Current Atherosclerosis Reports (2019) 21: 51
https://doi.org/10.1007/s11883-019-0811-9

EVIDENCE-BASED MEDICINE, CLINICAL TRIALS AND THEIR INTERPRETATIONS (L. ROEVER, SECTION EDITOR)

Anatomical References to Evaluate Thoracic Aorta Calcium by Computed Tomography

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Published online: 20 November 2019
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Abstract

Purpose of Review Thoracic aortic calcium (TAC) has received some interest in recent studies as an important subclinical marker of atherosclerosis. Besides that, using computed tomography (CT) scans performed with cardiac or chest protocols, ECG-gated, or non-gated, TAC can be easily evaluated with no addition in radiation dose. This review discusses the particularities of the aortic wall calcium formation, as well as the differences between the aortic segments and summarizes the current status of TAC evaluation, mainly concerning the anatomical references used in the studies.

Recent Findings The studies have evaluated TAC considering different anatomical references. It was identified two different study groups. In the first one, researchers have analyzed the aorta as the sum of calcium in the ascending aorta (ATAC), aortic arch (AAC), and descending thoracic aorta (DTAC). The second group has used cardiac CT scans to assess TAC; therefore, they did not include AAC; however, the aortic root calcium (ARC) was added in the analysis. So, caution is advisable when interpreting and comparing studies that used different TAC anatomical references.

Summary The broad methodological variability, in addition to the variations in the population characteristics of the studies on TAC, may be in part contributing to the differences between results of different studies. Currently TAC does not have a role in clinical decisions, so it is necessary to create a standard protocol for the aortic calcium research as well as exists for the coronary artery calcium evaluation.

Keywords Computed tomography · Thoracic aorta · Vascular calcification · Cardiovascular disease · Aortic Atherosclerosis · Aortic Arteriosclerosis

Introduction

Atherosclerosis is a systemic, progressive, and chronic condition that can affect the entire vascular tree [1]. Calcium in the artery wall is considered a direct marker of atherosclerotic disease [1] and can be easily evaluated through computed tomography (CT) [2]. There are remarkable mass of robust data supporting the prime role of coronary artery calcium (CAC) in cardiovascular risk assessment of the intermediate-risk population, as well as specific subgroups, as patients with diabetes and family history of premature coronary heart disease (CHD) [3]. Several studies have shown that thoracic aortic calcium (TAC) is also a marker of subclinical atherosclerosis [4]. Distinct associations of TAC arouse interest in its particularities compared with CAC analysis. TAC also impacts the CV system, as aortic wall calcium worsen arterial stiffening [5], which is associated with several implications for end-organ damage [6]. CAC and TAC prevalence also seem to differ between men and women and race/skin color [7–11], though results are inconsistent. Moreover, unlike CAC, TAC has not been evaluated through standard CT protocol, mainly with regard to TAC anatomical extension [12–14] and the use of ECG synchrony during exam [15].

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11883-019-0811-9) contains supplementary material, which is available to authorized users.

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Because differences in TAC definition and acquisition might impair the evaluation of study's results on the predictive value of TAC both at individual and population levels, our aim was to review recent studies about TAC, discussing the particularities of the aortic wall calcium formation and the differences between the aortic segments. And, finally, emphasize the anatomical references and the extension of the aorta included in the TAC studies.

Mechanisms Related to the Calcium Formation in the Thoracic Aorta Wall

The distribution of calcium along the aorta is usually very heterogeneous. It is possible to identify coarse calcium in one segment, while there is no calcium in another segment from the same individual, as shown in Fig. 1. In the first case (images 1a and 1b), there was calcium in large amount in the arch and descending thoracic segments, while there was no calcium in the ascending aorta. In the second case (images 1c and 1d), the calcium concentration was much higher in the aortic arch compared with ascending and descending thoracic portions.

The variation in the distribution of calcium across aorta segments may be in part associated with different embryonic origin of the vascular smooth muscle cells colonizing the aorta, which in the aortic arch derives from cardiac neural crest cells, whereas the calcium found in the descending aorta derives from the mesoderm [16]. The Leroux-Berger et al. study found correlation between the embryonic origin of vascular smooth muscle cells and the timing of the appearance of calcium [16]. Thus each aortic segment differs in their embryonic origin and is subject to different hemodynamic stress, which also appears to affect susceptibility to calcium [16], as the rate of calcium seems to differ among individuals [17]. Therefore, the calcium found in each aortic segment may be associated differently to cardiovascular risk factors [18] and probably has distinct predictive value for cardiovascular (CV) and non-CV morbidity and mortality, as suggested in some studies [12, 13, 19, 20•, 21•].

Another important particularity refers to the molecular mechanism of plaque calcium in the aortic wall, which is mainly composed by two mechanisms:

1) Intimal calcium: atherosclerosis, inflammatory response of tunica intima;
2) Medial calcium: occurs independently of intimal calcium in the tunica media.

The intimal layer consists of endothelial cells that eventually form atheromatous plaques which can rupture and cause thromboembolic events, whereas the medial layer consists of smooth muscle cells and elastic fibers that are associated with blood flow and arterial pressure regulation [2]. Medial

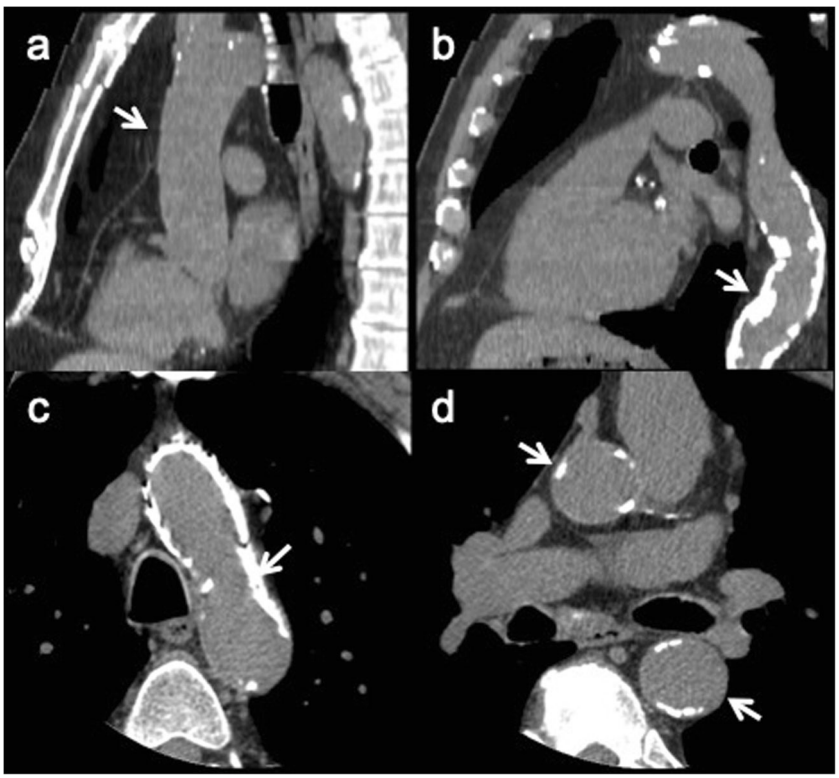

Fig. 1 Heterogeneous distribution of calcium along the aorta. a, b CT reconstructions in the parasagittal plane. In this case, ascending aorta had no calcium (arrow in a), whereas in the arch and descending portions (arrow in b) there were circumferential plaques covering almost all aortic wall. c, d CT reconstructions in the axial plane. The most calcium concentration was in the aortic arch (arrow in c), while in ascending (superior arrow in d) and descending (inferior arrow in d) segments calcium were coarse, but sparse

calcium is thought to cause arterial stiffening, reduce compliance, and limit distensibility [2]. Actually the way to distinguish intimal and medial calcium is through ex vivo histological analysis [22]. Then CT scans cannot define if the calcium is in the intimal or medial layer of aortic wall [2].

However, the patterns of calcium distribution observed in CT scans may suggest the predominance of intimal or medial calcium. Intimal calcium usually has a patchy distribution within atherosclerotic lesions and is most commonly amorphous without distinct architecture [23•]. On the other hand, vascular medial calcium is generally concentric, appears more circumferential, and has a diffuse distribution [23•]. Figure 2 shows schematically the patterns of calcium distribution in the tunica intima and media.

Frequently, medial calcium is associated with uremia, radiotherapy, or vascular inflammation which induces a phenotypic change of vascular smooth muscle cells into osteoblasts, a process of metabolite-induced (toxic) vascular changes in the absence of lipid deposits [24•]. However aging, chronic kidney disease, diabetes mellitus, and mediastinal radiation are also associated with accelerated intimal atherosclerosis [24•]. Therefore, the overlap of these two processes in the aortic wall might explain some differences in findings on cardiovascular risk factors associated with calcium in different vascular beds, and mainly between distinct aorta territories.

Differences in the Anatomical References Used at TAC Evaluation

The differences in TAC evaluation can impact both the identification of calcium as well as its quantification either in volume or using the Agatston score. So, caution is advisable when interpreting and comparing studies that used different TAC extensions. Table 1 shows selected studies published in the last 5 years evaluating calcium in the thoracic aorta. They were grouped based on the aortic segments included in the analysis. The first group evaluated calcium in three segments: ascending thoracic aorta (ATA), aortic arch, and descending thoracic aorta (DTA). The aortic root calcium was not included in this group. The second group represents the largest one, and evaluated TAC in the ATA, DTA, and in the aortic root, but not in the aortic arch. The third, fourth, and fifth groups included each a single study that used distinct anatomical references, respectively: the extended versions of ATA plus DTA, aortic arch, and aortic root. These studies shown in Table 1 also differ with respect on how they measured or analyzed the presence of calcium: yes/no [11], and/or Agatston [4, 12, 13, 25•,26–32] and/or volume [5, 33–35, 36••], and/or density [19, 20•, 21•], and/or semi-qualitative evaluation [14].

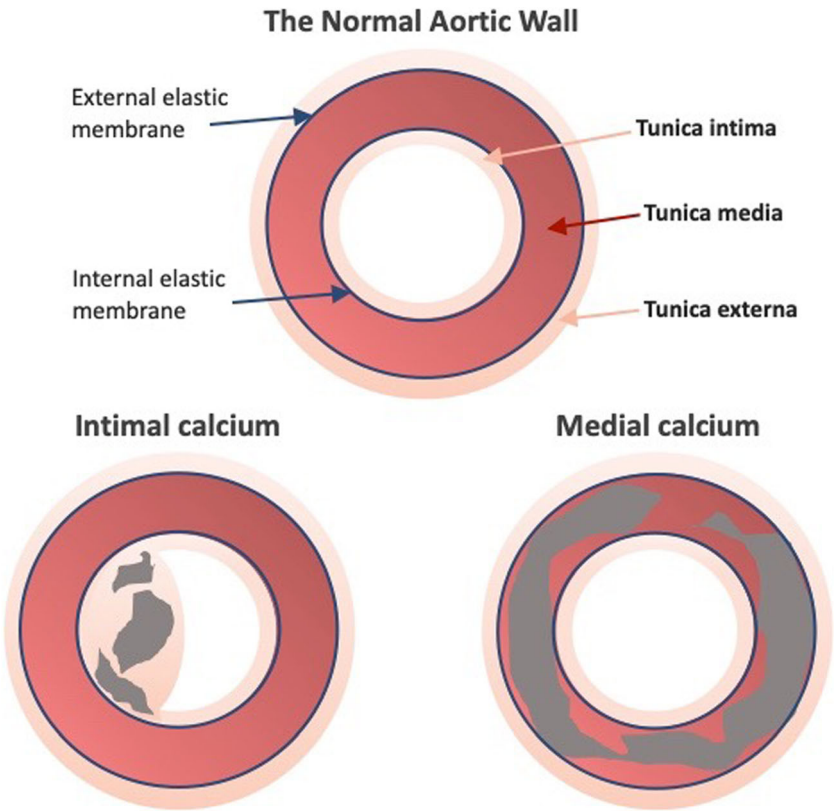

Fig. 2 Patterns of calcium distribution in the aortic wall. Intimal calcium has a patchy distribution in the atherosclerotic lesion and medial calcium is generally diffuse and circumferential

Table 1 Recent thoracic aorta calcium studies organized according to each group of thoracic aorta anatomical references used in the computed tomography evaluation

Anatomical references	Study reference (design)	Population	TAC analysis	Objective	Conclusion
Total TAC: from the apex of the heart until the top of the aortic arch. Total TAC = ATAC + AAC + DTAC ATAC: from the origin of left coronary artery to the lower edge of the pulmonary bifurcation AAC: above ATAC and DTAC DTAC: From the lower edge of pulmonary artery bifurcation to cardiac apex Obs.: ARC was not included.	Craiem et al. 2014 (cross sectional) [25•]	*n* = 970; 77% men; mean age 57 ± 9 years	Agatston	To investigate the prevalence and spatial distribution of TAC all along the thoracic aorta.	Aortic arch and proximal descending thoracic aorta concentrated most of the calcium. Middle-aged women were more prone to have calcium in those segments. TAC prevalence doubled from 31% to 64% comparing TAC evaluation without and with aortic arch, respectively.
	Craiem et al. 2016 (cross sectional)[26]	*n* = 1000; 78% men; mean age 57 ± 9 years		To assess TAC and CAC relations with non-CV events history in a cohort of subjects at risk for CVD and compare the findings between total TAC, partial TAC, and only aortic arch calcium	History of non-CV events was significant for total TAC, partial TAC, aortic arch, but not for CAC. But when entering total TAC and CAC together in the logistic regression as well as risk factors, of all covariates, OR was significant only for total TAC.
	Pedrosa et al. 2019 ELSA-Brasil (cross sectional)[11]	*n* = 2433; 54% women; mean age 56 ± 9 years	Calcium presence or absence	To assess the prevalence of TAC and CAC and verify if TAC is associated with the same cardiovascular risk factors as is CAC	Prevalence of TAC was much higher than CAC. Chances of CAC were higher in men and lower among blacks. There were no differences in TAC chances regarding gender and race/skin color.
	Rodríguez-Granillo et al. 2019 (longitudinal) [14]	*n* = 1250; women 55%; mean age 56.5 ± 10.1 years; Follow-up 3.7 years; Patients underwent clinically indicated chest CT scans for nonmalignant conditions.	Segment-involvement score	To explore the interplay and prognostic value of vascular calcifications and adipose tissue depots.	Age, pericardial fat volume upper tertile, and extensive CAC were independent predictors of all-cause death. Aortic calcium was not identified as predictor of death.
	Cho et al. 2015 (Longitudinal) [5]	*n* = 164; 100% men; mean age 73 years; Patients with hypertension	Volume	To investigate the relationship between TAC, arterial stiffening, left ventricular hypertrophy, and diastolic dysfunction	Heavy TAC and resultant arterial stiffening might underline left ventricular hypertrophy and diastolic dysfunction in elderly male patients with hypertension.
	Cho et al. 2016 (longitudinal) [34]	*n* = 702; 58% women; mean age 69 ± 4 years		To investigate the relationship of TAC and exercise SBP with all-cause death, (heart	TAC was related to SBP response during exercise and was an independent

Table 1 (continued)

Anatomical references	Study reference (design)	Population	TAC analysis	Objective	Conclusion
		Elderly individuals without obstructive CAD (luminal stenosis < 50%)		failure, obstructive CAD, and stroke)	predictor for outcomes, especially stroke, regardless SBP
TAC = ATAC + DTAC ATAC: from the aortic annulus to the lower edge of the pulmonary artery bifurcation Obs.: Aortic root was included. DTAC: from the lower edge of pulmonary artery bifurcation to apex of the heart. Obs.: Aortic arch was not included.	Ong et al. 2014 MESA (cross sectional)[27]	$n = 1632$; Participants without diabetes with valid data on homeostasis model assessment index.	Agatston	To investigate the association of insulin resistance with AAC, CAC and TAC, and whether it differs according to different levels of subcutaneous fat area and visceral fat area.	There was a modest association of insulin resistance with the presence but not extent of calcified atherosclerosis, especially CAC. For TAC, the association tended to be stronger in participants with abdominal obesity.
	Yeboah et al. 2014 MESA (longitudinal) [28]	$N = 5745$; Follow-up 9 years; Diabetics were excluded		To assess the improvement in discrimination afforded by the addition TAC, AVC, MVC, pericardial adipose tissue volume (PAT) and liver attenuation (LA) to FRFs plus CAC for incident CHD and CVD	CAC, TAC, AVC, MVC were independent predictors of incident CHD and CVD. When added to the FRFs, CAC has superior discriminative ability compared with TAC, AVC, MVC, PAT, or LA. Compared with FRFs plus CAC, the addition of TAC, AVC, MVC, PAT, or LA to the FRFs and CAC resulted in significant worsening of discrimination.
TAC = ATAC + DTAC ATAC: from the aortic annulus to the lower edge of the pulmonary artery bifurcation Obs.: ARC was included. DTAC: from the lower edge of pulmonary artery bifurcation to apex of the heart. Obs.: AAC was not included	Youssef et al. 2015 MESA (longitudinal) [29]	$n = 5886$; 52% women; mean age 62 years; Follow-up 2.4 ± 0.8 years	Agatston	To evaluate TAC progression.	Traditional CV risk factors were related to both TAC incidence and progression. Blacks had the lowest incidence and median changes across ethnic groups. The strongest risk factors for TAC incidence and progression were smoking, age, and hypertension.
	Kim et al. 2017 MESA (longitudinal) [30]	$n = 3415$; 63% women; median age 55 years; Follow-up 11 years; CAC = 0 at baseline		To study the association between TAC and incident CHD, CVD events and all-cause mortality.	TAC did not improve 10-year estimation of prognosis beyond traditional risk factors.
	Katz et al. 2016 MESA (cross sectional) [35]	$n = 6778$; 53% women; mean age 62 years (range 45–84 years); Follow-up 5 years	Agatston and volume	To examine the relation of the MetS, and each of its components, to the prevalence of TAC	MetS and diabetes are both independently associated with increased prevalence and severity of TAC after adjustment for age, gender, and ethnicity.
	Thomas et al. 2017 MESA	$n = 6811$; Follow-up 10 years	Density and volume	To test the hypothesis that ATAC volume and density predict	One-SD higher ATAC density was associated with a lower

Table 1 (continued)

Anatomical references	Study reference (design)	Population	TAC analysis	Objective	Conclusion
	(longitudinal) [19]			incident CVD events independently of CAC.	risk of CHD and CVD after full adjustment, while ATAC volume was not associated with outcomes after full adjustments
	Thomas et al. 2018 MESA (longitudinal) [20•]	$n = 5887$; Follow-up 2.4 years.		To evaluate changes in ATAC volume and density scores and incident atherosclerotic CVD.	After adjusting for CVD risk factors and baseline levels of ATAC volume and density, there were a significant association between an increase in ATAC volume over time and incident CHD, CVD, and ischemic stroke, while an increase in ATAC density over time was associated with a lower incidence of CHD and CVD, but not stroke.
	Thomas et al. 2018 MESA (longitudinal)[21•]	$n = 6765$; mean age 62 years Follow-up 12 years		To evaluate the association of DTAC with non-CV morbidity and mortality.	DTAC is associated with non-CV morbidity and mortality.
	Kälsch et al. 2017 Heinz Nixdorf Recall Study (longitudinal) [12]	$n = 3270$; 53% women; 45–74 years of age; Follow-up 5 ± 0.3 years	Agatston	To investigate associations of CV risk factors with incident TAC, of baseline TAC with incident CAC, and for baseline CAC with incident TAC.	TAC and CAC share similar major determinants for incidence and progression of calcification. High extent of TAC, especially ATAC, revealed considerably elevated risk of incidence and accelerated progression of CAC.
	Mahabadi et al. 2016 Heinz Nixdorf Recall Study (longitudinal) [31]	$n = 3630$; 54% women; mean age 59 ± 8 years; Follow-up of 10 ± 3 years		To determine whether noncoronary measures from cardiac CT may enhance the prognostic value of this diagnostic imaging tool.	Combined assessment of left ventricular and atrial axial area index, epicardial adipose tissue volume, and TAC from cardiac CT improves the prediction of incident hard CV events above CAC and established CV risk factors.
	Hoffmann et al. 2016 Framingham Heart Study (longitudinal)[32]	$n = 3486$; 51% women; mean age 50 ± 10 years; Follow-up 8 years		To determine whether TAC, CAC, AAC, MVC and AVC predict incident major CHD, CVD, and all-cause mortality independent of FRFs.	After adjustment for age and sex, FRFs, and CAC, TAC was not statistically significant for prediction of CHD events and major CVD. However, TAC remained significantly associated with all-cause

Table 1 (continued)

Anatomical references	Study reference (design)	Population	TAC analysis	Objective	Conclusion
					mortality even after these adjustments.
	Brodov et al. 2015 EISNER (longitudinal) [4]	$n = 1648$; 54% men; mean age 52 ± 9; Follow-up 5 years; CAC = 0 at baseline		To evaluate the predictive value of TAC for CAC conversion.	TAC ≥ 100 Agatston is an independent predictor of CAC
TAC = ATAC + DTAC ATAC: above the origin of the right coronary artery to the end of scan range or up to the origin of the brachiocephalic artery. Obs.: ARC was not included. DTAC: distal from the origin of the left subclavian artery up to the diaphragm. Obs.: AAC was not included.	Dudink et al. 2018 (longitudinal) [13]	$n = 327$; 66% men; mean age 56 years; Follow-up 67 ± 12 months; Low-risk population	Agatston	To determine the feasibility of assessing ATAC and DTAC on standard CAC scans and their associations of with coronary events	In patients without CAC, the event rate was higher in the patients with DTAC than in those without, which is comparable with patients with CAC without DAC. The event rate in patients with both CAC and DTAC was the highest. DTAC appears to improve the identification of those patients that will experience coronary events. ATAC showed no significant association with the occurrence of coronary events.
ATAC = AC Aortic arch: from the slice on which the ascending and descending aorta merge into the inner curvature of the arch to the first centimeter of the common carotid arteries, vertebral arteries, and subclavian arteries beyond the origin of the vertebral arteries.	Bos et al. 2015 Rotterdam Study (longitudinal)[33••]	$n = 2408$; 52% women; mean age 69 ± 7; Follow-up 15775 person years	Volume	To investigate associations of CAC, aortic arch, extracranial and intracranial internal carotid arteries with mortality adjusting for age, sex, and CV risk factors	Independent of calcification elsewhere, aortic arch calcium was related to a higher risk of CV mortality and non-CV mortality.
TAC = ARC ARC: the region of ATAC between the aortic annulus and the sinutubular junction.	Tesche et al. 2017 (Longitudinal) [36••]	$n = 189$; 53% women; mean age 60 ± 11 years; Patients with intermediate pre-test probability of CAD	Volume and Agatston	To evaluate the correlation between ARC and CAC and their ability to predict obstructive CAD.	ARC is a strong and independent predictor of CAC and obstructive CAD.

AAC, abdominal aortic calcium; *ARC*, aortic root calcium; *AAC*, aortic arch calcium; *ATAC*, ascending thoracic aorta calcium; *AVC*, aortic valve calcium; *CAC*, coronary artery calcium; *CAD*, coronary artery disease; *CHD*, coronary heart disease; *CV*, cardiovascular; *CVD*, cardiovascular disease; *DTAC*, descending thoracic aorta calcium; *EISNER*, Early Identification of Subclinical Atherosclerosis by Noninvasive Imaging research; *FRFs*, Framingham risk factors score; *LA*, liver attenuation; *MVC*, mitral valve calcium; *MESA*, Multi-ethnic Study of Atherosclerosis; *MetS*, metabolic syndrome; *OR*, Odds ratio; *PAT*, pericardial adipose tissue; *SBP*, systolic blood pressure; *SD*, Standard Deviation; *TAC*, thoracic aortic calcium

Does the Aortic Arch Add Relevant Information to TAC?

As shown by Craiem et al., the inclusion of aortic arch in combination with ATA and DTA doubled the TAC prevalence, mainly in middle-aged women [25•]. Besides the impact on the overall and sex-specific prevalence of TAC, the inclusion of the aortic arch in TAC evaluation might also relate to TAC predictive value on morbidity and mortality. Bos et al., for instance, analyzed only the aortic arch and found that the volume of calcium in this segment was related to increased CV and non-CV mortality, after adjustment for many CV risk factors including CAC, intracranial, and extracranial internal carotids calcium [33••]. A recent study of Cho et al. used the same TAC extension described by Craiem et al. and followed 702 patients without obstructive coronary artery disease (CAD) during 64 months and also found TAC as an independent predictor for outcomes, especially stroke [34]. Thus, taking account these latter results, it appears that calcium in the aortic arch might contribute to TAC prediction, but we cannot rule out that it may be also a marker of calcium in other thoracic aorta segments.

What Do We Know About the Presence of Calcium in ATA and DTA?

The largest study group presented in Table 1 is the ones that assessed TAC using the same scan performed for CAC assessment. Thus, only the presence of calcium in the ascending thoracic aorta (ATAC) and descending thoracic aorta (DTAC) were evaluated. Eight studies are from Multi-ethnic Study of Atherosclerosis (MESA), and they measured calcium using Agatston, volume, and/or density [19, 20•, 21•, 27–30, 35]. The others are from Heinz Nixdorf Recall Study [12, 31], Framingham Heart Study [37], and EISNER [4], and all of them used Agatston to measure TAC. All these studies included the aortic root in the TAC and excluded the aortic arch. As demonstrated by Tesche et al., calcium in the aortic root is a stronger and independent predictor of CAC and of obstructive CAD [36••], suggesting that a similar process lead to calcium in these vascular beds. Thus, like the CAC [38], it is possible that calcium in aortic root reflects more localized than generalized atherosclerosis, differently from other thoracic aorta segments.

When taken together, results on ATAC plus DTAC associations and predictive value are controversial [27–32, 35]. However, when Thomas et al. and Kälsch et al. studied the ATAC and DTAC separately, they found that while greater ATAC volume predicted the incidence and progression of CHD and CVD [12, 21•], DTAC was associated with the occurrence of non-CV morbidity and mortality [20•]. These authors also showed that greater ATAC density, contrary to greater volume, was associated with lower risk of CAD [19, 21•], and explained such differences between aorta segments in terms of embryology, wall constitution and pathophysiologic mechanisms of calcium formation. It is thus, possible, that such differences in DTAC and ATAC also account for the controversial results reported by the other studies included in this group, as they are based on ATAC plus DTAC [27, 28, 30, 32]. In light of these recent findings, further research using the same anatomical references for each thoracic aorta segment should be stimulated.

Anatomical References for TAC Segmentation

Based on the current anatomical references used in some TAC studies, and understanding the possible value of studying each aortic segment separately, including the aortic arch, we created the video 1 to show each portion of the aorta slice-by-slice in axial CT images. Since aorta has an oblique path, some details are of importance. The following anatomical references were used for TAC segmentation:

1) ATAC: from the sinutubular junction to the lower edge of pulmonary artery bifurcation (Some caution with the first slices, because of the initial curvature of ascending aorta above aortic root, where there are some slices that both appear in the same axial slice).
2) Aortic arch calcium: from ascending to descending thoracic aorta at the same anatomical reference, which is the level of the lower edge of pulmonary artery bifurcation.
3) DTAC: from the lower edge of pulmonary artery bifurcation to the apex of the heart.

What Is the Best Way to Measure TAC?

In addition to anatomical definitions, other methodological TAC parameters deserve to be considered. Agatston method has been widely used; however, the quantification of TAC can vary considerably between different CT systems once the acquisition of CAC scans, usually used to measure TAC, was not created for this application [39]. Mori et al. in 2015 described and validated a new volume-rendering approach to quantify TAC that demonstrated an excellent agreement of the pixel-based TAC score with volumetric TAC score and observed that volume-based score was less influenced by slice thickness as compared with pixel-based score [40••]. Agatston score depends nonlinearly on the measured Hounsfield Unit density of each pixel in the calcium, which changes with different x-ray energies, while the calcium volume is only slightly affected by scanning at different energies [41]. Since TAC is in the early development phase, perhaps now is the time to think about more accurate measures of quantifying the TAC [39].

Is TAC Radiation Exposure Justified?

The last, but a very important consideration to be made, refers to the radiation dose involved in TAC extended exams (all segments). Although the increase in the radiation dose of extended CAC, necessary to include the aortic arch, is lower than that delivered for a bilateral mammogram [25•], its value remains uncertain. So far, there appear to be no doubt regarding the value of evaluating DTAC and ATAC on CAC scans, as CAC clinical indication is already established. Lung cancer screening trials [42] seem to offer some opportunity to evaluate the predictive value of all segments, especially the aortic arch.

Limitations

The current review of the literature is limited mostly due to the high variability across the studies included in the analysis. As previously detailed, there is no current standards to define which aortic segments to include or the most appropriate tool to quantify the presence and extent of TAC. Moreover, the outcomes included in each analysis are not similar. Collectively, those issues limit the comparison between studies and the potential to fully interpret those results in other populations or scenarios.

Future Directions

Future studies should focus on the standardization of image acquisition, areas of the thoracic aorta to be included and most appropriate tools to quantify TAC. Moreover, detailed investigation on the different role of each thoracic aorta segment for the prediction of different outcomes, including separate analysis for coronary artery disease events, cerebrovascular events, and incidence of acute aortic syndromes.

Additionally, more studies on the implications of such findings for clinical management are needed. Currently, TAC is understood to be atherosclerosis. However, the clinical management of asymptomatic individuals with atherosclerosis is currently based on the individual's clinical risk profile with the potential use of other diagnostic tools, such as CAC scores in selected individuals. Yet, not clear role for TAC in selecting the most appropriate management strategy for those individuals exist.

Conclusions

TAC has been considered as subclinical marker of atherosclerosis; however, the lack of standard protocol regarding the anatomical segments included and measurement analytical unit have contributed to controversial results and studies comparability. The accumulated evidences indicate that each aorta segment should be evaluated separately, as they differ in terms of structural characteristics, embryologic origin, and pathophysiologic mechanisms of calcium formation along the aorta and predictive value.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Abbreviations AAC, abdominal aortic calcium; ATA, ascending thoracic aorta; ATAC, ascending thoracic aorta calcium; CAC, coronary artery calcium; CAD, coronary artery disease; CHD, coronary heart disease; CV, cardiovascular; CVD, cardiovascular disease; CT, computed tomography; DTA, descending thoracic aorta; DTAC, descending thoracic aorta calcium; MESA, Multi-ethnic Study of Atherosclerosis; TAC, thoracic aortic calcium

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Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

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