Diagnosticaccuracyofcalcifiedaorticknob found in chest radiograph for detection ofcoronaryarterycalcification

ABSTRACT

Aims:Tovalidatethediagnosticperformanceofacalcifiedaorticknobfoundinchest radiographs in relation to coronary calcification.
Studydesign:Thisstudyisanobservationalanalyticalcross-sectionalstudy.
PlaceandDurationofStudy:Thisstudyexaminedparticipantswhowerereferredfora CT coronary calcium scoring (CT-CAC). at theCentralChestInstituteofThailand, DepartmentofMedicalServices,MinistryofPublic Health, during the period from November 1, 2019, to October 31, 2021.
Methodology: This cross-sectional study aims to evaluate the association between calcified aortic knobs on chest radiographs and coronary artery calcification as determined by CT-CAC. The study included 664 patients who underwent CT-CAC between November 1, 2019 and October 31, 2021. We selected participants aged 40 to 75 years without known historyofcoronaryarterydisease(CAD)ordiabetes(fastingbloodsugarlevelsunder 126 mg/dl within past 6 months). A total of 441 eligible patients were included in the final analysis.

Standard chest radiographs within 6 months interval were evaluated and classified into 4 grades, Grade0(novisiblecalcification),Grade1(<50%calcificationofaorticknob),Grade2(>50%calcification oftheaorticknob),andGrade3(circularcalcificationoftheaortic knob). These findings were then compared with CAC obtained via dual source CT scanner to evaluate the diagnostic accuracy of chest radiographs. Key performance metrics, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were calculated to determine the effectiveness of aortic knob calcification as a predictor for coronary calcification.
Results:PositiveCAC(CAC >0)wasstronglyassociatedwithacalcifiedaorticknob(grades1-3), with a high positive predictive value of 88.07%. The diagnostic accuracy, sensitivity, and specificity were 66.9%, 61.5%, and 79.8%, respectively. The negative predictive value was low, at 41.8%.
Conclusion: A calcified aortic knob (grades 1-3)correlatesstronglywithpositiveCAC(positive predictive value 88.07%).The study's findings of low sensitivity (61.5%) and negative predictive value (46.18%) indicate limitations in using calcified aortic knob onchestradiographasastandalonescreeningtoolforcoronaryarterycalcification.

KEYWORDS: **Coronaryarterycalciumscore(CAC),Calcifiedaorticknob,chestradiograph (CXR),computedtomography (CT),CTcoronaryarterycalcium score(CTCAC)**

1.INTRODUCTION

Cardiovasculardiseasesarecurrentlyamajorpublichealthissue in Thailand. Coronaryarterydiseaseleadingtomyocardialischemiaisoneoftheleadingcausesof death,rankingfourthinmenandthirdinwomen[1].Themaincauseofcoronaryartery diseaseistheaccumulationoffatandthickeningofthearterialwall,whichisconsidereda formofatherosclerosis,leadingtonarrowingofthecoronaryarteries.Thisresultsin insufficient bloodsupplytotheheartmuscle,causingsymptomssuchaschest painoreasy fatigue.Iftheaccumulatedfatruptures,itcanleadtosuddencoronaryarteryblockage, causingacutemyocardialinfarction,complications,orsuddendeath.Theriskofcoronary arterydiseaseisassessedusingtheFraminghamRiskScore,whichcategorizespatients intolow,medium,andhighrisk,consideringfactorssuchasgender,age,comorbiditieslike diabetes,hypertension,hyperlipidemia,smoking,andfamilyhistory[2].Currently,CT coronaryarterycalciumscore(CTCAC)isrecommendedasascreeningmethodfor patientsatriskofcoronaryarterydiseasetohelpguidetreatmentwithstatintherapy[3]. Studiesinasymptomaticpatientswithintermediateriskofcoronaryarterydiseasehave foundthatpositiveCACisoneofthefactorsusedtoconsiderstatintherapyforprimary preventiontopreventplaquerupture[4,5].Fataccumulationinthearterialwallisoften associatedwithcalciumaccumulation;therefore,CACcanhelpassessthepresenceof atherosclerosis[6].AlthoughCTCACisusefulfordeterminingtreatment,itisexpensiveand lessaccessible.Studieshavefoundthatchestradiographmayhelppredictcoronary calcification[7-10]andcerebrovascularcalcification[11]byassessingthecalcifiedaortic knob.Itisevidentthatchestradiographsarewidelyusedandoffersubstantialvaluein screeningduetotheirlowcostandaccessibility. InthepreviousstudybyWooetal[7], thegradingofcalcifiedaorticknobonchestradiographswasdividedintofourlevels:Grade 0(novisiblecalcification),Grade1(smallspotsofcalcificationorasinglethinareaof calcification),Grade2(oneormoreareasofthickcalcification),andGrade3(circular calcificationoftheaorticknob).Ifcalcificationisvisibleatgrade2orhigher,thereisa correlationwiththeCT CACshowingcoronary artery calcification[9, 12].

Thisstudyaimstodeterminethecorrelationbetweencalcifiedaorticknobdetected onchestradiographsandcoronaryarterycalcificationdetectedonCTCACinindividuals withoutdiabetesandfreeofcoronaryarterydisease(CAD).Diabeteswasexcludedfromthestudy populationbecauseitisasignificantriskfactorforCAD,oftenleadingtohigherlikelihoodofcoronary arterycalcification.TheFraminghamheartstudyhasshownthatdiabetesposesparticularlyhigh cardiovascularrisk,oftensurpassingthatofhypertensionorsmoking.Diabetesincreasestheriskof CAD bytwoorthreetimes.Thiselevatedriskmakesdiabetesasignificantfactorforearlyandaggressive cardiovascularinterventions,oftenprioritizingmanagementstrategiesthatincludestatintherapy.The exclusionhelpsmaintainfocusonapopulationwithnoknownCACriskfactor.Thiscouldhelpinutilizing chestradiographsasaguidelineforconsideringstatintherapy.

2.MATERIALANDMETHODS

Studydesignand participants

Thestudyincluded664patientswhounderwentCT-CACbetweenNovember1,2019,and October31,2021.Weselectedparticipantsaged40to75yearswithout knownhistoryofcoronaryarterydisease(CAD)ordiabetes(fastingbloodsugarlevelsunder 126mg/dlwithinpast6months).Atotalof441eligiblepatientswereincludedinthefinal analysis.BothchestradiographandCTcoronarycalciumscore(CAC)assessmentwere conductedwithinasixmonthsinterval.ThestudytookplacefromNovember1,2019,to October31,2021attheCentralChestInstituteofThailand.Thesamplesizewascalculated basedonpriorresearchbyParkHE[13],usingBuderer'sformulawith95%confidence levelandexpectedsensitivity andspecificity of 90%.71

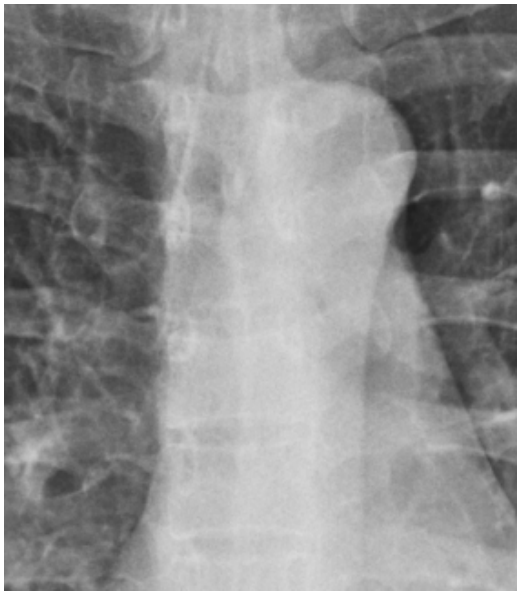
DiagnosticComparison

Standardposterior-anteriorchestradiographswereevaluatedforthepresenceofcalcifiedaortic knob,gradeonascaleof0to3basedoncriteriaestablishedinapriorstudybyWooJS (figure 1).Twoexperienceradiologists,eachwithovertenyearsofpractice,independentlygradedthe radiographswhilebeingblindedtotheCACresultstopreventbias.Theanalysis compared chestradiographsgrades,focusingoncasesgradedas0(novisiblecalcificationoftheaortic

knob)againstthosegraded1-3(indicatingvaryingdegreesofcalcification).Thiswascross-referencedwithCACscoresobtainedfromCTdual-sourceSOMATOMDefinitionFlashscannerand qualifiedfollowingtheAgatstonmethod.ThefocuswasoncaseswithCACscoreof0(nocoronary calcification)versusthosewithascoregreaterthan0(indicatingcoronarycalcification). Statisticalmethodsemployedincludedcalculationsforsensitivity,specificity,positivepredictive value(PPV)andnegativepredictivevalue(NPV)toevaluatedthediagnosticaccuracyof radiographsinpredictingthepresenceofCAC. 76

Figure1:Assessmentofaorticarchcalcificationfromchestradiograph[7]

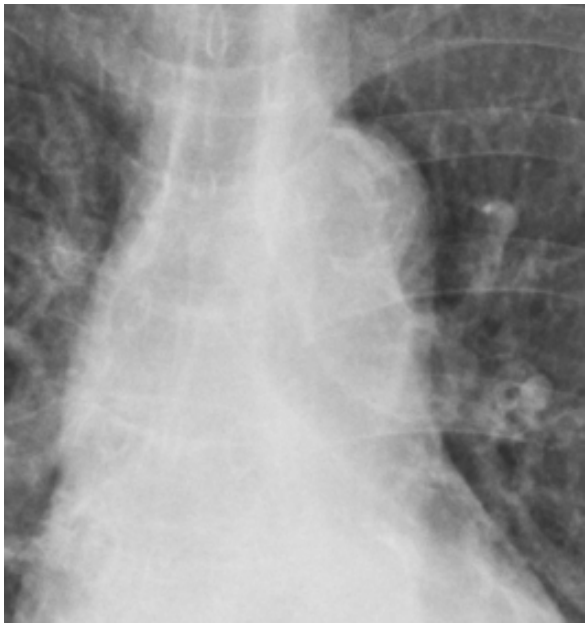
Grade0



Grade1

Grade2

Grade3



- Grade0:Novisiblecalcificationinaorticknob
- Grade1:<50%calcificationinaorticknob

- Grade2:>50%calcificationinaorticknob
- Grade3:circumferentialcalcificationinaorticknob

DataAnalysis

DatawasconductedusingIBMSPSSversion22.Descriptivestatisticsarereportedas percentagesforcategoricalvariablesandasmeanswithstandarddeviationsforcontinuous variablesiftheyfollowanormaldistribution.Inferentialanalysisofcategoricaldatawas performedusingMcNemar'stest.Statisticalsignificancewassetap-valueoflessthan0.05 Thediagnosticperformancemetricsofthechestradiographs,includingsensitivity, specificity,accuracy,positivepredictivevalue(PPV),andnegativepredictivevalue(NPV) werecalculated.

3.RESULTSANDDISCUSSION

RESULTS

Thestudyincluded441individualswith236females(53.5%)and205males(46.5%). Fromtheanalysis,generalcharacteristicsofthesampleweresummarizedbycomparing thosewithand withoutacalcifiedaorticknob onchestradiographs.Therewereslightlymore femalesthanmales(table1),andthemeanagewas66.02yearsforthosewithacalcified aorticknoband57.82yearsforthosewithout(table2).

Table1:Thepopulationbetweenmalesandfemalesinbothgroups

Variable	Male	Female
Total=441	205	236
CXRgrade0	106	117
CXRgrade1-3	99	119

Table2:Theagegroupsofthepopulationwithandwithoutcalcifiedaorticknob

Group	N	Meanage	Standarddeviation	95%confidence interval
CXR grade0	223	57.82	9.09	56.62/59.02
CXR grade1-3	218	66.02	6.66	65.13/66.91

Table3:Diagnosistestaccuracy 163

	CAC>0	CAC=0	Total
CXR-calcifiedaorticknob (grade1-3)	192	120	312
CXR-nocalcifiedaorticknob (grade 0)	26	103	129
Total	218	223	441

Figure2:Thediagnosticperformanceofthepredictingmodel

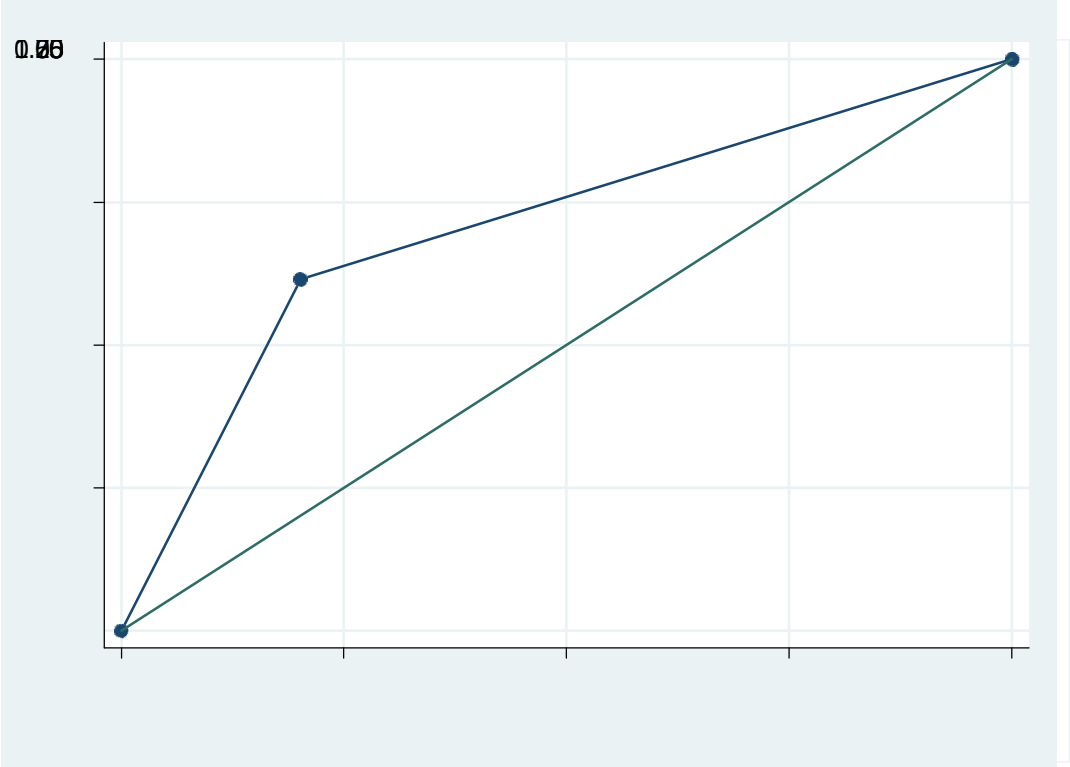


Table4:Resultstatisticofthepredictingmodel

ResultsStatistic	Value	95%CI

Sensitivity	61.54%	55.89%to66.96%
Specificity	79.84%	71.88%to86.39%
PositiveLikelihood Ratio	3.05	2.14to4.35
NegativeLikelihoodRatio	0.48	0.41to0.57
Diseaseprevalence(*)	70.75%	66.26%to74.96%
PositivePredictiveValue(*)	88.07%	83.82%to91.32%
NegativePredictiveValue(*)	46.19%	42.12%to50.31%
Accuracy(*)	66.89%	62.29%to71.27%

(*)Thesevaluesaredependentondiseaseprevalence.

The study reported a sensitivity of 61.54% (95%CI: 55.89 to 66.96%) and specificity of 79.84% (95%CI: 71.88% to 86.39%). While the specificity is reasonably strong, the low sensitivity raises concerns about the potential for undetected CAC in participants. This suggests that a significant proportion of cases with CAC may be missed when relying solelyonthisimaging method.

Thepositivepredictivevalue (PPV) ofthe studywasnotablyhighas88.07 %(95%CI: 83.82%-91.32%).Thisindicatesastronglikelihoodthataparticipantwithacalcifiedaortic knobwouldhavecoronaryarterycalcification.

Conversely,thenegativepredictivevalue(NPV)waslow46.18%(95%CI:42.12%-50.31%).Thissuggeststhatabsenceofcalcifiedaorticknobdoesnotreliableexcluded coronarycalcification.

Discussion:

Coronaryarterycalciumscore(CAC) is increasinglyrecommendedas ascreening methodforpatientsatriskofcoronaryarterydiseasetohelpguidetreatmentdecisions, particularly for statin therapy (3).

AlthoughCACisanaccurateassessmentmethodandusefulfordeterminingtreatment, its relativelyhighcostandlimitedaccessibilitycanbebarrier towidespreadimplementation. In contrast, chest radiographs are widely used and offer substantial value in screening due to their low cost and broad accessibility.

Previous studies have found that chest radiograph may help predict coronary calcificationby assessing the calcified aortic knob. The grading system for calcified aortic knob on chest radiographs was divided into four levels: Grade 0 (no visible calcification) Grade1(smallspotsofcalcificationor<50%calcificationofaorticknob),Grade2(>50%of calcified aortic knob), and Grade 3 (circular calcification of the aortic knob).

Our study's sensitivity and specificity values are similar to those found in Adar et al (12) which have sensitivity, specificity of 68 % and 98 %, respectively, suggesting of comparable diagnostic capability in detecting CAC using chest radiographs for initial screening, although radiographs are less sensitive than CT in smaller calcification. Our study's lower diagnostic accuracy possible due to differences in grading criteria. While Adar et al. focused on higher grades of aortic calcification (grade 2 or above) to predict high coronary calcium scores, our study utilized a different approach. We compared cases with no calcification (grade 0) to those with varying degrees of calcification (grades 1-3) on chest radiographs to determine the presence or absence of coronary artery calcification. This methodological difference allowed us to explore the diagnostic potential of even minimal aortic calcification in predicting CAC, aiming to assess the broader applicability of chest radiography in initial screenings

Ourstudy’shighersensitivitycomparedtoBannasetal(9)meansitmaybetteridentifycases with coronary artery calcification using chest radiographs.

However,thelowerNPVindicatesaweakerabilitytoruleoutCACwhencalcificationisabsent on radiograph. Although the PPV is comparable, the lower NPV suggests that despite catching more cases, our method is less reliable at excluding CAC when no calcification is visible. This could be due to variations in imaging protocols, grading thresholds, or patient demographics.

Comparing our study to Kalsch et al (14). Our study shows lower sensitivity and specificity. The difference could stem from the imaging techniques. While Kalsch et al focusingonthepredictivevalueofaorticcalcificationinassessinglong-termcoronaryrisk.They found that aortic calcification was significantly associated with an increased risk of developing CAC. In contrast, our study is cross-sectional, aiming to assess the immediate association between calcified aortic knobs on chest radiographs and the presence of CAC identified through CT calcium scoring. Rather than tracking progression, we evaluated diagnostic metrics like sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) to determine the effectiveness of chest radiographs as a screening tool for CAC.By comparing cases with different degrees of aortic calcification (grades 0-3) against CAC presence or absence, we provide insights into the potential role of chest radiographs in immediate risk assessment, especially in settings where CT is less accessible.

Our study supports findings from prior studies that demonstrated a significant relationship between aortic calcification and coronary artery calcification. Specifically, our study indicates that the detection of calcified aortic knobs via chest radiographs can be a useful predictor for coronary artery calcification with a positive predictive value of 88.07%. Given the high cost and limited accessibility of CT coronary calcium scoring, using chest radiographs to screen for aortic calcification provides a cost-effective and accessible alternativeforinitialscreening.Thehighspecificity(79.8%)inourstudysuggeststhataortic knob calcification detected on chest radiographs can help identify patients who may benefit from more definitive testing with CT calcium scoring. This has implications for clinical decision-making, particularly in resource-limited settings where CT scans are not widely available.

Conclusion

Inconclusion,usingchestradiographstodetectcalcifiedaorticknobsmaybeusefulin predictingcoronaryarterycalcification,especiallyincaseswhereacalcifiedaorticknobis detected,asthereisahighprobabilityofconcurrentcoronaryarterycalcification.However, incaseswherenoaorticcalcificationisdetectedonchestradiographs,itdoesnotcorrelate withthepresenceorabsenceofcoronarycalcification.

Limitations

Althoughthe specificityandpositive predictive valueare high,thesensitivitywas found to be relativelylowat61.5%.Thisindicatesthatasignificantproportionofpatientswithcoronary calcificationmaynotbeidentifiedsolelythroughchestradiographs.Therefore,theabsence ofaorticcalcificationdoesnotruleoutcoronaryarterydisease.Thenegativepredictivevalue (46.18%)alsosuggeststhattheabsenceofcalcifiedaorticknobsisnotareliableindicatorof theabsenceofCAC.LowsensitivityandNPVhavesignificantimplicationinclinical settings, especially in the context of screening for CAC which highlights the need for additionalriskfactorassessmentsin patients without visible aortic calcification. The potential reasons could be from the limitation of chest radiograph which have lowersensitivity indetectingearly orless extensive calcification, as their resolution may not capture smallerdeposits of calcium that could indicate early stage CAC.

Beneficialandlimitedscenarios

In healthcare settings with limited access to advanced imaging technologies, chest radiographs are a practical tool for initial CAC screening due to their low cost and wide availability. Patients in rural of low resource areas, where access to CT scans is limited, may still benefit for chest radiographs as a preliminary step to identify those a higher risk who need further investigation. For patients with multiple risk factors for CAD, the presence of calcified aortic knob on chest radiograph can indicate a higher likelihood of CAC. This can prompt clinicians to prioritize these patient for further testing or initiating statin therapy.Fow the individuals at lower cardiovascular risk, the limited sensitivity of chest radiograph makes them less reliable for CAC screening. In these cases, a non-calcifiedaortic knob does not reliably rule of the presence of CAC, and the test low NPV may lead toa false sense of security.

PotentialAreasforFutureResearch

Future studies should focus on larger, prospective cohorts to validate the utility of chest radiographs in predicting CAC and coronary artery disease (CAD). Long-term follow-up studies could help determine whether the progression of aortic calcification, as seen onserial chest radiographs, corresponds to the development of coronary artery disease. Additional research could explore whether incorporating other risk factors, such as age, gender, and comorbidities, alongside chest radiographic findings could enhance the predictive value of CAC detection.

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COMPETINGINTERESTS

Authorshavedeclaredthatnocompetinginterests exist.

Consent

As per international standards or university standards, patient(s) written consent has been collected and preserved by the author(s).

ETHICALAPPROVAL

This study has received ethical approval from the Thoracic Disease Institute, Department of Medical Services, reference number COA 001/2565.

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UNDERPEERREVIEW