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ORIGINAL ARTICLE

Morphological variations of the lung: Accessory fissures and lobes

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Abstract

Anatomical variability in the human body is not as rare as was previously hypothesised. Indeed, as recently reviewed, the term 'norm' in anatomy can be considered an approximation. Thus, anatomical variations occur quite often, as largely demonstrated during non-invasive diagnosis, surgical intervention, or post mortem investigations. In the present study, we describe different anatomical variations in both the right and left lungs derived from cadavers of different ethnicities. The analysed organs were collected during dissection, and accessory lobes and fissures were observed in both the right and left lungs. Moreover, a horizontal fissure was missing from the right lung, resulting in only two lobes. Since lung anatomical variability is common in clinical practice and preclinical imaging studies can miss different morphologies, a deep and accurate knowledge of the anatomical variations of the lung is of extreme importance to avoid difficulties or changes during the surgical procedure.

KEYWORDS
accessory fissures, accessory lobes, bronchopulmonary segments, lung, respiratory system

1 | INTRODUCTION

The lungs are essential paired respiratory organs located in the thoracic cavity, on either side of the mediastinum in the pleural cavity. The right and left lung weights are approximately 625 and 565 g, respectively, even if the range is variable because it depends on the blood or serous fluid within them.

Morphologically, the lung has a conical shape, and it is possible to distinguish between the apex, base and two surfaces with three borders. Furthermore, the human lungs are divided into lobes by fissures. Commonly, the right lung has two fissures: the shorter and upper is the transverse/horizontal fissure (HF) dividing the upper lobe (UL) from the middle lobe (ML), and the oblique fissure (OF), the major fissure, divides the ML from the lower lobe (LL). In contrast, the left lung usually has two lobes, the upper and lower, separated by an OF (Figure 1) (Standring, 2012).

Fissures are crucial because they allow proper lung expansion during respiration, enclosing and restricting infections in a particular lobe.

However, as previously reported, fissures can be categorized as complete, incomplete, absent, or additional/accessory (Berkmen et al., 1994; George et al., 2014; Heřmanová et al., 2014; Jacob et al., 2019; Mathangasinghe et al., 2021; Murlimanju et al., 2012; Sailaja, 2015). Furthermore, owing to the importance of this organ, lung variations play a pivotal role in clinical medicine. Indeed, knowledge of lung lobes and fissure variations is useful during lobectomy or segmental resection to treat lung cancer, and is especially useful in predicting morbidity (Li, Wang, et al., 2018). Additional fissures can

limit lung inflammation or neoplasia; however, the absence or incomplete fissures may favour the development of pneumonia (Das, 2021).

Such knowledge is also important for anaesthesiologists, since airway management is a crucial point in their approach to patients, and tracheobronchial tree variants are to be well known (García Araque et al., 2014; Wooten et al., 2014).

Therefore, a better understanding of these anatomical variants may have significant implications in treatment strategies, surgical planning and disease prognosis.

In the present study, we describe four different case reports concerning the presence of an accessory fissure in both the right and left lungs.

2 | MATERIALS AND METHODS

The study was conducted at the ICLO Teaching and Research Center (Verona, Italy).

Consent to conduct the study on self-donated cadavers was obtained from the same donor before their death.

The study protocol conformed to the guidelines set out by the Declaration of Helsinki.

The right and left lungs exhibited anatomical variations derived from four adult cadavers of 67- to 82-year-old males and females of different ethnicities. The lungs were collected during a routine undergraduate dissection of the thorax. Frozen body cadavers were thawed for at least 12 h. Briefly, lung resection was performed at the hilar level of the vascular and bronchial pedicles. The adhesions between the parietal and visceral pleura were manually removed. No exclusion criteria were applied, and no lung pathologies were detected in the reported cases.

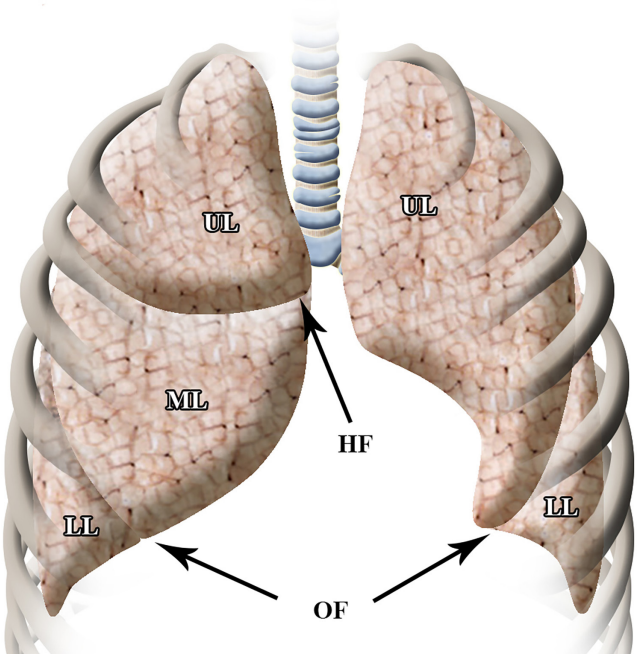

FIGURE 1 Localization and morphology of right and left lung. The image shows the 'perfect' lung with the common morphological pattern of lobes and fissures (UL, upper lobe; ML, middle lobe; LL, lower lobe; HF, horizontal fissure; OF, oblique fissure).

3 | RESULTS

The right lung of a 67-year-old female Caucasian cadaver who died due to colorectal cancer, was found to have additional fissures and lobes. As shown in Figure 2, the right lung showed complete OF, complete HF, and an incomplete superior accessory fissure (AF). The lung weight was approximately 590 g and the lengths of the fissures were within the normal range (Devi et al., 2011; Hema, 2014):

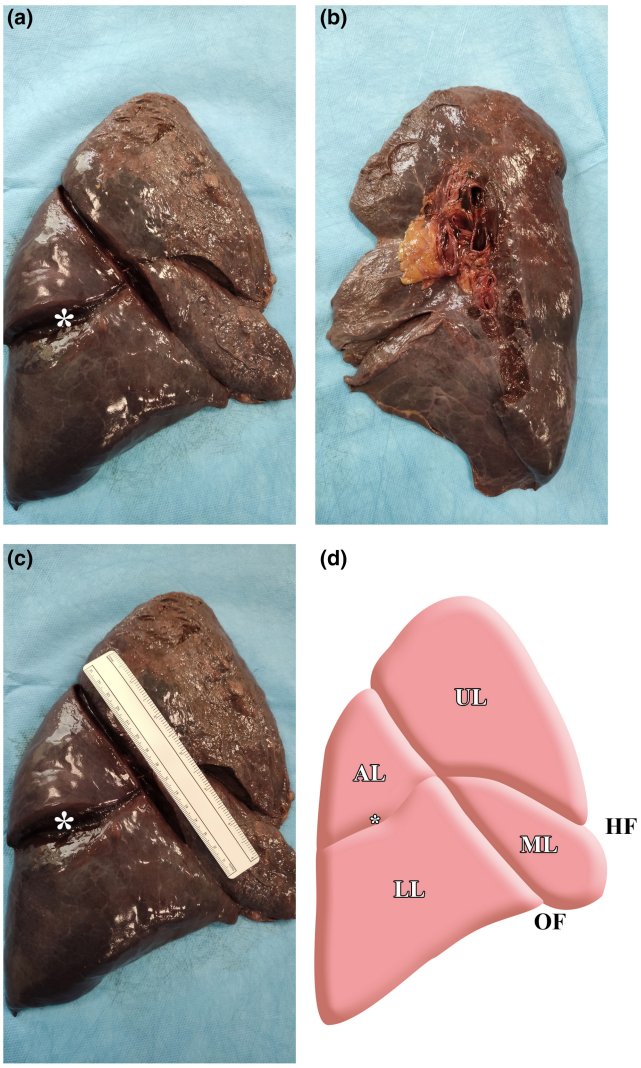

FIGURE 2 Accessory fissure and lobe of a right lung. (a) Costal surface of the right lung clearly shows the incomplete OF, the complete HF and superior AF. (b) Mediastinal surface where it is shown the lower portion of the OF. (c) A ruler used as scale bar on the costal surface close to the incomplete OF. (d) Illustration describing the AL and AF of the right lung. The superior AF is highlighted by asterisks (*). AL, accessory lobe; UL, upper lobe; ML, middle lobe; LL, lower lobe; HF, horizontal fissure; OF, oblique fissure.

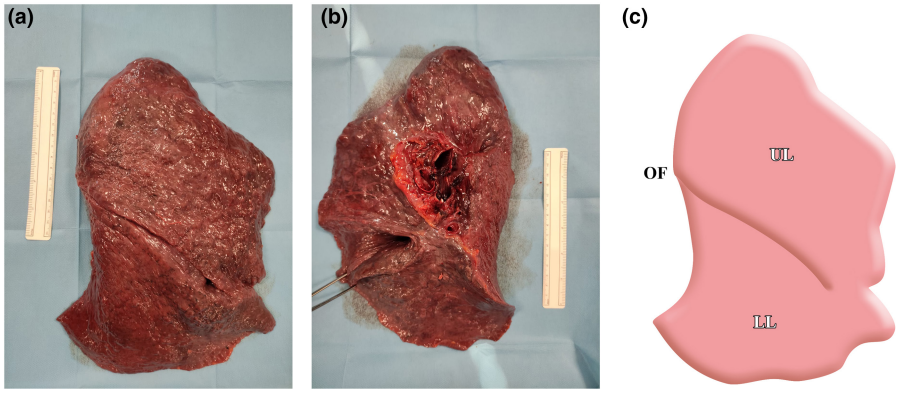

FIGURE 3 Anatomical variation of the right lung without horizontal fissure. (a) Costal surface of the right lung clearly shows the incomplete OF without the presence of the HF. (b) Mediastinal surface with the lower and medial part of the OF. (c) Illustration describing the incomplete OF separating the UL and LL. UL, upper lobe; LL, lower lobe; OF, oblique fissure.

OF was 16.6 cm, HF was 8.96 cm and incomplete superior AF was 8.42 cm. All measurements were obtained from the coastal surface. In contrast, the OF and HF on the mediastinal surface measured, respectively, 5.73 and 1.5 cm.

The surface of the whole right lung measured about 345.54 cm^2, holding the UL, the ML, the LL and the accessory lobe (AL) measuring, respectively, 118.05, 51.09, 124.96 and 49.67 cm^2.

Variations in the right lung can also occur without an accessory fissure or lobe. Indeed, as reported in Figure 3, a single OF in the right lobe may be present, dividing the lung into two lobes: UL and LL. Furthermore, it is worth noting, as clearly shown in Figure 3, panel C, the OF was incomplete and measured 17.4 cm. By contrast, the lower medial OF at the mediastinal surface was 3.61 cm.

The whole surface of the two lobed right lungs was approximately 418.98 cm^2, with the UL measuring 247.39 and the LL 170.69 cm^2. The lung's total weight was 608 g.

Instead, the left lung, derived from a 72-year-old African American woman who died of other pathologies unrelated to the respiratory system, reported AF, as shown in the original images (Figure 4), thus exhibiting a 'middle' AL. Both OF and AF were complete, and the fissures measured, respectively, 15.57 and 10.74 cm, respectively, on the costal surface. In contrast, on the mediastinal face, the upper OF measured 2.94, lower OF measured 8.88, and AF measured 7.14 cm. The left lung weighed approximately 580 g. The whole left lung surface measured about 213.52 cm^2, holding the UL (67.82 cm^2), the AL (37.77 cm^2) and LL (107.17 cm^2).

The other left lung, derived from a 82-year-old Caucasian woman, reported a horizontal AF, as showed in the original images (Figure 5), thus exhibiting a 'superior' AL. Focusing on the fissures, the OF was incomplete and measured 10.23 cm. In contrast, horizontal AF was complete and measured 10.56 cm from the costal surface. On the mediastinal face, the upper OF was 3.65, medial AF was 2.15, and lateral AF was 3.74 cm. The left lung weighed approximately 580 g, and the whole left lung surface measured about 225.37 cm^2, holding the UL (66.49 cm^2), AL (63.72 cm^2) and LL (95.17 cm^2).

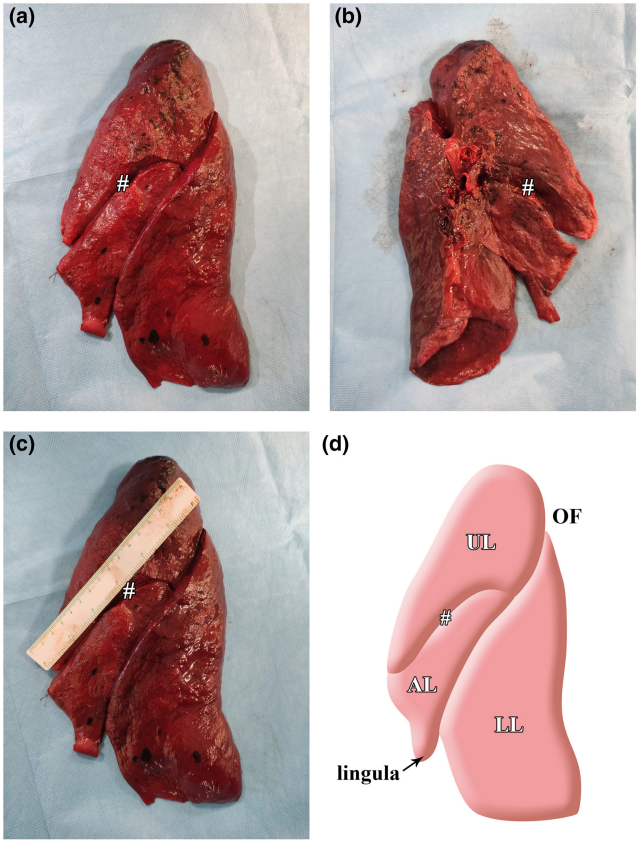

FIGURE 4 Accessory fissure and lobe of a left lung. (a) Costal surface of the right lung reporting the complete OF together with a complete superior AF. (b) Mediastinal surface where it is shown the oblique and minor AF. (c) A ruler used as scale bar laid on the costal surface of the UL, near the complete AF. (d) illustration describing the AL and AF of the left lung. The minor AF is highlighted by hashtags (#). AL, accessory lobe; UL, upper lobe; LL, lower lobe; OF, oblique fissure.

4 | DISCUSSION

The term 'gold standard' in a discipline such as anatomy may be considered relative and obsolete: The clinical and dissection practice underlines the presence and importance of anatomical variability (Żytkowski et al., 2021).

Morphological and macroscopic variations can occur in different parts of the body such as the circulatory system (Branca et al., 2022; Recto, Boddi, et al., 2019; Recto, Pilia, et al., 2019) or organs (Calder et al., 2017; Srinivas et al., 2016).

Thus, correct and deep knowledge of anatomical variations and variability plays a pivotal role in clinical practice, such as surgical

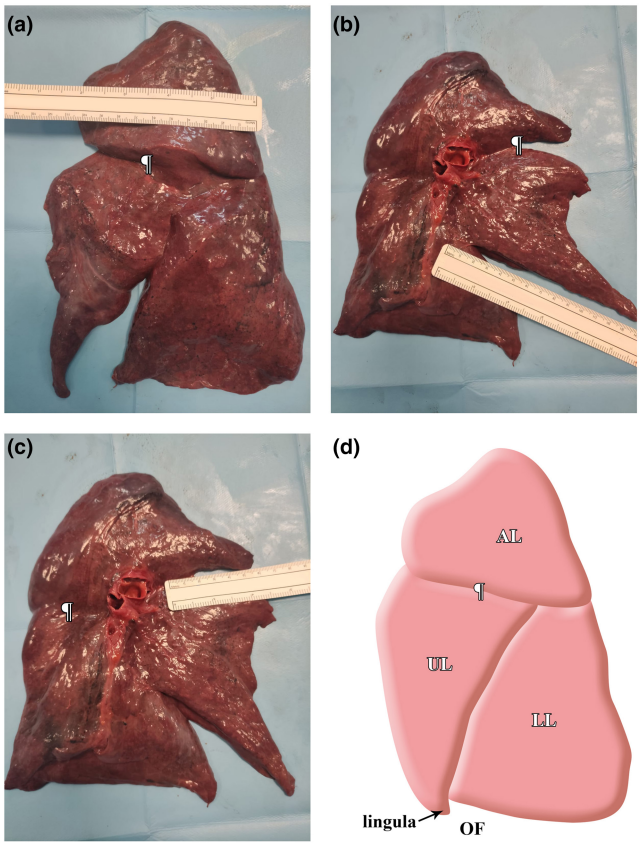

FIGURE 5 Accessory fissure and lobe of a left lung. (a) Costal surface of the right lung reporting the complete OF together with a complete superior AF. The ruler, used as scale bar, was located just above the AF. (b) Mediastinal surface where it is shown the OF (highlighted by the ruler) and the minor AF. (c) A ruler used as scale bar on the mediastinal surface at the level of the medial portion of the AF. (d) Illustration describing the AL and AF of the left lung. The minor AF is highlighted by 'pi' (¶). AL, accessory lobe; UL, upper lobe; LL, lower lobe; OF, oblique fissure.

interventions or procedures, thus leading physicians to different management strategies.

For this reason, the study of such anomalies in cadavers or using in vivo noninvasive techniques is the best way to overcome this issue.

In the field of anatomical variability, the lung is of particular interest for the presence of additional lobes and fissures (Paternostro et al., 2007), as it might be considered an evolutionary mechanism of defence as previously mentioned (Taverne et al., 2015), thus making the 'anormality' common.

However, the fissures can be present (complete or incomplete) or absent (Mamatha et al., 2016; Thapa & Desai, 2016), even in the latter case, as recently reported, they should be detected by new techniques, thus allowing the identification and dissection of intralobular fissures (Li, Zhou, et al., 2018).

Incomplete HF or OF are some of the most common causes, especially in the right lung (Kumari & Latha, 2015; Radha & Durai, 2015). Such a predominance of right lung fissure variations was also observed in a cross-sectional study conducted over 2 years, analysing 560 cases (Manjunath et al., 2021). Furthermore, in the study conducted by Manjunath et al., variations in fissures were predominant in males than females.

Fissures can also be added, thereby increasing the number of lobes. Indeed, many cases of lower and/or superior AF was reported (Channabasanagouda & Halagatti, 2020; Heřmanová et al., 2014; Manjunath et al., 2021; Nene et al., 2011), especially, again, for the right lung. Moreover, the right lung can undergo a very rare and congenital variations presenting an upper and medial additional lobe, the so-called 'azygos lobe' (Akhtar et al., 2018; Awal et al., 2021; Ndiaye et al., 2012).

However, as reported in the present study, no azygos lobes were observed, and lung weight and fissures were within the normal range.

5 | CONCLUSIONS

In conclusion, a deep knowledge of the fissures that may be complete, incomplete, or absent and lobes is useful to appreciate the lobar anatomy, thus helping clinicians and radiologists make correct diagnoses together with better planning and execution of surgical procedures, thus decreasing morbidity and mortality induced by lung surgery.

AUTHOR CONTRIBUTIONS

Conceptualisation: Ferdinando Paternostro. *Validation*: Alessandra Pacini. *Formal analysis*: Jacopo Junio Valerio Branca. *Investigation*: Cristiana Veltro. *Resources*: Ferdinando Paternostro and Cristiana Veltro. *Writing—original draft preparation*: Jacopo Junio Valerio Branca. *Writing—review and editing*: Giulia Guarnieri and Alessandra Pacini. *Visualization*: Jacopo Junio Valerio Branca and Giulia Guarnieri. *Supervision*: Ferdinando Paternostro. *Project administration*: Ferdinando Paternostro. *Funding acquisition*: Ferdinando Paternostro. All authors read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The Authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CONSENT FOR PUBLICATION

The consent was obtained from all subjects involved in the study.

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