



# Variations in the Morphology of Human Lungs and its Clinical Implications

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## Abstract

**Objective** To observe variations in the fissures, in the lobes, and in the hilar pattern of lungs and correlate these findings with clinical implications.

**Materials and Methods** The present study was performed on random lung specimens available in the Department of Anatomy. A total of 96 lungs (47 right and 49 left) were studied for variations in the fissures and lobes, and 92 lungs (45 right and 47 left) for variations in the hilar pattern.

**Results** Among the right-sided lungs, 70% presented incomplete horizontal fissure, 15% with absence of the horizontal fissure, and 51% with incomplete oblique fissure. Accessory fissures were also seen, but incomplete, and accounted for 17% of the total number of right lungs.

Among the left-sided lungs, 62% presented incomplete oblique fissures, and 4% with absence of the oblique fissure. Accessory fissures accounted for 6% of the total number of left lungs.

Regarding hilar pattern variations, 11% of the right-sided lungs showed > 2 bronchi, 69% showed > 2 pulmonary veins, and 37% showed > 1 pulmonary artery.

Among the left-sided lungs, 57% showed > 1 bronchi, 21% showed > 2 pulmonary veins, and 17% showed > 1 pulmonary artery.

**Conclusion** The field of pulmonary surgery is now highly advanced, with well-developed radiological and endoscopic techniques. Hence, a proper understanding and knowledge of these morphological variations of lung fissures and of the hilar pattern would be advantageous for surgeons, as well as for radiologists.

## Keywords

- ▶ accessory fissure
- ▶ horizontal fissure
- ▶ lung hilum
- ▶ oblique fissure

## Introduction

The right and left lungs normally present only the main fissures, which are usually complete with their lobes connected by the lobar bronchi and vessels at the hilum. The right lung is divided by the horizontal and oblique fissures, and the left only by the oblique fissure. These fissures enable the movement of the lobes against each other, thus allowing greater distention and movement of the lower lobes during

respiration and, therefore, assisting in a more uniform expansion of the whole lung.<sup>1</sup>

The position of the lung fissures are useful landmarks in citing lesions within the thorax as a whole and within the lungs specifically.<sup>2</sup> Considering the clinical importance, we took keen interest to look for any variations in the normal anatomy of lungs, which were removed from cadavers embalmed with 10% formalin and were being used for routine dissection in our department. We had performed a pilot study on the same

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lungs, and had observed many variations, such as incompleteness of the main fissures, and the presence of accessory fissures that are normally obliterated.<sup>3</sup> In addition to these, in the present study, we have also encountered variations in the hilar pattern of the lungs, contradictory to the hilar pattern mentioned in the standard textbooks of anatomy.

In the clinical practice, radiologists and clinicians often misinterpret these kinds of variations present in the lungs. Each lobe segregates a definite number of bronchopulmonary segments and, with this knowledge, clinicians approach further with preoperative planning and strategy for pulmonary lobectomy and segmental resection. But their strategy may have to change when confronted with a variation in the lung.<sup>4</sup> Hence, it is important for the clinicians to have detailed knowledge of these variations before performing any pulmonary surgery concerned with the diseases of the lungs. Knowledge of these anatomical variations is also of utmost importance for radiologists to correctly interpret X-rays and computed tomography (CT) scans.

## Materials and Methods

The present study was performed on intact lung specimens in good condition available at the Department of Anatomy. Diseased and mutilated specimens were excluded from the study. The lungs were removed from cadavers embalmed with 10% formalin, which were utilized for routine dissection, during the course of undergraduate and postgraduate medical training. A total of 96 lungs (47 right and 49 left) were studied for variations in fissures and lobes, and 92 lungs (45 right and 47 left) for variations in the hilar pattern. Only those lungs in which the fissures were clearly visible and those in which the hilar pattern was intact were considered for the study. These were examined carefully for the presence of any variant fissure as well as for variable hilar pattern. It was not possible to do gender differentiation of the lung specimens as the study was performed on specimens already removed from the cadavers during the course of routine dissection and were available at the Department of Anatomy.

## Results

Among the 96 lungs, the prevalence of variation in the horizontal and oblique fissures of 47 right-sided lungs, and in the oblique fissure of 49 left-sided lungs was tabulated (►Table 1). A higher prevalence of variation was observed in the incompleteness of the horizontal and oblique fissures of right lungs, of



**Fig. 1** Lateral view – Costal surface of a right lung with incomplete horizontal fissure (IHF), and incomplete oblique fissure (IOF).

which 70% had incomplete horizontal fissure and 51% had incomplete oblique fissure (►Fig. 1). The same is the case with left lungs, in which a higher prevalence of variation was observed in the incompleteness of the oblique fissure (62%).

The presence of accessory fissures in both right and left lungs was also tabulated (►Table 2). The accessory fissures observed in almost all of the lung specimens were incomplete, with the exception of one left lung having a complete accessory fissure separating an accessory lobe (►Fig. 2).

The hilar pattern of right and left lungs showed a varying percentage of variations regarding the number of bronchi, of pulmonary veins, and of pulmonary arteries, as tabulated in ►Tables 3 and 4. Of the right lungs, 11% showed > 2 bronchi (normal pattern), of which the highest number was 6, in 2% of the lungs (►Fig. 3); 69% showed > 2 veins (superior and inferior pulmonary veins), the highest being 4 in 13% of the lungs (►Fig. 4), and 37% with > 1 pulmonary artery, the highest being 3 in 4% of the lungs (►Fig. 5).

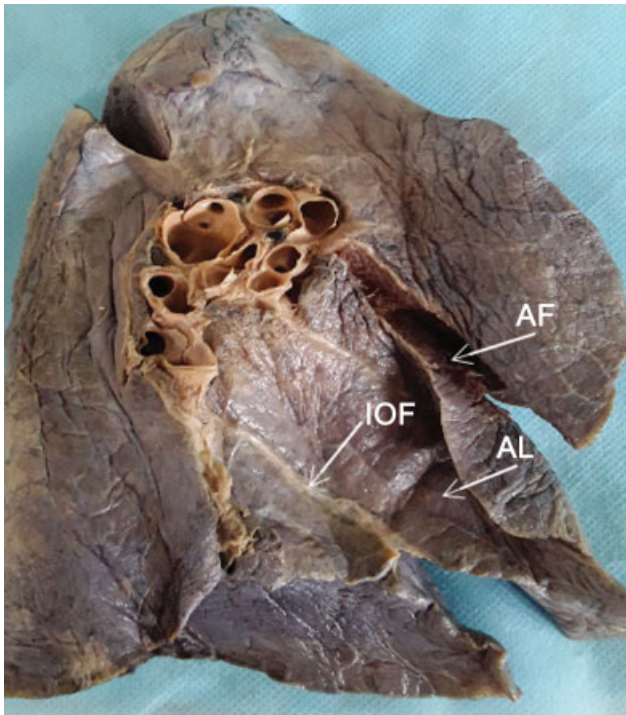
Among the left lungs, 57% showed > 1 bronchus (normal pattern) of which the highest number was 3 in 8% of the

**Table 1** Distribution of main lung fissures

Category	Right Lungs				Left Lungs	
	Oblique Fissure		Horizontal Fissure		Oblique Fissure	
	Number of lungs	Percentage	Number of lungs	Percentage	Number of lungs	Percentage
Complete	23	49%	7	15%	16	34%
Incomplete	24	51%	33	70%	29	62%
Absence	NA	NA	7	15%	2	4%

**Table 2** Distribution of accessory fissures of lungs

Category	Accessory Fissures			
	Right Lungs		Left Lungs	
	Number of lungs	Percentage	Number of lungs	Percentage
Superior	1	2%	2	4%
Middle	2	4%	NA	NA
Inferior	5	11%	1	2%



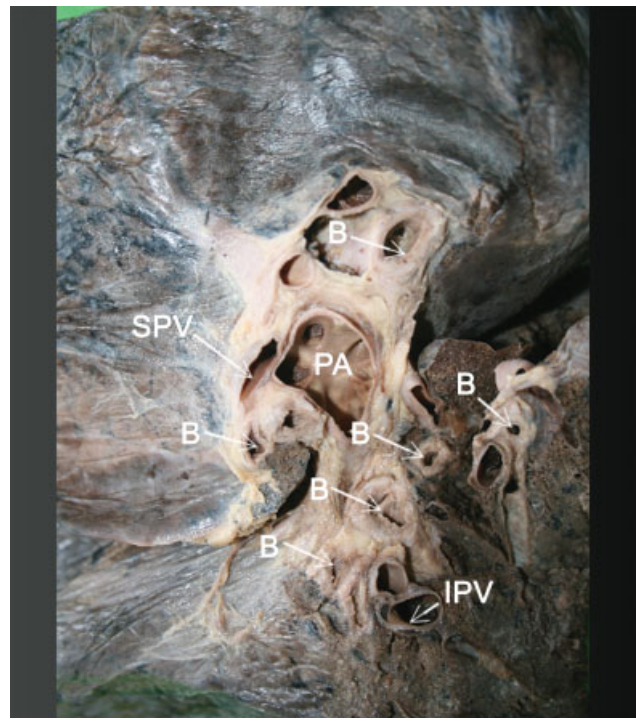
**Fig. 2** Medial view – Left lung showing accessory lobe (AL), accessory fissure (AF), and incomplete oblique fissure (IOF).

**Table 3** Pattern of hilar structures in right lungs

Right lungs	Present Study	George et al <sup>5</sup>
<b>Bronchi</b>	<b>Percentage</b>	<b>Percentage</b>
One	2%	NA
Two	87%	98.46%
Three	9%	1.53%
Six	2%	NA
<b>Pulmonary veins</b>	<b>Percentage</b>	<b>Percentage</b>
One	2%	NA
Two	29%	63.07%
Three	56%	32.30%
Four	13%	NA
<b>Pulmonary arteries</b>	<b>Percentage</b>	<b>Percentage</b>
One	62%	29.23%
Two	33%	67.69%
Three	4%	3.07%

**Table 4** Pattern of hilar structures in left lungs

Left lungs	Present Study	George et al <sup>5</sup>
<b>Bronchi</b>	<b>Percentage</b>	<b>Percentage</b>
One	43%	76.71%
Two	49%	21.91%
Three	8%	NA
<b>Pulmonary veins</b>	<b>Percentage</b>	<b>Percentage</b>
One	4%	NA
Two	75%	80.82%
Three	17%	19.17%
Four	2%	NA
Five	2%	NA
<b>Pulmonary arteries</b>	<b>Percentage</b>	<b>Percentage</b>
One	83%	94.52%
Two	17%	5.47%

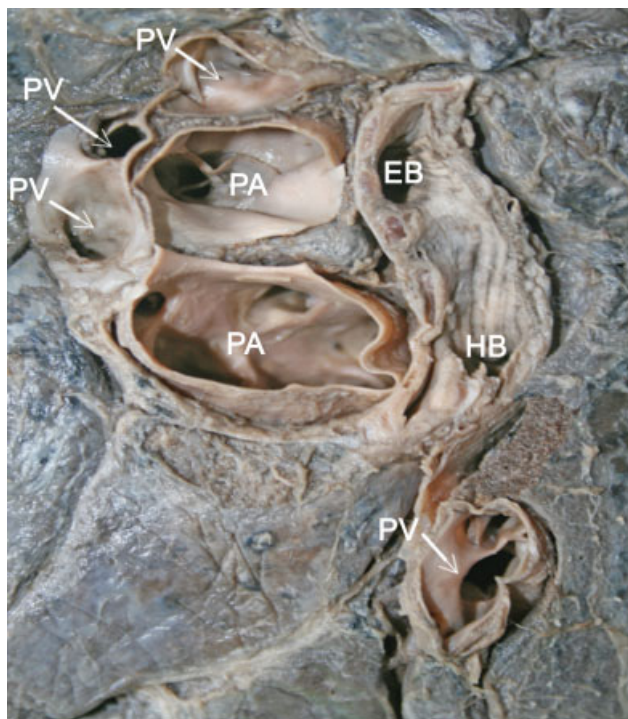


**Fig. 3** Medial view – Mediastinal surface of a right lung with its hilum indicating five bronchi (B) and related structures: pulmonary artery (PA), superior pulmonary vein (SPV), and inferior pulmonary vein (IPV).

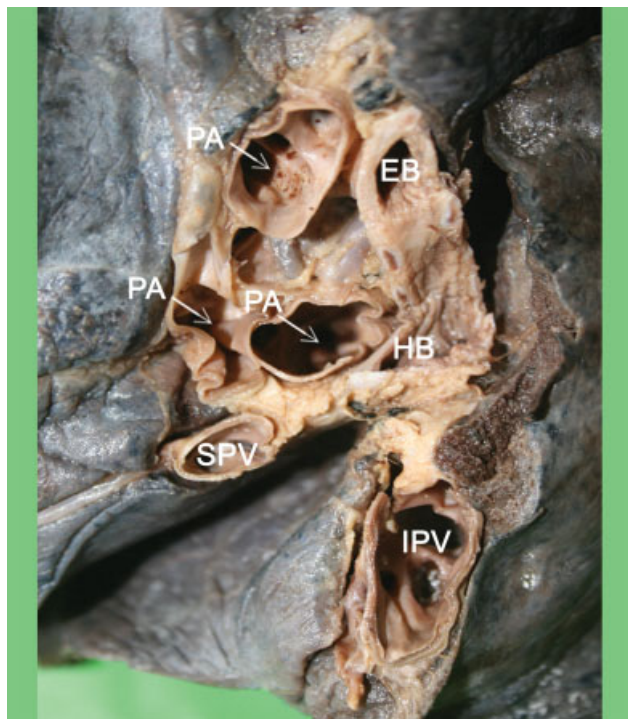
lungs; 21% showed > 2 pulmonary veins, the highest being 5 in 2% of the lungs, and 17% with > 1 pulmonary artery, the highest being 2 in 17% of the lungs.

**Discussion**

Lungs begin to develop during the embryonic period, initially arising as a lung bud from the ventral wall of the foregut as early as in the 4<sup>th</sup> week of gestation. This gives rise to two bronchial buds; each one enlarges to form the right and left primary bronchi, which differentiate into secondary and



**Fig. 4** Medial view – Mediastinal surface of a right lung with its hilum indicating four pulmonary veins (PV) and related structures: pulmonary artery (PA), eparterial bronchus (EB), and hyarterial bronchus (HB).



**Fig. 5** Medial view – Mediastinal surface of a right lung with its hilum indicating three pulmonary arteries (PA) and related structures: eparterial bronchus (EB), hyarterial bronchus (HB), superior pulmonary vein (SPV) and inferior pulmonary vein (IPV).

tertiary bronchi consecutively. As they expand, they come to occupy the narrow pericardioperitoneal canals that lie on either side of the foregut. Eventually, they come in contact with the splanchnic mesoderm that later develops into the

visceral pleura.<sup>6</sup> The pleura lines each bronchopulmonary segment of both lungs, which remain separated by fissures.

Most of these lung fissures obliterate, leaving only the main fissures intact, that is, the horizontal and the oblique fissures.<sup>7</sup> Generally, they form the normal pattern in humans, with the right lung exhibiting both the horizontal and the oblique fissures, and the left lung exhibiting only the oblique fissure. They are usually complete, with the lobes connected only by the hilum.<sup>8</sup>

In the present study, we have observed that the prevalence of incomplete lung fissures and of accessory fissures are not uncommon. It has also been observed that the prevalence of incomplete lung fissures on both sides appears to be higher than that of accessory fissures.

► **Table 5** is a comparison of data collected from studies conducted by various authors with those of the present study based on different parameters, including the prevalence of incomplete lung fissures and of accessory fissures.

In an analysis of the data tabulated by various authors, including the present study, it is observed that a higher prevalence of variation is in the incompleteness of the normal fissures in both right and left lungs. The prevalence of accessory fissures reported is comparatively low, as is the absence of normal fissures.

Among the right-sided lungs, a higher prevalence of incomplete horizontal fissure was observed. The highest percentage was reported by our earlier study<sup>3</sup> (83.4%) followed by the present study (70%), and by the study by Meenakshi et al<sup>8</sup> (63%). The prevalence of incomplete oblique fissure in the right-sided lungs is low when compared with that of the incomplete horizontal fissure, and this is seen in the present study (51%), followed by other studies.<sup>5,8,9,11,12</sup> However, according to Magadam et al,<sup>10</sup> the prevalence of incomplete oblique fissure was higher than that of the incomplete horizontal fissure.

The absence of the oblique fissure in right lungs is reported by Jacob et al<sup>3</sup> (3.4%), by Prakash et al<sup>9</sup> (7%), and by Magadam et al<sup>10</sup> (10%), whereas other authors have not reported the same, as is the case in the present study. The prevalence of the absence of the horizontal fissure of right lungs is quite low, the highest being reported by Meenakshi et al<sup>8</sup> (17%), followed by the present study (15%), and the lowest being reported by George et al<sup>5</sup> (3%). Mamatha et al<sup>11</sup> did not observe any absence of horizontal fissure in her study.

The presence of accessory fissures among right lungs is interestingly found to be high in the study by Prakash et al<sup>9</sup> (39%) when compared with studies by other authors,<sup>5,8,10-12</sup> which vary from 3% to 17%. The presence of complete accessory fissures results in accessory lobes.

Azygos lobe is rarely encountered in the right lung, its prevalence ranging from 0.4 to 1%. During development, the posterior cardinal vein from which the thoracic portion of the azygos vein develops penetrates the upper lobe of the right lung along with the parietal and visceral pleura, creating an accessory fissure along the depth of which passes the azygos vein, which is suspended from the thoracic wall by the mesoazygos, a fold of the parietal pleura. This results in the detachment of the upper and of the medial portion of the

**Table 5** Comparative analysis of the variant fissures of lungs as observed by various authors

Fissures	Parameters	Present study	Jacob et al <sup>3</sup>	Meenakshi et al <sup>8</sup>	Prakash et al <sup>9</sup>	Magadum et al <sup>10</sup>	George et al <sup>5</sup>	Mamatha et al <sup>11</sup>	Arora et al <sup>12</sup>
Right oblique	Incomplete	51%	50%	37%	39%	60%	NA	15%	20%
	Absence	NA	3.4%	NA	7%	10%	NA	NA	NA
Right horizontal	Incomplete	70%	83.4%	63%	50%	52.5%	35%	50%	27%
	Absence	15%	6.6%	17%	7%	12.5%	3%	NA	9%
Right accessory		17%	13.3%	3%	39%	7.5%	5%	15%	16%
Left oblique	Incomplete	62%	38.9%	47%	36%	42.5%	15%	35%	11%
	Absence	4%	NA	NA	11%	7.5%	NA	5%	7%
Left accessory		6%	27.7%	10%	18%	7.5%	3%	NA	7%

upper lobe of the right lung located medial to the accessory fissure just above the hilum, resulting in the azygos lobe.<sup>13-15</sup> However, we did not encounter an azygos lobe in our study.

Among the left-sided lungs, the prevalence of incomplete oblique fissure is comparatively high, with the highest reported prevalence in the present study (62%), followed by Meenakshi et al<sup>8</sup> (47%). The prevalence of absence of the oblique fissure was reportedly low in the present study (4%), the highest being 11%, reported by Prakash et al.<sup>9</sup> The absence of the oblique fissure has not been reported by Jacob et al,<sup>3</sup> by Meenakshi et al,<sup>8</sup> and by George et al.<sup>5</sup> The presence of accessory fissures among left lungs is found to be high in the study by Jacob et al<sup>3</sup> (27.7%), followed by Prakash et al<sup>9</sup> (18%). The present study has reported only 6% of accessory fissures in left lungs, which is comparatively similar with what has been reported by Arora et al<sup>12</sup> (7%). In one of the left sided specimens, a complete accessory fissure that was obliquely oriented, separating a separate lingular lobe, was observed. The fissure probably separates the anterior segment of the left upper lobe from the lingular segments. There is mention by Bergman of a common fissure that separates the superior segment of the right or left lower lobe, which is also referred to as the dorsal lobe of Nelson.<sup>16</sup> Deve<sup>17</sup> found it bilaterally in 12 cases, in the right lower lobe in 40 cases, and in the left lower lobe in 14 cases. They referred to the separated part as the "posterior lobe"<sup>16</sup>. Parenchymal fusion occurs between major lung lobes, which may be partial or complete, leading to incompleteness of the normal lung fissures or to their absence. This fusion is usually seen towards the mediastinal side of the lung. Such a fusion between lung lobes paves way to the spread of disease and collateral air drift.<sup>18</sup> The usual patterns of collapse seen in patients with endobronchial lesions can alter and may also give rise to an atypical type of pleural effusion.<sup>8</sup> A thorough understanding of the appearance and of the implications of an incomplete fissure is significant for planning of lobar resection due to the possibility of a higher prevalence of air leak in lobar fusion.<sup>18</sup> Another variant lung fissure is the accessory fissure, which usually occurs at the boundaries between bronchopulmonary segments. Anatomically, an accessory fissure is a cleft of varying depth lined by visceral pleura.<sup>19</sup> Accessory fissures could be the result of the nonobliteration of spaces that are normally obliterated.<sup>8</sup> An accessory fissure may cause misinterpretation of an infection as

atelectasis or consolidation as it acts as a barrier to the spread of infection causing a sharply marginated pneumonia.<sup>19</sup> Radiologically, an accessory fissure can be mistaken for a lung lesion.<sup>20</sup>

Along with the study of variant lung fissures, an attempt has also been made to study the hilar pattern of lungs as they presented variability in the number of structures forming the root of the lung, contrary to what is mentioned in the standard textbooks, but their significance is yet unknown. Hardly any studies have been done on the hilar pattern as revealed by our literature search. A similar study has been reported by George et al.<sup>5</sup> A comparison between our study and the study by George et al<sup>5</sup> is depicted in **Tables 3 and 4**.

## Conclusion

In the present study, a high prevalence of incomplete horizontal and oblique fissures were observed amongst right lungs, and this was also the case with left lungs regarding the oblique fissure. The horizontal fissure was absent in 15% of the right lungs, whereas the oblique fissure was absent in 4% of the left lungs. Accessory fissures, mostly incomplete, were observed in right (17%) and left (6%), lungs, with the exception of a single left lung with a complete accessory fissure separating an accessory lobe.

The hilar pattern demonstrated a wide range of variations regarding the pulmonary artery, vein and bronchi, both in their number and arrangement, unlike what is mentioned in the standard textbooks of anatomy. As is evident from the present study, it is imperative for surgeons to be aware of the variant morphology of lungs, which is quite common, in order to plan effectively their surgical procedures, and for radiologists to accurately interpret the radiological images.

## Conflicts of Interests

The authors have no conflicts of interests to declare.

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