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Original Research Article

Anatomical variations of bronchial distribution in the upper lobe of the right lung

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ABSTRACT

Bronchial distribution in the upper lobe of the right lung is subject to many anatomical variations. The control of these variations is essential for the interpretation of endoscopic examinations. It also offers a better guarantee for safe surgery during segmentations in the right upper lobe. In this preliminary work, the operation of 30 heart-lung blocks treated by the injection-corrosion method, 100 CT chest and dissections of 3 resected specimen of right upper lobectomy, allowed us to study the bronchial distribution in the upper lobe of the right lung as well as their anatomical variations in melanoderm subjects. Our results were as follows: out of the 133 specimens, the right upper lobar bronchus was born on average 1.8 cm from the tracheal bifurcation, with an average length of 1.75 cm. There were 6 termination modes, dominated by bifurcations, which involved 52% of the specimens, and in 5 modes. Trifurcation accounted for 47.37% of cases. There was a case of quadrifurcation. These results allowed us to discuss anatomical variations of the bronchial shaft of the upper lobe of the right lung. Taking into account these variations will allow to avoid pitfalls and accidents during endoscopic examinations, medical imaging and pulmonary exeresis.

KEY WORDS: Bronchi-Right Upper Lobe-Anatomy-Variations- Endoscopy-Imaging-Surgery.

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INTRODUCTION

Classically, the right upper lobar bronchus ends with trifurcation in apical segmental bronchi (B1), dorsal (B2) and ventral (B3) [1]. Bronchial segmentation is subject to many variations that involve 43% of normal subjects [2]. These variations, which predominate in the right upper lobe with a prevalence of 16.6 to 71.6% [2-3], are dominated by bifurcations. Knowledge of these variations is essential for the performance of segmentectomies in the right upper lobe [4]; but also for imaging, diagnostic and interventional endoscopy, brachytherapy and anesthetic tracheal intubation [5]. Taking these anatomical variations into account should allow to avoid diagnostic mistakes, as well as surgical or anaesthetic incident.

The purpose of this preliminary work is to study variations in bronchial distribution in

the upper lobe of the right lung in the Senegalese subject.

MATERIALS AND METHODS

This work has obtained the approval of the ethics committee of the faculty of medicine, pharmacy and odontostomatology of Cheikh Anta DIOP University in Dakar.

We used a hybrid material composed of 30 broncho-arterial casts, 100 chest scanners and 3 lobectomy operating parts.

The bronchial casts were made by the injection-corrosion technique.

To do this, we collected 15 heart-lung blocks from fresh corpses of adults of both sexes, with no trauma or macroscopic thoraco-pulmonary lesions. The samples were taken at the Laboratory of Pathological Anatomy of A. Le Dantec University Hospital. The evisceration of the heart-lung block was performed as during a conventional autopsy.

The heart-lung block was sent to the Anatomy Laboratory where it was processed, either immediately or after being served in the freezer. Using recovery tracheal tube, number 6 or 8, the trachea was intubated from its section and the trunk of the pulmonary artery cannulated with an incision made at its root. We infused the lungs with air with a manual pneumatic pump to check for bronchial permeability and to ensure the re-expansion of the lung. We were irrigation-washing the circulatory system of each pair of lungs with tap water by the arterial tube and under low pressure.

This filling water gradually came out through the tracheal tube, which also allowed the bronchial tree to be washed retrograde until a clear flow was obtained.

Five pairs of lungs were injected with rhodopas, diluted to 30% in acetone. It was colored in blue extemporaneous for the pulmonary arteries and colorless for the bronchi. The arteries were injected first, while the lungs were breathed in air. The bronchi were injected after the plastic was taken into the vessels. The solidification of the resin by polymerization required a freezing of the part for 24 to 48 hours.

Ten other pairs of lungs were injected with polyester resin. We used the same colors as before. The injection was performed manually using 60 cc syringes; arteries first.

The corrosion was achieved by dipping the part in a bath of 30% hydrochloric acid for 7 to 10 days. After corrosion, the resulting part was rinsed under a small stream of tap water to remove necrotic residue.

Each cast was finely analyzed, specifying the bronchial branching mode of the right upper lobe. We looked at the situation, the origin, the route, the distribution method and the measurements. Each preparation was photographed and drawn.

One hundred and twenty-seven thoracic scans were performed in adults of both sexes during the period from July 2013 to June 2014 in the Department of Radiology and Medical Imaging of the CHUN of FANN (Pr S. Bâ). Twenty seven examinations were excluded, due to artifacts or poor clouding of the trunk of the pulmonary artery and its branches. One hundred exams were held.

The examinations were carried out using two HITACHI scanners of 16 (ECLOS) and 64 bars (SCENARIA).

An amount of 80 to 100 cc of iodized contrast product was injected using a MEDRAD dual-body automatic injector.

We studied the branching mode of the right upper lobar bronchus, specifying the situation, origin, path and mode of distribution.

We dissected of 3 resected specimen of right upper lobectomy, performed for the exeresis of a peripheric tumor. These procedures were performed in the thoracic and cardiovascular surgery department of the FANN CHUN (Pr. Ndiaye). Only the casts allowed a complete morphometric study

RESULTS

Bronchoarterial casts: The upper lobar bronchus was present on 29 pieces and was still born from the lateral edge of the right main bronchus, at an average of 1.8 cm from the tracheal bifurcation. It was oblique at the top and sideways, its average length was 1.75 cm (extreme: 0.8 and 1.8 cm).

It typically ended in trifurcation in 17 cases

(56.7%), giving an apical segmental bronchi (B1), a dorsal segmental bronchi (B2) and a ventral segmental bronchi (B3) (Figure 1). In 3 of these cases, the apical segmental bronchi (B1) was reduced to its posterior twig, the anterior twig from the ventral segmental bronchus (B3) in 2 cases and from the dorsal segmental bronchus (B2) in another case. In these cases, we noted a splitting of the apical segmental bronchi (B1).

We noted variations in the termination mode. Bifurcation was rated in11 cases (36.6%): it was a bifurcation in segmental bronchi (B2) and apical ventral trunk (B1-B3) in 1 case (3.3%), apical dorsal trunk (B1-B2) and ventral segmental bronchi (B3) in 4 cases (13.3%) (Figure 2); in dorsal segmental bronchus (B2) and ventral segmental bronchus(B3) each giving an apical twig in 5 cases (16.3%) (Figure 3); once in apical segmental bronchus (B1) and ventral segmental bronchus (B3) giving each a dorsal twig (3.3%). A quadrifurcation was noted in 1 case (3.3%) (Figure 4): the right upper lobar bronchus was divided into apical segmental bronchi (B1), dorsal (B2), ventral (B3) and axillary (BX).

In one case (3.3%), there was no typical upper lobar bronchus. It was split into an apico-ventral trunk that was born 1.2 cm from the tracheal bifurcation, followed by a dorsal segmental bronchi (B2) that separated 0.8 cm below the lateral side of the right main bronchi (intermediate trunk) (Figure 5).

Table 1: Types of distribution of the right upper lobar bronchus on casts.

Termination		Number of cases	Frequency
Trifurcation Type	B1; B2; B3	17	56,66%
Bifurcation	B2; (B1-B3)	2	6,66%
Bifurcation	B3; (B1-B2)	4	13,34%
Bifurcation	(B1- B2b); (B3- B2a)	1	3,34%
Bifurcation	(B2- B1a); (B3- B1b)	5	16,66%
Quadrifurcation	B1; B2; B3; BX	1	3,34%
Total		30	100%

Table 1 summarizes the different types of distribution of the right upper lobar bronchus in casts.

The apical segmental bronchus (B1) had a typical configuration in 22 cases, emerging either directly from the upper lobar bronchus (17 cases), or from an apical ventral trunk(1 case), or from an apical dorsal trunk (4 cases). Focused at the top, a little outside and often slightly forward. Its average length was 0.94 cm (extreme 0.5 and 1.2 cm). It typically ended in an anterior and a posterior sub- segmental twigs for the apical segment. In 3 cases, only the posterior sub segmental twig was born from the trifurcation of the upper lobar bronchus, the anterior1sub segmental branch emerging from the ventral segmental bronchus (B3) twice and from the dorsal segmental bronchus once. Absent in 5 cases, its anterior and posterior sub segmental twigs were born respectively of the ventral and dorsal segmental bronchi.

The dorsal segmental bronchus (B2) was born directly from the upper lobar bronchus in 24 cases, from an apical dorsal trunk in 4 cases and directly from the intermediate trunk in 1 case. It was oblique back, up and laterally. Its average length was 1.07 cm (extremes of 0.6 and 1.5 cm). It was distributed to the dorsal segment by its two lateral and posterior sub-segmental twigs.

In 1 case, it was represented only by its external sub-segmental branch. Its posterior sub-segmental branch was carried by the apical bronchus (B1).

In 1 case, the posterior and lateral sub-segmental twigs were born, respectively, with apical and ventral segmental bronchi.

The ventral segmental bronchus (B3) was born directly from the upper lobar bronchus in 29 cases and 1 time from an apical ventral trunk. Its average length was 1.02 cm (extremes of 0.5 and 1.8 cm) and its slanting direction forward and slightly down. It forked into an anterior twig that generally continued the direction of the ventral bronchus, and an external branch that deviates more openly from the direction of the segmental bronchus and is carried out a little forward and slightly down. In 2 (6.6%) cases it gave the anterior sub-segmental branch of the apical bronchus.

The apical ventral trunk was observing in 2 cases; it was born from the bifurcation of the right upper lobar bronchus. At 0.75 cm long, it was divided into apical and ventral segmental bronchi.

The apical dorsal trunk was found in 4 cases,

emerging from the bifurcation of the right upper lobar bronchus. Its length was 1.1 cm. It ended with bifurcation in apical and dorsal segmental bronchi.

Scanners: The upper lobar bronchus were always born from the lateral edge of the right main bronchus on the 100 cases observed. It was oblique at the top and laterally. It typically ended in trifurcation in 45 cases (45%), giving the apical (B1), dorsal (B2) and ventral (B3) segmental bronchi. Of these 45 cases, once (1%), the apical segmental bronchus (B1) was reduced to its posterior twig, the anterior branch from the ventral segmental bronchus (B3) and another time (1%) we observed an axillary bronchus forming a common trunk with the segmental bronchus B3 coexisting with another apical ventral trunk and an independent dorsal segmental bronchus (B2).

Table 2: Types of distribution of the right upper lobar bronchus on CT scanners.

Termination		Number of cases	Frequency
Trifurcation	B1; B2; B3	45	45%
Bifurcation	B2; (B1-B3)	30	30%
Bifurcation	B3; (B1-B2)	16	16%
Bifurcation	(B2- B1a); (B3- B1b)	9	9%
Total		**100**	**100%**

We noted variations in this bifurcation type ending in apical dorsal trunk (B1-B2) and ventral segmental bronchus (B3) in 16 cases (16%) (Figure 6); dorsal segmental bronchus (B2) and apical ventral trunk (B1-B3) in 30 cases (30%) (Figure 7); dorsal (B2) and ventral (B3) segmental bronchi each giving an apical twig in 9 cases (9%). Table 2 summarizes the type of distribution of the right upper lobar bronchus on the scanners.

Table 3: Types of distribution of the right upper lobar bronchus on surgical cases.

Termination		Staff
OP CASE 1	Trifurcation B1; B2; B3	1
OP CASE 2	Bifurcation B2; (B1-B3)	1
OP CASE 3	Bifurcation B3; (B1-B2)	1
Total		**3**

Surgical cases: Of the 3 surgical cases, the right upper lobar bronchus forked once (33.3%) in apical dorsal trunk (B1-B2) and ventral segmental bronchus B3 (Figure 8), another time (33.3%) in apical ventral trunk (B1-B3) and dorsal segmental bronchus (B2) and in the last case it was trifurcated in apical segmental bronchi (B1), ventral (B3) and dorsal (B2) (33.4%). Table 3 summarizes the types of distribution of right upper lobar bronchus in all surgical cases.

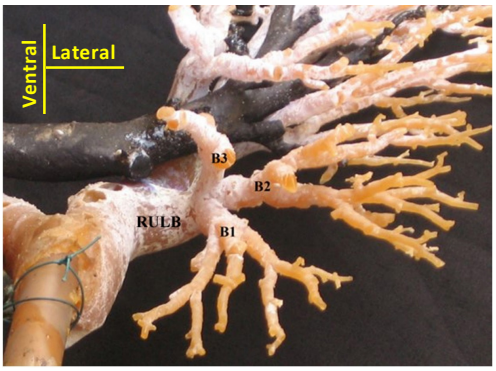

Fig. 1: Trifurcation of the right upper lobar bronchus without the vessels (superior-ventral view)
RULB: Right upper lobar bronchus, **B1:** Apical segmental bronchus, **B2:** Dorsal Segmental bronchus **B3:** Ventral segmental bronchus

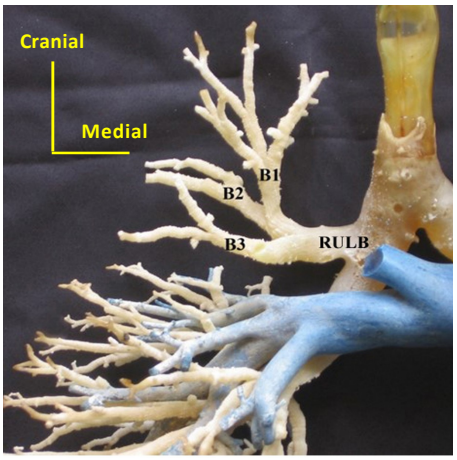

Fig. 2: Bifurcation of the right upper lobar bronchus into an apical dorsal (B1-B2) trunk and a ventral segmental bronchus (B3)
RULB: Right upper lobar bronchus, **B1:** Apical segmental bronchus (B3), **B2:** Dorsal segmental bronchus (B2), **B3:** Ventral segmental bronchus (B1)

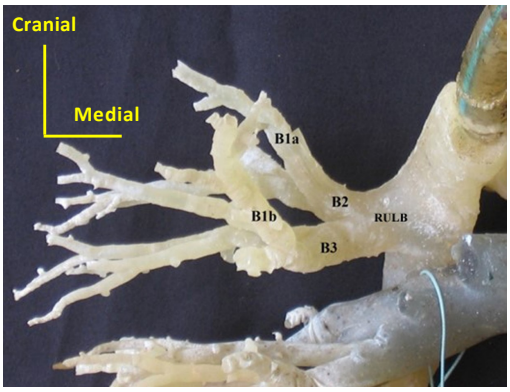

Fig. 3: Splitting of the apical segmental bronchus (previous view)
RULB: Right upper lobar bronchus, **B1b:** Anterior branch of the apical segmental bronchus, **B1a:** Posterior branch of the apical segmental bronchus, **B2:** Dorsal Segmental bronchus, **B3:** Ventral segmental bronchus

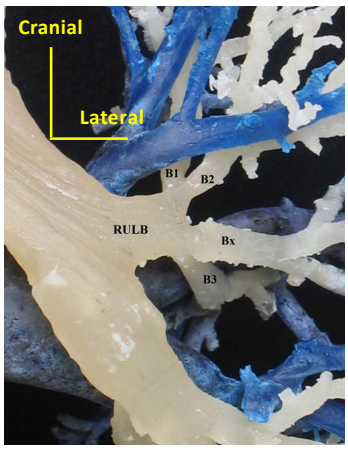

Fig. 4: Quadrifurcation of the right upper lobar bronchus (posterior view)
RULB: Right upper lobar bronchus, **B1:** Apical segmental bronchus, **B2:** Dorsal Segmental bronchus, **Bx:** Axillary segmental bronchus, **B3:** Ventral segmental bronchus

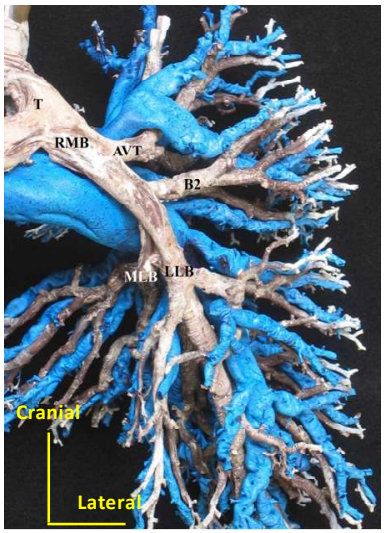

Fig 5: Posterior view of the right broncho-arterial pedicle "Double stem Right upper lobar bronchus"
T: trachea, **RMB:** Right main bronchus, **AVT:** Apical ventral trunk, **B2:** Dorsal segmental bronchus
MLB: Middle lobar bronchus, **LLB:** Lower lobar bronchus

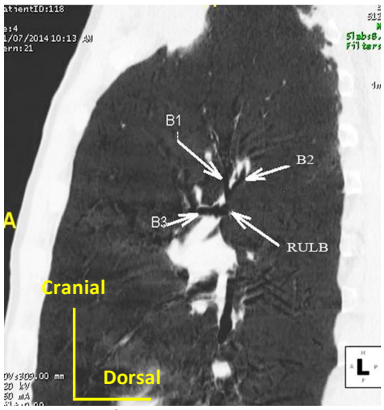

Fig. 6: Bifurcation of the right upper lobar bronchus into an apical dorsal trunk and a ventral segmental bronchus: parenchymatous window sagittal reconstruction: MinIP mode
B1: Apical segmental bronchus, **B2:** Dorsal segmental bronchus, **B3:** Ventral segmental bronchus, **RULB:** Right upper lobar bronchus

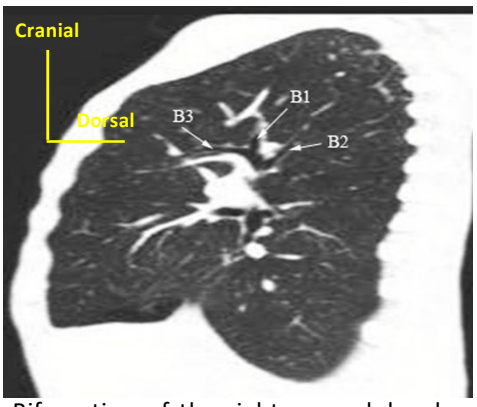

Fig. 7: Bifurcation of the right upper lobar bronchus into an apical ventral trunk and a dorsal segmental bronchus. Sagittal window reconstruction in parenchymatous window: MPR mode
B1: Apical segmental bronchus, **B2:** Dorsal segmental bronchus, **B3:** Ventral segmental bronchus.

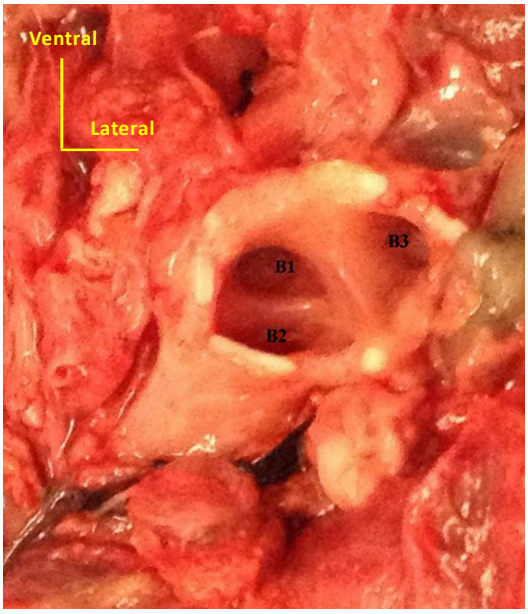

Fig. 8: Bifurcation into an apical dorsal trunk and a ventral segmental bronchus (section of the right upper lobar bronchus on a right upper lobectomy operating part)

B1: Apical segmental bronchus, **B2:** Dorsal segmental bronchus, **B3:** Ventral segmental bronchus

Summary of results: Of the 133 specimens, we observed 6 types of right upper lobar bronchus ending. Variations were noted in 52.63%

i. Type I: Trifurcation of the right upper lobar bronchus in apical (B1), dorsal (B2) and ventral (B3) segmental bronchi in 63 cases (47.37%);

ii. Type II: Bifurcation into an apical ventral trunk (B1-B3) and dorsal segmental bronchus (B2) in 33 cases (24.8%);

iii. Type III: Bifurcation into an apical dorsal trunk (B1-B2) and ventral segmental bronchus (B3) in 21 cases 15.8%;

iv. Type IV: Bifurcation in dorsal (B2) and ventral (B3) segmental bronchi each giving an apical sub-segmental bronchus in 14 cases (10, 5%);

v. Type V: Bifurcation in apical (B1) and ventral (B3) segmental bronchi each giving a dorsal sub-segmental bronchus in 1 case (0.75%);

vi. Type VI: Quadrifurcation in 1 case (0.75%) in B1, B2, B3, BX.

DISCUSSION

The configuration of the right upper lobar bronchus is consistent with the literature data [1, 6.7]. The upper right lobar bronchus is born on the outer flank of the right main bronchus at a variable level. Its origin is always above the crossing point of the bronchial trunk by the pulmonary artery, hence the ancient term "eparterial bronchus" (AEBY).

Boyden [8] and OverHolt [9] place this origin almost at the height of the tracheal fork. Our findings are identical to those of Cordier [1] which places it at 1.8 cm on average from the origin of the right main bronchus. It is therefore a little higher than Oeconomos [10] and Hovelacque [11] claim, which found it at an average of 2 and 2.5 cm respectively. In any case, this birth does not hinder with the realization of a right pneumonectomy as Boyden fears [8]. Its length is 1.7 cm on average. Riquet [12] and Ugalde and *al*. [13] report shorter lengths: 1.2 cm and 1cm respectively. The length of the right upper lobar bronchus is always sufficient to allow its section, and a careful closure of the stump after a right upper lobectomy [14]. It is noted that the three segmental bronchi are about the same length (about 1 cm). Classically, the upper lobar bronchus ends with trifurcation in apical, dorsal and ventral segmental bronchi. This mode of termination is predominant in the series of Oho [15],Collins [16], and Nagashima [17]. However, Nagaishi [18] reports six different types of branching of the right upper lobar bronchus.Bifurcation is the most common termination mode in our series where it accounts for 52% of cases. This is claimed by Boyden [19] and Gonlugur [3] with 54% and 47.7% of bifurcations respectively) (table 4). We believe, like Cordier **[1],** that the existence of a common trunk giving a bifurcation ending does not affect the usual path and arrangement of the segmental bronchi. We observed 4 types of bifurcations.

Table 4: Types of distribution of the right upper lobar bronchus according to authors.

	Nagaishi [18]	Boyden [19]	Nagashima[17]	Ndiaye
Trifurcation	40%	46%	44,1%	47,37%
B1; B2 ;B3				
Bifurcation			**36,5%**	**52%**
(B1+B3); B2			8,8%	24,8%
(B1+B2) ;B3	**60%**	**54%**	14,4%	15,8%
(B2+B3) ;B1			6,1%	-
(B1+B2a);(B3+B2b)	24%	14%	2,3%	0,75%
(B2+B1a);(B3+B1a)			4,9%	10,5%
	14%	4%		
Quadrifurcation			0,8%	0,75%
B1;B2;B3;BX	10%	10%		
	10%			
	2%	10%		
		16%		

In 10.53% of our cases, there was no apical segmental bronchi, there were 2 apical sub-segmental bronchi emerging separately from the dorsal and ventral segmental bronchi (B2-B1a), (B3-B1b). Beder [5] reports this situation in 9.8% of cases. This type of variation was rare in Nagaishi's study [18] and represented Type VI in its classification. We have not found the variation of Nagaishi Type IV [18] which produces a dorso-ventral trunk (B2-B3) and an isolated apical bronchus, unlike Cordier (1 case) [1]. The quadrifurcation of the right upper lobar bronchus, observed in 1case, which gives the ending the classic appearance of a four-branched candelabra, is thought to be the result of the slippage of the

lateral sub-segmental air twig of the dorsal bronchus [1] (table 4).

This segmental bronchi is the first external parabronchi [6] or axillary bronchi of the Anglo-Saxons. It constantly ventilates a particular area of the axillary region, located above the horizontal fissure, back of the upper ventral territory, in front of the upper dorsal territory and below the apical territory [20]. In contrast to Beder [5], we note that a frequency varies according to the authors: 10.4% for Gonlugur [3], 20% for Scannell [21] and 16% for Boyden [19].

The existence of a double stem right upper lobar double bronchus was reported in 2 cases by Boyden[22] and once by Wang [23]. Unlike us, they found an apical bronchus and a ventral dorsal trunk instead of a dorsal bronchus and an apical ventral trunk. In our case, the apical ventral trunk represents the local (eparterial) bronchus because its original level is within the limits of the distance that separates the origin of the normal right upper lobar bronchus from the tracheal bifurcation; the ectopic bronchus (B2) is born from the intermediate trunk in the post parterial position, i.e. under the origin of the upper lobe. The bronchial abnormality is of a displaced type, because the upper lobar bronchus is reduced to the apico-ventral trunk. This variation of the right upper lobar bronchus that is widely discussed in an earlier publication [24]. In contrast, displaced preeparterial bronchial ectopies in the right side are more well known.

This type of variation confirms the full value of preoperative endoscopy before any pulmonary exercises, in order to avoid accidents during the bronchial section during the right upper lobectomy or segmentectomy. These abnormalities can also lead to anesthetic accidents by unexpected bronchial obstruction with secondary atelectasis.

CONCLUSION

The bronchial division in the right upper lobe has many anatomical variations dominated by bifurcations. These variations due to frequent slippage and splitting events must be taken into account during endoscopic examinations, médical imaging, lung surgery, including increasingly performed segmentectomies and bronchial navigation.

Authors' contributions

The injection and corrosion and surgical cases were carried out by Professor Assane NDIAYE as well as the supervision of all the work. The CT scan patterns were collected and analysed by Dr Sokhna Astou THIAM.The Datas analysis is carried out by Docteurs Sokhna Astou THIAM, Ndèye Bigué MAR and Karim YACOUBA GARBA; then the writing and correction is carried out by Docteurs Sokhna Astou THIAM, Ndèye Bigué MAR and Issa Dior SECK, Harouna Daouda TIREIRA, Racky WADE, Professors Abdoulaye NDIAYE and Assane NDIAYE ; and finally everyone participated in the reading. The directors of the anatomy laboratories in which the work was carried out was Professors Assane NDIAYE and Professor Abdoulaye NDIAYE.

Conflicts of Interests: None

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