Correlation between coronary artery calcium score and aorta diameter in population with long-standing hypertension using noncontrast CT scan

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Abstract

Background: Early detection of aortic aneurysms is challenging in hypertensive patients due to the high risk of life-threatening ruptures. Limited studies on the relationship between coronary artery calcium and aortic diameter are present. This study evaluated the correlation between coronary artery calcium score (CACS) and maximal thoracic and abdominal aortic diameters in hypertensive patients, using a noncontrast CT scan.

Material and methods: We prospectively enrolled 180 hypertensive patients older than 45 who had no aortic aneurysm or heart disease. We split the study population into five classes according to CACS (0, 1–10, 10–100, 100–400, and > 400). We calculated coronary artery calcium and maximal diameters of the ascending thoracic aorta (ATA_{MAX}), descending thoracic aorta (DTA_{MAX}), and abdominal aorta (AA_{MAX}) using native computed tomography imaging.

Results: Coronary artery calcium score was high in patients with high abdominal aorta diameter but not with the high diameters of the thoracic aorta. The cut-off point of the abdominal aorta's maximum diameter was 34 mm, so AA_{MAX} > 34 mm is predictive of a diagnosis of CACS category five (CACS > 400). There were no differences in ascending and descending thoracic aorta measurements between patients with a coronary artery calcium score of more than 400 (category 5) and the rest.

Conclusion: Screening for an abdominal aortic aneurysm is essential in hypertensive patients as the coronary artery calcium score is associated significantly with increased abdominal aorta diameter. However, the necessity for thoracic aortic aneurysm screening is not apparent in these patients as no significant association is found between CACS and thoracic aorta diameter.

Key words: aorta; coronary artery calcium; CT scan

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Introduction

Aorta aneurysm is a life-threatening potential in hypertensive patients. Since these aneurysms are usually asymptomatic, early detection is essential to prevent the grave event of rupture, a catastrophic event [1]. Some studies have reported that abdominal aortic aneurysms (AAA) are more common in patients undergoing cardiac catheterization for coronary artery disease (CAD) or awaiting coronary artery bypass grafting [2, 3]. We suspected that AAA and CAD are associated as both conditions have common risk factors and pathophysiological substrates [4].

Ascending thoracic aortic aneurysms (ATA) may have a different etiology than abdominal aneurysms; the correlation between CAD and thoracic aortic aneurysms has not been clearly defined [5].

The relationship between coronary artery atherosclerotic plaques and high coronary calcium score (CACS) is well known [6, 7]. Therefore, in the asymptomatic population, CACS is used as screening in non-contrast CT to identify patients at high risk [8, 9].

Since most aortic aneurysms are asymptomatic unless they leak or rupture, they are commonly diagnosed incidentally during imaging for other indications.

Coronary artery calcification and aortic aneurysms share similar risk factors, including advanced age and hypertension, requiring screening in asymptomatic patients [10]. In addition, they can be obtained simultaneously using a noncontrast CT scan. However, data on the relationship between CACS and aortic diameter are scarce [10, 11].

Therefore, our study aimed to determine whether CACS correlates with aortic diameter in hypertensive patients.

Material and methods

Study population

Two hundred four consecutive patients with long-standing hypertension without a history of aortic aneurysm were prospectively enrolled from January 2018 to February 2020. Subjects were eligible if they were ≥ 45 years old, hypertensive, and had provided signed informed consent. We defined hypertension as systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure as ≥ 90 mm Hg or treatment with antihypertensive agents. Of these 204 patients who had done CT of the whole aorta, 16 patients with a suboptimal CT image, and eight patients with a history of coronary artery stent insertion (CACS could not be calculated accurately) were excluded. The remaining 180 patients comprised the study population. The Institutional Review Board approved this study.

CT protocol and image acquisition

We performed CT examinations on a 64-slice scanner (PHILIPS Medical Systems, Best, the Netherlands and Siemens Medical system, Germany). We examined all patients for both CASC and aortic diameter without contrast administration. The scanning protocol for CT covers the whole aorta from the aortic arch to the aortic bifurcation. Patients underwent CACS with a prospective ECG gating. Data were collected from 40% to 50% of the R/R interval. The tube voltage was 120 kV, and the tube current adjusted automatically. Images were reconstructed using a soft-tissue kernel (FC43), with a slice thickness of 1 mm. CACS examination was performed, and image reconstruction was done at a single cardiac phase.

Diameter measurements of the ascending and descending thoracic aorta (ATA_{PAB} and DTA_{PAB}) were performed at the outer vessel wall perpendicular to its long axis in the axial plane at the level of the pulmonary artery bifurcation. The maximal ascending thoracic aorta diameter (ATA_{MAX}) was measured from the axial plane above the aortic root to the aortic arch. Then the maximal descending thoracic aorta diameter (DTA_{MAX}) was measured from below the aortic arch to the diaphragm. Maximal abdominal aortic diameter (AA_{MAX}) was defined as the maximal diameter of the abdominal aorta from the diaphragm to the vessel bifurcation. Vessel diameter at the superior mesenteric artery level (AA_{SMA}) was measured at the first slice below the root of the superior mesenteric artery. We confirmed aortic diameters in the sagittal and coronal planes using reconstructed images to avoid a falsely large diameter (Fig. 1).

Thoracic aortic aneurysm (TAA) was defined as TA_{MAX} ≥ 40 mm, and abdominal aortic aneurysm (AAA) was defined as AA_{MAX} ≥ 30 mm [11].

CACS is the volume of the calcium by the density factor. Patients were categorized as CACS equal to 0, CACS between 0 and ≤ 10, between 10 and ≤ 100, between 100 and ≤ 400, and CACS > 400 [12].

Statistical analysis

The data was analyzed using Statistical Package for Social Sciences (SPSS) version 25. The data are presented as mean, standard deviation, and ranges. Frequencies and percentages present categorical data. Analysis of variances (ANOVA) (two-tailed)

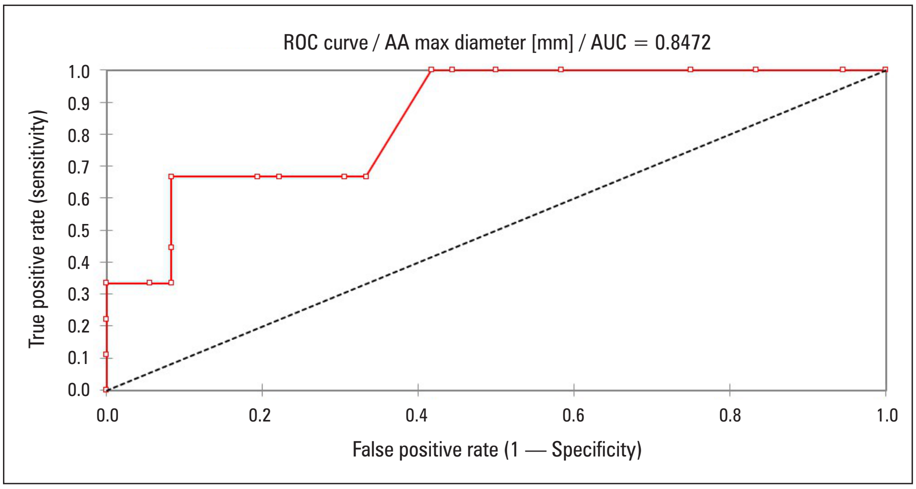

Figure 1. Measurement of aortic diameters. **A.** Descending thoracic aorta at the maximum diameter (DTA_{MAX}); **BC.** Abdominal aorta at the superior mesenteric artery (AA_{SMA}), and abdominal aorta at the maximum diameter (AA_{MAX}) in the axial planes. **DE.** The maximal diameter of ascending thoracic (ATA_{MAX}) and abdominal aorta (AA_{MAX}) was measured in the coronal (**D**) and sagittal planes (**E**) using reconstructed images. ATA — ascending thoracic aorta; DTA — descending thoracic aorta; AA — abdominal aorta

was used to compare the continuous variables among study groups accordingly. Receiver operating characteristic (ROC) curve analysis was used for the prediction of AA_{MAX} as a diagnosis of CACS category five (CACS > 400). A significant P-value was set at less than 0.05.

Results

The total number of patients included in the study was 180. All of them were hypertensive and underwent aortic CT to measure the diameters and coronary scans to identify each focus of calcification along the course of the coronary artery.

General characteristics

In this study, mean systolic and diastolic blood pressures were 153.6 ± 13.4 mm Hg and 100.4 ± 10.4 mm Hg. The study participant's ages ranged from 45 to 80 years, with a mean (SD) of 60.75 (± 11.84). The highest proportion of study patients was between 50 and 69 years (60%). Regarding gender, the proportion of males was slightly higher than females (53.3% *vs.* 46.7%), with a ratio set at 1.14:1.

Coronary Artery Calcium Score (CACS)

Figure 2 shows the distribution of patients by CACS categories. We noticed that categories three and four of CACS included 48 patients (26.7%).

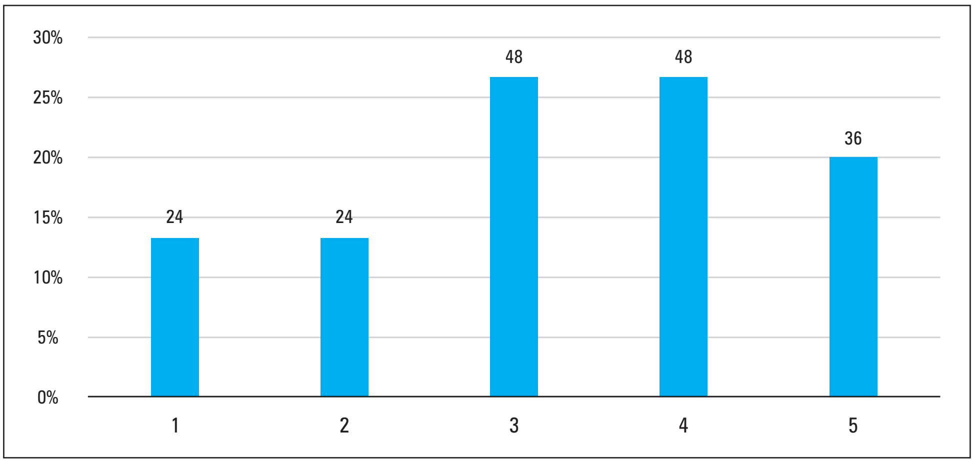

Figure 2. Distribution of the study population according to coronary artery calcium score (CACS) categories

Table 1. Comparison of diameters of ascending thoracic aorta (ATA), descending thoracic aorta (DTA), and abdominal aorta (AA) according to coronary artery calcium score (CACS) category

Variable	Diameter [mm]					p-value
	CACS 1 Mean ± SD	CACS 2 Mean ± SD	CACS 3 Mean ± SD	CACS 4 Mean ± SD	CACS 5 Mean ± SD	
ATA_{MAX}	24.3 ± 0.8	31.3 ± 6.1	35.5 ± 6.2	33.2 ± 1.7	35.3 ± 2.5	0.001
ATA_{PAB}	24.7 ± 0.5	30.2 ± 4.6	35.3 ± 5.8	34.7 ± 2.4	35.1 ± 2.5	0.001
DTA_{MAX}	22.5 ± 0.5	34.8 ± 21.5	32.8± 6.3	31.7± 2.5	31.9± 4.2	0.057
DTA_{PAB}	23.5 ± 0.5	31.3 ± 12.5	33.3± 5.0	30.3± 3.7	32.6± 3.0	0.07
AA_{MAX}	22.6 ± 0.5	34.3 ± 11.3	27.8 ± 3.5	30.4 ± 3.0	43.0 ± 13.0	0.001
AA_{SMA}	22.5 ± 0.5	33.8 ± 10.9	27.6 ± 3.8	30.1 ± 3.4	34.9 ± 5.3	0.001

SD — standard deviation; ATA_{MAX} — ascending thoracic aorta at the maximum diameter; ATA_{PAB} — ascending thoracic aorta diameter at the level of pulmonary artery bifurcation; DTA_{MAX} — descending thoracic aorta at the maximum diameter; DTA_{PAB} — descending thoracic aorta diameter at the level of pulmonary artery bifurcation; AA_{MAX} — abdominal aorta at the maximum diameter; AA_{SMA} — abdominal aorta diameter at the level of superior mesenteric artery

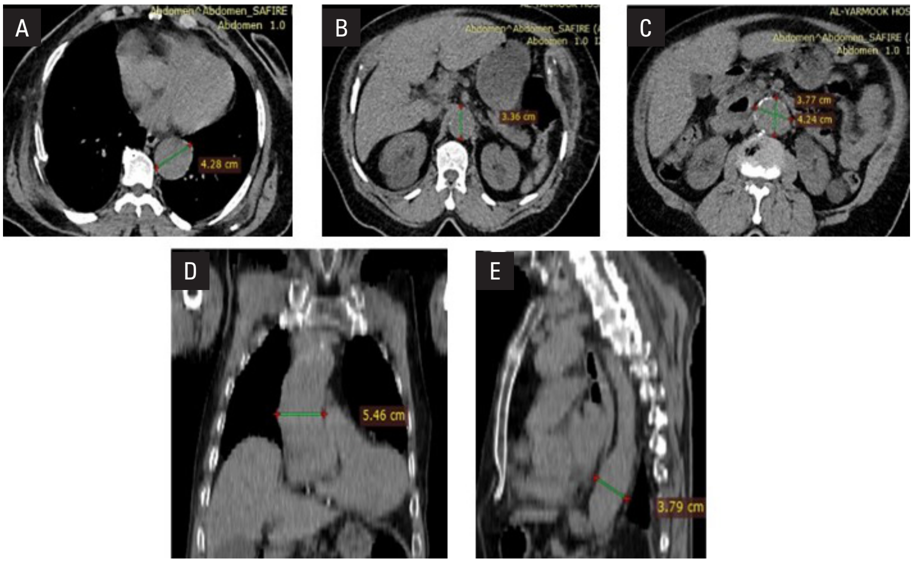

Figure 3. Receiver operating characteristic (ROC) curve for abdominal aorta at the maximum diameter (AA_{MAX}) as a marker of coronary artery calcium score (CACS) category five (CACS > 400)

Aortic diameter

Table 1 compares ATA_{MAX}, ATA_{PAB}, DTA_{MAX}, DTA_{PAB}, AA_{MAX}, and AA_{SMA} according to the CACS category. The highest mean of ATA_{MAX} and ATA_{PAB} was detected in patients with category three of CACS. There was a significant difference ($p < 0.001$) in ATA_{MAX} and ATA_{PAB} diameters among the CACS categories. There was no significant difference ($p \geq 0.05$) in DTA_{MAX} and DTA_{PAB} diameters among CACS categories. The highest mean of AA_{MAX} and AA_{SMA} was detected in patients with category five of CACS. A significant difference ($p < 0.001$) was founded in AA_{MAX} and AA_{SMA} diameters among CACS categories.

Receiver operating characteristic (ROC) curve analysis was constructed for AA_{MAX} as a diagnostic for CACS category five (CACS > 400). As shown in Figure 3, the cut-off point of AA_{MAX} diameter was 34 mm, so AA_{MAX} > 34 mm is predictive for diagnosis of CACS category five (CACS > 400). Abdominal aortic maximum diameter was 66.7% sensitive, 91.7% specific, and 86.7% accurate as a marker for diagnosis of CACS category five (CACS > 400).

Discussion

Arterial calcium development is strongly associated with hypertension, vascular injury, and atherosclerosis plaque formation [13]. The presence of coronary artery calcium reflects the prevalence of coronary atherosclerosis, and calcification of the coronary arteries occurs in proportion to the severity and extent of coronary disease [14]. According to a meta-analysis by Pletcher et al., the risk of significant CAD events increases 2.1-fold and 10-fold for scores ranging from 1–100 to 400, respectively, compared with scores of 0 [15].

As we hypothesized, the current study found that CACS was significantly correlated with AA diameter, with the common pathophysiology of coronary calcification and AA aneurysm. Patients with a CACS over 400 had a cut-off value of 34 mm, which means that CACS more than 400 is predictive for diagnosis of AA aneurysm and vice versa. Several previous studies have concentrated on the relationship between CAD and AA aneurysms. CAD and AA have many of the same atherosclerotic risk factors, although the causes are not the same. Significant CAD was found in 33% of scheduled patients for abdominal aortic aneurysm surgical correction [16]. The prevalence of AA aneurysms was 14% in elderly patients with proven CAD, much higher than in same-age controls (3%) [4]. However, the overall prevalence of AA aneurysms with a high rupture risk (AA aneurysm diameter of 50–59 mm) was 6.7%, all belonged to the CACS of 400 or more subgroup. These findings point to CACS screening to rule out abdominal aortic aneurysms.

Cystic medial degeneration, the primary pathophysiology of the aneurysm, is associated with the aging process and long-standing hypertension, thus leading to dilatation of ATA [5]. However, our study found a difference in ATA diameter between CACS categories of more than ten (category 3) and the rest. This result differed from old studies with no association between CACS categories [17]. Although old age and hypertension are risk factors for thoracic aneurysms and atherosclerosis, there were no differences in ascending and descending thoracic aorta measurements between patients with CACS of more than 400 (category 5) and the rest. This is probably related to different age group populations, since all these previous studies made on age group more than 65y, diabetic, and probably due to different circumstances at our country where the history of chest trauma and old surgery is seen in some of our patients, with its risk of thoracic aneurysm. Nevertheless, CACS was not associated with descending thoracic aorta dilation in the current study.

This result leads to the notion that, in contrast to AA aneurysms, ATA aneurysms are considered to be the result of the clinical component of heritable connective tissue disorders such as Marfan syndrome, Ehlers-Danlos syndrome, and bicuspid aortic valve, as well as atherosclerosis [18–20].

In our study, 4.4% of patients had a history of thoracic surgery; half of these are surgeries for previous shell injury, with suspected ascending aortic dilation due to aorta injury or post-surgical sequel as infection.

The primary outcomes of the present study are (1) CACS was correlated with increased AA diameter, and to less extent with ascending thoracic aorta diameter, but not with the diameters of the DTA, and (2) the prevalence of AA aneurysm was most significant in patients with a CACS of 400 or more.

Study limitations

The weak points of our study were:

- the measurement of aortic diameter by native CT scan (without contrast) in the transverse plane may not represent the actual short axis;
- the only measurement of aortic transverse diameter, did not allow us to assess the exact relation between CACS and aortic size, unlike aortic volume which is more reliable than the transverse diameter.

Conclusion

CACS is associated with increased abdominal aorta diameter, to a lesser extent with ascending thoracic aorta diameter, but not with the descending thoracic aorta, so screening the abdominal aorta to rule out an aneurysm might be considered in hypertensive patients who have a CACS more than 400. However, screening for a thoracic aortic aneurysm is still not proven necessary in those patients.

Conflict of interest

The authors declare no conflict of interest.

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