J Anesth (2009) 23:260–265
DOI 10.1007/s00540-008-0716-1

Journal of
Anesthesia



*Clinical reports*

# Three-dimensional CT image analysis of a tracheal bronchus in a patient undergoing cardiac surgery with one-lung ventilation

Tatsushige Iwamoto[1], Yoshihiro Takasugi[1], Kenji Hiramatsu[1], Yoshihisa Koga[1], Tatsuo Konishi[3], Kensuke Kozuka[2], and Takamichi Murakami[2]

[1] Department of Anesthesiology, Kinki University School of Medicine, 377-2 Ohno-higashi, Osaka-sayama 589-8511, Japan
[2] Department of Radiology, Kinki University School of Medicine, Osaka, Japan
[3] Department of Radiology, Kinki University Hospital, Osaka, Japan

**Abstract**
The incidence of a tracheal bronchus—that is, a congenitally abnormal bronchus originating from the trachea or main bronchi—is 0.1%–2%. Serious hypoxia and atelectasis can develop in such patients with intubation and one-lung ventilation. We experienced a remarkable decrease in peripheral oxygen saturation ($S_{PO_2}$) and a rise in airway pressure during placement of a double-lumen endobronchial tube in a patient with patent ductus arteriosus and tracheal bronchus. Substitution of the double-lumen tube with a bronchial blocker tube provided secure isolation of the lung intraoperatively. A type I tracheal bronchus and segmental tracheal stenosis were identified on postoperative three-dimensional (3D) computed tomographic (CT) images. Preoperative examination of chest X-rays, CT images, and preoperative tracheal 3D images should preempt such complications and assist in securing safe and optimal one-lung ventilation.

**Key words** Tracheal bronchus · Three-dimensional computed tomography · One-lung ventilation · Tracheal stenosis · Congenital heart disease

## Introduction

A tracheal bronchus is an aberrant or accessory bronchus originating from the trachea rather than at the carina [1]. Although the reported incidence of the condition is very low, approximately 0.1%–2% [2], right upper-lobe atelectasis and hypoxemia can develop when a tracheal tube obstructs or migrates into a tracheal bronchus [3,4]. Furthermore, difficulty with isolation of the lung with a bronchial blocker tube or double-lumen tube (DLT) has been described previously in a patient with a tracheal bronchus [5,6]. We report a patient with a tracheal bronchus that was detected during attempts at lung isolation with a DLT, and that was classified as a type I tracheal bronchus, according to Conacher's classification [7] by analysis of postoperative three-dimensional (3D) image reconstruction.

*Address correspondence to*: T. Iwamoto
Received: August 28, 2008 / Accepted: November 6, 2008

## Case report

A 51-year-old woman with patent ductus arteriosus (PDA) was scheduled to undergo closure of the persistent connection. She had previously undergone an ovariectomy at the age of 39 and a mastectomy and subtotal thyroidectomy at the age of 50, under general anesthesia using a standard endotracheal tube, without any respiratory complications. An abnormal ECG was pointed out in preoperative assessment at the age of 50, and PDA with a left-to-right shunt (QP/QS = 1.5) was diagnosed using ultrasonic cardiograms. During preoperative assessment, auscultation of the chest demonstrated normal breath sounds, and arterial blood gas analysis indicated normal blood gas values. Preoperative chest X-ray was unremarkable (Fig. 1).

Surgical access was planned through a left lateral thoracotomy. In the operating room, anesthesia was induced with fentanyl, propofol, and vecuronium. A flexible fiberoptic bronchoscope was utilized as a guide to placement of a 35-Fr DLT (Blue Line Endobroncheal Tube (Left); Smiths Medical Japan, Aichi, Japan) into the trachea. Because the endobronchial limb of the 35-Fr DLT could not be inserted into the left bronchus, a 32-Fr DLT was substituted and the bronchial cuff inflated. Immediately after left bronchial blockage, end-inspiratory pressure rose to 30 $cmH_2O$ and $S_{PO_2}$ fell to 80%, while tidal volume was reduced to 100 ml. Suspecting a morphologic abnormality of the trachea or bronchus, we reassessed the divergence of the bronchus with fiberoptic bronchoscopy and observed the preoperative CT images for cardiovascular volume rendering (Fig. 2a–c). We noted a tracheal bronchus approxi-

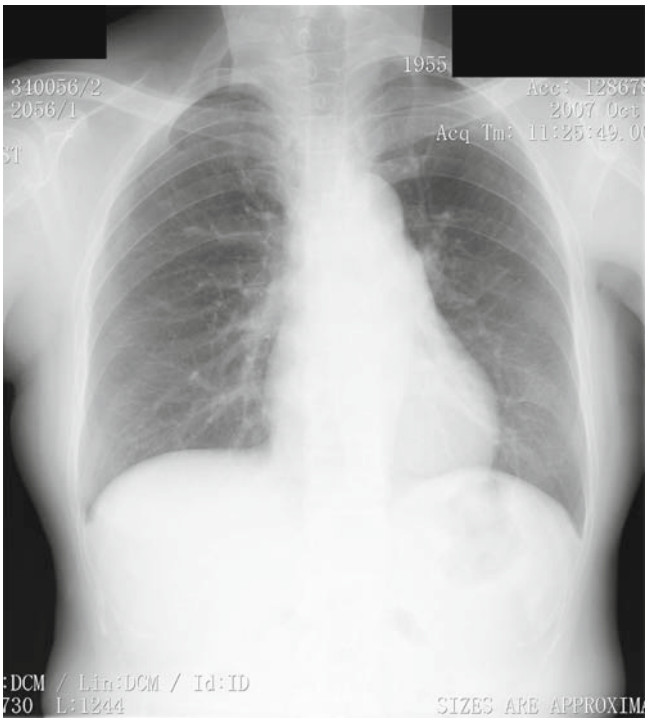


**Fig. 1.** Preoperative chest X-ray could not detect the tracheal bronchus owing to overlap with the mediastinal shadow

mately 3 cm proximal to the carina with notable narrowing of the trachea between the tracheal bronchus and the carina. The DLT was replaced by a bronchial blocker tube (COOPDECH Endobronchial Blockertube; Daiken Medical, Osaka, Japan), and isolation of the lung with insertion of the bronchial blocker into the left main stem bronchus was successfully achieved. Thereafter, surgery proceeded uneventfully under one-lung ventilation (OLV). At the end of the operation, a standard endotracheal tube was inserted in place of the bronchial blocker tube. After chest X-ray exclusion of atelectasis in all lobes, the patient was transferred to the intensive care unit with the standard tube in situ. Her trachea was extubated without incident 12 h after her arrival in the intensive care unit.

### 3D Image reconstruction analysis

On the third postoperative day, CT images for 3D reconstruction of the tracheobronchus were taken from the patient. In the anterior view, 3D images of the trachea demonstrated that the right upper-lobe bronchus (tracheal bronchus) originated from the right aspect of the trachea, 2.7 cm proximal to the carina, with segmental tracheal stenosis that was comparable in size to that of the tracheal bronchus (Fig. 3a). The posterior image showed that the tracheal bronchus arched over the main pulmonary artery, being located in front of the segmental tracheal stenosis, with the right pulmonary arteries and veins lying between the tracheal bronchus and the right intermediate bronchus (Fig. 3b). In the virtual bronchoscopic view of the trachea, the trachea was narrower than the tracheal bronchus at the level of the upper tracheal bifurcation, while the left main bronchus and the right intermediate bronchus were comparable in size at the level of the carina (Fig. 4a, b).

## Discussion

We encountered a case of unsuspected tracheal bronchus while attempting to provide OLV in a patient undergoing surgical correction of PDA. In our patient, the bifurcation at the level of the tracheal bronchus was misdiagnosed as occurring at the carina by fiberoptic bronchoscopy, such that blockage of the trachea by the DLT caused ventilatory impairment. Postoperative 3D image analysis identified the upper tracheal bifurcation as type I according to Conacher's classification (Fig. 5) [7].

Most tracheobronchial variations are seen in the upper lobes, upper-lobe abnormalities accounting for approximately 70% of such anomalies [2]. Further, Huntington [8] observed that right-sided anomalies were more common, and postulated that the reason for this is that the left upper lobe is isolated from the left main bronchus by the aortic arch and the left subclavian artery, while the azygos vein and mediastinal pleura are all that separate the right upper lobe and right main bronchus.

Although the reported morbidity of tracheal anomalies in patients without congenital heart disease is only 0.29% [9], the morbidity of tracheobronchial anomalies in patients with congenital heart diseases ranges from 3.74% to 12.85% [9,10]. Kairamkonde et al. [11] and Fowler et al. [12] have reported that the tracheal bronchus develops during the embryonal stage and hence is often associated with congenital cardiac anomalies of structures that develop during the same embryonic stage of development. The 3D images of our patient with PDA showed segmental tracheal stenosis adjacent to the dorsal border of the right main pulmonary artery. Chen et al. [9] reported that the incidence of tracheal stenosis in association with right upper-lobe tracheal bronchus was 31%, and the overall incidence of tracheal stenosis in patients with congenital tracheobronchial anomalies was 11.2%. Patients with congenital heart disease with abnormally enlarged vascular structures, due to high pulmonary artery pressure or high left atrial pressure, can develop extrinsic airway compression [13,14]. Conacher [7] reported cases of

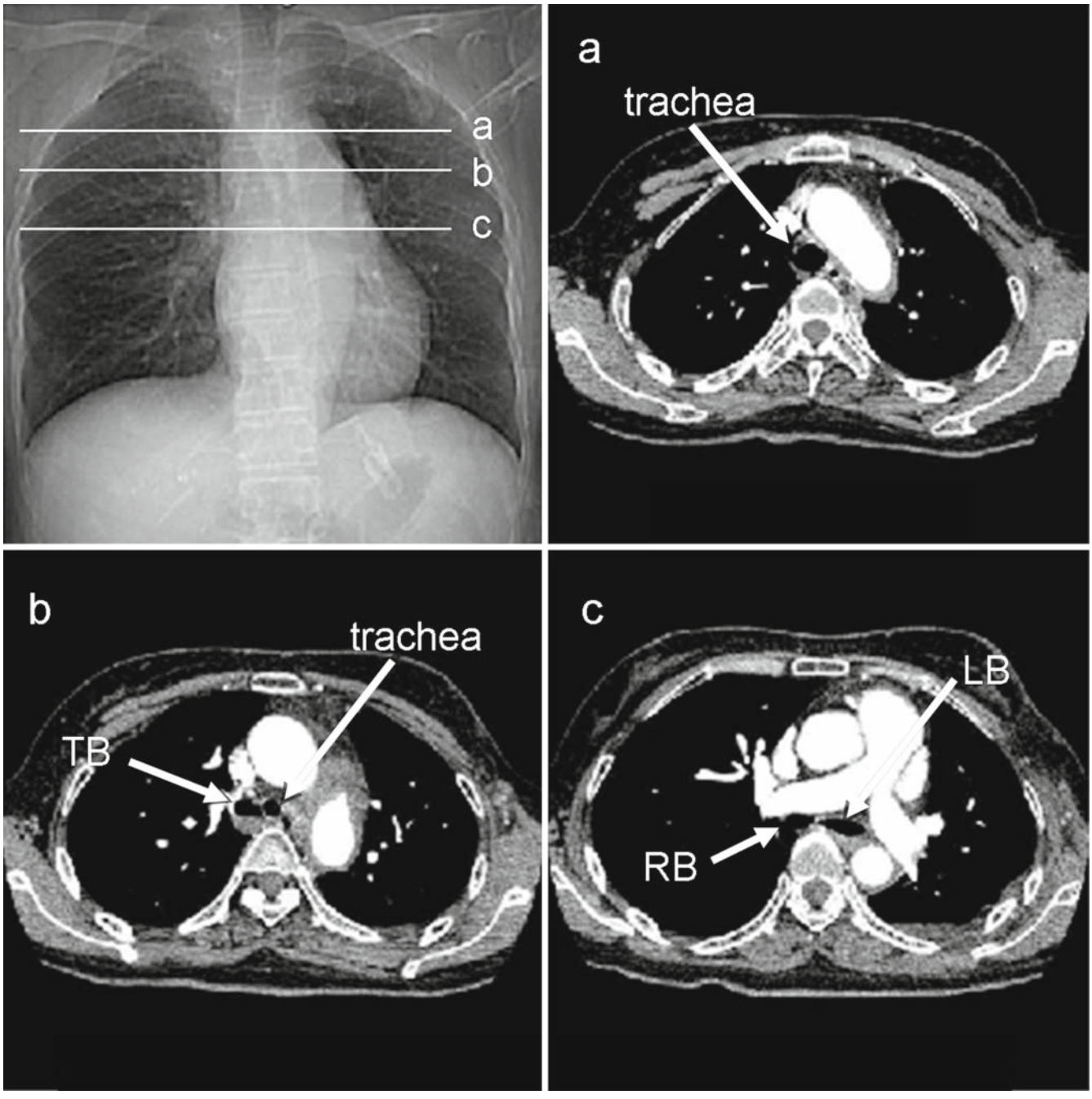


**Fig. 2a–c.** Preoperative plain chest computed tomography (CT) images at levels of the upper trachea (**a**), tracheal bronchus (**b**), and carina (**c**). *TB*, Tracheal bronchus; *LB*, left main bronchus; *RB*, right intermediate bronchus

type I tracheal bronchus, right tracheal bronchus, and tracheal stenosis in patients with PDA. We speculate that the remarkable segmental tracheal stenosis in our patient was aggravated by extrinsic airway compression due to pulmonary hypertension following PDA.

A tracheal bronchus can arise anywhere between the carina and cricoid cartilage [15], but is usually within 2 cm of the carina [2] and up to 6 cm from the carina [16,17]. An upper-lobe bronchus (type II) can be potentially obstructed by an endotracheal tube, resulting in atelectasis and shunting [7]. Because the distance from the carina to the tip of the endotracheal tube in our patient was not longer than that in the average Japanese patient receiving orotracheal intubation (28 ± 15 mm [mean ± SD]) [18], endotracheal intubation could be easily performed in our patient during her previous surgeries without any respiratory complications. However, isolation of the left lung with the DLT could not be

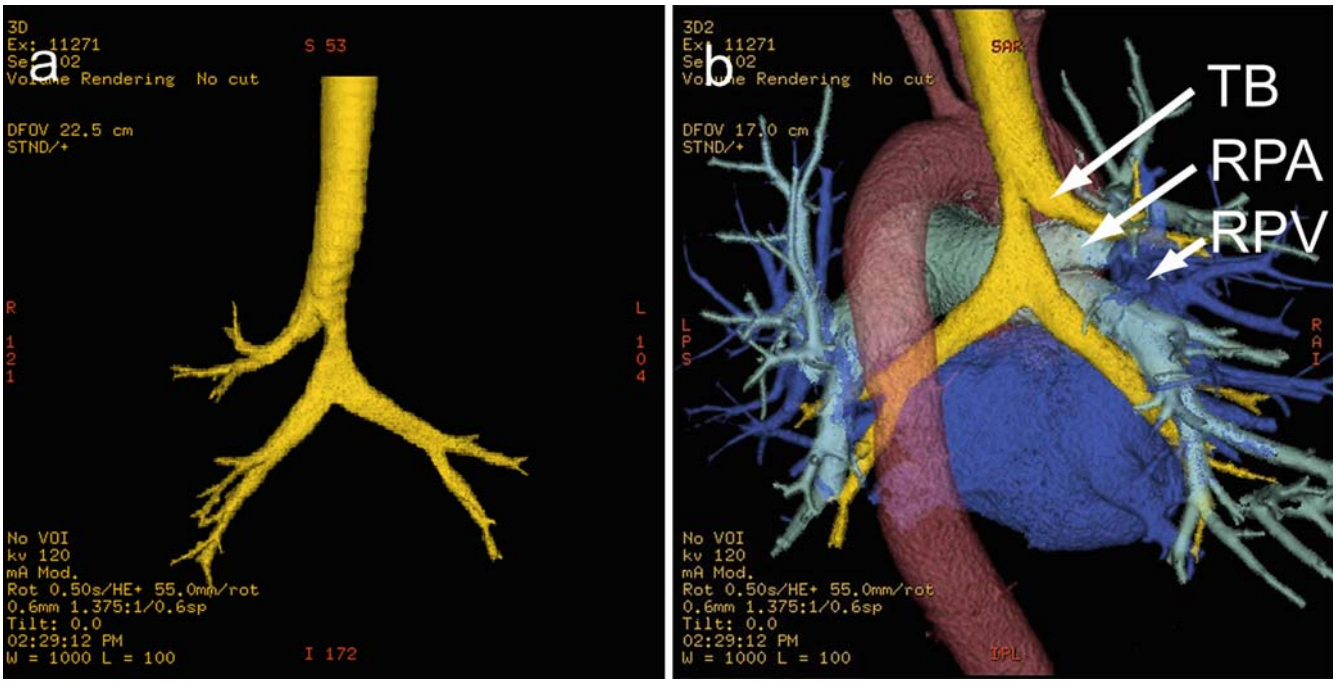


**Fig. 3a,b.** Postoperative three-dimensional (3D) reconstruction of the tracheobronchus. The tracheal bronchus originated from the right aspect of the trachea, 2.7 cm proximal to the carina, with segmental tracheal stenosis (**a**). The tracheal bronchus arched over the main pulmonary artery, being located in front of the segmental tracheal stenosis, with the right pulmonary arteries and veins lying between the tracheal bronchus and the right intermediate bronchus (**b**). *TB*, Tracheal bronchus; *RPA*, right pulmonary artery; *RPV*, right pulmonary vein

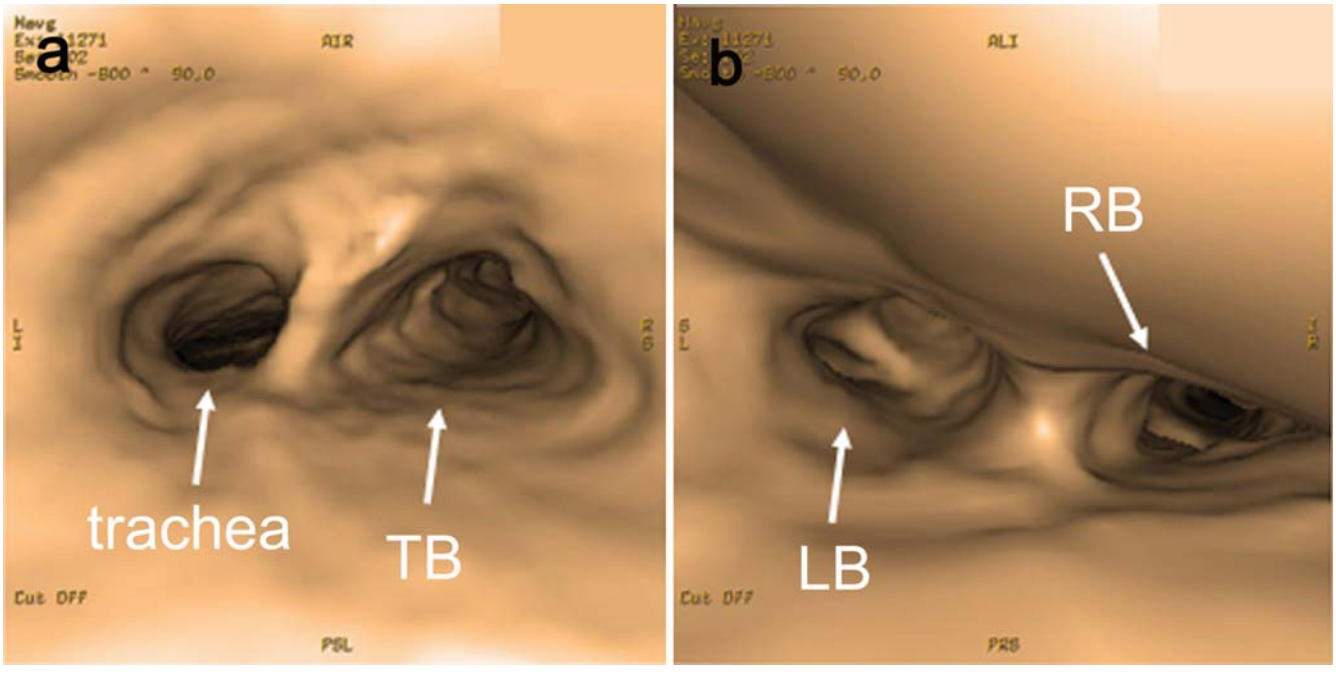


**Fig. 4a,b.** Virtual bronchoscopy at the levels of the upper tracheal bifurcation (**a**) and the carina (**b**). The sizes of the orifices of the trachea and tracheal bronchus were 8 × 5.6 mm and 7.1 × 10.3 mm, respectively, and those of the left main bronchus and right intermediate bronchus were 12.6 × 14 mm and 15.2 × 4.4 mm, respectively. *TB*, Tracheal bronchus; *LB*, left main bronchus; *RB*, right intermediate bronchus

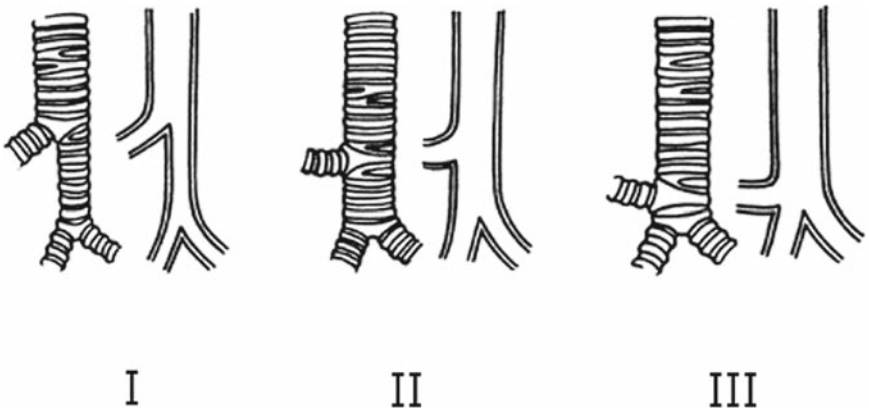


**Fig. 5.** Schematic representation of the three types of tracheal bronchus. Type *I*, Right tracheal bronchus and tracheal stenosis; type *II*, supernumerary right upper-lobe tracheal bronchus; type *III*, displaced right upper-lobe tracheal bronchus as tracheal trifurcation. Reprinted from Conacher [7], with permission from Oxford University Press

performed due to the ectopic bifurcation and segmental tracheal stenosis up to the carina. Bronchial blockers are reportedly available for OLV in patients with type I tracheal bronchus [7]. We adopted a bronchial blocker tube for OLV in our patient owing to her type I tracheal bronchus and the segmental tracheal stenosis resulting in an inability to ventilate the right lung using a DLT.

Anesthesia in patients with tracheal bronchus is associated with a greater risk of atelectasis or hypoxia, especially when OLV is used. Although symptomatic anomalous bronchi have been reported in the literature [19,20], many patients with bronchial anomalies are asymptomatic [2]. Hence, the preoperative identification of anomalies of the bronchial tree is of critical importance in such patients. In general, the diagnosis of tracheobronchial anomalies can be made with bronchoscopy or with imaging studies. Although it is reported that careful preoperative observation of chest X-rays can identify a tracheal bronchus [7,21], the difficulty in diagnosis arises when the tracheal bronchus overlaps the mediastinal shadow on the chest X-ray, as occurred in our patient. Tracheal bronchus is well diagnosed with chest CT [2,9,10,15,22]. Spiral CT has especially broadened the potential of the imaging of lung anatomy by offering various reformation techniques, including multiplanar reconstruction, 3D reconstruction, shaded-surface display, and virtual bronchoscopy [2]. Preoperative tracheal 3D images allow for an accurate definition of the airway and can demonstrate the anatomy of lesions such as tracheal bronchus, tracheobronchial stenosis, and distortion of the trachea with respect to other mediastinal organs and great vessels [23]. Because chest CT images are taken preoperatively in most patients undergoing surgeries that require lung isolation, the preoperative CT images should be scrutinized to exclude possible tracheobronchial anomalies in patients with congenital heart disease.

Airway difficulty may not appear when an endotracheal tube is placed proximal to a tracheal bronchus; however, once the endotracheal tube is advanced farther into the trachea, airway obstruction and further complications could occur [20]. An understanding of congenital bronchial abnormalities may have important implications for respiratory management during anesthesia, and careful preoperative examination of chest X-rays and CT images, and the use of preoperative tracheal 3D images should facilitate securing of the airway and provide optimal OLV.

## References

1. Doolittle AM, Mair EA. Tracheal bronchus: classification, endoscopic analysis, and airway management. Otolaryngol Head Neck Surg. 2002;126:240–3.
2. Ghaye B, Szapiro D, Fanchamps JM, Dondelinger RF. Congenital bronchial abnormalities revisited. Radiographics. 2001;21: 105–19.
3. Pribble CG, Dean JM. An unusual cause of intraoperative hypoxemia. J Clin Anesth. 1994;6:247–9.
4. Vredevoe LA, Brechner T, Moy P. Obstruction of anomalous tracheal bronchus with endotracheal intubation. Anesthesiology. 1981;55:581–3.
5. Peragallo RA, Swenson JD. Congenital tracheal bronchus: the inability to isolate the right lung with a univent bronchial blocker tube. Anesth Analg. 2000;91:300–1.
6. Brodsky JB, Mark JB. Bilateral upper lobe obstruction from a single double-lumen tube. Anesthesiology. 1991;74:1163–4.
7. Conacher ID. Implications of a tracheal bronchus for adult anaesthetic practice. Br J Anaesth. 2000;85:317–20.
8. Huntington GS. Critique of theories of pulmonary evolution in mammalia. Am J Anat. 1920;27:99–201.
9. Chen SJ, Lee WJ, Wang JK, Wu MH, Chang CI, Liu KL, Chiu IS, Chen HY, Su CT, Li YW. Usefulness of three-dimensional electron beam computed tomography for evaluating tracheobronchial anomalies in children with congenital heart disease. Am J Cardiol. 2003;92:483–6
10. Ming Z, Lin Z. Evaluation of tracheal bronchus in Chinese children using multidetector CT. Pediatr Radiol. 2007;37:1230–4.
11. Kairamkonda V, Thorburn K, Sarginson R. Tracheal bronchus associated with VACTERL. Eur J Pediatr. 2003;162:165–7.
12. Fowler CL, Pokorny WJ, Wagner ML, Kessler MS. Review of bronchopulmonary foregut malformations. J Pediatr Surg. 1988; 23:793–7.
13. Donnelly LF, Strife JL, Bailey WW. Extrinsic airway compression secondary to pulmonary arterial conduits: MR findings. Pediatr Radiol. 1997;27:268–70.

14. Dailey ME, O'Laughlin MP, Smith RJ. Airway compression secondary to left atrial enlargement and increased pulmonary artery pressure. Int J Pediatr Otorhinolaryngol. 1990;19:33–44.
15. Wong DT, Kumar A. Case report: endotracheal tube malposition in a patient with a tracheal bronchus. Can J Anaesth. 2006;53: 810–3.
16. Siegel MJ, Shackelford GD, Francis RS, McAlister WH. Tracheal bronchus. Radiology. 1979;130:353–5.
17. Gerson CE, Rothstein E. An anomalous tracheal bronchus to the right upper lobe. Am Rev Tuberc. 1951;64:686–90.
18. Inada T, Uesugi F, Kawachi S, Takubo K. Changes in tracheal tube position during laparoscopic cholecystectomy. Anaesthesia. 1996;51:823–6.
19. Lee HL, Ho AC, Cheng RK, Shyr MH. Successful one-lung ventilation in a patient with aberrant tracheal bronchus. Anesth Analg. 2002;95:492–3.
20. Middleton RM, Littleton JT, Brickey DA, Picone AL. Obstructed tracheal bronchus as a cause of post-obstructive pneumonia. J Thorac Imaging. 1995;10:223–4.
21. O'Sullivan BP, Frassica JJ, Rayder SM. Tracheal bronchus: a cause of prolonged atelectasis in intubated children. Chest. 1998;113:537–40.
22. Ikeno S, Mitsuhata H, Saito K, Hirabayashi Y, Akazawa S, Kasuda H, Shimizu R. Airway management for patients with a tracheal bronchus. Br J Anaesth. 1996;76:573–5.
23. Newell JD, Thomas HM, Maurer JW. Computed tomographic demonstration of displaced right upper lobe bronchus in an adult woman with congenital heart disease. J Comput Tomogr. 1984;8:75–9.