Visualization of Azygos Arch Valves using Computed Tomography: Comparison of Scanning Delay Times

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(Received March 7, 2008; Accepted April 22, 2008)

Objective: To evaluate the frequency and appearance of azygos arch valves after short and long scanning delays and high injection rates of contrast material (CM) using a 64-slice multi-detector-row computed tomography (MDCT).
Methods: We retrospectively reviewed the findings from 264 contrast-enhanced MDCT chest examinations. The rate of injection for 300 mg I/ml CM was 3.0 ml/sec; the short and long scanning delays were 20 and 180 sec, respectively. The presence of residual CM in the azygos arch valves and reflux of CM into the azygos arch were recorded. A chi-square test was used to compare the frequency of residual CM in azygos arch valves and reflux of CM into the azygos arch in both groups.
Results: Of the 132 examinations with short scanning delays, 91 (68.9%) demonstrated residual CM in azygos arch valves and 103 (78.0%) demonstrated reflux of CM into the azygos arch. A significantly higher frequency of reflux of CMinto the azygos arch and residual CM in azygos arch valves was seen with short scanning delays than with long scanning delays ($P < 0.05$). However, no reflux of CM into azygos arch was seen with long scanning delays.
Conclusions: Both reflux of CM into azygos arch valve and residual CM in the azygos arch were frequently seen using short scanning delays.

Key words: azygos arch, azygos arch valves, contrast-enhanced CT, contrast material

INTRODUCTION

Multi-detector-row computed tomography (MDCT) is performed frequently using a high injection rate of the contrast material (CM) to diagnose vascular lesions [1–3]. The phenomena of reflux of CM into the azygos arch from the superior vena cava (SVC) and residual CM in the azygos arch valves are sometimes observed after the high injection rate of the CM [4]. We evaluated the frequency and appearance of the azygos arch valves by conducting routine chest examinations and injecting the CM at a low rate using single-slice helical CT and 6-slice MDCT [5]. We reported that CM remained more frequently in the azygos arch valves after a rate of CM injection of 2 ml/sec using 6-slice MDCT (45 of 100 examinations; 45%) than after a rate of CM injection of 1 ml/second using single-slice helical CT (15 of 100 examinations; 15%) [5]. Furthermore, we evaluated the frequency and appearance of azygos arch valves after high and low injection rates of CM using 64-slice MDCT at contrast-enhanced CT of the chest [6]. In our previous study, we showed that residual CM in azygos arch valves and reflux of CM into the azygos arch were seen more frequently with a high injection rate of CM with a short scanning delay than with a low injection rate of CM with a long scanning delay [5, 6].

The purpose of this study was to evaluate the frequency and appearance of azygos arch valves using 64-slice MDCT after long and short scanning delays using high injection rates of CM.

MATERIALS AND METHODS

Informed written consent was not required because this was a retrospective study approved by our institutional review board. We conducted a computerized search for all intravascular contrast-enhanced CT examinations of the chest performed over a 16-month period and identified 132 (15 men, 117 women) patients (mean age: 52.8 years; range: 24–88 years). CT examinations were performed to rule out pulmonary embolism and deep venous thrombosis. In almost all the women, CT was performed before the gynecologic surgery. Patients with heart failure, postoperative thoracoplasty, pleuritis with excessive pleural effusion, mediastinal tumor, lymphadenopathy, or massive pulmonary embolism were excluded. The body weight ranged from 40 to 75 kg. All patients were examined in the supine position.

CT examinations were performed with a CM injection rate of 3.0 ml/sec and scanning delays of 25 (short) and 180 (long) sec. The short scanning delay was performed to rule out pulmonary embolism, and the long scanning delay was performed to evaluate for deep venous thrombosis. All scans were performed cranial-to-caudal from the apex of the lung. The es-

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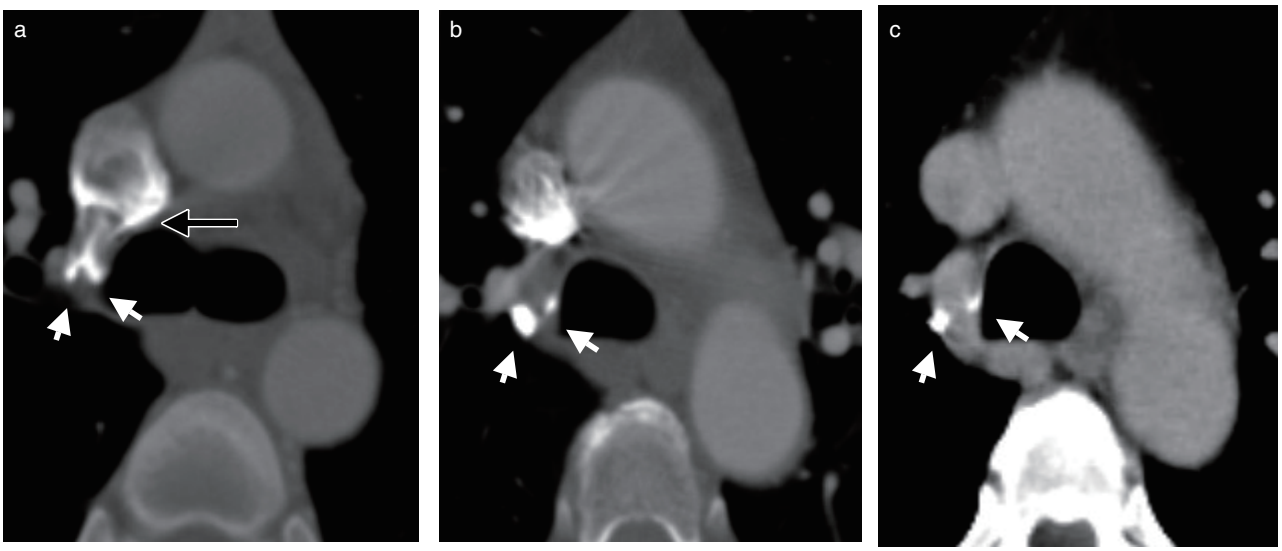

Fig. 1. Reflux of contrast material into the azygos arch and residual contrast material in the azygos arch valves
a, b : Contrast-enhanced axial CT images on short scanning delay of bone window shows reflux of contrast material from superior vena cava into the azygos arch (black arrow). Note residual contrast material in both sides of the azygos arch valves (white arrows).
c: Contrast-enhanced axial CT image on long scanning delay of bone window shows residual contrast material in both sides of the azygos arch valves (white arrows).

timated scanning time at the level of the azygos arch before and after administration of CM were 83 and 183 sec, respectively. All examinations were performed by intravenously injecting isohexol (Omnipapue ™300; Dai-ichi) at 2 ml/kg using a power injector. Fifty-one patients were injected with CM in the right arm, and another 51 patients were injected with CM in the left arm. The examinations were performed using a 64-slice MDCT scanner (Somatom Cardiac Sensation 64; Siemens, Forchheim) with collimation of 0.6 mm, 0.5 sec of rotation time, and a reconstruction interval of 5 mm.

Two board-certified radiologists (J. E. and T. I.) with more than 15 years of experience interpreted the chest CT images and reviewed all CT images using a picture archiving and communication system workstation to reach consensus. Images were systematically evaluated for residual CM in azygos arch valves and reflux of CM into the azygos arch from the SVC, which was considered to be present when the enhancement of the azygos arch and vein valves was more intense than enhanced SVC (Fig. 1). The frequency of residual CM in azygos arch valves and reflux of CM into the azygos arch was recorded. When residual CM was seen in azygos arch valves, the degree of residual CM in the azygos arch valves was graded as Grade 1 if one side of the valves was enhanced and as Grade 2 if both sides of the valves were enhanced (Fig. 1). All axial CT images were evaluated on mediastinal windows (window level: 50 Hounsfield units (HU); window width: 350 HU). However, setting of the window level and width of the CT images were adjusted by the observer at the time of image evaluation to minimize streak artifacts and often approached those of bone window (window level: 600 HU; window width: 2000 HU) (Fig. 1).

Chi-square analysis was used to compare the frequency of residual CM in the azygos arch valves and reflex of CM into the azygos arch with short and long scanning delays. Mann–Whitney's *U* test was used to evaluate the correlation between injection site and frequency of residual CM in azygos arch valves and CM reflux into the azygos arch. Statistical significance was set at $P < 0.05$.

RESULTS

Of the 264 examinations, 129 (49.0%) demonstrated residual CM in the azygos arch valves, and 103 (39.0%) demonstrated reflux of CM into the azygos arch. In a short scanning delay, 91 (68.9%) demonstrated residual CM in the azygos arch valves, and 103 (78.0%) demonstrated reflux of CM into the azygos arch. In contrast, during a long scanning delay, 38 (28.8%) demonstrated residual CM in azygos arch valves and reflux of CM was not observed in any of the examinations. A significantly higher frequency of residual CM in azygos arch valves was seen on short scanning delay than on long scanning delay ($P < 0.0001$). The frequency of residual CM in azygos arch valves and reflux of CM into the azygos arch is shown in Table 1. Residual CM in the azygos arch valves was demonstrated more frequently when CM was administered in the right arm (65 of 84 examinations; 78.3%) than in the left arm (26 of 48 examinations; 54.1%) on short scanning delay ($P = 0.0057$); whereas, the frequency of residual CM in the azygos arch valves was independent of CM injection site on long scanning delay ($P = 0.7446$). In addition, the frequency of reflux of CM into the azygos arch valves was independent of CM injection site on short scanning delay ($P = 0.1311$). The degree of residual CM in azygos arch valves is shown in Table 2. Of the 129 examinations that showed residual CM in azygos arch valves, 77 (60.2%) showed enhancement of both sides of the azygos arch valve.

None of the patients had azygos lobe. One case of

Table 1 Frequency of residual contrast material in the azygos arch valves and reflux of contrast material into the azygos arch

a. Residual CM in the azgos arch valves

	Short scanning delay	Long scanning delay
Right side injection of CM	78.3% (65/84)	29.8% (25/84)
Left side injection of CM	54.2% (26/48)	27.1% (13/48)
Total	68.9% (91/132)	28.8% (38/132)

b. Reflux of CM into the azygos arch on short scanning delay

Right side injection of CM	82.1% (69/84)
Left side injection of CM	70.8% (34/48)
Total	78.0% (103/132)

CM: contrast material

Table 2 Degree of residual contrast material in the azygos arch valves

Scanning delay	Grade 1: one side	Grade 2: both sides
Short (N=91)	24	67
Long (N= 38)	28	10
Total (N=129)	52	77

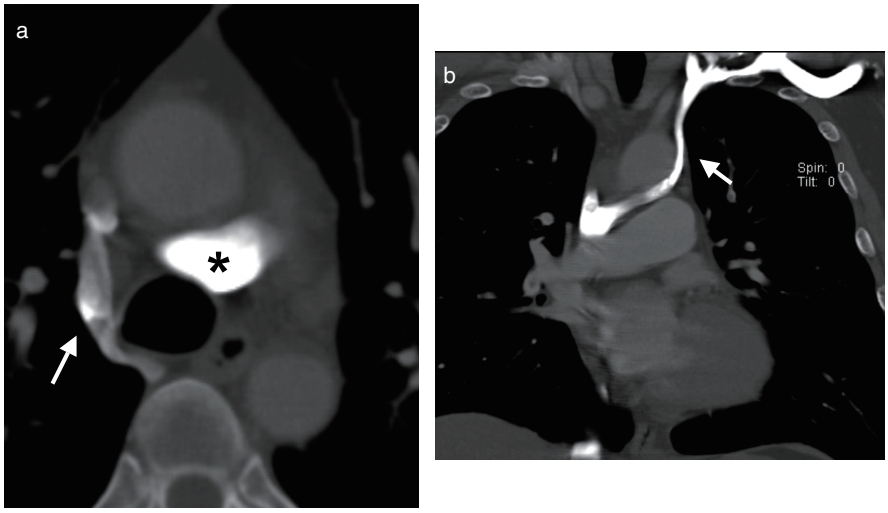

Fig. 2. 57-years-old women with the aberrant left brachiocephalic vein
a : Contrast-enhanced axial CT image on short scanning delay with left side of injection of contrast material shows the aberrant left brachiocephalic vein (asterisk) courses behind the ascending aorta and enters the superior vena cave. Note residual contrast material in one side of the azygos arch valves (arrow).
c: Coronal reformatted image shows the aberrant left brachiocephalic vein (arrow).

aberrant left brachiocephalic vein with a high level of entry to the SVC was observed when the CM was injected in the left arm, and CM reflux into azygos arch and residual CM in both sides of the azygos arch valve were observed on short scanning delay (Fig. 2). There was one case of persistence of left SVC with right arm injection of the CM, and CM reflux into the azygos arch and residual CM in one side of the azygos arch valve were observed on short scanning delay.

DISCUSSION

The azygos vein is a large vein with a bicuspid valve in the thoracic cavity (Fig. 3). The azygos system is a paired venous pathway of the posterior thorax that may be affected by numerous congenital and acquired conditions. Contrast-enhanced CT is able to depict anatomical changes in the azygos vein and disorders of the azygos system (Fig. 2) [7–9]. A few articles have reported reflux of CM into the azygos vein and artifacts to be caused by CM in the azygos vein [10, 11]. In addition, previous case reports have suggested that refulx of CM into the azygos vein may be an indicator of abnormal right heart hemodynamics, such as cardiac tamponade [12, 13]. However, Yeh's group has supported the stance that limited azygos reflux is a non-specific phenomenon. Filling of the azygos or hemiazygos veins after bolus injection of CM is occasionally seen in healthy persons, and it is likely explained by a simple gravitational effect [4].

However, no true functional valves exist in the azygos system, and the presence of azygos arch valves is not known to be of clinical importance [12]. Azygos arch valves may result because of a ruptured vein associated with the migration of the guidewire into

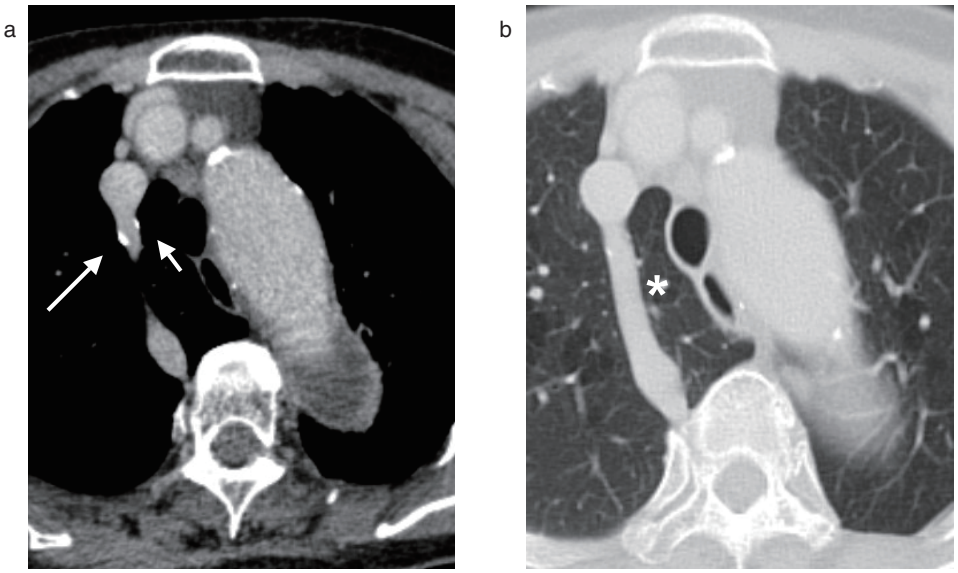

Fig. 3. 57-years-old women with azygos lobe
a: Contrast-enhanced axial CT image shows azygos arch valves (arrows).
b: Axial CT of lung window shows the azygos lobe (asterisk).

azygos arch valves when a central venous catheter is mistakenly inserted into the azygos arch. We found that the frequency of CM reflux into the azygos arch and residual CM in azygos arch valves were associated with the injection rate, scanning delay time, injection site, concentration of CM, and other factors [5, 6]. Yeh and colleagues reported that a high frequency of CM refluxed into the azygos vein in case of high injection rates (3.5–5.0 ml/sec) as compared with the low injection rates (2.0–3.5 ml/sec) of highly concentrated CM (350 mg I/ml) [4]. Many common limitations including the use of various injection rates of CM, different scanning delays, collimations, and thicknesses of the reconstruction slice were seen in our previous study and that conducted by Yeh and colleagues. As a result, we were unable to precisely evaluate the frequency of reflux of CM into the azygos arch and of residual CM in azygos arch valves associated with scanning delay [5, 6]. In the present study, we used the same injection rate of CM and the same collimation and thickness of the reconstruction slice to evaluate the frequency of CM reflux into the azygos arch and residual CM in azygos arch valves based on scanning delay. The results showed that reflux of CM into azygos arch and residual CM in azygos arch valves were seen more frequently with short scanning delays than with long scanning delays at a CM injection rate of 3.0 ml/sec. The results of the present study agree with our previous study, i.e., that residual CM in azygos arch valves was more frequently seen after right arm injection of CM than after left arm injection of CM on short scanning delay. Because residual CM in azygos arch valves was washed out during long scanning delay, the injection site had no effect on the frequency of residual CM in azygos arch valves. We previously reported that the age of the patient was independent of the frequency of residual CM in the azygos arch valves and CM reflux into azygos arch [6].

When only a delayed scan was performed, the reflux of CM into the azygos arch subsided, which made the vein more inconspicuous. Consequently, residual CM in the cusps of azygos arch valves tended to be visualized as isolated areas of high density and could easily be mistaken for other hyperdense structures, such as calcified lymph nodes, surgical clips, tracheal calcifications, or calcification of mediastinal tumor (Fig. 4). The possibility of frequency of residual CM in the azygos arch valves is increased when the azygos arch valves are compressed by lung tumors or atelectasis and by excessive pleural or pericardial effusion (Fig. 5). We had measured CT attenuations of residual CM in the azygos arch valves, and those were more than 800 HU [5]. Image evaluation on bone window was useful to distinguish residual CM in the azygos arch valves from as calcified lymph nodes or surgical clips (Fig. 4). It is important to understand the normal appearance and frequency of residual CM in the azygos arch valves. We found that residual CM in one side of the azygos arch valves was seen in 28 of 38 examinations and that residual CM in both sides of the azygos arch valves was seen in 10 of 38 examinations at a CM injection rate of 3 ml/sec and with a long scanning delay.

We obtained a huge volume of high-quality multiplanar reformation images with the 64-slice MDCT [14]. The azygos vein valves were reported to be present within 4 cm of the SVC, and the median distance of the azygos arch valve from the SVC was 1.9 cm on CT [4]. We found that the mean maximum length of the azygos arch valves was 8.51±0.42 mm [5]. If residual CM is suspected on axial image, the problem can be solved by adding multiplanar reformatted, three dimensional and maximum intensity projection images (Fig. 5, 7).

High temporal and spatial resolution of MDCT results in visualization of structures and pathologies, which were undetected until date. The knowledge of minute anatomy and structures, such as azygos arch valves, is considered important in enhancing the diagnostic capabilities of MDCT.

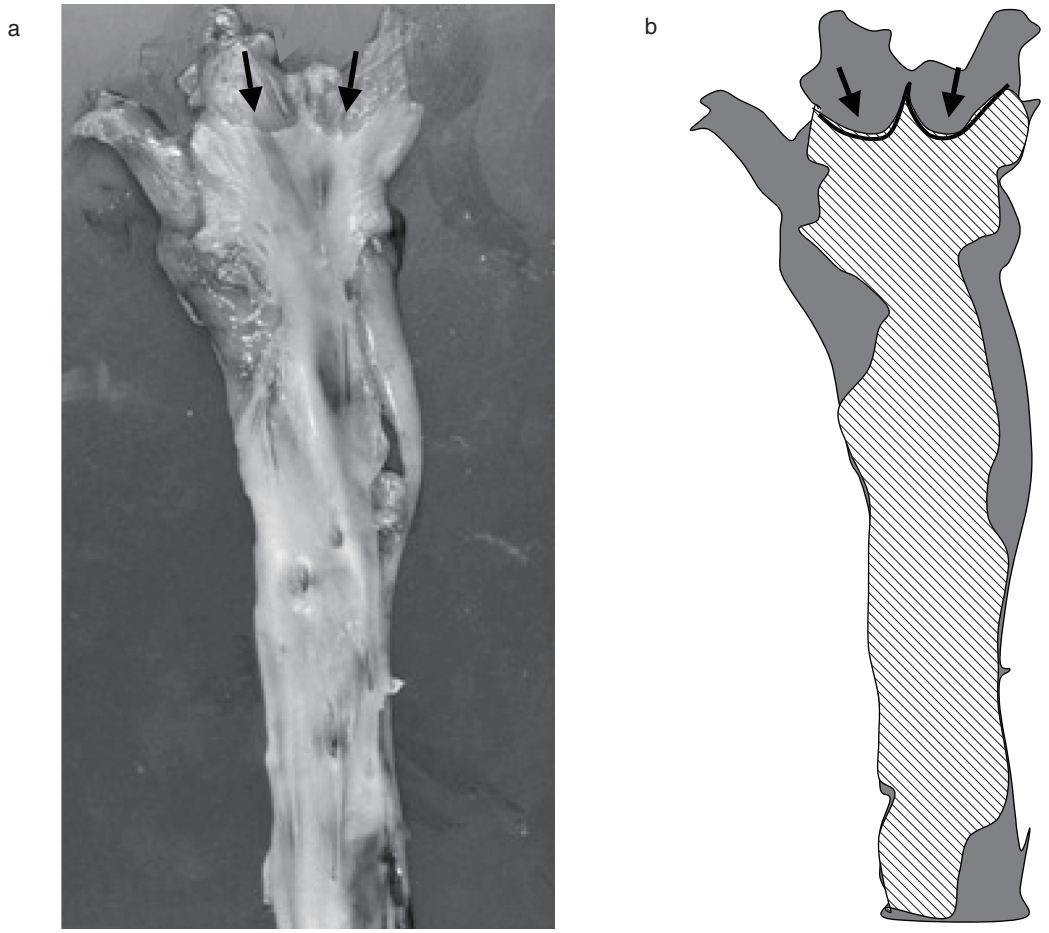

Fig. 4. a: Gross specimen of the azygos vein demonstrates a bicuspid valve of the azygos arch (arrows).
b: Schem of the aztgos vein and azygos arch valves (arrows).

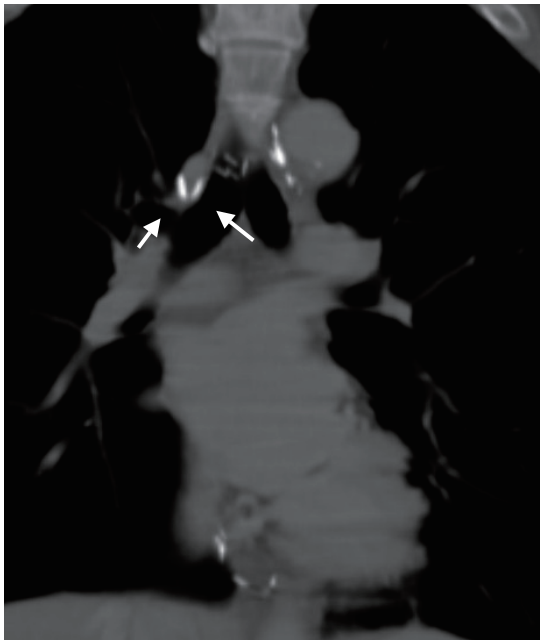

Fig. 5. 58-years-old man with post-operative state of esophageal cancer
Coronal reformatted image on bone window shows residual contrast material in both sides of the azygos arch valves (arrows) distinguished from multiple surgical clips

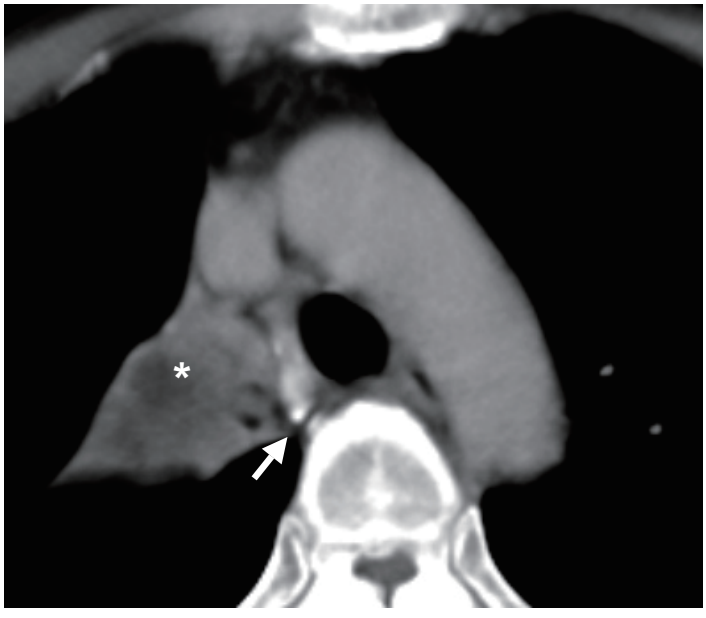

Fig. 6. 48-years-old man with lung cancer
Contrast-enhanced axial CT image shows residual contrast material in one side of the azygos arch valves (arrow) adjacent to lung tumor and atelectasis (asterisk).

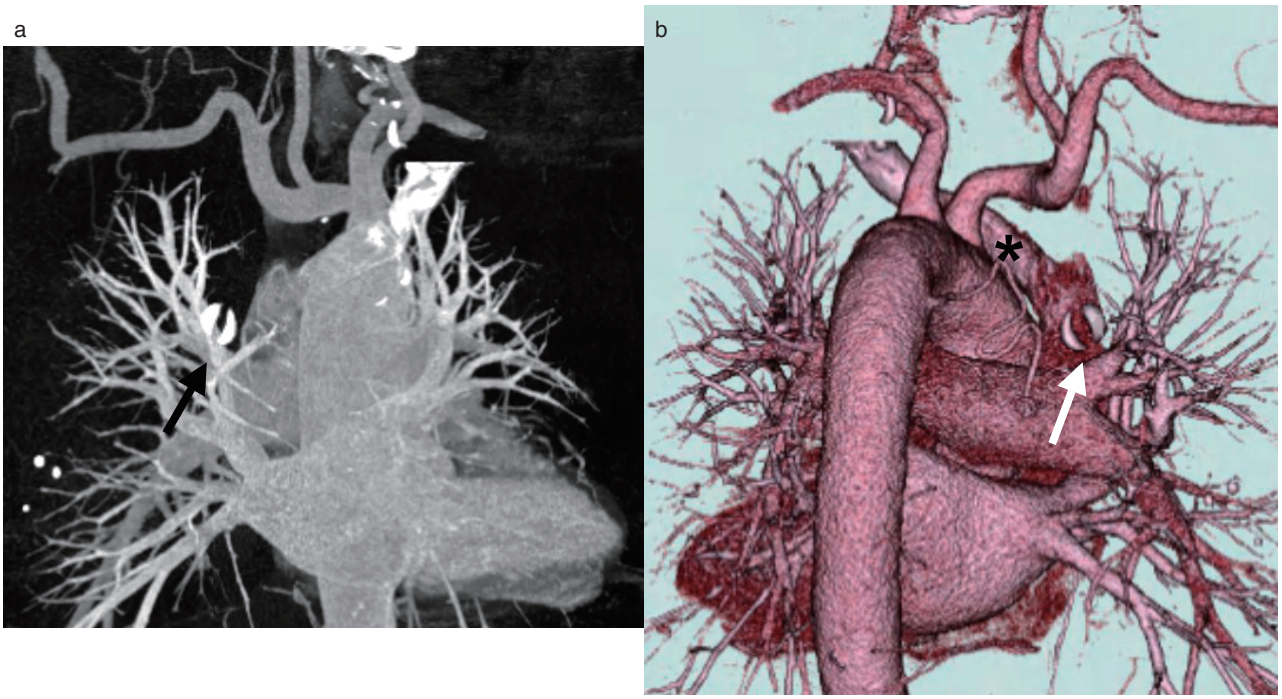

Fig. 7. Typical appearance of the azygos arch valves.
a: Maximum intensity projection image shows residual contrast material in both sides of tha azygos arch valves (black arrow).
b: Volume rendering image shows the azygos arch valves (white arrow) posterior to the superior vena cave (asterisk).

In conclusion, our results indicate that residual CM in the azygos arch valves and reflux of CM into the azygos arch after high injection rates of CM were seen more frequently with a short scanning delay than with a long scanning delay. Residual CM in both sides of azygos arch valves was frequently seen after a high rate of CM injection with a short scanning delay.

ACKNOWLEDGEMENTS

The authors are grateful to Fumiko Kimura M. D. who reviewed a part of this manuscript with her excellent suggestions.

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