Can preoperative computed tomography of the chest predict completeness of the major pulmonary fissure at surgery?

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Background: An incomplete major pulmonary fissure can make anatomic lung resection technically more difficult and may increase the risk of complications, such as prolonged postoperative air leak. The objective of this study was to determine if preoperative computed tomography (CT) of the chest could accurately predict the completeness of the major pulmonary fissure observed at the time of surgery.

Methods: From October 2008 to June 2009, patients at a single university institution were enrolled if they underwent surgery for a pulmonary nodule, mass or known cancer. At the time of surgery, completeness of the major pulmonary fissure was graded 1 if pulmonary lobes were entirely separate, 2 if the visceral cleft was complete with an exposed pulmonary artery at the base with some parenchyma fusion, 3 if the visceral cleft was only evident for part of the fissure without a visible pulmonary artery and 4 if the fissure was absent. The preoperative CT scan of each patient was graded by a single, blinded chest radiologist using the same scale. We used the Pearson χ^2 test with 2-tailed significance to test the independence of the operative and radiologic grading.

Results: In 48% (29 of 61) of patients, the radiologic and operative grading were the same. Of those graded differently, 94% (30 of 32) were within 1 grade. Despite this agreement, we observed no statistically significant correlation between the operative and radiologic grading ($p = 0.24$).

Conclusion: The major fissure can often be well-visualized on a preoperative CT scan, but preoperative CT cannot accurately predict the completeness of the major pulmonary fissure discovered at surgery.

Contexte : Une scissure pulmonaire majeure incomplète peut rendre la résection pulmonaire anatomique plus difficile sur le plan technique et accroître le risque de complications, notamment la fuite d'air prolongée après l'intervention. Cette étude visait à déterminer si une tomodensitométrie (TDM) pulmonaire préopératoire pourrait prédire avec précision le caractère complet de la scissure pulmonaire observée au moment de l'intervention chirurgicale.

Méthodes : D'octobre 2008 à juin 2009, les patients d'un même établissement universitaire ont été inscrits à l'étude s'ils subissaient une intervention chirurgicale pour un nodule, une masse ou un cancer connu au poumon. Au moment de l'intervention, le caractère complet de la scissure pulmonaire a été coté 1 si les lobes pulmonaires étaient entièrement séparés, 2 si le sillon branchial était complet et conjugué à une exposition de l'artère pulmonaire à la base et à une fusion du parenchyme, 3 si le sillon branchial était évident dans une partie seulement de la scissure sans que l'artère pulmonaire soit visible, et 4 s'il n'y avait pas de scissure. Le résultat de la TDM préopératoire de chaque patient a été coté par 1 seul radiologiste travaillant à l'insu et utilisant la même échelle. Nous avons utilisé le test χ^2 de Pearson avec signification bilatérale pour vérifier l'indépendance de l'évaluation opératoire et radiologique.

Résultats : Chez 48 % des patients (29 sur 61), les évaluations radiologique et opératoire ont été identiques. Parmi ceux qui ont fait l'objet d'une évaluation différente, l'écart de cote ne dépassait pas 1 chez 94 % (30 sur 32). En dépit de cette convergence, nous n'avons observé aucun lien statistiquement significatif entre l'évaluation opératoire et radiologique ($p = 0,24$).

Conclusion : Une TDM préopératoire permet souvent de bien visualiser la scissure majeure, mais elle ne peut prédire avec exactitude le caractère complet de la scissure pulmonaire majeure au moment de l'intervention chirurgicale.

Anatomic lung resections are the most commonly performed thoracic surgical procedure. These resections are typically performed as the primary, curative treatment for non-small cell lung cancer. The technical difficulty of a conventional anatomic lung resection, which most often involves the removal of a complete pulmonary lobe, is largely determined by the completeness of the major pulmonary fissure. The pulmonary fissure is the anatomic division between the lobes of the lung, and it may exist anywhere on a continuum from complete anatomically distinct lobes to fused, indistinguishable lobes. The depth of the cleft within the fissure is important for anatomic resections because it allows the safe identification of the pulmonary artery and the bronchus. A fused or incomplete fissure has to be divided surgically, which makes for a more challenging surgery. Surgical division of the fissure is also thought to increase the risk of postoperative complications, including prolonged air leak, which is the most common cause of prolonged stay in hospital after lung resection.¹ Therefore, the completeness of the major pulmonary fissure is a critical component in determining the complexity of a lung resection and, potentially, postoperative recovery. If a patient's preoperative computed tomography (CT) scan could accurately predict the completeness of the major pulmonary fissure, it may impact the thoracic surgeon's choice of approach (thoracotomy v. video-assisted), the suitability of cases for trainees and the patient's anticipated recovery time.

METHODS

This study was granted ethical and scientific approval by the Calgary Health Region's Centre for Advancement of Health Institutional Review Board.

Patient eligibility

Inclusion was restricted to patients 18 years or older who underwent either thoracotomy or video-assisted thoracoscopic surgery (VATS) for a lung nodule, mass or known cancer performed by a fellowship-trained thoracic surgeon (A.G., S.P.M., G.G. or S.C.G.) at the Foothills Hospital in Calgary, Alta., from October 2008 to June 2009. Patients were excluded if they had some component of pleural disease, such as pleural effusions, tumours involving the pulmonary fissure, empyema, hemothorax or extensive adhesions, owing to potential confounding of radiologic interpretation.

Grading of the pulmonary fissure

The fissure is not commonly graded in routine thoracic care, and there is no agreed-on scale or technique of grading the completeness of the major pulmonary fissure. Furthermore, there is no validated classification of the pulmonary fissures in the published literature. We modified a previously published but not validated anatomic classification system for the pulmonary fissures² to create an intuitive, simple and reproducible classification system for grading the pulmonary fissures that could be used by the 4 participating surgeons and the study radiologist. At the time of surgery, completeness of the major pulmonary fissure was graded as 1 if the pulmonary lobes were entirely separate, 2 if the visceral cleft was complete with an exposed pulmonary artery at the base with some parenchymal fusion, 3 if the visceral cleft was only evident for part of the fissure without a visible pulmonary artery and 4 if the fissure was absent. The preoperative CT scan of each enrolled patient was graded by a single, blinded chest radiologist (J.H.M.) using the same scale. When multiple CT

Fig. 1. An example of a radiologic grade 1 complete fissure, as seen on a computed tomography scan with coronal reformatting. The fissure extends to (A) the mediastinum superiorly, (B) the pulmonary artery medially and (C) the mediastinum inferiorly.

scans were available for any given patient, the scan with the highest resolution was used. Similarly, when available, multiplanar reformatted views were used to assess the fissure. A radiologically complete fissure was defined by a clearly identified white line of the fissure extending from the lateral lung surface to the pulmonary artery medially with no visible breaks or interruptions from the top to the bottom of the hilum over multiple image sections. When the fissure extended to the hilum medially along all cuts, the fissure was graded as 1 (Fig. 1). If the fissure extended to the artery medially but not to the mediastinum along all cuts it was graded as 2. When the fissure line could not be clearly seen or seemed to end in the lung tissue without extending entirely to the pulmonary artery medially the fissure was graded as incomplete (grades 3 or 4). If the fissure extended into the lung for a distance and ended before reaching the pulmonary artery it was graded as 3, and if there was no visible fissure line it was graded as 4. This grading scale is summarized in Table 1.

Statistical analysis

We used the Pearson χ^2 test with 2-tailed significance to test the independence of the operative and radiologic grading. The primary analysis compared operative and radiologic grades for all included patients. Owing to concerns about the difficulty of differentiating grade 2 from grade 3 both intraoperatively and radiologically, we performed secondary χ^2 analysis comparing patients more broadly categorized as having a complete fissure (grades 1 and 2) with those categorized as having an incomplete fissure (grade 3 or 4). To investigate the potential influence of CT scan resolution on the accuracy of the radiologic grade, secondary analysis was performed for all patients with CT scans obtained with a slice thickness less than 5 mm.

RESULTS

The data set is summarized in Table 2. We included 61 of a

total 72 enrolled patients in our analyses. Patients were well-distributed among the 4 participating surgeons. Seventy-seven percent of the procedures (47 of 61) were performed for known lung cancers. Fifty-two percent (32 of 61) of the patients had an open thoracotomy.

Intraoperative and radiologic grading

Table 3 demonstrates the operative and radiologic grading of the included patients. Forty-eight percent (29 of 61) of the patients had the same intraoperative and radiologic grading. Of those not assigned the same grade, 94% (30 of 32) were within 1 grade. Despite this agreement, the Pearson χ^2 test did not demonstrate a significant correlation between intraoperative and radiologic grading for completeness of the major pulmonary fissure ($p = 0.24$).

Further subset analysis of the data was performed with the scale dichotomized to those with a complete fissure

Table 2. Clinical characteristics of study patients ($n = 61^*$)

Characteristic	No.
Indications for surgery	
Lung cancer	47
Lung metastases	4
Benign lung mass	6
Pulmonary nodule	4
Procedure approach	
Video-assisted thoracic surgery	29
Thoracotomy	32
Procedure type	
Lobectomy	33
Wedge	17
Pneumonectomy	6
Aborted resection (extensive mediastinal nodal metastases, vertebral invasion)	2
Other procedure	3
Procedure side	
Right	25
Left	36
Contrast enhanced computed tomography	
Yes	50
No	11

*Exclusions, $n = 11$: mediastinal mass, pneumothorax, incomplete data, pleural disease on computed tomography, computed tomography not interpretable (i.e., motion artifact).

Table 1. Scale used to grade the completeness of the major pulmonary fissure, surgically and radiologically

Grade	Surgical identification	Radiologic identification
1	Entirely separate pulmonary lobes	Fissure extended to the hilum medially along all cuts
2	Complete visceral cleft with an exposed pulmonary artery at the base and some parenchymal fusion	Fissure extended to the artery medially, but not along the hilum along all cuts (including instances when the fissure line could not be clearly seen or seemed to terminate in the lung tissue without extending entirely to the pulmonary artery medially)
3	A visceral cleft only evident for part of the fissure without a visible pulmonary artery	Fissure extended into the lung for a distance and terminated before reaching the pulmonary artery
4	Absent fissure	No visible fissure line

Table 3. Comparison of the intraoperative and radiologic grading of the major pulmonary fissure

Operative grade of major fissure	Radiologic grade of major fissure				Total
	1	2	3	4	
1	3	3	1	0	7
2	8	17	8	0	33
3	1	10	9	0	20
4	0	1	0	0	1
Total	12	31	18	0	61

(i.e., the fissure extends to the exposed pulmonary artery: grades 1 and 2), and to those with an incomplete fissure (i.e., the pulmonary artery is not visible: grades 3 and 4). This dichotomization improved the correlation between intraoperative and radiologic grading, but the correlation remained nonsignificant ($p = 0.10$).

When inclusion was restricted to only those patients who had CT scans with a slice thickness less than 5 mm, correlation between intraoperative and radiologic grading of completeness of the major pulmonary fissure improved but remained nonsignificant ($p = 0.22$).

DISCUSSION

We were not able to predict the completeness of the major pulmonary fissure observed at the time of surgery based on the preoperative CT scan. Given an absence of existing literature investigating this question, it is difficult to understand or extrapolate these findings in a broader context. However, there is little question that the completeness of the major pulmonary fissure is one of the key determinants of technical difficulty when performing a pulmonary lobectomy. When the lobes are completely separate and the pulmonary artery is visible, there is minimal lung parenchyma to be divided and minimal arterial dissection required, facilitating safe and easy arterial transection. A fused fissure, on the other hand, classically requires extensive division of lung parenchyma, which increases bleeding and the risk of pulmonary artery injury and air leak.¹ The increased risk of air leak following division of an incomplete fissure has been substantiated in dog and human studies, demonstrating that these areas of parenchymal fusion provide a pathway for collateral ventilation to adjacent lobes and can prevent atelectasis of an entirely occluded lobar bronchus.^{3,4}

Despite the demonstrated importance of the pulmonary fissure, it is only recently that investigators have studied their ability to assess the fissure with imaging modalities such as CT. This may in part be because of the limitations of traditional CT. For example, Quint and colleagues⁵ reported poor sensitivity in detecting transfissural tumour extension on contiguous axial CT scans with a slice thickness of 10 mm. Contrary to this, Takahashi and colleagues⁶ demonstrated that with advanced CT scanning techniques with 0.5- to 1-mm collimation and multiplanar reformatting, the interlobar fissure could be consistently visualized as a sharp line. Wei and colleagues⁷ have demonstrated that with such high-resolution CT data 3-dimensional reconstruction of the lungs is possible, allowing for more accurate identification of the pulmonary fissures. Unfortunately, these studies had only radiologic outcomes with no clinical or surgical validation. Despite a lack of significant correlation between our intraoperative and radiologic grading of completeness of the major pulmonary fissure subjectively, we found that the use of multiplanar reformats, often in

the coronal plane, provided us with much clearer images of the pulmonary fissure. On conventional axial CT scans the fissure is typically a blurred white shadow or area of lucency between upper and lower lobes and is considerably more difficult to characterize in any meaningful way. On coronal reformats the fissure generally resolves to a clearly identifiable white line, which can be followed easily from image to image. In fact, the utility of coronal reformats in assessing the completeness of the major pulmonary fissure was one of the surprises of this study. To our knowledge, the use of coronal reformatting as it relates to the identification and characterization of the fissure has not been studied or published elsewhere. As imaging quality and processing continues to improve, it may one day be possible to accurately predict the completeness of the major pulmonary fissure.

With the increasing use of the VATS approach to pulmonary lobectomy, several authors have described a “fissureless” or “no-fissure” technique for anatomic pulmonary lobectomy.^{1,8} In essence, with a fissureless technique, the lobectomy is conducted from a top-down or bottom-up direction, with sequential isolation and endoscopic stapled transection of structures, such as the pulmonary vein, bronchus, pulmonary arterial branches and lung parenchyma, without ever formally dissecting the interlobar pulmonary artery in the fissure. Advocates for this approach cite a reduced rate of postoperative air leak as the key advantage of avoiding dissection in the fissure. It is possible that if fissureless techniques become widely adopted, then the grading of completeness of the major pulmonary fissure would become less important, but at the present time dissection in the interlobar fissure remains a common technique.

This study did not confirm a significant correlation between the intraoperative and radiologic grading of completeness of the major pulmonary fissure as it relates to pulmonary resection. To our knowledge, this relation has not been previously investigated. It is possible that the nonsignificant result in this study relates to our small sample size, a flawed definition of fissure completeness or the wide-ranging image formatting and quality. Further improvements in imaging may allow for better identification and characterization of the pulmonary fissures.

CONCLUSION

We were not able to accurately predict the completeness of the major pulmonary fissure found at the time of surgery based on preoperative CT scans of the chest. Despite a lack of significance, we found that coronal reformatting aided in the identification of the major pulmonary fissure, proximity of tumours to the fissure and pulmonary arterial anatomy as it relates to surgical planning. Future improvements in imaging may permit better characterization of the pulmonary fissures and improve surgical planning.

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