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CASE REPORT

Airflow patterns in the trachebronchial tree of a patient with an accessory cardiac bronchus: A rare congenital anomaly

Gizem KÖYBAŞI[1](ID)
Celal SATICI[1](ID)
Ufuk DEMİR[2](ID)
Furkan ATASEVER[1](ID)
Cengiz ÖZDEMİR[1](ID)
Filiz KOŞAR[1](ID)

[1] Clinic of Chest Diseases, Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital, İstanbul, Türkiye
[2] Department of Mechanical Engineering, İstanbul Technical University, İstanbul, Türkiye

ABSTRACT

Airflow patterns in the trachebronchial tree of a patient with an accessory cardiac bronchus: A rare congenital anomaly

Accessory cardiac bronchus (ACB) is a rare congenital anomaly mainly located in the medial wall of the intermediate bronchus. This anomaly can present with dyspnea, recurrent infections, and hemoptysis. It usually has a blind ending, which may have an impact on airflow patterns and lobar distribution regardless of its diameter and depth. There have been very few cases with ACB. However, the airflow pattern and lobar distribution have not been well studied. In our case with ACB, the proportion of airflow in the right lung was higher than in the model without ACB, while mean airflow velocities were similar in both models. In this regard, quantitative lung ventilation scintigraphy could be better than the anatomical formula in predicting postoperative forced expiratory volume 1 in patients with accessory cardiac bronchus who will undergo lung resection.

Key words: *Accessory cardiac bronchus; airflow patterns; rare congenital anomaly*

ÖZ

Aksesuar kardiyak bronş tespit edilen bir olguda trakeobronşiyal hava akımı paternlerinin incelenmesi: Nadir bir konjenital anomali

Aksesuar kardiyak bronş (AKB), esas olarak ara bronşların medial duvarında yerleşim gösteren nadir bir konjenital anomalidir. Bu anomali nefes darlığı, tekrarlayan enfeksiyonlar ve hemoptizi ile kendini gösterebilir. Genellikle, çapı ve derinliği ne olursa olsun hava akım paternleri ve lober dağılım üzerinde etkisi olabilecek kör bir ucu vardır. AKB bildirilen çok az sayıda vaka mevcuttur. Bununla birlikte, hava akım paterni ve lober dağılım iyi çalışılmamıştır. AKB bulunan olgumuzda sağ akciğerdeki hava akımı oranı AKB bulunmayan modele göre daha yüksek iken, ortalama hava akım hızları her iki modelde de benzer bulundu. Bu bağlamda, akciğer rezeksiyonu uygulanacak

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Address for Correspondence

Dr. Gizem KÖYBAŞI
Clinic of Chest Diseases, Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital,
İSTANBUL - TÜRKİYE
e-mail: gizemkoybasi@gmail.com

AKB eşlik eden hastalarda postoperatif birinci saniyedeki zorlu ekspiratuar volümü öngörmede kantitatif akciğer ventilasyon sintigrafisi anatomik formülden daha iyi olabilir.

Anahtar kelimeler: *Aksesuar kardiyak bronş; hava akım paterni; nadir konjenital anomali*

INTRODUCTION

Accessory cardiac bronchus (ACB) is a rare congenital developmental anomaly of the bronchial system. It is generally an unrecognizable anomaly originating mainly from the medial wall of the intermediate bronchus at the level of the right upper lobe (1). There have been several case series of patients reported with ACB (2,3). However, to the best of our knowledge, there is no data regarding the airflow patterns in the tracheobronchial tree of patients with ACB. Computational fluid dynamics techniques were used to investigate the effects of ACB on airflow characteristics.

CASE REPORT

A 35-year-old man was admitted to the outpatient clinic with a bloody cough. Hemoptysis started 24 hours ago and occurred only twice with a total volume of 20-30 mL. He had no previous history of hemoptysis, no chronic diseases, and was a life-long non-smoker. He did not have any additional symptoms like dyspnea or chest pain and he was not on any anticoagulant therapy. On physical examination, his vital signs were within normal limits, and his chest auscultation and other system examinations were also normal. The chest X-ray revealed no abnormal findings, therefore a thorax computed tomography (CT) was ordered. There was no evidence of parenchymal or vascular abnormalities. An accessory bronchus emerging from the medial side of the bronchus intermedius and descending towards the heart was discovered on chest CT (Figure 1). The patient underwent a bronchoscopy. There was an accessory cardiac bronchus with a diameter of 12 mm and a depth of 12.75 mm on the medial wall of the intermediate bronchus at the level of the right upper lobe (Figure 1).

To investigate the effects of ACB on airflow characteristics, a real human respiratory tract model was created using the medical software package Mimics 21 and 3D modeling software 3-Matic (Materialise, Leuven, Belgium). CT images of the 35 year-old-male adult subject (BMI= 25.2 kg/m^2) were segmented. Within the scope of this study, we trimmed the cardiac bronchus from the original model to obtain a normal respiratory tract model.

The fluid domain, which was prepared for numerical simulations was exported in FLUENT format and imported into ANSYS Fluent-Meshing (ANSYS, Inc., Canonsburg, PA) software. In the present study, numerical simulations were performed on two respiratory tract models. Numerical analyses were performed on the normal model, then the effects of cardiac bronchus on the respiratory tract were investigated at a 17 L/min flow rate. Maximum airflow velocities, lobar distribution rates of inspired air, and changes in airflow characteristics were compared.

1.48 m/s velocity was obtained for the ACB model, and 1.49 m/s velocity was obtained for the normal model with the created pressure profile for a quiet breathing pattern (17 L/min). In terms of lobar distribution, the proportion of airflow to both lungs was nearly

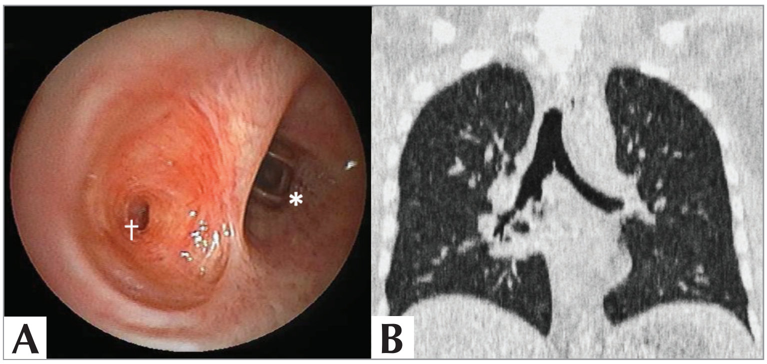

Figure 1.A. Bronchoscopic image of the ACB. **B.** Lung window shows ACB on the coronal unenhanced chest CT image.
*stands for intermediary bronchus, †stands for accessory cardiac bronchus.

Table 1. The lobar distribution and airflow velocities for both models

		Lobar distribution	
	Mean airflow velocity (m/s)	**Right lung**	**Left lung**
Model with ACB	1.48	48%	52%
Model without ACB	1.49	55%	45%

equal in the model with cardiac bronchus, whereas the proportion of airflow to the right lung was greater than the left lung in the model without ACB (Table 1).

Figure 2 depicts the velocity contours for inhalation and expiration in both models. The effects of the cardiac bronchus on airflow are clearly seen during inhalation compared to expiration. During inhalation, a part of the inhaled air that is near the wall region enters the ACB region due to the angle between the right bronchus wall and the entrance of the ACB region. As can be seen in Figure 2, the angle between the right bronchus wall and the ACB region entrance is almost perpendicular. This caused a low-pressure region in the ACB and strong secondary flow patterns appeared in the cardiac bronchus region, and these recirculation zones pushed the air streamlines from the wall region to the center of the right bronchus. During inhalation, however, significant turbulence zones were observed in the trachea region right above the carina in both models.

DISCUSSION

ACB is a rare congenital bronchial abnormality. It was initially described with bronchographic imaging by Brock in 1994 (4). Subsequently, it was demonstrated

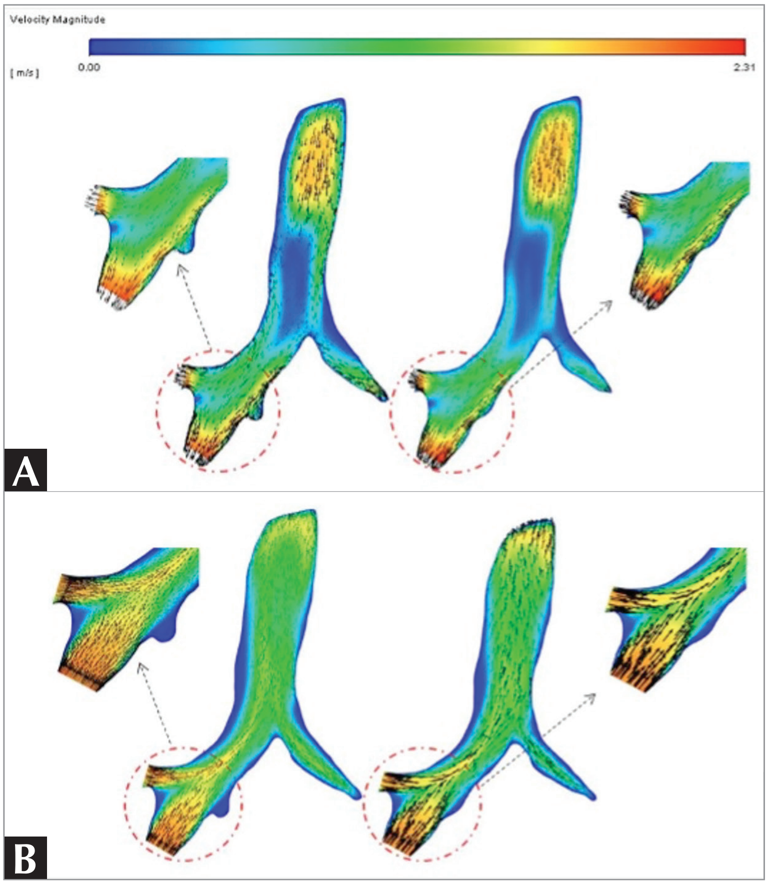

Figure 2. Velocity contours in the right bronchus for both models during inhalation **A.** and exhalation **B.** (coronal plane view).

by bronchoscopy and computed tomography (CT), and studies suggest that the incidence varies between 0.08% and 0.5%, with the frequency appearing to be increasing due to new imaging techniques (3,5).

ACB was first described as “supernumerary bronchus arising from the inner wall of the right main bronchus or intermediate bronchus” by Brock with an incidence of 0.09-0.5% (4). The ACBs ended with a blind diverticulum in two-thirds of the cases (6). The inner surface is covered with normal bronchial mucosa and its wall is covered with cartilage tissues. Mangiluea et al. have defined three types of ACB by bronchographic findings;

1) Short type; blind-ending,

2) Long type; ventilates a small rudimentary parenchyma,

3) Intermediate type; with long diverticulum but no alveolar branching.

Although the majority of the ACB cases have been detected incidentally, cases with symptoms such as fever, cough, and hemoptysis have also been reported. This anomaly may act as a reservoir for organisms, resulting in recurrent infections and hemoptysis in individuals, especially with the blind-ending type (7). Another potential problem for this type might be the abnormal airflow pattern in the tracheobronchial tree. This might be critical for patients who also have chronic respiratory diseases.

The impact of the ACB on the airflow pattern is influenced by two critical parameters: diameter, and the presence of a blind ending. In our case, the cardiac bronchus was significantly smaller in diameter compared to the right main bronchus and had a blind ending. Due to the above-mentioned factors, the impact of the cardiac bronchus on inhalation and expiration airflow patterns is less than predicted in our case. However, we discovered that the inspired air volume was 7% higher in the right lung compared to the left. This might have some clinical impact. To calculate the postoperative forced expiratory volume 1 in patients with accessory cardiac bronchus who will undergo lung resection, quantitative lung ventilation scintigraphy may be more accurate than using a formula based on the anatomical method (8).

Qi et al. investigated the effects of the open-ended tracheal bronchus (TB) on the airflow patterns, lobar distribution rates, and pressure drops by using six tracheae bronchial and three healthy CT-based models and found no significant change in lobar distribution rates between healthy and TB models (9). But in terms of airflow patterns, they indicated that the mixing pattern in TB models might contribute to the dyspnea and recurrent pneumonia symptoms. However, we indicated that the proportion of airflow to the right lung is slightly higher in patients with ACB than in those with the normal model. The possible explanation could be that the airflow was more disturbed because of the higher shear stress values due to the non-uniform wall morphology in the ACB model. This phenomenon may cause an increase in airway resistance in the right main bronchus and affect the inhaled air distribution rates directly.

CONCLUSION

In conclusion, recognizing this rare anomaly is critical in determining the causes of pulmonary symptoms such as recurrent infections, hemoptysis, and dyspnea. Individuals with ACB could have a lower proportion of airflow in the right lung regardless of the depth and diameter of ACB.

CONFLICT of INTEREST

The authors have no conflict of interest to declare.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: GK, CS, UD

Analysis/Interpretation: GK, FK

Data acqusition: CG, FA

Writing: CS, GK

Clinical Revision: CÖ, FK

Final Approval: CS

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