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Original Research Article

CT-Based Anatomy of the Normal Human Lung

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Abstract:

Background: Understanding normal anatomic variation on CT is essential for accurate interpretation and teaching.

Objective: To quantify key airway, vascular, and fissural features on chest CT in adults with radiology reports of "normal," and to document common variants.

Methods: Seventy consecutive adult chest CTs (≤1.25 mm slices) were analyzed. Tracheal/AP and transverse diameters (1 cm above carina), carinal angle, main bronchial diameters, pulmonary artery (PA) diameters, fissure completeness, accessory fissures, and azygos lobe were recorded. Two observers assessed 20 scans twice for reliability.

Results: Mean age was 42.3 ± 13.9 years; 42/70 (60%) were male. Mean tracheal AP and transverse diameters were 17.6 ± 2.4 mm and 20.9 ± 2.6 mm; mean carinal angle was 69.4° ± 9.3°. Right and left main bronchus inner diameters measured 12.0 ± 1.7 mm and 10.6 ± 1.6 mm. Mean main PA diameter was 27.3 ± 2.9 mm (PA:A ratio <1 in 93%). Major fissure completeness was 79% right, 83% left; minor fissure complete in 57%. Accessory fissures occurred in 19% (95% CI, 11–30%), and an azygos lobe in 7% (95% CI, 3–15%). Sex-stratified analyses showed larger airway diameters in males ($p < 0.01$) but similar carinal angles ($p = 0.21$). Reliability was excellent (ICC 0.88–0.95 for continuous measures; $\kappa = 0.78$ for fissure grading).

Conclusion: In this cohort of normal CTs, airway calibers and carinal angle values provide practical reference ranges, and variants such as accessory fissures (~1 in 5) and azygos lobe (~1 in 14) were not rare. These baselines can support teaching files and local reporting standards.

Keywords: Lung Anatomy, Chest CT, Carinal Angle, Fissure Completeness, Accessory Fissures, Azygos Lobe.

Introduction

Computed tomography (CT) has emerged as an indispensable modality for the detailed evaluation of thoracic anatomy, offering unparalleled spatial resolution and the ability to visualize airways, vessels, and fissural patterns in vivo. In recent decades, advances in multidetector CT (MDCT) technology have enhanced our ability to detect subtle anatomical variations, improving both diagnostic accuracy and pre-procedural planning for pulmonary interventions [1, 2]. In routine clinical practice, recognition of normal variations is critical to avoiding misinterpretation, preventing unnecessary investigations, and guiding surgical or bronchoscopic approaches.

A variety of studies have investigated the morphometry and anatomical variants of the lung using CT, with particular emphasis on bronchial branching patterns, fissural completeness, and the prevalence of accessory structures such as azygos lobes or accessory fissures [3]. These investigations consistently demonstrate that the lungs exhibit substantial individual variability, and that accurate identification of such features is essential in differentiating normal anatomy from pathology 11:57 AM. Moreover, detailed CT-based anatomical mapping supports the development of teaching atlases for medical students and residents, thereby strengthening the anatomical foundation for clinical training.

In India, published literature on CT-based lung anatomy has been relatively limited, with most available studies arising from radiology departments and focusing on disease-related changes rather than baseline anatomical norms [6]. However, population-specific reference values and variant frequencies are important, as anatomical dimensions and patterns may vary with ethnicity, body habitus, and environmental exposures [7]. Furthermore, local reference data can assist in tailoring interventional strategies such as segmentectomy, lobectomy, or targeted bronchoscopic navigation to the patient population being served.

Despite the recognized importance of detailed anatomical knowledge, there remains a paucity of

CT-based normative data from Indian populations, particularly from western regions such as Rajasthan. Existing studies often combine normal and pathological cases, potentially obscuring true baseline variation. Establishing normative morphometric parameters and variant frequencies in a healthy adult cohort is therefore essential for accurate diagnosis, procedural planning, and education.

This study aims to describe the CT-based anatomy of the normal human lung in an adult population drawn from western India, quantifying airway and vascular dimensions, evaluating fissural completeness, and documenting the prevalence of common anatomical variants. By doing so, it seeks to generate locally relevant reference data that can aid clinicians, anatomists, and educators in enhancing diagnostic precision and procedural safety.

Methods

Design and setting: Retrospective descriptive cross-sectional study conducted in the Department of Anatomy, RNT Medical College, Udaipur over 12 months.

Participants: Seventy consecutive adult chest CTs reported "normal" by board-certified radiologists were included. Inclusion: age 18–80 y, full-inspiratory acquisition, reconstructed slice thickness ≤1.25 mm. Exclusion: prior thoracic surgery, known cardiopulmonary disease, acute infection on imaging, significant artifact, incomplete metadata. The Institutional Ethics Committee approved the study; consent was waived (anonymized data).

CT acquisition: Scans acquired on 64–128 slice scanners at 100–120 kVp, automated mAs, collimation ≤1.25 mm, pitch 1–1.5; reconstructed with soft tissue and lung kernels at 0.75–1.25 mm. Window settings standardized (lung W/L ≈1500/−600 HU; mediastinal ≈350/50 HU).

Measurements

- Airways: Tracheal AP and transverse diameters measured 1 cm above carina; carinal angle between main bronchi axes; right/left main bronchus inner diameters 5 mm distal to origins.
- Vessels: Main PA at bifurcation; proximal RPA and LPA; PA:A ratio at RPA level.
- Fissures/variants: Completeness of major/minor fissures (complete/partial/absent); accessory fissures (superior/inferior accessory; azygos fissure); azygos lobe.
- Demographics: Age, sex (height optional if available).

Two observers (anatomy faculty + radiology resident) measured all cases. Twenty randomly sampled scans were re-measured after two weeks for intra- and inter-observer reliability.

Statistics: Continuous variables summarized as mean ± SD (or median [IQR] if skewed); categorical as n (%). 95% CIs for key prevalences. Sex comparisons used t-tests or Mann–Whitney as appropriate; χ^2/Fisher's for categorical. ICC (two-way random, absolute agreement) and Cohen's κ assessed reliability. $\alpha = 0.05$.

Results

A total of 70 chest CT examinations were analyzed. The mean (SD) age of participants was 42.3 (13.9) years (range, 19–78 years); 42 participants (60.0%) were men and 28 (40.0%) were women. The mean (SD) reconstructed slice thickness was 0.9 (0.2) mm (median, 1.0 mm) **(Table 1)**.

Table 1: Participant Characteristics and Core CT Parameter

Variable	Mean±SD/n (%)
Age (years)	43.3±13.9
Male sex	42 (60.0)
Slice thickness (mm)	0.9±0.2
Trachea AP (mm)	17.6±2.4
Trachea Transverse (mm)	20.0±2.6
Carinal angle (°)	69.4±9.3
Right main bronchus (mm)	12.0±1.7
Left main brochus (mm)	10.6±1.6
Main pulmonary artery (mm)	27.3±2.9
PA:A ratio< 1	65 (92.9)

Airway and Vascular Measurements: Overall, the mean (SD) tracheal anteroposterior (AP) diameter was 17.6 (2.4) mm and the transverse diameter was 20.9 (2.6) mm. The mean (SD) carinal angle was 69.4° (9.3°) (range, 48°–92°). The mean (SD) right main bronchus diameter was 12.0 (1.7) mm and the left main bronchus diameter was 10.6 (1.6) mm. The mean (SD) main pulmonary artery diameter was 27.3 (2.9) mm; the right and left pulmonary artery diameters were 20.6 (2.5) mm and 20.0 (2.4) mm, respectively. A PA:A ratio less than 1 was observed in 65 participants (92.9%).

Sex-Stratified Analysis: Men had significantly larger mean (SD) tracheal AP diameters (18.4 [2.2] mm vs 16.4 [2.1] mm), transverse diameters (21.7 [2.3] mm vs 19.7 [2.4] mm), right main bronchus diameters (12.5 [1.6] mm vs 11.2 [1.5] mm), and left main bronchus diameters (11.0 [1.5] mm vs 10.0 [1.4] mm) compared with women. The carinal angle did not differ significantly between men and women (68.6° [9.1°] vs 70.5° [9.6°]) **(Table 2)**.

Table 2: Sex-stratified airway measurements

Measure (mm)	Male (n=42)	Female (28)	p-value
Trachea AP	18.4±2.2	16.4±2.1	<0.001
Trachea Transverse	21.7±2.3	19.7±2.4	0.001
RMB	12.5±1.6	11.2±1.5	0.002
LMB	11.0±1.5	10.0±1.4	0.006
Carinal angle (°)	68.6±9.1	70.5±9.6	0.21

Fissures and Anatomical Variants: The right major fissure was complete in 55 participants (78.6%), partial in 12 (17.1%), and absent in 3 (4.3%). The left major fissure was complete in 58 participants (82.9%), partial in 10 (14.3%), and absent in 2 (2.9%). The minor (horizontal) fissure was complete in 40 participants (57.1%), partial in 24 (34.3%), and absent in 6 (8.6%). Accessory fissures of any type were identified in 13 participants (18.6%; 95% CI, 10.6%-29.7%), including superior accessory fissures in 6 (8.6%), inferior accessory fissures in 5 (7.1%), and azygos fissures in 7 (10.0%). An azygos lobe was present in 5 participants (7.1%; 95% CI, 2.4%-15.9%). Some participants had more than 1 variant **(Table 3)**.

Table 3: Fissure completeness and variants

Feature	n (%)
Right major fissure complete	55 (78.6)
Left major fissure complete	58 (82.9)
Minor fissure complete	40 (57.1)
Accessory fissure (any)	13 (18.6)
Superior accessory fissure	6 (8.6)
Inferior accessory fissure	5 (7.1)
Azygos fissure	7 (10.0)
Azygos lobe	5 (7.1)

Interobserver Reliability: Interobserver agreement for continuous measurements was excellent, with intraclass correlation coefficients of 0.93 (95% CI, 0.86-0.97) for tracheal diameters, 0.90 (95% CI, 0.81-0.96) for carinal angle, 0.95 (95% CI, 0.90-0.98) for right main bronchus diameter, and 0.92 (95% CI, 0.84-0.96) for left main bronchus diameter. Agreement for fissure completeness was substantial **(Table 4)**.

Table 4: Observer reliability (n = 20 scans x 2 reads)

Variable	ICC (95% CI)	Agreement
Tracheal diameters	0.93 (0.86-0.97)	Excellent
Carinal angle	0.90 (0.81-0.96)	Excellent
RMB	0.95 (0.90-0.98)	Excellent
LMB	0.92 (0.84-0.96)	Excellent
Fissure grading (κ)	0.78	Substantial

Discussion

This year-long study, carried out in the Department of Anatomy at RNT Medical College, Udaipur, establishes baseline CT morphometric parameters and documents the prevalence of normal anatomical variants in the adult lung within a western Indian cohort. Evaluation of 70 chest CT scans with normal radiology reports showed that tracheal and main bronchial measurements, as well as carinal angle and pulmonary artery dimensions, were broadly comparable to those described in prior national and international research on healthy individuals (8). In our sample, the mean tracheal AP diameter measured 17.6 mm, the transverse diameter 20.9 mm, and the mean carinal angle 69.4°, aligning closely with published reference values of approximately 66°–72° in asymptomatic populations (9).

Clear sex-related differences in airway calibers were evident, with men having significantly larger

tracheal and bronchial diameters than women (10). This pattern echoes previous studies attributing such differences mainly to variations in body size, lung capacity, and other anthropometric traits (11). Conversely, the carinal angle showed no significant sex variation, in agreement with earlier findings that suggest this measure is more influenced by lung inflation and scanning position than by sex.

Normal anatomical variants were also frequently observed. Accessory fissures were present in 18.6% of cases, with superior and inferior accessory fissures found in 8.6% and 7.1%, respectively. An azygos fissure was seen in 10% and an azygos lobe in 7.1% of participants. These rates fall within previously reported ranges from Indian CT series, where accessory fissures have been found in 10–22% and azygos lobes in 5–8% of normal scans (12). The minor fissure was complete in just over half of participants (57.1%), reflecting the high frequency of incomplete fissures noted in earlier work. Awareness of such fissural variations is important for clinicians, as they can influence patterns of disease spread and have implications for lobar surgical procedures (13).

Measurement reproducibility in this study was high, with excellent interobserver agreement for airway and vascular dimensions (ICC 0.90–0.95) and substantial concordance for fissure grading (κ = 0.78). This demonstrates that a consistent measurement protocol allows reliable assessment of thoracic morphometry, even between observers with differing clinical backgrounds. Our observations align with literature underscoring the value of region-specific reference data for improving diagnostic interpretation, guiding interventional planning, and enhancing anatomical education(14). Establishing such normative datasets is particularly relevant for Indian populations, given potential differences from Western values arising from ethnic, environmental, and anthropometric diversity (15).

Several study limitations should be noted. The single-center, retrospective design and modest sample size may restrict the general applicability of findings. Inclusion was limited to scans labeled as normal, which may have excluded subtle or unreported variations. Anthropometric data such as height, weight, and body surface area were not uniformly available, preventing adjustment of measurements for body size. Functional assessments, including spirometry or bronchoscopic correlation, were not performed. Despite these constraints, this work contributes important CT-based reference data for lung anatomy in an Indian context and highlights the frequency of normal variants with potential clinical relevance. Larger, multicenter investigations incorporating volumetric techniques, 3D reconstruction, and functional correlation are warranted to develop a comprehensive national database of thoracic anatomy.

Conclusion

In 70 normal adult CTs from a tertiary Indian center, we observed carinal angles around 69°, tracheal diameters near 18×21 mm, and main PA of ~27 mm. Accessory fissures (~1 in 5) and azygos lobe (~1 in 14) were not rare. These data provide practical local references for education and reporting.

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