Anatomical lung variations: A study conducted on cadaveric specimens

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Cognizance of lung anatomical variations is essential for surgeons performing lobectomies or segmentectomies. Knowledge of lung variations is essential; clinicians may misinterpret such variations in radiological images. During cadaveric dissection of fifty cadavers, we chose the three most unique lung anatomic variations noted to highlight as case studies. These three were an azygos lobe, a five-lobed right lung, and a markedly enlarged lingula of a left lung. The anatomical variations we describe in this article are of both clinical importance and academic interest. Cardiothoracic surgeons should consider these variants to avoid or reduce mortality associated with invasive procedures.

Key Words: *Accessory fissures; Supernumerary lobes; Azygos lobe; Meso-azygos; Enlarged lingula; Lung variations; Anatomical lung variations*

INTRODUCTION

Surgeons must be aware of anatomical lung variations during lobar or segmental resections of the lung. Knowledge of such variations is essential to preclude misinterpretation of radiological images when such variations occur [1].

In normal lung anatomy, complete fissures divide the lungs into distinct lobes that connect only at the hilum of the lung. The left lung has the oblique fissure that separates its superior and inferior lobes. The right lung also contains an oblique fissure, in addition to a horizontal fissure in the superior lobe, which creates the third middle lobe. The oblique fissure begins at the level of the fourth thoracic vertebra in both the right and left lungs. It continues laterally in a downward direction along the costal surface of the sixth rib, extending anteriorly terminating just below the hilum. The horizontal fissure of the right lung follows the contour of the fourth rib. Each of the three lobes of the right lung contains specific tertiary bronchi. The superior lobe of the right lung consists of the apical, posterior, and anterior tertiary bronchi, the middle lobe consists of the lateral and medial tertiary bronchi, and the inferior lobe is made up of the superior, medial-basal, anterior-basal, lateral-basal, and posterior-basal tertiary bronchi.

The left lung also contains a structure associated with the superior lobe: the lingula. In Latin, *lingula* means "little tongue". Embryologically, the lingula is the homologue of the right middle lobe [2]. It normally contains the superior and inferior lingular tertiary bronchi, while the apical-posterior and the anterior tertiary bronchi occur in the rest of the superior lobe and the superior, antero-medial, lateral basal, and posterior basal tertiary bronchi occur in the inferior lobe. The lingula is found just below the cardiac notch of the anterior portion of the superior lobe and is usually neither large nor very prominent. Pulmonary fissures result from retention of specific borders of the bronchopulmonary segments during embryological development. They are critical for facilitating lobar movement and uniform expansion during respiration [3].

Several studies found numerous variations in the fissure and lobar patterns of both lungs. Fissures can be complete, incomplete or absent altogether, affecting the number of lobes present in each lung [3-5]. These fissures and lobar variants occur as normal anatomical variations.

In this study, we assessed fifty cadavers for anatomical lung variations. The Maryland State Anatomy Board donated forty-four of these cadaveric specimens. The remaining six were private donations to the Anatomy Teaching Lab of the Uniformed Services University of the Health Sciences. Of the fifty cadavers, 26 were female and 24 were male, and range in age from 66 to 103 years old. We observed the fissure and lobar patterns in each cadaver. Twenty-six percent of the studied cadavers had incomplete and absent fissures, supernumerary lobes, variation in lobe size (enlarged lingula) and/or an azygos lobe. We noted the anatomical variations and highlighted the three most unique in this article (Table 1).

CASE REPORT

We observed the following three rare anatomical variations during dissection of the fifty cadaveric specimens: An azygos lobe, a five-lobed right lung, and a markedly enlarged lingula of a left lung.

Case 1

An azygos lobe occurred in the right lung of a 94 year-old Hispanic female whose cause of death was listed as heart disease. The lung from apex to the inferior border measured 21 cm in length. The azygos lobe occurred at the apex of the right superior lobe. It was concave in shape, measured 9 cm in length, 3 cm in width at the superior ("meso-azygos" to lateral border) and inferior (inferomedial aspect to lateral border) portions and only 2 cm width in the middle of the lobe. The superior lobe measured 8 cm in width and 11 cm including the azygos lobe. The distance from the primary bronchus to the inferior edge of the azygos lobe was 2.75 cm (Figures 1a and 1b).

Case 2

A five-lobed right lung occurred in a 78 year-old White female whose cause of death was listed as Chronic Obstructive Pulmonary Disease (COPD). The oblique and horizontal fissures contained the expected tertiary bronchi in the superior and middle lobes. The inferior lobe displayed two distinct accessory fissures spanning from the oblique fissure laterally to create three separate lobes in the inferior portion of the lung. The right lung measured 22 cm from the apex to the inferior edge and 11 cm in width along the bottom edge. The middle lobe was 2.5 cm in height. The superior lobe of the inferior portion of the lung (the first right inferior lobe or RIL1) measured 10 cm along the oblique fissure. The middle lobe of the inferior portion (the second right inferior lobe or RIL2) measured 3.5 cm along the oblique fissure. The inferior lobe of the inferior portion of the lung (the third right inferior lobe or RIL3) measured 3.25 cm along the oblique fissure

TABLE 1

List of anatomical lung variations presented in cadaveric specimen population.

Type of Variation	No. of Cases
Right incomplete horizontal fissure	6
Right absent horizontal fissure	3
Right accessory azygos fissure (Azygos lobe)	1
Right accessory fissures of inferior lobe	1
Left accessory horizontal fissure	1
Enlarged lingula	1

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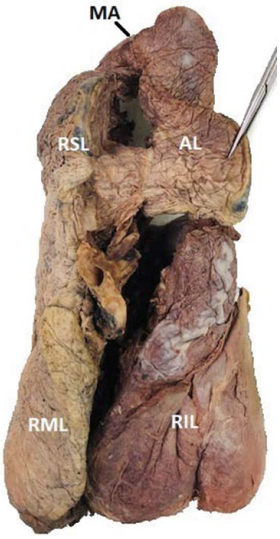

Figure 1a) *Medial view of the right lung with an azygos lobe.*
MA Meso-azygos; AL Azygos Lobe; RSL Right Superior Lobe; RML Right Middle Lobe; RIL Right Inferior Lobe

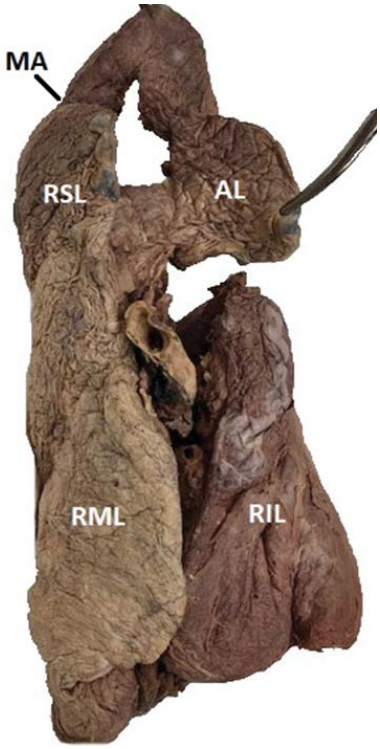

Figure 1b) *Anteromedial view of the right lung with an azygos lobe.*
MA Meso-azygos; AL Azygos Lobe; RSL Right Superior Lobe; RML Right Middle Lobe; RIL Right Inferior Lobe

(Figure 2a). The tertiary bronchi infrastructure was consistent with normal lung anatomy. The superior lobe contained the apical, posterior, and anterior tertiary bronchi. The middle lobe contained the lateral and medial tertiary bronchi. The four tertiary bronchi for the inferior lobe were divided among the three lobes. The superior and lateral-basal tertiary bronchi supplied the first inferior lobe (RIL1). The posterior basal tertiary bronchi supplied the second inferior lobe (RIL2). The anterior and medial-basal tertiary bronchi supplied the third inferior lobe (RIL3) (Figure 2b).

Case 3

An enlarged or overdeveloped lingula occurred in the left lung of an 82 year-old White male whose cause of death was listed as heart disease. The lingula measured 8 cm in length from the beginning of the margin creating the protrusion. The superior lobe, which contained the enlarged lingula, measured 10 cm in width and 12 cm in height from the region at which the lingula emerged at the apex of the lobe (Figures 3a and 3b). Only the inferior lingular tertiary bronchus supplied the lingula. The superior lingular tertiary bronchus traveled laterally supplying

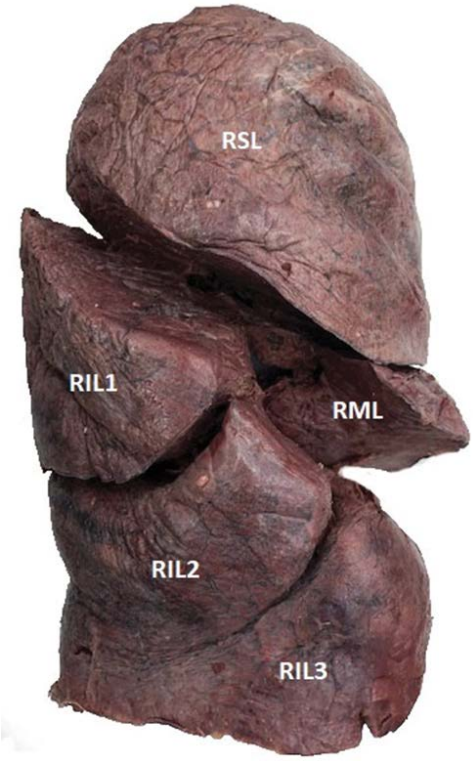

Figure 2a) *Lateral view of the right lung with accessory fissures creating five lobes.*
RSL Right Superior Lobe; RML Right Middle Lobe; RIL1 Right Inferior Lobe 1; RIL2 Right Inferior Lobe 2; RIL3 Right Inferior Lobe 3

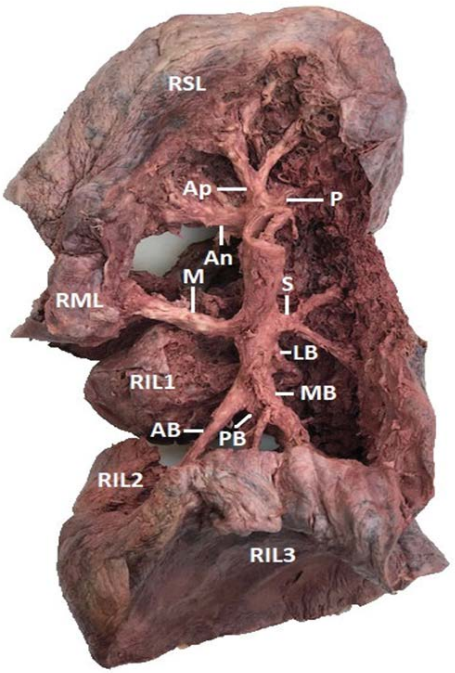

Figure 2b) *Medial view of the five-lobed right lung showing its segmental (tertiary) bronchi.*
RSL Right Superior Lobe; RML Right Middle Lobe; RIL1 Right Inferior Lobe 1; RIL2 Right Inferior Lobe 2; RIL3 Right Inferior Lobe 3; Ap Apical; P Posterior; An Anterior; M Medial (Lateral is not pictured); S Superior; LB Lateral-Basal; MB Medial-Basal; AB Anterior Basal; PB Posterior-Basal

the inferior aspect of the left superior lobe (Figure 3b).

DISCUSSION

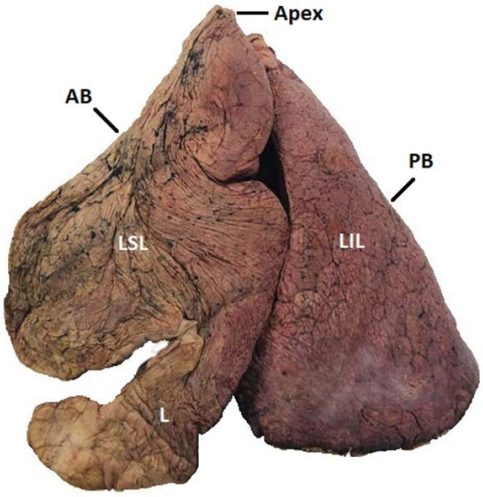

Figure 3a) *Lateral view of the left lung with an enlarged lingula. Apex Apex of Lung; AB Anterior Border; PB Posterior Border; LSL Left Superior Lobe; LIL Left Inferior Lobe; L Lingula*

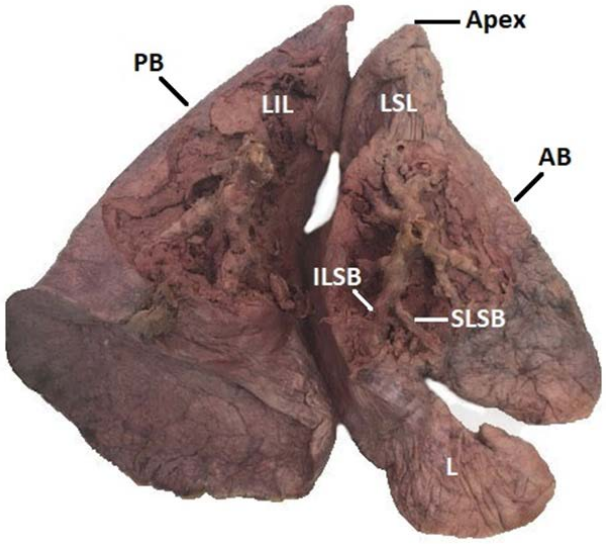

Figure 3b) *Medial view of the left lung with an enlarged lingula. Apex Apex of Lung; AB Anterior Border; PB Posterior Border; LSL Left Superior Lobe; LIL Left Inferior Lobe; L Lingula; SLSB Superior Lingular Segmental Bronchus; ILSB Inferior Lingular Segmental Bronchus*

Aberrant development of the azygos vein through the superomedial portion of the right superior lobe creates a fissure in the lung parenchyma, resulting in an azygos lobe [6]. While described as normal, it is rare, occurring in about 0.5-1% of the population [6-10]. Wessler and Jaches in 1923 documented the first radiological description of an azygos lobe [6,10]. On imaging studies and during dissection, the azygos lobe is described as concave in shape, extending from the apex of the right lung to the first costal cartilage [11]. In this cadaveric cohort, the occurrence rate of an azygos lobe was 2% (1 out of 50). Normally, the azygos vein migrates in an arch shape around the apex of the right lung and situates itself between the vertebral column and the right lung. For an azygos lobe to form, the azygos vein must develop more laterally than expected. This leads to penetration of the right lung as the azygos vein drags the parietal and visceral pleura down through the apex into the superior lobe, creating a fissure. In addition, a small reconnection of tissue occurs near the apex of the lung, known as a "meso-azygos." This tissue adherence reconnects the parietal pleura to form a mesentery around the azygos vein [12]. The resulting azygos lobe is not a true accessory lobe. It is not penetrated by its own bronchus and does not result from non-obliteration of bronchopulmonary segments [11].

Quadros et al. [4] reported a five-lobed right lung found during a study of 36 right lungs (2.77% incidence rate). The lung displayed both incomplete oblique and horizontal fissures along with two accessory fissures; one occurring in the center of the inferior lobe and one separating a portion of the superior lobe, producing five separate lobes. George et al. [1] described additional cases of supernumerary lobes in 3 out of 65 right lungs (4.61%). Each contains four lobes separated by three fissures. Normally, such accessory fissures in the right lung result from the non-obliteration of the boundaries of certain bronchopulmonary segments during embryonic development. Each of the ten tertiary bronchi develops separately during early stages of embryogenesis. As development progresses, the boundaries of select bronchopulmonary segments obliterate and come together to form lobes of the right lung leaving the oblique and horizontal fissures unfused. When supernumerary lobes are present, obliteration of certain bronchopulmonary segments did not occur as expected, leaving additional fissures and lobes in the lungs. As in the case of the five-lobed lung, the supernumerary lobes are most likely the result of non-obliteration. When an azygos lobe is present, the formation of a fissure (meso-azygos), unrelated to the obliteration of the bronchopulmonary segments in the superior lobe, interrupts the tertiary bronchi of the superior lobe.

Although the lingula of the left lung is often described as the embryological homologue of the right middle lobe, it is not separated from the left superior lobe by any fissures nor is it normally of substantial size [2]. In similarity, the right middle lobe and the lingula of the left lung are each supplied by two tertiary bronchi. Also, these "embryological homologues" may share a predisposition to similar infections and anatomical complications, suggesting even more that the lingula is comparable to the right middle lobe [13]. Arguably, from an anatomical standpoint, the lingula of the left lung appears to be a forced protrusion due to the cardiac notch below the curved groove in the left superior lobe where the heart lies. In Case 3, the lingula has a clearly defined and a substantial separation between it and the left superior lobe, resulting in an 8 cm protrusion that may suggest an independent lobe with an incomplete fissure causing the separation.

CONCLUSION

Anatomical variations of the lungs are very common and are usually asymptomatic. Twenty-six percent of the studied cadavers had incomplete and absent fissures, supernumerary lobes, and/or an azygos lobe. The azygos lobe with normal incidence of 0.5%-1% was found in 2% of this studied cadaver cohort, displaying the concave shape described in other studies. We found only one other article in the literature describing the five-lobed right lung we observed among the fifty studied cadavers. This right lung displayed normal bronchi patterning with supernumerary lobes due to non-obliteration of bronchopulmonary segments in the inferior lobe. Finally, we found no other articles describing such an enlarged lingula. This protrusion of the left superior lobe measured about ten times larger than the normal expected lingula. This suggests that this lingula is more comparable to an independent lobe, mirroring the actual morphology of a right middle lobe.

The anatomical variations we describe in this article are of clinical importance and academic interest. Surgeons and radiologists need to be aware of these normal anatomical variations. Such variations can alter surgical margins for lobectomies or segmentectomies and lead to misinterpretation of radiological images. Cardiothoracic surgeons should consider these variants to avoid or reduce mortality associated with invasive procedures.

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