The Mediastinal Courses of the Bronchial Arteries: Helical CT Evaluation

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気管支動脈入口部の位置と縦隔内経路の関係について検討した．原発性肺癌患者261例に術前検査として施行した5 mmヘリカルCTを気管支動脈の描出に注目して見直した．大動脈入口部より左右主気管支あるいは右中間気管支幹まで追うことのできた動脈を気管支動脈とした．右気管支動脈は77例(29.5％)，左気管支動脈は102例(39.1％)で認められた．主に右気管支動脈は下行大動脈右壁から(56動脈)，左気管支動脈は下行大動脈前壁から(93動脈)起始してそれぞれの主気管支に後方より接近していた．それ以外では右気管支動脈は弓部大動脈あるいは下行大動脈前壁から起始して気管分岐部前方(19動脈)あるいは食道前方(7動脈)を走行していた．一部左気管支動脈は下行大動脈右壁から起始して食道後方を走行していた(9動脈)．気管支動脈入口部と縦隔内経路の関係にある程度の傾向がみられた．

Research Code No.: 506.1

Key words : *Bronchial arteries, Helical CT, Mediastinum*

Received Nov. 27, 2000; revision Feb. 7, 2001
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INTRODUCTION

The bronchial arteries, which enter the lungs through the pulmonary hili and usually run alongside around the bronchi and bronchioli in the lungs, supply nutrition to the lung parenchyma. They feed air-conducting airways, walls of central pulmonary arteries and veins, intra-pulmonary lymph nodes and nerves, pleurae and axial connective tissues, but to the periphery in the respiratory zone of the lungs, it has not been made clear how pulmonary arteries and bronchial arteries share the role of feeding the lung parenchyma[1-3].

In the mediastinum, the bronchial arteries are the most significant arteries except for the great vessels, because the lungs which the bronchial arteries feed are the biggest organs in the thoracic cage. But most bronchial arteries are too thin to be seen on CT images, and few reports have described the mediastinal courses of the bronchial arteries in the radiological literature[4,5]. We reviewed the helical CT examinations, which were preoperatively performed for patients with lung cancers, paying attention to where the bronchial arteries are seen in the mediastinum and how the mediastinal courses of the bronchial arteries correspond to the location of the orifices. Factors which affect the CT demonstration of the bronchial arteries were also evaluated.

MATERIALS AND METHODS

For patients with primary lung cancers who are referred to the respiratory surgical department, mediastinal and hilar lymph node resection combined with lobectomy or pneumonectomy is performed at our hospital[6]. To determine resectability, the resected extent of the lymph nodes, and gain information at the pulmonary hilus, a helical CT examination is routinely performed in addition to the 1-cm thickness enhanced thoracic CT. 266 consecutive patients with non-small cell lung cancers from July 1995 to July 1998 were included in this study. They were 203 males and 63 females, aged from 25 to 84 years

Table　Demonstration of bronchial arteries in the mediastinum

	Demonstrated	Partly seen	Not seen
Right bronchial artery	77	96	88
Left bronchial artery	102	59	100

Note. - Numbers are patients among the total of 261 patients. The bronchial arteries were "demonstrated" when the arteries could be pursued from the aorta to the area of the main bronchus or bronchus intermedius.

(average, 64 years).

Helical CT had small fields of view of 170-mm and spans of 11.5-cm during 23 seconds of a breath hold under the rapid injection of contrast medium, with a target to the upper mediastinum and pulmonary hili. The parameters were 5-mm collimation, table speed of 5-mm/sec (a pitch of 1 : 1), reconstruction of 5-mm, 120KV, 250mA. A total of 100ml of 20% iodinated contrast medium prepared by diluting 30% Iopamidol (Iopamiron, Japan Shering, Osaka, Japan) was injected through an antecubital vein. 50 ml of contrast medium was injected at a rate of 3 ml/sec and then the rest was injected at 2 ml/sec. This injection protocol was adopted to reduce streak artifacts from the innominate vein and superior vena cava. Two series of scans at the same location started at 20 and 90 seconds after initiating the injection of contrast medium were obtained. Helical CT was performed with a X-Vigor scanner (Toshiba Medical, Tokyo, Japan)

Two experienced radiologists reviewed the helical CT scans of all patients in conference. When both radiologists agreed to the demonstration of the bronchial arteries, the bronchial arteries were judged to be seen. The arteries were seen as enhanced dot or cord structures in the mediastinum in the first series of helical CT scans. Other high density areas in the mediastinum such as calcified lymph nodes, calcification of bronchial wall cartilage, and contrast medium backflow into veins, could be differentiated from arteries by referring to the second series of helical CT scans. The arteries were recognized as bronchial arteries on condition that they could be pursued from the orifice in the thoracic aorta to around the main bronchi or the bronchus intermedius. Even though the orifice itself in the thoracic aorta could not be detected, dot enhancement just around the aorta was instead decided as the orifice spot. The aortic arch was defined as the transverse portion of the aorta on the CT images, with the small part more posterior than the esophagus included in the highest descending aorta. The midway of the bronchial arteries in the mediastinum could be more easily detected as dot enhancement when they ran vertically in the cranio-caudal direction than as cord structures when they ran horizontally. Even when poorly enhanced, cord structures which were connected with the proximal and distal parts of the bronchial arteries were treated as arteries. As to the end spot, the arteries which ran slightly apart from the walls of the main bronchi or the bronchus intermedius (within 3-mm) were also included, in addition to the arteries in contact with the walls of the main bronchi or the bronchus intermedius.

Small fields of view, the rapid injection of the contrast medium, and the arteries in the mediastinal fat tissues could lead to the demonstration of the bronchial arteries' in spite of the thicker CT collimation than the arteries' diameter. The influence of the gender of the patients, CT number value of the thoracic aorta, lung tumors per se and the size of lung tumors on the demonstration of the bronchial arteries was also evaluated (Stat View, Abacus Concepts, Berkeley, CA). Bronchiectasis, a well-known cause for the dilation of bronchial arteries affected two of the subjects.

RESULTS

DEMONSTRATION OF THE BRONCHIAL ARTERIES

Five of the 266 patients were excluded from the study; one patient did not undergo an enhanced CT examination due to severe allergy to contrast medium; in three patients the descending aorta was not included in the CT fields of view; the CT data of one patient were lost. Right bronchial arteries were demonstrated in 77 patients (29.5%), and left bronchial arteries in 102 patients (39.1%), including 45 in whom both the right and left bronchial arteries were seen. In 15 patients bronchial arteries of the common trunk type were seen. Bronchial arteries were not seen at all in 52 patients (19.9%), and right or left bronchial arteries were partly seen in the mediastinum in 96, 59 patients each when arteries on the courses were treated as bronchial arteries (Table).

At least one bronchial artery was demonstrated in 111 of the 199 male patients (55.8%), and in 23 of the 62 female patients (37.1%) ($P < 0.05$, χ^2 test). The bronchial arteries were not seen at all in 28 of 62 female patients (45.2%), and in 24 of 199 male patients (12.1%) ($P < 0.01$, χ^2 test).

The CT number values of the descending aorta were measured in 20 male patients whose bilateral bronchial arteries were demonstrated (average, 236 Hounsfield Units) and in 20 male patients whose bronchial arteries were not seen at

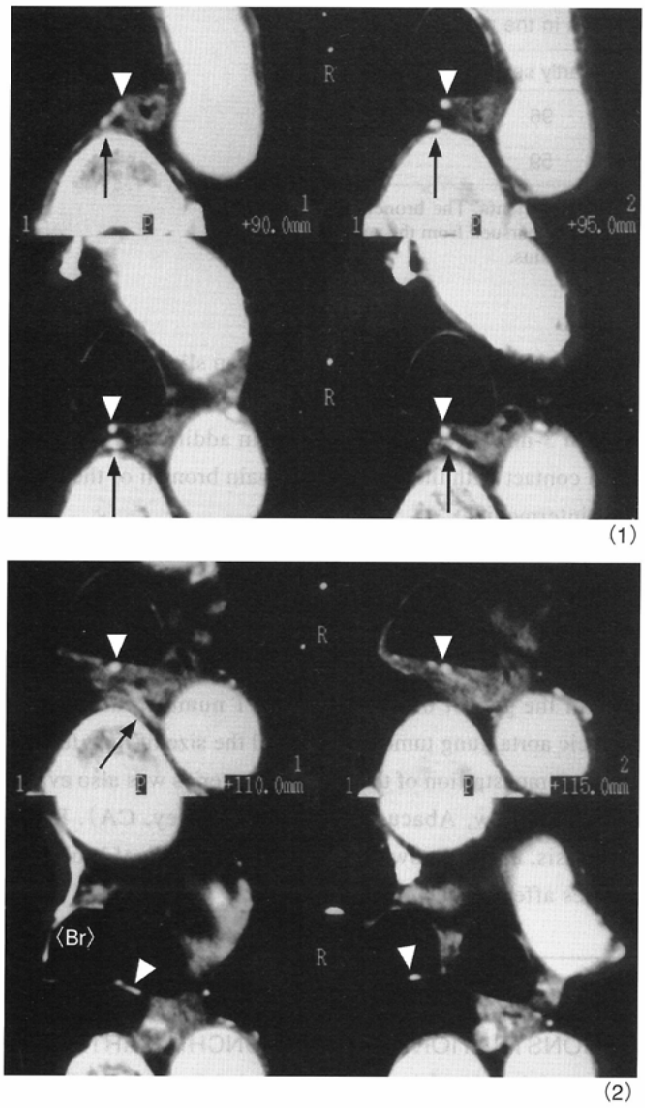


Fig. 1 Right bronchial artery of the intercosto-bronchial type
Right bronchial artery with the orifice in the right wall of the descending aorta ascends rightward along the anterior edge of the vertebral body (arrow), and descends anteriorly to reach the posterior wall of the right main bronchus (arrowhead).
Br: right main bronchus

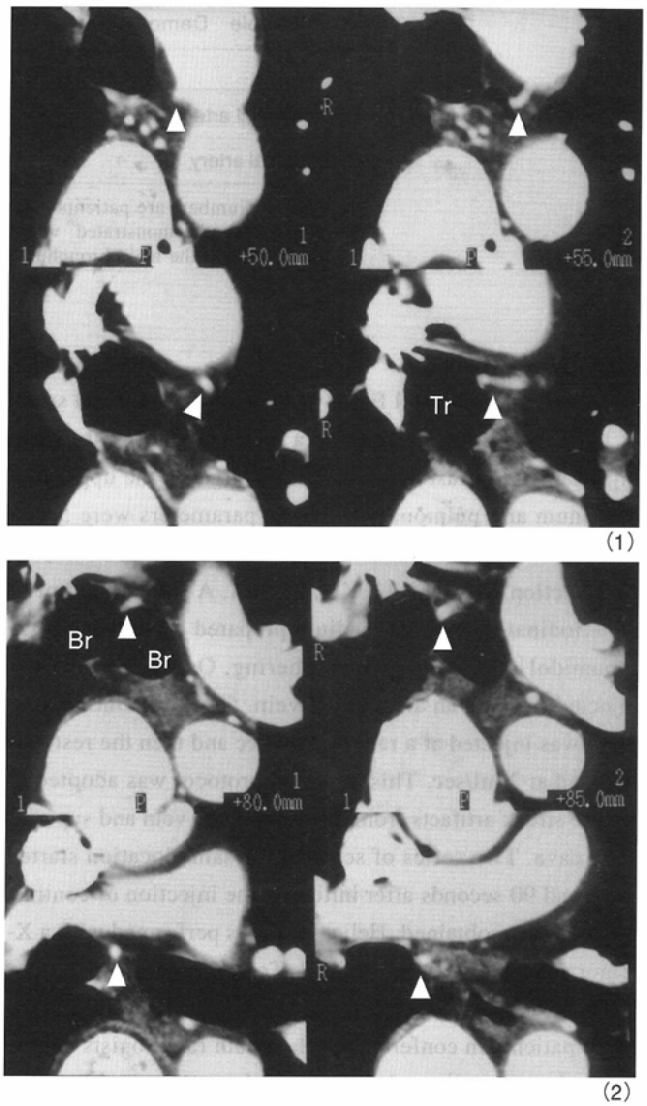


Fig. 2 Right bronchial artery of the pre-carinal type
Both the right and left bronchial arteries are dilated in this case. Right bronchial artery with the orifice in the posterior wall of the aortic arch, passes anterior to the tracheal carina after descending to the left of the trachea, and reaches the medial walls of the right main bronchus and bronchus intermedius (arrowhead).
Tr: trachea, Br: main bronchi

all (average, 216), but there was no significant difference between the two groups ($P = 0.064$, unpaired t test).

Right bronchial arteries were demonstrated in 58 of 159 patients with right lung cancers (36.5%), and in 19 of 103 patients with left lung cancers (18.4%) ($P < 0.05$, χ^2 test). Left bronchial arteries were demonstrated in 49 of 103 patients with left lung cancers (47.6%), and in 53 of 159 patients with right lung cancers (33.3%) ($P < 0.05$, χ^2 test). Right bronchial arteries were seen in 30 of 65 patients with right lung cancers, the diameter of which was 5-cm or more (46.2%), and in 28 of 94 patients with right lung cancers, less than 5-cm (29.8%) ($P < 0.05$, χ^2 test). Left bronchial arteries were seen in 25 of 39 patients with left lung cancers, 5-cm or more (64.1%), and in 24 of 64 patients with left lung cancers, less than 5-cm (37.5%) ($P < 0.01$, χ^2 test).

MEDIASTINAL COURSES OF THE RIGHT BRONCHIAL ARTERIES

The right bronchial arteries were demonstrated in 77 patients, including eight in whom two distinct right bronchial arteries were recognized. The mediastinal courses of the right bronchial arteries could be divided into four types.

(1) Intercosto-bronchial type (Fig. 1)

56 right bronchial arteries took the mediastinal course of this type and one of 56 arteries showed common trunks with the left bronchial arteries.

The right bronchial arteries of this type emerged from the right wall of the descending aorta in all and ascended rightward along the vertebral body at the average cranio-caudal distance of 1.8 cm. And then the arteries descended anteriorly, and reached the posterior walls of the right main bron-

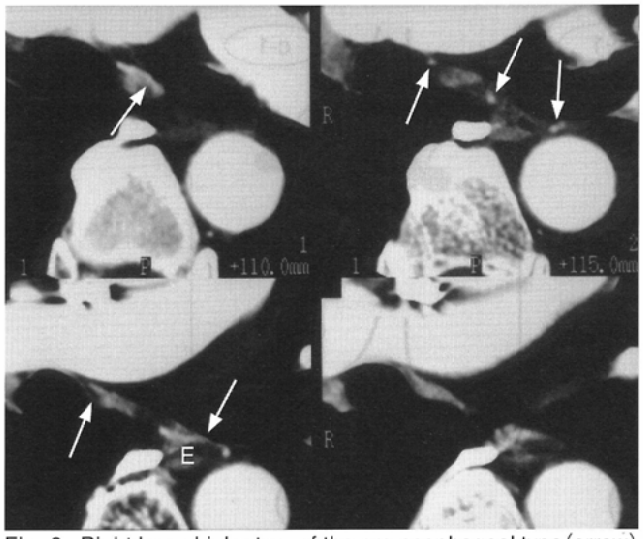


Fig. 3　Right bronchial artery of the pre-esophageal type (arrow)
Right bronchial artery emerges from the anterior wall of the aorta below the level of the tracheal carina though the exact location of the orifice is not seen, runs rightward between the esophagus (E) and the left main bronchus to reach the medial wall of the bronchus intermedius.

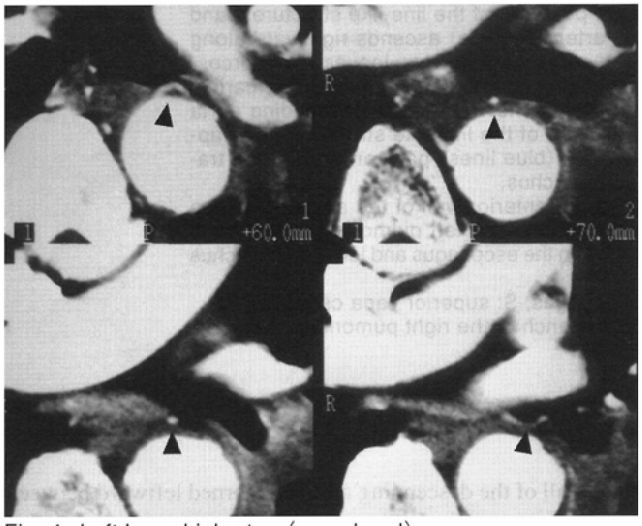
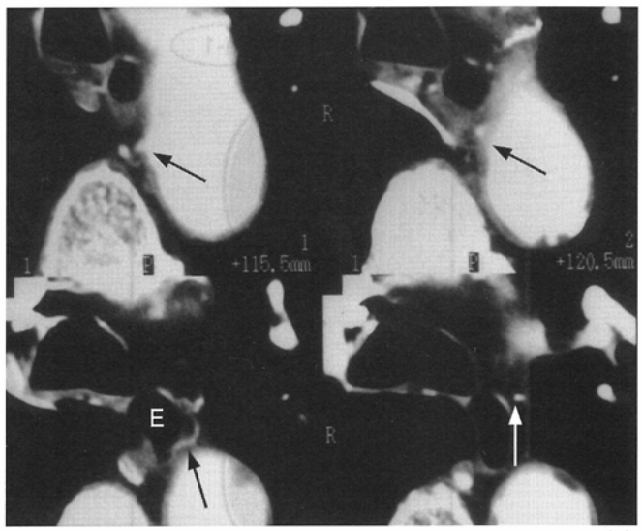


Fig. 4　Left bronchial artery (arrowhead)
Left bronchial artery emerges from the anterior wall of the descending aorta and descends anteriorly along the left main bronchus.



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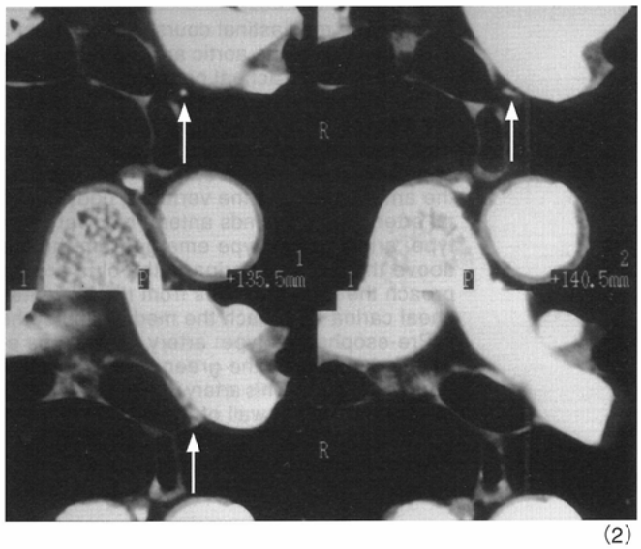

(2)

Fig. 5　Left bronchial artery with the orifice in the right wall of the aorta (arrow)
Left bronchial artery emerges from the right wall of the highest descending aorta, turns leftward posterior to the esophagus (E) and reaches the left main bronchus.

chi in 42, the medial-posterior walls of the bronchi intermedius in eight, the lateral walls of the bronchi intermedius by way of the posterior side of the bronchi in six. In 29 cases (51.8%) the right intercostal arteries could be seen along the right side of the vertebral body after the bronchial arteries left anteriorly.

(2) Pre-carinal type (Fig. 2)

19 right bronchial arteries took the mediastinal course of this type and 11 of 19 arteries showed common trunks with the left bronchial arteries.

The orifices were the right walls of the aortic arch in nine, probably the inferior walls of the aortic arch in three, and the anterior walls of the descending aorta above the tracheal carina in six and below the carina in one. The one bronchial artery, after emerging from the anterior wall of the descending aorta below the carina, once ascended and ran rightward toward anterior to the tracheal carina. After passing anterior to the tracheal carina, the arteries reached the medial walls of the right main bronchi and bronchi intermedius in all but one. The other one artery ran rightward along the anterior wall of the right main bronchus from the anterior to the tracheal carina.

(3) Pre-esophageal type (Fig. 3)

Seven right bronchial arteries took the mediastinal course of this type and three of seven arteries showed common trunks with the left bronchial arteries. The orifices were the anterior walls of the descending aorta above the tracheal carina

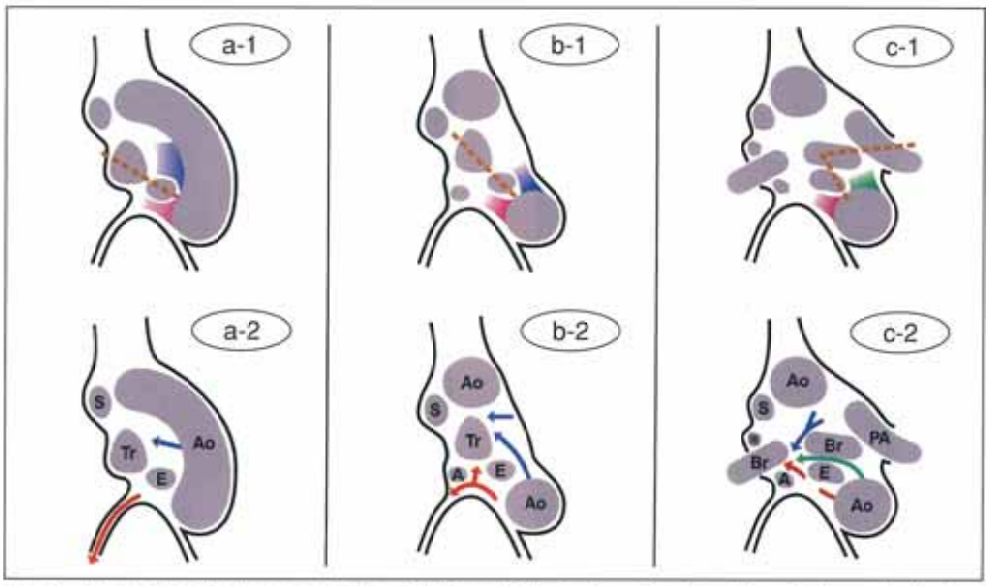

Fig. 6 The mediastinal courses of the right bronchial arteries with the orifices in the aorta (a-1, a-2) at the level of the aortic arch, (b-1, b-2) the level above the tracheal carina, and (c-1, c-2) at the level below the tracheal carina.

The trachea, esophagus, and aorta are situated in line and border between the right and anterior walls of the descending aorta (dotted line). Intercosto-bronchial type: arteries of this type emerges from the right wall of the aorta in the red area to the right-posterior of the line-like structures, and approaches the right bronchus from the posterior. This artery (red line) ascends rightward along the anterior edge of the vertebral body in common with the intercostal artery, leaves the intercostal artery and descends anteriorly toward the posterior wall of the right main bronchus. Pre-carinal type: artery of this type emerge from the aortic arch or the anterior wall of the descending aorta above the tracheal carina in the blue area to the left-anterior of the line-like structures, and approach the right bronchus from the left-anterior. The arteries (blue lines) pass anterior to the tracheal carina and reach the medial wall of the right main bronchus.

Pre-esophageal type: artery of this type emerges from the anterior wall of the aorta below the tracheal carina, in the green area where the left main bronchus and left pulmonary artery lie in front of the aorta. This artery (green line) runs rightward between the esophagus and left main bronchus toward the medial wall of the bronchus intermedius.

Ao: thoracic aorta, Tr: trachea, Br: main bronchi, E: esophagus, S: superior vena cava, PA: left pulmonary artery, A: azygos vein, ※: upper lobe branch of the right pumonary artery

in two and below the carina in five. The arteries passed between the esophagus and the left main bronchus at the height 0-1 cm caudal from the carina in one, 1-2 cm caudal in three, and 2.5-3 cm caudal in three. The end spots of the bronchial arteries recognized on CT were the medial walls of the bronchi intermedius in all.

(4) Subclavian artery type

Two right bronchial arteries were recognized to emerge from the root of the right subclavian artery and another from the right internal thoracic artery. They descended a long way in the mediastinum to the right of the trachea and reached the right lung hilus.

MEDIASTINAL COURSES OF THE LEFT BRONCHIAL ARTERIES

The left bronchial arteries were demonstrated in 102 patients. In 93 patients left bronchial arteries emerged from the anterior wall of the descending aorta and went anteriorly to meet the posterior wall of the left main bronchus (Fig. 4). Exceptionally, nine left bronchial arteries emerged from the right wall of the descending aorta and turned leftward between the esophagus and the descending aorta to reach the left main bronchus (Fig. 5). Four of these nine arteries were in common with the right intercostal arteries.

DISCUSSION

The bronchial arteries emerged mostly from the descending aorta or the aortic arch. The courses of the bronchial arteries in the mediastinum were more direct toward the left lung than toward the right lung because the descending aorta and the aortic arch lie closer to the former than to the latter. Usually the left bronchial arteries emerged from the anterior wall of the descending aorta and ran anteriorly to meet the left main bronchus. The mediastinal courses of the right bronchial arteries with the orifices in the aorta could be divided into three patterns. The most frequently encountered pattern by far was the intercosto-bronchial type, in which the right bronchial arteries emerged from the right wall of the descending aorta

and approached the right main bronchus from the posterior side. When the right bronchial arteries emerged from the anterior wall of the descending aorta or the aortic arch, they took the course of either the pre-carinal or pre-esophageal type according to the height of the orifices. The right bronchial arteries with the orifices at the higher position tended to follow the pre-carinal course, while those with the orifices at the lower position tended to follow the pre-esophageal course. The left and posterior walls of the descending aorta were covered by the left lung, and in our study no bronchial arteries were detected to emerge from these parts of the aorta.

In other words, it was observed that the trachea, esophagus, and descending aorta were almost always situated in contact with each other in the mediastinum, and these line-like structures bordered the right and anterior walls of the descending aorta (Fig. 6). The right bronchial arteries of the intercosto-bronchial type ran in the area to the right-posterior of the line-like structures. The right bronchial arteries of the pre-carinal type ran in the area to the left-anterior of the line-like structures and approached the right main bronchus from the left-anterior side. Below the level of the tracheal carina, the left main bronchus and the left pulmonary artery were situated in front of the aorta, and the right bronchial arteries ran toward the bronchus intermedius passing anterior to the esophagus (pre-esophageal type). Most left bronchial arteries also ran in the area to the left-anterior of the line-like structures.

Our investigation limited to the arteries which could be seen on the CT images is compatible with past anatomical papers[7)-9)]. Mostly the left bronchial arteries were reported to emerge from the anterior wall of the descending aorta and the right bronchial arteries from the right wall of the aorta. Otherwise, the right bronchial arteries arise from the anterior wall of the descending aorta or the aortic arch, then they pass anterior to the tracheal carina or anterior to the esophagus. Whenever the right bronchial arteries ran anterior to the esophagus, the courses were depicted between the esophagus and the left main bronchus below the tracheal carina. When the left bronchial arteries emerged from the right wall of the descending aorta, the courses to reach the left bronchus were reported to be between the esophagus and the aorta (Fig. 5). The right bronchial arteries of the pre-carinal and pre-esophageal types made common trunks with the left bronchial arteries more frequently than those of the intercosto-bronchial type. The frequencies according to Cauldwell were 21 of 30 (70%) for the former and 3 of 133 (2%) for the latter. This seems reasonable because the right bronchial arteries of the pre-carinal and pre-esophageal types run in the same mediastinal area, to the left-anterior of the line-like structures by the trachea-esophagus-aorta, as the left bronchial arteries. As aberrant orifices other than the thoracic aorta, the subclavian artery, the innominate artery, the internal thoracic artery, the pericardioco-phrenic artery, the inferior thyroid artery, the proper esophageal artery, the inferior phrenic artery, and the abdominal aorta were reported.

Our study has several limitations. First, our investigation is based on the arteries which could be seen on the CT images, so other mediastinal courses and orifices of the bronchial arteries are also possible. For example, the bronchial arteries along the superior wall of the main bronchus were hard to recognize, and the great vasculature such as the pulmonary artery and superior vena cava, prevented the pre-hilar course of the bronchial arteries from being recognized. Moreover, the exact orifice spot of all the arteries included in this study could not be detected. Second, the artery was recognized as a bronchial artery on condition that it could be followed until around the main bronchus or bronchus intermedius. This was based on an assumption, namely that the bronchial arteries were the thickest arteries in the mediastinum except for the great vessels, so other mediastinal arteries were hardly seen on the CT images. These arteries might be the mediastinal arteries feeding only the main bronchus, pericard, esophagus, subcarinal lymph nodes or connective tissues.

Clinical applications from our investigation are possible. Bronchial arterial embolization has no risk of spinal cord injury when the orifice of the bronchial artery is the anterior wall of the descending aorta, because the spinal cord branch is delivered from the intercostal artery in the thorax and this bronchial artery has no connections with the intercostal artery[10)]. In the case of bronchial arterial drug infusion for lung cancer, complications resulting from stimulation of the esophagus can be caused when a bronchial artery of any type is cannulated. The esophageal arteries in the upper thorax are described to be delivered from the bronchial arteries, the right bronchial artery of any type and the left bronchial artery can deliver the esophageal branch[11, 12)]. In patients, specially males with large lung tumors, the information provided by helical CT may be useful before the procedures such as pre-carinal lymph node biopsy by mediastinoscopy or operation to the esophagus. The dilated bronchial arteries of the pre-carinal or pre-esophageal type can suggest an enhanced risk of bleeding.

In summary, the mediastinal courses that the right bronchial arteries pass anterior to the tracheal carina or anterior to the esophagus, and that the left bronchial arteries pass posterior to the esophagus after emerging from the right wall of the descending aorta, have not been described in the radiologic literature. These are less frequent than the course of the right intercosto-bronchial arteries and the more direct

course of the left bronchial arteries from the anterior wall of the aorta. By using up-to-date modality such as multi-detector row CT, other mediastinal courses and orifices of the bronchial arteries and even the intra-pulmonary courses of the bronchial arteries could be demonstrated, which helps to improve the success rate of bronchial arterial embolization and decrease the risk of bleeding in surgical procedures.

ACKNOWLEGMENTS

The author thanks Hozumi Fukuda, M.D. for his reviewing the films.

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