Section: Anatomy

Original Research Article

CADAVERIC STUDY OF ANATOMICAL VARIATIONS OF LUNG FISSURES AND LOBES WITH ITS EMBRYOLOGICAL BASIS AND CLINICAL IMPLICATIONS

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ABSTRACT

Background: Lung anatomy typically features well-defined fissures and lobes; however, anatomical variations such as incomplete, accessory, or absent fissures are common and hold significant clinical importance. Understanding these variations is crucial for accurate diagnosis, surgical planning, and radiological assessment. **Objectives:** To study the morphological variations of lung fissures and lobes in cadaveric specimens, elucidate their embryological basis, and discuss their clinical implications. **Materials and Methods:** A descriptive cadaveric study was conducted on adult formalin-fixed lungs obtained through routine dissection. Both right and left lungs were examined macroscopically for the presence, completeness, and accessory fissures of the lobes. Systematic documentation and classification of variations were performed by two independent observers. Data from 16 specimens were analyzed and compared with existing literature. **Result:** Variations observed included incomplete fissures, absent fissures, and accessory fissures such as azygos, dorsal, and tracheal lobes. The incidence of these variations aligns with previous studies, with incomplete fissures occurring with notable frequency. The presence of accessory lobes and fissures was attributed to persistent embryonic fissures or anomalous bronchial branching. Images demonstrated examples of complete and incomplete fissures, highlighting their morphological diversity. **Conclusions:** Anatomical variations of lung fissures and lobes are common and have significant clinical repercussions, particularly in thoracic surgery, radiology, and pulmonary interventions. Knowledge of these variations, underpinned by their embryological origins, is essential for accurate interpretation of imaging, effective surgical procedures, and minimizing complications.

INTRODUCTION

The lungs are the main organs of respiration, located on either side of mediastinum laterally adjacent to the heart. In anatomical configuration, the right lung demonstrates a trilobular structure comprising superior, middle, and inferior lobes, which are delineated by the oblique and horizontal fissure divisions. Conversely, the left lung exhibits a bilobular arrangement with superior and inferior segments separated by a singular oblique fissure. Notably, the right lung's major oblique fissure demonstrates a more horizontal orientation compared to its left-sided counterpart, creating the boundary between the inferior lobe and the combined middle-superior lobar region.

Both pulmonary oblique fissures initiate from the posterior-superior hilar region along the mediastinal lung surface, traverse the vertebral margin at the fourth thoracic vertebral level, extend across the costal surface and inferior margin, and terminate at the anterior-inferior hilar aspect of the mediastinal surface. The horizontal minor fissure extends transversely from the major fissure line to the sternal lung border, positioned at the fourth costal cartilage level. These pulmonary fissure systems, particularly the major and minor divisions, facilitate synchronized lobar expansion during respiratory inspiration.[1]

Complete fissure anatomy involves full-thickness lung penetration, creating lobar separation except at the hilar junction. Normal pulmonary fissures typically demonstrate complete formation. However, lung fissure patterns may exhibit anatomical variations including incomplete development, accessory formations, and complete absence. Incomplete fissures maintain lobar connection through intact parenchymal bridges rather than complete separation. Complete fissure absence represents an uncommon anatomical finding.[2]

Additional fissure patterns may manifest as single or multiple accessory divisions, resulting in supernumerary lobar formations.[3]

Throughout embryological development, the primary bronchial trunk subdivides into lobar and segmental bronchial branches. Multiple fissures initially separate the bronchopulmonary segments during this developmental phase. Subsequently, major and minor fissure patterns persist while remaining embryonic fissures undergo obliteration.[4] Retained embryonic fissure patterns contribute to accessory lung fissure formation.[5]

Supernumerary or accessory lung lobes represent pulmonary tissue segments isolated from primary lobes through accessory fissure boundaries, resulting from asymmetrical main bronchial branching patterns. These uncommon anatomical variants include azygos, dorsal, caudal, and tracheal lobar formations.[6]

The azygos lobe represents an infrequent anatomical variant affecting the right upper lobe, documented in 1% of cadaveric specimens during anatomical examination and 0.4% of radiological populations. During developmental processes, azygos venous penetration through lung tissue creates upper lobe division, with the medial portion forming the azygos lobar variant.[7]

Recognition of incomplete and absent pulmonary fissures holds significant importance before lobectomy and segmental resection procedures, as incomplete fissure anatomy may precipitate post-operative complications requiring additional surgical management. Azygos lobes may present diagnostic challenges on chest imaging or computed tomography, potentially mimicking pulmonary nodules, lymphadenopathy, pulmonary bullae, abscesses, or neoplastic processes.

Comprehensive understanding of these fissure variations and accessory lobar formations remains essential for anatomical education, surgical planning, and radiological assessment of pulmonary structures due to their clinical and surgical significance. Therefore, our study focuses on characterizing these atypical fissure patterns and supernumerary lobar formations in human lung specimens.

MATERIALS AND METHODS

Study Design and Setting

This observational descriptive cross-sectional study was conducted over a period of three years (2022-2025) in the Anatomy Department, dissection practical laboratory. The study was performed as part of routine anatomical dissection for first-year MBBS students and for preparing museum specimens for teaching purposes.

Ethical Considerations

The study was conducted in accordance with the ethical guidelines for cadaveric studies. All cadavers used in this study were legally obtained through body donation programs and had proper documentation.

Sample Size and Selection Criteria

A total of 60 lung specimens were examined, comprising 30 right lungs and 30 left lungs. The sample size was determined based on the prevalence rate of fissure variations from previous similar studies in the literature [8,9]. Sample selection was also based on specific inclusion and exclusion criteria to ensure the quality and reliability of observations.

Inclusion Criteria

- Formalin-fixed adult cadaveric lungs
- Lungs obtained from routine anatomical dissection
- Both right and left lung specimens
- Lungs with intact anatomical structures suitable for morphological examination

Exclusion Criteria

- Lung specimens with evident pathological conditions (tumors, infections, fibrosis, or other gross pathological changes)
- Severely damaged or fragmented lung specimens that would compromise accurate assessment
- Specimens with incomplete fixation or preservation artifacts

Specimen Preparation and Processing

All lung specimens were fixed in 10% neutral buffered formalin solution for a minimum period of 72 hours before examination. The thoracic cavity was opened following standard anatomical dissection protocols, and lungs were carefully dissected free from surrounding structures, maintaining the integrity of pleural surfaces and fissures [10]. Specimens were gently cleaned to remove excess fixative and debris while preserving delicate anatomical structures.

Specimen examination and documentation

Each lung specimen underwent systematic macroscopic examination by two independent qualified observers to ensure consistency and accuracy of observations. For right lung specimens, oblique fissure evaluation was performed using standardized criteria where complete fissures were defined as extending from posterior border to anterior border and completely separating lung lobes, incomplete fissures were those present but with parenchymal bridges connecting adjacent lobes, and

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absent fissures showed complete absence of the oblique fissure. Similarly, horizontal fissure evaluation classified fissures as complete when completely separating the middle lobe from upper lobe, incomplete when showing partial fissure with tissue bridges between middle and upper lobes, and absent when showing no evidence of horizontal fissure [1]. The presence of accessory elements including azygos lobes and additional accessory fissures beyond normal anatomical configuration was also documented. For left lung specimens, oblique fissure evaluation followed similar criteria as the right lung, and any accessory fissures were systematically documented.

Standard anatomical landmarks were used for consistent observations throughout the study. High-resolution digital photographs were taken of each specimen. Multiple angles were captured to document all fissure variations comprehensively. Images were stored with appropriate labeling and cataloging for future reference and documentation. Structured data collection forms were used to ensure systematic recording of all observations, with each specimen assigned a unique identification number. All observations were recorded by two independent observers to minimize bias and ensure reliability of data collection.

Statistical Analysis

Data were entered into Microsoft Excel spreadsheets. The same was used to perform all the statistical analyses. Descriptive statistics were calculated including frequencies, percentages, and proportions. Categorical variables were presented as numbers and percentages, and comparative analysis between right and left lungs was done in the form of frequencies and percentages.

RESULTS

Figure 1: Right lung specimens showing absent horizontal fissures

Figure 2: Right lung specimens showing incomplete horizontal fissures

Figure 3: Right lung specimens showing incomplete oblique fissures

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Figure 4: Right lung specimen showing azygos lobe

Figure 6: Left lung specimens showing incomplete oblique fissures

Figure 5: Right lung specimen showing accessory fissure

Figure 7: Left lung specimens showing accessory fissure

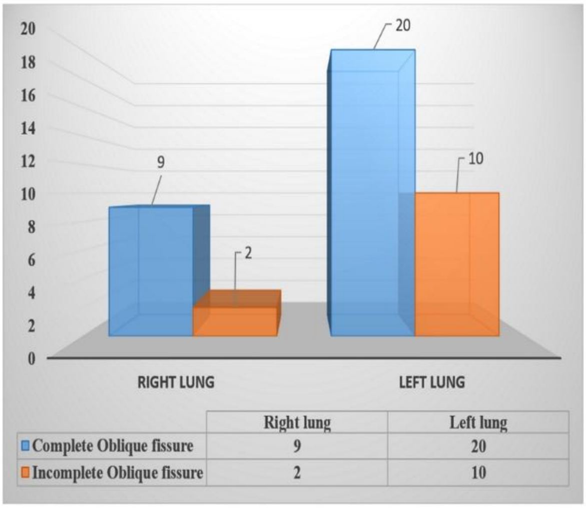

Figure 8: A comparison of oblique fissure completeness in right and left lung

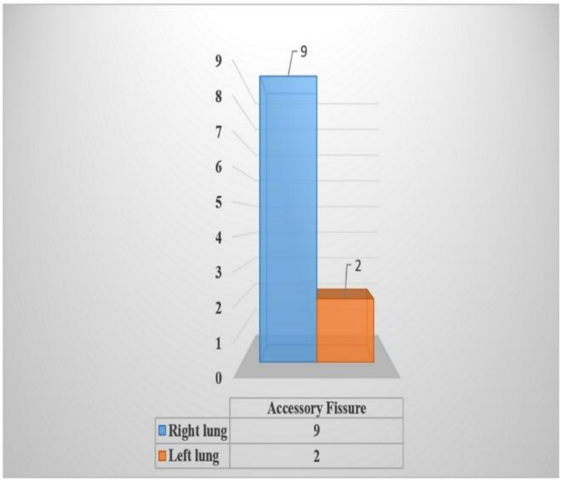

Figure 9: A comparison of accessory fissures in right and left lung

In the current study employing 60 total specimens with 30 right and 30 left lungs we observed a wide range of anatomical variations.

Table 1: Shows the Incidence of morphological variations of right lung fissures and lobes

S.no	FISSURES OF RIGHT LUNG	Out of 30 specimens	Percentage%
1	RIGHT Complete Horizontal Fissure	4	13.3
2	RIGHT Absent Horizontal Fissure	4	13.3
3	RIGHT Incomplete Horizontal Fissure	10	33.3
4	RIGHT Complete Oblique Fissure	9	30.0
5	RIGHT Absent Oblique Fissure	0	0.0
6	RIGHT Incomplete Oblique Fissure	2	6.7
7	RIGHT Azygos lobe	1	3.3
8	RIGHT Accessory Fissure	4	13.3

Table 1 shows the various variations observed in the present study among the 30 right lung specimens. Regarding right horizontal fissures, Complete right Horizontal Fissure was seen in 4 specimens (13.3%), indicating it is relatively uncommon. Absent Horizontal Fissure (Figure 1) was also seen in 4 specimens (13.3%), showing that in a notable subset, this fissure may not develop at all. Incomplete Horizontal Fissure (Figure 2) was the most common variation at 33.3%, suggesting frequent developmental variations or fusion anomalies in the horizontal fissure.

Regarding right oblique fissures, Complete Oblique Fissure appeared in 9 specimens (30%), making it more commonly complete than the horizontal fissure. Absent Oblique Fissure was not observed in any specimen, indicating the oblique fissure is consistently present in some form. Incomplete Oblique Fissure (Figure 3) was present in 2 specimens (6.7%), showing occasional variation. Regarding right accessory fissures and lobes, the following was observed. Azygos Lobe (Figure 4), a rare anatomical variant, was found in 1 specimen (3.3%). This is a known variant where an azygos vein indents the upper lobe creating a false fissure. Accessory Fissures (Figure 5) were seen in 4 specimens (13.3%), indicating the presence of additional fissures beyond the typical horizontal and oblique types.

Table 2: Shows the incidence of variations of fissures of left lung

S.no	Fissures of Left Lung	Out of 30 specimens	Percentage%
1	LEFT Complete Oblique Fissure	20	66.7
2	LEFT Absent Oblique Fissure	0	0.0
3	LEFT Incomplete Oblique Fissure	10	33.3
4	LEFT Accessory Fissure	2	6.7

Table 2 shows the various variations observed in the present study among the 30 left lung specimens. Regarding left oblique fissures, the most striking finding is that 66.7% (20 out of 30 specimens) presented with a complete left oblique fissure. This represents the normal anatomical configuration where the fissure completely separates the upper and lower lobes of the left lung. One-third of specimens (33.3% or 10 cases) showed incomplete oblique fissures (Figure 6). This anatomical variation indicates that the fissure doesn't fully separate the lung lobes, potentially creating parenchymal bridges between the upper and lower lobes. Left accessory fissures (Figure 7) were found in only 6.7% (2 specimens), representing uncommon additional fissure pattern. Complete absence of the oblique fissure was not observed in any specimen (0%), suggesting this is a non-existent anatomical variant in the current study.

Figure 8 shows the number of lung specimens with complete and incomplete oblique fissures. The right lung demonstrates superior fissure completeness with 81.8% complete oblique fissures compared to 66.7% in the left lung. The left lung exhibits nearly double the rate of incomplete oblique fissures (33.3%) compared to the right lung (18.2%), representing a 15.1 percentage higher incidence of incomplete oblique fissure.

Figure 9 shows the number of right and left lung specimens with accessory fissures. The right lung demonstrates a 4.5:1 ratio advantage over the left lung in accessory fissure occurrence, indicating a strong anatomical predisposition for accessory fissure development on the right side. With 81.8% of all accessory fissures occurring in right lungs, this represents a highly significant anatomical pattern that deviates substantially from bilateral symmetry.

DISCUSSION

Cadavers play a vital part in scientific research and learning anatomy. The practice of teaching and scientific research on cadavers remains the powerful tool in medical education, particularly for medical students, health care professionals and especially surgical specialities. The present study is performed on 60 cadaveric lung specimens of right and left lungs, the presence of anatomical variations of lung fissures, lobes are noted and also various studies on cadaveric lungs is compared with the present study.

Lobes of the lung are formed by means of fissures. Anatomical variations of lung fissures have been reported earlier by number of authors. Comparision of previous studies with present study depicted in Table 3 and Table 4.

Table 3: Shows comparsion with other studies performed on cadaveric lungs regarding the completeness of right and left lung fissures. Analyzed variables and results are expressed in percentual relative frequency

Authors	Left Lung			Right Lung					
	Oblique Fissure			Oblique Fissure			Horizontal Fissure		
	Complete	Incomplete	Absent	Complete	Incomplete	Absent	Complete	Incomplete	Absent
Present Study	66.70%	33.30%	0.00%	81.80%	18.20%	0.00%	22.20%	55.50%	22.20%
Sudikshya et al. (2017)	48.15%	51.85%	0%	69.57%	30.43%	0%	52.18%	34.78%	13.04%
Mamatha et al. (2016)	65%	35%	0%	85%	15%	0%	50%	50%	0%
Dhanalakshmi et al. (2016)	62%	38%	0%	68%	32%	0%	30%	52%	18%
Anbusudar and Dhivya (2016)	68%	32%	0%	72%	28%	0%	36%	44%	20%
Magadum et al. (2015)	50%	42.50%	7.50%	30%	60%	0%	35%	52.50%	12.50%
George et al. (2014)	84.94%	15.06%	0%	96.93%	3.07%	0%	61.55%	35.38%	3.07%
Jaruguli (2014)	90%	8%	2%	90%	10%	0%	82%	8%	10%
Quadros et al. (2014)	97.50%	2.50%	0%	94.44%	5.55%	0%	63.88%	25%	11.11%
Jacob and Pillay (2013)	61.10%	38.90%	0%	46.60%	50%	3.40%	10%	83.40%	6.60%
Dutta et al. (2013)	44%	48%	8%	26.92%	61.54%	11.54%	26.49%	38.89%	34.62%
Nene et al. (2011)	88%	12%	0%	92%	6%	2%	78%	8%	14%
Prakash et al. (2010)	53.60%	35.70%	10.70%	53.60%	39.30%	7.10%	42.90%	50%	7.10%
Bergman et al. (2008)	70%	30%	0%	70%	30%	0%	12%	67%	21%
Meenakshi et al. (2004)	53.40%	46.60%	0%	63.40%	36.60%	0%	20.10%	63.30%	16.60%
Lukose et al. (1999)	79%	21%	0%	100%	0%	0%	68.50%	21%	10.50%
Medler (1947)	82.10%	10.60%	7.30%	69.60%	25.60%	4.80%	37.70%	17.10%	45.20%

In present study, absent oblique fissure of right and left lungs reported in none of the cases. But previous studies,[11] observed missing oblique fissure of right lung in 3.4%cases. while other studies,[12,13,14,15,16,17,18,19,20] did not report absent oblique fissure of right lung, which is similar to our present study finding.

Incidence of absent oblique fissures of left lung in previous studies was observed,[13] in 2% and,[15] in 7.5% cases. But in present study absent oblique fissure of left lung was not found which was similar to the data of previous studies.[11,12,14,16,17,18,19]

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Table 4: Shows comparsion with other studies performed on cadaveric lungs regarding the the Incidence of accessory fissures

S.No	Studies on presence of accessory fissure	Right lung accessory fissure	Left lung accessory fissure
1.	Quadros et al (2014) (9)	13.8%	22.5%
2.	Magadum et al (2015) (12)	7.5%	15.5%
3.	Sudikshya et al. (2017) (16)	26%	33.3%
4.	Present study	13.3%	6.7%

In our present study the incidence of incomplete oblique fissure of right lung is found to be 18.2%, whereas least was 5.55%,[12] and higher incidence of incomplete oblique fissure of right lung 60%,[15] were found in previous studies.

Our study reported, the incidence of incomplete oblique fissure of left lung is higher than in right lung. Absent horizontal fissure is observed to be a mildly common occurring variation, according to the previous studies (Table 3). The current study reports the absence of right horizontal fissure in 22.2% cases which is similar the findings of previous studies.[16] Incidence of absent horizontal fissure in our study (22.2%) is higher than previous studies.[11,12,13,14,15,16,17,18,19,21] It is observed that, the absent horizontal fissure is more common variation than the absent oblique fissure as reported by many researchers (Table 3). But as per previous literature,[18] absent horizontal fissure was not reported.

Absent fissures of lung allow spread of disease because lobes are not clearly defined. Absence of fissures may even impact the normal expansion of lobes during inspiration. The presence of incomplete fissure has clinical significance. Lung surgeries of such anomalous lungs are more challenging and face difficult to isolate lobes during lobectomy and also incomplete fissures allow the spread of lung infection from one lobe to other.

The incidence of incomplete horizontal fissure in our study is 55.5% while the highest incidence rate of 83.40%,[11] and least incidence of 8%,[13] was observed in previous studies. It was found that incomplete horizontal fissure of right lung was reported in all the previous studies. It is observed that the prevalence of incomplete horizontal fissure was higher than the incomplete oblique fissure of right lung and left lung as reported by many researchers (Table 3) which is similar to our present study while one previous study,[19] showed higher prevalence of incomplete horizontal fissure than the incomplete oblique fissure of right and left lungs.

Our study (Table 4) shows incidence of Accessory fissure of right lung 13.3% is higher than the left lung which 6.7% is similar with previous literature,[19] whereas in some studies,[12,15] the incidence of accessory fissure of right lung is less than the left lung.

Presence of anomalous accessory fissure with no lung pathology, might misinterpret as a lesion on imaging or may even lead to misdiagnosis of a patient with pulmonary tumour or lung abscess because such accessory fissure might alter the pattern of lung pathology.

The incidence of azygos lobe of right lung is 3.3% in our study, which is a rare anomaly and similar variation was reported in a previous study.[7,19,22] Azygos lobe on chest radiograph or CT scan may be confused as pulmonary nodule or enlarged lymph node or lung bulla or lung abscess or neoplasm. Thus, the comparison with previous studies shows broad spectrum of variations in pulmonary fissures, accessory fissures and lobes.

Limitation

This study did not assess or quantify the completeness of the lung fissures. The study only provides the proportion and frequency of the lung fissure variations. Sixty cadaveric lungs were used in this investigation. Therefore, further researchers must perform this study on more cadavers to help promote a more generalizable outcome.

CONCLUSION

A sound knowledge about atypical pulmonary fissures and accessory lobes are essential for radiologists, anatomists, pulmonologists and thoracic surgeons for accurate diagnosis of lung pathology on imaging, for correct identification of bronchopulmonary segments of lung, for accurate performance of bronchoscopy procedures and to perform surgical resections.

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