


# Variations of bronchial artery origin in 600 patients

## Systematic analysis with multidetector computed tomography and digital subtraction angiography

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### Abstract

To identify and evaluate the spectrum and prevalence of variations in bronchial artery (BA) origin by multidetector computed tomography (MDCT) and digital subtraction angiography (DSA) in a large population with hemoptysis.

From July 2008 to June 2015, data from 600 individuals with hemoptysis who underwent MDCT and DSA were retrospectively analyzed. The pattern of BA origin was investigated and classified according to distribution.

A total of 1674 BAs were evaluated, 866 were right BA and 808 were left BA. Most BAs originated from the upper descending thoracic aorta, classified as orthotopic origin (n = 1464, 87.5%). Among ectopic origin BAs (n = 210, 12.5%), concavity of the aortic arch was the most common (n = 107). The most common distribution pattern was a single artery in each side (n = 262). According to our classification, Type I was most common (n = 457), including BAs originating in orthotopic fashion from the descending thoracic aorta. Type II (n = 2) was defined as BAs originating from the aortic arch or ascending aorta. Type III (not found) was defined as BAs originating from subclavian arteries, common carotid arteries, and their branch vessels. Type IV (n = 92) was Type I and II combined, Type V (n = 41) was Type I and III combined, Type VI (not found) was Type II and III combined, and Type VII (n = 8) was Type I, II, and III combined.

Variations of BA origin could be systematically described in detail.

**Abbreviations:** BA = bronchial artery, BAE = bronchial artery embolization, DSA = digital subtraction angiography, IBT = intercostobronchial trunk, MDCT = multidetector computed tomography.

**Keywords:** bronchial artery, digital subtraction angiography, hemoptysis, multidetector computed tomography

### 1. Introduction

The bronchial artery (BA) dilates in various of pathological conditions as follows; diseases involving the pulmonary artery, acute or chronic inflammation of the lungs and airways, pulmonary hypertension, and BA anomalies.<sup>[1]</sup> In this setting, increased arterial

blood flow via the BA and anastomotic vessels between the bronchial and pulmonary arteries can induce arteriolar rupture, causing varying degrees of hemoptysis.<sup>[2]</sup> As reported by Remy et al<sup>[3]</sup> in 1973, BA embolization (BAE) has been the first-line treatment of hemoptysis with proven safety and efficacy.<sup>[4–7]</sup>

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There are several studies regarding the BA anatomy using cadavers and multidetector computed tomography (MDCT).<sup>[8–12]</sup> However, enrolled population of most of the studies are heterogeneous and studies regarding patients with hemoptysis are rare. Furthermore, specific and systematic demonstrations of the origin-based analysis of BAs are rare. In describing BA anatomy and its variations, it is essential to clearly define the terms related to ectopic BA, because the origin of the ectopic BA is the key component of the variant anatomy. Clinically, a missing ectopic BA during BAE can cause treatment failure and early recurrence of hemoptysis. Therefore, it is of great significance to understand the anatomy and the variants BA origins.

Owing to recent advances in multidetector computed tomography (MDCT), thin-section dynamic MDCT offers detailed anatomical information on bronchial vasculature. Even in interventional radiology, preprocedural MDCT evaluation of BAs for patients with hemoptysis can help one to perform and interpret the findings of conventional angiography for the BAE procedure. Therefore, diagnostic as well as interventional radiologists should be aware of the spectrum and MDCT appearances of variations of the BA system.

The purpose of the present study was to determine the orthotopic and ectopic BA anatomy based on MDCT and conventional angiography in a large study population with hemoptysis and to summarize the observed variations.

## 2. Methods

### 2.1. Study population

This single center, retrospective study was approved by the institutional review board and the requirement for patients' informed consent was waived. Between July 2008 and June 2015, a total of 839 patients with hemoptysis underwent first-time BAE. Of the 839 patients, 669 patients underwent thin-section MDCT and 627 patients showed at least one visible BA each side. According to following exclusion criteria, 27 patients were excluded from this study: underwent a prior BAE procedure at another hospital ( $n=11$ ), too poor computed tomography (CT) quality to evaluate the anatomy of the BA ( $n=8$ ), such as due to severe motion artifact, limited evaluation of the anatomy of the BA due to an arteriovenous malformation like lesion ( $n=6$ ), anatomical variation of the aorta ( $n=1$ ), and underwent Ivor-Lewis operation prior to the evaluation ( $n=1$ ). The final study population included 600 patients (362 men, 238 women; mean age:  $62.13 \pm 12.43$  [standard deviation] years, range: 18–92 years) (Fig. 1).

### 2.2. CT examination

All thin-section dynamic chest CT scans were performed using 1 of 7 available 64-detector MDCT scanners in our hospital; Somatom Definition (Siemens Medical Systems, Forchheim, Germany), Brilliance-64, Ingenuity, IQon Spectral CT, iCT (Phillips Healthcare, Andover, MA), Discovery CT750 HD (GE Medical Systems, Milwaukee, WI), and Aquilion ONE (Canon Medical Systems, Otawara, Japan).

### 2.3. Angiographic procedure

After careful interpretation of chest CT findings, BAE was performed for the indicated patients. The following steps are the BAE procedure in our hospital. First, ascending aortography was

performed by using a 5-French pigtail shape angiographic catheter (Cook, Bloomington, IN). Second, right and left BA angiography were performed after selection of each BA using a 5-French conventional angiographic catheter (Cook, Bloomington, IN). Various types of angiographic catheter were used for selection of the diverse origins of both BAs. In case of an aberrant BA and non-bronchial systemic supply, appropriate angiographic catheters were chosen for selection of those vessels. Third, in indicated cases such as intercostobronchial trunk (IBT) or common trunk of both BAs, further super-selective angiography was performed by using a 1.7- or 2.0-French microcatheter and microwire system (Terumo, Tokyo, Japan). Fourth, after selection of causal arteries of hemoptysis, embolization was performed using polyvinyl alcohol particles 255 to 500  $\mu\text{m}$  (Contour, Boston Scientific, Marlborough, MA). In some cases, gelfoam particles, histoacryl, and microcoil were also used for embolization. Before and during the infusion of embolic materials, careful observation of regurgitation or backflow was performed to prevent inadvertent embolization, which can cause complications such as spinal ischemia or stroke.

### 2.4. Image interpretation

Retrospective image analysis was performed by 2 board-certified interventional radiologists (WSC and MUK, with 5 and 10 years of experience, respectively), independently. All thin-section dynamic chest MDCTs and corresponding angiographic images were interpreted complementarily with respect to the anatomy of the BA and origin sites. In case of discrepancy, the MDCT and angiography images were assessed again in consensus. The image analysis was performed to elucidate 4 parts: type of each BA (a single right or left BA, an IBT, and a common trunk of both BAs), presence and origin of ectopic BA, type of ectopic BA (a single right or left BA, an IBT, and a common trunk of both BAs), distribution of BAs.

The classic definition for ectopic BA is BAs originating at the level of the descending aorta other than T5 to T6 or from any aortic collateral vessels.<sup>[11]</sup> In this study, a new definition of ectopic BA was proposed for MDCT interpretation, that BAs originating at a level of the descending aorta other than between the lower margin of the concavity of aortic arch and the upper margin of pulmonary artery bifurcation or from any aortic collateral vessel. Because of the difficulty to recognize the exact vertebral level on an axial CT image, this new definition was used for comfortability and clarity of analysis. Thus, the origins of ectopic BAs were classified as follows: aortic arch, ascending aorta, lower descending thoracic aorta, which BAs are originated from the descending thoracic aorta, lower than the upper margin of pulmonary artery bifurcation innominate artery, both common carotid artery, both subclavian artery, both internal mammary artery, both thyrocervical trunk.

In this study, a new classification of the BA distribution pattern according to the origin of BA was proposed considering vascular access (femoral access vs radial access) as follows: Type I, BAs originating from orthotopic bronchial fashion (descending thoracic aorta), Type II, BAs originating from the aortic arch or ascending aorta, Type III, BAs originating from both subclavian arteries, common carotid arteries, and their branch vessels, Type IV, combination of Type I and Type II, Type V, combination of Type I and Type III, Type VI, combination of Type II and Type III, Type VII, combination of Type I, Type II, and Type III (Fig. 2).

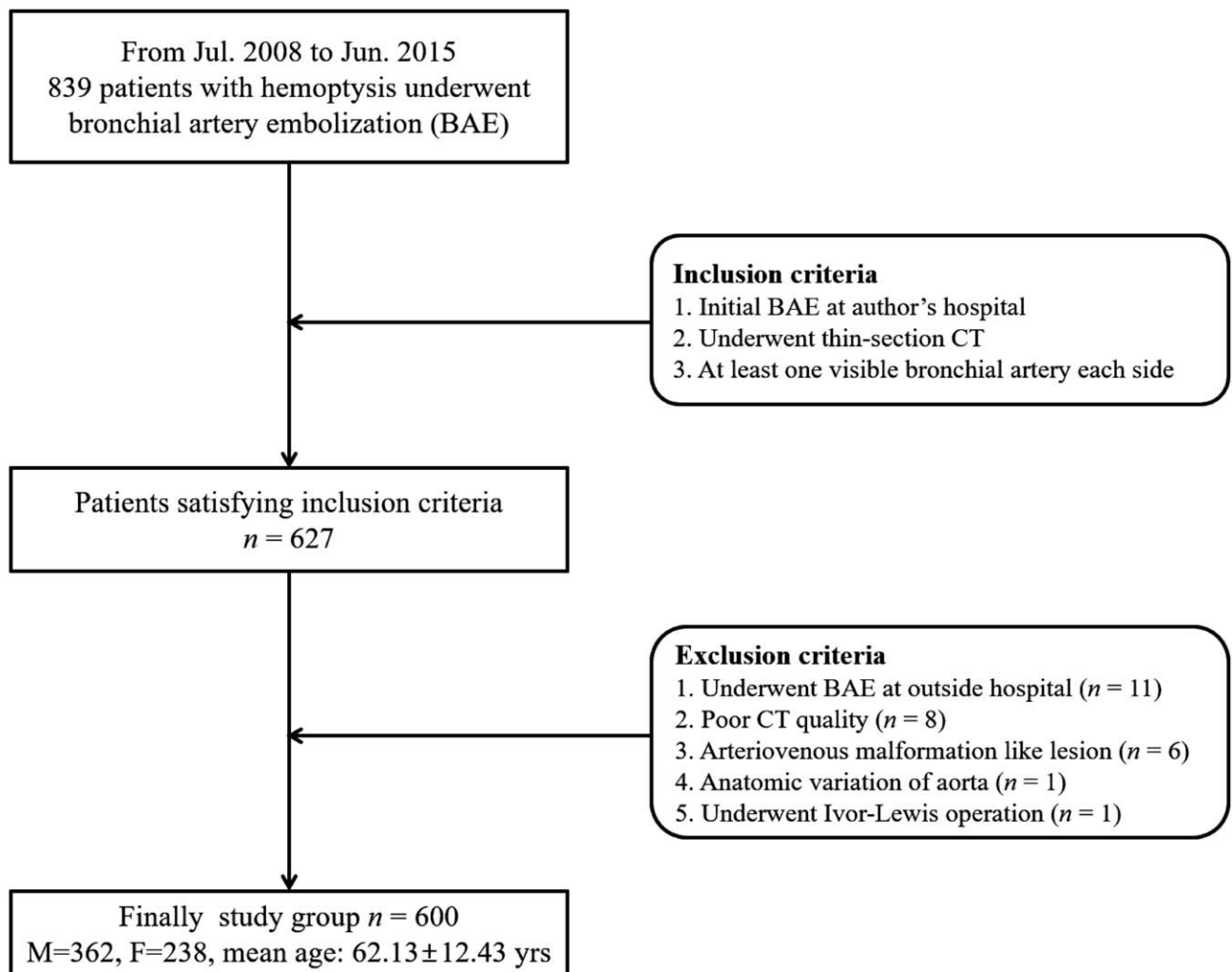


Figure 1. Flow chart of inclusion and exclusion in 839 patients with hemoptysis.

For Type V, Type VI, and Type VII, each Type was subdivided with “R,” “L,” and “B” according to laterality of the BA. For example, a patient with Type VR has at least one BA from right subclavian artery, carotid artery, or their branch vessels.

### 3. Results

A total of 600 patients (362 men and 238 women) were enrolled. The mean age of patients was  $62.1 \pm 12.4$  years (range: 18–92 years). A total of 1674 BAs were evaluated, 866 were right BA and 808 were left BA. The mean number of right BAs was  $1.44 \pm 0.58$  per patient (range: 1–3 per patient) and that of left BAs was  $1.35 \pm 0.54$  per patient (range: 1–4 per patient).

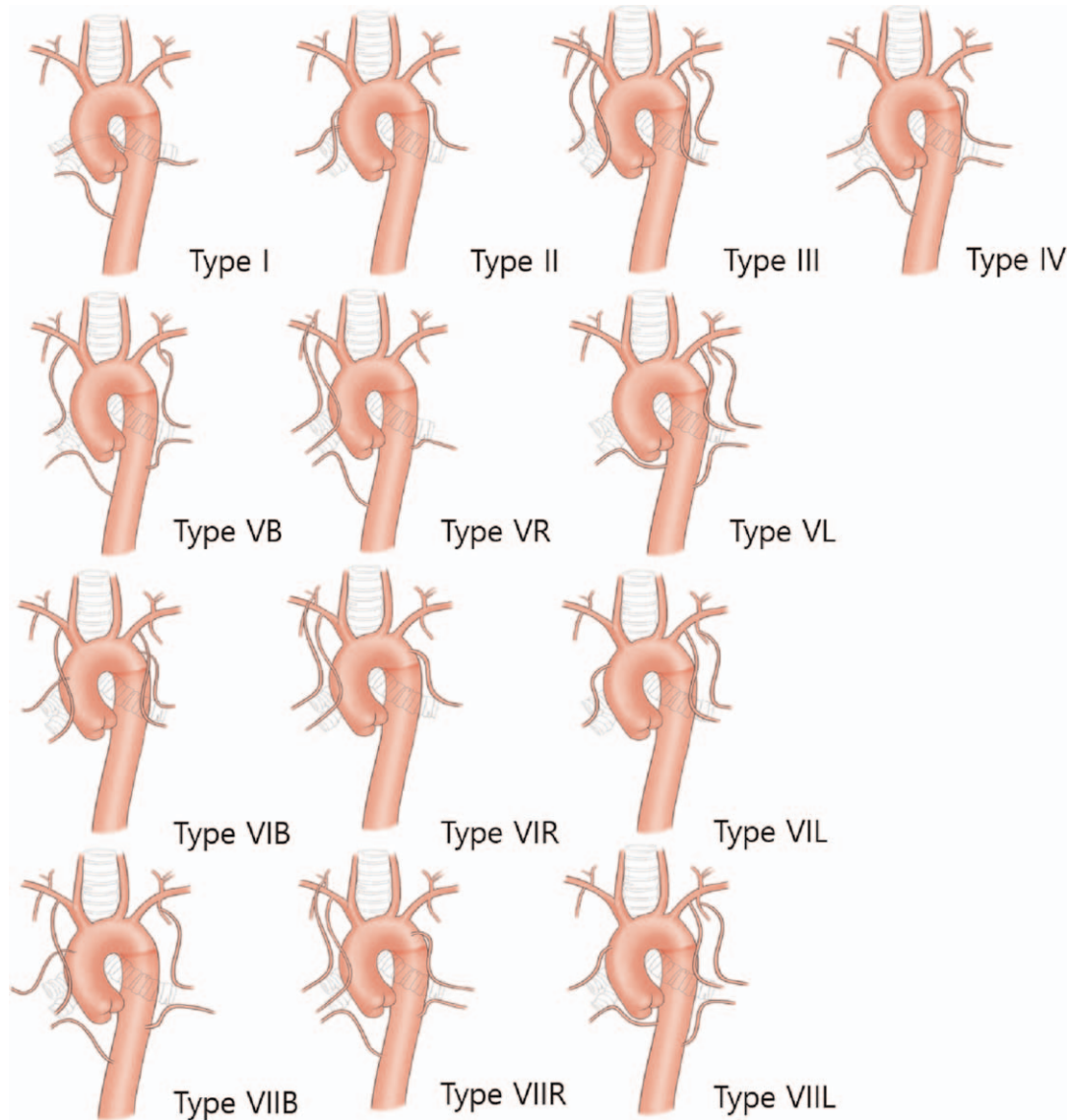
#### 3.1. Type of each BA

The total number of single BA was 634 (37.9%, 634/1674) with 144 (16.6%, 144/866) of right BAs and 490 (60.6%, 490/808) of left BAs. There were 430 (25.7%, 430/1674) IBTs with 417 (48.2%, 417/866) of right BAs and 13 (1.6%, 13/808) of left BAs were found. The total number of common trunk of both BAs was 305 (36.4%, 610/1674) (Table 1). The number of patients who

have only a single right BA at the right side was 35 (5.83%, 35/600), and that of patients who have only a single left BA at the left side was 228 (38.0%, 228/600). An IBT was found in 418 patients (69.7%, 418/600) and common trunk of both BAs was found in 286 patients (47.7%, 286/600).

#### 3.2. Ectopic BAs

The total number of ectopic BAs was 210 (12.5%, 210/1674) with 118 of right BAs and 92 of left BAs in 148 (24.7%, 148/600) patients. Among them, 126 (85.1%, 126/148) patients had a single ectopic BA, 19 (12.8%, 19/148) patients had 2 ectopic BAs, 2 (1.4%, 2/148) patients had 3 ectopic BAs, and 1 (0.7%, 1/148) patient had 4 ectopic BAs. The type of ectopic BAs was shown in Table 1. The most common origin of ectopic BAs was the aortic arch ( $n=138$ , 65.7%, 138/210) (Fig. 3), followed by the left subclavian artery ( $n=14$ , 6.7%, 14/210) (Fig. 4), right internal mammary artery (Fig. 5), right thyrocervical trunk, and lower descending thoracic aorta ( $n=12$ , 5.7%, 12/210), right subclavian artery ( $n=11$ , 5.2%, 11/210), left internal mammary artery and left thyrocervical trunk ( $n=4$ , 1.9%, 4/210), ascending aorta ( $n=2$ , 1.0%, 2/210) (Fig. 6), and left common carotid



**Figure 2.** New classification of the bronchial distribution pattern according to the origin of bronchial artery. Type I, bronchial arteries (BAs) originating from orthotopic bronchial fashion (descending thoracic aorta); Type II, BAs originating from the aortic arch or ascending aorta; Type III, BAs originating from both subclavian arteries, common carotid arteries, and their branch vessels; Type IV, combination of Type I and Type II; Type V, combination of Type I and Type III; Type VI, combination of Type II and Type III; Type VII, combination of Type I, Type II, and Type III. For Type V, Type VI, and Type VII, we subdivided each Type with “R,” “L,” and “B” according to laterality of the BA. For example, a patient with Type VR has at least one BA from right subclavian artery, carotid artery, or their branch vessels.

artery ( $n = 1$ , 0.5%, 1/210). The origin of ectopic BAs is presented in Table 2.

When it comes to the type of ectopic BA, single BA ( $n = 119$ , 56.7%, 119/210) was most common with 63 (53.8%, 63/117) of right BAs and 56 (60.2%, 56/93) of left BAs. The total number of common trunk of both BA was 72 (34.3%, 72/210) and that of an IBT was 19 (9.0%, 19/210) with 18 (15.4%, 18/117) of right BAs and 1 (1.1%, 1/93) of left BAs.

### 3.3. Distribution pattern of BAs

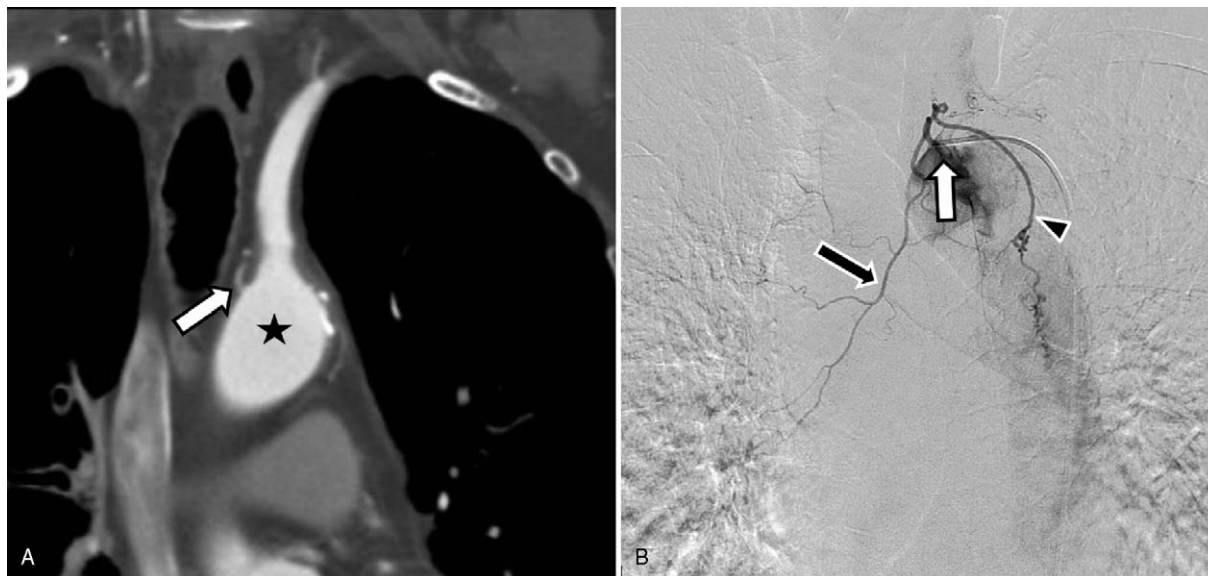
The most common distribution pattern was 1 right and 1 left BA ( $n = 262$ , 43.7%, 262/600), followed by 2 right and 1 left BA ( $n = 136$ , 22.7%, 136/600), and 1 right and 2 left BA ( $n = 89$ , 14.8%, 89/600). According to new classification system, there

were 457 patients with Type I, 2 patients with Type II, 92 patients with Type IV, 41 patients with Type V (25 Type VR, 12 Type VL, and 4 Type VB), and 8 patients with Type VII (5 Type VIIR and 3 Type VIIL). There were no patients with a Type III

**Table 1**

**Type of orthotopic and ectopic bronchial artery.**

Origin	Orthotopic	Ectopic	Total
Right single bronchial artery	81	63	144
Left single bronchial artery	434	56	490
Right intercostobronchial trunk	399	18	417
Left intercostobronchial trunk	12	1	13
Common trunk (pair)	269	36	305



**Figure 3.** Ectopic bronchial artery from aortic arch. (A) Chest CT shows common trunk of bronchial artery (white arrow) originate from aortic arch (star). (B) Digital subtraction angiography shows common trunk of bronchial artery (white arrow) divide into right bronchial artery (black arrow) and left bronchial artery (black arrowhead). CT=computed tomography.

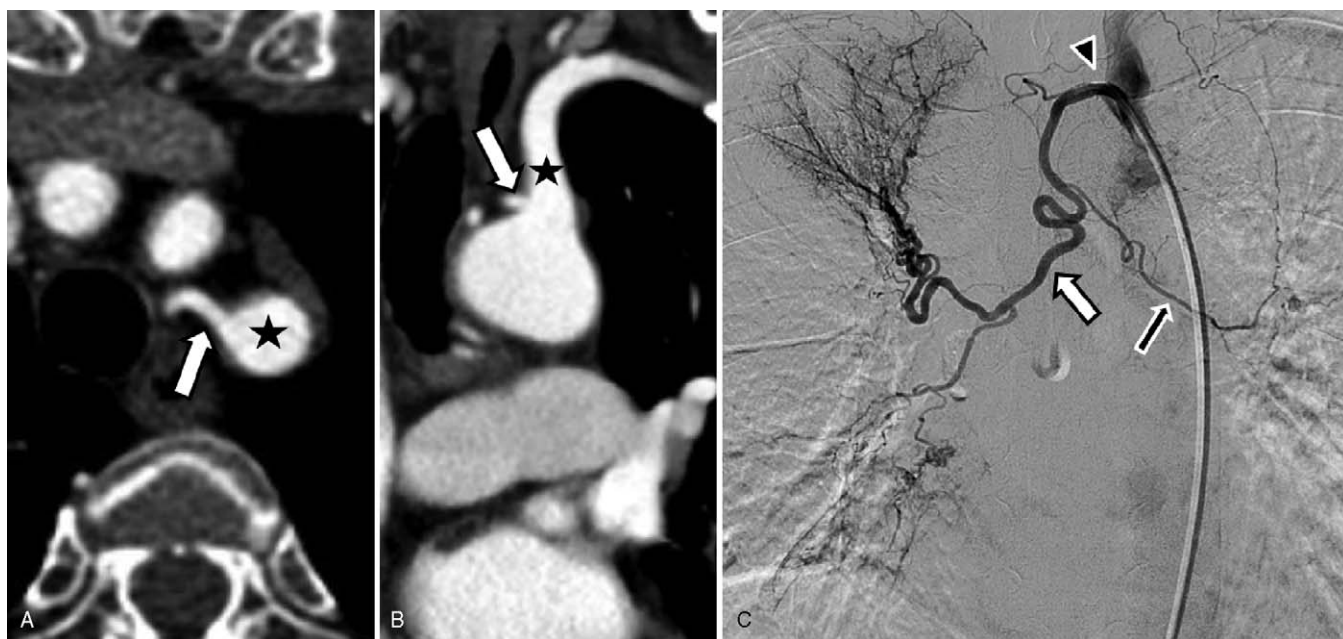
or Type VI distribution pattern. The distribution pattern according to our new classification system is summarized in Table 3.

**4. Discussion**

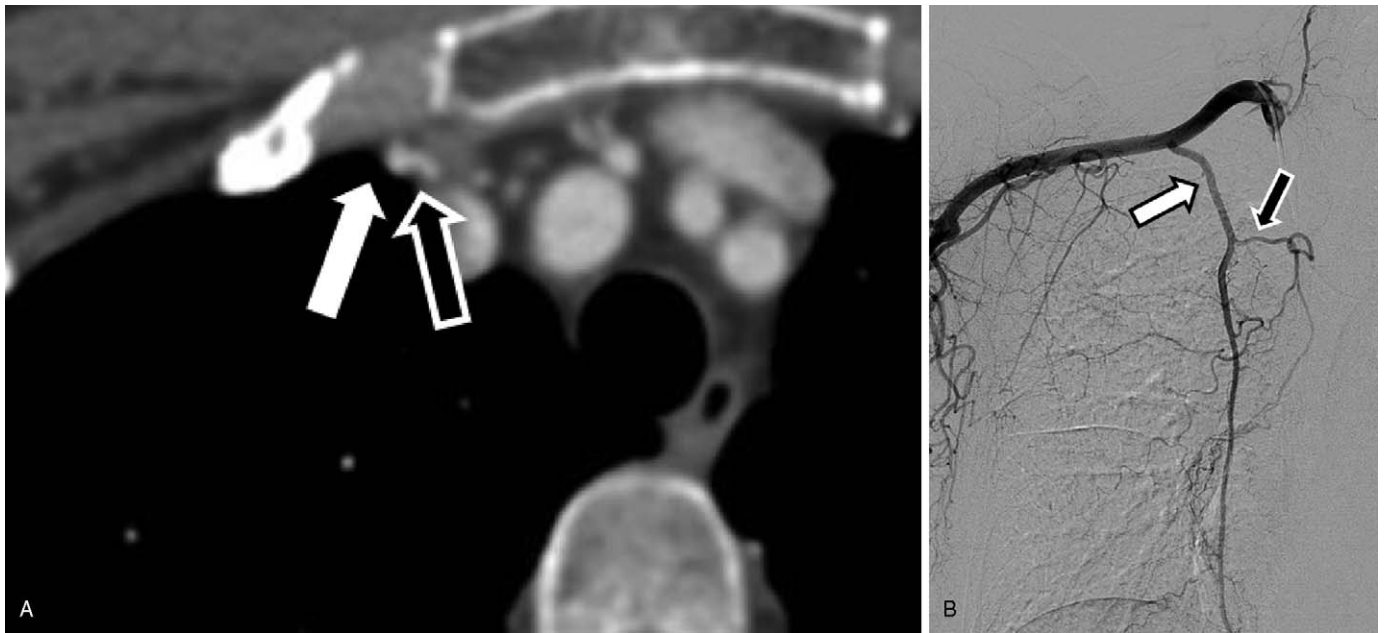
The present was study designed to analyze anatomical information of both orthotopic and ectopic BAs using MDCT. To the best

of our knowledge, as an anatomical study using MDCT, the present study has the largest study population regarding the number of patients (n=600), BAs (n=1674), and ectopic BAs (n=210). Furthermore, we propose a new classification of BAs considering the arterial access site.

In our study, all bronchial arteries found on MDCT were visible on angiography. Despite good MDCT quality, 15 bronchial arteries, which were rarely found on MDCT, but



**Figure 4.** Ectopic bronchial artery from left subclavian artery. (A, B) Chest CT shows common trunk of bronchial artery (white arrow) originate from left subclavian artery (star). (C) Digital subtraction angiography shows common trunk of bronchial artery (black arrowhead) divide into right bronchial artery (white arrow) and left bronchial artery (black arrow). CT=computed tomography.



**Figure 5.** Ectopic bronchial artery from right internal mammary artery. (A) Chest CT image shows right bronchial artery (black arrow) originate from right internal mammary artery (white arrow). (B, C) Subclavian arteriography (B) and selective right bronchial arteriography (C) show right bronchial artery (black arrow) originate from right internal mammary artery (white arrow). Systemic-pulmonary shunts (dotted circles) are shown in the right lung field. CT=computed tomography.

accidentally found on angiography; 10 single bronchial arteries originated from descending aorta and 5 bronchial arteries originated from common trunk. In the current study, we can say that the accuracy of MDCT is 97.5%, but this is a biased result as MDCT and angiographic findings were not analyzed independently.

A mean number of right and left BAs were  $1.44 \pm 0.58$  and  $1.35 \pm 0.54$  per patient, respectively, which is consistent with previous studies.<sup>[9,11-15]</sup> Also, proportion of IBT and CBT showed similarity to previous studies.<sup>[9,15-17]</sup> More than half of patients had IBT (69.7% in the present study, 58-84% in previous studies), almost half of right BAs originated as IBT



**Figure 6.** Ectopic bronchial artery from ascending aorta. (A, B) Chest CT shows common trunk of bronchial artery (white arrow) originates from ascending aorta (star). (C) Digital subtraction angiography shows common trunk of bronchial artery (black arrowhead) divide into right bronchial artery (white arrow) and left bronchial artery (black arrow). CT=computed tomography.

**Table 2****Origin of ectopic bronchial arteries.**

Origin	Right	Left	Cases (%)
Aortic arch	77	61	138 (65.7)
Lower descending thoracic aorta	4	8	12 (5.7)
Ascending aorta	1	1	2 (1.0)
Right subclavian artery	11	0	11 (5.2)
Right internal mammary artery	12	0	12 (5.7)
Right thyrocervical trunk	12	0	12 (5.7)
Left common carotid artery	0	1	1 (0.5)
Left subclavian artery	0	14	14 (6.7)
Left internal mammary artery	0	4	4 (1.9)
Left thyrocervical trunk	1	3	4 (1.9)
Total	118	92	210 (100)

(48.2% in present study, 52–53% in previous studies), and <10% of left BAs originated as IBT (1.6% in the present study, 3.6–4% in previous studies). The proportion of patients with CBT was variable between studies (47.7% in the present study, 33.09–86% in previous studies), and approximately one-third of both right and left BAs originated as CBT (35.2% right BA and 37.7% left BA).

Cauldwell et al<sup>[18]</sup> reported that 16.7% of BAs had an ectopic origin. Furthermore, numerous studies have demonstrated various proportions (ranging from 7.4% to 38.3%) of ectopic BAs.<sup>[11–13,15,17,19,20]</sup> In the present study, 12.5% (n = 210) of BAs and 24.7% (n = 148) of patients showed ectopic BAs. The most common site of origin of ectopic BAs was the aortic arch, followed by the left subclavian artery, which is consistent with previous studies.<sup>[11,15]</sup> Also in agreement with previous studies,<sup>[21,22]</sup> a relatively rare ectopic origin of the ascending aorta and left common carotid artery were observed. Previously reported rare ectopic origins of the left gastric artery<sup>[23]</sup> and vertebral artery<sup>[24]</sup> were not found in present study.

Embryologically, adult BAs originate due to involution of the primitive branches, which originate from the dorsal aortas and initially feed the pulmonary plexus during embryonic development. The persistence of one of these early branches results in an ectopic BA of high origin, which originates from the brachiocephalic, carotid, subclavian, internal mammary, and vertebral arteries, the thyrocervical and costocervical trunks, and the upper portion of aortic arch.<sup>[25,26]</sup>

**Table 3****Distribution pattern according to new classification system.**

Type	Cases	Percent
Type I	457	76.17
Type II	2	0.33
Type III	0	0
Type IV	92	15.33
Type V	41	6.83
Type VR	25	
Type VL	12	
Type VB	4	
Type VI	0	0
Type VII	8	1.33
Type VII R	5	
Type VII L	3	
Total	174	100

According to recent interest in using radial access in interventional radiology fields, some BAEs were performed with radial access at our institute. Thus, in this study, a new classification of BA distribution pattern according to origin of the BA was suggested considering vascular access. With our experience in BAE at our institute, selection of the BA with both femoral and radial access was easy in the case of an orthotopic BA or ectopic BA originating from the descending thoracic aorta. In case of an ectopic BA originating from the aortic arch or ascending aorta, selection of the BA with femoral access was possible, but radial access was difficult. When the origin of an ectopic BA was the subclavian artery, carotid artery, or their branch vessels, selection of the BA with femoral access was difficult, but radial access was easy. In this context, either femoral or radial access was available in type I, femoral access was favorable in type II, IV, radial access was favorable in type III, V, and both femoral and radial access were required in type VI, VII. Applying this strategy to patients with current study, both femoral and radial access were available in 457 (76.16%) patients, femoral access was favorable in 94 (15.6%) patients, and radial access was favorable in 41 (6.83%) patients. Eight (1.3%) patients required both femoral and radial access.

The present study has several limitations. First, due to the limitation in spatial resolution of CT imaging, there were several undetected small normal BAs. In present study, a few cases were excluded as MDCT could not visualize at least one BA on each side. Furthermore, because this study analyzed the BA anatomy of patients with hemoptysis, the dilated BA by disease involvement would have been more recognized on CT and angiography and could be relatively different from the actual anatomy of the normal population. A more accurate result would be promising in a further study using CT with advanced technology such as high spatial resolution. Second, the present study was retrospective in design and was not concerned with the technical and clinical outcome of interventional procedure. Thus, it is difficult to express the usefulness of anatomical information based on MDCT during interventional procedures. Further study with a prospective design could reveal the effectiveness of MDCT during BAE. Third, like previous studies,<sup>[17,19]</sup> the present study failed to analyze the anterior spinal artery on MDCT because of the limited spatial resolution of MDCT, which could barely demonstrate the fine anterior spinal artery. Further studies with advanced CT technology, especially in spatial resolution, may be needed.

In conclusion, MDCT and angiographic findings could provide precise anatomical information such as the origin and distribution pattern of BAs. In particular, the origin of both orthotopic and ectopic BAs were well visualized with MDCT, which is important anatomical information for locating and selecting those BAs easily during an interventional procedure.

**Author contributions**

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**Visualization:** Won Seok Choi.

**Writing – original draft:** Won Seok Choi.

**Writing – review & editing:** Won Seok Choi, Min Uk Kim, Chang Jin Yoon, Jae Hwan Lee.

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