Thoracic Cancer

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Thoracic Cancer ISSN 1759-7706

ORIGINAL ARTICLE

Variations of pulmonary vein drainage critical for lung resection assessed by three-dimensional computed tomography angiography

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Keywords
Anatomy; anomaly; pulmonary vein; three-dimensional CT angiography; video-assisted thoracoscopic surgery.

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Received: 8 January 2018;
Accepted: 6 February 2018.

doi: 10.1111/1759-7714.12621

Thoracic Cancer **9** (2018) 584–588

Abstract

Background: It is important to understand pulmonary vein drainage pattern variations and their frequency in order to perform safe anatomical pulmonary resection.

Methods: Variations and frequencies were assessed using three-dimensional computed tomography angiography (3D-CT) in 194 patients. In cases where the tumor or lymph node caused atelectasis or compression of hilar structures, the involved lobes were excluded from the analyses.

Results: We confirmed variant drainage patterns in 15/189 (8.0%) patients in the right upper lobe (RUL), 29/189 (15.3%) in the right middle lobe (RML), 18/192 (9.5%) in the right lower lobe (RLL), and 5/187 (2.6%) in the left upper lobe (LUL). There was no variant type in the left lower lobe (LLL). There were 14 (7.4%) cases of anomalous superior posterior pulmonary vein of RUL (V^2) drainage: V2 draining to the superior pulmonary vein (SPV) (n = 2, 1.1%), V2 to the inferior pulmonary vein (IPV) (n = 7, 3.7%), V2 to the left atrium (LA) (n = 2, 1.1%), and V^6 to the apical pulmonary vein of the RLL (n = 3, 1.6%). There was a posterior pulmonary vein, V^3 to RML pulmonary vein in one case (0.5%). The RML pulmonary vein drained into the IPV in 14 (7.4%) and into the LA in 15 (7.9%) cases. The right V6 directly drained into the LA in 15 (7.9%) and V^6 into the SPV in 3 (1.6%) cases. The lingular pulmonary vein drained into the IPV in one case (0.5%) and into the LA in two cases (1.1%). The inferior lingular pulmonary vein V^5 drained into the IPV and into the LA in one case (0.5%), respectively.

Conclusion: We describe anomalous pulmonary venous drainage patterns and their frequencies particular to anatomic surgical resection. 3D-CT is useful to find such variations.

Introduction

It is important to understand pulmonary vein variations and frequency in order to perform anatomical pulmonary resections, such as pneumonectomy, lobectomy, and segmentectomy, safely for lung cancer. The anatomy of pulmonary vessel structures is important for thoracic surgery, especially during video-assisted thoracic surgery (VATS), because of the limitation of recognizing three-dimensional structures on a two-dimensional monitor. Human lung anatomy is studied using surgical specimens, cadavers, and two-dimensional images such as chest X-rays and computed tomography (CT).[1] Recently, with advances in CT technology, preoperative evaluation of individual anatomy has been reported.[2,3] Hagiwara *et al.* reported that preoperative 3D-CT evaluation led to shorter surgical duration.[4] They also preoperatively reported anomalous pulmonary veins in five out of 125 cases, with no intraoperative injury to the pulmonary veins. Oizumi *et al.* described the utilities of preoperative 3D-CT for VATS pulmonary segmentectomy after completing the procedure in 98% of 51 consecutive cases without mortality.[5]

Recently, several papers have described variation and frequency of pulmonary artery branching in surgical cases using 3D-CT.[6–8] Previous studies have also reported variations in pulmonary vein drainage.[1] Taking advantage of 3D-CT, Cronin *et al.* and Thorning *et al.* reported pulmonary vein anatomy for abrasion procedures; however, these studies did not address anatomic lung resection.[9,10] In this study, we analyzed the drainage patterns of pulmonary veins to understand the variations and frequencies to plan safe lung resection and avoid pulmonary vein injuries.

Methods

We evaluated the records of 194 patients who underwent anatomic pulmonary resection, including pneumonectomy, lobectomy, bi-lobectomy, and segmentectomy following preoperative 3D-CT at Hokkaido University Hospital between February 2007 and September 2010. In cases that the tumor or involved lymph node caused atelectasis or compression of hilar structures, the involved lobes were excluded from the analyses. Finally, 189 right upper lobes (RULs) and right middle lobes (RML), 192 right lower lobes (RLL), 187 left upper lobes (LUL), and 188 left lower lobes (LLL) were reviewed.

Patients underwent a CT (Aquilion 64; Toshiba, Tokyo, Japan) scan after intravenous administration of an iodinated contrast medium (400 mg I/kg) using a mechanical injector (Dual Shot GX; Nemoto Kyorindo, Tokyo, Japan) to their upper limb for 13 seconds of high pressure and normal saline injected for 25 seconds. Radiological technicians constructed 3D-CT images of the pulmonary vessels and bronchi using four colors (Fig 1a). CT scanning was performed using the following parameters: gantry rotation speed of 0.35 second per rotation, 0.5 mm collimation, 45 helical pitch, tube voltage of 120 kV, and tube current of 300 mA. Axial sections (0.5 mm thickness) were reconstructed at 0.3 mm intervals and transferred to a standalone workstation (Zio Software, Tokyo, Japan).

Two thoracic surgeons independently reviewed each CT image. We recorded each pulmonary vein drainage pattern and classified these into common and variant types. We defined "variant type" as drainage of the segmental or RML pulmonary vein directly into the left atrium (LA), segmental pulmonary veins from the upper lobes or RML into the inferior pulmonary vein (IPV), or segmental pulmonary veins from lower lobes into the superior pulmonary veins (SPV). When there was discrepancy over branching patterns between investigators, the case was again reviewed with 3D-CT and thin slice axial views, and consensus was reached. Pulmonary segments were defined according to the international nomenclature accepted in 1949.[11] The Hokkaido University institutional review board approved this retrospective study.

Results

We confirmed variant drainage patterns of the pulmonary vein in 15/189 (8.0%) RULs, 29/189 (15.3%) RMLs, 18/192 (9.5%) RLLs, and 5/187 (2.6%) LULs. There was no variant type in LLLs. The variant pulmonary vein was much more frequent on the right (32.8%) than the left (2.6%) side.

There were 14 (7.4%) cases of anomalous superior posterior pulmonary vein in the RUL (V^2) drainage (Table 1): V^2 draining to the SPV (n = 2, 1.1%), V^2 to the IPV (n = 7, 3.7%), V^2 to the LA (n = 2, 1.1%), and to the apical pulmonary vein of the RLL (V^6, n = 3, 1.6%) (Fig 1b). There was a V^3 to RML pulmonary vein in one case (0.5%) and a report of anomalous V^2 directly.

In RML, the pulmonary vein drained into the IPV in 14 (7.4%) and into the LA in 15 (7.9%) cases as variant types. Figure 1c shows V^4 and V^5 directly draining into the LA, while Figure 1d shows the intraoperative finding during right lower lobectomy while preserving the pulmonary veins.

In RLL, V^6 directly drained into the LA in 15 (7.9%) and V^6 into the SPV in 3 (1.6%) cases (Fig 1e).

In the LULs, lingular pulmonary veins drained into the IPV in one (0.5%) and into the LA in two (1.1%) cases. The inferior lingular pulmonary veins (V^5) drained into the IPV and into the LA in one case (0.5%), respectively. Figure 1f shows V^5 draining into the IPV.

Table 1 combines our results with data from two articles that reported bilateral pulmonary drainage patterns during pulmonary resection,[12,13] and in a textbook by Yamashita. Yamashita's publication is one of the most read and cited textbooks describing the anatomy of pulmonary segments.[1]

Discussion

In this study, we describe variations of pulmonary vessel drainage patterns assessed by 3D-CT angiography. We reviewed 192 cases and investigated segmental and middle lobe pulmonary veins. The number of variants described here is comparable to previous reports.[1,12,13] However, we detail the drainage points, such as the SPV, IPV, RML pulmonary vein, V^6, and LA, more clearly than in previous studies. Variant types were more common on the right (32.8%) than the left (2.6%) side.

Anomalous drainage of right V^2 occurred in 7.5% of cases. The most frequent site of drainage was the IPV

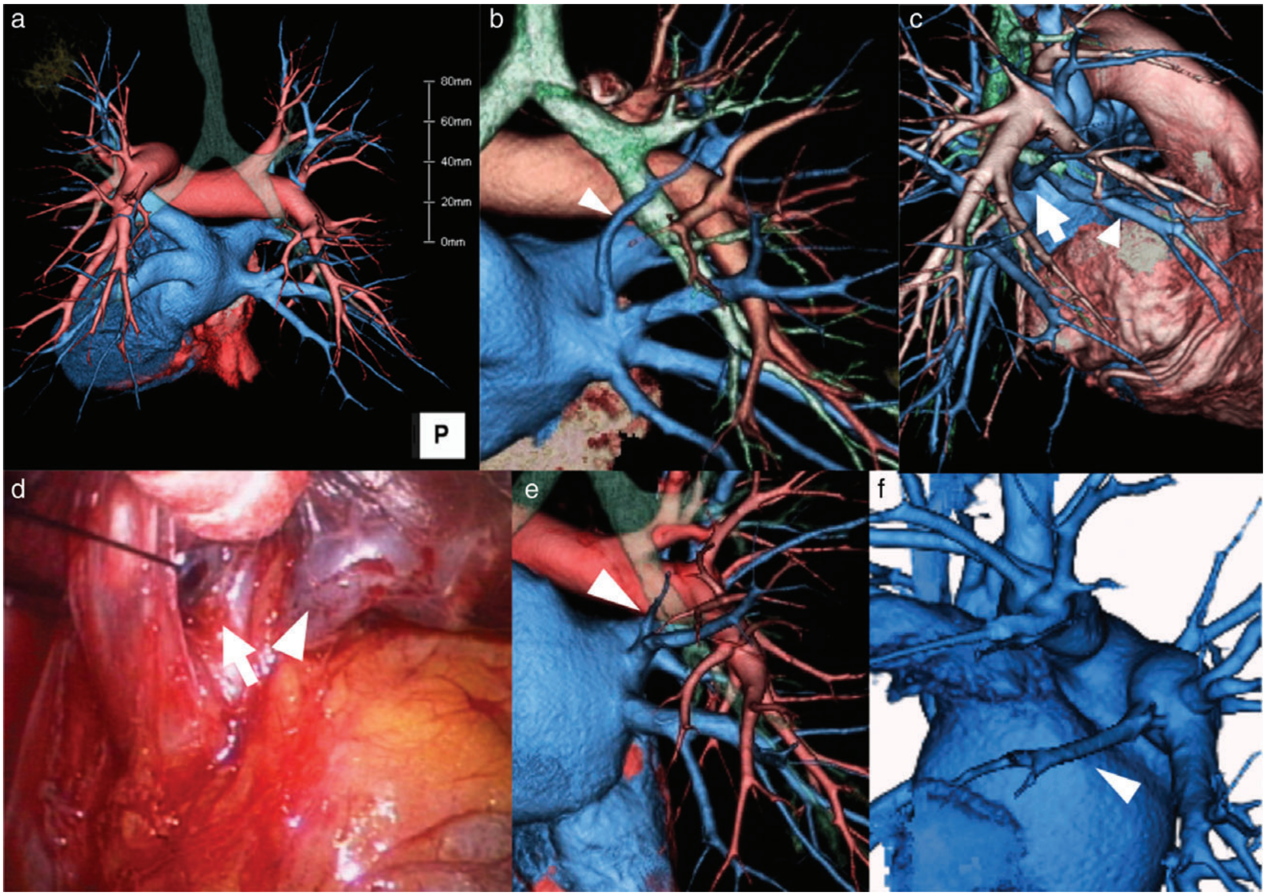

Figure 1 (**a**) Three-dimensional reconstructed computed tomography is shown in four colors: the pulmonary artery is shown in red, the pulmonary vein in blue, the bronchus in green, and a tumor in grey. (**b**) The apical pulmonary vein of the right upper lobe (V^2) drains into the right inferior pulmonary vein (IPV). (**c**) The medial (V^4, white arrow) and the lateral (V^5, white arrowhead) middle lobe pulmonary veins directly drain into the left atrium. (**d**) Intraoperative finding during right lower lobectomy while preserving V^4 (white arrow) and V^5 (white arrowhead). IPV is encircled with a black silk string. (**e**) The right apical pulmonary vein of the right lower lobe, V^6 (white arrowhead), drains into the superior pulmonary vein. (**f**) The lower lingular vein, V^5 drains into the left IPV.

(3.7%), followed by V^6 (1.6%), the LA (1.1%), and the SPV (1.1%). Pulmonary veins must be carefully resected at RULs and should be protected during RLL and/or mediastinal lymph node dissection to avoid injury.

Preservation of an anomalous RML pulmonary vein is essential during both RUL and RLL resection. RML pulmonary vein drainage into the IPV or LA occurs in 15.3% of cases. Surgeons should pay particular attention to avoid injury during RLL resection. The frequency of variants detected in this study is comparable to three previous reports (Table 1). Akiba *et al.* found V4 draining into the IPV on preoperative 3D-CT and reported that they could avoid injury during RLL resection.[14] They also described the preservation of the RML pulmonary vein directly draining into the LV during VATS RLL resection.[15]

Anomalous drainage of the right V^6 occurs in 9.5% of cases. Drainage into the SPV was observed in 1.6% of cases. This rare anomaly was not reported in the three articles we used to compare our results.[1,12,13]

All anomalous pulmonary vein drainages involved the lingular pulmonary veins (2.6%). The inferior branch of the lingular pulmonary vein (V^5) is more likely to drain into the LA, followed by the IPV. The frequency of this anomaly in our study is consistent with previous reports.[12] These anomalies are significant during LLL resection. Akiba *et al.* reported successful VATS LUL resection by recognizing anomalous left V^5 drainage into the IPV detected by preoperative 3D-CT.[16] Aragaki *et al.* reported preoperative recognition of the left V^2 draining into V^6 on 3D-CT and the successful preservation of the V^5 during VATS LLL resection.[17] Ishikawa *et al.* reported left V^2 draining into the IPV and performed LUL resection with successful dissection of the V^2 during thoracotomy.[18] This V^2 variant was not found in our study.

Table 1 Segmental or middle lobe pulmonary veins with anomalous drainage

Lobes (*n*)	Pulmonary veins	Drainage points	This study Number of variants	%	Yamashita[1] %	Akiba *et al.*[12] %	Fourdrain *et al.*[13] %
RUL (189)			15	8.0			
	V^2	SPV	2	1.1			
		IPV	7	3.7	2.4		
		V6	3	1.6			
		LA	2	1.1			
	V^3	RMLV	1	0.5	18.2		
RML (189)			29	15.3	6.0	13.5	9.0
		IPV	14	7.4	6.0	5.6	5.0
		LA	15	7.9		7.9	4.0
RLL (192)			18	9.5			
	V^6	SPV	3	1.6			
	V^6	LA	15	7.9			
LUL (187)			5	2.6		2.5	11.0
	Lingular	IPV	1	0.5			1.0
		LA	2	1.1			10.0
	V^5	IPV	1	0.5			
		LA	1	0.5			
LLL (188)			0	0.0		1.7	

IPV, Inferior pulmonary vein; LA, left atrium; LLL, left lower lobe; LUL, left upper lobe; RLL, right lower lobe; RML, right middle lobe; SPV, superior pulmonary vein; V^2, posterior pulmonary vein of the upper lobe; V^3, anterior pulmonary of the upper lobe; V^5, inferior lingular pulmonary vein; V^6, apical pulmonary vein of the lower lobe.

There was no variant type in LLL in our series. Akiba *et al.* also did not report any anomalous IPV among their 121 cases.[12] The variant of the left IPV seems to be relatively rare.

We described anomalous pulmonary venous drainage patterns and their frequencies, particularly in regard to anatomic surgical resection. Three-dimensional CT is useful to find such variations.

Disclosure

No authors report any conflict of interest.

References

1 Yamashita H. Variations in the Pulmonary Segments and the Bronchovascular Trees. In: Yamashita H (ed). *Roentgenologic Anatomy of the Lung*. Igaku-shoin, Tokyo 1978; 70–107.

2 Watanabe S, Arai K, Watanabe T, Koda W, Urayama H. Use of three-dimensional computed tomographic angiography of pulmonary vessels for lung resections. *Ann Thorac Surg* 2003; **75**: 388–92.

3 Akiba T, Marushima H, Harada J, Kobayashi S, Morikawa T. Importance of preoperative imaging with 64-row three-dimensional multidetector computed tomography for safer video-assisted thoracic surgery in lung cancer. *Surg Today* 2009; **39**: 844–7.

4 Hagiwara M, Shimada Y, Kato Y et al. High-quality 3-dimensional image simulation for pulmonary lobectomy and segmentectomy: Results of preoperative assessment of pulmonary vessels and short-term surgical outcomes in consecutive patients undergoing video-assisted thoracic surgery. *Eur J Cardiothorac Surg* 2014;**46**(6):e120–6.

5 Oizumi H, Kanauchi N, Kato H et al. Anatomic thoracoscopic pulmonary segmentectomy under 3-dimensional multidetector computed tomography simulation: A report of 52 consecutive cases. *J Thorac Cardiovasc Surg* 2011;**141**:678–82.

6 Subotich D, Mandarich D, Milisavljevich M, Filipovich B, Nikolich V. Variations of pulmonary vessels: Some practical implications for lung resections. *Clin Anat* 2009; **22**: 698–705.

7 Sivrikoz MC, Tulay CM. Variations of lobar branches of pulmonary arteries in thoracic surgery patients. *Surg Radiol Anat* 2011; **33**: 509–14.

8 Fourdrain A, De Dominicis F, Blanchard C *et al*. Three-dimensional CT angiography of anatomic variations in the pulmonary arterial tree. *Surg Radiol Anat* 2018; **40**: 45–53.

9 Cronin P, Kelly AM, Desjardins B et al. Normative analysis of pulmonary vein drainage patterns on multidetector CT with measurements of pulmonary vein ostial diameter and distance to first bifurcation. *Acad Radiol* 2007;**14**:178–88.

10 Thorning C, Hamady M, Liaw JV *et al*. CT evaluation of pulmonary venous anatomy variation in patients undergoing catheter ablation for atrial fibrillation. *Clin Imaging* 2011; **35**: 1–9.

11 NOMENCLATURE of broncho-pulmonary anatomy; an international nomenclature accepted by the Thoracic Society. *Thorax* 1950; **5**: 222–8.

12 Akiba T, Marushima H, Odaka M, Harada J, Kobayashi S, Morikawa T. Pulmonary vein analysis using three-

dimensional computed tomography angiography for thoracic surgery. *Gen Thorac Cardiovasc Surg* 2010; **58**: 331–5.

13 Fourdrain A, De Dominicis F, Bensussan M *et al*. Three-dimensional computed tomography angiography of the pulmonary veins and their anatomical variations: Involvement in video-assisted thoracoscopic surgery-lobectomy for lung cancer. *Folia Morphol* 2017; **76**: 388–93.

14 Akiba T, Marushima H, Harada J, Kobayashi S, Morikawa T. Anomalous pulmonary vein detected using three-dimensional computed tomography in a patient with lung cancer undergoing thoracoscopic lobectomy. *Gen Thorac Cardiovasc Surg* 2008; **56**: 413–6.

15 Akiba T, Tabei I, Kinoshita S et al. Three-dimensional computed tomography for lung cancer in a patient with three right vein ostia. *Gen Thorac Cardiovasc Surg* 2011;**59**:376–9.

16 Akiba T, Marushima H, Morikawa T. Confirmation of a variant lingular vein anatomy during thoracoscopic surgery. *Ann Thorac Cardiovasc Surg* 2010; **16**: 351–3.

17 Aragaki M, Iimura Y, Yoshida Y, Hasegawa N. Anomalous V^2 of the left pulmonary vein detected using three-dimensional computed tomography in a patient with lung cancer: A case report. *Int J Surg Case Rep* 2017; **37**: 208–10.

18 Ishikawa Y, Iwano S, Usami N, Yokoi K. An anomalous segmental vein of the left upper lobe of the lung: Preoperative identification by three-dimensional computed tomography pulmonary angiography. *Interact Cardiovasc Thorac Surg* 2012; **15**: 512–3.

