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CLINICAL INVESTIGATIONS

Coronary artery calcification is common on nongated chest computed tomography imaging

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Background: Coronary artery calcification as assessed by computed tomography (CT) is a validated predictor of cardiovascular risk, whether identified on a dedicated cardiac study or on a routine non-gated chest CT. The prevalence of incidentally detected coronary artery calcification on non-gated chest CT imaging and consistency of reporting have not been well characterized.

Hypothesis: Coronary calcification is present on chest CT in some patients not taking statin therapy and may be under-reported.

Methods: Non-gated chest CT images dated 1/1/2012 to 1/1/2013 were retrospectively reviewed. Demographics and medical history were obtained from charts. Patients with known history of coronary revascularization and/or pacemaker/defibrillator were excluded. Two independent readers with cardiac CT expertise evaluated images for the presence and anatomical distribution of any coronary calcification, blinded to all clinical information including CT reports. Original clinical CT reports were subsequently reviewed.

Results: Coronary calcification was identified in 204/304 (68%) chest CTs. Patients with calcification were older and had more hyperlipidemia, smoking history, and known coronary artery disease. Of patients with calcification, 43% were on aspirin and 62% were on statin medication at the time of CT. Coronary calcification was identified in 69% of reports when present.

Conclusions: A high prevalence of coronary calcification was found in non-gated chest CT scans performed for non-cardiac indications. In one-third, coronary calcification was not mentioned in the clinical report when actually present. In this population of patients with cardiac risk factors, standard reporting of the presence of coronary calcification may provide an opportunity for risk factor modification.

KEYWORDS

coronary artery disease, Imaging, coronary calcification, Preventive cardiology, General clinical cardiology/adult, computed tomography < Imaging

1 | INTRODUCTION

Coronary artery calcification as assessed by computed tomography (CT) is a validated predictor of cardiovascular risk and can be identified on a dedicated cardiac CT study or non-electrocardiogram (ECG) gated chest CT. Although coronary calcium incidentally found on nongated chest CT is not scored in a standardized manner as on dedicated cardiac CT, the presence of any coronary calcium is associated with increased cardiovascular risk compared to those without any calcium.[1,2] In this study, we sought to estimate the prevalence of coronary calcification in nongated chest CTs performed for noncardiac indications, and when present, the rate of reporting.

The number of CT scans performed in the United States has been growing at an exponential rate. Nearly 70 million CT scans were performed in 2007, with approximately 17% (~11 million) including the chest.[3] Given growing public concerns about radiation exposure

in medical imaging, it is important to extract all potentially valuable information from these studies. Although coronary calcium can be detected on nongated chest CT imaging, the prevalence of coronary calcium in unselected patients undergoing chest CT for a variety of clinical indications has not been well characterized. In addition, consistency of reporting has not been systematically evaluated.

One prior lung cancer screening study showed that visual estimation of coronary calcification found on non-gated chest CT are comparably predictive of cardiovascular events compared to Agatston scoring.[4] The incidental identification of coronary calcification itself can be predictive of future cardiovascular events, and these results emphasize the importance of identifying these higher-risk patients to provide preventive care.[5]

2 | METHODS

2.1 | Study cohort

All noncontrast, non-ECG gated CT scans from consecutive patients referred for noncardiac indications from January 1, 2012 to December 31, 2012 at a private, academic, tertiary referral center were reviewed for inclusion. Patients were excluded if they met 1 of the following criteria: below the age of 35 years or above 90 years, unavailable medical history or incomplete documentation in the electronic medical record (EMR), presence of a pacemaker or implantable cardioverter-defibrillator (ICD), or history of percutaneous coronary intervention or coronary artery bypass graft based on chart review. If more than 1 chest CT was available for the eligible patient over the study period, only the first scan was included. The study was approved by the New York University School of Medicine Institutional Review Board.

2.2 | Data collection

Detailed data regarding age, gender, race, body mass index, smoking history, comorbidities, medication history, and history of prior chest CT imaging were recorded from review of the EMR. Coronary artery disease was defined by listing of coronary artery disease or myocardial infarction (MI) in the medical history section of the EMR. Hypertension was defined per prior documentation in the patient's EMR. Dyslipidemia and diabetes were defined using documentation review in the EMR or if lipid-lowering medications or diabetic medications were prescribed, respectively. Chronic kidney disease was defined using EMR documentation or estimated glomerular filtration rate <60. Family history of coronary artery disease was defined per the EMR review. Types of medication recorded included aspirin, β-blockers, statins, and other lipid-lowering agents including fibrates, niacin, fish oil, ezetimibe, and red yeast rice. Smoking history was defined as current or prior use as recorded in the EMR.

Clinical CT reports were reviewed to assess for coronary calcium reporting, indication for chest CT, and dominant extracardiac findings (if present). We recorded the presence or absence of calcification without regard to location of calcification, if specified. Dominant extracardiac findings were classified as malignant or nonmalignant, and pleural, parenchymal, mediastinal, or other. Chest CT indications were classified as lung/mediastinal abnormalities, pulmonary malignancy, or other indication.

2.3 | Imaging

CT images were acquired using standard clinical protocols at our institution. To meet inclusion criteria, all studies were noncontrast, non–ECG-gated chest CT scans. Scans were performed on 1 of 3 available scanners (Somatom Definition Edge, Somatom Definition AS [128-slice], Somatom Definition Flash; Siemens Medical Solutions, Forchheim, Germany). Tube voltage was either 100 or 120 KVp, using an automatic scanner algorithm adjusting for patient size. Detector collimation was 64×0.6 mm. Reconstruction slice thickness was 5 mm, with a reconstruction increment of 5 mm. Images were reconstructed using a medium convolution kernel (B40f).

Two readers with expertise in cardiac CT imaging reviewed CT images for the presence or absence of coronary calcium, as well as distribution in the coronary arterial tree. Readers were blinded to all clinical data, including the clinical CT report. Neither reader was the original clinical reader of the chest CT for any case. All images were reviewed for the presence or absence of calcium in each of the following 3 coronary vessels: (1) left main or left anterior descending (LAD) coronary artery and its branches, (2) left circumflex coronary artery and branches, and (3) right coronary artery (RCA).

A subset of randomly selected CT studies (n = 22) was analyzed by both reviewers to determine interobserver reliability. Analysis of interobserver variability was done for both presence/absence of calcium overall and for presence/absence of calcium by vessel.

2.4 | Statistical analysis

Kappa statistic was calculated to determine the degree of agreement between readers. Dichotomous variables, presented as proportions, were compared between patients with calcium on chest CT and without calcium on chest CT, and between patients with calcium reported on chest CT and with calcium not reported using the Pearson χ^2 test. Independent 2-sample *t* tests were used to compare continuous variables between groups after checking for normality. Statistical analyses were performed using SPSS statistical analysis software (IBM, Armonk, NY). All tests were 2-tailed, and values of $P < 0.05$ were considered statistically significant.

3 | RESULTS

A total of 749 CT scans from consecutive patients referred for noncardiac indications were assessed for inclusion. Among these, 304 subjects met inclusion/exclusion criteria and were included in the analysis. The mean age of the cohort was 71 years; the group was predominantly female (62.5%). In the entire cohort (n = 304), 59.9% had a history of smoking, 56.9% dyslipidemia, and 52.1% were on statin therapy. Coronary calcification was detected on 68% (204/304) of CT scans. Only 12.5% of these patients had a known history of coronary artery disease at the time of CT based on chart

review. Only 6 patients had previous coronary artery calcium scoring available in the EMR.

Demographics, comorbidities and medications are presented in Table 1. Patients who had coronary calcium were older and more likely to have a history of smoking, hypertension, dyslipidemia, and known coronary artery disease. Among those with coronary calcification, 43% were on aspirin, and 62% were on statin therapy at the time of the CT scan.

When present, coronary calcium was mentioned in 69% of clinical reports. There was no difference in reporting of existing calcium based on indication for study, medical history, dominant extracardiac finding, age, sex, or race (Table 2). Coronary calcium was more likely to be reported, when present, if more vessels were involved.

3.1 | Interobserver variability

Agreement was 100% for presence/absence of coronary calcium on a per-patient analysis. For individual coronary vessels, interobserver agreement was excellent for the left main/LAD (κ 0.8, $P < 0.001$) and RCA (κ 0.9, $P < 0.001$) but poor for the left circumflex (κ 0.4, $P = 0.04$).

4 | DISCUSSION

Approximately two-thirds of CT scans performed for noncardiac, routine indications were found to have coronary calcification (68%) in this study. A large majority of these patients did not have a diagnosis of coronary artery disease on chart review. Given that the mean age of this group was over 70, over half were smokers, and half had dyslipidemia, the prevalence of coronary calcification is not unexpected. Yet less than half of those with coronary calcium were on aspirin and yearly 40% were not on statin therapy. Therefore, identification and awareness of the presence of coronary calcium on a routine chest CT could provide an opportunity for cardiovascular risk reduction. However, only about two-thirds of CT scan reports mentioned coronary calcium when it was present.

Prior retrospective studies of chest CT scans done as part of lung cancer screening protocols reported a wide range of coronary calcium prevalence, from 14% to 93%; in our study, we found a prevalence of 68%.[6–8] Our findings may be more applicable to clinical practice in that we assessed consecutive CT scans performed for a variety of noncardiac indications.

Coronary artery calcium measurement on ECG-gated or triggered cardiac CT is a powerful cardiovascular risk assessment technique using a well-validated score (typically Agatson units).[2] Both the presence and the amount of calcium are associated with increased risk of cardiovascular events.[9] Although scoring coronary calcium on chest CT acquired without timing to the cardiac cycle is not currently standardized and may suffer significant limitations (eg, motion artifact), a recent study showed an excellent correlation between scores derived from gated and nongated scans in the same patients.[4] A meta-analysis of 6 studies involving coronary artery calcium scoring showed an increased overall relative risk for cardiovascular death or MI (relative risk = 4.3) for any measurable calcium compared to a low or 0 score.[2] Similarly, a coronary artery calcium score above 0 in women with low Framingham risk was associated with a hazard ratio of 5.2 for cardiovascular events in the Multi-ethnic Study of Atherosclerosis (MESA) study.[1] Thus, assessment for any coronary calcification, regardless of the extent, may be useful in clinical decision making for risk factor modification.

In our study, nearly a third of patients found to have coronary calcification did not have coronary calcium mentioned in the clinical report. There was no difference in reporting based on age, sex, or chest CT indication, even in the presence of dominant extracardiac findings, which we hypothesized might distract the reader from assessing for coronary calcification. We cannot speculate about why calcification was reported in some cases and not others, other than the higher likelihood of reporting when there was calcification in a

TABLE 1 Comparison of characteristics between patients with and without calcification on chest CT

Characteristics	All, n = 304	Any Calcification n = 204	No Calcification n = 100	*P* Value
Age, y	70.7 ± 9.6	73.6 ± 8.8	64.8 ± 8.6	<0.001
Female, no. (%)	190 (62.5)	120 (58.8)	70 (70.0)	0.059
Nonwhite, no. (%)	32 (14)	17 (11.3)	15 (19.5)	0.091
BMI, mean, kg/m^2	27.1 ± 6.1	27.1 ± 6.7	27.1 ± 5.8	0.960
Any smoking history, no. (%)	167 (59.9)	118 (64.1)	49 (51.6)	0.043
Comorbid conditions, no. (%)				
Hypertension	129 (44.6)	72 (37.5)	57(58.8)	0.001
Dyslipidemia	165 (56.9)	124 (64.6)	41 (41.8)	<0.001
Diabetes	62 (21.4)	45 (23.4)	17 (17.3)	0.231
Chronic kidney disease	40 (13.8)	26 (13.6)	14 (14.3)	0.875
Known coronary artery disease	27 (12.5)	24 (12.5)	3 (3.1)	0.009
Medications, n = 290				
Aspirin	112 (38.6)	82 (42.7)	30 (30.6)	0.083
Statin	151 (52.1)	118 (61.5)	33 (33.7)	<0.001
β-Blocker	105 (36.2)	84 (43.8)	21 (21.4)	<0.001
Other lipid-lowering drugs	25 (8.6)	16 (8.3)	9 (9.1)	0.73

Abbreviations: BMI, body mass index; CT, computed tomography.

TABLE 2 Comparison of characteristics between patients with coronary calcification reported and not reported on chest CT

Characteristics	Calcification Reported, n = 139	Calcification Not Reported, n = 65	*P* Value
Age, y	73.7 ± 8.8	73.4 ± 8.9	0.816
Female (%)	83 (59.7)	37 (56.9)	0.706
Nonwhite, no. (%)	37 (26.6)	19 (29.2)	0.599
Chest CT indication, no. (%)			0.528
Lung/mediastinal abnormality	95 (68.3)	41 (63.1)	
Pulmonary malignancy	20 (14.4)	13 (20.0)	
Other indications	23 (16.5)	10 (15.4)	
Vessels with calcium, no. (%)			
LAD and LM	136 (97.8)	61 (93.8)	0.144
RCA	78 (56.1)	28 (43.1)	0.082
LCx	77 (55.4)	19 (29.2)	<0.001
Number of vessels affected, no. (%)			0.002
1	41 (29.5)	35 (53.8)	
2	44 (31.7)	17 (26.2)	
3	54 (38.8)	13 (20.0)	

Abbreviations: CT, computed tomography; LAD, left anterior descending; LCx, left circumflex; LM, left main; RCA, right coronary artery.

greater number of vessels. A recent survey of radiologists reported that only 17% of noncardiac imagers were aware of the correlation between calcium scores on gated and nongated chest CT scans; thus, the interpreting radiologists may not have recognized the potential importance of this issue.[10]

We believe that coronary calcium should be routinely reported because, as an incidental finding, it provides an opportunity for risk factor modification prior to clinically evident cardiovascular disease. Prior studies have shown that the presence of any coronary calcification confers elevated cardiovascular disease risk above the absence of any calcification. The MESA study showed that nearly half of participants classified as having intermediate cardiovascular risk based on traditional risk factors were reclassified using coronary calcium scoring into lower and higher risk groups.[11] Therefore, additional knowledge of the presence of coronary calcium is a valuable tool for preventive care.

We advocate for the standardization of reporting of coronary calcium on routine chest CT scans. This is not specifically addressed in current CT guidelines.[12] Current American College of Cardiology/American Heart Association (ACC/AHA) prevention guidelines suggest that coronary artery calcium scoring can be used as an additive decision making tool when cardiovascular risk is indeterminate.[13] This is in line with a recent study showing that standard clinical risk scores alone are limited for predicting the presence of coronary atherosclerosis.[14] Thus, it behooves clinicians to review any available chest CTs to determine whether coronary calcification is present. In our study population, only 62% of those with coronary calcification were already taking statin therapy at the time they presented for chest CT, and 43% were on aspirin at the time of CT. Therefore, there was an opportunity for reporting of coronary calcification to influence preventive care.

4.1 | Limitations

There are several limitations to our study. We examined the presence or absence of calcium on CT, but did not assess the extent of calcium in our cohort. Additionally, visual interpretation of coronary calcification on a noncardiac chest CT can miss small calcific lesions, particularly with the 5-mm slice thickness used in these clinical scans. Dedicated cardiac CT scans for coronary calcium typically use 3-mm slice thickness, and thus prevalence of calcium may be underestimated in our study. At our tertiary referral center, the population studied may have more complex medical disease than a community cohort and therefore higher prevalence of disease. We did not have access to future ordering practices of all referring physicians (if patients were sent for additional calcium scores or cardiac testing), and due to the high number of patients referred from outside our institution, medical history was not available for review in a nearly half the original patients identified. In addition, interobserver variability was assessed in a limited subset of our study population.

5 | CONCLUSION

In our study of nongated chest CT scans done for noncardiac indications, we found a high prevalence of coronary calcification. Nearly one-third of cases with coronary calcification did not include this information in the clinical report. Utilizing chart review, we were able to identify that large proportions of these patients were not on preventive medications for cardiovascular risk reduction. Thus, the reporting of coronary calcification has potential value to referring providers, and we advocate for the standardization of chest CT reporting in this regard.

CONFLICTS OF INTEREST

The authors declare no potential conflicts of interest.

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