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Anatomical variations of the pulmonary hilum in Nepalese population: a contrast CT scan study

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Abstract

Introduction: The pulmonary hilum is where bronchi, pulmonary vessels, and lymphatics converge; variations in its arrangement can influence thoracic surgical planning, bronchoscopy, and radiological interpretation. Existing evidence derives largely from cadaveric studies, and in vivo, population-specific South Asian data remain limited. This study aimed to determine the prevalence and pattern of pulmonary hilar variations in a Nepalese population using contrast-enhanced chest CT.

Method: This descriptive cross-sectional study was conducted from January 2025 to January 2026 at the Department of Radiology and Imaging, Patan Academy of Health Sciences, Patan Hospital, Nepal, with ethical approval from the Institutional Review Committee (Ref no: drs2501171982). Using stratified random sampling, 369 participants were recruited, with sample size calculated from prior prevalence data. Adults aged 16 years and above undergoing contrast-enhanced chest CT for diagnostic purposes were included; those with prior thoracic surgery, pregnancy, or CT contraindications were excluded. CT images were reviewed by radiologists to classify hilar arrangements, and analysed descriptively using R.

Result: Of 369 participants, 219 (59.35%) were female and 150 (40.65%) male, mean age 56.81±15.82 years (range 16-93). On the right, Type B (36.04%) and Type E (22.76%) were most common; on the left, Type A (34.69%) and Type E (30.62%) predominated. Bilateral symmetry was seen in 86 (23.31%), most often as E-E (8.40%) and A-A (7.59%).

Conclusion: Contrast-enhanced CT revealed diverse, clinically relevant hilar variations in this Nepalese cohort, with Type B most common on the right and Type A on the left, supporting population-specific anatomical mapping for surgical planning.

Keywords: Anatomy; Bronchi; Computed Tomography; Lung; Nepal; Pulmonary Artery; Pulmonary Hilum; Pulmonary Veins

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Introduction

The lungs, situated within the pleural cavities on either side of the mediastinum, are the primary organs of respiration. On the mediastinal surface, each lung presents a triangular depression known as the hilum, through which the structures forming the root of the lung pass. Both lungs receive one pulmonary artery and two pulmonary veins at the hilum, though the bronchial branching pattern differs between the right and left sides. In the right lung, the superior lobar bronchus arises approximately 2.5 cm from the tracheal bifurcation, above the pulmonary artery, and is termed the eparterial bronchus. All other branches are hyparterial. In contrast, the left main bronchus passes beneath the pulmonary artery before dividing, so all its branches are hyparterial.[1]

Anatomical variations at the pulmonary hilum are clinically significant, influencing thoracic surgical approaches, bronchoscopy, and radiological interpretation. Although previous studies have addressed certain aspects of hilar anatomy, gaps remain in understanding the frequency, patterns, and population-specific differences of these variations. Existing literature predominantly derives from cadaveric studies, offering intricate insights into anatomical details.[2] However, the translation of cadaveric findings to clinical scenarios is debated, necessitating exploration in living populations. [3]

Regional studies, such as those in South Indian populations, suggest unique anatomical patterns, highlighting the influence of ethnicity.[3] This study aims to examine the prevalence and types of pulmonary hilar variations in a Nepalese population using contrast-enhanced chest CT scans, thereby contributing to surgical planning, radiological accuracy, and anatomical research.[4]

Method

This descriptive study was conducted from Jan, 2025 to Jan 2026 in the Department of Radiology and Imaging at Patan Academy of Health Sciences, Patan Hospital, Lagankhel, Nepal. The primary objective was to comprehensively document and analyze anatomical variations in the arrangement of structures at the pulmonary hilum using non contrast computed tomography (CT) scans of the chest.

A stratified random sampling technique was employed to ensure that the study population was representative of the broader demographic distribution. The sample size was calculated using the standard formula for estimating proportions, based on prevalence data from previous studies. With an estimated prevalence of 48.2% for anatomical variations in the left lung and 16.1% in the right lung,[3] a 95% confidence level (Z = 1.96), and a 5% margin of error, the required sample size was determined to be 369.

Eligible participants included adults aged 16 years and above of both genders who were undergoing contrast-enhanced CT scans of the chest for diagnostic purposes. Individuals with a history of thoracic surgery, pregnant women, and those with contraindications to CT imaging were excluded from the study.

All CT scans were performed using standard departmental protocols for contrast chest imaging. The acquired images were reviewed by qualified radiologists, and variations were documented in detail. Data were entered into a secure electronic database using Microsoft Excel and subsequently analyzed with R statistical software (version 4.2.2). Descriptive statistics were used to summarize the frequency and types of anatomical variations.

In this study, anatomical variations at the pulmonary hilum are defined as deviations from the conventional arrangement of key thoracic structures. These include differences in the number, branching patterns, and spatial relationships of the principal bronchi, pulmonary arteries and veins, bronchial vessels, lymphatic channels, and components of the pulmonary plexus, Figure 1.

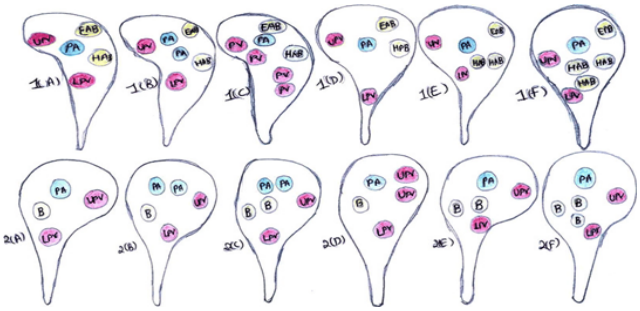

Figure 1. The schematic drawings of the anatomical variants of structures at the pulmonary hilum expected to be observed in the present study

Ethical approval for the study was obtained from the Institutional Review Committee (IRC) of the Institutional Review Board (IRC) of Patan Academy of Health Sciences. Written informed consent was obtained from all participants prior to imaging, with verbal explanations provided regarding the study's purpose, potential risks, and benefits.

Result

Demographics

Of the 369 participants, 219(59.35%) were female and 150(40.65%) were male. The mean age was 56.81±15.82 (range: 16–93 years). The largest proportion were in the age group 60-79 years, 150(40.65%), Table 1.

Contrast enhanced chest CT evaluation of the pulmonary hila in the participants demonstrated a range of anatomical variations in the number and arrangement of bronchi, pulmonary arteries, and pulmonary veins. On the right side, the most

frequent configuration was Type B in 133(36.04%), followed by Type E in 84(22.76%). Bilateral symmetry in hilar configuration was observed in 86(23.31%) participants, most commonly as E–E in 31(8.40%) participants and A–A in 28(7.59%) participants. Variants involving additional bronchial branches, atypical arterial courses, or anomalous venous drainage were less frequent but present across multiple categories.

Table 1. Demographic characteristics of the study population

Characteristics	n (%)
Gender	
Female	219(59.35%)
Male	150(40.65%)
Age	
<40	56(15.18%)
40-59	141(38.21%)
60-79	150(40.65%)
>=80	22(5.96%)
Mean	56.81+-15.82

Table 2, frequency and distribution of anatomical variations, including variations in the number and arrangement of bronchi, pulmonary arteries, and pulmonary veins, at the pulmonary hilum using contrast enhanced chest CT scans according to categorized type of anatomical variants.

Table 2. Frequency and distribution of anatomical variations

Arrangement type	Side	
	Right *f* (%)	Left *f* (%)
A	71(19.24%)	128(34.69%)
B	133(36.04%)	12(3.25%)
C	20(5.42%)	47(12.74%)
D	1(0.27%)	10(2.71%)
E	84(22.76%)	113(30.62%)
F	60(16.26%)	59(15.99%)
Total	369(100%)	369(100%)

Gender-based distribution of pulmonary hilar anatomical variations

On the right side, females most frequently demonstrated Type B 68(31.05%), followed by Type A and Type E, each in 49(22.37%) participants. In males, Type B was also the most common 65(43.33%) followed by Type E 35(23.33%) and Type A in 22(14.67%) participants, occurring in slightly different proportions. Less common types (C, D, F) were distributed similarly between genders, though Type F was marginally more frequent in females 38(17.35%) than males 22(14.67%), Table 3.

On the left side, females most often exhibited Type E 68(31.05%), followed by Type A 66(30.14%) and Type F 39(17.81%). Similar in males, Type A was noted in 62(41.33%) participants followed by Type E in 45(30.00%) participants. Type F was more frequent in females 39(17.81%) than males 20(13.33%), while Type B and Type D remained relatively uncommon in both sexes, Table 3.

Table 3. Gender-based distribution of anatomical variations at the pulmonary hilum

Variation	Right Side		Left Side	
	Male *f* (%)	Female *f* (%)	Male *f* (%)	Female *f* (%)
A	22(14.67%)	49(22.37%)	62(41.33%)	66(30.14%)
B	65(43.33%)	68(31.05%)	5(3.33%)	7(3.20%)
C	6(4.00%)	14(6.39%)	15(10.00%)	32(14.61%)
D	0(0.00%)	1(0.46%)	3(2.00%)	7(3.20%)
E	35(23.33%)	49(22.37%)	45(30.00%)	68(31.05%)
F	22(14.67%)	38(17.36%)	20(13.34%)	39(17.81%)
Total	**150**	**219**	**150**	**219**

Discussion

This study provides a detailed description of anatomical variations at the pulmonary hilum in a Nepalese population using contrast enhanced chest CT. The most frequent right sided configuration was Type B (37.04%), followed by Type E (22.76%) and Type A (19.24%), whereas on the left side, Type A predominated (34.69%), followed by Type E (30.62%) and Type F (15.99%). Bilateral symmetry was observed in 23.31% of participants, most commonly as A–A and E–E patterns. This distribution reflects the predominance of a limited number of common configurations interspersed with rarer, clinically relevant variants that may influence bronchoscopic navigation, surgical planning, and interpretation of cross-sectional imaging. Therefore, findings highlight both the predominance of certain configurations and the presence of rarer variants that may have procedural and diagnostic implications.

The predominance of Type B on the right and Type A on the left aligns with previous cadaveric and imaging studies that have documented consistent laterality differences in hilar anatomy.[5,6] Such asymmetry is likely related to embryological development, with the right lung typically exhibiting a more complex bronchial branching pattern and the left lung demonstrating a more superior position of the pulmonary artery relative to the bronchus.

The proportion of symmetrical hilar patterns in our cohort (23.31%) is comparable to reports from South Asian and African populations, but lower than some Western series where symmetry rates exceeding 40% have been described.[7,8,9] This variation may reflect ethnic or genetic influences on pulmonary vascular and bronchial development, as well as methodological differences in classification criteria.

Gender stratified analysis revealed subtle differences in the distribution of variants. While Type B remained the most common right-sided pattern in both sexes, it was more frequent in males (43.33%) than females (31.05%). On the left, Type A predominated in males (41.33%), whereas females showed a near equal distribution of Types E (31.05%) and A (30.14%). Although these differences did not appear large,

they may warrant further investigation, as sex related anatomical variation has been reported in other thoracic structures and may have implications for procedural planning and interpretation of cross-sectional imaging in clinical practice.

From a clinical perspective, awareness of these variations is critical for thoracic surgeons, interventional pulmonologists, and radiologists. Variants in the number and arrangement of bronchi, pulmonary arteries, and veins can influence bronchoscopic navigation, segmentectomy planning, and interpretation of cross-sectional imaging.[10, 11] For example, an atypical arterial course or accessory bronchus may increase the risk of intraoperative injury if unrecognized.[12] Similarly, anomalous venous drainage patterns can complicate pulmonary vein isolation procedures in electrophysiology.[13]

Our findings also underscore the value of high resolution, contrast enhanced CT in pre/procedural mapping of hilar anatomy. Compared to cadaveric studies, CT offers the advantage of in vivo assessment, enabling correlation with patient demographics and clinical context. However, classification of variants remains partly subjective, and inter observer variability can influence reported prevalence.

Limitations of this study include its single center design and the absence of correlation with surgical or bronchoscopic findings, which could validate CT based classification. Additionally, while our sample size was relatively large, it may not fully represent the diversity of the Nepalese population.

Conclusion

This study adds to the limited literature on pulmonary hilar anatomy in South Asian populations, demonstrating both common and rare variants, with subtle gender differences. Incorporating such anatomical knowledge into clinical practice can enhance procedural safety and diagnostic accuracy.

Conflict of Interest

None

Funding

None

Author Contribution

Concept, design, planning: LS; Literature review: BD;Data collection: LS,BD; Data analysis: LS,BD; Draft manuscript: LS,BD; Revision of draft: LS,BD; Final manuscript: LS,BD; Accountability of the work: LS,BD; Guarantor: LS.

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