Review Article

# Anatomical variations and pitfalls to know during thoracoscopic segmentectomies

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**Abstract:** The rate of sublobar resection (SLR) for early-stage non-small cell lung carcinoma (NSCLC) is increasing, mainly because of a growing rate of early-stage lung carcinomas and ground-glass opacities. More and more SLRs are now performed by a thoracoscopic, a video-assisted or a robotically-assisted approach. Although surgeons are performing pulmonary segmentectomies for years, they need a better understanding of anatomy when using a closed chest approach, because vision is more limited and they cannot stretch and expose the parenchyma and broncho-vascular elements. In this article, we will describe most of the significant anatomical variations we have encountered during a consecutive series of 390 full thoracoscopic segmentectomies, either at surgery or preoperatively by studying the 3-dimensional (3D) modelisation.

**Keywords:** Sublobar resection (SLR); segmentectomy; lung cancer; anatomy

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With growing experience with thoracoscopic anatomical segmentectomies, the surgeon becomes more and more prudent and cautious during vascular dissection as he/she realizes there is not a unique and standard anatomy with variations but there is actually no regular anatomy. In other words, there are only variations. Although surgeons are performing pulmonary segmentectomies for years, they need a better understanding of anatomy when using a closed chest approach, because the vision is more limited and they cannot stretch and expose the parenchyma and broncho-vascular elements as they used to do with hands inside the chest cavity.

Throughout this article, we will describe most of the anatomical variations we have encountered during a consecutive series of 390 full thoracoscopic segmentectomies, either at surgery—with systematic shooting of anatomical features—or preoperatively by studying the 3-dimensional (3D) modelisation (1,2). This underlines the need for a thorough preparation of these procedures with use of 3D reconstructions, whose benefit has been stressed by many authors (3-9). By reading this paper and looking at the figures, those of the younger surgeons or those just embarking in this surgery will realize that even segmentectomies taken to be straightforward, e.g., lingulectomies or $S^6$ segmentectomy, can be tricky.

This article will be based not only on our own experience but also on the "Illustrated anatomical segmentectomy for lung cancer" atlas by Nomori and Okada (10) that is a unique contribution to this topic and a precious support to the surgeon. Most data reported in this paper have been borrowed to this atlas.

In this article, we will describe only significant anatomical features of most common sublobar resections (SLR) and only those which have surgical consequences.

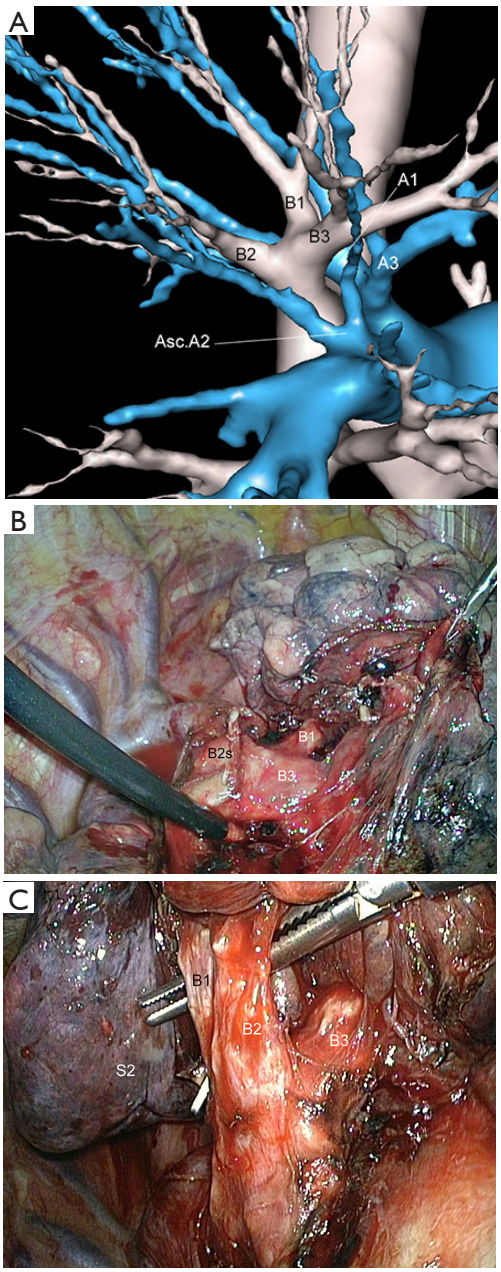


**Figure 1** Independent bronchi as seen on 3D reconstruction (A) and at thoracoscopy (B), (C) shows common $B^{1+2}$ and independent $B^3$.

## Right apico-posterior ($S^{1+2}$) and posterior ($S^2$) segmentectomies

### *Bronchus*

As it enters the parenchyma, the upper lobe bronchus triplicates into three segmental bronchi: apical ($B^1$), posterior ($B^2$) and anterior ($B^3$). $B^1$ and $B^2$ can originate separately or as a common trunk ($B^{1+2}$) (*Figure 1*). During a posterior approach, $B^2$ can be mistaken for $B^{1+2}$ if $B^1$ and $B^2$ are independent and if both bronchi are short.

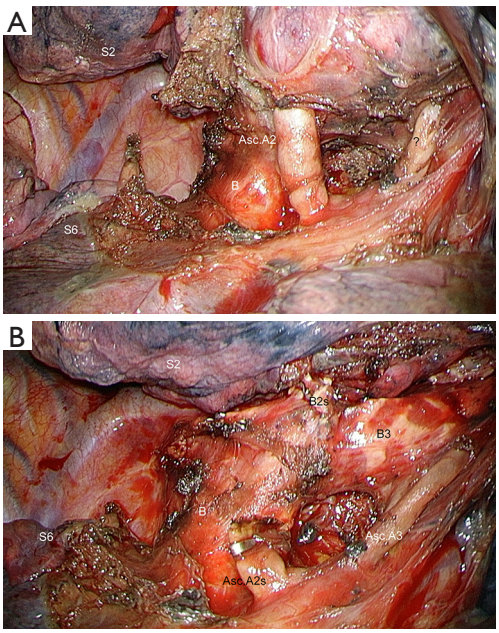


**Figure 2** Thoracoscopic dissection demonstrating two ascending arteries within the fissure. (A) The most anterior artery (indicated by "?") could be a second Asc.$A^2$ or an Asc.$A^3$; (B) as dissection is continued, it becomes clear that this artery is for $S^3$. Asc.$A^2$s, stump of Asc.$A^2$; B, upper lobe bronchus.

### *Arteries*

They arise from the truncus anterior (TA) and from the PA in the fissure, also named arterial truncus intermedius (ascending arteries). The TA duplicates into two branches: the apical artery $A^1$ and the anterior artery $A^3$ that must be preserved. The posterior segment is supplied by the ascending $A^2$ (Asc.$A^2$) that originates within the fissure from the posterior aspect of the pulmonary artery, opposite the middle lobe artery. It ascends to $S^2$ and lies posteriorly to the lobar bronchus. In most patients, there is only one artery, while there are none or two in some patients. When there are two ascending $A^2$, the most anterior one must not be mistaken for an anterior ascending branch ($A^3$) which supplies the anterior segment (*Figure 2*).

In 72% of patients, a branch of the TA supplies $S^2$ and is named recurrent $A^2$ (Rec.$A^2$). It usually runs along the

 

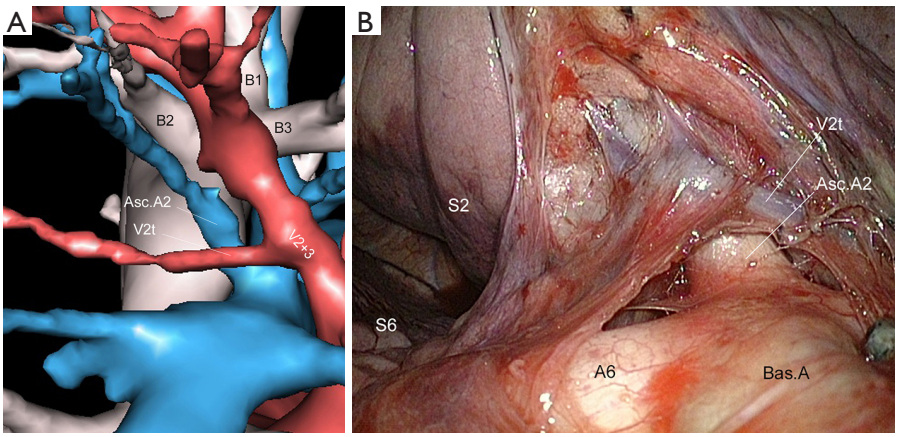


**Figure 3** $V^{2t}$ crossing the posterior aspect of $Asc.A^2$. (A) 3D reconstruction; (B) thoracoscopic view.

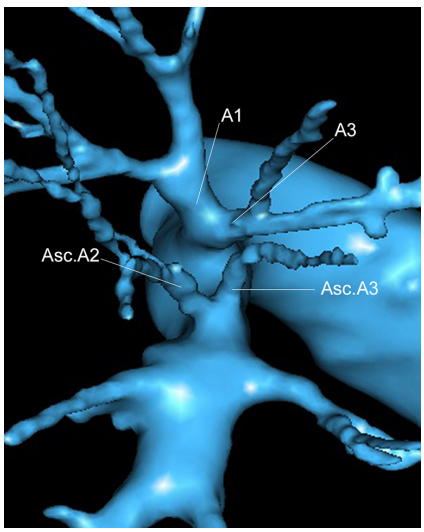


**Figure 4** 3D reconstruction demonstrating two ascending arteries from the main pulmonary artery, one for $S^2$ and one for $S^3$.

bronchus. When present, the recurrent $A^2$ can be at risk during dissection of $B^1$ or $B^2$.

In about 10% of patients, the ascending $A^2$ artery originates from the superior supply of the lower lobe or forms a common trunk with $A^6$.

### *Veins*

In most cases, the segmental veins of the upper lobe are the two upper tributaries of the upper lobe vein: (I) $V^1$ is the uppermost branch and is found in the hilum of the upper lobe. It is the most anterior and superior vessel; (II) $V^{2+3}$ is the central vein and runs in the parenchyma and within the fissure. It gives a large posterior branch for $V^2$ and small tributaries for $V^3$. A small vein ($V^{2t}$) draining $S^2$ frequently cross the posterior aspect of the ascending $A^2$ (*Figure 3*) and must be severed before dissecting this artery (11).

## Right anterior segmentectomy ($S^3$)

### *Bronchus*

$B^3$ is the anterior branch of the upper bronchus. It is usually independent from the apico-posterior truncus ($B^{1+2}$) or from $B^1$ and $B^2$ and is usually easily recognized by its anterior direction, while $B^1$ and $B^2$ have a cephalad direction. Lymph nodes are frequently found at the origin of $B^3$. Even for benign conditions, removal of these nodes is required for an optimal disclosure of $B^3$ root.

### *Arteries*

$A^3$ is the lowermost branch of the TA. An ascending $A^3$ is present in some patients, raising close to the ascending $A^2$ and recognizable by its anterior direction. In some cases, there are two ascending arteries in the fissure. The posterior one ($Asc.A^2$) for segment 2 and the anterior one ($Asc.A^3$) for segment 3 (*Figure 4*). The latter must not be confused with a middle lobe artery which must always be identified before any ligation or clipping of an ascending artery.

### *Veins*

There are two types of veins: (I) a large V3 that is the

 

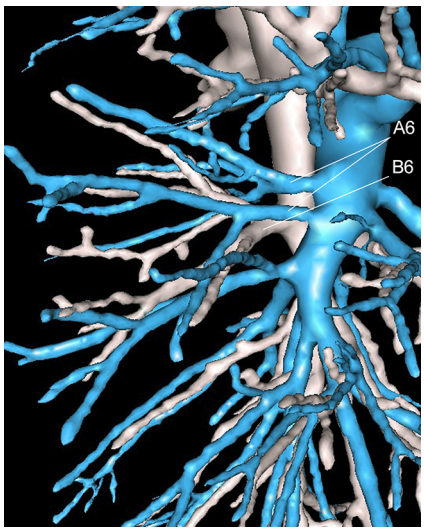


**Figure 5** Double $A^6$ artery.

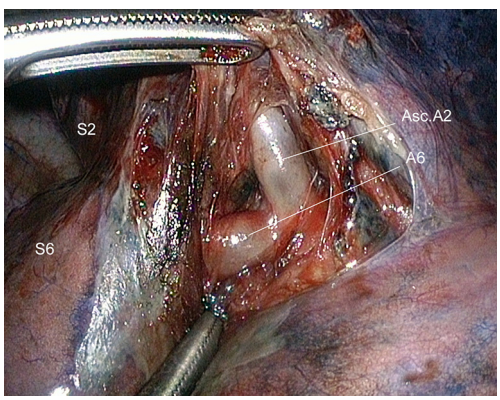


**Figure 6** Common origin of $A^6$ and $A^2$.

lowermost branch of the central vein and (II) 1 or 2 small ascending veins branching from the central vein that are easily recognized as they come directly from the anterior segment.

## Right superior segmentectomy of the lower lobe ($S^6$)

### *Bronchus*

The superior segmental bronchus originates opposite or slightly above the middle lobe bronchus. It lies posteriorly to the segmental artery and separates into two main branches, rarely into 3. $B^6$ is single in most patients but can seldom be double.

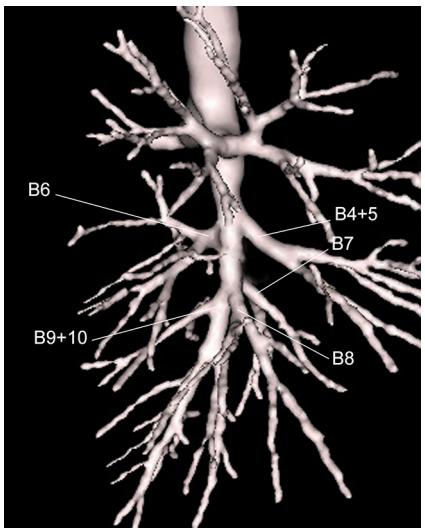


**Figure 7** Usual pattern of right basilar bronchi, with a common trunk for $B^9$ and $B^{10}$.

### *Arteries*

The superior segment of the right lower lobe is supplied by an artery ($A^6$) which originates within the fissure at the same level than the basal trunk. It is usually single, but can be double (*Figure 5*) and even triple. In some patients, the superior segmental artery originates from the ascending artery of the upper lobe ($A^2$), or from the basal trunk (12) (*Figure 6*).

### *Veins*

The vein to the superior segment is the uppermost and smaller segmental tributary ($V^6$) of the inferior pulmonary vein (IPV).

## Right basilar segmentectomy ($S^{7-10}$)

### *Bronchus*

The origin of the common basal trunk is found in the fissure 1 to 2 cm beyond the origin of $B^6$. The basilar bronchial trunk usually separates in three branches: $B^7$, $B^8$ and $B^{9+10}$ (*Figure 7*) that run posterior to the corresponding segmental arteries. In rare cases (8%), instead of the usual $B^8$ and $B^{9+10}$ pattern, the branching is reverse, i.e., $B^{8+9}$ and $B^{10}$ and in 6% of patients, $B^7$, $B^8$, $B^9$ and $B^{10}$ are independent.

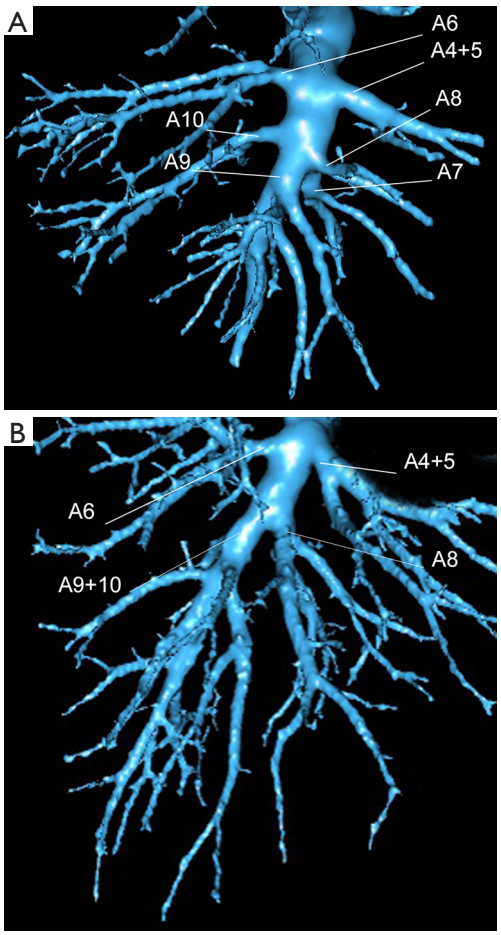


**Figure 8** Two different pattern of the arteries to the basilar segments. (A) Four independent branches to each of the segments; (B) $A^{9+10}$ and one $A^{8}$ with lacking $A^{7}$.

### *Arteries*

The arterial supply of the basal segments is the termination of the pulmonary artery after the birth of $A^{6}$. It runs anterior to the segmental bronchus and usually separates into two main trunks, one for $S^{7+8}$ and one for the posterior and lateral segments $S^{9+10}$. It can also separate into 3 to 4 segmental branches. $A^{7}$ can be lacking (16%). $A^{8}$ and $A^{9+10}$ are usually presenting as 2 separate trunks (90%) (*Figure 8*).

A middle lobe artery can arise from the basilar trunk, sometimes at a low level (*Figure 9*). This means an extensive dissection or the basilar trunk and/or segmental arteries is necessary to avoid accidental stapling of a middle lobe artery.

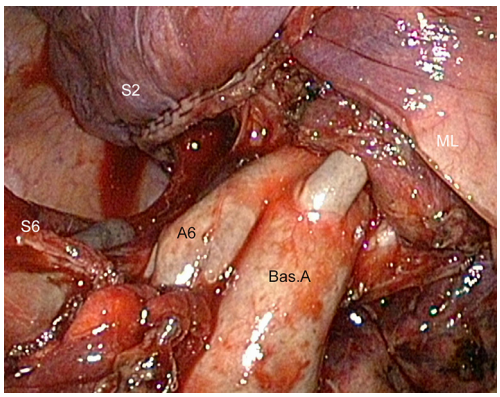


**Figure 9** Example of a middle lobe artery arising from the basilar arterial trunk and that could be damaged if dissection of the basilar arteries is insufficient.

### *Veins*

The basal segments are drained by two venous trunks, the inferior basilar vein (IBV) for $S^{9+10}$ and the superior basilar vein (SBV) for $S^{7+8}$. In some patients, there is only one common venous trunk or, on the contrary, a multiramified vein. In most cases, the two basilar veins receive tributaries from adjacent segments. This means that—as an example—ligating the $S^{9+10}$ vein at the level of the central vein when performing a segmentectomy is at risk of sacrificing a venous branch draining $S^{8}$.

The superior vein ($V^{6}$) must be clearly identified before stapling these two trunks. The middle lobe vein can join the IPV (*Figure 10*). Conversely, the basilar vein can drain into the middle lobe vein.

## Lingula sparing left upper lobectomy ($S^{1-3}$)

### *Bronchi*

In its most common pattern, the upper lobe bronchus splits immediately into the lingular bronchus and a common stem that usually separates into an anterior bronchus ($B^{3}$) and an apico-posterior bronchus ($B^{1+2}$). These three segmental bronchi have a short course that can make their identification and dissection difficult. Confusion between the anterior bronchus ($B^{3}$) and the lingular bronchus is theoretically possible, as both $B^{3}$ and $B^{4+5}$, have an anterior course. However, when dissected in the fissure, the lingular bronchus is usually not visible if the lingular artery has not been divided. Only its origin is usually seen.

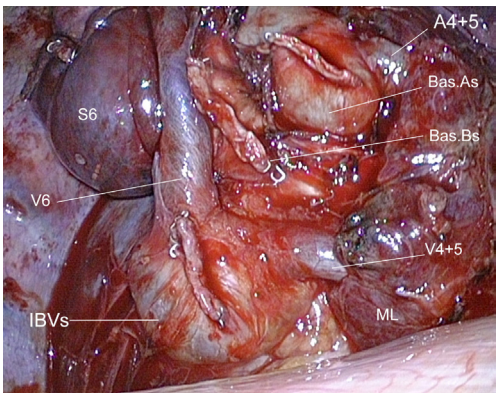


**Figure 10** Basilar vein and middle lobe vein draining together in the inferior pulmonary vein. Bas.As, stump of the basilar arterial trunk; Bas.Bs, stump of the basilar bronchial trunk; IBVs, stump of the inferior basal vein.

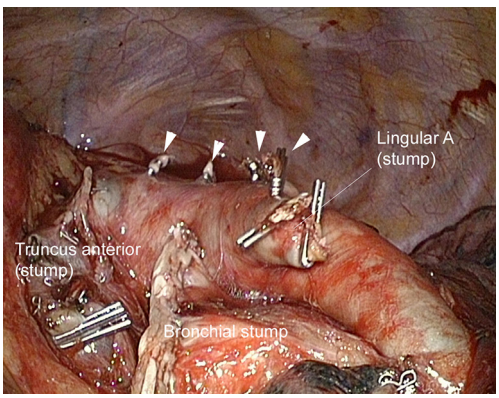


**Figure 11** Multiple arterial stumps (arrowheads) after control of all arteries to segments 1, 2 and 3 of the left upper lobe.

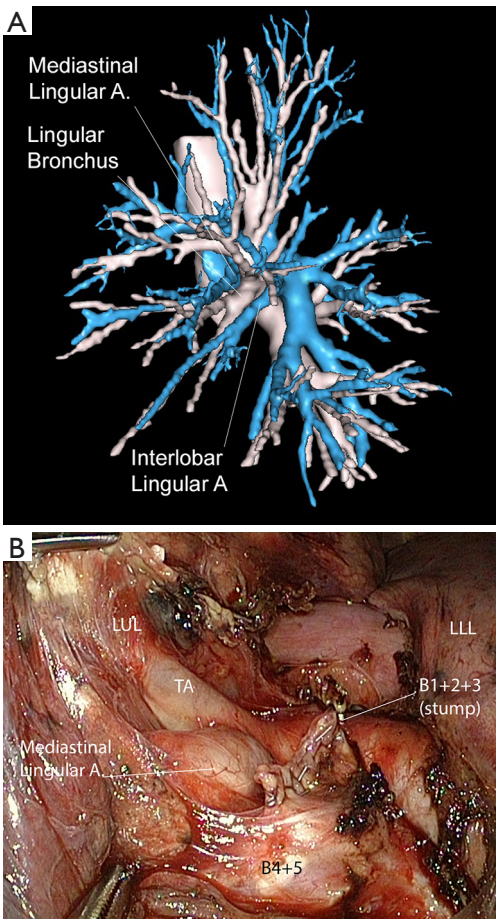


**Figure 12** Mediastinal lingular artery. (A) 3D modelisation; (B) thoracoscopic view after division of the bronchial trunk B1-3. LUL, left upper lobe; LLL, left upper lobe; TA, truncus anterior.

### *Arteries*

There are two different supplies to the let upper lobe: the TA and the posterior arteries. The TA is often broad and short. It usually gives two main tributaries, the uppermost ($A^{1+2}$) for $S^1$ and $S^2$ and the lowermost ($A^3$) for $S^3$. The posterior arteries originate in the fissure and distribute themselves over the curve of the pulmonary artery (*Figure 11*). Their number varies from 1 to 5, but most often from 2 to 3.

The presence of a mediastinal lingular artery (18%) should be search on 3D reconstruction (*Figure 12*). If present, dissection of the TA must be conducted with caution as this artery runs anterior between the vein and the $B^{1+2+3}$ bronchial trunk and is in close contact with the bronchus. Dissecting around the bronchus should be done smoothly.

### *Veins*

The superior pulmonary vein has usually three major tributaries (*Figure 13A*). The superior branch ($V^{1+2}$) drains $S^1$ and $S^2$ segments. The middle branch ($V^3$) drains $S^3$ and the lowermost branch drains the lingula. In some rare cases, $V^{1+2}$ can form a common trunk with $V^3$. Even when 3D reconstruction demonstrates a clear pattern of the venous anatomy with a distribution of the lowermost venous branch to the lingula, $V^{4+5}$ can be tiny (*Figure 13B*). It can be preferable to preserve the inferior branch of $V^3$. In some cases, it is almost impossible to determine if the adjacent vein to the lingular one comes from the lingula or from $S^3$. It seems prudent to preserve this vein, especially if the lingular vein is small.

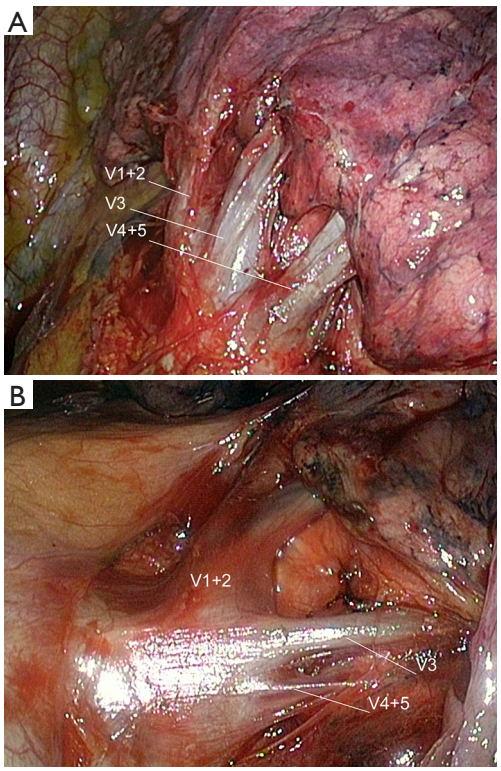


**Figure 13** The left superior pulmonary vein. (A) Usual pattern with three main branches; (B) tiny lingular vein at risk of torsion and/or thrombosis.

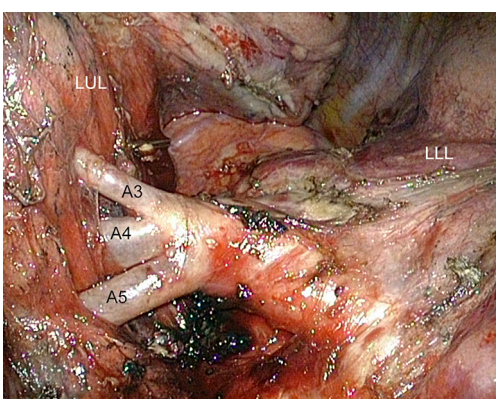


**Figure 14** Common trunk between the lingular arteries and $A^3$. LUL, left upper lobe; LLL, left upper lobe.

## Lingulectomy ($S^{4+5}$)

### *Bronchus*

The lingular bronchus originates from the bifurcation of the upper lobe bronchus and has a short course before it enters the parenchyma. In rare cases, the lingular bronchus can rise from the basilar bronchial trunk.

### *Arteries*

The main supply to the lingula comes from the lingular trunk, which is the most anterior branch of the posterior segmental arteries. It originates from the anterior aspect of the pulmonary artery within the fissure and splits into two segmental branches. In 26% of the patients, these two branches car rise separately from the main pulmonary artery.

An accessory lingular artery coming from the mediastinum, also named mediastinal or prebronchial lingular artery, is present in 18% of the patients. Its presence should be suspected when the usual lingular artery is tiny or absent. However, having 2 of these arteries with a normal diameter is not unusual.

An $A^3$ artery can rise close to $A^{4+5}$ or even form a common trunk with the lingular artery (*Figure 14*).

An artery to the basilar trunk or to $A^8$ can rise from $A^4$. This underlines the need for an extensive dissection of the lingular artery. If this variation is encountered, the branches of the lingular artery must be controlled separately.

### *Veins*

The lingular vein is the lowermost tributary of the superior pulmonary vein. It is easily recognizable when the superior pulmonary vein has three major roots ($V^{1+2}$, $V^3$ and lingular). However, in some patients, there are multiple radiating venous branches. In these cases, it is safer to divide only the lowermost branch. Once the lingula will become mobile thanks to the arterial and bronchial division, the venous drainage will become more apparent.

A lingular vein can drain into the IPV (*Figure 15*).

## Left superior segmentectomy of the lower lobe ($S^6$)

### *Bronchus*

The superior segmental bronchus $B^6$ is the first branch of the lower lobe bronchus. It arises laterally and posteriorly and lies posterior to the segmental artery. In obese or in some kyphotic patients, the bronchus can be located deeply and remote from $A^6$, so that its identification and dissection can be difficult. It may be advisable to approach $B^6$ from the back and from below, after division of $V^6$ (*Figure 16*).

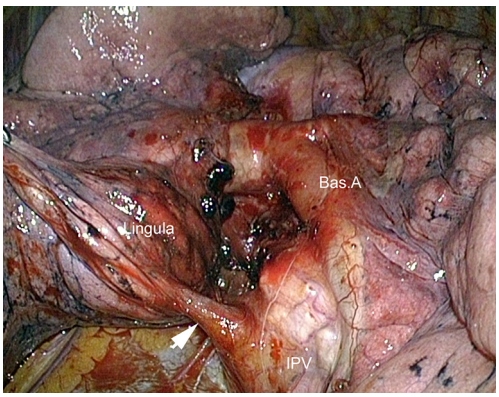


**Figure 15** Venous drainage of the lingula into the inferior pulmonary vein (arrow). IPV, inferior pulmonary vein.

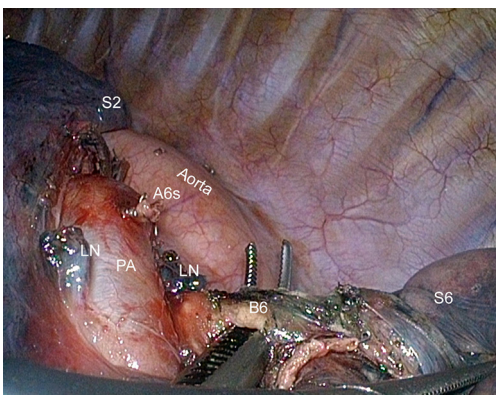


**Figure 16** Exposure and dissection of $B^6$. Note that the bronchus can be at some distance from the artery. LN, lymph nodes; A6s, stump of $A^6$; PA, pulmonary artery.

### *Arteries*

The superior segment of the left lower lobe is supplied by a single (80%) (*Figure 17A*) or double (18%) (*Figure 17B,C*) or even triple (2%) artery that originates from the posterior surface of the pulmonary artery in the posterior portion of the fissure. When single, $A^6$ artery bifurcates in 2 or 3 branches. The artery runs anterior to the segmental bronchus. A lymph node is frequently encountered close to the posterior aspect of $A^6$. It can tightly adhere to the artery and exposes to a vascular tear during dissection.

Branches to segments 9 and 10 can be close to $A^6$ and should not be confused with a branch of $A^6$ (*Figure 18*).

### *Vein*

The superior segment is drained by the superior branch of the IPV ($V^6$).

$V^6$ can receive a venous branch from the basilar segments (*Figure 19*). In this case, only the uppermost tributary of $V^6$ must be clipped.

## Left basilar segmentectomy ($S^{8-10}$)

### *Bronchus*

The origin of the common basal trunk is found in the fissure 1 to 2 cm beyond the origin of $B^6$ and the lingular bronchus.

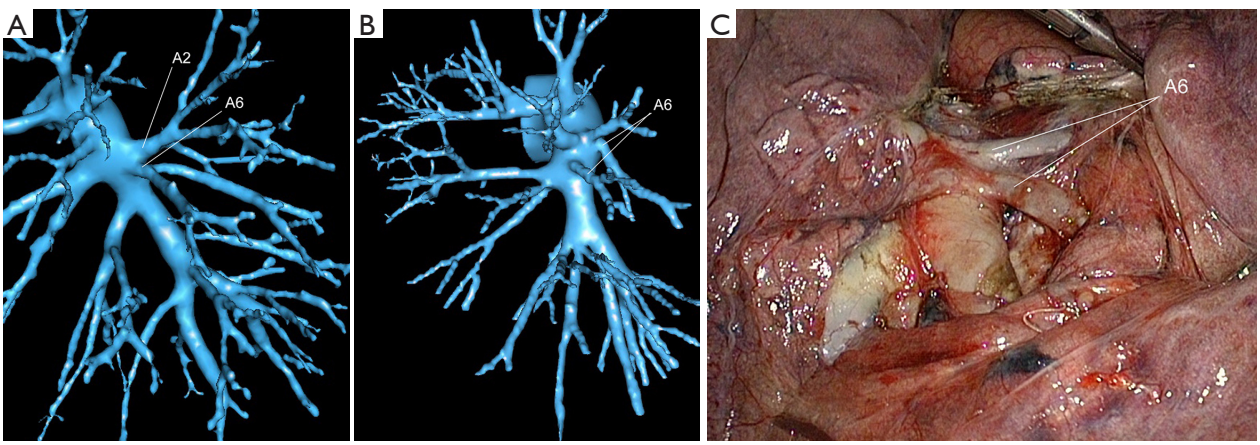


**Figure 17** $A^6$ artery, in its most common pattern. (A) Early bifurcation in two branches; (B) double $A^6$ artery (3D reconstruction); (C) double $A^6$ artery (thoracoscopic view).

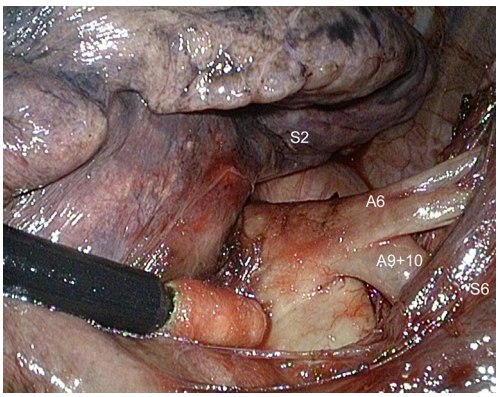


**Figure 18** Common rise of $A^6$and $A^{10}$.

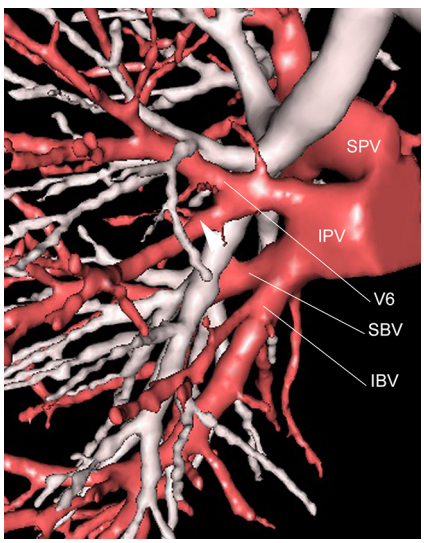


**Figure 19** Bifurcation of the $V^6$ vein: upper tributary for $S^6$ and lower tributary for the basilar segments (white arrow). SPV, superior pulmonary vein; IPV, inferior pulmonary vein; SBV, superior basal vein; IBV, inferior basilar vein.

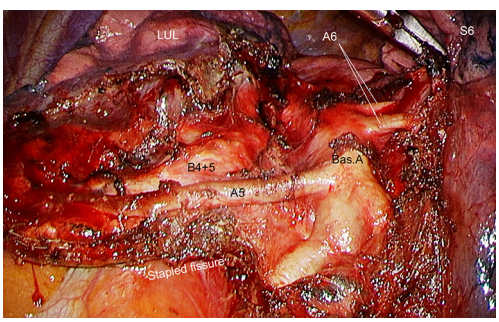


**Figure 20** Lingular artery originating from the basilar arterial trunk. LUL, left upper lobe.

### *Arteries*

The arterial supply of the basal segments is the termination of the pulmonary artery after the birth of the lingular artery and $A^6$. It runs anterior to the segmental bronchus and usually divides into two main trunks, one for $S^8$ and one for the posterior and lateral segments $S^{9+10}$. It can also separate into 3 or 4 segmental branches.

A lingular artery can originate from the basilar artery, sometimes at a low level (*Figure 20*). It is thus essential to dissect the basilar arteries on a sufficient length to avoid inadvertent clipping of the lingular artery.

### *Veins*

The basal segments are drained by two venous trunks, the inferior basilar vein (IBV) for $S^{9+10}$ and the superior basilar vein (SBV) for $S^8$. The superior vein ($V^6$) must be clearly identified before stapling these two trunks.

The lingular vein can meet up with the IPV (*Figure 21*).

## Left $S^8$ segmentectomy ($S^8$)

### *Bronchus*

In most patients (80%), the basilar bronchial trunk usually separates in two branches: $B^8$ and $B^{9+10}$ which lie posterior to the segmental arteries. In rare cases (16%), the three bronchi are independent.

### *Arteries*

The basilar arterial trunk branches separate in most cases (74%) in two arteries: $A^8$ and $A^{9+10}$, more seldom (10%) in three independent arteries or in two trunks $A^{8+9}$ and $A^{10}$ (16%). But all arteries to the lower lobe must be clearly identified to avoid misidentification, such as a low $A^{8a}$ being mistaken for an $A^{9+10}$ (*Figure 22*) When in doubt during dissection, it is preferable to control only the anterior branch of $A^8$ ($A^{8b}$), then the bronchus and eventually check the direction of the second branch. The branching of the arteries and bronchi can be difficult to understand without help of a 3D modelisation. Instead of common $B^{9+10}$ trunk, $B^9$ can have a common birth with $B^8$. Same as for the corresponding arteries. There is a risk of dividing $B^9$ with $B^8$ or $A^9$ together with $A^8$.

### *Vein*

The superior basal vein (SBV), which is the middle root of

 

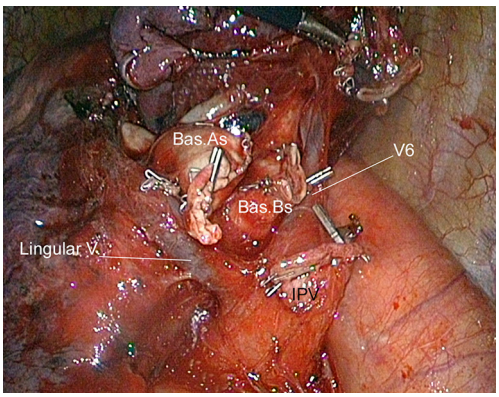


**Figure 21** Lingular vein joining the inferior pulmonary vein. Bas. As, stump of the basilar arterial trunk; Bas.Bs, stump of the basilar bronchial trunk; IPV, inferior pulmonary vein.

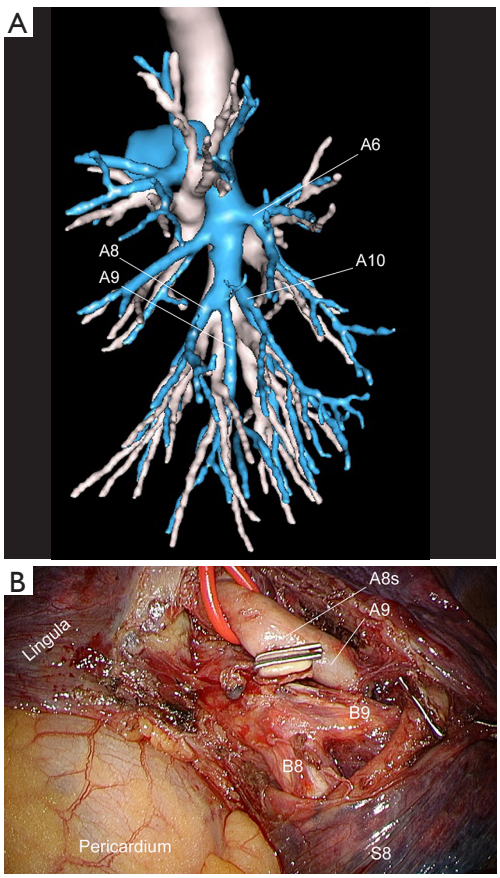


**Figure 22** Common bronchial $B^8$ and $B^9$ trunk and common arterial $A^8$ and $A^9$ trunk. (A) 3D modelisation; (B) thoracoscopic view after clipping of $A^8$. A8s, stump of $A^8$.

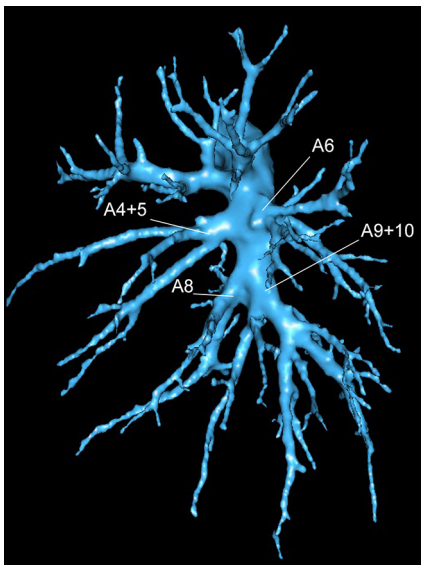


**Figure 23** Arteries to left segment $S^8$: common pattern.

the IPV, does not always represent the venous drainage of segment 8. Its posterior branch can drain segment 9. It is advisable to divide only the anterior branch of the vein ($V^{8a}$) which runs immediately behind the bronchus, rather than controlling $V^8$ centrally in the IPV.

## Left $^{S9+10}$ segmentectomy $^{(S9+10)}$

### *Bronchus and arteries*

These have been described in the previous paragraph. Instead of $A^8$ and $A^{9+10}$ (*Figure 23*), the following branching pattern can be encountered in 20% of patients: $A^{8+9}$ and $A^{10}$ (*Figure 22A,B*) or totally independent basal arteries ($A^8$ , $A^9$ and $A^{10}$). The same distribution is valid for bronchi. Preoperative modelisation is helpful to avoid anatomical misjudgment.

### *Vein*

The inferior basal vein (IBV), which is the lower root of the IPV, does not always represent the venous drainage of $S^9$ and $S^{10}$. One of its branches can drain $S^8$. If any doubt, only the lowermost branch of the vein must be divided. It is however safer to control veins in the parenchyma. There are frequently no basal veins but just a branching into a common basal vein and $V^6$. This stress the need to favor venous control in the parenchyma rather than centrally in the IPV.

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## Footnote

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

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