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Original Article

Evaluation of the Correlation between Abdominal Aortic Lumen Distortion and Atherosclerotic Risk of Vascular Branches in Older Adults by Dual-Source Computed Tomography

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SUMMARY

Objective: To evaluate the correlation between abdominal aortic atherosclerotic lumen distortion and atherosclerosis risk in vascular branches in older adults by dual-source computed tomography (CT).
Methods: CT angiography data of 275 patients with abdominal aortic atherosclerosis in our hospital were collected to record vascular distortion and compare the involvement of the celiac trunk branch, superior mesenteric artery (SMA), bilateral renal artery (RA), and inferior mesenteric artery. Study participants were grouped as follows: group A (age, 65–74 years; n = 68), group B (age, 75-85 years old; n = 123), and group C (age, > 85 years old; n = 84).
Results: The rate of arterial distortion in senile abdominal aortic atherosclerosis was 44.4% (122 cases), which was positively correlated with age ($r = 0.759$, $p < 0.05$). SMA and RA involvement were highest in all age groups (61.5% and 77.0%, respectively), and distortion did not occur in 153 cases (55.6%). There was no significant correlation between the incidence of branch lesions and patient age ($r = 0.354$, $p < 0.05$), although age was associated with the degree of the lesion.
Conclusions: The risk of secondary atherosclerosis in the vascular branches of older adult patients with abdominal aortic atherosclerosis increases with age. Concomitant morphological changes secondary to vascular lumen distortion greatly increase the incidence of SMA and RA involvement.

1. Introduction

Atherosclerosis is an asymptomatic disease characterized by massive deposition of blood lipids into the intima. This results from increased permeability of the intima due to impaired endothelial cells of the large and middle arteries under various risk factors.[1] Atherosclerosis is accompanied by the infiltration of inflammatory cells, migration and proliferation of smooth muscle cells from the media to the intima, and foam cell formation with an increase in extracellular matrix synthesis, eventually forming an atherosclerotic plaque.[2] An atherosclerotic plaque affecting the secondary branch arteries or small arteries has severe impacts on the organs and tissues the blood vessels supply.[3] Particularly in older adult patients with abdominal aortic atherosclerosis, insidious clinical manifestations often occur past the optimal treatment period, and the delayed treatment thus causes physical adverse effects.[4] The clinical applications of multi-slice spiral computed tomography (CT) and color Doppler ultrasound play an important role in disease detection. Mainly, multi-slice spiral CT[5] is a rapid, non-invasive, and efficient method for accurate diagnosis of the degree, section, and scope of atherosclerosis. Additionally, post-processing can show the three-dimensional (3D) vascular lumens.[6] In a study on a population of older adults, it was reported that the majority of the distortion in blood vessels occurs at the vertical axis, while some bend and fold at approximately 90 degrees. These patients likely have secondary lesions in different branches, such as the celiac trunk branch (CTB), superior mesenteric artery (SMA), bilateral renal artery (RA), and inferior mesenteric artery (IMA). The location of the lesion is a vital factor in clinical diagnosis, treatment, and prognosis. In previous studies, the relationship between vascular stenosis and plaque has been reported;[7] however, the correlation between the morphologic changes from vascular stenosis and imaging findings has not been investigated. Nonetheless, there have been qualitative evaluations of plaques and studies on their predictive value for myocardial ischemia,[8,9] including applications of positron emission tomography and CT.[10,11] The present study aimed to retrospectively analyze the correlation between vascular distortion and the involvement of vascular branches in older adult patients with abdominal aortic atherosclerosis.

2. Materials and methods

2.1. Case data

A total of 275 older adult patients with abdominal aortic atherosclerosis admitted to Wuhan Central Hospital, affiliated with Tongji Medical College of Huazhong University of Science and Technology, from January 2015 to December 2017 were included. The

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study population comprised 167 men and 108 women aged 67–90 years (mean, 78.5 years). The patients were divided into three groups according to age, as follows: group A, aged 65–74 years (n = 68); group B, aged 75–85 years (n = 123); and group C, aged > 85 years (n = 84). The inclusion criteria were as follows: patients 1) aged ≥ 65 years, 2) who had been diagnosed with hypertension, peripheral vascular thrombosis, diabetes, or arteriosclerosis-related diseases, 3) with normal liver and kidney functions, and 4) were able to cooperate with the inspection during imaging for the avoidance of motion artifacts. This study was conducted in accordance with the declaration of Helsinki and approval from the Ethics Committee of Huazhong university of science and technology. Written informed consent was obtained from all participants.

2.2. Inspection method

All study participants were allowed a minimal liquid diet prior to the examination. Liver and kidney functions were normal, allergy tests were negative, and no additional special treatments were administered. A dual-source spiral CT machine (Siemens, Germany) and an Ante double cylinder high-pressure syringe (Shenzhen Ante GaoKe Industrial Co) were used for the inspection. The contrast used was iohexol (370 mg/ml), and approximately 50–60 ml of contrast agent was injected at a flow rate of 4.0 ml/s. After injection, 30 ml of normal saline was injected at the same flow rate. The Surestart intelligence triggering (trigger threshold, 130–150 Hu; ROI placed in the abdominal aorta trunk at the renal level) was used for the arterial phase scan. The scan range covered the entire abdomen, from the liver to the pelvic level. The scanning parameters were as follows: detector, 0.5 × 128 layers; tube voltage, 120 kV; tube current, 300–350 mA; scanning time, 6.5–8.0 s; field of view, 250 mm × 250 mm; and acquisition matrix, 512 × 512. The main advantage of the Siemens dual-source spiral CT is its "double low" technology, particularly, the low radiation dose (i.e., the automatic low-dose Caredose mode) and the low-dose (< 60 ml) iodine contrast.[12]

2.3. Post-processing of images

The CT findings (DICOM format) were uploaded and processed by the built-in Siemens workstation, which can generate 3D virtual reality (3D VR) images using surface imaging technology. The vascular probe technique was subsequently used to probe the CTB, SMA, RA, and IMA to obtain the multiple planar reformation (MPR) and maximum intensity projection (MIP) images of each blood vessel. All lesions in each vessel were recorded.

2.4. Statistical analysis

The SPSS 18.0 software was used for the statistical analysis. Quantitative data were expressed as constituent ratios, and Pearson correlation analysis was performed to evaluate the relationship between patient age and degree of abdominal aorta/branch distortion, as well as between the age and number of abdominal aorta/branch lesions. $p < 0.05$ was considered statistically significant.

3. Results

3.1. DVR reconstruction of abdominal aorta/branches

The VR images of each patient allow clear and stereoscopic visualization of the shape, path, and origin of large blood vessels and their branches (Figure 1). Vascular distortion occurs secondary to the reduction of vascular compliance from atherosclerosis. It is confirmed when the angle between the upper and lower aorta at the kink is ≤ 150°. The vascular walls were clear without any artifact or interference. The abdominal aorta was distorted, twisted, folded, or had formed angles along the vertical axis due to various reasons. It can be presented via 3D rotation for visual identification of the morphologic diversity, specifically, the diameter, thickness, and wall of each blood vessel and corresponding branch. The orientation and extent of each distortion were accurately indicated (Figure 2 and 3).

3.2. Arterial distortion in all age groups

Among 275 patients, a certain degree of distortion of the abdominal aorta occurred in 122 cases (35.4%). The distortion rate was 30.9%, 43.1%, and 57.1% in groups A, B, and C, respectively. Pearson correlation analysis showed a positive correlation between the incidence of abdominal aortic distortion and age ($r = 0.759$, $p < 0.05$).

3.3. Correlation analysis

Tables 1 and 2 show that in all 122 older adult patients with abdominal aortic distortion, the incidence of atherosclerosis in the five major branch arteries increased with age; however, the extent of the lesion was not significantly correlated with age. The incidence of atherosclerosis in SMA and RA was significantly higher than that in CTB and IMA, particularly in group C patients, in whom all the lumens were distorted and the branches at the kink were affected (Figures 4 and 5). Lumen distortion was essentially accompanied by an SMA (72.9%) and/or RA (87.5%) lesion (Table 1). Of 153 older adult patients without abdominal aorta distortion (Table 2), there was no association be-

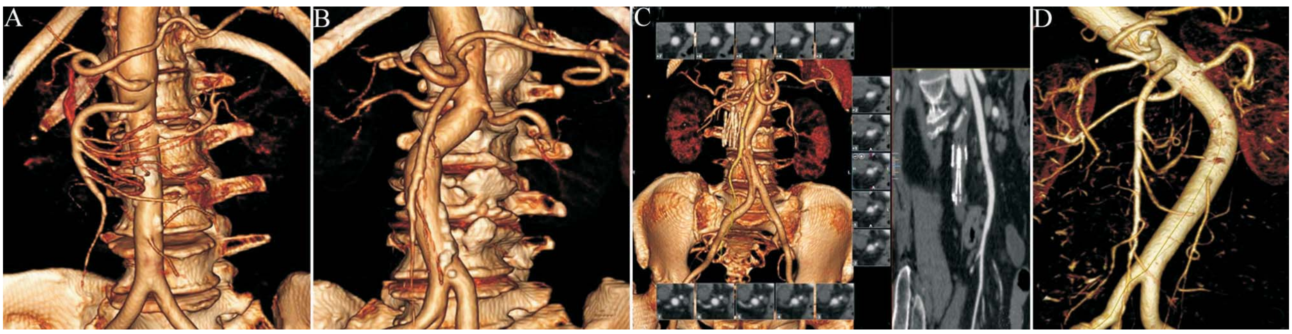

Figure 1. VR images to show the shape, walking, and origin of large blood vessels and branches in a stereoscopic and clear way. A: Male, 68 years old, mild abdominal aortic atherosclerosis, with normal arterial walking and normal branching. B: Female, 75 years old, abdominal aortic atherosclerosis with distortion at the renal artery level, accompanied by right RA atherosclerotic stenosis and SMA atherosclerosis. C: Male, 77 years old, the probe technique finds small atherosclerotic plaques in the proximal and middle SMA, together with abdominal aortic distortion. D: Male, 86 years old, abdominal aortic folding with open hardened plaque formation in the left RA and CTB. CTB, celiac trunk branch; SMA, superior mesenteric artery; RA, renal artery; IMA, inferior mesenteric artery.

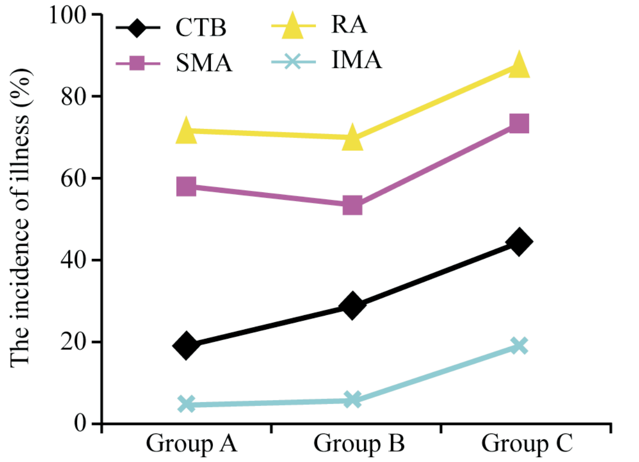

Figure 2. Distribution of vascular distortion in different age groups. Group A, aged 65–74 years; Group B, aged 75–85 years; and Group C, aged > 85 years. CTB, celiac trunk branch; SMA, superior mesenteric artery; RA, renal artery; IMA, inferior mesenteric artery.

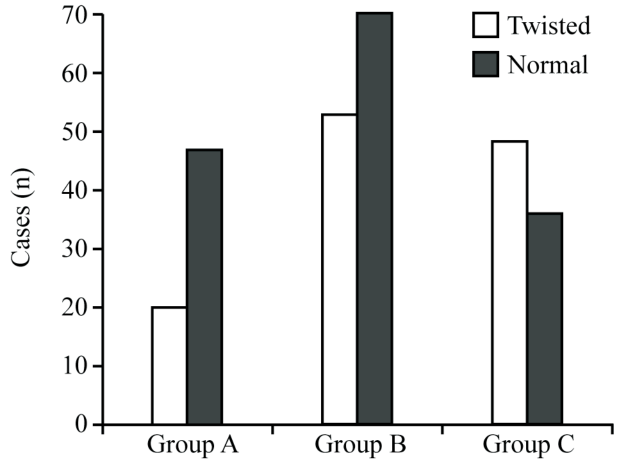

Figure 3. Trend of vascular distortion in different age groups. Group A, aged 65-74 years; Group B, aged 75–85 years; and Group C, aged > 85 years.

Table 1
Composition of vascular torsion and branch lesion in different age groups.

Group (years)	Sum (%)	Distortion (%)	Companion (%)			
			CTB lesion	SMA lesion	RA lesion	IMA lesion
A (65–74)	68 (24.7)	21 (30.9)	4 (19.0)	12 (57.1)	15 (71.4)	1 (4.8)
B (75–85)	123 (44.7)	53 (43.1)	15 (28.3)	28 (52.8)	37 (69.8)	3 (5.7)
C (> 85)	84 (30.5)	48 (57.1)	21 (43.8)	35 (72.9)	42 (87.5)	9 (18.8)
Sum (%)	275 (100)	122 (44.4)	40 (32.8)	75 (61.5)	94 (77.0)	13 (10.7)

Note: CTB, celiac trunk branch; IMA, inferior mesenteric artery; RA, renal artery; SMA, superior mesenteric artery. "Companion" means incidence of angiogenic atherosclerosis.
The data in () are percentage (%), comparison among groups A, B, and C, $p < 0.05$.

Table 2
Construction ratio of branch lesions in different age groups without vascular distortion.

Group (years)	Sum (%)	Without vascular distortion (%)	Companion (%)			
			CTB lesion	SMA lesion	RA lesion	IMA lesion
A (65–74)	68 (24.7)	47 (69.1)	2 (4.2)	9 (19.1)	11 (23.4)	0 (0)
B (75–85)	123 (44.7)	70 (56.9)	10 (14.2)	33 (47.1)	23 (32.9)	8 (11.4)
C (> 85)	84 (30.5)	36 (42.9)	9 (25.0)	17 (47.2)	13 (36.1)	5 (13.9)
Sum (%)	275 (100)	153 (55.6)	21 (13.7)	59 (38.6)	47 (30.7)	13 (8.5)

Note: CTB, celiac trunk branch; IMA, inferior mesenteric artery; RA, renal artery; SMA, superior mesenteric artery. "Companion" means incidence of angiogenic atherosclerosis.
The data in () are percentage (%), comparison among groups A, B, and C, $p < 0.05$.

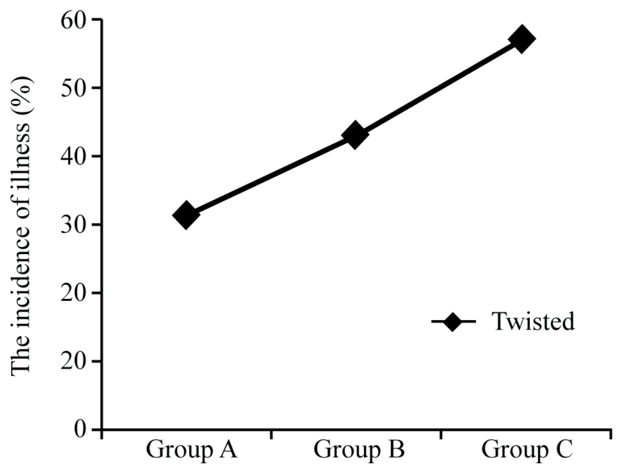

Figure 4. Distribution of vascular involvement in 122 patients with abdominal aorta distortion. Group A, aged 65–74 years; Group B, aged 75–85 years; and Group C, aged > 85 years.

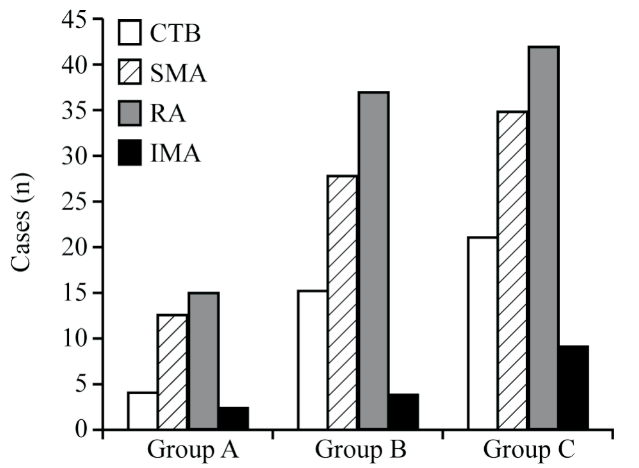

Figure 5. Trend of incidence of involvement of various branches in 122 patients with abdominal aortic atherosclerosis. Group A, aged 65–74 years; Group B, aged 75–85 years; and Group C, aged > 85 years. CTB, celiac trunk branch; SMA, superior mesenteric artery; RA, renal artery; IMA, inferior mesenteric artery.

tween patient age and the risk of atherosclerosis in branch arteries (r = 0.354, $p < 0.05$), but age was related to the extent of the lesions. Furthermore, the incidence of SMA was slightly higher than that of RA. In older adult patients with atherosclerosis, the risk of abdominal aortic distortion with branch atherosclerosis was significantly higher than that in older adult patients without vascular distortion.

4. Discussion

Atherosclerosis severely impacts human health and quality of life[13] and threatens the health of the older adult population. It is primarily diagnosed through imaging, and it can lead to myocardial ischemia, myocardial infarction, stroke, or peripheral vascular diseases. AS the main pathogenic factor of cardiovascular disease (CVD) and cerebrovascular disease.[14,15] CVD caused by atherosclerosis ranks first among the causes of death in developed countries.[16,17] The abdominal aorta is a predominant site for atherosclerosis, and the involvement of its may have detrimental effects on the blood supply in the mesenteric, celiac trunk, and renal arteries. In older adults, such insidious clinical manifestations are hardly detected during routine examinations.

The consensus diagnostic criteria for abdominal aortic atherosclerosis are abdominal aortic wall plaque and calcification on plain CT,[18] in which ring- or shell-like lesions, lumen narrowing, or tumor-like expansion are observed in severe cases. Meanwhile, enhanced CT or CT angiography may be used to detect low-density plaques and thrombus in walls.[19] Until the rapid development of CT, showing morphological changes such as arterial distortion,[20] digital subtraction angiography was previously considered the diagnostic gold standard.[21] However, with the development of 64-slice spiral CT, the use of MIP, two-dimensional MPR, and 3D VR technologies has been able to clearly show the 3D anatomical structure of the abdominal aorta, as well as calcified and non-calcified plaques. In particular, the vascular probe technique can directly and accurately diagnose the plaque size, intraluminal lesions, and the scope and extent of luminal stenosis, and it provides an overall assessment. Currently, the vascular probe technique is superior to traditional DSA imaging[22] due to its non-invasiveness and better safety profile.[23]

Through this probe and 3D VR technology, the scope and extent of lesions in individual patients can be identified directly.[24] There have been numerous reports on atherosclerosis in clinical settings,[25] but the risk of arterial distortion with atherosclerotic branches has rarely been investigated. When the distortion of the lumen requires vascular intervention, a certain degree of influence may be generated during the delivery of drugs, embolic agents, or implants. A greater severity of distortion and folding of vessels corresponds to a higher risk of occurrence of intimal tear and arterial rupture.[26] Accordingly, this study analyzed the risk of involvement of main arterial branches in older adult patients with arterial distortion in the abdominal aorta and found a strong correlation between vascular distortion and branch involvement. Specifically, if the distortion occurs at the site of arterial bifurcation, the risk of secondary atherosclerotic embolization in the affected branch vessel is significantly increased. Therefore, the direction and degree of arterial distortion in patients with abdominal aortic atherosclerosis should be thoroughly evaluated to provide a more appropriate and comprehensive follow-up clinical management, particularly for those requiring intravessel intervention.[27]

The generalizability of the study findings is limited by its small sample size. Thus, further prospective, multi-center, randomized clinical studies involving larger populations are necessary for a more comprehensive evaluation of the characteristics, correlation, and clinical applicability of abdominal aortic and branch atherosclerosis.

Conflicts of interest

The authors declare no conflict of interest.

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