JBM J Bone Metab 2024;31(3):236-245
https://doi.org/10.11005/jbm.2024.31.3.236
pISSN 2287-6375 eISSN 2287-7029

Original Article

Abdominal Aorta Calcification Identified on DXA Scans and the Risk of Mortality in Adults

Carlos H. Orces

Department of Medicine, Laredo Medical Center, Laredo, TX, USA

Corresponding author
Carlos H. Orces
Department of Medicine, Laredo Medical Center, 1700 East Saunders Street, Laredo, TX 78041, USA
Tel: +1-956-645-7309
Fax: +1-956-712-3555
E-mail: corces07@yahoo.com

Received: May 13, 2024
Revised: July 17, 2024
Accepted: July 22, 2024

Background: Abdominal aortic calcification (AAC) on lateral lumbar radiographs increases the risk of cardiovascular events and mortality. However, data on the association between AAC detected in dual energy X-ray absorptiometry (DXA) and the risk of mortality in the general population are scarce. **Methods:** The present study was based on data from participants aged ≥40 years in the National Health and Nutrition Examination Survey (NHANES) cycle of 2013 to 2014. Vertebral assessment of lateral spine DXA scans was used to provide AAC measurements at vertebrae L1–L4. The extent of AAC was defined according to the Kauppila AAC-24 scores (0–1, 2–5, ≥6), and the NHANES 2019 public-use linked mortality files were used to assess mortality status. **Results:** Of the 2,962 participants who were included in this study, with a mean age of 57.4 years and a median follow-up of 69.9 months, 252 (8.5%) died. Of the deaths, 84 (33.3%) occurred due to cardiovascular disease. The Cox proportional hazards models revealed that participants with AAC-24 scores ≥6 were 1.7 times more likely to die than those with AAC-24 scores 0–1 (Hazard ratio, 1.75; 95% confidence interval, 1.13–2.71). Moreover, older adults and women with AAC-24 scores ≥6 were 2.8 and 2.4 times more likely to die than their counterparts with AAC-24 scores 0–1, respectively. Conversely, a non-significant risk of cardiovascular mortality was found among participants with AAC-24 scores ≥6. **Conclusions:** The extent of AAC detected on vertebral fracture assessment DXA was associated with an increased risk of all-cause mortality in adults, particularly older adults and women.

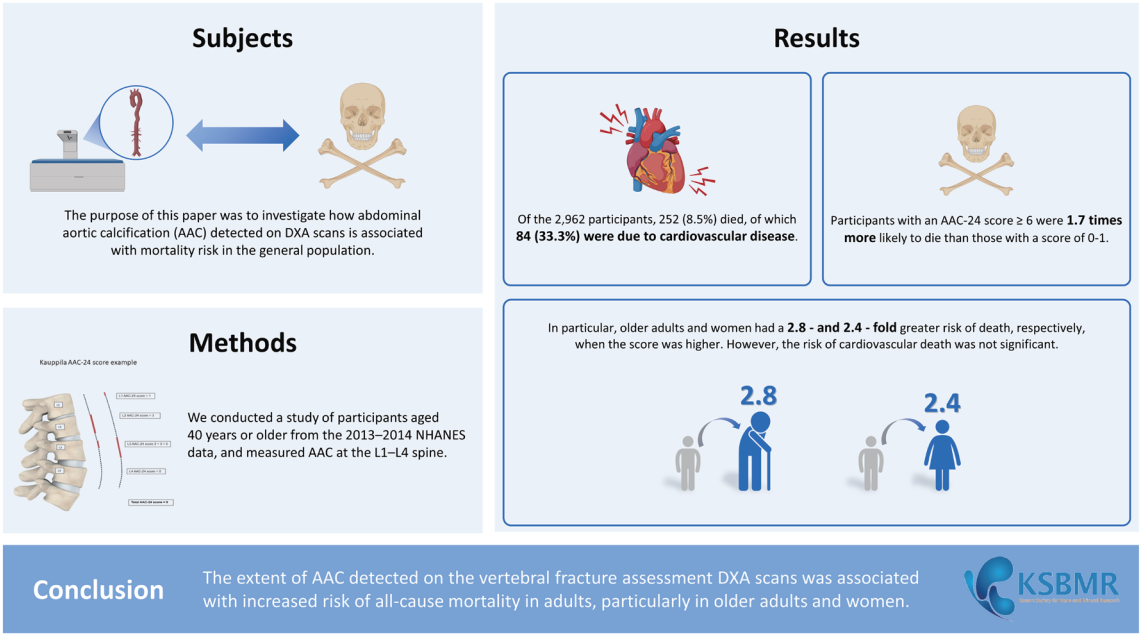
Key Words: Abdominal aorta calcification · DXA scan · Mortality

INTRODUCTION

The prevalence of abdominal aortic calcification (AAC) increases with age and is similarly distributed by gender in the general population.[1,2] AAC is also highly prevalent among subjects with established cardiovascular risk factors and correlates with subclinical atherosclerosis in other vascular beds.[3-5] The characteristic morphological trait of AAC is the calcification in the tunica media resulting from differentiation of vascular smooth muscle cells into osteoblast-like cells.[6]

Longitudinal studies have consistently reported that AAC detected by dual energy X-ray absorptiometry (DXA), computed tomography (CT), or lateral lumbar radiographs (X-rays) is a strong predictor of cardiovascular events and mortality, independently of traditional cardiovascular risk factors.[7-13] Leow et al. [1], in a recent systematic review and meta-analysis of observational studies with a higher

Graphical Abstract



prevalence of chronic kidney disease, demonstrated that subjects with any or more advanced AAC had 1.8- and 1.9-fold excess risk of cardiovascular and all-cause mortality than those without or less severe AAC, respectively.

Previous studies have also shown that AAC detected by X-rays or CT scan significantly increase the risk of all-cause mortality.[9-13] Lewis et al. [7] originally described that Australian older women with high AAC scores detected on lateral spine DXA scans had a 1.5 higher risk of all-cause mortality than their counterparts with low AAC scores. Despite this evidence, there is scarce data regarding the association between AAC detected on lateral lumbar spine DXA scans and the risk of mortality in the general population. Given the aging of the population, the instant vertebral assessment (IVA) lateral lumbar spine scans may simultaneously detect vertebral fractures and identify individuals with subclinical atherosclerosis at potential risk of mortality. Therefore, the present observational study aimed to examine the association between the extent of AAC identified on lateral lumbar spine DXA scans and the risk of all-cause and cardiovascular mortality in a nationwide representative sample of middle-aged and older adults.

METHODS

1. Study population

The present study was based on data from participants aged 40 years and older in the National Health and Nutrition Examination Survey (NHANES) cycle 2013–2014. The NHANES is a continuous biannual study conducted by the National Center for Health Statistics (NCHS) to assess the health and nutritional status of adults in the United States. The NHANES protocol was approved by the NCHS Research Ethics Review Board (continuation of protocol #2011–17), and informed consent was obtained from all participants included in the study. A detailed description of the NAHNES methods and analytic guidelines can be found at: https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx.

2. Abdominal aorta calcification scores

The IVA lateral lumbar spine scans acquired on Hologic Discovery model A densitometers (Hologic Inc., Bedford, MA, USA), provided AAC measurement with low radiation exposure for vertebrae L1–L4. The IVA lateral spine images were viewed using Optasia Spinalizer software and AAC-24 scoring semi-quantitative techniques were used for the AAC evaluation. The anterior and posterior lumbar aortic

walls were divided into 4 segments (L1–L4). Within these 8 segments, aortic calcification was recognized visually as either a diffused white stippling of the aorta, extending out to the anterior and/or posterior aortic walls, or as white linear calcification of the anterior and/or posterior walls. Aortic abdominal calcification was scored as "0" if there was no calcification; "1" if one-third or less of the aortic wall in that segment was calcified; "2" if more than one-third but less than two-thirds was calcified; or "3" if more than two-thirds were calcified. The scores were obtained separately for the anterior and posterior aortic walls, resulting in a range from "0" to "6" for each vertebral level and "0" to "24" for the total score.[14] IVA images were read by a single reader at the University of California San Francisco quality control center.

3. Covariates

The demographic characteristics of the participants were self-reported. Smoking status was categorized as never, former, or current smoker. Similarly, alcohol use was defined as never, moderate, and heavy.[15] Participants reported the time spent in moderate or intense recreational physical activity during the previous week. Then, the level of physical activity was classified according to the Physical Activity Guidelines for Americans.[16] In the mobile examination center, trained health technicians calculated participants' body mass index (BMI) as weight in kilograms divided by height in meters squared. Diabetes mellitus was defined if participants reported a physician's diagnosis of diabetes or had a hemoglobin A1c ≥6.5%.[17] Hypertension was defined as a systolic blood pressure (BP) ≥140 mmHg or diastolic BP ≥90 mmHg based on the mean of three consecutive BP readings or a report of taking prescribed medicine for hypertension.[18] Participants reported their health status which was grouped as good to excellent and fair to poor. Cardiovascular disease was considered to be prevalent if participants answered affirmatively to the question "Has a doctor ever told you that you had coronary heart disease, angina pectoris, heart attack, or stroke? " High-density lipoprotein (HDL)-cholesterol and triglyceride levels were measured according to NHANES laboratory methods. The estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease formula.[19]

4. Mortality data

The public-use linked mortality files provided mortality follow-up data from the date of survey participation through December 31, 2019. These data were obtained from the National Death Index, a service of the NCHS. Time to death was calculated in months and the underlying cause of death (UCOD) was defined according to the International Classification of Diseases, Tenth Revision (ICD-10). The UCOD was derived from UCOD 113 causes of death, tenth revision, which was created to assist researchers in conducting mortality analysis across years using ICD-10 coding. For the present study, diseases of the heart UCOD 113 codes 054–068 (ICD-10 codes I00–I09, I11, I13, I20–I51) and cerebrovascular diseases UCOD 113 code 070 (ICD-10 codes I60–I69) were reported as cardiovascular deaths. A detailed description of the UCOD 113 codes used in the public-use linked mortality files can be found at: https://www.cdc.gov/nchs/data/datalinkage/underlying-and-multiple-cause-of-death-codes-508.pdf.

5. Statistical analysis

The baseline characteristics of participants grouped according to AAC-24 scores (0–1, 2–5, and ≥6) were compared using ANOVA and χ^2 tests for continuous and categorical variables, respectively. Kaplan-Meir curves showed the overall and cardiovascular survival of participants stratified according to AAC-24 scores during the study period, which were compared using the log-rank test. Cox proportional hazard models were assembled to evaluate the risk of all-cause and cardiovascular mortality. Model 1 was adjusted for age, gender, race/ethnicity, education, and BMI; Model 2 was further adjusted for Model 1 and smoking status, alcohol use, physical activity, eGFR, self-reported health status, diabetes, hypertension, cardiovascular disease, triglycerides, and HDL cholesterol levels. In a subgroup analysis, the risk of all-cause mortality according to AAC-24 scores was examined by age groups (40–59 and ≥60 years) and gender. The results are presented as hazard ratios (HR) with their corresponding 95% confidence intervals (95% CI). Receiver operating characteristic curve analysis by gender was performed to determine the discriminative power of the AAC-24 scores in predicting all-cause and cardiovascular mortality. The area under the curve (AUC) is a good indicator of the goodness of the test and values 0.5 or lower are non-discriminating.[20] Stata

https://doi.org/10.11005/jbm.2024.31.3.236

version 18 (Stata Corp., College Station, TX, USA) was used to incorporate NHANES examination sampled weights to adjust for nonresponse and oversampling of certain populations. A *P* value of less than 0.05 was considered statistically significant.

RESULTS

A total of 2,962 participants with a mean age of 57.4±standard error (SE) 0.21 years comprised the study sample. The overall crude prevalence of AAC was 28.7%±SE 1.0 and 9.4%±SE 0.6 of participants had evidence of extensive AAC. As shown in Table 1, participants with AAC 24 scores ≥6 tended to be older, non-Hispanic white, physically inactive, lower BMI, and decreased eGFR. Similarly, diabetes, hypertension, and cardiovascular diseases were more prevalent among participants with AAC-24 scores ≥6. During a median follow-up of 69.9 months, a total of 252 (8.5%) participants died. Of those, 86 (33.3%) deaths were reported from cardiovascular diseases.

As shown in Figure 1, Kaplan-Meir curves showed that the probability of survival in participants with AAC-24 scores ≥6 was significantly decreased compared with their counterparts with lower AAC-24 scores. In addition, it appears that survival across AAC-24 scores diverged about 40 months into the study. Although less accentuated, the probability of survival from cardiovascular was also decreased with higher AAC-24 scores (Fig. 2).

Table 2 shows the association between AAC-24 scores and the risk of all-cause and cardiovascular mortality in

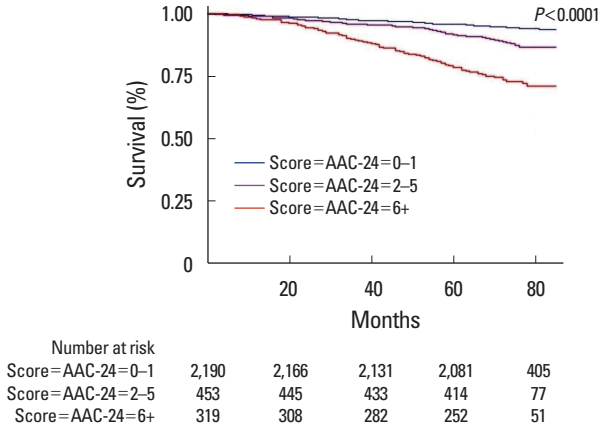


Fig. 1. Abdominal aorta calcification (AAC)-24 scores and all-cause mortality.

Table 1. Characteristics of participants according to AAC-24 scores

Variables	AAC-24 score 0–1 (N=2,190)	AAC-24 score 2–5 (N=453)	AAC-24 score 6 (N=319)	*P*-value
Age (yr)	55.1	60.7	70.5	<0.0001
Gender (%)				0.089
Male	47.5	53.2	48.3	
Female	52.5	46.8	51.7	
Race/ethnicity (%)				<0.0001
Hispanic	24.5	21.4	13.7	
Non-Hispanic white	40.7	49.1	62.3	
Non-Hispanic black	20.6	15.9	13.4	
Multiracial	14.2	13.6	10.6	
Education (%)				0.330
≤11th grade	22.6	22.5	25.1	
High school graduate/GED	21.5	25.4	25.1	
Some college	28.7	27.3	26.3	
College graduate and above	27.2	24.8	23.5	
BMI (kg/m^2)	28.8	27.9	27.3	<0.0001
Smoking (%)				<0.05
Never	41.0	40.7	48.3	
Former	23.3	23.5	24.9	
Current	35.7	35.8	26.8	
Alcohol use (%)				<0.0001
Never	57.4	46.3	40.4	
Moderate	25.1	32.8	39.1	
Heavy	17.5	20.9	20.5	
Physical activity (%)				<0.0001
Yes	32.3	25.2	22.9	
No	67.7	74.8	77.1	
eGFR (mL/min)	81.9	78.6	68.7	<0.0001
Health status (%)				0.239
Fair to poor	24.8	25.9	29.2	
Good to excellent	75.2	74.1	70.8	
Diabetes (%)				<0.0001
Yes	17.5	22.1	33.3	
No	82.5	77.9	62.7	
Hypertension (%)				<0.0001
Yes	20.3	26.2	37.3	
No	79.7	73.8	62.7	
Cardiovascular conditions (%)				<0.0001
Yes	8.4	15.6	29.4	
No	91.6	84.4	70.6	
HDL-cholesterol (mg/dL)	55.3	52.2	53.2	<0.0001
Triglycerides (mg/dL)	157.4	169.9	168.6	<0.0001

AAC, abdominal aorta calcification; BMI, body mass index; GED, General Educational Development; eGFR, estimated glomerular filtration rate; HDL, high-density lipoprotein.

Table 2. The association between AAC-24 scores and mortality risk

AAC-24 scores	No. deaths (%)	HR (95% CI)[a]	HR (95% CI)[b]
All-cause mortality			
0–1	117 (5.3)	1.00	1.00
2–5	51 (11.2)	1.34 (0.88–2.00)	1.22 (0.81–1.84)
≥6	84 (26.3)	**2.12 (1.40–3.22)**	**1.75 (1.13–2.71)**
Cardiovascular mortality			
0–1	36 (1.6)	1.00	1.00
2–5	17 (3.7)	1.26 (0.65–2.45)	1.28 (0.66–2.48)
≥6	33 (10.3)	1.70 (0.96–3.01)	1.17 (0.60–2.30)

Bold values indicate statistical significance ($P<0.05$).
[a]Model 1: adjusted for age, gender, race/ethnicity, education, and body mass index (kg/m^2).
[b]Model 2: adjusted for model 1 and alcohol use, smoking status, physical activity, health status, diabetes, hypertension, cardiovascular conditions, estimated glomerular filtration rate (mL/min), high-density lipoprotein cholesterol (mg/dL), and triglycerides (mg/dL).
AAC, abdominal aorta calcification; HR, hazard ratio; CI, confidence interval.

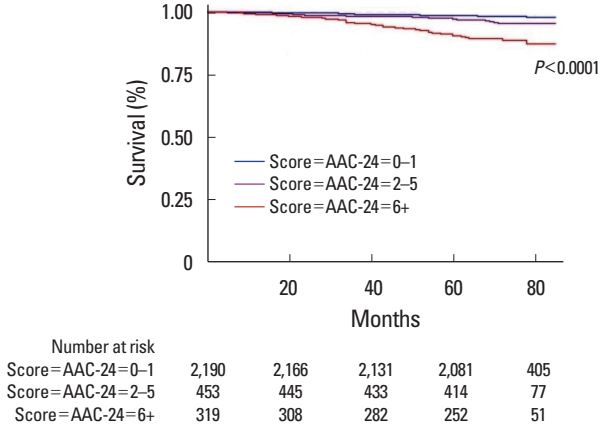


Fig. 2. Abdominal aorta calcification (AAC)-24 scores and cardiovascular mortality.

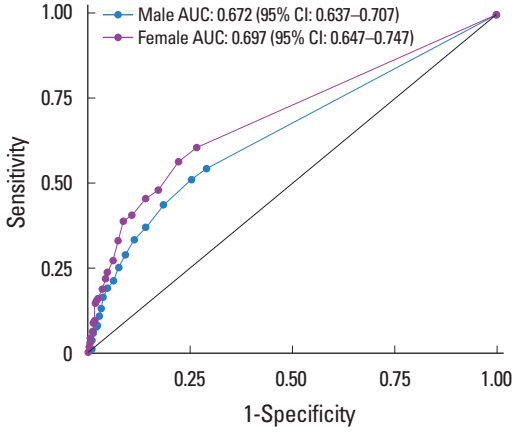


Fig. 3. Receiver operating characteristic curve for abdominal aorta calcification-24 and all-cause mortality. AUC, area under the curve; CI, confidence interval.

adults. After adjusting for age, sex, race/ethnicity, education, and BMI, the risk of all-cause mortality was 2-fold higher among participants with AAC-24 ≥6 score than those with AAC-24 scores 0–1 (HR, 2.12; 95% CI, 1.40–3.22; $P<0.0001$). This association was mildly attenuated after adjusting for lifestyle characteristics, prevalent cardiovascular risk factors, and eGFR (HR, 1.75; 95% CI, 1.13–2.71). Conversely, a non-significant slight increase in cardiovascular mortality was seen among subjects with AAC-24 score ≥6 (HR, 1.17; 95% CI, 0.60–2.30).

Table 3 shows the association between AAC-24 scores and HR for all-cause mortality according to age groups and gender. In general, AAC-24 scores were similarly distributed by gender, but significantly differed by age groups. Notably, 82.1% of the deaths occurred among participants aged ≥60 years. After adjusting for potential confounders, older adults and women with AAC-24 scores ≥6 were 2.8 (HR, 2.88; 95% CI, 1.79–4.63) and 2.4 times (HR, 2.44; 95% CI, 1.23–4.83) more likely to die than their counterparts with AAC-24 scores 0–1, respectively.

As shown in Figure 3, the AUC of AAC-24 scores for predicting all-cause mortality were 0.67 (95% CI, 0.63–0.70) in men and 0.69 (95% CI, 0.64–0.74) in women. Similarly, as shown in Figure 4, the AUC for predicting cardiovascular mortality was 0.68 (95% CI, 0.60–0.76) in men and 0.70 (95% CI, 0.61–0.79) in women for predicting cardiovascular mortality, corresponding to AUC with acceptable to good discriminating capacity.

https://doi.org/10.11005/jbm.2024.31.3.236

Table 3. The association between AAC-24 scores and all-cause mortality risk by age groups and gender

AAC-24 scores	No. deaths (%)	HR (95% CI)[a]	HR (95% CI)[b]
Age-group			
40–59 yr			
0–1 (N=1,341)	34 (2.5)	1.00	1.00
2–5 (N=192)	7 (3.6)	1.30 (0.42–3.98)	0.67 (0.30–1.48)
≥6 (N=44)	4 (9.0)	3.34 (1.02–10.90)	2.01 (0.72–5.59)
≥60 yr			
0–1 (N=849)	83 (9.7)	1.00	1.00
2–5 (N=261)	44 (16.8)	1.80 (1.15–2.82)	1.87 (1.16–3.01)
≥6 (N=275)	80 (29.0)	**3.64 (2.43–5.45)**	**2.88 (1.79–4.63)**
Gender			
Male			
0–1 (N=1,041)	65 (6.2)	1.00	1.00
2–5 (N=241)	30 (12.4)	1.19 (0.66–1.87)	1.17 (0.67–2.04)
≥6 (N=154)	38 (24.6)	1.39 (0.78–2.48)	1.33 (0.73–2.44)
Female			
0–1 (N=1,149)	52 (4.5)	1.00	1.00
2–5 (N=212)	21 (9.9)	1.61 (0.84–3.08)	1.43 (0.78–2.62)
≥6 (N=165)	46 (27.8)	**3.20 (1.74–5.89)**	**2.44 (1.23–4.83)**

Bold values indicate statistical significance ($P<0.05$).
[a]Model 1: adjusted for age, gender race/ethnicity, education, and body mass index (kg/m^2).
[b]Model 2: adjusted for model 1 and alcohol use, smoking status, physical activity, health status, diabetes, hypertension, cardiovascular conditions, estimated glomerular filtration rate (mL/min), high-density lipoprotein cholesterol (mg/dL), and triglycerides (mg/dL).
AAC, abdominal aorta calcification; HR, hazard ratio; CI, confidence interval.

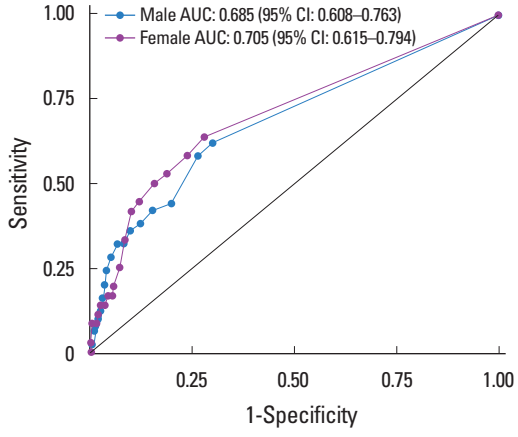


Fig. 4. Receiver operating characteristic curve for abdominal aorta calcification-24 score and cardiovascular mortality. AUC, area under the curve; CI, confidence interval.

DISCUSSION

The present findings indicate that adults aged 40 years and older with baseline AAC-24 scores ≥6 detected on the vertebral assessment lateral spine DXA scans and after a median follow-up of 69.9 months had 1.7-fold higher risk of all-cause mortality than their counterparts with AAC-24 scores 0–1. Notably, the risk of all-cause mortality in older adults and women with AAC-24 scores ≥6 was 2.8- and 2.4-fold higher than their counterparts with AAC-24 scores 0-1, respectively.

Previously, Lewis et al. [7] reported that older Australian women with a baseline AAC-24 scores ≥6 detected on lumbar spine DXA scans and after a mean follow-up of 14.5 years had 1.5-fold higher risk of all-cause mortality than those with AAC-24 score 0–1, which is consistent with the present results. Likewise, in the Study of Osteoporotic Fractures, white women with AAC identified by lumbar spine X-ray and a mean follow-up of 13 years had 37% higher risk of all-cause mortality.[10] Moreover, a systematic review and meta-analysis of population-based studies reported that subjects with any or more advanced AAC had a 1.9-fold higher absolute and relative risk for all-cause mortality than their counterparts with no or less advanced AAC.[1]

Studies conducted predominantly in older women have demonstrated a significant association between the extent

Table 4. Summary characteristics of studies reporting the association between abdominal aorta calcification and mortality risk

References	No. participants	Gender	Age (yr)	Follow-up (yr)	HR (95% CI)	Imaging
All-cause mortality						
Lewis et al. (2018) [7]	1,052	F	≥70	14.5	1.53 (1.17–2.00)	DXA scan
Criqui et al. (2014) [11]	1,974	M/F	45–84	5.5	2.71	CT scan
Rodondi et al. (2007) [10]	2,056	F	≥65	13.0	1.37 (1.15–1.64)	X-rays
Leow et al. (2021) [1][a]	36,092	M/F	≥40	3.3–22.0	1.98 (1.55–2.53)	Multiple
Current study	2,962	M/F	≥40	5.8	1.75 (1.13–2.71)	DXA scan
Cardiovascular mortality						
Lewis et al. (2018) [7]	1,052	F	≥70	14.5	1.80 (1.26–2.57)	DXA scan
Criqui et al. (2014) [11]	1,974	M/F	45–84	5.5	5.89	CT scan
Rodondi et al. (2007) [10]	2,056	F	≥65	13.0	1.18 (0.88–1.57)	X-rays
Leow et al. (2021) [1][a]	36,092	M/F	≥40	3.3–22.0	1.85 (1.44–2.39)	Multiple
Wilson et al. (2001) [13]	2,515	M/F	≥60	22.0	2.26 (1.66–3.09)	Radiograph
Bastos Gonçalves et al. (2012) [21][a]	4,986	M/F	≥57	2.0	1.72 (1.03–2.86)	Multiple
Current study	2,962	M/F	≥40	5.8	1.17 (0.60–2.30)	DXA scan

[a]Systematic review and meta-analysis.
HR, hazard ratio; CI, confidence interval; F, female; M, male; DXA, dual energy X-ray absorptiometry; CT, computed tomography.

of AAC detected on lateral lumbar spine DXA scans and the incidence of myocardial infarction and stroke.[7,8] As expected, the present results indicate that participants with more advanced AAC had a higher prevalence of self-reported cardiovascular conditions, diabetes, hypertension. Moreover, the probability of cardiovascular survival among individuals with AAC-24 score ≥6 was considerably lower than those with lower AAC-24 scores. However, after adjusting for potential confounders, including traditional cardiovascular risk factors, cardiovascular mortality did not significantly differ according to AAC-24 scores. Likewise, Rodondi et al. [10] reported that older women with prevalent AAC detected on lumbar spine X-ray did not have a significant risk of cardiovascular mortality, which is consistent with the present findings.

Previously, Lewis et al. [7] demonstrated that older women with AAC-24 scores ≥6 detected on lumbar spine DXA scans had a 1.8-fold higher risk of atherosclerotic vascular mortality than those with AAC-24 scores 0–1. Likewise, in the Multiethnic Study of Atherosclerosis, participants grouped in the highest AAC quartile detected on CT scans had 5.9-fold increased risk of cardiovascular mortality compared with their counterparts in the lowest quartile. [11] Moreover, participants in the Framingham Heart Study with the highest tertile of AAC detected on lumbar spine X-ray at baseline examination and followed over 22 years were 2.2 times more likely to die from cardiovascular diseases than those in the lowest tertile, which contrasts with the present findings.[13] The characteristics of the participants from the present and previous studies and their all-cause and cardiovascular risk associated with AAC were summarized in Table 4.

Possible explanations for these contradictory results regarding the association between AAC-24 scores and cardiovascular mortality might be related to the radiographic technique used to detect AAC, characteristics of the participants, follow-up study period, and atherosclerotic-related cardiovascular deaths as study outcomes. Nevertheless, a meta-analysis of three longitudinal observational studies with a least 2 years of follow-up, originally demonstrated that the risk of cardiovascular mortality was 1.7-fold higher among individuals with baseline AAC.[21] A recent systematic review and meta-analysis of five cohort studies also reported that subjects with any or more advanced AAC had a 1.8-fold higher risk of fatal cardiovascular events.[1]

Notably, women with AAC-24 score ≥6 were 2.4 times more likely to die than those with AAC-24 score 0–1, despite of having a lower prevalence of cardiovascular risk factors and diabetes (data not shown). In contrast, higher AAC-24 scores in men did not significantly increase the risk of all-cause mortality. Of interest, AAC-24 scores did not significantly differ by gender in the present study. Similarly, Michos et al. [22], in the multiethnic study of atherosclerosis previously reported that sex hormones in both genders

https://doi.org/10.11005/jbm.2024.31.3.236

were not significantly associated with the presence and severity of AAC. Nevertheless, the exact reasons for the observed gender disparities in mortality risk associated with prevalent AAC are unclear and merit further investigation. Notably, a large study conducted to examine trends in mortality after elective abdominal aorta aneurysm surgery in England also demonstrated that all-cause mortality at 30 days, 1 year, and 5 years were higher in women than in men. Moreover, 30-day mortality risk was increased in women regardless of the type of surgical procedure (open vs. endovascular repair).[23]

Wong et al. [4] reported that AAC detected by CT scans was correlated with subclinical cardiovascular disease of the coronary, carotids, and leg arteries. The severity AAC was also associated with an increased likelihood of coronary artery calcification and carotid intima medial thickening. AAC-24 scores identified on lumbar spine DXA scans were also significantly correlated with carotid ultrasound measures of atherosclerosis in older women.[5] These findings were also reported in autopsy specimens of cadavers with gross calcification of the abdominal aorta who had concomitantly lumbar spine X-ray films. Indeed, AAC identified on X-ray was 100% correlated with post-mortem abdominal aorta calcification. In contrast, among cadavers without lumbar spine X-ray calcification, only 16% of abdominal aorta specimens demonstrated calcification. In addition, in specimens of abdominal aorta with calcification, there was evidence of advanced atherosclerosis.[24] Similarly, Vos et al. [25], in a postmortem study conducted to validate the location of aortic calcification on CT scans reported that aortic calcifications were predominantly located in the distal abdominal aorta and atherosclerotic intimal layer. In addition, these calcifications were exclusively found in calcified fibrous cap atheroma and fibrocalcific atherosclerotic lesions.[25]

Although there is scarce data regarding the validity of the vertebral fracture assessment lateral DXA scans to detect AAC, Schousboe et al. [9] demonstrated that the AAC-8 score performed well on vertebral fracture images to detect postmenopausal women with a radiographic AAC-24 score of ≥ 5, which is associated with 2.4-fold increased risk of cardiovascular mortality. Sharif et al. [26] also reported good level of agreement between a large collection of lateral spine images with AAC-24 scored by an experienced imaging specialist and machine learning AAC-24 scores across DXA machines from different manufactures used over the past three decades. The present findings also demonstrated that AAC-24 scores have good discriminating capacity in predicting all-cause and cardiovascular mortality in women.

This study has several limitations that should be mentioned. First, as an observational study, the causality of the association between AAC and all-cause mortality risk may not be established. Second, it is unknown whether calcifications detected by DXA scans in other segments of the aorta may increase the risk of mortality. Third, the confounder effect of low-density lipoprotein (LDL) cholesterol on the association of AAC and mortality was not examined. Nevertheless, data from the UK Biobank imaging cohort demonstrated that AAC was not correlated with LDL cholesterol.[2] Despite these limitations, the present findings may be generalized to the U.S. adults aged 40 years and older.

In conclusion, the extent of AAC detected on lateral lumbar spine DXA scans among U.S. adults was associated with an increased risk of all-cause mortality, particularly among older adults and women. The present findings underscore the importance of routinely evaluate the presence of AAC on lateral lumbar spine DXA scans to identify subjects with subclinical atherosclerosis and concurrently implement cardiovascular risk stratification.

DECLARATIONS

Ethics approval and consent to participate

This study conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

ORCID

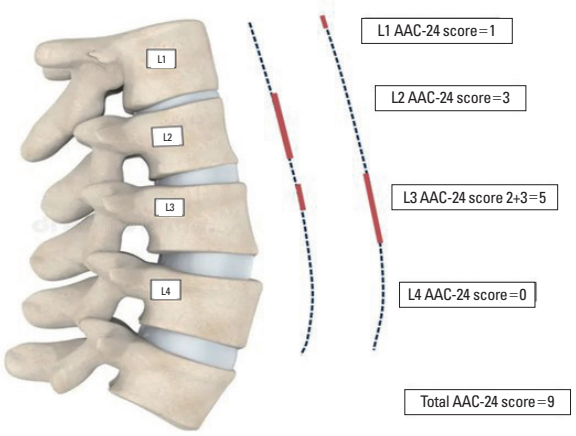
Carlos H. Orces *https://orcid.org/0000-0003-2452-3423*

REFERENCES

1. Leow K, Szulc P, Schousboe JT, et al. Prognostic value of abdominal aortic calcification: a systematic review and meta-analysis of observational studies. J Am Heart Assoc

2021;10:e017205. https://doi.org/10.1161/jaha.120.017205.
2. Sethi A, Taylor DL, Ruby JG, et al. Calcification of the abdominal aorta is an under-appreciated cardiovascular disease risk factor in the general population. Front Cardiovasc Med 2022;9:1003246. https://doi.org/10.3389/fcvm.2022.1003246.
3. Forbang NI, McClelland RL, Remigio-Baker RA, et al. Associations of cardiovascular disease risk factors with abdominal aortic calcium volume and density: the Multi-Ethnic Study of Atherosclerosis (MESA). Atherosclerosis 2016;255:54-8. https://doi.org/10.1016/j.atherosclerosis.2016.10.036.
4. Wong ND, Lopez VA, Allison M, et al. Abdominal aortic calcium and multi-site atherosclerosis: the multiethnic study of atherosclerosis. Atherosclerosis 2011;214:436-41. https://doi.org/10.1016/j.atherosclerosis.2010.09.011.
5. Lewis JR, Schousboe JT, Lim WH, et al. Abdominal aortic calcification identified on lateral spine images from bone densitometers are a marker of generalized atherosclerosis in elderly women. Arterioscler Thromb Vasc Biol 2016;36:166-73. https://doi.org/10.1161/atvbaha.115.306383.
6. Szulc P. Abdominal aortic calcification: a reappraisal of epidemiological and pathophysiological data. Bone 2016;84:25-37. https://doi.org/10.1016/j.bone.2015.12.004.
7. Lewis JR, Schousboe JT, Lim WH, et al. Long-term atherosclerotic vascular disease risk and prognosis in elderly women with abdominal aortic calcification on lateral spine images captured during bone density testing: a prospective study. J Bone Miner Res 2018;33:1001-10. https://doi.org/10.1002/jbmr.3405.
8. Bolland MJ, Wang TK, van Pelt NC, et al. Abdominal aortic calcification on vertebral morphometry images predicts incident myocardial infarction. J Bone Miner Res 2010;25:505-12. https://doi.org/10.1359/jbmr.091005.
9. Schousboe JT, Taylor BC, Kiel DP, et al. Abdominal aortic calcification detected on lateral spine images from a bone densitometer predicts incident myocardial infarction or stroke in older women. J Bone Miner Res 2008;23:409-16. https://doi.org/10.1359/jbmr.071024.
10. Rodondi N, Taylor BC, Bauer DC, et al. Association between aortic calcification and total and cardiovascular mortality in older women. J Intern Med 2007;261:238-44. https://doi.org/10.1111/j.1365-2796.2007.01769.x.
11. Criqui MH, Denenberg JO, McClelland RL, et al. Abdominal aortic calcium, coronary artery calcium, and cardiovascular morbidity and mortality in the Multi-Ethnic Study of Atherosclerosis. Arterioscler Thromb Vasc Biol 2014;34:1574-9. https://doi.org/10.1161/atvbaha.114.303268.
12. Szulc P, Kiel DP, Delmas PD. Calcifications in the abdominal aorta predict fractures in men: MINOS study. J Bone Miner Res 2008;23:95-102. https://doi.org/10.1359/jbmr.070903.
13. Wilson PW, Kauppila LI, O'Donnell CJ, et al. Abdominal aortic calcific deposits are an important predictor of vascular morbidity and mortality. Circulation 2001;103:1529-34. https://doi.org/10.1161/01.cir.103.11.1529.
14. Kauppila LI, Polak JF, Cupples LA, et al. New indices to classify location, severity and progression of calcific lesions in the abdominal aorta: a 25-year follow-up study. Atherosclerosis 1997;132:245-50. https://doi.org/10.1016/s0021-9150(97)00106-8.
15. Laszkowska M, Rodriguez S, Kim J, et al. Heavy alcohol use Is associated with gastric cancer: analysis of the national health and nutrition examination survey from 1999 to 2010. Am J Gastroenterol 2021;116:1083-6. https://doi.org/10.14309/ajg.0000000000001166.
16. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. JAMA 2018;320:2020-8. https://doi.org/10.1001/jama.2018.14854.
17. American Diabetes Association. (2) Classification and diagnosis of diabetes. Diabetes Care 2015;38 Suppl:S8-S16. https://doi.org/10.2337/dc15-S005.
18. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension 2003;42:1206-52. https://doi.org/10.1161/01.HYP.0000107251.49515.c2.
19. National Kidney Foundation. MDRD study equation. 2024 [cited by 2024 Mar 1]. Available from: https://www.kidney.org/mdrd-study-equation
20. Trebach J, Su MK. Biostatistics and epidemiology for the toxicologist: rock the ROC curve. J Med Toxicol 2022;18:163-7. https://doi.org/10.1007/s13181-022-00879-2.
21. Bastos Gonçalves F, Voûte MT, Hoeks SE, et al. Calcification of the abdominal aorta as an independent predictor of cardiovascular events: a meta-analysis. Heart 2012;98:988-94. https://doi.org/10.1136/heartjnl-2011-301464.
22. Michos ED, Vaidya D, Gapstur SM, et al. Sex hormones, sex hormone binding globulin, and abdominal aortic calcification in women and men in the multi-ethnic study of atherosclerosis (MESA). Atherosclerosis 2008;200:432-8. https://doi.org/10.1016/j.atherosclerosis.2007.12.032.
23. Desai M, Choke E, Sayers RD, et al. Sex-related trends in

mortality after elective abdominal aortic aneurysm surgery between 2002 and 2013 at National Health Service hospitals in England: less benefit for women compared with men. Eur Heart J 2016;37:3452-60. https://doi.org/10.1093/eurheartj/ehw335.
24. Hyman JB, Epstein FH. A study of the correlation between roentgenographic and post-mortem calcification of the aorta. Am Heart J 1954;48:540-3. https://doi.org/10.1016/0002-8703(54)90119-2.
25. Vos A, Houben IB, Celeng C, et al. Aortic calcification: a postmortem CT validation study in a middle-aged population. Eur J Radiol 2023;159:110687. https://doi.org/10.1016/j.ejrad.2023.110687.
26. Sharif N, Gilani SZ, Suter D, et al. Machine learning for abdominal aortic calcification assessment from bone density machine-derived lateral spine images. EBioMedicine 2023;94:104676. https://doi.org/10.1016/j.ebiom.2023.104676.



Supplementary Fig. 1. Kauppila abdominal aorta calcification (AAC)-24 score example.

https://doi.org/10.11005/jbm.2024.31.3.236