

Thoracoscopic stapler-based “bidirectional” segmentectomy for posterior basal segment (S10) and its variants

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Abstract: Thoracoscopic segmentectomy for the posterior basal segment (S10) and its variant (e.g., S9+10 and S10b+c combined subsegmentectomy) is one of the most challenging anatomical segmentectomies. Stapler-based segmentectomy is attractive to simplify the operation and to prevent post-operative air leakage. However, this approach makes thoracoscopic S10 segmentectomy even more tricky. The challenges are caused mostly from the following three reasons: first, similar to other basal segments, “three-dimensional” stapling is needed to fold a cuboidal segment; second, the belonging pulmonary artery is not directly facing the interlobar fissure or the hilum, making identification of target artery difficult; third, the anatomy of S10 and adjacent segments such as superior (S6) and medial basal (S7) is variable. To overcome these challenges, this article summarizes the “bidirectional approach” that allows for solid confirmation of anatomy while avoiding separation of S6 and the basal segment. To assist this approach under limited thoracoscopic view, we also show stapling techniques to fold the cuboidal segment with the aid of “standing stiches”. Attention should also be paid to the anatomy of adjacent segments particularly that of S7, which tends to be congested after stapling. The use of virtual-assisted lung mapping (VAL-MAP) is also recommended to demark resection lines because it flexibly allows for complex procedures such as combined subsegmentectomy such as S10b+c, extended segmentectomy such as S10+S9b, and non-anatomically extended segmentectomy.

Keywords: Video-assisted thoracic surgery; segmentectomy; virtual-assisted lung mapping (VAL-MAP); stapler

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Introduction

Segmentectomy for the posterior basal segment (S10) may be the most challenging anatomical segmentectomy, particularly if it is thoracoscopically conducted. Stapler-based segmentectomy provides better sealing of the lung parenchyma and thus expected to reduce post-operative air-leakage and associated complications such as empyema (1). However, the application of stapler-based segmentectomy to S10 is challenging for multiple reasons: (I) similar to other basal segments [e.g., anterior basal segment (S8)], three-dimensional stapling to fold a cuboidal segment is necessary (1); (II) the belonging pulmonary artery is not directly facing the interlobar fissure or the hilum, which makes identification of target artery difficult; (III) the anatomy of S10 and adjacent segments is variable.

There are several different strategies proposed. One is to separate superior (S6) and basal segments first and then resect the posterior part of the basal segment. However, this results in complete separation of S8 and S6 (2). Leaving a small segment alone is concerning regarding possible torsion of the segment. The effect on the lung volume may also be a relative concern. Another strategy is complete posterior approach, tracking the anatomy from the pulmonary vein, and then the riding bronchus and pulmonary artery. Although successful tracking of the hilar structures enables anatomical S10 segmentectomy without separating S6 and S8, the surgery tends to be tricky because of the difficulty in obtaining good exposure of hilar anatomy and resulting confusion, particularly the bronchus and pulmonary artery. For example, even if the exposed pulmonary artery

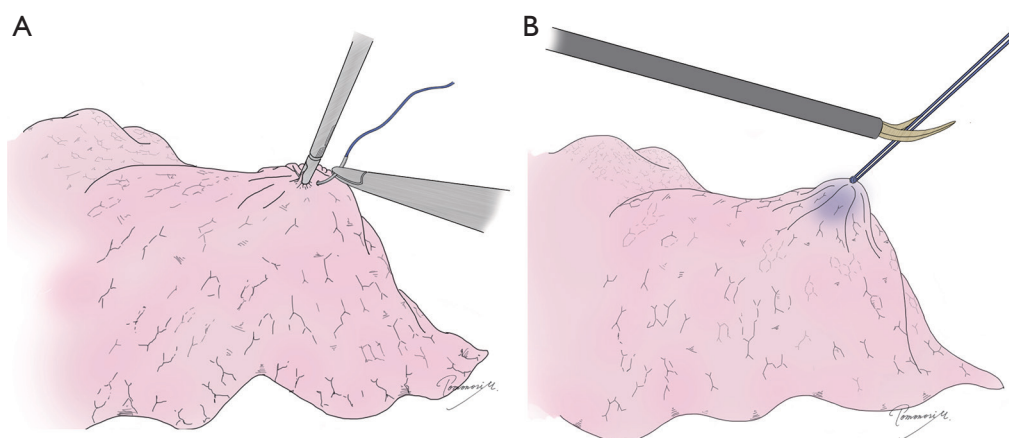


Figure 1 Placing “standing” stitches along the resection line. (A) At the very beginning of the operation, several “standing” stitches are placed along the resection lines. Slightly hard monofilament stitches are ideal because they stand out of the lung usually at corner and intermediate points if necessary; (B) the stitch should be kept somewhat long (1 cm or more) for better visualization from a distance or a tangential direction, especially at the time of stapling. This figure and legend was reproduced from (1).

and bronchus are considered to be A10 and B10, they are frequently more peripheral structures such as A10c and B10c, respectively. This kind of misunderstanding on anatomy may lead to unsatisfactory outcomes such as resection of insufficient lung tissue. Conversely, resection of a wrong hilar structure without appropriate confirmation of anatomy may necessitate larger resection than the original plan such as basal segmentectomy or even lobectomy.

To overcome the challenges and to achieve satisfactory outcomes, we herein report the “bidirectional” approach, by which surgeons can easily resolve the potential problems of S10 segmentectomy.

Operative techniques

Technical principle of stapler-based segmentectomy

Technical details of stapler-based segmentectomy in general have been described previously (1). We usually use virtual-assisted lung mapping (VAL-MAP), a preoperative bronchoscopic multi-spot dye marking technique, to determine appropriate resection lines intraoperatively (3,4), although other methods such as conventional and applied inflation-deflation line (5), and intravenous or bronchoscopic indocyanine green (ICG) injection (6-8) are also usable. Regardless of the methods to demarcate resection lines, we recommend placing “standing stitches” along resection lines with a monofilament stitch such as 3-0 proline, especially at the corner of intersegmental

plane(s) (Figure 1). These stitches are well visible at stapling even in limited vision of thoracoscope (Figure 1), even in a uniportal VATS approach of our recent experience.

After dissection of hilar structures, confirmation of anatomy is another key for successful segmentectomy. The hilar anatomy should be carefully inspected in the light of preoperative 3D images, and intraoperative bronchoscopy. Removal of hilar lymph nodes is also important not only for lymph node sampling but for exposure of clean anatomy (1). And then the target bronchus and vessels are resected by a stapler, energy device, or simply after tying. The hilar pulmonary parenchyma should be further resected along the intersegmental plane by approximately 1 cm. This maneuver creates space to allow for a stapler to be placed smoothly at the hilum (1).

Finally, the intersegmental planes are resected by a stapler. The recommended principle of stapling is “peripherally to centrally” and “step-by-step” stapling. Namely, stapling is started from the thin, peripheral, and easy parts of the lung and continued to reach the most difficult hilar stapling and/or stapling of the thick lung tissue in a step-by-step manner. Especially in segmentectomies involving the basal segment of the lower lobe necessitating three-dimensional stapling, different peripheral stapling are done first and then the staple lines are connected together toward the center (1). Notably it is safe to place the cartilage side of the stapler to the hilum rather than the anvil side, which can easily damage the lung parenchyma or vessels (Figure 2). After removal of the specimen, sealing of the hilum using soft coagulation is

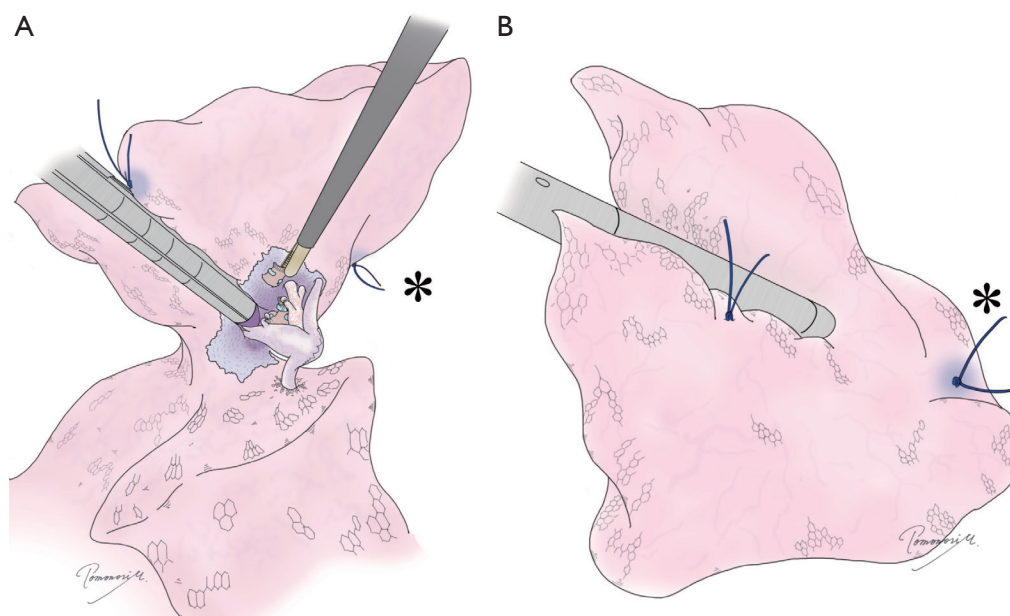


Figure 2 The principle of the “step-by-step” stapling technique. A stapler should be placed from the periphery to the central area. The position of both the cartilage (A) and anvil (B) of the stapler should be visually confirmed by twisting the lung, changing the angle of the thoracoscope, or changing the camera port. The cartilage rather than the anvil of a stapler should be placed toward the hilum to avoid the risk of vascular damage. Also, the anvil tends to stick into the lung parenchyma, causing bleeding. The “standing” stitch markings should be used as a guide to determine the location of stapling and to determine the direction. Note that the most cephalic stitch (*) can be seen from both sides because it is standing out of the lung. This figure and legend was reproduced from (1).

effective in preventing air leakage.

Techniques specific to S10 segmentectomy step 1: anterior approach

Nowadays construction of 3D images based on thin-slice CT images is almost mandatory. Particularly the vascular and bronchial anatomy of S10 and adjacent segments such as S6, 9, and S7 is variable.

In the two-directional S10 segmentectomy, hilar dissection is started from the interlobar fissure. The purpose of this dissection is to obtain correct orientation of pulmonary artery, especially A9, A10, and their branches, which are often located deep in the lung. The interlobar pulmonary artery is exposed and then A6 and basal pulmonary artery should be easily identified. Although A8 is usually easily identified as well, the separation of A9, A10, and their branches are located deep in the lung. The visualization is often interfered with the existence of A8a and/or A9a, which stands up in front of the targeted deep structures. A technical tip is to encircle basal artery and retract it with a vessel tape. This maneuver helps to “pull

up” the artery to visualize peripheral branches (*Figure 3*). Usually branching as far as to A10 or A10a can be visualized without resecting any pulmonary parenchyma. If the resection is S9+10, A9a for example can be resected at this stage, which help visualizing the deep structures. The taping of pulmonary artery also helps to visualize bronchus behind (*Figure 3*). It is ideal to encircle the target artery and resect it, followed by the target bronchus at this stage. However, as a reality, it is often felt too deep to safely encircle (especially A10 in S10 segmentectomy or A10b and c in subsegmentectomy). If this was the case, we leave the vessel tape encircling the basal artery or encircle a more peripheral branch such as A9+10 and then proceed to the next step. Once again, the key at this stage is clarify the anatomy of pulmonary artery from the interlobar fissure. Resection of pulmonary artery and bronchus can be done later from the posterior hilum.

Techniques specific to S10 segmentectomy step 2: posterior approach

As the second step, the posterior hilum is exposed. This is

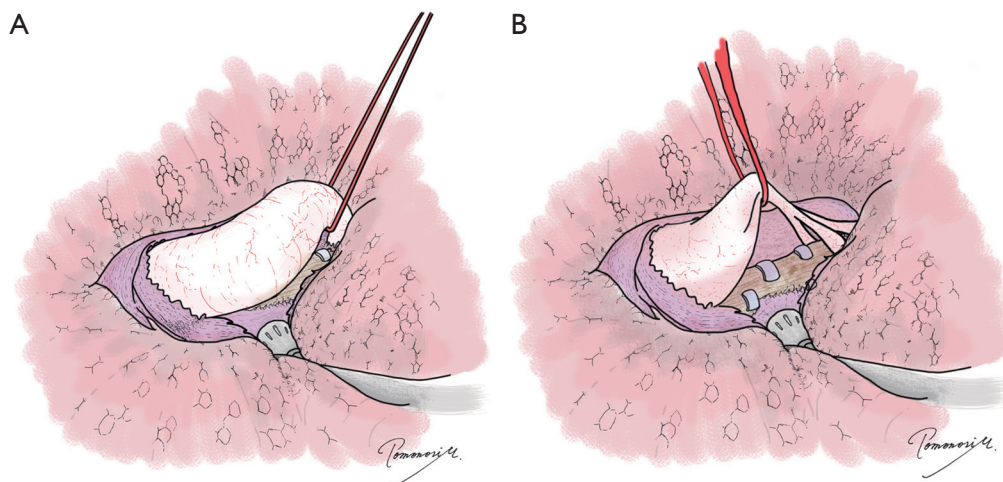


Figure 3 Techniques specific to S10 segmentectomy step 1: anterior approach. The dissection of the interlobar fissure followed by taping (A) and retraction (B) of the interlobar pulmonary artery allows for dissection and identification of peripheral branches of pulmonary artery and bronchus behind. Note that it is not mandatory to identify and resect the target pulmonary artery and bronchus at this stage. If this is the case, a vessel tape encircling the pulmonary is left for later identification of target pulmonary artery from the posterior hilum.

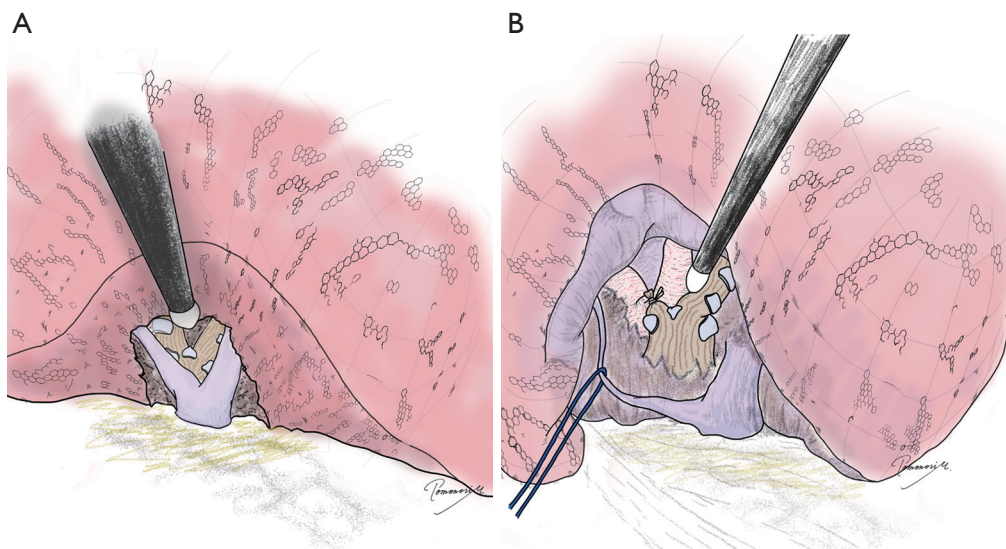


Figure 4 Techniques specific to S10 segmentectomy step 2: posterior approach. Dissection of the posterior hilum, exposure of the inferior pulmonary vein (A) and identification of bronchus and pulmonary artery (B). Note that the anatomy of bronchus and pulmonary artery exposed needs careful confirmation. They are frequently more peripheral branches than anticipated.

why we call this approach “bidirectional”. The pulmonary ligament is resected and the inferior pulmonary vein is exposed to examine the branching referring to the prepared 3D images. By tracking the pulmonary vein peripherally, the bronchus and pulmonary artery behind the venous branch can be exposed relatively easily (Figure 4). However, this posterior approach

alone is difficult in correctly nominate the exposed pulmonary artery and bronchus. Very often, the exposed bronchus and artery are more peripheral ones than presumed. Also note that the lung is usually retracted anteriorly to expose the posterior hilum, pulmonary artery and bronchus are retracted as well, making the anatomy even more confusing. A10 running

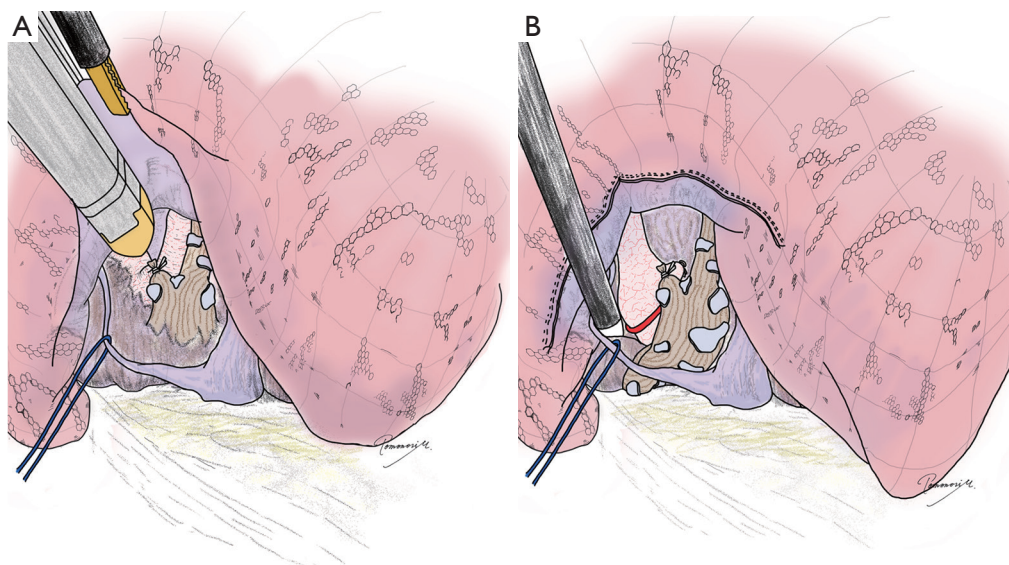


Figure 5 Tricks for better exposure of the posterior hilum. (A) Development of the posterior intersegmental plane between S6 and S10 from the posterior approach. Standing stitches are helpful to set an appropriate staple line; (B) exposure of the posterior hilum facilitated by retraction of V6.

caudally may look running even anteriorly. At this stage, identification of the pulmonary artery and bronchus from the interlobar fissure is of great help. By tracking the pulmonary artery and bronchus centrally, the vessel tape encircling the pulmonary artery can be identified. If the target artery and bronchus are already resected from the fissure side, the stumps can be reached relatively easily.

Exposure of the bronchus and pulmonary artery is often felt unsatisfactory and difficult because they are still hidden behind the lung parenchyma. We do not hesitate to start creating the posterior intersegmental plane between S6 and S10 from the posterior approach (*Figure 5A*). Just a single stapling dramatically improves the hilar exposure. If the posterior space is felt too small for stapling, energy device could also be used to resect the lung parenchyma.

If the vessel tape encircling the pulmonary artery cannot be visualized yet, exposure of structures belonging to S6 (V6 and B6) is also recommended. Namely, by taping V6 and retracting it cranially, the basal bronchus can easily be tracked centrally toward the bronchus intermedius on the right side or the main bronchus on the left side (*Figure 5B*). Once branching to B6 is identified, it becomes an important landmark to expose more central pulmonary artery. This maneuver is particularly useful when the anatomy of S6 is complex such as the case of dual branching of B6, wherein S6 tends to be larger than usual.

These maneuvers of resecting S6–S10 intersegmental plane and exposure of S6 structures make the approach much safer than “digging a hole” along a peripheral pulmonary artery. Bronchial anatomy can and should always be confirmed by intraoperative bronchoscope.

Techniques specific to S10 segmentectomy step 3: stapler-based development of intersegmental line

Once the anatomy is clear, the target artery, vein, and bronchus are resected. Confirmation of bronchial branching by interoperative bronchoscopy is mandatory. Following resection of all the targeted hilar structures, the intersegmental planes are made using staplers based on the principle of “peripherally to centrally” and “step-by-step stapling” as was described previously (1). For S10 segmentectomy, followed by the posterior separation of S6/S10 (*Figure 5A*), we usually staple the lung facing the diaphragm (*Figure 6A,B,C*; arrows b to f, and c to g, and then f to g). And then the lung tissue between the two resection lines are further stapled (*Figure 6A,B,C*; arrows g to h, and h to e). The resulting lung after completion of S10 segmentectomy is shown in *Figure 6D,E*.

Management of S7

Particularly on the right side, special attention should be

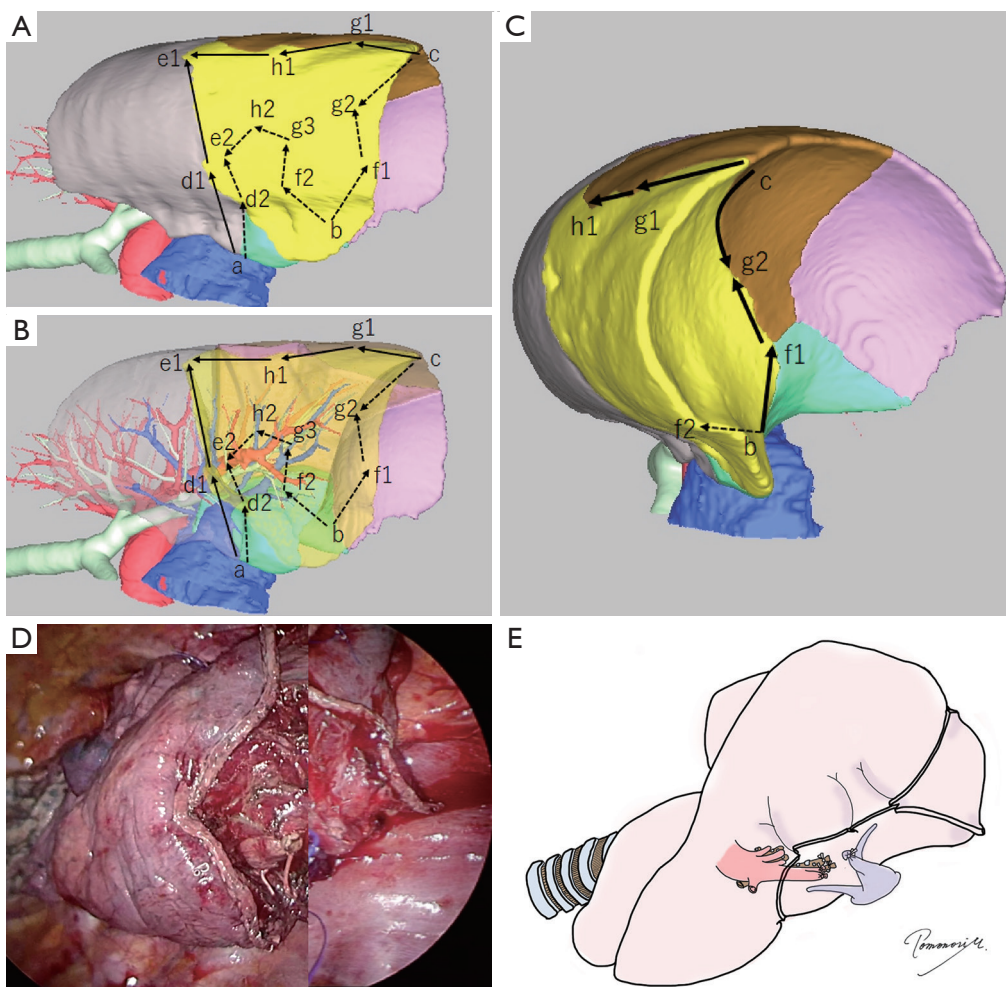


Figure 6 Techniques specific to S10 segmentectomy step 3: stapler-based development of intersegmental line. (A-C) The design of three-dimensional stapling in right S10 segmentectomy. Illustrations of stapler-based S10 segmentectomy showing a superficial lateral view (A), a semi-transparent lateral view showing the hilar structures (B), and a superficial diaphragmatic view (C). An actual intraoperative view (D) and an illustration (E) of completed S10 segmentectomy using stapler-based approach. Note that multiple points such as d1 and d2, and g1, g2, and g3 are stapled together into points D and G, respectively. Although the stapling process may appear to be complex, the principles of “going peripherally to centrally” and “step-by-step stapling” following the “standing” marking stitches allow for thoracoscopic smooth completion of S10 segmentectomy. In (D), two intraoperative pictures were merged to visualize the whole right lower lobe.

paid to the resection line between S7 and S10 (arrow b to f in *Figure 6*). A typical mistake is to set this line “downwards” as shown in the interrupted arrow in *Figure 7*, which tends to result in congested, useless S7 shaping like a “peninsula”. Because surgeons intend to preserve the lung volume as much as possible, such a downward resection line seems especially tempting if a part of S7 is protruding laterally beyond the pulmonary ligament (*Figure 7B*). Rather we recommend stapling this part in a relatively “upward” manner, somewhat medial to the pulmonary ligament (solid arrows in *Figure 7*).

On the diaphragm side, it is better not to go too deep toward the center of the diaphragm (i.e., to make the angle b-f in *Figure 6C* not too sharp). At the hilum, attention should also be paid to preserve the pulmonary vein draining from S7.

This technique usually results in resecting a part of S7, although the loss of the lung volume and/or lung function appears to be minimal. If it is really necessary to preserve the complete S7, the technique using electrocautery may be better than stapling. Indeed, at the extension of the pulmonary ligament, there may be a fibrous layer bordering

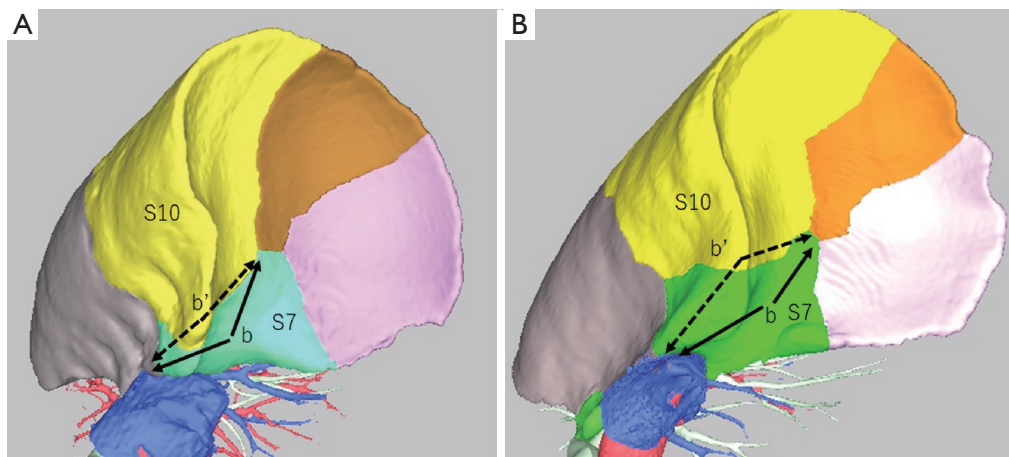


Figure 7 Variation of S7 anatomy and stapling between S10 and S7. (A) A common S7 anatomy and (B) a more protruding S7 toward S10. The interrupted arrows indicate “upward” stapling, which may result in a peninsula-like shape of the remaining S7 and congestion. The solid arrows indicate an “upward” stapling that can avoid such a problem of S7, although a part of S7 may need to be resected. A tip is to start stapling somewhat more anteromedially (point b) than the tip of the pulmonary ligament (point b’).

S7 and S10, which is well separated by electrocautery without causing air leakage.

Comments

The stapler-based segmentectomy for S10 or related ones (e.g., S9+10 segmentectomy, S9b+c combined subsegmentectomy) is probably the most challenging one among different types of segmentectomies. This is because of the anatomical property of this segment, including (I) three-dimensional stapling is necessary similar to other basal segments (1); (II) the belonging pulmonary artery is not directly facing the interlobar fissure or the hilum but hidden behind the pulmonary vein and thus disorientation could happen relatively easily; (III) the anatomy of S10 and adjacent segments is variable. To overcome these challenges one by one, we herein summarized the technique of S10 segmentectomy, particularly focusing on the stapler-based “bidirectional” method wherein complete separation of S6 and basal segment is not necessary.

Stapler-based segmentectomy is easier if it can be completed by “linear” stapling (e.g., S2, S6, and lingular) or U-shaper or V-shaped stapling (e.g., right S1, left S3, right S2b+3a) (1). Conversely, in what we call “three-dimensional” segmentectomy, the intersegmental planes make a cuboid-shaped segment primarily because of the plane phasing the diaphragm. This anatomical characteristic of the segment makes it difficult to imagine how multiple stapling folds the

cuboidal segment. As was described previously, the principle of “staple from the periphery to the center” and “step-by-step” stapling along the “standing” marking stitches allows for effective stapling even in limited thoracoscopic view (1).

In addition to the necessity of the three-dimensional stapling, segmentectomy of S10 and its variants is further challenging because the belonging pulmonary artery, the primary landmark of segmentectomy, is not facing either the interlobar fissure or the hilum, but hidden behind the inferior pulmonary vein from the posterior view. The anatomy of pulmonary artery cannot be tracked from the central part where the anatomy is obvious. We herein described the advantage of the two-directional approach, which allows for correct understanding of the patient’s hilar anatomy from the posterior hilum without separating S6 and basal segments. As was described previously, complete separation of S6 and basal segment allows for clear visualization of hilar anatomy (2). Although this approach is technically easier, it leaves relatively small segments separated, which is potentially concerning in the function and the torsion of the segment. The two-directional approach allows for anatomical confirmation from the fissure, while stapler-based resection of the segment from the posterior hilum.

Lastly, the anatomy of S10 and its adjacent segments is quite variable among patients. It is critical to understand the patient’s anatomy using three-dimensional imaging and to confirm it using multiple modalities during operation such as bronchoscopy, reference of preoperative three-dimensional imaging, and the two-directional approach as was mentioned

above. Particularly, we herein focused on the management of S7 in this article because this relatively minor segment is rarely under the spotlight but actually almost always a problem in S10 segmentectomy on the right side. Unfortunately, complete resection of S10 using a stapler often results in resection of a part of S7 to avoid excessive congestion. We consider it is important to understand this anatomical property before operation and to appropriately manage it.

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Footnote

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

Informed Consent: We do not obtain informed consent for this particular publication, although the patients participated in a study with written informed consent. We consider registration at a research comprehensively include potential publication.

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