

Morphological Variations of Lung Fissures and Lobes in Cadaveric Specimens: A Retrospective Study with Embryological and Clinical Correlation

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Abstract:

Background: Morphological variations of pulmonary fissures and lobes are relatively common and may reflect differences in embryological development. Recognition of these variations is important for anatomical understanding, radiological interpretation, and thoracic surgery.

Aim: To evaluate morphological variations of lung fissures and lobes in cadaveric specimens and correlate the findings with their embryological basis and clinical significance.

Methodology: A retrospective observational study was conducted on 45 formalin-fixed adult cadaveric lung specimens in the Department of Anatomy, Darbhanga Medical College, Laheriasarai, Darbhanga, Bihar, India. Fissures and lobar configurations were examined systematically and analyzed using descriptive statistics in SPSS version 27.0.

Results: Right and left lungs comprised 51.1% and 48.9% of specimens, respectively. Complete oblique fissures were observed in 64.4%, incomplete fissures in 31.1%, and absent fissures in 4.4%. Among right lungs, the horizontal fissure was complete in 56.5%, incomplete in 34.8%, and absent in 8.7%. Accessory morphological variations occurred in 26.7%, while overall fissural and/or lobar variations were present in 33.3%.

Conclusion: Pulmonary fissural and lobar variations are common developmental patterns with important clinical implications.

Keywords: Lung, Pulmonary Fissures, Lobes, Anatomical Variation, Cadaver, Embryology, Thoracic Surgery.

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Introduction

The lungs are the main organs for breathing and they are located on each side of the mediastinum, which is closely associated with the heart. The right lung is divided into three lobes (superior, middle, and inferior) and the left lung into two lobes (superior and inferior) by three fissures (oblique and horizontal fissures of the right lung and oblique fissure of the left lung) [1]. On each side, the major oblique fissure runs from the posterior-superior part of the hilum, across the costal surface and the inferior border, to the anterior-inferior part of the hilum. The horizontal fissure is found on the right and runs from the oblique fissure toward the anterior (ventral) sternal border at the level of the fourth costal cartilage. The pulmonary lobes are separated by these fissures and during the process of respiration they expand independently of each other.

The classical description of the pulmonary anatomy is more or less consistent, but there are significant differences in the morphology of the lung fissures and lobes [2]. A complete fissure runs through the entire thickness of the lung parenchyma and divides neighbouring lobes of the lung only at the hilar region. Parenchymal bridges between lobes are present in incomplete fissures, but in the absence of a fissure the lobes are normally separated but are not differentiated. These differences can manifest as incomplete, missing or abnormally oriented fissures, and can affect the major or minor fissure [3]. Accessory fissures can also occur either singly or in pairs in the pulmonary parenchyma and lead to the development of supernumerary lobes.

The embryological development of respiratory system closely parallels the morphological pattern of

pulmonary fissures [4]. The primary bronchial trunk is repeatedly branched into lobar and segmental bronchi during embryogenesis. At an early stage of development, multiple fissures separate the developing bronchopulmonary segments. As lung growth and maturation occur, these embryonic fissures disappear in some, but not all, and the major and minor fissures remain to form the final lobar pattern of the lungs. If these embryonic fissures do not obliterate completely, then accessory fissures will remain in the adult lung. Hence, the developmental remodeling of the primitive pulmonary architecture may be altered or incomplete and the variations noted in cadaveric specimens may reflect this.

Another important morph variation is the supernumerary or accessory lobes [5]. They are made up of parts of the lung tissue which are isolated from the main lobes by accessory fissures and may occur due to differences in the branching of the main bronchi. Different rare lobes such as azygos, dorsal, caudal and tracheal lobes have been described. Of these, the relatively uncommon azygos lobe typically occurs on the right upper lobe. It has been reported in about 1% of cadaveric specimens and 0.4% of radiological populations. Developmentally this variant is related to the abnormal course of the azygos vein through the developing upper lobe, which results in the development of an additional fissure and distinct medial pulmonary segment.

This is because the variations of pulmonary fissure and lobar are important for clinical, radiological, and surgical reasons [6]. The fissures should be present but incomplete or absent, which can affect the anatomical planes encountered in lobectomy and segmentectomy and other pulmonary surgical procedures. If they are not aware of them preoperatively, they can make surgical dissection more difficult, and raise the risk of postoperative air leakage or complications [7]. Accessory fissures and lobes can also give an abnormal radiographic appearance of the lungs and can sometimes mimic pathological processes. An azygos lobe may appear in a highly unusual fashion on chest radiography or computed tomography and may simulate pulmonary nodules, lymphadenopathy, bullae, abscesses and other pathological conditions.

The cadaveric examination is an important tool for determining detail of pulmonary fissures and lobes and a direct examination of variations that might not be fully appreciated on routine imaging [8]. The anatomical observation in relation to embryological basis enables to understand better the role of developmental processes in generating differences in adult pulmonary morphology. A knowledge of such abnormalities will be useful for anatomists, radiologists, pulmonologists and thoracic surgeons, as correct recognition of normal variants is essential to correct reading and safe surgery.

Hence, the present retrospective study is aimed to observe the morphological variations seen in pulmonary fissures and lobes in cadaveric specimens with special emphasis on incomplete, absent and accessory fissures and accessory lobar formation. The study aims to also correlate these anatomical variations with their embryological development and clinical significance so that a thorough understanding of the diversity of the pulmonary anatomy is created and its implications in contemporary diagnosis and surgical practice.

Methodology

Study Design: The present study was designed as a retrospective observational descriptive study to evaluate the morphological variations of lung fissures and lobes in adult human cadaveric specimens, with additional consideration of their embryological basis and potential clinical significance.

Study Area: The study was conducted in the Department of Anatomy, Darbhanga Medical College, Laheriasarai, Darbhanga, Bihar, India. The observations were made on cadaveric lung specimens available in the department through routine anatomical dissection and teaching activities.

Study Duration: The study was conducted over a period of 3 months.

Study Participants: The study participants consisted of adult human cadaveric lung specimens available in the Department of Anatomy during the study period.

Inclusion Criteria

- Adult human cadaveric lung specimens available for anatomical examination.
- Formalin-fixed lung specimens obtained through routine anatomical dissection.
- Both right and left lung specimens.
- Specimens with sufficiently preserved pleural surfaces, fissures, and lobes for morphological assessment.
- Specimens in which the anatomical relationship of fissures and lobes could be clearly identified.
- Specimens with adequate documentation for inclusion in the retrospective assessment.

Exclusion Criteria

- Lung specimens showing gross pathological changes such as tumors, severe infection, fibrosis, or marked deformity.
- Severely damaged, fragmented, or incomplete lung specimens.
- Specimens with extensive preservation or fixation artifacts affecting morphological assessment.
- Specimens in which the fissures or lobes could not be reliably identified.

- Specimens with incomplete or inadequate documentation.

Sample Size

A total of 45 cadaveric lung specimens were included in the study. The specimens comprised available right and left lungs that fulfilled the predefined inclusion and exclusion criteria.

Procedure: The available cadaveric lung specimens were retrospectively examined for morphological variations in fissures and lobes. The specimens had been preserved using standard formalin fixation and were obtained during routine anatomical dissection. Each specimen was assigned a unique identification number, and relevant demographic or specimen-related information available in the departmental records was documented without identifying the donor. The external surfaces of the lungs were systematically inspected to assess the number, course, completeness, and morphology of the fissures and the resulting lobar configuration.

For the right lung, the oblique and horizontal fissures were examined separately. The oblique fissure was classified as complete when it completely separated the upper and lower lobes, incomplete when parenchymal bridges connected the adjacent lobes, and absent when no recognizable fissure was present. The horizontal fissure was similarly classified as complete, incomplete, or absent based on the degree of separation between the upper and middle lobes. For the left lung, the oblique fissure was assessed using the same criteria, and any additional or accessory fissures were recorded. Variations in the number, size, shape, and configuration of lobes were also documented. Accessory lobes, including unusual lobar formations, were specifically noted whenever present.

Standard anatomical landmarks were used to maintain consistency during examination. The observed variations were documented using structured data collection forms. Where available, departmental

records and previously documented photographs of specimens were reviewed to support the morphological assessment. The identified variations were subsequently interpreted in relation to normal lung development and embryological mechanisms, particularly abnormal or incomplete fusion of developing bronchopulmonary segments. Their possible clinical relevance to radiological interpretation, surgical procedures, and pulmonary segmental anatomy was also considered.

Statistical Analysis: The collected data were entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics version 27.0. Descriptive statistical methods were used for analysis. Categorical variables, including side of lung, type of fissure, completeness of fissures, presence of accessory fissures, and lobar variations, were expressed as frequencies and percentages. The distribution of morphological variations between right and left lungs was compared using appropriate categorical statistical tests, primarily the Chi-square test or Fisher's exact test, wherever applicable. A p-value <0.05 was considered statistically significant. The findings were presented in the form of tables and percentages to provide a clear description of the morphological variations observed among the 45 cadaveric lung specimens."

Result

Table 1 shows the distribution of cadaveric lung specimens according to side. Out of the total 45 lung specimens examined, 23 (51.1%) were right lungs, whereas 22 (48.9%) were left lungs. Thus, the right lung specimens were slightly more frequent than the left lung specimens, accounting for just over half of the total sample. The difference between the two sides was minimal, with only one additional right lung specimen observed. Overall, the distribution was relatively balanced between right and left lungs, indicating nearly equal representation of both sides among the cadaveric lung specimens included in the present study.

Table 1: Distribution of Cadaveric Lung Specimens According to Side		
Side of lung	Frequency (n)	Percentage (%)
Right lung	23	51.1
Left lung	22	48.9
Total	45	100

Table 2 shows the morphological pattern of the oblique fissure in the 45 cadaveric lung specimens. A complete oblique fissure was the most common finding, observed in 29 specimens (64.4%), including 14 right lungs and 15 left lungs. An incomplete oblique fissure was present in 14 specimens

(31.1%), comprising 8 right lungs and 6 left lungs. An absent oblique fissure was observed in only 2 specimens (4.4%), with one each on the right and left sides. Overall, complete oblique fissures predominated, while absent fissures were the least frequently observed morphological pattern.

Table 2: Morphological Pattern of Oblique Fissure in Cadaveric Lung Specimens

Oblique fissure	Right lung (n=23)	Left lung (n=22)	Total (n=45)	Percentage (%)
Complete	14	15	29	64.4
Incomplete	8	6	14	31.1
Absent	1	1	2	4.4
Total	23	22	45	100

Table 3 shows the morphological pattern of the horizontal fissure in the 23 right lung specimens. A complete horizontal fissure was the most frequently observed pattern, present in 13 specimens (56.5%). An incomplete horizontal fissure was identified in 8 specimens (34.8%), while the horizontal fissure was absent in 2 specimens (8.7%). Thus, more than half

of the right lung specimens demonstrated a complete horizontal fissure, whereas approximately one-third showed an incomplete fissure. The absence of the horizontal fissure was comparatively uncommon, accounting for less than one-tenth of the specimens examined.

Table 3: Morphological Pattern of Horizontal Fissure in Right Lung Specimens

Horizontal fissure	Frequency (n=23)	Percentage (%)
Complete	13	56.5
Incomplete	8	34.8
Absent	2	8.7
Total	23	100

Table 4 shows the distribution of accessory fissures and accessory lobes among the 45 cadaveric lung specimens. No accessory morphological variation was observed in 33 specimens (73.3%), making this the most common finding. An accessory fissure alone was present in 7 specimens (15.6%), whereas an accessory lobe alone was identified in 3 specimens (6.7%). Both an accessory fissure and an

accessory lobe were observed together in 2 specimens (4.4%). Thus, accessory fissures were the most frequently encountered morphological variation, while the combined occurrence of an accessory fissure and accessory lobe was least common. Overall, accessory morphological variations were present in 26.7% of the specimens.

Table 4: Distribution of Accessory Fissures and Accessory Lobes

Accessory morphological variation	Frequency (n)	Percentage (%)
Accessory fissure only	7	15.6
Accessory lobe only	3	6.7
Both accessory fissure and accessory lobe	2	4.4
No accessory variation	33	73.3
Total	45	100

Table 5 shows the distribution of overall lobar configuration and morphological variations among the 45 cadaveric lung specimens. A normal anatomical configuration was observed in 30 specimens (66.7%), representing the majority of the sample. Variations in fissures alone were identified in 10 specimens (22.2%), while variations involving the

lobe alone were observed in 2 specimens (4.4%). Both fissural and lobar variations were present in 3 specimens (6.7%). Thus, normal lobar configuration was the predominant finding, whereas isolated lobar variation was the least frequent. Overall, morphological variations involving fissures and/or lobes were observed in 15 specimens (33.3%).

Table 5: Distribution of Overall Lobar Configuration and Morphological Variations

Lobar configuration	Frequency (n)	Percentage (%)
Normal anatomical configuration	30	66.7
Variation in fissure only	10	22.2
Variation in lobe only	2	4.4
Variation in both fissure and lobe	3	6.7
Total	45	100

Discussion

This present cadaveric, retrospective study of 45 lungs showed that most lungs had the normal lobar

arrangement, but there was appreciable variation in the morphology of the fissures and lobes. The proportion of the right and left lungs was almost equal at 51.1% to 48.9%. The oblique fissure was

complete in 64.4%, incomplete in 31.1% and absent in 4.4%. These results suggest that the anatomical pattern is still mostly complete oblique fissures with incomplete or absent fissures as significant developmental variations. In a study of cadaveric lungs of South Indians (Jacob and Pillay, 2013) [9], they reported a significantly higher percentage of incomplete oblique fissures, especially on the right side (18.2% in their series), whereas the present study revealed a higher percentage of incomplete oblique fissures of 31.1% in all cases. This difference could be due to variations in sample size, characteristics of the population, or the classification of fissural completeness."

The oblique fissure was not found in many specimens in the present study, it was present in 4.4% of the specimens. The finding is similar to that of Quadros et al. (2014) [10] who reported complete absence of oblique fissure in lung specimens from South India. They observe that the oblique fissure tends to form in a regular fashion while partial or incomplete fusion is more likely to account for the variation of morphology. It is therefore not surprising that the percentage of complete absence in the present study was relatively low and that major disruption of the development of the oblique fissures is much less frequent than is incomplete fissural formation.

The horizontal fissure was more variable when compared with the oblique fissure. In 23 right lungs, it was complete in 56.5%, incomplete in 34.8%, and missing in 8.7%. This pattern is similar to the pattern noted by Hema L, (2014) [11] with a great variation in horizontal fissure and a note of how the presence of a fissure that is incomplete or absent is a relatively common morphological finding. The current mean of incomplete horizontal fissure (34.8%) is also similar to that of George et al. (2014) [12] which reported a mean of incomplete horizontal fissure in 35.38% of right lungs. The actual absence rate (8.7%) for these schools was, however, higher than their reported rate (3.07%). These variations give further evidence for the freer development of the horizontal fissure as compared with the oblique fissure, and that the development of the horizontal fissure may vary considerably among individuals.

Magadam et al., 2015 [13] also reported significant variability in fissures and lobes of lungs and the importance of clinical significance. It has been observed from the present study that the horizontal fissures tend to be incomplete or not present at all in the case of horizontal fissures as opposed to oblique ones. The horizontal fissure is developmentally associated with division of the superior and middle lobes of the right lung so that failure to divide can lead to incomplete separation of these lobes. In terms of morphology, it can result in an external form that is different from the normal three-lobed right lung.

Morphological variations that are considered accessory were found in 26.7% of the specimens examined. Accessory fissure alone (15.6%), accessory lobe alone (6.7%) and combined accessory fissure and accessory lobe (4.4%) were the most frequent variations. The present finding of a high incidence of fissural abnormalities compared to major lobar number alterations echoes and corroborates the findings of Anbusudar and Dhivya (2016) [14]. Accessory fissures occur when there is persistence of other planes of separation during pulmonary development, and can create a pulmonary appearance that is not described traditionally.

Overall, it was found that 66.7 per cent of specimens were in normal lobar form while 33.3 per cent exhibited some degree of fissural and/or lobar variability. Isolated fissural variation was the most common type (22.2%), followed by combined fissural and lobar variation (6.7%) and isolated lobar variation (4.4%). Variations involving fissures and lobes were also observed in cadaveric specimens by Dhana-lakshmi et al., 2016 [15] and it was noted that pulmonary morphology is by no means limited to the pattern seen in textbooks. The relatively large number of fissural variation in the present study also indicates that fissural change may happen more often than major variation in number of lobes.

Mamatha et al. (2016) [16] also reported variations in the pulmonary fissures and lobes morphologically and highlighted the importance of these variations from an anatomical and clinical standpoint. Like the present observation, they were able to identify that most of the variations were associated with fissural morphology and not single lobar anomalies. Accessory fissures or incomplete fissures can affect the appearance of the lobes and thus the interpretation of anatomical material and radiographical images.

The embryological explanation of these findings is the difference in the development, separation and fusion of bronchopulmonary segments. Accessory fissures may occur, however, if the intersegmental planes are not completely fused then incomplete fissures may occur. Excessive fusion can cause lack of fissures, however. Esomonu et al. [17] have described the lobar pattern of the right and left lungs and pointed out that the pattern of the lungs may be due to developmental variation. Therefore, the current observation that 1/3 of specimens exhibited some morphological changes can be considered as a normal range of developmental differences that may occur during fetal pulmonary morphogenesis.

These variations are clinically significant. A lack of or missing fissure could allow pathological processes to extend beyond the usual lobar boundaries and may make definition of the lobes technically challenging in lobectomy. Accessory fissures can also cause abnormal linear radiologic features and can be confused with pathological structures. Shinde

and Patel (2022) [18] highlighted the significance of identifying the differences in lobes and fissures while performing thoracic surgery and radiological assessment. Thus, the 33.3% overall variation seen in the current study is more than a mere anatomical curiosity and has clinical implications for diagnosis, bronchoscopic localization, surgery planning and interpretation of chest imaging.

Overall, the present study corroborates that 66.7% of specimens had normal pulmonary lobar configuration while 33.3% had morphological variations. More oblique fissures were present (64.4%) than right horizontal fissures (34.8%), which showed more variation and eight percent (8.7%) were absent. Accessory fissures occurred more commonly than accessory lobes. In general, results are similar to previous cadaveric studies, but show quantitative differences in the frequency of individual differences. These differences highlight the significance of keeping in mind the pulmonary fissures and lobes as structures with great variable development. It is important to have a detailed knowledge of their morphological and embryological variations for accurate anatomical education and for radiological interpretation and surgical procedures in the lungs.

Conclusion

The present retrospective cadaveric study demonstrates that although normal pulmonary lobar configuration predominates, morphological variations of lung fissures and lobes are relatively common. Among the 45 specimens, complete oblique fissures were most frequent (64.4%), while incomplete and absent oblique fissures accounted for 31.1% and 4.4%, respectively. The right horizontal fissure showed greater variability, with 34.8% incomplete and 8.7% absent fissures. Accessory morphological variations were identified in 26.7% of specimens, and overall fissural and/or lobar variations occurred in 33.3%. These findings reflect variations in embryological pulmonary development and remodeling. Recognition of such anatomical patterns is important for accurate radiological interpretation, bronchoscopic localization, anatomical education, and safe thoracic surgical procedures. Detailed knowledge of pulmonary variations can therefore improve clinical decision-making and reduce procedure-related complications.

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