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RESEARCH ARTICLE

Comprehensive study of pulmonary hilam with its clinical correlation

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ABSTRACT

Introduction: Awareness of pulmonary hilar variations is essential for lobectomy of lung.
Materials and methods: We studied 54 left and 49 right hilum of formalin fixed adult cadaveric lungs. Morphologic and mophometric details were recorded and variations were noted.
Results: Classical picture of hilum was found in 35.19% left lung and 40.82% right lung. Morphological variations were more on left side (64.81%) than right side (59.18%) in terms of numbers of structures. On the left side, highest percentage of variable structure was bronchus (46.3%) followed by pulmonary artery (37.31%) and lowest by pulmonary vein (31.48%) whereas on right side, percentage for variable pulmonary artery and vein were same (36.73%) followed by bronchi (20.41%). Maximum number of pulmonary veins was five, pulmonary artery was three and accessory bronchus was two on both side hila. In morphometric measurement, mean vertical length of hilum was more on right side whereas anteroposterior length was more on left side. Right hilum is slightly lower and anteriorly placed than left hilum in the mediastinal surface of lung. Significant correlations between vertical length of lung and hilum and antero-postero length of lung and hilum of left and right sides were found.
Conclusions: By analysis and comparison with previous studies, present study concludes that morphology of pulmonary hila is extremely variable which contributes significant consequences in the field of pulmonary resection.

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1. Introduction

Hilum of lung represents a fixed portion where the relatively mobile lung is tethered to the mediastinum. The reflection of visceral to parietal pleura at hilum offers additional support to the area. Structurally, hilum is a large triangular depressed area located just postero-superior to the cardiac impression of each mediastinal surface of lung close to the posterior border. Conventionally, one pulmonary artery and two pulmonary veins pass through the hilum but bronchi differ in their mode of subdivision between the left and right lung. Interpretation of the hilar structures in chest x-ray is challenging and very difficult. Normally bronchi and lymph nodes do not cast any radiological shadow. Pulmonary arteries take upper hand for most of the radiographic hilar density where superior pulmonary veins make a smaller contribution and inferior pulmonary veins offer no contribution. However, hila are not identical in majority of chest x-ray though both are expected as equal in size and density (Sarkar et al., 2013). Understanding of the normal hilar anatomy is the basic and essential foundation in both clinical and surgical field. It was suggested that the pulmonary veins should be interrupted first in lobectomy for lung cancer patients to arrest circulatory tumor cells dissemination for prevention of metastasis and treatment failure (Yamashita et al., 2000). But disease recurrence or survival would not interfere with accordance of vein or artery dissection (Refaely et al., 2003). Though sequence of vessels interruption remains controversial still identification of pulmonary structures deserves its importance as the presence of aberrant components might be an obstacle during operation if overlooked (Subotich et al., 2009). Moreover, division of pulmonary vessels that should be preserved during lobectomy can also lead to potentially life-threatening complications (Sugimoto et al., 1998). Variable pulmonary vessels are often associated with misinterpretation of a radiograph or computed tomography (CT) scan (Ghaye et al., 2001; Nakamura et al., 2009). Therefore knowledge and careful evaluation of hilar anatomy yield significant information about normal as well as variant structures. Previously a lot of measures are reported on fissures and lobar pattern of lungs, but the hilar anatomy of lungs has always been neglected with few exceptions. Present study was attempted to explore the morphology of hilum of both lung with an efforts aimed at their morphometry also.

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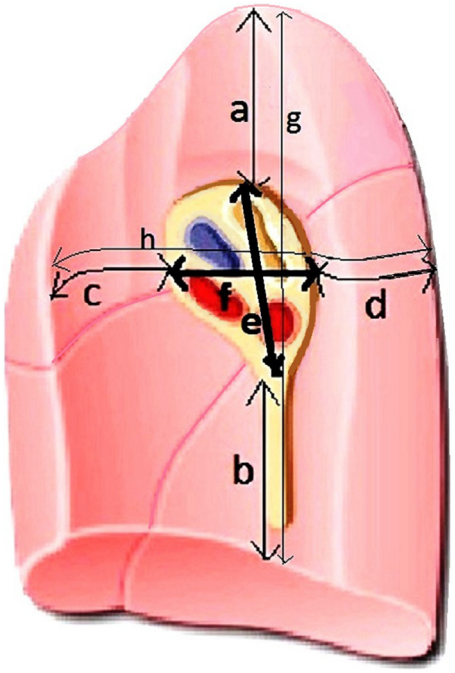

Fig. 1. Morphometric measurements. (a — apex of lung to summit of hilum, b — inferior border to lower end of hilum, c — anterior border of lung to anterior end of hilum, d — posterior border to posterior end of hilum, e — vertical length of hilum, f — antero-posterior length of hilum, g — vertical length of lung, h — antero-posterior length of lung).

2. Materials and methods

One hundred and three isolated formalin fixed adult cadaveric lungs of unknown age and sex were observed. The specimens having any pathological lesion or damage were excluded. Among 103 lungs, 49 were right and 54 were left side. Details morphology and morphometry of both sides' lung hila with fissures on the medial surface were studied also. The following morphological parameters were observed in each hilum: number of pulmonary arteries, pulmonary veins and bronchi. Specimens deviated from its standard number of structures as 2 pulmonary veins, 1 pulmonary artery and 1 bronchus for left side and 2 bronchi for right side were marked as variant. Variations were noted carefully with photographs and results were summarized as normal and variable hilar category. Classifications of variable hila were done separately for left and right side on the basis of increasing number of pulmonary vein associated with ascending sequence of artery and bronchus. The classified types were marked as I–XI for left side and i–xi for right side.

By using Vernier caliper and malleable ruler, the following morphometric parameters were measured:

1) Position of hilum in the medial surface of each lung: distances from (i) apex of lung to the summit of hilum, (ii) inferior border of lung to lower end of hilum, (iii) anterior border of lung to anterior most convexity of hilum, (iv) posterior border of lung to posterior end of hilum.
2) Hilar height and width: measurement of vertical length and antero-posterior length at maximum convexity.
3) Vertical and antero-posterior length of lung: distance from apex to inferior border and anterior border to posterior border (at the level of hilum) of lung respectively.

Schematic representation of morphometric measurements was shown in Fig. 1. All data were documented and summarized by descriptive statistics. Mean, median, standard deviation (S.D.), 95% confidence interval (CI) was calculated, and results were tabulated. Correlations between vertical and antero-posterior length of lung and hilum of both sides were done separately. All the statistical calculations were performed using software SPSS for Windows.

3. Results

Standard representation of hilum as 2 pulmonary veins, 1 pulmonary artery and 1 bronchus for left side and 2 bronchi for right side was found in 19 out of 54 left lungs (35.19%) and 20 out of 49 right lungs (40.82%). Rests 35 left lung (64.81%) and 29 right lungs (59.18%) were variants in terms of numbers of either by pulmonary vein or pulmonary artery or bronchus or in combinations. On the left side, highest percentage of normal appearing hilar structures was pulmonary vein followed by pulmonary artery and bronchus whereas on right side, normal presentation was highest for bronchi, followed by pulmonary vessels.

Details about the hilar structures were as follows.

3.1. Pulmonary vein

Conventional two pulmonary veins were present in 68.52% left and in 63.27% right lung. In rest, vein was either single or appeared as three or four or five in numbers. Single pulmonary vein was seen more on left side (9.26%) than right side (6.12%) but triple pulmonary veins were considerably high on right side (22.45%) as compared to left side (14.81%). Hila with four and five pulmonary veins were found in both sides more or less in same incidence.

3.2. Pulmonary artery

The usual presentation with single pulmonary artery was noted almost in same percentage in both sides (62.96% and 63.27% cases in left and right lung respectively). In rests, artery was variable in numbers as two or three. Double arteries were seen in higher percentage on right side (30.61%) than left (27.78%) but triple arteries were more on left side (9.26%) as compared to right side (6.12%).

3.3. Bronchus

In present study, normal appearance of one bronchus for left side and two bronchi for right side was present in 53.70% and 79.59% cases respectively indicating that variations are high on left side. One or two accessory bronchus on both sides was noted in rest of the specimens. One accessory bronchus was found in greater percentage on left side (37.04%) than right side (16.33%), whereas incidence of two accessory bronchi was almost double in left side as compare to right side (9.26% and 4.06% respectively).

Details about the numbers of structures of both lung hilum were tabulated in Table 1. Figs. 2–4 represented the variations of vein, artery and bronchus respectively on both sides.

3.4. Types of hilum

On both sides eleven variable hila were found as Type I–XI for left side and Type i–xi for right side. Type I and Type i represented the minimum number of pulmonary vein with minimum number of artery and bronchi in same specimen for left and right side respectively whereas type XI and Type xi represented the maximum number of structures. Different types of both side hilum were schematically represented in Fig. 5.

Table 1
Morphology of left and right Pulmonary Hila.

Hilar structures	Left Lung [54 Specimens]					Right Lung [49 Specimens]				
	One n (%)	Two n (%)	Three n (%)	Four n (%)	Five n (%)	One n (%)	Two n (%)	Three n (%)	Four n (%)	Five n (%)
Pulmonary vein	5 [09.26%]	37 [68.52%]	8 [14.81%]	2 [03.70%]	2 [03.70%]	3 [06.12%]	31 [63.27%]	11 [22.45%]	2 [04.08%]	2 [04.08%]
Pulmonary artery	34 [62.96%]	15 [27.78%]	5 [09.26%]	0 0	0 0	31 [63.27%]	15 [30.61%]	3 [06.12%]	0 0	0 0
Bronchus	29 [53.70%]	20 [37.04%]	5 [09.26%]	0 0	0 0	0 0	39 [79.59%]	8 [16.33%]	2 [04.08%]	0 0

Fig. 2. Pulmonary vein in variable hilum. (V — pulmonary vein, A — pulmonary artery, B — bronchus).

3.5. *Extent of fissures on medial surface*

On right side, both horizontal and oblique fissures were completely present among 32 (65.3%) specimens, rest (34.7%) were variable in terms of absence of horizontal fissures. On left side, partial incomplete oblique fissures were observed among 5 (9.26%) specimens and rests were normal (Fig. 6)

Detail morphometric data was tabulated in Table 2. It was noted that mean distance from apex of lung to summit of hilum on left side was 0.16 cm less than right side but 1.29 cm more when measurement was taken from inferior border of lung to the lower end of hilum. In antero-posterior measurement, mean distance from anterior border of lung to anterior end of hilum was 0.41 cm shorter on right side than left side. Mean vertical length of hilum was slightly more on right side whereas antero-posterior length exceeded on

Fig. 3. Pulmonary artery in variable hilum. (V — pulmonary vein, A — pulmonary artery, B — bronchus).

Table 2
Morphometric detail of both Hila.

		Position of hilum								Hilum measurement			
		Apex — hilum distance (cm)		Inferior border — hilum distance(cm)		Anterior border — hilum distance (cm)		Posterior border — hilum distance (cm)		Vertical length (cm)		Antero-posterior length (cm)	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Mean		5.71	5.87	4.55	3.26	5.22	4.81	3.63	3.83	6.37	6.99	3.96	3.68
Median		6.00	6.00	4.50	3.00	5.00	5.00	4.00	4.00	6.00	7.00	4.00	3.50
SD		0.99	0.95	0.98	1.23	1.29	1.19	0.78	1.32	0.77	1.29	0.78	0.62
95%CI	LL	5.28	5.43	4.12	2.68	4.66	4.25	3.29	3.21	6.04	6.39	3.63	3.39
	UL	6.14	6.32	4.97	3.83	5.77	5.37	3.96	4.44	6.70	7.59	4.30	3.97

Fig. 4. Bronchus in variable hilum. (V — pulmonary vein, A — pulmonary artery, B — bronchus).

left side. So, right hilum is slightly lower and anteriorly placed than left hilum. Significant correlations between vertical lengths of lung and hilum (r −0.45 and 0.70 for left and right side respectively) and antero-postero lengths of lung and hilum (r −0.54 for both sides) were found on left and right sides which have been represented graphically in Fig. 7.

4. Discussion

Introduction of minimally invasive methods such as video-assisted thoracoscopic surgery (VATS) are still more challenging for surgeons as it require better understanding of anatomy in ever smaller operating field. During pulmonary resections, they are also burdened with the risk of potential vessel collisions, a dangerous complication of such procedures (Polaczek et al., 2013). Nowadays, 3D-CT of the pulmonary vessels and bronchus is performed pre-operatively for identification of variations in patients who have undergone pulmonary segmental resection, but intra and inter observer variations for interpretation of images depends on experiences in radiological and anatomical fields. The dimension of normal hila, delineated most by the large pulmonary arteries and upper lobe pulmonary veins varies considerably within and among individuals (left versus right). Moreover, right upper lobectomy for most primary lung cancers (29.2%–37.2%) requires different surgical strategies due to most complicated hilar anatomical structures (Zhai et al., 2017). The main way to minimize the interpretation errors are thorough knowledge of normal anatomy (Delrue et al., 2011).

Pulmonary venous anatomy and drainage pattern is important for lobar resection. Closer attention is required especially in thoracoscopic procedures as the surgical view is limited more than in thoracotomy (Sultana and Chandrupatla, 2017). In previous tho-

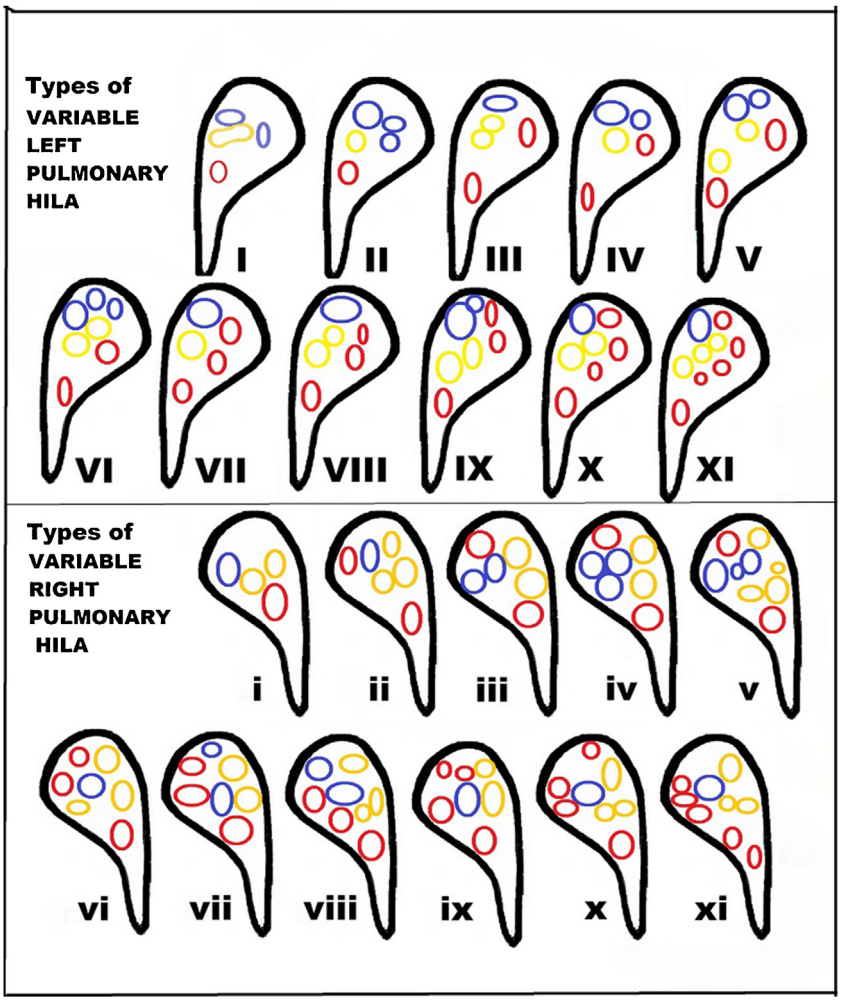

Fig. 5. Types of hilum. (Red — pulmonary vein, Blue — pulmonary artery, Yellow — bronchus). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

racic anatomic resections, abnormalities of vasculature was found in 16.4% cases with incidence of middle lobe vessel variation and single unilateral pulmonary vein were 8.57% and 2.14% respectively (Subotich et al., 2009). Single pulmonary vein that drains the lung was seen more frequently during surgery on the left side as suggested by Brantigan (1952). Sultana and Chandrupatla (2017) in their cadaveric study, found three separate lobar venous opening in 27% cases and single common venous opening in 12% cases of right lung. In the present study, single vein was present in 9.26% and 6.12% cases and more than two veins were in 22.21% and 30.61% cases in left and right lung respectively. We found maximum five pulmonary veins on both sides whereas another Indian study showed four veins on right side and two upper pulmonary veins on left side (Murlimanju et al., 2017). Previous evaluation shows that accessory opening for pulmonary veins at left atrium are much common on right side than left (Shkula et al., 2012). If more than one pulmonary vein drains anomalously, the volume is usually sufficient to produce the characteristic pattern of the right ventricular diastolic overload. Not only that, pulmonary veins played a critical role in the patho-physiology of atrial fibrillation as ostia of anomalous veins produce ectopic beats. Thus, for pre-ablation planning and post-ablation complication evaluation, knowledge of normal pulmonary venous anatomy is critical (Hauser et al., 2008).

During pulmonary resection, unexpected bleeding from pulmonary artery is occasionally encountered by surgeons due to massive blood flow and very fragile wall. Thus pre-control of artery is essential in VATS lobectomy. If individual information about the exact number, location, or anatomic variation of pulmonary artery branches that have to be divided can be evaluated preoperatively in each case, the subsequent lung resection will be safer and more compatable (Watanabe et al., 2003). In present study, accessory arteries were present in 37.04% and 36.73% on left and right hilum respectively. George et al. (2014), in their study has found accessory arteries in a remarkable high percentage on right side (70.76%) but less (5.47%) on left side. Maximum number of pulmonary arteries were three on both side in the present study whereas in other study, authors observed two arteries maximally (Murlimanju et al., 2017).

Bronchial anatomy is adequately demonstrated with appropriate spiral computed tomographic technique, but the anomalous bronchi are frequently missed at the time of examinations because of their asymptomatic nature and lack of awareness among the clinicians and radiologists (Yildiz et al., 2006). Contrary to the numerous variations of lobar or segmental bronchial subdivisions, abnormal bronchi originating from the trachea or from main bronchi ("tracheal" bronchus and accessory cardiac bronchus) are though rare but understanding of such congenital bronchial anomalies is important for trachea-bronchial interventions and diagnosis (Ghaye et al., 2001). In present study, accessory bronchus in left hilum is present in quite higher percentage (46.3%) than right (20.41%), same as found by George et al. (2014) also but incidences are different. No bronchial agenesis was found in this study.

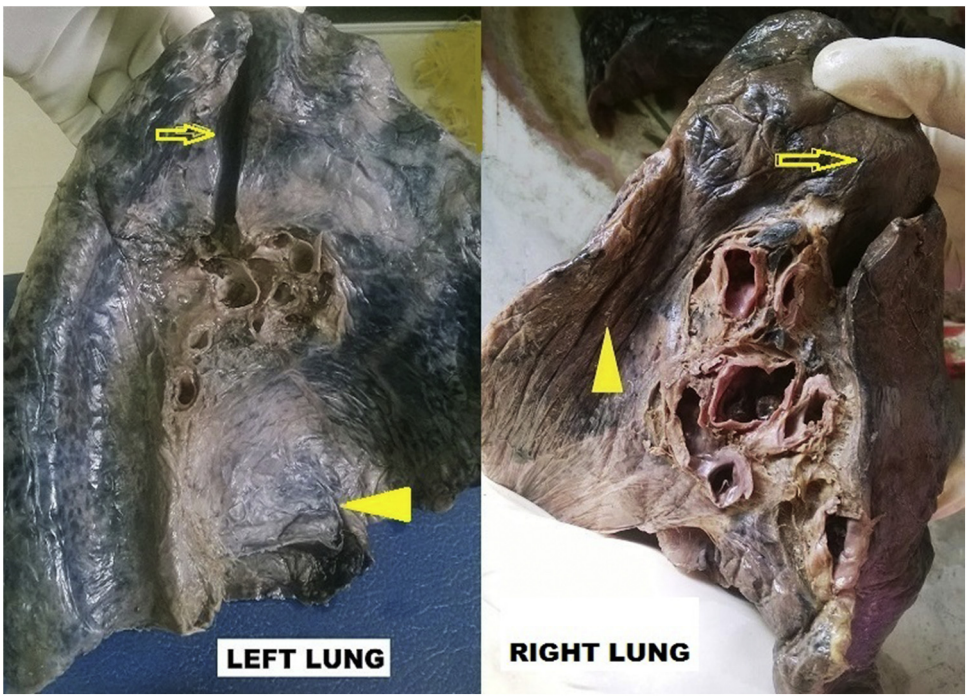

Fig. 6. Non-existence (partial or complete) of fissures on medial surface of left and right lung (yellow arrow head represents non-existence; yellow arrow represents existence). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

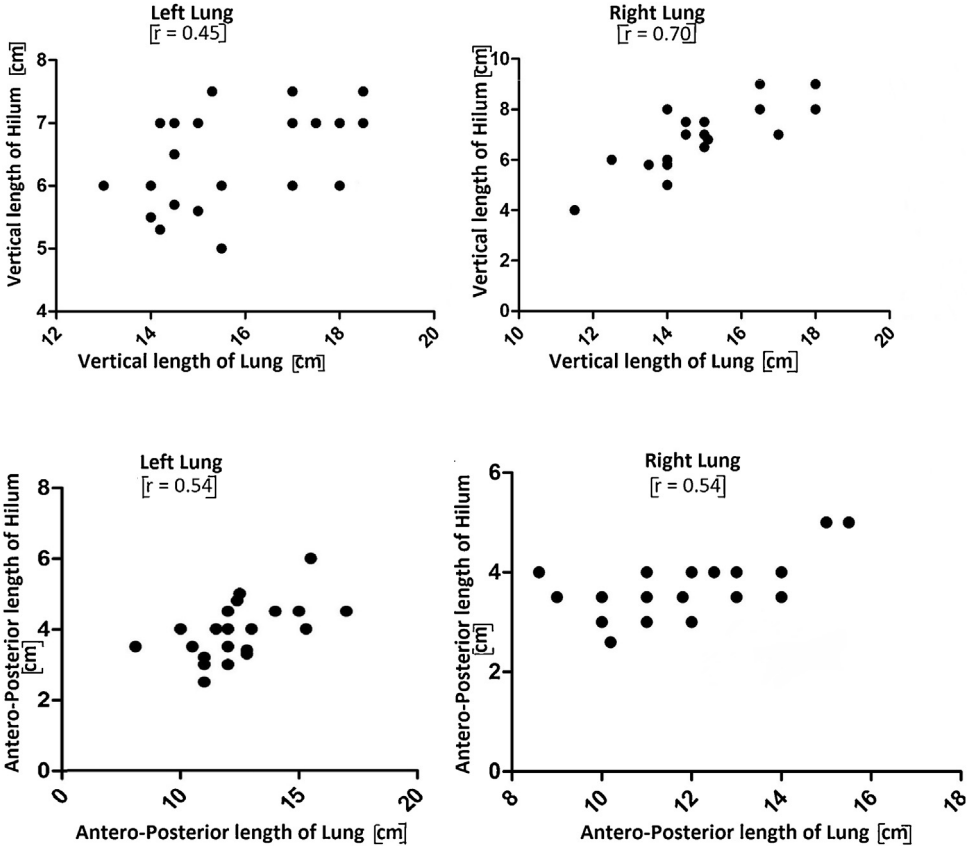

Fig. 7. Correlations of lung and hilum by vertical and antero-posterior length.

In the present study, overall variable hilar morphology was observed among 64.81% on left side and 59.18% on right side which differed from the findings of previous study, (Murlimanju et al., 2017) in which authors reported 48.2% on left side and 16.1% on right side. Comparing hilar categorization, we found few additional morphological variations in terms of 11 types of variable hila as compared to Murlimanju et al. (2017) in which authors observed only 6 types. A detail comparison regarding pulmonary vein, artery

Table 3
Comparison of present and previous studies.

Side	Number in hilum of lung		Present study	George et al. (2014)	Khedekar and Hattangdi (2017)	Jaiswal et al. (2017)
Left side	Pulmonary vein	One	09.26%	–	–	–
		Two	68.52%	80.82%	–	–
		Three	14.81%	19.17%	04%	–
		More	07.04%	–	–	–
	Pulmonary artery	One	62.96%	94.52%	–	–
		Two	27.78%	05.47%	08%	–
		Three	09.26%	–	–	–
		More	00	–	–	–
	Bronchus	One	53.70%	76.71%	–	–
		Two	37.04%	21.91%	24%	–
		Three	09.26%	–	–	–
		More	00	–	04%	–
Right side	Pulmonary veins	One	06.12%	–	–	–
		Two	63.27%	63.07%	–	70.90%
		Three	22.45%	32.30%	08%	20%
		More	08.16%	04.61%	–	1.81%
	Pulmonary arteries	One	63.27%	29.23%	04%	20%
		Two	30.61%	67.69%	–	70.90%
		Three	06.12%	03.07%	12%	09.09%
		More	00	–	–	–
	Bronchus	One	00	–	04%	–
		Two	79.59%	98.46%	–	76.36%
		Three	16.33%	1.53%	–	09.09%
		More	04.08%	–	–	–

and bronchus of present and previous studies is represented in Table 3. Incidence of variant pulmonary vein, artery and bronchus on left side is higher in present study than previous works. On right side, anomalous pulmonary artery is lower in present study than others, veins are in same percentage as George et al. (2014) but bronchi variations are higher than other studies. This indicates that number and pattern of hilar structures are extremely variable.

Fissures are essential for performing lobectomy and segmental resection of lung and nature of fissure is thus of great importance in planning operative strategy of thoracoscopic pulmonary resection where an incomplete fissure may contribute to post-operative air leakage (Meenakshi et al., 2004). Not only that, degree of completeness of pulmonary fissure is an excellent categorical key factor of overall morbidity for VATS lobectomy (Li et al., 2018). The present study, on right side, both horizontal and oblique fissures were completely present among 32 (65.3%) specimens, rest (34.7%) were variable in terms of absence of horizontal fissures. On left side, partial incomplete oblique fissures were observed among 5 (9.26%) specimens and rests were normal.

Knowledge about hilar morphometry is also essential. Displacement of hilum is one of the significant sign of pulmonary volume change. It is well known that the left hilum is usually higher in most of normal radiograph. If hila appear at the same level, diagnosis of right upper lobe collapse or left lower lobe collapse is being considered (Lubert and Krause, 1951). Lobar collapse or over-aeration more specifically confirmed by an abnormal hilar height ratio of each lung without comparing relative hilar position (Homer, 1978). Present study also supports that position of left hilum is slightly higher than right.

Size of hilum is another challenging subject for pulmonologist. Plain and digital x-ray usually give some clue about hila. Unequal hila in majority of x-ray often considered as pathological if pseudoinequality by malpositioning of patient is excluded (Sarkar et al., 2013). But present study shows that vertical length of hilum is more on right side whereas antero-posterior length exceeds on left side. This information is important to avoid misinterpretation of x-ray, wrong diagnosis and unnecessary investigation hazards. As hila are best appreciated in lateral view, both vertical and antero-posterior length is crucial. Till now, no definite measurement by radiological or anatomical studies has been done. Thus present results could not be compared. There are significant correlations seen between hilar lengths (both vertical and antero-posterior) and lengths of lung (vertical and antero-posterior) in the present study which indicates that nonpleural hilar area varies according to lung size.

A difference might be there in measurements of parameters by cadaveric study and radiological study due to formalin fixation in former specimens. This can be minimized by using fresh lung specimens in future study. Further study also needed to evaluate age and gender differences between parameters.

5. Conclusion

Alteration of anatomical position and relation of hilar structures are not infrequent as previously believed. That's why; preoperative identification of the variation is useful for decreasing the incidence of unexpected intraoperative complications. In this study, variations in pulmonary hilar anatomy are seen in 64.81% and 59.18% of left and right lungs respectively. Accordingly, eleven morphological categories of hila were described. Thus, high incidence of variations helped us to come to a conclusion on an anatomical classification, depending on the number of structural pattern at the hilum which may contribute additional benefit particularly in the field of pulmonary surgery. Till now no anatomical study regarding morphometry of hilum has been reported as per our knowledge which needs to be highlighted. Left hilum is vertically shorter but anteroposteriorly wider than right hilum and slightly higher in position as compared to contralateral side. Hilar measurements and its correlation with lung in present study definitely add a database to this field.

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