Anatomical study of pulmonary fissures

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SUMMARY

The lungs have three main fissures: in the right lung, the oblique and horizontal fissure, and in the left lung the oblique fissure. These can be complete, incomplete or absent. "Classical anatomy" textbooks frequently describe pulmonary fissures as complete, although knowledge of their variations is important both for thoracic surgery and to understand the spread of disease. The objective of this study is to assess the frequency and extension of the main pulmonary fissures, as well as to determine the frequency and location of accessory fissures in cadaveric material.

An observational descriptive study was carried out and consisted of the dissection of 86 ex-situ lungs (43 right and 43 left lungs) of adult corpses from both sexes previously fixed in formaldehyde solution. The presence of complete, incomplete or absent main fissures and the presence of accessory fissures were assessed. For incomplete fissures, the integrity percentage of the fissure was calculated.

In both lungs, incomplete fissures predominated; the oblique fissure of the right lung with a percentage of 65%, the horizontal fissure of 79% and the oblique fissure of the left lung of 58%. Regarding accessory fissures, the overall prevalence was 6%.

The anatomy of pulmonary fissures is highly variable. In our study, incomplete fissures predominated in both lungs. There are differences between the studies regarding the prevalence of the completeness of the fissures because, actually, the literature is not concluding.

Key words: Pulmonary fissures – Right oblique fissure – Right horizontal fissure – Left oblique fissure – Accessory fissures

INTRODUCTION

Classically, the lungs are divided into lobes by three main fissures. There are two main fissures in the right lung: the oblique fissure, which has an anteroinferior direction and divides the inferior lobe from the superior and medium lobes; and the horizontal fissure, which extends from the medium part of the oblique fissure to the anterior aspect of pulmonary hilum, separating the superior lobe from the medium lobe. The left lung consists of two lobes, superior and inferior, separated by the oblique fissure.

These fissures form during embryologic development as a consequence of parenchymal obliteration between bronchopulmonary segments. They have variable depth and they are covered by a double visceral pleura layer in all the extension. Fissures facilitate the movement of the pulmonary lobes, allowing the uniform expansion of the entire lung (Sudikshya et al., 2018).

Variations in fissure were described by Medlar in 1947 through autopsies demonstrating that these can be complete, incomplete, or, less frequently, absent (Medlar., 1947; Sudikshya et al., 2018). When the fissure is complete, lobes remain

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attached only in the hilum by the bronchus and pulmonary vessels; when it is incomplete, there exist parenchymal fusion areas between the lobes, and the fissure does not reach the hilum. The presence of incomplete fissures permits to spread benign illnesses, as well as malignant, to the adjacent lobes through parenchymal fusion (Sudikshya et al., 2018).

Regarding thorax surgery, the bibliography demonstrates a higher incidence of postoperative complications when the fissure is incomplete. Therefore, the more incomplete the pulmonary fissures are, the highest the morbidity (West et al., 2020).

Accessory fissures have also been described. The presence of the accessory fissures has imaging importance, which could lead to confusing interpretations and mistaken diagnosis.

The aim of this study is to determine the frequency and extension of the main pulmonary fissures, and to determine the frequency and location of the accessory fissures in cadaveric material.

MATERIALS AND METHODS

An observational descriptive study was carried out and consisted of the dissection of 86 ex-situ lungs (43 right and 43 left lungs) of adult corpses from both sexes previously fixed in formaldehyde solution. Those corpses were all Caucasian between sixty and seventy years old, without any evident pleuropulmonary pathologies. Due to ex-situ dissections, we were not able to identify the sex of each of the samples, and therefore our data do not allow considering differences between males and females. Corpses in which the thorax had been approached and which could have altered the normal pleuropulmonary anatomy were excluded.

The torax was approached through full sternotomy, and cardio-bipulmonary blocks were extracted.

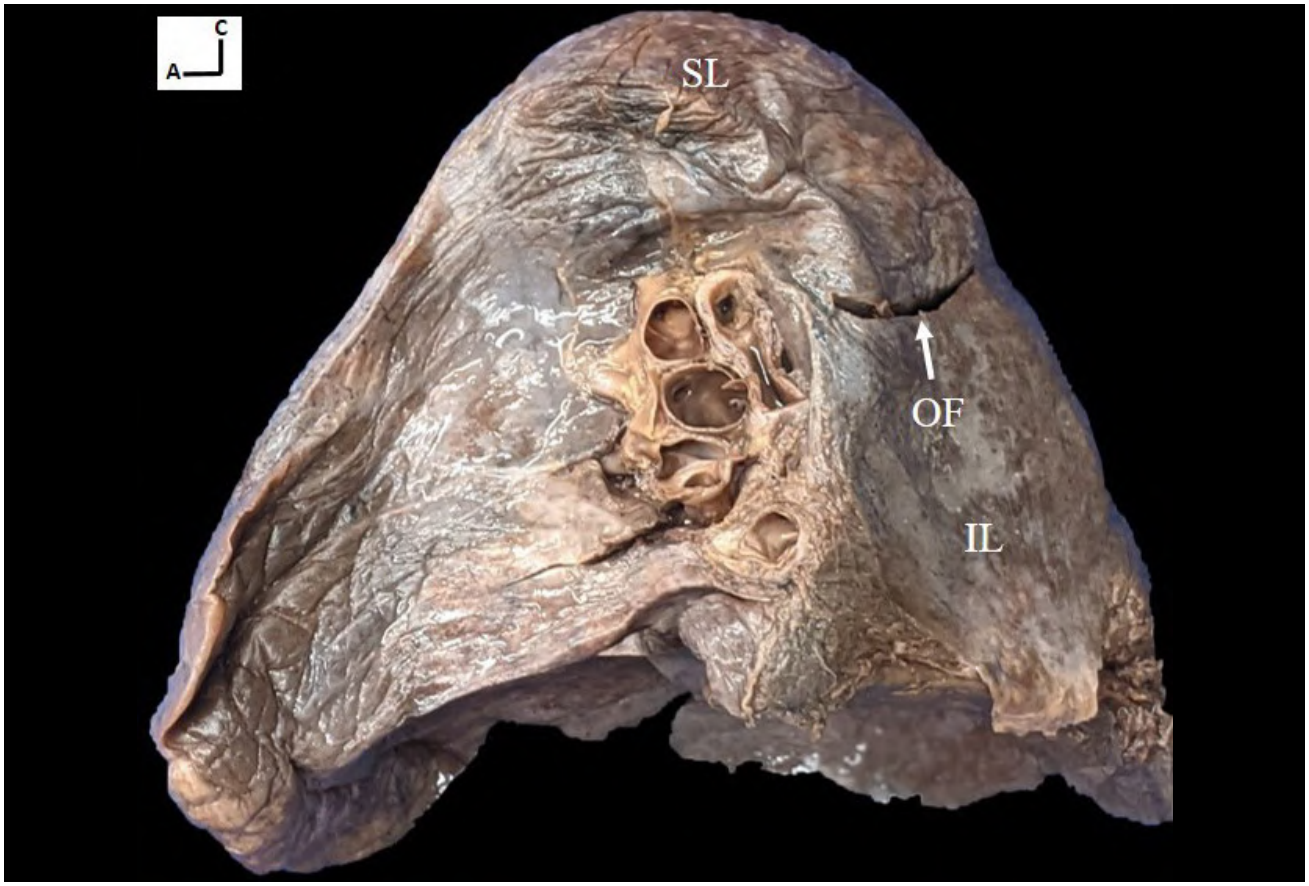


Fig. 1.- Mediastinal surface of the right lung. An incomplete oblique and horizontal fissure is observed; the first portion of the oblique fissure is in the posterosuperior part of the hilium, and in the anterior part of the hilium both fissures are absent. SL: Superior lobe; OF: Oblique fissure; IL: Inferior lobe.

The recorded variables were the following: presence of complete, incomplete or absent main fissures, and presence of accessory fissures.

Incomplete fissures were measured with a measuring tape on the pulmonary surface. Both length and projection of the fissure were measured. Right and left oblique fissure measures were taken from the posterior aspect of the hilum to its anterior aspect, following the path of the fissures. The measure of the horizontal fissure was taken from its origin in the anterior aspect of the oblique fissure to the anterior aspect of the hilium, following the path of the fissure.

In incomplete fissures, the integrity percentage of the fissure was calculated (length/length+projection). Posteriorly, it has been classified into four groups: group 1 (0% - 25%); group 2 (26% - 50%); group 3 (51% - 75%); and group 4 (76% - 99%).

RESULTS

In both lungs (see Figs. 1-3 for morphological details), incomplete fissures were predominant (Table 1). The integrity percentage varies according to the analyzed fissure, obtaining, in the right lung, an average of 81.2% for the oblique fissure; and 47.6% for the horizontal fissure. In the left lung, the average percentage was of 76.2%.

Regarding the accessory fissures, a global prevalence of 6% was obtained (see Figs. 4-6). In the right lung, there were observed 3 superior accessory fissures in the inferior lobe, and, in the left lung, 2 horizontal fissures (Table 1).

DISCUSSION

Many authors have studied pulmonary fissures in cadaveric material, mostly in Indian population (Prakash et al., 2010; Bhimai Devi et al., 2011; Nene et al., 2011; Dutta et al., 2013; Ghosh et al., 2013; Jacob and Pillay, 2013; George et al., 2014;

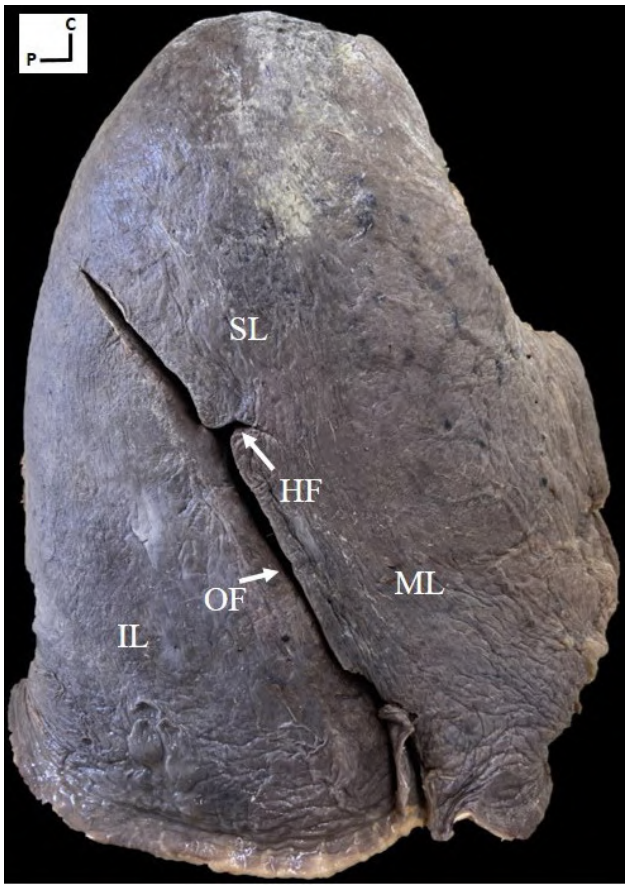


Fig. 2.- Costal surface of the right lung. An incomplete horizontal fissure is observed. SL: Superior lobe; ML; Medium lobe; IL: Inferior lobe; OF: Oblique fissure; HF: Horizontal fissure.

Fig. 3.- Mediastinal surface of the left lung. An incomplete oblique fissure is observed; the first portion of the oblique fissure is in the posterosuperior part of the hilium, and in the anterior part of the hilium the fissure is absent. SL: Superior lobe; OF: Oblique fissure; IL: Inferior lobe.

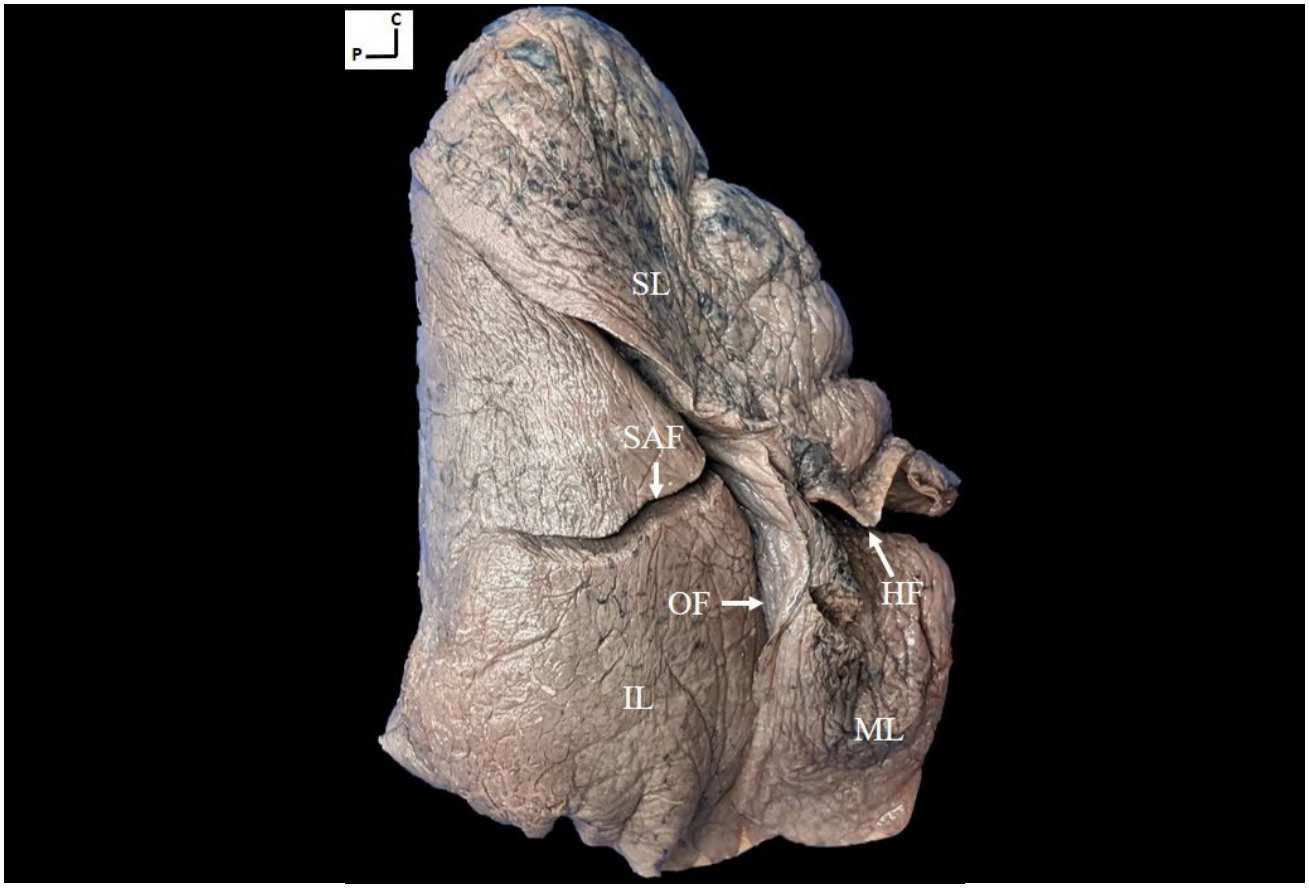
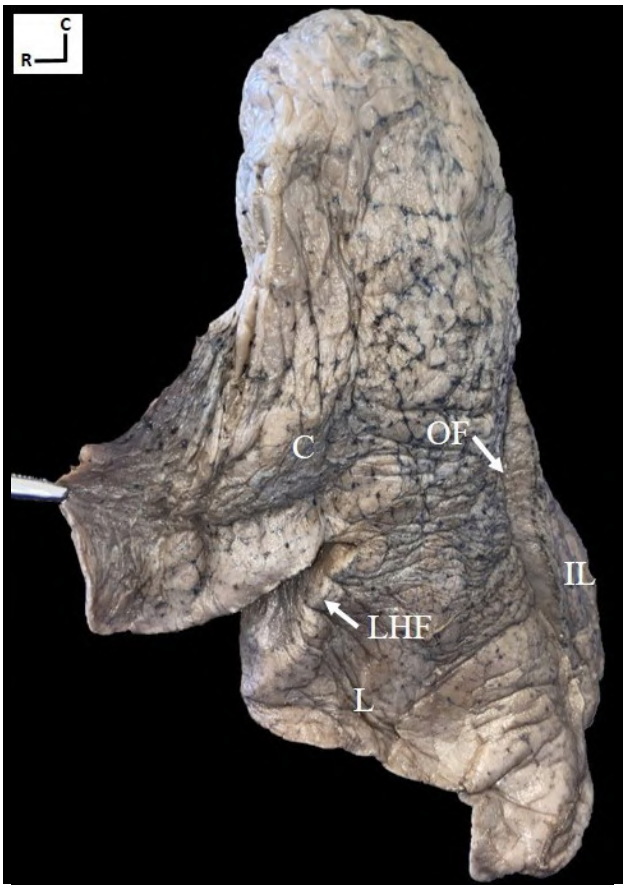
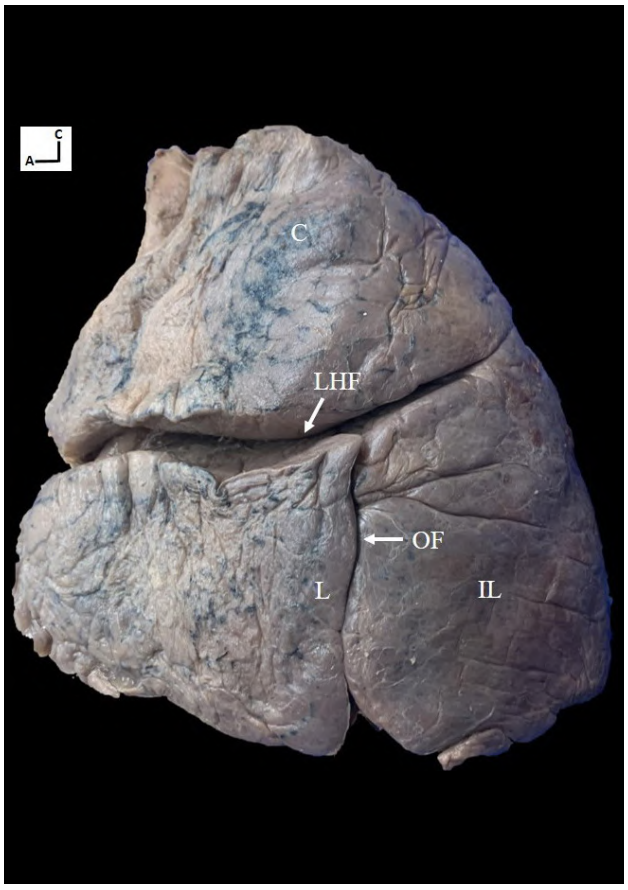


Fig. 4.- Costal surface of the right lung. In the inferior lobe, a superior accessory fissure is observed. SL: Superior lobe; ML; Medium lobe; IL: Inferior lobe; OF: Oblique fissure; HF: Horizontal fissure. SAF: Superior accessory fissure.





Figs. 5 and 6.- Costal surface of the left lung. In the superior lobe, a horizontal fissure is observed. C: Culmen; L: Lingula; LHF: Left horizontal fissure; OF: Oblique fissure; IL: Inferior lobe.

Table 1. Analyzed variables and results are expressed as absolute frequency and percentual relative frequency.

Right lung			
Oblique fissure	**Nº (%)**	**Horizontal fissure**	**Nº (%)**
Complete fissure	15 (35%)	Complete fissure	9 (21%)
Incomplete fissure	28 (65%)	Incomplete fissure	34 (79%)
Absent fissure	0 (0%)	Absent fissure	0 (0%)
Integrity percentage of fissure	**Nº (%)**	**Integrity percentage of fissure**	**Nº (%)**
0% - 25%	0 (0%)	0% - 25%	4 (11.8%)
26% - 50%	0 (0%)	26% - 50%	17 (50%)
51% - 75%	6 (21.4%)	51% - 75%	10 (29.4%)
76% - 99%	22 (78.6%)	76% - 99%	3 (8.8%)
Average	81.2%	Average	47.6%
Left lung			
Oblique fissure	**Nº (%)**	**Integrity percentage of fissure**	**Nº (%)**
Complete fissure	18 (42%)	0% - 25%	0 (0%)
Incomplete fissure	25 (58%)	26% - 50%	1 (4%)
Absent fissure	0 (0%)	51% - 75%	8 (32%)
		76% - 99%	16 (64%)
		Average	0.762
Accesory fissure			
	Prevalence	**Type of fissure**	
Right lung	3 (7%)	Superior accessory fissure of inferior lobe	
Left lung	2 (4.7%)	Horizontal fissure of superior lobe	

Kaul et al., 2014; Quadros et al., 2014; Magadum et al., 2015; Mamatha et al., 2016; Sudikshya et al., 2018; Jacob et al., 2019) and, to a lesser extent, in European studies (Unver Dogan, 2015; Bostanci et al., 2019; West et al., 2020). The current study is the first cadaveric study of the pulmonary fissures in Uruguayan population.

The anatomy of the pulmonary fissures is highly variable. Differences among the studies concern the prevalence of complete, incomplete and absent fissures (see Table 2). These differences could be attributed to methodological heterogeneity and, probably, ethnicity (West et al., 2020).

Regarding the oblique fissure of the right lung, in the literature there is a higher predominance of complete fissures (Table 2). However, the current study is concordant with the studies by Dutta et al. (2013), Jacob and Pillay (2013), Magadum et al. (2015), Bostanci et al. (2019) and Jacob et al. (2019) in that a predominance of incomplete fissures is observed.

At the same time, the highest prevalence of incomplete oblique fissures was obtained in the current study (65%). The absent fissure was less frequent, even though Magadum et al. (2015) reported a prevalence of 10%.

The horizontal fissure is the most variable of the main fissures (Table 2). Most of the studies observed a predominance of the complete horizontal fissures, even though our current study and six analyzed studies (Prakash et al., 2010; Jacob and Pillay, 2013; Magadum et al., 2015; Bostanci et al., 2019; Jacob et al., 2019; West et al., 2020) reported a predominance of incomplete horizontal fissure with a range between 50% and 83.4%. The horizontal fissure is also the most frequently reported as absent. Ghosh et al. (2013) and Kaul et al. (2014) reported percentages of 47.8% and 40% of absent horizontal fissure, respectively. In the current study we did not report absent horizontal fissure, as in the study by Mamatha et al. (2016).

Table 2. Comparison of the completeness of right oblique fissure and horizontal fissure within the literature. Analyzed variables and results are expressed as absolute frequency and percentual relative frequency.

Authors (year of publication)	Right lung						
	Nº	Oblique fissure			Horizontal fissure		
		Complete	Incomplete	Absent	Complete	Incomplete	Absent
Prakash et al. 2010	28	15 (53.6%)	11 (39.3%)	2 (7.1%)	12 (42.9%)	14 (50%)	2 (7.1%)
Bhimai Devi et al. 2011	22	20 (91%)	2 (9%)	-	16 (72.7%)	4 (18.2%)	2 (9.1%)
Nene et al. 2011	50	46 (92%)	3 (6%)	1 (2%)	39 (78%)	4 (8%)	7 (14%)
Dutta et al. 2013	52	14 (26.9%)	32 (61.5%)	6 (11.5%)	31 (59.6%)	13 (25%)	18 (34.6%)
Ghosh et al. 2013	46	36 (78.2%)	9 (19.6%)	1 (2.2%)	12 (26.1%)	12 (26.1%)	22 (47.8%)
Jacob and Pillay, 2013	30	14 (46.6%)	15 (50%)	1 (3.4%)	3 (10%)	25 (83.4%)	2 (6.6%)
George et al. 2014	65	63 (97%)	2 (3%)	-	40 (61.6%)	23 (35.4%)	2 (3%)
Kaul et al. 2014	50	34 (68%)	12 (24%)	4 (8%)	14 (28%)	16 (32%)	20 (40%)
Quadros et al. 2014	36	34 (94.4%)	2 (5.6%)	-	23 (64%)	9 (25%)	4 (11%)
Magadum et al. 2015	40	12 (30%)	24 (60%)	4 (10%)	14 (35%)	21 (52.5%)	5 (12.5%)
Unver Dogan et al. 2015	210	207 (98.6%)	3 (1.4%)	-	188 (89.5%)	18 (8.6%)	4 (1.9%)
Mamatha et al. 2016	20	17 (85%)	3 (15%)	-	10 (50%)	10 (50%)	-
Sudikshya et al. 2018	50	16 (69.6%)	7 (30.4%)	-	12 (52.2%)	8 (34.8%)	3 (13%)
Bostanci et al. 2019	256	91 (35.5%)	165 (64.5%)	-	70 (27.3%)	175 (68.4%)	11 (4.3%)
Jacob et al. 2019	47	23 (49%)	24 (51%)	-	7 (15%)	33 (70%)	7 (15%)
West et al. 2020	81	52 (64.2%)	29 (35.8%)	-	18 (22.2%)	54 (66.7%)	9 (11.1%)

Concerning the oblique fissure of the left lung, most of the authors obtained a predominance of complete fissure (Table 3). However, in the current study as well as in other analyzed studies (Dutta et al., 2013; Sudikshya et al., 2018; Bostanci et al., 2019; Jacob et al., 2019) a predominance of the 48% and 63% of the incomplete oblique fissures were reported. Bostanci et al. (2019) is the study which includes the highest number of lungs (256), and reports the highest prevalence of incomplete oblique fissure (63%) The left absent oblique fissure is less frequent. Prakash et al. (2010) reported the highest prevalence of absent fissure (10%).

There also exists a wide variety of pulmonary fissures reported in studies using computed tomography (CT). The anatomy of the pulmonary fissures differs from those reported in cadaveric studies. Ozmen et al. (2010) carried out a retrospective study which included 387 CT and observed that the right oblique and horizontal fissures, as well as the left oblique fissures were incomplete in 69.7%, 86.9% and 48.3%, respectively (Ozmen et al., 2010). These results differ from the studies analysed in Tables 2 and 3.

Further studies have demonstrated that preoperative CT is not a completeness predictor of pulmonary fissures in thoracic surgery (Schieman et al., 2011; Kent et al., 2015). This highlights the importance of studying fissure anatomy with cadaveric material. Therefore, we emphasize the value of carrying out more cadaveric studies with a larger population in order to obtain an approximate prevalence of the completeness of the main pulmonary fissures, due to the fact that, actually, the literature is not concluding.

In the current study, the percentage of the pulmonary fissure integrity was calculated in the surface of the lung. This allows us to know how complete the pulmonary fissures are when they are incomplete. In order to do this, we divided it into 4 groups (Table 1), as Ozmen et al. (2010) did in their study using CT. The results of this study and the present one are similar, taking into consideration that there may be differences between both study methods (cadaveric study

Table 3. Comparison of the completeness of left oblique fissure within the literature. Analyzed variables and results are expressed as absolute frequency and percentual relative frequency.

Authors (year of publication)	Left lung			
	Nº	Oblique fissure		
		Complete	Incomplete	Absent
Prakash et al. 2010	28	15 (53.6%)	10 (35.7%)	3 (10.7%)
Bhimai Devi et al. 2011	22	12 (54.5%)	8 (36.4%)	2 (9.1%)
Nene et al. 2011	50	44 (88%)	6 (12%)	-
Dutta et al. 2013	50	22 (44%)	24 (48%)	4 (8%)
Ghosh et al. 2013	36	29 (80.6%)	5 (13.9%)	2 (5.5%)
Jacob & Pillay 2013	18	11 (61.1%)	7 (38.9%)	-
George et al. 2014	73	62 (85%)	11 (15%)	-
Kaul et al. 2014	50	30 (60%)	20 (40%)	-
Quadros et al. 2014	40	39 (97.5%)	1 (2.5%)	-
Magadum et al. 2015	40	20 (50%)	17 (42.5%)	3 (7.5%)
Unver Dogan et al. 2015	210	208 (99%)	2 (1%)	-
Mamatha et al. 2016	20	12 (60%)	7 (35%)	1 (5%)
Sudikshya et al. 2018	50	13 (48.2%)	14 (51.8%)	-
Bostanci et al. 2019	256	95 (37%)	161 (63%)	-
Jacob et al. 2019	49	16 (34%)	29 (62%)	2 (4%)
West et al. 2020	81	66 (81.5%)	13 (16%)	2 (2.5%)

vs in vivo study). In both, right and left oblique fissure completeness predominates in group 4. In the case of the horizontal fissure, the completeness is more heterogeneous among the groups, predominating in group 3 in the study of Ozmen et al. (2010) and in group 2 in the current study.

There are others classifications for the completeness of pulmonary fissures, such as the ones described by Craig and Walker (1997), which classify it into 4 grades. However, this classification is qualitative and do not allow us to characterize the incomplete fissure. Establishing the integrity percentage, as in the current study, will allow us to understand how complete the incomplete pulmonary fissure is, collaborating with thorax surgeons in their surgical plan (West et al., 2020).

Accessory fissures could be the result of the absence of parenchyma fusion in spaces where they would normally fusion. Any factor that alters the parenchyma fusion during the embryologic development is going to cause variations in lobes and pulmonary fissures (Meenakshi et al., 2004). These are generally situated in the limits of bronchopulmonary segments (Sudikshya et al., 2018; West et al., 2020). In the right lung, the most frequent are the following: in the superior lobe, the azygos fissure, which includes the azygos vein and it is called “azygos lobe”; in the inferior lobe, the superior accessory fissure, which separates superior segments from the basal segments; and the inferior accessory fissure, which separates the medial basal segment from the rest of the inferior lobe. In the left lung, the most frequent are the following: in the superior lobe, the horizontal fissure, which separates the lingula from the rest of the lobe; and, in the inferior lobe, the superior accessory fissure, which separates the superior segment from the basal segments (Sudikshya et al., 2018; West et al., 2020).

The accessory fissures found in the current study were the superior accessory fissure of the right inferior lobe, and the left horizontal fissure. In the reviewed bibliography, the superior accessory fissure is reported between 4% and 13.3% (Nene

et al., 2011; Jacob and Pillay, 2013; Bostanci et al., 2019). In the present study, we obtained a similar prevalence (7%). On the other hand, the left horizontal fissure is reported between 4.6% and 27.7%. In our study we obtained a prevalence of 4.7%.

Many authors highlighted the importance of knowledge about their frequency and location of accessory fissures due to the fact it could lead to mistaken interpretations in radiographies and CT. Furthermore, these could also be confused with pathologic process such as lineal atelectasis or pleural scars (Godwin and Tarver, 1985).

At the same time, the presence of accessory fissures can act as a barrier for spread of infection and malignant processes. It also explains the interlobar liquid distribution. Acknowledging their existence is of great importance for the thoracic surgeon in order to carry out a surgical plan for segmentary resections or pulmonary lobectomies (Ghosh et al., 2013).

Lastly, we highlight that a "classical anatomy" textbook lung describes 3 main pulmonary fissures and no accessory fissures. In our study, 18 out of 43 left lungs presented complete pulmonary fissure, as this "classical anatomy" textbook describes; and, in the right lung, only 3 out of 43 had both complete fissures. This should make us think about changing the concept given by "classical anatomy" textbooks; so anatomists, imaging specialist and thoracic surgeons must know that fissures are more variable than textbooks describe.

As for the limitations, we could not value the extension on depth of pulmonary fissures that also has surgical importance. This study was carried out in lungs fixed in formaldehyde, which determines changes that affect measures, however, unavoidable with cadaveric studies.

CONCLUSIONS

The anatomy of pulmonary fissures is highly variable. In our study, incomplete fissures predominated for the 3 main fissures. In the literature, we observed differences between the studies regarding the prevalence of complete, incomplete and absent fissures, as analyzed. For this reason, we emphasize the value of carrying out more cadaveric studies with a larger population in order to obtain an approximate prevalence of the completeness of the main pulmonary fissures, because, actually, the literature is not concluding.

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