Aortic Calcification on Plain Chest Radiography Increases Risk for Coronary Artery Disease*

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Study objectives: To determine whether an association exists between aortic calcification viewed on plain chest radiography and coronary artery disease.

Methods: Retrospective review of all chest radiographs obtained from consecutive patients undergoing coronary angiography at a primary cardiac center during 1999. Plain chest radiographs were reviewed by blinded radiologists, and interobserver consistency was measured. The presence or absence of aortic arch calcification was abstracted and compared with the results of coronary angiography.

Results: Of 654 cases, 329 of 360 patients with aortic arch calcification vs 241 of 294 patients without aortic arch calcification had coronary artery disease demonstrated on angiography. The 9% absolute difference in proportions was significant (p = 0.0003). The relative risk (measured by risk ratio) was 1.11 (95% confidence interval, 1.05 to 1.19).

Conclusion: Several objective signs (e.g., hypertension, hyperlipidemia, and ECG changes) have been associated previously with the presence of coronary artery disease. This study further suggests an association between coronary disease and aortic arch calcification on plain chest radiography. These results may assist primary-care providers performing routine health assessments as well as emergency practitioners evaluating patients with potential angina.

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Key words: aorta; calcification; coronary artery disease; radiograph; risk

Cardiac disease is the leading cause of death in the developed world. In the United States, it accounts for approximately 725,000 deaths annually. This represents 31% of all deaths and an annual mortality rate of 268 deaths per 100,000 population. Of various contributors to cardiac disease, coronary artery disease remains the most significant, and efforts toward the early identification and treatment of patients with such disease are attributed to the reported reduction of atherosclerotic death rates.1

Other authors have demonstrated an increased risk for coronary artery disease with advanced age, male sex, estrogen status, smoking, hypertension, hyperlipidemia, resting ECG changes, family history of coronary disease, diabetes, and obesity.2

Chest radiography is a common, noninvasive, and relatively inexpensive screening test that is performed on patients for routine health risk assessment. Furthermore, it is routinely ordered during emergency department evaluations of patients with suspected myocardial angina to screen for other causes of undifferentiated chest pain such as pneumothorax, aortic dissection, abdominal free air, or pneumonia. Iribarren and colleagues3 have observed an independent association between aortic arch calcification seen on chest radiography and the presence of coronary artery disease after retrospectively reviewing a large health maintenance organization patient database and controlling for other risk factors. The magnitude of increased relative risk, 1.2, prompted these investigators to conclude that aortic arch calcification may have prognostic value beyond the traditional risk factors for coronary disease.3

If the conclusions of these investigators are confirmed, the utility of chest radiography for both routine and emergency screening purposes could be...
significantly improved. However, despite the persuasiveness inherent in its power (n = 116,309), the study was limited by radiologist interobserver variability (the radiographs were not reviewed for the analysis) and classification bias (coronary disease was quantified by hospital admission diagnostic codes rather than by disease that was demonstrated directly by coronary angiography).

We also sought to determine whether a correlation exists between aortic arch calcification (Fig 1) and coronary disease. Accordingly, we performed a study using blinded radiologists who were specifically tasked to review chest radiographs for aortic arch calcification. These findings were compared to findings of coronary disease in the same patients, based on objective measurements from coronary angiography.

**Materials and Methods**

The Mount Auburn Hospital is a primary cardiovascular teaching hospital and performs in excess of 1,000 coronary angiography procedures annually. We performed a retrospective review of all patients undergoing both diagnostic and therapeutic coronary angiography during the 1-year period from October 1, 1998, to September 30, 1999. Two radiologists (one specializing in chest radiography) independently reviewed all chest radiographs obtained from patients who had undergone coronary angiography during this period. Each radiologist was blinded to the readings of the other and to the patients’ coronary angiography results. For patients who had undergone multiple radiographs, the chest radiograph closest in time to the angiogram procedure was chosen for review. Radiographs were assessed for the presence or absence of aortic arch calcification. If present, aortic arch calcification was qualified further by length (either ≤ 1 cm or > 1 cm). The length, 1 cm, was chosen to simplify the determination of aortic arch calcification severity, so that if such severity turned out to be important during our analysis of secondary end points, the measurement could be easily remembered and objectively reproduced.

Any differences between radiologist interpretations were to be resolved by the consensus reading of a committee of three additional investigators who also were blinded to the angiography results. Frequent meetings were held with all investigators in order to maintain rigor in the abstraction methods.

Coronary angiography reports were reviewed by investigators blinded to the radiologist readings and were assessed for presence or absence of coronary disease. Patients who underwent more than one angiogram during the study period were counted only once, with the worst disease present used for purposes of the analysis. If present, coronary disease was further qualified by severity (ie, not severe or severe). Severe coronary disease was defined by findings that resulted in coronary artery angioplasty.

**Figure 1.** Plain chest radiogram showing typical appearance of calcification within the aortic arch.
stent placement, or bypass graft surgery. Nonoperable patients who met the criteria for coronary bypass graft surgery also were deemed to have severe disease, based on practice guidelines published by the American College of Cardiology.4 (Specific criteria were disease in the left main coronary artery, left anterior descending artery stenosis of $>70\%$, a combination of left anterior descending and circumflex stenoses, combination left and right coronary stenoses, or diffuse coronary disease.)

The study population was necessarily limited to patients previously selected for coronary angiography, a primary bias of this study that was imposed by the ethical inability to perform angiography on a sample of healthy patients. Given this limitation, primary a priori end points were as follows: (1) calculation of the rate of coronary disease in patients with aortic arch calcification; (2) calculation of the rate of coronary disease in patients without aortic arch calcification; and (3) the relative risk of coronary disease associated with aortic arch calcification. Secondary a priori end points were as follows: (1) calculation of the rate of severe coronary disease in patients with aortic arch calcification of $>1$ cm; (2) calculation of the rate of severe coronary disease in patients with aortic arch calcification measuring $\leq 1$ cm; and (3) the relative risk of severe coronary disease associated with aortic arch calcification of $>1$ cm.

The study was approved by the Mount Auburn institutional review board. The $\chi^2$ test was used to compare proportions. Relative risk was reported as risk ratios. The 95% confidence intervals for risk ratios were calculated using the method of Cornfield. Interobserver reliability was measured using the $\kappa$ statistic and a standard interpretation of $\kappa$ results was applied.8 Statistical significance was deemed to be $p \leq 0.05$. Statistical results were confirmed using a software package (Stata, version 6.0; Stata Corporation; College Station, TX).

**Results**

At our institution between October 1, 1998, and September 30, 1999, a total of 1,156 coronary angiograms (International Classification of Disease, 9th revision-clinical modification, procedure codes 88.55, 88.56, and 88.57) were performed on 1,093 patients. Multiple angiograms were performed on 54 patients (two angiograms were performed on 47 patients, three angiograms were performed on 5 patients, and four angiograms were performed on 2 patients). The results of angiograms were similar for all patients who received angiograms were used for our analysis. In comparison to the previous study in which 12% of radiographs were excluded from analysis for poor quality, we excluded none. Finally, in the previous study, coronary disease was not defined by objective criteria but by diagnostic discharge codes, introducing the possibility of classification bias (where the symptoms and signs being evaluated as risk factors may have prompted clinicians to code the diagnosis without a confirmatory angiogram).

While attempting to quantify the relationship between coronary and aortic disease, our secondary

**Discussion**

Our study confirms the work by Iribarren and colleagues3 demonstrating a small but real increased incidence of angiogram-proven coronary disease in patients with aortic arch calcification detected by plain chest radiography. The relative risk in the previous study was 1.27 among men and 1.22 among women, with confidence intervals that include our own value of 1.11. Although smaller, our study was rigorous. Radiographs were intentionally read for aortic arch calcification, interobserver reliability was assessed, and objective results of actual coronary angiography were used for our analysis. In comparison to the previous study in which 12% of radiographs were excluded from analysis for poor quality, we excluded none. Finally, in the previous study, coronary disease was not defined by objective criteria but by diagnostic discharge codes, introducing the possibility of classification bias (where the symptoms and signs being evaluated as risk factors may have prompted clinicians to code the diagnosis without a confirmatory angiogram).
analysis did not reach significance. This was likely due to the fact that nearly all patients with aortic calcification fell into the >1-cm-length category. Such an unexpected finding, however, led us to conclude that aortic arch calcification, when present on plain radiography, is usually large enough to be readily identifiable. This is confirmed by the high degree of interobserver consistency that we observed for the identification of any aortic arch calcification whatsoever.

Our analysis was limited by its study population, since it included only those patients preselected by other risk factors to undergo coronary angiography. As suspected, the prevalence of coronary disease in our study population was high both generally (overall prevalence, 87%) and specifically (prevalence among patients without aortic arch calcification, 82%). The observation that aortic arch calcification is associated with coronary disease must be placed in the context of a population with potentially unique characteristics, making generalizations to other populations difficult. However, until technology improves so that coronary disease can be diagnosed with noninvasive imaging, it will be ethically impossible to carry out a prospective randomized trial to further quantify the risk for coronary disease in otherwise healthy patients with aortic arch calcification. Consequently, when combined with the previous work that was described, this study represents the best available evidence that patients with aortic arch calcification seen on plain chest radiography are at an increased risk for coronary artery disease.

As with hyperlipidemia and hypertension, clinicians should be educated on the potential association between aortic arch calcification and coronary disease. Plain chest radiography already is performed ubiquitously for adult health screenings as well as for the evaluation of emergency patients with potential angina. The additional review of chest radiographs for aortic arch calcification adds no cost and is exceptionally simple. These preliminary findings may give further utility to the chest radiograph as a screening examination and, if confirmed, could assist risk stratification in patients suspected of having coronary disease.

REFERENCES
5 StataCorp. Stata user’s guide. College Station, TX: Stata Press, 1999; 132–143