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The Role of Dual-Source Computed Tomography Angiography in Evaluating the Aortic Arch Vessels in Acute Type A Aortic Dissection: A Retrospective Study of 42 Patients

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Background: This study aimed to investigate the role of dual-source computed tomography angiography (DSCTA) to evaluate the anatomy of the aortic arch vessels in patients with acute Type A aortic dissection (AD).

Material/Methods: A retrospective clinical study included 42 patients with acute Type A AD who underwent DSCTA and were treated in our hospital between January 2018 and December 2018. The findings were compared with a control group of 45 healthy individuals with hypertension and without aortic arch lesions.

Results: The diagnostic accuracy of DSCTA in patients with acute Type A AD was almost 100%. The innominate artery was most frequently affected. The mean DSCTA imaging measurements for the root of the innominate artery, the left common carotid artery, and the left subclavian artery, in the coronal plane of the aortic arch, were 17.7 ± 3.7 mm, 17.7 ± 3.7 mm, and 12.9 ± 3.1 mm, respectively. The angles formed by the origin of the three aortic arch branches vessels and the aortic arch were $70.5 \pm 10.2^\circ$, $58.5 \pm 15.5^\circ$, and $90.2 \pm 22.7^\circ$, respectively. In the transverse plane of the aortic arch, the mean angles were $110.5 \pm 22.3^\circ$, $100.3 \pm 15.2^\circ$, and $95.4 \pm 10.6^\circ$, respectively. These DSCTA imaging findings were significantly different in the patient group compared with the control group.

Conclusions: DCTA demonstrated that patients with Type A AD showed anatomic differences in the aortic arch vessels. These findings may help surgeons to develop treatment strategies and select the most appropriate vascular grafts and stents.

MeSH Keywords: **Aorta, Thoracic • Dissection • Multidetector Computed Tomography**

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26



Background

Type A aortic dissection (AD) arises in the ascending aorta and involves the aortic arch and the vessels arising from the aortic arch. Type B AD arises in the descending aorta. Patients with AD who do not have Marfan syndrome or other congenital conditions affecting the aorta, commonly have a history of hypertension [1–3]. Acute AD is a life-threatening condition that is associated with a high mortality rate from the rupture of the aorta [1–3]. The current management of acute Type A AD includes open surgery combined with intraoperative triple-vessel grafting, or intraoperative replacement of the aortic arch, and percutaneous transluminal vascular stent insertion [4–6]. Aortic arch repair is a key component of the surgical treatment of AD [7,8].

Currently, few studies have been reported on the anatomic change of the vascular branches of the aortic arch during AD. Treatment approaches for AD have very specific requirements according to the anatomic changes in the aortic arch. These requirements highlight the need for studies on the anatomy of the innominate artery, the left common carotid artery, and the left subclavian artery in AD. Therefore, this retrospective clinical study, conducted at our hospital, aimed to investigate the role of dual-source computed tomography angiography (DSCTA) to evaluate the anatomy of the aortic arch vessels in patients with acute Type A AD.

Material and Methods

Ethical considerations

The Board of the Ethics Committee of Fujian Medical University reviewed and approved this study. The patients who participated

in the study and who underwent dual-source computed tomography angiography (DSCTA) and surgery signed written informed consent, or their relatives signed consent on their behalf.

Patients studied

The retrospective study included 42 patients with acute Type A aortic dissection (AD) who were hospitalized from January 2018 and December 2018 and underwent DSCTA examination. The exclusion criteria included poor CT image quality, severe lung diseases or thoracic disease, anatomic abnormalities of the aortic arch, and a diagnosis of Marfan syndrome. All patients enrolled in the study presented with typical symptoms of AD, including acute onset of severe chest pain. Some patients reported pain radiating to the shoulders or the abdomen. Patients also had other symptoms, including syncope, hypotension, pericardial or pleural effusion, and pericardial tamponade.

All patients underwent cardiac ultrasound and DSCTA examination within 4 to 8 hours after the onset of symptoms, and the diagnosis of acute Type A AD was confirmed by the intraoperative findings [9]. Overall, 90% of patients could provide a clear history of hypertension, and the remaining patients could not confirm whether they had a history of hypertension. A control group of healthy individuals was selected and matched based on age, gender, weight, and body surface area (BSA). Consider the common etiology of the AD, 45 patients with hypertension and without aortic arch lesions, including aneurysm or atherosclerosis of the aortic arch, were included in the control group. The individuals in the control group had regular physical examinations, serious illnesses were excluded, and they had no history of major surgery, cardiovascular disease, hepatic or kidney dysfunction. Table 1 shows the clinical data of the study group and the control group.

Table 1. Clinical data of patients with acute Type A aortic dissection (AD) and healthy controls undergoing dual-source computed tomography angiography (DSCTA).

Variables	AD patient group	Control group	p-Value
	42	45	
Gender (M: F)	32: 10	33: 12	p>0.05
Age (years)	52.1±5.8	50.2±5.2	p>0.05
Weight (kg)	73.5±8.8	70.45±9.2	p>0.05
BSA	1.84±0.28	1.81±0.21	p>0.05
Aortic valve			
Mild-moderate regurgitation	36	10	
Severe regurgitation	3	0	
Hypertension	36	45	

BSA – body surface area; AD – aortic dissection.

DCTA imaging parameters

In this study, all patients underwent DCTA using low radiation dose electrocardiogram (ECG)-gated cardiac computed tomography (CT) (Siemens, Munich, Germany). The DSCTA parameters included a threshold of 100 HU, a layer thickness of 0.75 mm, tube voltage of 120KV, and automatic mA, as previously reported [9]. The contrast agent used was 60mL of 320 mgI/mL iodixanol injection (GE Healthcare, Dublin, Ireland), which was intravenous injected using an infusion pump with the speed of 4.5 mL/s, followed by injection of 20 mL of physiological saline at the same speed. The amount of contrast agent used was calculated according to the patient's weight. The image quality of the aorta was less affected by the dosage of contrast agent due to the anatomical position of the thoracic aorta. However, in our experience, for patients who weighed more than 80 kg, an additional 5–10 ml of contrast agent was required. The CT images were uploaded to a postprocessing workstation (Syngovia, Siemens, Germany) for further processing using virtual reality (VR) technology. A three-dimensional geometric shape of the arch of the aorta was manually constructed by the same senior radiologists, and the images of the cases were analyzed independently by two senior radiologists, as previously described [9].

DCTA imaging measurements

The parameters measured in this study included the proximal aortic diameter, the diameter of innominate artery, the distance from the innominate artery to the left common carotid artery, the diameter of the left common carotid artery, the distance from the left common carotid artery to left subclavian artery, the diameter of the left subclavian artery, the distal aortic diameter, the angles formed from the three branches vessels and the aortic arch on the coronal and the transverse imaging plane. In the transverse plane, we measured the angle of the branch blood vessel and the projection of the branch blood vessel onto the transverse plane of the aortic arch. Similarly, on the coronal plane, we measured the angle of the aortic arch and the projection of the branch blood vessel onto the coronal plane of the aortic arch.

Statistical analysis

Data were analyzed using SPSS version 20.0 software (IBM, Chicago, IL, USA). Continuous data were expressed as the mean±standard deviation (SD). Data were compared using independent sample t-tests. A p-value <0.05 was considered statistically significant.

Results

Imaging findings

The 42 patients studied who were diagnosed with acute Type A aortic dissection (AD) underwent dual-source computed tomography angiography (DSCTA) and surgical treatment, with the diagnosis confirmed at surgery. Of the aortic arch vessels, the innominate artery was the most frequently affected by acute Type A AD. In the patient group, DSCTA imaging was performed, and the mean measurement values were obtained for the root of the innominate artery, the root of the left common carotid artery, and the left subclavian artery. Imaging in the coronal plane of the aortic arch showed that mean diameter of the root of the innominate artery was 17.7 ± 3.7 mm, the mean diameter of the root of the left common carotid artery was 17.7 ± 3.7 mm, and the mean diameter of the left subclavian artery was 12.9 ± 3.1 mm in diameter. The mean distance from the innominate artery to the left common carotid artery was 11.1 ± 4.6 mm, and the mean distance from the left common carotid artery to the left subclavian artery was 12.5 ± 3.2 mm.

The angles formed by the origin of the three aortic arch branches vessels and the aortic arch were $70.5\pm 10.2^\circ$ for the innominate artery, $58.5\pm 15.5^\circ$ for the left common carotid artery, and $90.2\pm 22.7^\circ$ for the left subclavian artery. In the transverse plane of the aortic arch, the mean angles were $110.5\pm 22.3^\circ$ for the innominate artery, $100.3\pm 15.2^\circ$ for the left common carotid artery, and $95.4\pm 10.6^\circ$ for the left subclavian artery.

Comparison of the patient group and the control group

Table 2 shows the results of the comparison of the study group with the control group. The transverse diameter of the proximal aorta and the distal aorta, the diameter of the innominate artery and the left common carotid artery, the distance from the innominate artery to the left common carotid artery, and the distance from the left common carotid artery to the left subclavian artery were significantly greater in the patient group with acute Type A AD compared with the control group ($P<0.05$). For the diameter of the left subclavian artery, no significant difference was found between the two groups. The angles formed from the three branch vessels and the aortic arch also varied to different degrees in the patients with acute Type A AD but did not reach statistical significance.

Discussion

Acute Type A aortic dissection (AD) is a critical cardiovascular emergency with a high mortality rate of up to 80% if emergency surgical treatment is not performed [10,11]. Surgery with repair of the aortic arch is the most critical part of the surgical

Table 2. Comparison of clinical data of the aortic arch findings on dual-source computed tomography angiography (DSCTA) between the patient group with acute Type A aortic dissection (AD) and the control group.

Variables (mm)	AD patient group	Control group	p-Value
Diameter of the proximal aortic arch	45.1±8.6	30.6±4.2	p<0.05
Diameter of the distal aortic arch	40.5±6.7	28.2±3.8	p<0.05
Distance from the innominate to the left common carotid arteries	11.1±4.6	8.6±3.2	p<0.05
Distance from the left common carotid and the left subclavian arteries	12.5±3.2	9.2±2.1	p<0.05
Diameter of the innominate artery	17.7±3.7	14.2±2.5	p<0.05
The diameter of the left common carotid artery	12.5±3.5	10.2±1.9	p<0.05
The diameter of the left subclavian artery	12.9±3.1	11.2±2.5	p>0.05
The angle of arch and the innominate artery [#]	70.5±10.2	65.4±8.2	p>0.05
The angle of arch and left common carotid artery [#]	58.5±15.5	53.4±11.6	p>0.05
The angle of arch and the left subclavian artery [#]	90.2±22.7	85.4±16.5	p>0.05
The angle of arch and the innominate artery [*]	110.5±22.3	105.4±20.6	p>0.05
The angle of arch and left common carotid artery [*]	100.3±15.2	102.6±12.3	p>0.05
The angle of arch and the left subclavian artery [*]	95.4±10.6	85.4±11.2	p<0.05

[#] Coronal plane of aortic arch; ^{*} transverse plane of aortic arch.

treatment for AD. The most commonly used procedure is open surgery and intraoperative triple-vessel grafting, or intraoperative replacement of the aortic arch, and percutaneous transluminal vascular stent insertion [4–6]. Recently, the intraoperative three-vessel stent grafting has been simplified, resulting in reduced difficulty of aortic arch surgery [12,13]. Because of the large number of aortic branch vessels and the possibility of morphological variations [14,15], stents may not fully match the three main blood vessels of the aortic arch, resulting in residual leakage, failed false lumen closure, stent displacement, new dissection, and increased surgical difficulty. Therefore, timely and accurate preoperative evaluation of the detailed anatomy of the three branches vessels of the arch in AD facilitates the selection of appropriate replacement blood vessels or a three-branch stent and the development of preoperative surgical planning.

Recently, dual-source computed tomography angiography (DSCTA) has become widely used in the diagnosis of AD. Through a variety of three-dimensional reconstruction and post-processing techniques, the overall image of the aorta and its branch vessels, the rupture of the AD, and the false and true lumens, as well as the rupture range, can be visualized more clearly. Imaging with DSCTA can be performed to create three-dimensional images to reveal the involvement of the arch branches and obtain detailed anatomical data of the three branches vessels and the aortic arch. A DSCTA scan can be completed in a few seconds and increases the safety of the imaging process. Also, DSCTA has high sensitivity and specificity [16–18]. Previous studies have reported that DSCTA has

close to 100% specificity and sensitivity for the diagnosis of acute AD Type A [19,20], which were confirmed by the findings from the present study.

Data obtained from imaging the aortic arch can be affected by several factors, including gender, age, and body surface area (BSA) [21,22]. Previous studies have shown that the diameter of the aortic arch increases with age, is greater in men than in women, and is closely related to body surface area (BSA) [23,24]. Therefore, for younger patients with AD, vascular stents should be carefully selected, and the effect of BSA should be considered. Currently, few reports are available regarding the diameter of the aortic arch branches in AD [25].

In this study, in patients with acute Type A AD, the diameters of the left subclavian artery, the left common carotid artery, and the innominate artery at the root were 12.9±3.1 mm, 12.5±3.5 mm, and 17.7±3.7 mm, respectively, while the diameters of the three branches of the vascular grafts used were 10 mm, 8 mm, and 8 mm, with a fixed number of models. Therefore, a mismatch may occur in the diameters of the blood vessel grafts used and the vessels. For three-branch coated stent grafts and endovascular treatment, if a cylindrical branch stent is used and the diameter at the blood vessel opening is used as a reference, the radial support force at the distal end of the three branches vessels will be too large, which may cause vascular damage.

Also, in the normal population, the mean distance from the left subclavian artery to the left common carotid artery and the

distance from the left common carotid artery to the innominate artery are 10.9 mm and 5.1 mm, respectively, as measured by Finlay et al. [26]. In the present study, these mean measurements were significantly greater in patients with acute Type A AD compared with the control group. For a three-branch coated stent graft and an integrated branch stent for endovascular treatment, due to the limitation of the fixed positions of the openings of the three branches vessels, the mismatch from the stent and the actual aortic anatomy may significantly affect the surgical outcome. Furthermore, in most studies, measurement of the angles formed from the three branches vessels and the aortic arch was limited to the coronal plane of the aortic arch. This study measured these angles on both the coronal plane and the transverse plane of the aortic arch to describe the angles of the three branched vessels of the arch in three dimensions.

Among the three branch vessels of the aortic arch, the innominate artery is the most commonly involved vessel in AD, and the variability of its inner diameter is the greatest. The left subclavian artery and the left common carotid artery are relatively less commonly involved. The extent of their involvement is less, and the degree of variation of the inner diameters of these two vessels is small. This difference may arise because the innominate artery is located at the first major turn of the aortic arch, and when AD occurs, it is subject to a greater hemodynamic force. Theoretically, the vascular graft conforms to the morphology of the aortic arch after the impact of AD. Currently, the inner diameter of each branch of the vascular graft commonly used in aortic arch replacement is fixed. In practice, the three branch vessels and the vascular graft cannot achieve a perfect match.

Nevertheless, adjustment of the anastomotic technique is achieved using surgical sutures. With the use of intraoperative three-branch coated stent-grafts or endovascular treatment, since the distance and angle of the stent are fixed, use in the altered aortic arch will inevitably lead to mismatch from the stent vessel and the arch branches. Therefore, significant stent displacement or incomplete release may occur

in some patients. Stents that are too small can lead to leaks in the branches, while stents that are too large may result in damage to the branches. Therefore, the choice of an aortic arch stent should be made not only considering the requirements of the stent in the arch vessels but also the angles of the branch vessels. Theoretically, a vascular graft corresponds to the morphology of the aortic arch after the impact of dissection, and designing vascular grafts and stents according to normal anatomical data is not optimal.

This study had several limitations. As with any retrospective clinical study, this study included bias due to patient data collection and patient enrollment, which was conducted at a single center by clinical staff who also reported the findings of the study. Although the number of patients was in this study was small, the findings were of practical clinical significance for patients with acute Type A AD and the clinicians who manage these patients. The methods used in measuring the vascular angles require validation. The study was conducted at a single center in China and included patients from a single ethnic group. Given the findings from this preliminary study, future global, multicenter, large-scale studies should be conducted to determine the value of preoperative evaluation of DSCTA in aortic arch lesions.

Conclusions

This study aimed to investigate the role of dual-source computed tomography angiography (DSCTA) to evaluate the anatomy of the aortic arch vessels in patients with acute Type A aortic dissection (AD). DCTA demonstrated that patients with Type A AD showed anatomic differences in the aortic arch vessels. These findings may help surgeons to develop treatment strategies and select the most appropriate vascular grafts and stents.

Conflict of interest

None.

References:

1. Elsayed RS, Cohen RG, Fleischman F, Bowdish ME: Acute Type A aortic dissection. *Cardiol Clin*, 2017; 35(3): 331–45
2. Kosuge M, Kimura K, Uchida K et al: Clinical implications of electrocardiograms for patients with Type A acute aortic dissection. *Circ J*, 2017; 81(9): 1254–60
3. Pape LA, Awais M, Woznicki EM et al: Presentation, diagnosis, and outcomes of acute aortic dissection: 17-year trends from the international registry of acute aortic dissection. *J Am Coll Cardiol*, 2015; 66(4): 350–58
4. Di Marco L, Leone A, Murana G et al: Acute Type A aortic dissection: Rationale and outcomes of extensive repair of the arch and distal aorta. *Int J Cardiol*, 2018; 267: 145–49
5. Ozaki N, Yuji D, Sato M et al: Medical treatment for acute Type A aortic dissection. *Interact Cardiovasc Thorac Surg*, 2018; 26(4): 696–99
6. Chen LW, Wu XJ, Dai XF et al: A self-adaptive triple-branched stent graft for arch repair during open Type A dissection surgery. *J Thorac Cardiovasc Surg*, 2015; 149(5): 1278–83
7. Plichta RP, Aftab M, Roselli EE: Current management of aortic arch lesions with hybrid procedures: A tailored approach to a progressive disease. *J Cardiovasc Surg (Torino)*, 2016; 57(3): 437–47
8. Al-Atassi T, Khojzeshad A: Indications for aortic arch intervention. *Semin Cardiothorac Vasc Anesth*, 2016; 20(4): 259–64
9. Huang F, Chen Q, Lai QQ et al: Preoperative evaluation value of aortic arch lesions by dual source computed tomography angiography in Type A aortic dissection. *Medicine (Baltimore)*, 2016; 95(39): e4984

10. Di Eusanio M, Berretta P, Cefarelli M et al: Long-term outcomes after aortic arch surgery: Results of a study involving 623 patients. *Eur J Cardiothorac Surg*, 2015; 48(3): 483–90
11. Numata S, Tsutsumi Y, Monta O et al: Mid-long-term results after aortic arch repair using a four-branched graft with antegrade selective cerebral perfusion. *J Card Surg*, 2013; 28(5): 537–43
12. Chen LW, Dai XF, Wu XJ et al: Ascending aorta and hemiarch replacement combined with modified triple-branched stent graft implantation for repair of acute DeBakey type I aortic dissection. *Ann Thorac Surg*, 2017; 103(2): 595–601
13. Chen LW, Wu XJ, Dai XF et al: Total arch repair for acute Type A aortic dissection with open placement of a modified triple-branched stent graft and the arch open technique. *J Cardiothorac Surg*, 2014; 9: 135
14. Alberta HB, Takayama T, Smits TC et al: Aortic arch morphology and aortic distance in patients with dissection, traumatic, and aneurysmal disease. *Eur J Vasc Endovasc Surg*, 2015; 50(6): 754–60
15. Malkawi AH, Hinchliffe RJ, Yates M et al: Morphology of aortic arch pathology: Implications for endovascular repair. *J Endovasc Ther*, 2010; 17(4): 474–79
16. Valente T, Rossi G, Lassandro F et al: DSCT evaluation of acute aortic syndrome (AAS). *Br J Radiol*, 2016; 89(1061): 20150825
17. Abbas A, Brown IW, Peebles CR et al: The role of multidetector-row CT in the diagnosis, classification and management of acute aortic syndrome. *Br J Radiol*, 2014; 87(1043): 20140354
18. Yoo SM, Lee HY, White CS: DSCT evaluation of acute aortic syndrome. *Radiol Clin North Am*, 2010; 48(1): 67–83
19. Manghat NE, Morgan-Hughes GJ, Roobottom CA: Multi-detector row computed tomography: imaging in acute aortic syndrome. *Clin Radiol*, 2005; 60(12): 1256–67
20. Salvolini L, Renda P, Fiore D et al: Acute aortic syndromes: Role of multi-detector row CT. *Eur J Radiol*, 2008; 65(3): 350–58
21. Anyanwu GE, Agwuna KK: Aortic arch diameter and its significance in the clinical evaluation of cardiac and aortic enlargements. *Niger J Clin Pract*, 2009; 12(4): 453–56
22. Hannuksela M, Lundqvist S, Carlberg B: Thoracic aorta-dilated or not? *Scand Cardiovasc J*, 2006; 40(3): 175–78
23. Rylski B, Desjardins B, Moser W et al: Gender-related changes in aortic geometry throughout life. *Eur J Cardiothorac Surg*, 2014; 45(5): 805–11
24. Kältsch H, Lehmann N, Möhlenkamp S et al: Body-surface adjusted aortic reference diameters for improved identification of patients with thoracic aortic aneurysms: Results from the population-based Heinz Nixdorf Recall study. *Int J Cardiol*, 2013; 163(1): 72–78
25. Wu JL, Zhang L, Qiu JT, Yu CT: Morphological features of the thoracic aorta and supra-aortic branches in patients with acute Type A aortic dissection in China. *Interact Cardiovasc Thorac Surg*, 2018; 27(4): 555–60
26. Finlay A, Johnson M, Forbes TL: Surgically relevant aortic arch mapping using computed tomography. *Ann Vasc Surg*, 2012; 26(4): 483–90