

Determining Tracheobronchial Tree with Anatomical Dissection: 204 Cases

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Abstract

OBJECTIVES: There are various anatomic variations in the tracheobronchial system. The frequency in studies with bronchoscopy was contradictory. This study aimed to investigate the tracheobronchial tree of the deceased patients with anatomical dissection.

MATERIAL AND METHODS: We made anatomical dissections on 204 cases in the Council of Forensic Medicine, Ministry of Justice. The deceased patients who were older than 12 years of age and of Turkish origin were included in this study consecutively.

RESULTS: Of the 204 cases, 161 (78.9%) were males and 43 (21.1%) were females. The mean age was 44.15±19.23 years. Anatomical variations were found to be present in 200 cases (98% of total). The highest degree of variation of the right upper lobe was noted to be 16.6% (34/204). An anomalous arrangement (with three segments or different placement) of the middle lobe was noted in 16.1% of cases. For the basal lower lobe, b8+(b9+b10) pattern and basal orifice with four segments were noted to be the most frequent anatomical variant in the right and left lungs, respectively. The most frequent tracheobronchial variations were as follows: apical basal lobe with two subsegments in the right and left (39.7%), left lower lobe basal orifice with four segments (34.8%), left upper lobe with three segments (25.5%), and right lower lobe basal orifice with three main segmental bronchi (21.1%).

CONCLUSION: The tracheobronchial tree exhibits highly individualistic features. The knowledge of the frequency of different variations obtained in different studies and normal anatomic variants in return makes doing therapeutic or diagnostic interventions easier and more accurate.

KEYWORDS: Autopsy, tracheobronchial dissection, sequence of bronchial tree

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INTRODUCTION

Although the anatomy of the lungs was examined for centuries, a firm and well-established nomenclature of the bronchopulmonary anatomy was not present until the first half of the 20th century. Jackson and Huber [1] were the first ones to present a classification system for the tracheobronchial anatomy. Afterward, Boyden [2] published about the intrahilar and segmental anatomy of the lung in 1945. In 1974, Ikeda [3] modified the Boyden system and added the designation of more distal branching generations of airways, which was important for bronchoscopic examinations as the optic systems advanced. These signs of progress lead to revisions of the international classification system, and in 1987, Collins et al. [4] (Table 1) presented the international classification system, which is still in use today.

The knowledge of airway anatomy is the most basic requirement of every surgeon, bronchoscopist, anesthesiologist, and radiologist. The role of an anesthesiologist is to perform the optimal positioning of the endotracheal tubes for ventilation and lung isolation when it is necessary. However, variations of the tracheobronchial tree may cause complications. When a radiologist states the location of the lesions, a bronchoscopist can do therapeutic or diagnostic intervention more easily and accurately. Resection with preservation of nearly normal aeration and respiratory and mediastinal movement is of clinical importance to the surgeon. Knowing what disease is most likely to occur in a given segment is useful in differential diagnosis [5–8]. All these scenarios are proving to us the fact, that knowing tracheobronchial anatomy is crucial for all physicians dealing with the lung.

There are various anatomic variations in the tracheobronchial system. For many years, the diagnosis of tracheobronchial variations (TBVs) has been done by bronchoscopy, and the frequencies reported in bronchoscopic studies vary between 4.2% and 43% (9,10). As the precise values of anatomical variations are not well established, we aimed to investigate a

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Table 1. Revision of the international nomenclature of the endobronchial tree (Collins et al. [4])

Right	Left			
Upper lobe	b1:apical segment	Upper lobe division	Upper lobe	b1+2:apicoposterior segment
	b2:posterior segment			b3:anterior segment
	b3:anterior segment		Lingula	b4:superior segment
Middle lobe	b4:lateral segment			b5:inferior segment
	b5:medial segment			
Lower lobe	b6:apical basal segment	Lower lobe	b6:apical basal segment	
	b7: medial basal segment		b7+8:anterior basal segment	
	b8:anterior basal segment		b9:lateral basal segment	
	b9:lateral basal segment		b10:posterior basal segment	
	b10:posterior basal segment			

Table 2. Total number of TBVs at right and left lungs

Total number of TBVs	n	%
Never	4	2.0
Single	9	4.4
Two	20	9.8
Three	39	19.1
Four	51	25.0
Five	45	22.1
Six	25	12.3
Seven	9	4.4
Eight	2	1.0

tracheobronchial tree with a more precise method: anatomical dissection of the airways.

MATERIAL AND METHODS

In this study, we performed anatomical dissections on 204 cases in a period of 6 months at the Council of Forensic Science Medicine Institute of the Ministry of Justice. The deceased patients older than 12 years of age and of Caucasian origin were included in the study. Subjects were recruited consecutively. The cases with a deformed tracheobronchial tree owing to autopsy procedure, trauma, massive scarring, burns, or previous lung surgery were excluded. According to the restricted medical history taken from the relatives of the dead people, they had not any acute or chronic lung diseases or cause of death because of lung disease or history of lung surgery. The tongue, larynx, trachea, and lungs were removed from the chest cage as "bloc." Dissections were started from the posterior wall of the larynx and trachea and continued distally. We recorded

MAIN POINTS

- Frequency of variation of bronchial tree is higher by autopsy.
- Anatomical dissection is a better way to diagnose variations.
- All physicians know the details of the patient's pulmonary anatomy.

major pulmonary airways from the trachea down to basal segments, according to Collins's anatomical classification [4]. Because of the variations of orifice-lobe relations, we used a 60-cm guide wire to identify which orifice belongs to which lobe.

Our study has been approved by the Ethics Committee of Council of Forensic Medicine, Approval Number: 21589509/505. The informed consent of the relatives of the deceased patients for the study was obtained for the anatomical dissection of the lung.

Statistical Analysis

We used the Number Cruncher Statistical System 2007 (NCSS, LLC Kaysville, UT, USA) to perform statistical analysis of data. In analyzing the data, along with the descriptive analysis methods (mean, median, mode, frequency, and ratio standard deviation), the Mann-Whitney U test was used for between-group comparison for quantitative data. In figuring out the correlation between age and variation count, the Spearman correlation analysis was used. The results were based within the confidence interval of 95% and significance level $p < 0.05$.

RESULTS

Of the 204 cases, 161 (78.9%) were males and 43 (21.1%) were females. The mean age was 44.15 ± 19.23 years, with a range of 12–98 years. Anatomical variations were found to be present in 200 cases (98%). Single, four, and eight that are the total number of TBVs at the right and left lung were 9, 51, and 2 (4.4%, 25%, and 1%), respectively (Table 2).

The relationship between the frequency of TBV and gender was not statistically significant ($p > 0.05$).

The trifurcate pattern (emerging independently at the same level) of right upper lobe (RUL) was 60.3% (123/204). However, in 27.6% (34/123) of the cases, it was placed in a linear array (Figure 1). The second variation was b1+(b2+b3) (b2 and b3 originate together) in the RUL after linear array. Although, in 84% of the cases, left upper lobe (LUL) division showed the usual arrangement as two orifices, in 15.1% of the cases, a trifurcate pattern of LUL division was determined. In 62% (19/31) of the trifurcate pattern of LUL division, accessory bronchus opened to the LUL.

Prevalence of right and left subapical basal segments was 5.4% and 1.5%, respectively (Tables 3-5; Figure 2). The mediobasal segment was not present at the right lower lobe (RLL) in 2.5% of the cases (Table 3). The mediobasal segment was detected at the left lower lobe (LLL) in 14.2% of cases (Table 5).

Table 3. Systematic classifications of the anatomical variants of right lung and their frequencies

Anatomical variants	Number	%
Right upper lobe		
b1+b2+b3*	34	16.6
(b1+b3)+b2	10	4.9
(b1+b2)+b3	22	10.8
b1+(b2+b3)	33	16.2
b1+b3	7	3.4
b2+b3	1	0.5
Quadrivial pattern	8	3.9
Accessory lobe at distal of RUL	1	0.5
Total variation	116	56.8
Middle lobe		
Three segments	29	14.2
Incorrectly placed#	4	2
Total variation	33	16.1
Apical basal segment		
Absent	3	1.5
Two subsegments	81	39.7
Four subsegments	8	3.9
Bipartite branching at entrance	2	1
Total variation	94	46
RLL with subapical segment	11	5.4
Unavailable mediobasal segment	5	2.5

*Right upper lobe (RUL) with linear array.
 #Middle lobe arose from the medial surface of bronchus intermedius in one case. Middle lobe was originated from the lateral section of bronchus intermedius that had two sections in three cases.
 RLL: right lower lobe

Table 4. Arrangement of lower basal segments of the right and left and their frequency

Basal segments	Number of cases (right)	% (right)	Number of cases (left)	% (left)
b8+(b9+b10)	53	26.0	41	20.1
Main segmental bronchus with b8+b9+b10	43	21.1	40	19.6
(b8+b9+b10) in basal	18	8.8	15	7.4
(b8+b9)+b10	4	2.0	0	0
Two segments	40	19.6	7	3.4
Four segments	39	19.1	71	34.8
Five segments	4	2.0	25	12.3
Six segments	1	0.5	4	2.0
Seven segments	2	1.0	1	0.5
Total variation	151	74.0	163	79.9

Table 5. Systematic classifications of the anatomical variants of left lung and their frequencies

Anatomical variants	Number	%
Left upper lobe division		
Trifurcate pattern	31	15.1
Quadrivial pattern	2	1.0
Three segments in the lingula	33	16.2
Four segments in the lingula	2	1.0
Three segments in the upper lobe	52	25.5
Four segments in the upper lobe	2	1.0
Total variation	122	59.8
Apical basal segment		
Two subsegments	81	39.7
Four subsegments	13	16.4
Arise from the lateral surface of LLL	1	0.5
Total variation	95	46.5
LLL with subapical segment	3	1.5
Available mediobasal segment	29	14.2

LLL: left lower lobe

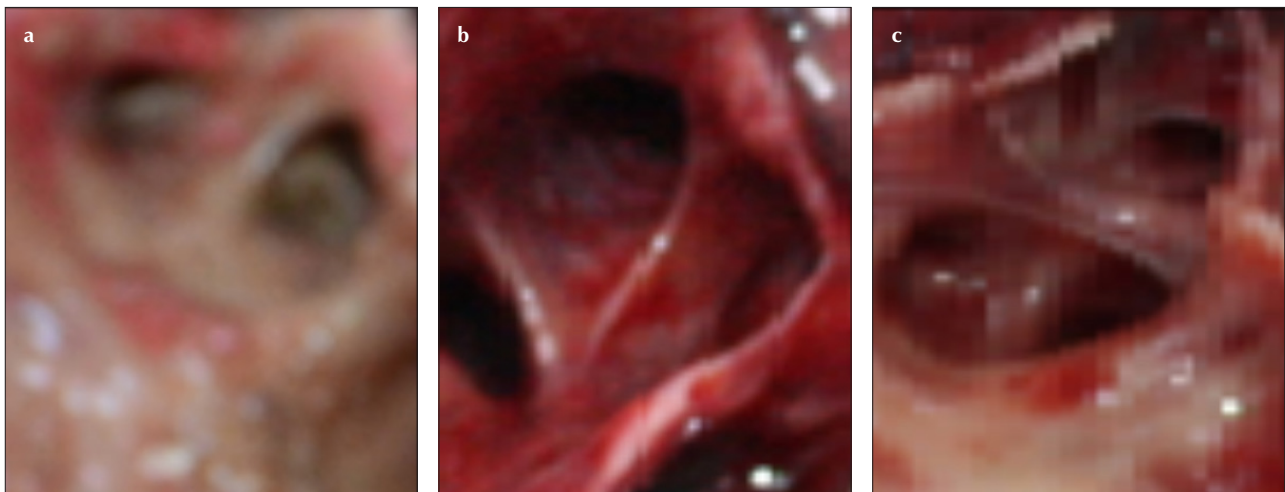


Figure 1. a-c. Right upper lobe: two segments (a), linear array (b), and four segments (c)

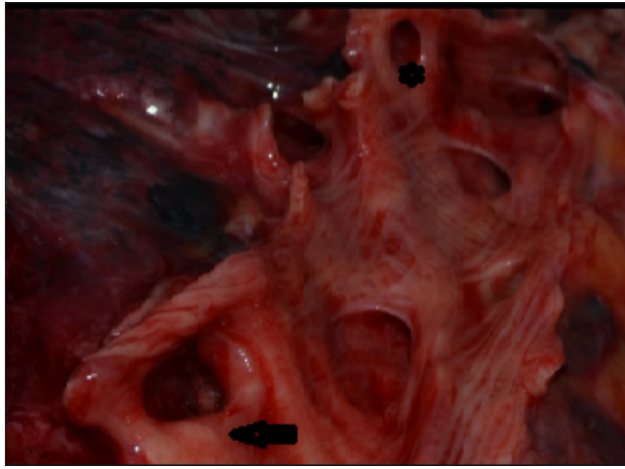


Figure 2. Accessory Lobe at distal of RUL (black arrow). Subapical basal segment (white arrow)

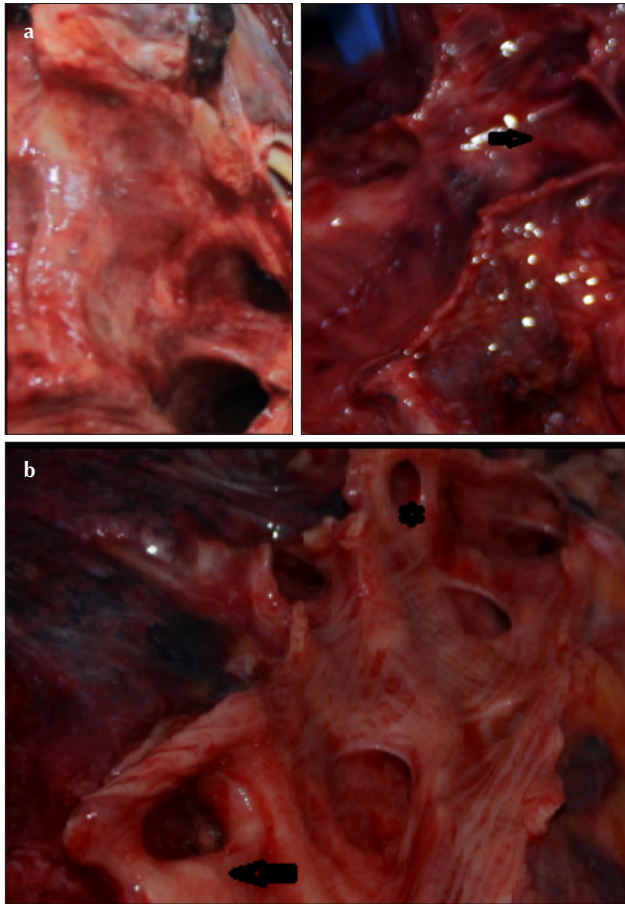


Figure 3. a, b. Middle lobe was originated from the lateral section of intermediate bronchus (a). Bipartite branching at entrance of the apical basal segment (b)

For the basal lower lobe, b8+(b9+b10) pattern (b8 emerges independently, but b9 and b10 originate together at the same level) and basal orifice with four segments were noted to be the most frequent anatomical variants in the right and left lungs, respectively. The RLL and LLL basal orifices with two segments were 19.6% and 3.4%, respectively (Table 4).

A variant arrangement (with three segments or different placement) of the middle lobe (ML) was noted in 16.1% of cases. In three cases, the ML originated from the lateral

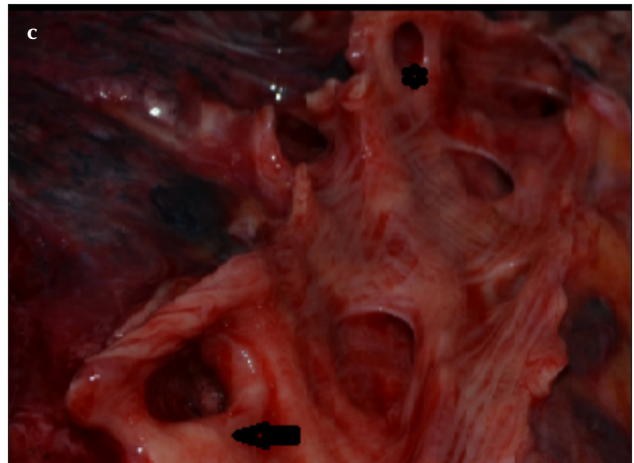
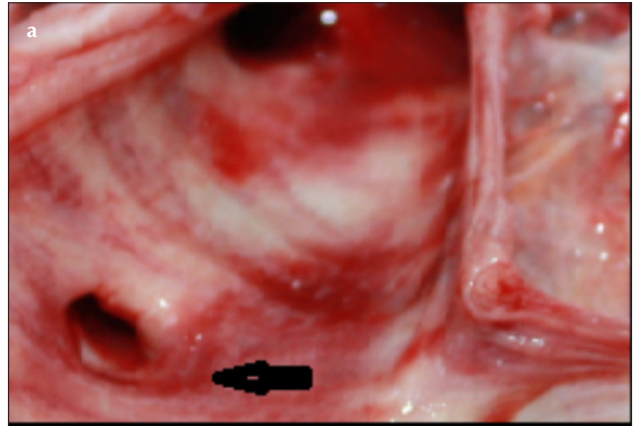


Figure 4. a-c. (a) Tracheal bronchus (black arrow). (b) Left upper lobe division with four segments (black arrows). (c) Left lower lobe basal with seven segments. (* indicates segment orifices.)

section of the intermediate bronchus that had two sections (Figure 3).

Total variations of the right and left lungs were 92.15% (188/204) and 96.1% (196/204), respectively. Isomerism was noted in only two cases.

The tracheal bronchus (Figure 4a) (0.5%), LUL division with four segments (Figure 4b), and LLL basal with seven segmental orifices (Figure 4c) were other observed rare TBVs.

The most frequent TBVs were as follows: apical basal lobe with two subsegments in the right and left (39.7%), LLL basal orifice with four segments (34.8%), LUL with three segments (25.5%), RLL basal orifice with three main segmental bronchus (21.1%), RLL basal orifice with two segments (19.6%), LLL basal orifice with three main segmental bronchus (19.6%), RLL basal orifice with four segments (19.1%), and linear array of the RUL (16.6%).

DISCUSSION

In our study, TBV prevalence was 98% in 204 dead cases observed through anatomical dissection. The prevalence was higher than those performed by bronchoscopy [9, 10]. The possible causes of this difference may be due to some reasons: (a) the bronchoscopist's sole focus on the reason for bronchoscopy (either diagnostic or interventional), hence doing an observational study, (b) inadequate quality of procedure because of patient-based factors especially under local anesthesia, (c) inability to clearly evaluate the lesion in case of bleeding or secretion, (d) not scanning the other lobe segments in detail since the intervention is aimed at the pathological lesion, and (e) inability to scan some distal lobes due to factors limiting procedure time (anesthesia, bleeding, desaturation, or arrhythmia). Another factor might be that the variations reported in this study (e.g., RUL with a linear array, different placement of ML, and different arrangement of lower lobe basal segments) were not taken into account in some other studies.

The most frequently reported TBV is in the RUL in the literature [9, 10]. However, the most frequent variations were present in lower lobe basal segments similar to the study of Beder et al. [11]. In addition, in the study of Beder et al. [11], RLL basal orifice with two segments was the most frequent TBV (21.4%) and LLL basal orifice with two segments was the second most frequent TBV (20.8%). In our study, we found the prevalence of RLL and LLL basal orifice with two segments was 19.6% and 3.4%, respectively (Table 4).

Many different types of variants of RUL have been depicted, and the most common type is all-three-segmental bronchi branch out independent of each other [12]. While this type was 45% (87/194) in the study of Koshino et al. [13], which was the most similar study to our study in terms of the number and methods (from postmortem treated cadavers). In this study, the frequency of the trifurcate pattern of RUL was 60.3% (123/204). In addition, Koshino et al. [13] reported that the most common bifurcated pattern of RUL was (b1+b3)+b2 in 23% of cases, whereas the most common variation of the bifurcated pattern of RUL was b1+(b2+b3) in 16.2% of cases in this study (Table 3). This difference may be related to regional and genetic factors.

We recorded RUL with a linear array in 16.7% of cases (Figure 1). This variant had been defined by Cortese et al. [14] at 3% of the cases but was never seen afterward anywhere in literature.

Usually, the ML bronchus that continues from the anterior wall of the bronchus intermedius is divided into two segmental bronchi [4]. Many studies defined the ML with three segments [9, 11], but no study defined different placement of the ML. In one of four cases, the ML arose from the medial surface of the bronchus intermedius; in the others, ML originated from the lateral section of the bronchus intermedius that had two sections (Figure 3).

The other variations that were not defined in literature but reported in our study were bipartite branching at the entrance of the right apical basal segment (1%) (Figure 3), right and left apical basal segments with four subsegments (3.9% and 16.4%), and apical basal segment that arose from the lateral surface of LLL (0.5%) (Tables 3 and 5).

When the entire RUL bronchus is displaced onto the trachea as pigs and other ruminant mammals, it is named as a "true tracheal bronchus." Individuals with a tracheal bronchus are usually asymptomatic. The most serious clinical finding of a tracheal bronchus becomes, when the endotracheal tube can occlude the lumen of the tracheal bronchus and result in atelectasis of the involved lobe, postobstructive pneumonia or respiratory failure. Tracheal bronchi are classified into four groups based on their morphologic pattern: displaced, rudimentary, supernumerary, and anomalous RUL bronchus. Although Wooten et al. [15] reported a case of bilateral tracheal bronchus, that situation was not considered in the classification owing to extreme rarity. The incidence of tracheal bronchus ranges from 0.1% to 3% [14, 16], which was consistent with our result (0.5%). This case was described as supernumerary because of coexisting with a classical branching of the upper lobe.

In this study, we observed that (1) especially the orifices of the segments in the RUL, ML, and lower lobes are small roughly without measuring (it could be due to difference of a vertical orientation or bronchial arterial anatomy), (2) some segments have multiple daughter segment orifices at the same level, and (3) the lower lobes that have more than 3 segments showed one under the other or side-to-side and one under the other array independently. We did not emphasize these findings in the context owing to unknown clinical significance. However, these unexpected results of the study lead us to think that the tracheobronchial tree exhibits highly individualistic features.

There are some limitations of our study. First, there were a limited number of cases compared with other bronchoscopic studies, but according to sample size calculation with $P < 0.05$ and 90% power, the minimum sample size should be 199, and we had 204 cases. In addition, the number of cases is less than that in bronchoscopic studies; there was an outstanding advantage of anatomic dissection over bronchoscopy with a much clearer evaluation of the tracheobronchial tree. Second, only cases with anatomical integrity were included in the study, which might lead us to miss some variations. However, the design of the study gave us the power to eliminate artificial or secondary defects in the anatomy. Finally, we have included subjects >12 years of age. This choice was made according to the studies of Szpinda et al. [17,18], in which,

it was shown that airways continue to develop at early life in size and diameter and accepting cases in childhood might lead us to miss variations.

Our study showed that the TBVs are much more common than expected and TBVs are so individualistic just as our fingerprints. Anatomical dissection is a better way to diagnose variations. Before attempting a pulmonary procedure, all physicians who are taking care should know the details of the patient's pulmonary anatomy. Consequently, conducting more studies with anatomical dissection can amend the problems encountered with the frequency of TBV.

In conclusion, the knowledge of the frequency of different variations obtained in different studies and usual anatomic variants in return makes doing therapeutic or diagnostic interventions easier and more accurate.

Ethics Committee Approval: This study was approved by Ethics committee of Council of Forensic Medicine (Approval No: 21589509/505).

Informed Consent: Written informed consent was obtained from the relatives of the deceased patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – A.A.; Design – A.A., E.K.; – Resources – A.A.; Materials – A.A.; Data Collection and/or Processing – A.A.; E.K.; Analysis and/or Interpretation – A.A.; Literature Search – A.A.; Writing Manuscript – A.A.; Critical Review – A.A.

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