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Anatomical Variation in Lung Fissures: a Cadaveric Study

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ABSTRACT

Introduction: introduction: Classically, human lungs are separated by fissures into lobes. The right lung has 2 major fissures separating 3 lobes, while the left lung has only one major fissure separating 2 lobes. The fissures embryologically separate the bronchopulmonary segments, which persist in adults, increasing the degree of distention of the lungs, and allowing more air to enter the alveoli. Malformation can generate fissure variations that might affect lung diseases and their treatment.

Methods: here we measured and evaluated the degree of completeness of lungs (60 right and 72 left) from Brazilian cadavers.

Results: the oblique fissure of the right lungs had a mean of 16.76cm, was complete in 50%, incomplete in 46.66%, and absent in 3.34%. The horizontal fissure of the right lungs had a mean of 8.79cm, was complete in 25%, incomplete in 53.33%, and absent in 21.67%. The oblique fissure of the left lungs had a mean of 17.92cm, was complete in 54.17%, incomplete in 43.06%, and absent in 2.77%. The incidence of accessory fissures was 11.66% in the right lungs and 15.28% in the left lungs.

Conclusion: Knowing the variations in lung fissures is very important to the interpretation of radiographs, and tomography scans, to diagnose, and plan a surgery. Given these differences, it is important to include knowledge of fissure variations in human anatomy classes.

Keywords: Lung fissures; Anatomical variation; Human anatomy; Lung; Cadaver.

Introduction

The lungs are the organs of respiration, where the pulmonary alveoli carry out gaseous exchanges with the blood. The 2 lungs are the largest organs of the thorax, occupying approximately two-thirds of the thoracic cavity. Each lung has its particularities, with the right lung usually being slightly larger than the left. Both lungs are normally separated into lobes by major fissures. This division of the lungs into lobes increases the degree of distention of the lungs, allowing more air to enter the alveoli. The right lung normally has 2 major fissures separating 3 lobes, upper, middle, and lower, while the left lung normally has only one major fissure separating 2 lobes, upper and lower. There are two major fissures in the right lung: oblique, separating the lower from the middle and upper lobes; and horizontal, separating the middle and upper lobes. The unique major fissure in the left lung is called the oblique and separates its two lobes. The major fissures are deep depressions surrounded by pulmonary pleura that run from the costal surface of the lung to the hilum[1]. When this happens, this is a so-called complete fissure. This "normal" anatomy of the lungs, however, has been largely challenged by the many variations in pulmonary fissures, such as incomplete and nonexistent major fissures or the presence of accessory fissures[2,3].

Radiologically, these fissures appear as white lines that can run from the costal surface to the mediastinal surface of the lungs[4,5]. As mentioned above, fissures can vary, whether present only partially or not at all[6]. There may also be accessory fissures in various parts of the lungs, which may not be detected on imaging tests[7]. Although image technology has evolved[5,6,8], some of the accessory fissures can be deep and may form supernumerary lobes that can be confused with lung lesions[9].

Approximately 70% of lung cancer patients are treated with lobectomy. Higher morbidity has been reported in patients with incomplete pulmonary fissures post-video-assisted thoracoscopic surgery lobectomies than in patients with well-developed lung fissures[10]. So, understanding the anatomy of the lungs is very important for clinical, surgical, and anatomy teaching practices[11].

Material and Method

The study was conducted in the Laboratory of Human Anatomy of the Department of Morphology of the Biosciences Center of the Federal University of Rio Grande do Norte, Natal-RN, Brazil. The lungs used were taken from formalin-fixed adult cadavers allotted for undergraduate dissection. As these had been separated from the rest of the bodies sometime in the past, gender or age could not be accessed. All the cadavers were retrieved from the institutional body donation program or donated by hospitals following the ethical guidelines and the Brazilian law for the use of human cadavers for science and study. Every effort was made to follow all local and international ethical guidelines and laws pertaining to using human cadaveric donors in anatomical research.

All the lungs had their posterior margin measured - from the apex to the inferior margin - as a reference length. The fissures were classified following Craig and

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Walker (1997)[12]. The completeness of a fissure is graded in four stages: grade I - complete fissure with entirely separate lobes; grade II - complete visceral cleft but parenchymal fusion at the base of the fissure; grade III - visceral cleft evident for part of the fissure; grade IV – a complete fusion of the lobes with no evident fissural line. Following most of the reports on the variations in lung fissures, we also classified the lung fissures as complete (grade III), incomplete (grade II + grade III), and absent (grade IV).

The fissures were analyzed and measured. To normalize the fissure length of each lung we measured the fissure, divided it by the posterior margin length (PML) of the lung, and multiplied it by 100, expressing the results in percentage. The results were expressed as the mean ± SEM. Specimens that contained fissural surfaces that were altered by gross pathology were not included in the study.

We used the Student's T test to compare the height of the right and left lungs. We ran the test using Excel and considered statistical significance when $p \leq 0,05$.

Figure 1. Photo of a left lung showing its complete oblique fissure, also classified as grade I. Notice that the fissure goes deep until the hilum (arrowhead), separating the upper and lower lobes entirely.

Results

We analyzed a total of 132 lungs (60 right and 72 left). The mean of the posterior margin measurement was 20.86±0.4cm for the right lung (min 12cm; max 26.7cm) and 19.97±0.36cm for the left lung (min 12.3cm; max 26.5cm). These differences had no statistical significance ($p \geq 0.1$).

The classifications of the lung's fissure are in Tables 1 and 2. Out of 60 right lungs, 30 oblique fissures were grade I (50%), 8 were grade II (13.33%), 20 were grade III (33.33%), and 2 were grade IV (3.34%). The horizontal fissures were grade I in 15 lungs (25%), grade II in 5 lungs (8.33%), grade III in 27 lungs (45%), and grade IV in 13 lungs (21.67%). The 2 right lungs whose oblique fissure was absent (grade IV) also had their horizontal fissure absent (grade IV).

Out of 72 left lungs analyzed, 39 oblique fissures were grade I (54.17%) (Figure 1), 21 were grade II (29.17%), 10 were grade III (13.89%), and 2 were grade IV (2.77%).

When the completeness of the fissures was analyzed, the right lungs had 50% of the oblique fissure complete, 46.66% incomplete (Figure 2) and 3.34% absent. The horizontal fissures in the right lungs were complete in 25% of the lungs, incomplete in 53.33%, and absent in 21.67% (Figure 3). The left lungs had the oblique fissure complete in 54.17% of the lungs, incomplete in 43.06%, and absent in 2.77%.

Seven right lungs (11.66%) presented accessory fissures (Figure 3), 6 of them with only 1 fissure and 1 with 2 fissures. Six of the lungs with accessory fissures were in the superior lobe and one was in the diaphragmatic face of the inferior lobe. Eleven left lungs (15.28%) presented accessory fissures, 2 with 2 fissures and 9 with only 1 fissure. In two of them, the accessory fissure was deep and looked like a horizontal fissure. All the accessory fissures in the left lung were in the superior lobe.

Of the 60 right lungs analyzed, only 13 (21.66%) presented a fissure morphology as described in textbooks, that is complete oblique and horizontal fissures (grade I) and no accessory fissures. Of the 39 left lungs with complete oblique fissures, 4 presented

Table 1. Craig and Walker (1997) classification of fissures of the lungs.

Antimer of lung	Fissure	Grade I	Grade II	Grade III	Grade IV
Right	**Oblique**	30 (50%)	8 (13.33%)	20 (33.33%)	2 (3.34%)
Right	**Horizontal**	15 (25%)	5 (8.33%)	27 (45%)	13 (21.67%)
Left	**Oblique**	34 (54.17%)	21 (29.17%)	10 (13.89%)	2 (2.77%)

Table 2. The pattern of completeness of the fissures.

Antimer of lung	Fissure	Complete	Incomplete	Absent
Right	**Oblique**	30 (50%)	28 (46.66%)	2 (3.34%)
Right	**Horizontal**	15 (25%)	32 (53.33%)	13 (21.67%)
Left	**Oblique**	34 (54.17%)	31 (43.06%)	2 (2.77%)

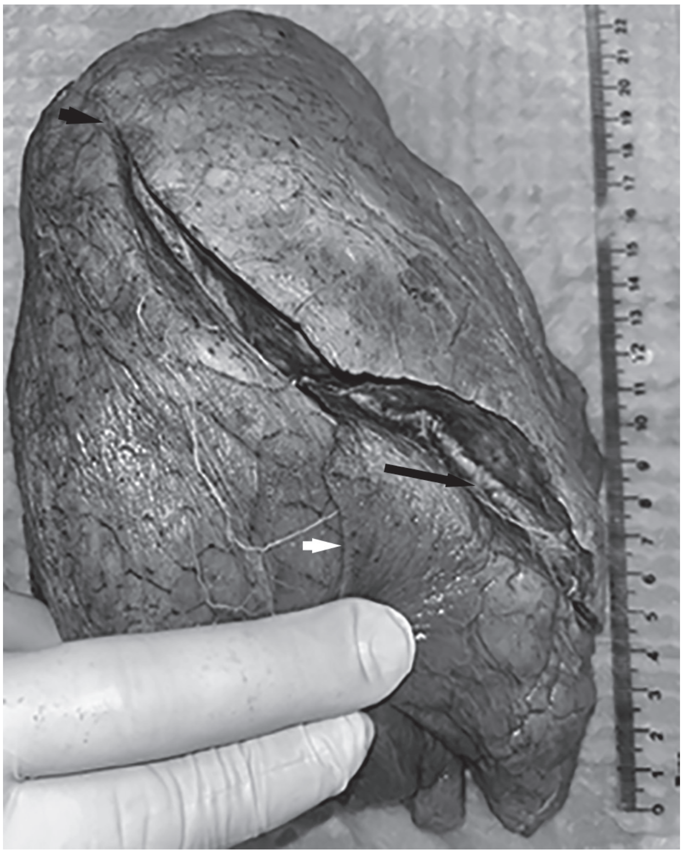

Figure 2. Photo of a right lung showing examples of incomplete fissures. The black arrow points to the horizontal fissure which shows a complete visceral cleft but parenchymal fusion at the base of the fissure (grade II). The black arrowhead points to the oblique fissure where it disappears (grade III). The white arrowhead points to the lower part of the oblique fissure.

Figure 3. Photo of a right lung with an absent horizontal fissure and the presence of accessory fissures (arrowheads).

accessory fissures. This means that less the half of the left lungs (48.61%) showed a fissure morphology as described in the textbooks.

Table 3 registers the measurement of the fissures. The oblique fissure of the right lung had a mean of 16.76±0.54cm (min 7cm, max 23.4cm), that is, 80.62±2.26% of the PML. The horizontal fissure of the right lung had a mean of 8.79±0.45cm (min 1.4cm, max 13.2cm), or 43.33±2.31% of the PML. The oblique fissure of the left lung had 17.92±0.43cm (min 8.4cm, max 23.8cm), which means 90.71±1.82% of the PML.

Table 3. Measurement of the fissures. Length of the fissures and the percentage of the posterior margin length (PML), expressed in mean ± SEM.

Antimer of lung	Fissure	Length	% of PML
Right	**Oblique**	16.76±0.54cm	80.62±2.26%
Right	**Horizontal**	8.79±0.45cm	43.33±2.31%
Left	**Oblique**	17.92±0.43cm	90.71±1.82%

Discussion

The embryology of the lungs includes mesodermal and endodermal tissue. The epithelial components of the lung are derived from the endoderm, while the vasculature, muscles, and cartilage are from the mesodermal germ layer. In the 4th week, during the embryogenic stage, a lung bud appears as an outgrowth from the ventral wall of the foregut. This primitive lung bud branches to form the 2 lung buds that lie on either side of the future esophagus. By the 5th week, the right bronchial bud branches into three secondary bronchial buds, while the left one branches into two, starting the process of differentiation of the right and left lungs. By the 7th week, the segmental branching of the airway becomes evident following the initial lobar and segmental branching processes[13]. Vasculogenesis occurs simultaneously. The spaces between segments are obliterated, except along the line of division of principal bronchi where deep complete fissures divide the right lung into 3 lobes and the left lung into 2 lobes. Any deviation in the bronchopulmonary bud fusion process results in the formation of variations involving lobes and fissures of the lungs[13].

There are many papers about the morphology of lung fissures, most of them from India. The present paper is the first one to use lungs from Brazilian cadavers. Generally speaking, the Brazilian lungs presented more variety than those reported from other nations.

In the Brazilian lungs, there were 50% variations in the oblique fissure of the right lungs, with 46.66% of incompleteness and 3.34% of absence. These data are similar to the one presented by Jacob and Pillay (2013)[14], whose incompleteness of the oblique fissures was found in 50% and absence in 3.34% of the right lungs of Indian cadavers. A study in Ethiopia reported 47.8% incompleteness in oblique fissures of the right lung, but 0% of an absence of fissures[15]. Other Indian studies pointed to nearly 3% of the absence of oblique fissures in the right lungs[16-20].

A 75% of variation was found in horizontal fissures in the Brazilian right lungs, with 53.33% incompleteness and 21.67% absence. In this case, we found many papers that described incomplete horizontal fissures in about 50% of the specimens[2,15,20-29]. An absence was found in about 20% of them[15,18,19,22,25-28,30-34].

We found 45.83% variations in the oblique fissures of left lungs, with 43.06% incompleteness and 2.77% absence. A few studies from India reported nearly 45% incompleteness in the oblique fissure of the left lung[23-25,35-37]. Works from India[18,22,30,38,39], Nepal[33], South Africa[40], and the United Kingdom[41] showed about 3% absence of oblique fissure of the left lungs.

The anatomy of the lung fissure can also be characterized in terms of grade (see Material and Methods). Grades I and IV indicate that the fissures are complete and absent, respectively. The incomplete fissures are divided into grades II and III, where in grade II the fissures show complete visceral cleft but there is parenchymal fusion at the base of the fissure. Grade III fissures show visceral cleft evident for only part of the fissure. From the papers that have classified the fissures by grade, Thapa and Desai (2016)[28] and Mutua and co-workers (2021)[42] were those whose data were more like ours, with 5 of the 12 samples (3 fissures x 4 grades) close to our data. Analysis of the lungs with incomplete fissures (grades II and III) in our study shows that the right lungs had more incidence of grade III than grade II for both fissures; the only major fissure in the left lungs was more frequently grade II than grade III. The literature shows a balance in the number of papers with more grade II or III in the fissures of the right lung. Our data about the fissure in the left lung agrees with what was found in the literature.

Some of the lungs analyzed here presented accessory fissures, with most of them having only one accessory fissure in the superior lobe. The accessory fissures presented here were 11.66% in the right lung and 15.28% in the left lung. Our data agree with Ranaweeera and co-workers (2022)[43] who reported an incidence of 11.5% and 16.7% of accessory fissures in the right and left lungs, respectively. A few other works also showed an incidence of accessory fissures of nearly 11% in the right lung[14, 18, 44] and nearly 15% in the left lung[41,45].

The length of the fissures was also measured. Those measured in our study were shorter reported than any other work that conducted the same measure. In the current study, oblique fissures of the right lung had a mean of 16.76cm. The data closest to this comes from a study in the United Kingdom with the oblique fissures of the right lung of 19.3cm[41]. Dutta and co-workers (2013)[36] presented a mean of 30.15cm for the same fissure in 52 right lungs in India. The horizontal fissures of the right lung had a mean of 8.79cm, similar to the other two studies which measured 9.25 and 10.06cm[38,41]. The oblique fissures of the left lung in our study were slightly bigger than the oblique fissure of the right lung, which is consistent with a study from the United Kingdom[41], but inconsistent with those from India[30,36,39,46]. The oblique fissures of the left lung presented here had a mean of 17.92cm, which agrees with previous data[39, 41]. In general, our measurement data is nearer to the United Kingdom's data than India's. However, this kind of data is scarce and needs more attention.

Understanding the anatomy of the lungs and their variations is very important to medical practices[47]. Surgeons make their incisions based on landmarks demarcated by fissures. The incompleteness of the fissures leads to the continuity of the lobes, playing a key role in the process of fluid and disease spread and progression. For example, pneumonia may spread through fused parenchyma to an adjacent lobe[43]. When a lobectomy is performed in a patient with an incomplete interlobar fissure, there is a higher risk of air leakage[48,49]. Incomplete major fissures can also lead to an inadequate result of therapeutical approaches in emphysema[50,51].

Conclusion

The present study shows that less than half (36.36%) of the lungs studied here were as described in the anatomy books. Although many papers have shown variations in the lung's fissures, regional studies are important to emphasize a local feature, giving clinicians and surgeons the knowledge about possible variations that they can face during their procedure. This approach is also valid for teachers of human anatomy, so that they understand and appreciate the major role that lung variation has in respiratory anatomy.

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