resections

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Abstract: We describe an alternative video-assisted thoracic surgery (VATS) fissureless pulmonary lobectomy technique. This involves opening the fissure completely and with staplers at an early stage of the procedure by making a tunnel between the bronchovascular structures and the lung parenchyma. To minimize air leak after anatomical lung resections, many surgeons use a "fissureless" VATS technique, using staplers to divide the hilar bronchovascular structures first and the main part of the parenchyma in the fissure last. Others try to find the artery by dissecting the parenchyma in the fissure. The advantage of the latter is clearance of N1 nodes and anatomical overview prior to division of bronchovascular structures. But, airleak can be induced when touching the parenchyma. The proposed alternative procedure tries to combine the advantages of both common techniques, i.e., reduce risk of airleak and obtain a good anatomical overview and N1 nodal clearance prior to division of the bronchovascular structures. To open the incomplete fissure first, with staplers, a tunnel dissection is started anterior between the triangle of pulmonary veins and the parenchyma. After identification of the pulmonary artery (PA), the anvil of a first stapler is placed on top of the artery and the anterior part of the fissure is divided. Dissection between artery and parenchyma is continued until the fissure is completely stapled. By making a tunnel between the bronchovascular structures and parenchyma from anteriorly to posteriorly, one can open the fissure completely with staplers at an early stage of an anatomical lung resection. This combines the advantages of both the "fissureless" hilum first technique and classic (open) fissure first dissection, i.e., minimal air leak and optimal anatomical overview before bronchovascular structures are divided, potentially avoiding inadvertent transections.

Keywords: Video-assisted thoracic surgery (VATS); lobectomy; fissure; fissureless; air leak; stapler

Introduction

During lung surgery, surgeons use mechanical staplers on the fissural parenchyma between different lobes to minimize the chance of postoperative prolonged airleak. Many video-assisted thoracic surgery (VATS) surgeons use a "hilum first, fissure last technique". The hilar bronchovascular structures are divided first and during the last step of the lobectomy the lobe is lifted and the fissural parenchyma is divided. Thanks to these fissureless techniques, incomplete or fused fissures are no longer contraindications for VATS anatomical resections (1,2).

Some VATS surgeons and many robotic surgeons continue to reveal the artery by dissecting into the fissural parenchyma. This technique, similar to open surgery, allows surgeons to remove N1 nodes on the artery and bronchus first, and to look for anatomical variations before starting to divide the bronchovascular structures. But, dissecting into the incomplete fissure can cause prolonged airleak.
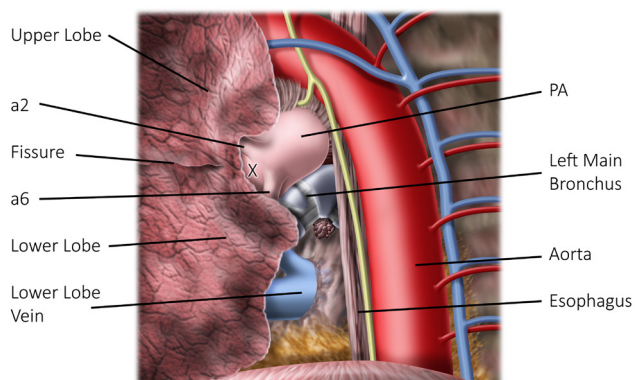
The objective of this paper is to present an alternative fissureless technique, combining the advantages of the techniques described above.

Methods
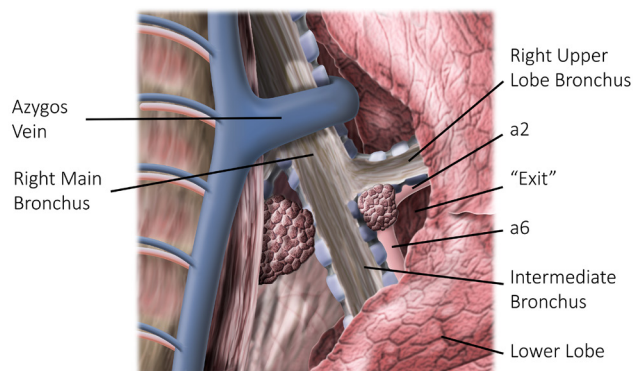
Technique

General principles

The objective of the presented technique is to open

Figure 1 Posterior view of the hilum of the left lung. The incomplete fissure ends between the artery of the posterior segment of the left upper lobe (a2) and the artery of the apical segment of the left lower lobe (a6). Freeing the artery at this level first (X), will greatly help to complete the tunnel between the bronchovascular structures and fissural parenchyma from anterior to posterior. PA, pulmonary artery.

Figure 2 Posterior view of the hilum of the right lung. The incomplete fissure ends at the secondary carina between the bronchus of the right upper lobe and the intermediate bronchus. Freeing the secondary carina will greatly help to exit the tunnel made between the bronchovascular structures and the fissural parenchyma between the upper and lower lobe.

an incomplete interlobar fissure with staplers before bronchovascular structures are divided (3). This can be achieved by making a tunnel between the bronchovascular structures and the parenchyma. We will only describe the technique to make this tunnel from anterior to posterior, although the other way around is also possible. For all three fissures, the technique starts with dissection between the lobar veins, removing all fat and lymph nodes. Next, dissection is continued between the bronchi (except for the horizontal fissure) and between the artery and the parenchyma. It is important to visualise the artery. Only then, the tip of a stapler should to be placed peripheral/lateral of the artery. It is important to keep the stapler steady and to pull the parenchyma into the stapler. Firing the stapler will open the anterior part of the incomplete fissure. Further dissection continues over the artery. The ideal dissection plane is close to the artery. Therefore, all connective tissue should be removed until the artery is free. In our experience, freeing the "exit" of the tunnel first, makes the procedures much easier. On the left side this exit is located at the artery, more specific, between the artery of the posterior segment (a2) and the apex of the lower lobe (a6) (*Figure 1*). On the right, the exit can be found at the secondary carina between upper lobe bronchus and intermediate bronchus (*Figure 2*).

Our routine VATS technique is a common three port

technique, similar to Hansen *et al.* (4). We often tilt the table anterior to better expose the posterior side of the hilum. The described technique can be performed multiportal, uniportal or robotic. But, camera view of the posterior side of the hilum is very helpful and the anterior to posterior view in the direction of the oblique fissure is essential.

Once the fissure is completed, a complete view on the bronchovascular anatomy is obtained. The anatomical resection, lobar or segmental, can then be performed in a smooth and safe manner.

Left oblique fissure (*Table 1*)

Transection of the lower pulmonary ligament exposes the lower pulmonary vein. Further opening of the posterior pleural reflexion reveals the pericardium, left main bronchus and pulmonary artery (PA) (*Figure 1*). We typically tilt the table anteriorly to achieve perfect exposure to the posterior hilum. Removing the connective tissue and lymph nodes over the artery and bronchus will bring the lung out of the mediastinum and gives easier access to the subcarinal nodes. We free the artery until we notice the origin of both the artery towards the posterior segment of the upper lobe (a2) and the apex of the lower lobe (a6). The exit of the tunnel lies between both.
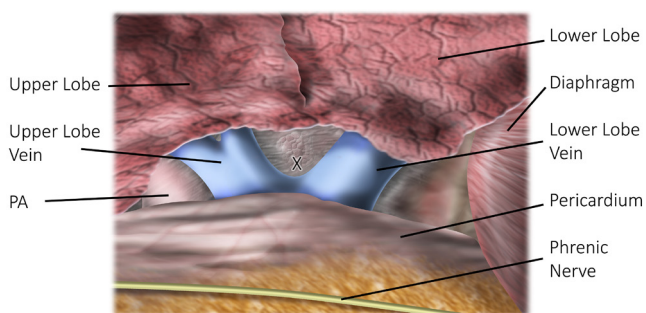
Then we change the camera view to a common anterior to posterior direction in line with the oblique fissure (*Figure 3*). We identify the upper and lower vein, open

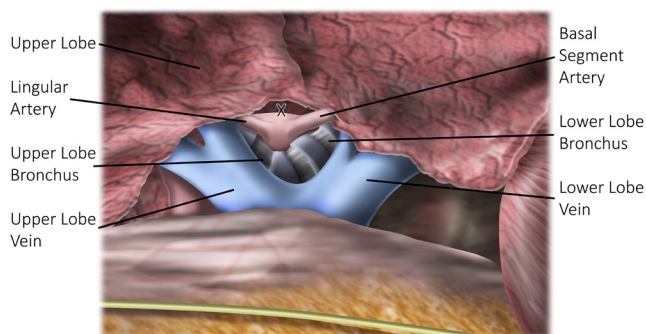**Table 1** Key points of tunnelling the left fissure

Free the artery posterior (Exit at level a2 & a6)

Start tunnel between upper and lower vein

Remove lymph node at position 11 (secondary carina)

Continue between upper and lower bronchus, identify artery

Dissect between artery and parenchyma

First stapler with tip on artery, pull in parenchyma

Continue between a2 & a6 towards exit

Divide the incomplete fissure with staplers

Caveat:

    Basal segment artery runs close to fissure

    Stapler not below a6, but between a2 & a6

    Tip of stapler away from vagal nerve, esophagus and aorta

Figure 4 Anterior view of the hilum of the left lung. After removal of the node the PA becomes visible. Typically, an artery to the lingula and one towards the anterior basal segment can be found. When this view is obtained, it is safe to place the tip of a stapler between the artery and the parenchyma (X) and open the anterior part of the incomplete fissure.
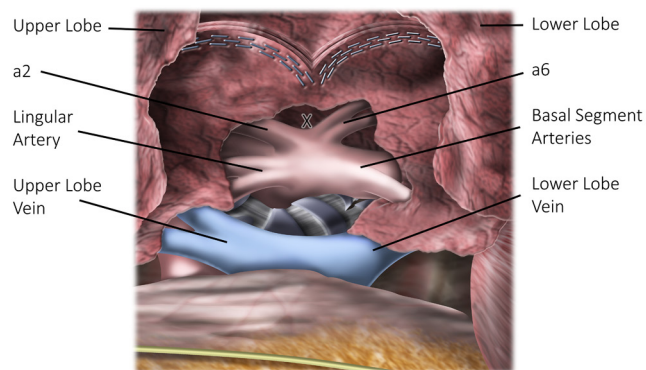

Figure 3 Anterior view of the hilum of the left lung. After opening the pleural reflexion, the tunnel is started between the upper and lower lobe vein (X). Typically, a lymph node (position 11) can be found at the secondary carina between the upper and lower lobe bronchus. PA, pulmonary artery.

Figure 5 Anterior view of the hilum of the left lung. When a first stapler is used, dissection over the artery will reveal the artery or arteries towards the apex of the lower lobe (a6) and towards the posterior segment of the upper lobe (a2). The exit of the tunnel lies between these two (X). With further staplers the fissure is then opened completely.

the pleural reflexion and remove hilar fat and nodes. This usually exposes the lower lobe bronchus. More cranially the secondary carina between the lower and upper lobe bronchus can be found. If necessary, the upper lobe vein should be retracted. Removal of the nodes at position 11 at the secondary carina reveals the PA (*Figure 4*). Pushing up the parenchyma over the artery creates the plane for the tunnel. The anvil of a 60 mm stapler is placed with the tip between the artery and parenchyma. The parenchyma is pulled into the stapler, while the tip is held in place. The anterior portion of the oblique fissure is divided. Then, dissection between artery and parenchyma is continued. The lingular and basal arteries are identified and dissection

over the main PA will end at the posterior and apical branches (a2 and a6) (*Figure 5*). The previous posterior dissection over the artery will greatly help to complete the tunnel. Overlying lymph nodes should be removed. With the next staplers the middle and posterior part of the fissure is opened.

After division of the fissure, the rest of the lobectomy can be performed swiftly and safely as the structures are mostly freed. For a left upper lobe, our typical sequence is the division of the lingular artery, the upper lobe vein,

Table 2 Key points of tunnelling the anterior part of the right oblique fissure

Identify lower and middle lobe vein, remove fat and nodes
Identify middle lobe bronchus
Find artery behind the bronchus
Dissect between artery and parenchyma
Stapler with tip on artery, pull in parenchyma of the incomplete fissure (not below bronchus or artery)

the upper lobe bronchus and finally the remainder of the arteries. For a left lower lobe this can be vein or artery first and finally the bronchus.

Right sided fissures

The fissures on the right can be divided in the anterior oblique fissure between middle lobe and lower lobe; the posterior oblique fissure between lower lobe and upper lobe, and the horizontal fissure between middle lobe and upper lobe.

Often the fissure is well developed at the intersection of these three parts. The artery can be found superficial under connective tissue. If so, opening the posterior part of the oblique fissure can be started at this point. If not, the anterior part can be opened first with a tunnel technique.

Transection of the lower pulmonary ligament exposes the right lower vein. We then tilt the table towards anterior to have a nice exposure of the posterior hilum. The pleural reflexion is opened all the way up, ending at azygos vein which is freed from the main bronchus. Removal of connective tissue brings the lung out of the mediastinum and eases the resection of the subcarinal nodes. The end of the oblique fissure can be found at the secondary carina formed by the upper lobe bronchus and the intermediate bronchus (*Figure 2*). Pushing the parenchyma laterally at this level reveals the exit of the tunnel under the posterior part of the incomplete oblique fissure. When the position 11 node at the secondary carina is removed, the artery towards the posterior segment of the upper lobe can be seen (a2). This will significantly help to complete the division of the posterior part of the fissure (5).

Right oblique fissure, anterior part (*Table 2*)

Switching to an anterior view, the veins of the lower lobe, middle lobe and upper lobe should be recognized (*Figure 6*).
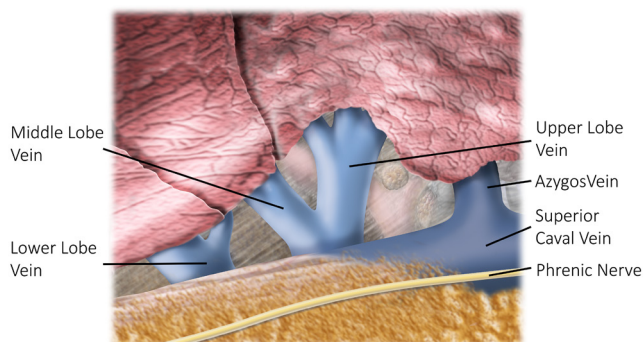
Figure 6 Anterior view of the hilum of the right lung.
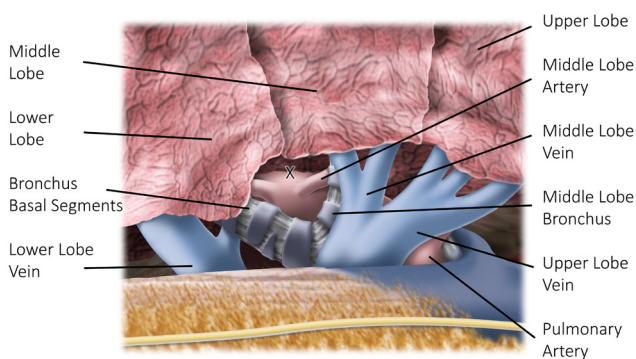
Figure 7 Anterior view of the hilum of the right lung after removing fat and nodes between the middle lobe vein and lower lobe vein. This exposes the middle lobe bronchus behind the middle lobe vein, the basal segment bronchi and the PA (posterior to the bronchi). When this view is obtained, it is safe to place the tip of a stapler between the artery and fissural parenchyma (marked by X). Keep the tip of the stapler steady while pulling the parenchyma into the stapler.

Between the lower lobe and middle lobe vein, fat and nodes needs to be removed to find the bronchus to the middle lobe. When this bronchus is followed centrally and towards posterior, the bronchus to the basal segments can be found. Between these bronchi, the PA can be revealed (*Figure 7*). Dissection between the artery and parenchyma is the plane to be followed to create the tunnel. The anvil of a 60 mm stapler is placed on top of the artery. The anterior part of the incomplete oblique fissure is pulled into the stapler and divided. This results in a better view on the artery.

Right oblique fissure, posterior part (*Table 3*)

To open the posterior part of the oblique fissure, the artery

Table 3 Key points of tunnelling the posterior part of the right oblique fissure

Free the exit of the tunnel first, i.e., the secondary carina at the posterior hilum

Anterior: dissect over artery, identify a2 and a6

In between a2 & a6: find the secondary carina
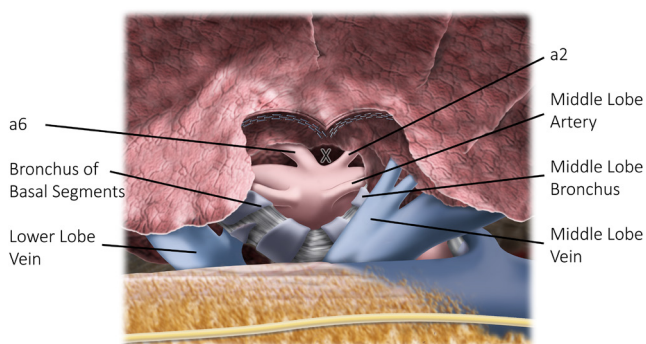
Stapler on parenchyma

Caveat with stapler:

    Not below a6

    Not underneath the intermediate bronchus

    Tip away from esophagus

Table 4 Key points of tunnelling the horizontal fissure

Identify upper and middle lobe vein, remove fat and nodes

Find artery behind upper and middle lobe vein

Place tip of stapler between a4 and v2

Divide parenchyma (anterior part)

Dissect over artery towards a2 and a6 between artery and parenchyma

Divide parenchyma with stapler
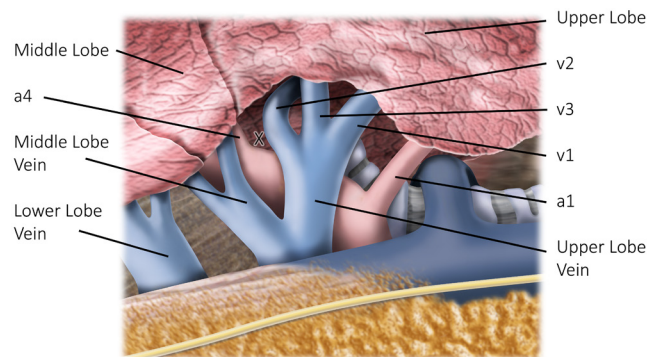
Continue with posterior part of oblique fissure

Figure 8 Anterior view of the hilum of the right lung after division of the anterior part of the oblique fissure. Further dissection over the artery will expose the artery to the apex of the lower lobe (a6) and the posterior segment of the upper lobe (a2). To open the posterior part of the oblique fissure, dissection has to be continued between a6 and a2 (X) towards the secondary carina. It is useful to free the secondary carina first, as shown in *Figure 2*. When making this tunnel it is important to identify a6 and a2 and to make sure to stay lateral of the intermediate bronchus.

branch to the apex of the lower lobe (a6) and the posterior ascending branch to upper lobe (a2). With staplers, the central part of the fissural parenchyma is divided. Next the tunnel is completed over the artery, in the direction of the previously freed secondary carina, which is the exit of the tunnel (*Figure 8*). If the position 11 node in the secondary carina was not removed completely, one can remove it after completion of the division of the fissure with a third stapler.

Right horizontal fissure (Table 4)

A right upper lobectomy requires the division of the horizontal fissure and the posterior part of the oblique fissure. Therefore, the first steps can be similar to a lower lobectomy with posterior release of the hilum, exposure of the bronchus and the secondary carina with removal of the lymph node there (*Figure 2*).

The middle lobe and upper lobe veins are identified from an anterior view (*Figure 6*). The veins that are draining the upper lobe are encircled, with care for the PA just posterior to it. Removal of fat and nodes and further dissection between the parenchyma and the confluence of both veins will reveal the PA behind the middle lobe vein. The further line of dissection is between the middle lobe artery (a4) and the vein draining the posterior segment of the upper lobe (v2) (*Figure 9*). Dissection close to the artery, between the artery and the parenchyma clears the plane of the tunnel. The tip of a 60 mm stapler is placed on top of the artery and the parenchyma of the horizontal fissure is pulled into the stapler. The division of the fissure will help visualize the inferior part of the PA, including the posterior ascending branch of the upper lobe (a2) (*Figure 10*). Sometimes the a2 is absent, very small or more anterior than anticipated. Dissection between parenchyma and artery ends at the

in the fissure should be freed first. This can be done by opening the anterior part of the oblique fissure as described above. In case of a good quality fissure at the junction of the three fissures, the artery can sometimes be exposed without parenchymal tears. In case of a right upper lobectomy, we divide the horizontal fissure first and continue with the posterior part of the oblique fissure.

After exposing the PA, the origins of a middle lobe artery and the basal segment arteries are identified and overlying lymph nodes removed. Further dissection between the artery and parenchyma reveals the segmental

Figure 9 Anterior view of the hilum of the right lung after removal of fat and nodes between the upper and middle lobe vein. This helps to identify the middle lobe artery (a4) and the vein draining the posterior segment of the upper lobe (v2). X marks the spot where to start the tunnel between the middle lobe and upper lobe. When this view is obtained, it is safe to place the tip of a stapler between the artery, a4, v2 and the overlying parenchyma. While holding the stapler in place, the parenchyma of the incomplete fissure between middle lobe and upper lobe is pulled into the stapler.

Figure 10 Anterior view of the hilum of the right lung after division of the horizontal fissure. Further dissection over the artery exposes the artery of the posterior segment of the upper lobe (a2) and the artery of the apex of the lower lobe (a6). Further steps are similar to the division of the posterior part of the oblique fissure (X). This means tunnel dissection over the artery towards the secondary carina and completion of the posterior part of the oblique fissure with staplers.
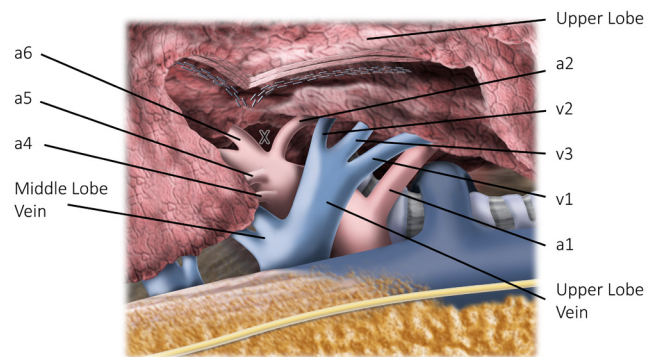
previously exposed secondary carina, completing the tunnel. At that time, the posterior part of the oblique fissure is divided.

Discussion

Dividing the parenchyma overlying the artery in the fissure can result in postoperative air leak, even in patients with nearly complete fissures. In VATS lobectomy patients, with an overall faster recovery and shorter hospital stay, the occurrence of an air leak might have more impact in comparison with thoracotomy patients with an overall longer hospital stay.

The use of staplers to divide incomplete interlobar fissures significantly reduces the duration of postoperative air leak and hospital stay compared with cautery (6,7). The level of completeness of lobar fissures is highly variable. A high-resolution CT analysis of 250 patients showed an incomplete main fissure on the left side in 24%, on the right in 35% and incomplete horizontal fissure in 74% (8). This results in a higher risk of postoperative air leak after right upper lobectomy compared with other lobectomies (9).

A fissureless technique by thoracotomy was published by Temes *et al.* Instead of dividing the overlying parenchyma to expose the PA in the fissure, the parenchyma was divided

from posteriorly to anteriorly with staplers at an early stage of the operation. They indicated that they developed the fissure completely before bronchovascular structures are divided, except for the right upper lobe (10).

Gomez-Caro described a fissureless technique where, for the upper lobes, the vein is transected first, next the first branches of the PA, the bronchus and then the posterior ascending or lingular artery. Finally, the fused fissure is stapled (11). This is known as a "hilum first, fissure last" technique.

With the rise of VATS with a superior lateral view on the hilum, it became more obvious to transect the hilar structures first and, in a final step of the lobectomy, to divide the incomplete fissure. Nomori *et al.*, Mitchell, Hansen *et al.* and Balsara *et al.* described a VATS "hilum first, fissure last" or "fissure no touch" technique (1,4,5,12).

However, we see several advantages in learning a VATS technique that helps to open fissures with staplers in an early stage of the operation.

(I) Mastering the "tunnel"-technique offers an alternative option when problems with a hilum first technique arise. This can be an incomplete fissure in combination with a technical issue that obstructs the "hilum first" technique: e.g., a central tumour, a tumor involved lymph node or a (near) bleeding of the anterior trunk of the PA;

(II) Opening the fissure with staplers in an early stage

of the operation greatly facilitates VATS segmental resections;

(III) A clear view of the intrafissural anatomy protects against erroneous transections of bronchovascular structures;

(IV) The lobectomy after the "tunnel" technique can be done with minimal retraction of the lung. Once the fissure is open, the weight of the lobes keeps the fissure exposed;

(V) As all bronchovascular structures are identified before the anatomical resection starts, one can divide the artery quickly after the vein. It diminishes the chances of a congestion of the lobe, obscuring the view;

(VI) Gomez-Caro stated that the "hilum first, fissure last" technique is not suitable for central tumours or patients with N1 disease (11). In contrast, when making a tunnel between artery and parenchyma, undermining and ultimately dividing the fissure, it is more evident not to miss the position 11 nodes, be it in the secondary carina or next to the artery.

We previously published a cohort of 198 consecutive patients operated with this alternative fissureless technique demonstrating the feasibility and non-inferiority regarding hospital stay, chest tube duration, operation time and complications in comparison with the hilum first technique (3). Since then, we continued to use the tunnel technique with early division of the lobar fissures with staplers as our standard VATS technique.

Conclusions

The depicted "tunnel"-technique involves early opening of the fissures with staplers during VATS anatomical resections.

For surgeons who normally use a hilum first, fissure last technique, this is an alternative option, when the hilar route is being "obstructed" by a central tumour, involved lymph node or (potential) bleeding. For surgeons who are used to dissecting into the fissure first to find the artery, we believe it is a valuable technique to open the fissure entirely with staplers, diminishing the chance of postoperative air leakage. Intrafissural N1 nodes are easily detected and removed. We think that this technique gives a superior view on the intrafissural anatomy before resection is started. This helps to detect anatomical variations, to perform segmental resections and to reduce the chance of inadvertent

transections.

Footnote

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Ethical Statement: The author has accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013).

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