Tracheobronchial variations evaluated by multidetector computed tomography and virtual bronchoscopy

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Abstract

Introduction
The tracheobronchial tree exhibits a wide range of variations. The purpose of this study is the investigation of the frequency and multidetector tomographic (MDCT) findings of anatomical variations of the main bronchi and of the lobar bronchi, as well as the detection of abnormal bronchi originating from the trachea, in subjects without severe bronchial pathology.

Materials and methods
About 872 consecutive patients who underwent thoracic MDCT examination were enrolled in the study. All MDCT data, including multiplanar reconstructions, maximum intensity projections and volume-rendered images, as well as virtual bronchoscopy, were evaluated for the detection of main bronchial variations. Various kinds of bronchial variations and anomalies, such as tracheal bronchi, accessory cardiac bronchi, bronchus hypoplasia and bronchial origin anomalies, were documented.

Results
In 872 subjects, the overall frequency of main bronchus variations is 2.52% (22/872). More specifically, tracheal bronchi were found in eight cases (0.9%), accessory cardiac bronchi was found in one case (0.1%), hypoplasia was found in one case (0.1%) and bronchial origin anomalies were found in 10 cases (1.14%).

Conclusion
The display of tracheobronchial variations is of clinical importance first because they are related to infections and, sometimes, malignancies and second in preoperative or in cases of bronchoscopic procedures. In our study, the commonest variation was the tracheal bronchus. MDCT and virtual bronchoscopy can depict tracheobronchial variations accurately and can be served as an alternative to bronchoscopy in certain cases of possible bronchial anomaly.

Introduction
Tracheobronchial tree variations (TBVs) are a rare clinical entity including anomalies of the main bronchus or abnormal bronchi originating from the trachea and anatomic variations of the lobar, segmental and subsegmental bronchi. The most common main bronchus anomalies are the tracheal bronchi and the accessory cardiac bronchi. Other bronchial anomalies include displaced or supernumerary segmental bronchi and bronchial agenesis.

Recognition and reporting of the TBV is important, as they are associated with clinical complications, such as episodes of infection, hemoptysis and perhaps malignancies in a small percentage of patients.1

Multidetector computed tomography (MDCT) with multiplanar reconstructions (MPRs) provides a precise investigation of the lung and the tracheobronchial tree.2 Computed tomography (CT) virtual bronchoscopy (VB) is a three-dimensional (3D) technique that is used as an adjunct to MDCT because it provides endobronchial evaluation of the tracheobronchial tree.

In this study, we present our experience on congenital bronchial anomalies concerning the main lobe bronchi in adults with no acquired deformity of the tracheobronchial tree, their MDCT and VB findings, and discuss the most common variation at our study population.

Materials and methods
This work conforms to the values laid down in the Declaration of Helsinki (1964). The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed. All subjects gave full informed consent to participate in this study.

Patient population
Over a 1-year period, 872 consecutive patients (521 men and 351 women; age range, 20–78 years; mean age, 54 years) who underwent thorax MDCT examination were evaluated for detection of bronchial variations and anomalies. Indications for thorax MDCT examinations were the evaluation of lung opacities detected on chest radiography, the investigation of primary lung tumours or vascular and airway pathologies, the follow-up of known pulmonary lesions and the follow-up of primary tumours anywhere else but the lung. Exclusion criteria were major surgical procedures that alter the bronchial anatomy or severe bronchial pathology.

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pathology that prevent the accurate bronchial detection.

**MDCT protocol**
CT imaging was performed on a 16-row multidetector scanner (Aquilion 16, Toshiba Medical Systems, Otawara, Japan). All patients were scanned in the supine position using a breath-hold technique. Scanning parameters were as follows: 120 kVp, 60–90 mAs, 0.5 gantry rotation time, pitch 0.9, scan slice thickness 1 mm × 16, reconstructed at 1 mm, average scan time 15 s. An automatic power injection was used to administer intravenously a 100 ml bolus of 300 mg/ml nonionic iodinated contrast material at a rate of 3.2–3.5 ml/s. The scan was acquired 30 s after the initiation of the injection (arterial phase).

**Image analysis**
Post-processing of the data was performed on a dedicated diagnostic workstation (Vitrea, Toshiba Medical Systems, Otawara, Japan). In all subjects, axial, sagittal, coronal MPRs, minimal and maximum intensity projection (MinIP, MIP) images were obtained. In addition, volume-rendered (VR) images were created with the opacity curve manipulated to remove all structures but the lung–air interface. Two radiologists evaluated all images at the same time in consensus for the presence of tracheal and bronchial anatomic anomalies and variations. Also, anatomic variations were demonstrated by CT VB.

**Results**
In our study, 22 cases (2.52%) with TBVs were identified. Fourteen of these (70%) were detected in males and eight (30%) were detected in females. TBVs were more frequent at the right bronchus (19/22, 86.3%).

Eight cases (0.9%) had tracheal bronchus. All of them were defined as right pre-eparterial. In three cases, the right pre-eparterial bronchi were arising from the junction between the trachea and carina, while in the remaining cases they were arising from the right main bronchus (Figure 1). In five cases, the bronchi were of the displaced type, and in three cases they were of the super-numerary type (Figure 2).

In one case, right accessory cardiac bronchus was found (0.1%) (Figure 3) and in another case hypoplastic right upper lobe bronchus (0.1%) was seen (Figure 4). Four cases were found (0.45%) with common origin of the right upper and middle lobe bronchus, two cases (0.22%) with origin of the right middle lobe bronchus from the right lower lobe bronchus and three cases with aplasia of the right middle lobe bronchus (0.34%) (Figure 4). In four cases (0.45%), the origin of the left lingual lobe bronchus was from the left lower lobe bronchus.

**Discussion**
In large bronchoscopic studies, anatomical variations of the tracheobronchial system are reported as 1–12%. Knowledge of tracheobronchial anatomy is of importance in cases of bronchoscopic processes, pulmonary surgery, intubation or other interventional procedures. TBVs may be associated with other abnormalities or clinical symptoms and may require interventional procedures. TBVs are demonstrated in large series by bronchscopy. To our knowledge, there are a number of studies involving the final manuscript.

All authors contributed to conception and design, data collection, analysis and interpretation, and approved the final manuscript.

All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

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Figure 2: Different types of tracheal bronchus. (a) Virtual bronchoscopy (VB) image shows displaced right tracheal bronchus (arrow). The right upper lobe bronchus splits into two segmental bronchus (asterisks) and one branch of the upper lobe bronchus is missing. (b) Coronal MPR shows a supernumerary right tracheal bronchus (arrow). The right upper lobe bronchus normally splits into three segmental bronchus.

Figure 3: Coronal MPR shows right accessory cardiac bronchus (arrow).

Although anatomical variations of the lobar and subsegmental bronchi are relatively common, anomalies of the main bronchus or abnormal bronchi originated from the trachea are rare. The most common main bronchus anomalies are the tracheal bronchus and the accessory cardiac bronchus which are of clinical importance as they may predispose to infections and, in some cases, to malignancies. In our study, we evaluated the anomalies of the main bronchus down to the lobar segment.

MDCT has become a very useful tool in the precise investigation of the lung, mainly because of the small slice thickness and the ability of performing various post-processing and reformation techniques. By using MDCT, the imaging of the trachea and bronchus is very sufficient down to the subsegmental level. Reforma

using MDCT and bronchoscopy showing cases of congenital tracheobronchial anomalies and two imaging studies that evaluated the congenital tracheobronchial anomalies in relatively small series of patients using MDCT. In our study, we evaluate the incidence and the demonstration of congenital tracheobronchial anatomical variation of the main bronchus by MDCT and CT bronchoscopy in a large series of 872 patients.

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Tracheobronchial system, and it can be used preoperatively. The operative field can be visualized before surgery, any anatomic variant can be seen and the relation between the bronchus and vessels can be detected.

In our study, the most common variation was the presence of right pre-eparterial tracheal bronchus (0.9%). Also, variations were more frequent in male and in the right lung. These data are in accordance with the literature.

Tracheal bronchus

Tracheal bronchus was first described by Sandifort in 1785 as a right upper lobe bronchus originated from the trachea. Tracheal bronchus is a rare anatomic variation with an incidence of 0.1–3%. In our study, it was detected at 0.9%.

The tracheal bronchus is a bronchus usually originated from the right side of the trachea above the carina and within 2–6 cm from it. Right tracheal bronchus has a prevalence of 0.1–2% and left tracheal bronchus has a prevalence of 0.3–1% according to bronchographic and bronchoscopic studies. Tracheal bronchus encompasses a wide morphological spectrum of variants. Sometimes it arises from the main bronchus and it supplies the upper lobe. It may be an aberrant or a displaced bronchus, and it depends on the anatomical right upper lobe bronchi. The tracheal bronchus is displaced in cases where the right upper bronchus bifurcates, but it is defined as aberrant when the right upper bronchus trifurcates. Its length ranges between 0.6 and 2.0 cm and its diameter varies from 0.5 to 1.0 cm.

In our study, in three cases, the right pre-eparterial bronchi were arising from the junction between the trachea and carina, while in the rest of the cases they were arising from the right main bronchus.

Embryologically, the tracheal bronchus is believed to be created by a failure of regression of the tracheal buds in utero. Normally, tracheal buds regress and when they remain, tracheal diverticuli or tracheal bronchi are developed. Another theory supports the disruption of normal embryogenesis as the cause of tracheal bronchus rather than the incomplete regression of the tracheal buds.

The presence of tracheal bronchus may cause some complications such as atelectasis or pneumothorax in cases of obstructing its entrance or entering into it during intubation. Also, there has been a reported case of carcinoma originated from tracheal bronchus.

Figure 4: (a) Coronal MPR shows hypoplastic right upper lobe bronchus (arrow). (b) Volume-rendered (VR) 3D image shows aplasia of the right middle lobe bronchus.
Accessory cardiac bronchus

Accessory cardiac bronchus is a rare congenital anomaly of the TB, and it was first described by Brock in 1946. It is a short and thin bronchus towards the pericardium originated either from the right main bronchus medial wall or from the intermediate bronchus opposite to the origin of the right upper lobe bronchus. It usually ends blindly and it terminates to a conical lobule located next to azygosophageal recess. Its incidence is referred to be 0.08%, and it can be differentiated from a fistula or diverticula because it is lined with bronchial mucosa and normal cartilage wall. Although it is an asymptomatic congenital anomaly, in some cases, it coexists with recurrent infections or tumours.

Conclusion

Precise knowledge of normal tracheobronchial anatomy and its variants is very important from a radiological and clinical aspect in pre-operative evaluation and in cases of interventional treatments like intubation or endobronchial procedures. Also, main lobe bronchus abnormalities are of clinical interest because they may predispose to infections, and possibly, to malignancies. MDCT with reformation techniques and VB are two complementary techniques that facilitate the accurate evaluation of the tracheobronchial tree and suspected airway abnormalities and can be used as an alternative to bronchoscopy in certain cases.

Abbreviations list

3D, three-dimensional; CT, computed tomography; MDCT, multidetector tomographic; MinIP, minimal intensity projection; MIP, maximum intensity projection; MPR, multiplanar reconstruction; TBV, Tracheobronchial tree variation; VB, virtual bronchoscopy; VR, volume-rendered

References