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Coronary artery calcium burden and coronary CT angiography evaluability in patients undergoing hemodialysis

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Abstract

Purpose

To investigate the association between coronary artery calcium (CAC) burden and coronary computed tomography angiography (CCTA) evaluability in patients undergoing maintenance hemodialysis.

Methods

This retrospective single-center study included 65 patients who underwent CAC scoring and CCTA. The right coronary artery, left anterior descending artery, and left circumflex artery were independently assessed by two blinded observers using a four-point image-quality scale. Arteries scored 3 or 4 were considered evaluable, and limited evaluability was defined as at least one non-evaluable major coronary artery. Associations were assessed using Spearman correlation, established CAC-score categories, receiver operating characteristic analysis with bootstrap confidence intervals, and multivariable logistic regression.

Results

The median total CAC score was 671 (interquartile range, 251–1,774). All three major coronary arteries were evaluable in 26 patients (40.0%), whereas 39 (60.0%) had limited evaluability. Median CAC scores increased stepwise as the number of evaluable arteries decreased from three to zero (162.5, 677.0, 1,663.0, and 2,180.0; Spearman's $\rho = -0.608$, $P < 0.001$). CAC score ≥ 400 was associated with limited evaluability (odds ratio, 6.30; 95% CI, 2.10–18.90; $P < 0.001$). The AUC was 0.831 (bootstrap 95% CI, 0.723–0.925). After adjustment for age and sex, each approximate doubling of CAC score was associated with higher odds of limited evaluability (adjusted odds ratio, 2.01; 95% CI, 1.40–2.88; $P < 0.001$).

Conclusion

Increasing CAC burden was associated with a progressive reduction in CCTA evaluability in patients undergoing hemodialysis. CAC scoring may help anticipate technical limitations of CCTA and inform coronary imaging strategy.

Introduction

Cardiovascular disease is a major cause of morbidity and mortality in patients undergoing hemodialysis. In addition to conventional atherosclerotic risk factors, abnormalities in mineral metabolism, chronic inflammation, and dialysis-related factors contribute to accelerated vascular calcification in this population [1, 2]. Consequently, coronary artery calcification is highly prevalent and often extensive in patients undergoing hemodialysis [3], and a high coronary artery calcium burden is associated with adverse cardiovascular outcomes in patients with end-stage kidney disease [4].

Coronary computed tomography angiography (CCTA) provides noninvasive assessment of coronary artery disease and may remain clinically feasible in patients undergoing dialysis despite substantial coronary calcification [5]. Nevertheless, extensive calcification produces blooming and beam-hardening artifacts that can obscure the contrast-enhanced coronary lumen, resulting in overestimation of stenosis or non-evaluable coronary segments [6, 7]. Previous studies have largely focused on the diagnostic performance or overall feasibility of CCTA in patients with advanced kidney disease or on the association between coronary calcium burden and coronary stenosis. Less is known about whether increasing total coronary artery calcium burden is accompanied by a progressive loss of evaluable major coronary arteries in patients undergoing hemodialysis.

Characterizing this relationship may be clinically relevant because complete evaluation of the major coronary arteries is particularly challenging in this population and may influence the expected diagnostic utility of CCTA. Therefore, this study aimed to investigate the association between total coronary artery calcium score and the number of evaluable major coronary arteries on CCTA in patients undergoing maintenance hemodialysis. We hypothesized that increasing coronary artery calcium burden would be associated with a progressive reduction in the number of evaluable major coronary arteries and a higher likelihood of limited CCTA evaluability.

Materials and methods

Study design and patients

This retrospective, single-center study was approved by the institutional review board, and the requirement for written informed consent was waived. A total of 72 consecutive patients undergoing maintenance hemodialysis who underwent both coronary CT angiography (CCTA) and coronary artery calcium scoring between April 2019 and April 2021 were retrospectively identified. Seven patients with a history of coronary artery bypass grafting (CABG) were excluded because the present study focused on the evaluability of native coronary arteries. Consequently, 65 patients were included in the final analysis. Clinical data, including age, sex, body mass index, duration of hemodialysis, heart rate at the time of CT examination, diabetes mellitus, hypertension, dyslipidemia, and smoking history, were obtained from the medical records.

CT acquisition

CT examinations were performed using a 64-detector-row CT scanner (LightSpeed VCT, GE Healthcare, USA). Coronary artery calcium scoring was performed using a non-contrast, electrocardiographically synchronized acquisition. The acquisition parameters were as follows: tube voltage, 120 kVp; tube current, 200–700 mA; rotation time, 0.35 s; detector collimation, 64 × 0.625 mm; and reconstructed slice thickness, 2.5 mm.

CCTA was subsequently performed after intravenous administration of iodinated contrast material (Iomeron 350, iomeprol 350 mgI/mL). The contrast material volume was determined according to body

weight at 0.8 mL/kg and was administered over a fixed injection duration of 12 s. The CCTA acquisition parameters were as follows: tube voltage, 120 kVp; tube current, 200–700 mA; rotation time, 0.35 s; detector collimation, 64 × 0.625 mm; and reconstructed slice thickness and interval, 0.625 and 0.625 mm, respectively. Scan timing was determined using a bolus-tracking technique (Real Prep), with the region of interest placed in the ascending aorta and a trigger threshold of 150 HU. Images were reconstructed using adaptive statistical iterative reconstruction (ASiR). Heart-rate control was performed using intravenous landiolol hydrochloride (Corebeta) in patients with a heart rate of ≥ 65 beats/min.

Coronary artery calcium scoring

Coronary artery calcification was quantified using commercially available calcium-scoring software on an Advantage Workstation version 4.8 (GE Healthcare, USA). Calcified lesions were defined as areas with an attenuation of at least 130 HU and an area of at least 1.0 mm^2. Coronary artery calcium scores were calculated according to the Agatston method [8] for the right coronary artery, left main coronary artery, left anterior descending artery, and left circumflex artery. The scores from all coronary arteries were summed to obtain the total coronary artery calcium score. For descriptive analyses, severe and very severe coronary calcification were defined as total calcium scores of ≥ 400 and ≥ 1,000, respectively.

Assessment of coronary artery evaluability

CCTA images were independently assessed by two observers: a radiologic technologist with 28 years of experience in cardiovascular CT and a cardiologist. Both observers were blinded to the patients' clinical information and coronary artery calcium scores. Disagreements between the two observers were resolved by consensus, and the consensus assessment was used for the final analysis. The three major coronary arteries—the right coronary artery (RCA), left anterior descending artery (LAD), and left circumflex artery (LCX)—were evaluated separately. Image quality was graded using a four-point scale: 1, non-diagnostic, severe artifacts preventing evaluation of the coronary lumen; 2, poor, substantial artifacts or blurring markedly limiting reliable evaluation of the coronary lumen; 3, good, minor artifacts or mild blurring but with reliable evaluation of the coronary lumen; and 4, excellent, no relevant artifacts with clear delineation of the coronary lumen. Arteries with image-quality scores of 3 or 4 were considered evaluable, whereas those with scores of 1 or 2 were considered non-evaluable. An artery was considered non-evaluable when severe coronary calcification, motion artifacts, inadequate contrast enhancement, or other artifacts prevented reliable assessment of the coronary lumen. The number of evaluable major coronary arteries was recorded for each patient and ranged from 0 to 3. Patients in whom all three major coronary arteries were evaluable were classified as the fully evaluable group, whereas those with at least one non-evaluable major coronary artery were classified as the limited-evaluability group. Limited evaluability was defined as the primary outcome.

Statistical analysis

Continuous variables were assessed for distribution and are presented as the median and interquartile range (IQR). Categorical variables are presented as numbers and percentages. Interobserver agreement

for the binary classification of coronary artery evaluability (evaluable vs. non-evaluable) was assessed using Cohen's kappa coefficient. The association between the total coronary artery calcium score and the number of evaluable major coronary arteries was assessed using Spearman's rank correlation coefficient. Total calcium scores were compared between patients with fully evaluable and limited-evaluability CCTA using the Mann–Whitney U test. The associations of clinically established calcium-score categories (≥ 400 and ≥ 1,000) with limited evaluability were assessed using Fisher's exact test, and odds ratios (ORs) with 95% confidence intervals (CIs) were calculated from the corresponding 2 × 2 contingency tables. Receiver operating characteristic (ROC) analysis was performed to evaluate the ability of the total calcium score to discriminate between fully evaluable and limited-evaluability CCTA. The area under the ROC curve (AUC) and its 95% CI were estimated using 5,000 bootstrap resamples. Because the cutoff was derived and evaluated in the same study population, the value maximizing the Youden index was considered exploratory. Sensitivity and specificity at this exploratory cutoff were calculated. Multivariable logistic regression analysis was performed with limited evaluability as the dependent variable. Because the calcium score had a markedly right-skewed distribution, it was transformed as $\log_2(\text{score} + 1)$; accordingly, the corresponding OR represents the change in the odds of limited evaluability associated with an approximate doubling of the calcium score. Age and sex were included as covariates. The number of covariates was restricted because of the limited sample size to reduce the risk of model overfitting.

All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using Python version 3.14.7 with SciPy version 1.18.1, scikit-learn version 1.9.0, and statsmodels version 0.15.0.

Results

Patient characteristics

A total of 65 patients undergoing maintenance hemodialysis were included in the analysis. The median age was 66 years (interquartile range [IQR], 60–73 years), and 39 patients (60.0%) were men. The median body mass index was 23.1 kg/m² (IQR, 21.0–24.6 kg/m²), the median duration of hemodialysis was 6.0 years (IQR, 1.5–11.0 years), and the median heart rate at CT examination was 62 beats/min (IQR, 57–69 beats/min). Diabetes mellitus, hypertension, dyslipidemia, and a history of smoking were present in 41 of 63 (65.1%), 32 of 63 (50.8%), 19 of 63 (30.2%), and 9 of 63 patients (14.3%), respectively. The median total coronary artery calcium score was 671 (IQR, 251–1,774; range, 0–7,637). A calcium score of ≥ 400 was observed in 39 patients (60.0%), and a score of ≥ 1,000 was observed in 23 patients (35.4%) (Table 1).

Table 1
Patient characteristics

Characteristic	Value
Number of patients	65
Age, years	66 (60–73)
Male sex	39 (60.0%)
Body mass index, kg/m²	23.1 (21.0–24.6)
Duration of hemodialysis, years	6.0 (1.5–11.0)
Heart rate, beats/min	62 (57–69)
Diabetes mellitus	41/63 (65.1%)
Hypertension	32/63 (50.8%)
Dyslipidemia	19/63 (30.2%)
History of smoking	9/63 (14.3%)
Total coronary artery calcium score	671 (251–1,774)
Calcium score ≥ 400	39 (60.0%)
Calcium score ≥ 1,000	23 (35.4%)
Data are presented as the median (interquartile range) or number (percentage).	

Evaluability of major coronary arteries

Interobserver agreement for coronary artery evaluability was substantial (Cohen's κ = 0.75). Disagreements between the two observers were resolved by consensus, and the consensus assessment was used for the final analysis. All three major native coronary arteries were evaluable on CCTA in 26 patients (40.0%). Two arteries were evaluable in 12 patients (18.5%), one artery in 13 patients (20.0%), and none of the three arteries in 14 patients (21.5%). Thus, at least one major coronary artery was non-evaluable in 39 patients (60.0%), who were classified as having limited evaluability.

Association between coronary artery calcium score and CCTA evaluability

The total coronary artery calcium score was significantly and inversely correlated with the number of evaluable major coronary arteries (Spearman's ρ = −0.608, P < 0.001). The median total calcium score increased stepwise as the number of evaluable arteries decreased. The median scores were 162.5 (IQR, 15.3–529.5) in patients with three evaluable arteries, 677.0 (IQR, 343.5–951.5) in those with two evaluable arteries, 1,663.0 (IQR, 441.0–3,024.0) in those with one evaluable artery, and 2,180.0 (IQR, 1,411.0–2,951.5) in those with no evaluable arteries (Table 2 and Fig. 1).

Table 2
Total calcium score according to the number of evaluable coronary arteries

Number of evaluable arteries	Number of patients	Total calcium score
3	26	162.5 (15.3–529.5)
2	12	677.0 (343.5–951.5)
1	13	1,663.0 (441.0–3,024.0)
0	14	2,180.0 (1,411.0–2,951.5)
Calcium scores are presented as the median (interquartile range). Spearman's ρ = −0.608, P < 0.001.		

Comparison between fully evaluable and limited-evaluability groups

The median total calcium score was significantly higher in patients with limited evaluability than in those with fully evaluable CCTA (995.0 [IQR, 459.0–2,777.0] vs. 162.5 [IQR, 15.3–529.5], P < 0.001).

Association of severe coronary calcification with limited evaluability

Among 26 patients with a calcium score < 400, 9 (34.6%) had at least one non-evaluable major coronary artery. In contrast, limited evaluability was present in 30 of 39 patients (76.9%) with a calcium score ≥ 400. A calcium score ≥ 400 was significantly associated with limited evaluability (odds ratio [OR], 6.30; 95% confidence interval [CI], 2.10–18.90; P < 0.001). Among 42 patients with a calcium score < 1,000, 20 (47.6%) had limited evaluability, compared with 19 of 23 patients (82.6%) with a calcium score ≥ 1,000. A calcium score ≥ 1,000 was also significantly associated with limited evaluability (OR, 5.23; 95% CI, 1.52–18.00; P = 0.008).

Receiver operating characteristic analysis

Receiver operating characteristic analysis showed good discrimination of the total coronary artery calcium score for identifying patients with limited CCTA evaluability. The area under the curve was 0.831 (bootstrap 95% CI, 0.723–0.925) (Fig. 2). The exploratory cutoff value determined using the Youden index was 671, which yielded a sensitivity of 71.8% and specificity of 80.8%.

Multivariable analysis

In multivariable logistic regression analysis adjusted for age and sex, each approximate doubling of the total coronary artery calcium score was independently associated with increased odds of limited CCTA evaluability (adjusted OR, 2.01; 95% CI, 1.40–2.88; P < 0.001). Age was not significantly associated with limited evaluability (adjusted OR per 10-year increase, 1.13; 95% CI, 0.61–2.09; P = 0.693). Male sex, with female sex as the reference category, was associated with lower odds of limited evaluability (adjusted OR, 0.14; 95% CI, 0.02–0.83; P = 0.030) (Table 3).

Table 3
Multivariable logistic regression analysis of limited coronary artery evaluability

Variable	Adjusted odds ratio	95% confidence interval	P value
Total calcium score, per doubling	2.01	1.40–2.88	< 0.001
Age, per 10-year increase	1.13	0.61–2.09	0.693
Male sex (reference: female)	0.14	0.02–0.83	0.030
Limited evaluability was defined as at least one non-evaluable major coronary artery.			

Discussion

The principal finding of this study was that increasing coronary artery calcium burden was associated with a progressive reduction in the number of evaluable major coronary arteries on CCTA in patients undergoing maintenance hemodialysis. The median total calcium score increased from 162.5 in patients with all three major coronary arteries evaluable to 2,180.0 in those with none evaluable, and the calcium score was inversely correlated with the number of evaluable arteries. Furthermore, each approximate doubling of the calcium score was associated with approximately twofold higher odds of limited CCTA evaluability after adjustment for age and sex. These findings suggest that the effect of coronary calcification on CCTA evaluability is not simply dichotomous but is characterized by a graded loss of evaluable coronary arteries with increasing calcium burden.

Extensive coronary calcification is a well-recognized limitation of CCTA. Calcified plaques can produce blooming and beam-hardening artifacts that increase the apparent size of calcification and obscure the adjacent contrast-enhanced lumen [6,7]. These effects may lead to overestimation of coronary stenosis and, when severe, prevent reliable luminal assessment. Previous multicenter studies have demonstrated reduced diagnostic performance of CCTA with increasing coronary calcium burden [9–12]. The present study extends these observations to patients undergoing hemodialysis by demonstrating a graded relationship between total calcium burden and the number of major coronary arteries that remain evaluable.

Previous studies have shown that CCTA can remain clinically feasible in patients undergoing dialysis despite extensive coronary calcification. De Bie et al. reported that more than 90% of coronary segments were interpretable in patients undergoing dialysis despite a high calcium burden [5]. Similarly, Winther et al. demonstrated high sensitivity and negative predictive value for CCTA in kidney transplantation candidates, although specificity was more limited [13]. These findings are not inconsistent with the present results. Rather, our study provides complementary information by showing that high overall or segment-level feasibility does not necessarily imply complete evaluability of all major coronary arteries. As calcium burden increased, the number of major coronary arteries that could be evaluated reliably progressively decreased.

The present findings also complement previous studies examining the relationship between coronary calcification and coronary stenosis in patients with kidney failure. Jansz et al. demonstrated that the relationship between coronary artery calcium burden and coronary stenosis differs between patients with kidney failure and individuals without kidney disease [14]. Thus, a high calcium score in patients with kidney failure does not necessarily correspond to a proportionally greater degree of luminal stenosis. The present study addresses a different but clinically relevant aspect of calcium burden by demonstrating its association with technical evaluability. Distinguishing coronary calcium as a marker of disease burden from its role as a determinant of CCTA evaluability may be particularly important in patients undergoing hemodialysis.

The total calcium score showed good discrimination for identifying patients with limited CCTA evaluability, with an area under the receiver operating characteristic curve of 0.831. Patients with a calcium score ≥ 400 had approximately sixfold higher odds of having at least one non-evaluable major coronary artery than those with a score < 400. A calcium score of approximately 400 has traditionally been used to indicate a high coronary calcium burden [15,16]. The exploratory cutoff of 671 yielded a sensitivity of 71.8% and specificity of 80.8%; however, because this threshold was derived and evaluated in the same cohort, it should not be regarded as a validated clinical cutoff or as a criterion for determining whether CCTA should be performed. Rather, the calcium score may provide an estimate of the anticipated technical difficulty of coronary evaluation.

Importantly, a high calcium score did not invariably result in limited CCTA evaluability. Among patients with calcium scores ≥ 400, 23.1% still had all three major coronary arteries evaluable, whereas 34.6% of patients with calcium scores < 400 had at least one non-evaluable artery. These observations indicate that factors other than calcification, including coronary motion, heart rate, vessel caliber, and contrast enhancement, also influence CCTA evaluability [17–19]. Calcium scoring should therefore not be used as an absolute gatekeeper for CCTA. Instead, it may be considered together with patient-related and acquisition-related factors when anticipating image evaluability and selecting or optimizing a coronary imaging strategy.

Male sex was associated with lower odds of limited evaluability in the adjusted analysis. Because this was not a prespecified hypothesis, the sample size was relatively small, and the confidence interval was wide, this finding should be interpreted cautiously. Larger studies are required to determine whether this association is reproducible or reflects residual confounding or sampling variability.

In patients with a high anticipated risk of limited evaluability, techniques designed to reduce calcification-related artifacts may improve coronary assessment. Subtraction CCTA has been reported to improve evaluation of heavily calcified coronary segments [20,21], whereas photon-counting CT may offer improved spatial resolution and reduced calcium blooming [22]. Such techniques may be particularly relevant in patients undergoing hemodialysis, in whom extensive coronary calcification is common, although their clinical value in this population requires further investigation.

The high prevalence of severe coronary calcification in the present cohort is consistent with previous observations in patients undergoing hemodialysis. Sixty percent of patients had a calcium score ≥ 400 and 35.4% had a score ≥ 1,000. Coronary calcification is common and progressive in patients undergoing dialysis and has been associated with age, diabetes, dialysis duration, abnormalities in mineral metabolism, inflammation, and adverse cardiovascular outcomes [1–4,23,24]. The combination of a high prevalence of coronary artery disease and extensive calcification makes the technical limitations of CCTA particularly relevant in this population.

Several limitations should be acknowledged. First, this was a retrospective, single-center study with a relatively small sample size, which limits the generalizability and precision of the estimates. Second, although coronary artery evaluability was independently assessed by two observers and interobserver agreement was substantial, image-quality assessment remains partly subjective. Third, non-evaluability could result from factors other than severe coronary calcification, including motion artifacts, inadequate contrast enhancement, and other technical factors; therefore, the observed association does not establish coronary calcification as the sole cause of non-evaluability. Fourth, the exploratory cutoff of 671 was derived and evaluated in the same cohort and may therefore overestimate its discriminatory performance; external validation is required before clinical application. Fifth, the multivariable model included only a limited number of covariates to reduce the risk of overfitting, and potentially relevant factors such as heart-rate variability, vessel caliber, calcification distribution, coronary motion, and vascular enhancement were not fully evaluated. Sixth, evaluability was assessed at the level of the three major coronary arteries rather than individual coronary segments, which may have obscured regional differences in the effects of calcification. Seventh, all examinations were performed using a single 64-detector-row CT system and a single reconstruction approach; therefore, the findings may not be directly generalizable to contemporary high-spatial-resolution, subtraction, or photon-counting CT techniques. Finally, the present study evaluated CCTA evaluability rather than diagnostic accuracy against invasive coronary angiography. Accordingly, the findings should not be interpreted as demonstrating that coronary calcium scoring predicts obstructive coronary artery disease.

Conclusion

Increasing coronary artery calcium burden was associated with a progressive reduction in the number of evaluable major coronary arteries on CCTA in patients undergoing maintenance hemodialysis. Total calcium score showed good discrimination for identifying limited evaluability and remained associated with limited evaluability after adjustment for age and sex. Coronary artery calcium scoring may therefore help anticipate the technical limitations of CCTA and inform the selection or optimization of coronary imaging strategies in patients undergoing hemodialysis.

Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose. The authors had full control of the primary data and agree to allow the journal to review the data if requested.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the institutional review board of institution to be confirmed Approval No. (E221226-1).

Consent to participate

The requirement for written informed consent was waived by the institutional review board because of the retrospective nature of the study.

Consent to publish

Not applicable. No identifiable individual participant data are presented.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

Author contributions

TM, TN, YF, TO,TO: Conceptualisation, Methodology, Software

TM, TN: Data curation, Writing- Original Draft preparation

TM, TN: Visualisation, Investigation

TM, TN: Supervision

TM, TN, YF, TO,TO: Software, Validation

TM, TN: Writing- Reviewing and Editing

References

1. Coen G, Pierantozzi A, Spizzichino D, et al. Risk factors of one-year increment of coronary calcifications and survival in hemodialysis patients. BMC Nephrol. 2010;11:10.

2. Wang XR, Yuan L, Shi R, et al. Predictors of coronary artery calcification and its association with cardiovascular events in patients with chronic kidney disease. Ren Fail. 2021;43:1172–1179.
3. Goodman WG, Goldin J, Kuizon BD, et al. Coronary-artery calcification in young adults with end-stage renal disease who are undergoing dialysis. N Engl J Med. 2000;342:1478–1483.
4. Wilkieson TJ, Rahman MO, Gangji AS, et al. Coronary artery calcification, cardiovascular events, and death: a prospective cohort study of incident patients on hemodialysis. Can J Kidney Health Dis. 2015;2:29.
5. de Bie MK, Buiten MS, Gaasbeek A, et al. CT coronary angiography is feasible for the assessment of coronary artery disease in chronic dialysis patients, despite high average calcium scores. PLoS One. 2013;8.
6. Pack JD, Xu M, Wang G, et al. Cardiac CT blooming artifacts: clinical significance, root causes and potential solutions. Vis Comput Ind Biomed Art. 2022;5:29.
7. Kalisz K, Buethe J, Saboo SS, et al. Artifacts at cardiac CT: physics and solutions. Radiographics. 2016;36:2064–2083.
8. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol. 1990;15:827–832.
9. Vavere AL, Arbab-Zadeh A, Rochitte CE, et al. Coronary artery stenoses: accuracy of 64-detector row CT angiography in segments with mild, moderate, or severe calcification—a subanalysis of the CORE-64 trial. Radiology. 2011;261:100–108.
10. Budoff MJ, Dowe D, Jollis JG, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY trial. J Am Coll Cardiol. 2008;52:1724–1732.
11. Meijboom WB, Meijs MFL, Schuijf JD, et al. Diagnostic accuracy of 64-slice computed tomography coronary angiography: a prospective, multicenter, multivendor study. J Am Coll Cardiol. 2008;52:2135–2144.
12. Arbab-Zadeh A, Miller JM, Rochitte CE, et al. Diagnostic accuracy of computed tomography coronary angiography according to pre-test probability of coronary artery disease and severity of coronary arterial calcification. J Am Coll Cardiol. 2012;59:379–387.
13. Winther S, Svensson M, Jørgensen HS, et al. Diagnostic performance of coronary CT angiography and myocardial perfusion imaging in kidney transplantation candidates. JACC Cardiovasc Imaging. 2015;8:553–562.
14. Jansz TT, Go MHY, Hartkamp NS, et al. Coronary artery calcification as a marker for coronary artery stenosis: comparing kidney failure to the general population. Kidney Med. 2021;3:386–394.e1.
15. Hecht HS, Blaha MJ, Kazerooni EA, et al. CAC-DRS: Coronary Artery Calcium Data and Reporting System. An expert consensus document of the Society of Cardiovascular Computed Tomography. J Cardiovasc Comput Tomogr. 2018;12:185–191.

16. Cheong BYC, Wilson JM, Spann SJ, et al. Coronary artery calcium scoring: an evidence-based guide for primary care physicians. J Intern Med. 2021;289:309–324.
17. Abbara S, Blanke P, Maroules CD, et al. SCCT guidelines for the performance and acquisition of coronary computed tomographic angiography. J Cardiovasc Comput Tomogr. 2016;10:435–449.
18. Leschka S, Husmann L, Desbiolles LM, et al. Optimal image reconstruction intervals for non-invasive coronary angiography with 64-slice CT. Eur Radiol. 2006;16:1964–1972.
19. Dewey M, Vavere AL, Arbab-Zadeh A, et al. Patient characteristics as predictors of image quality and diagnostic accuracy of MDCT compared with conventional coronary angiography for detecting coronary artery stenoses: CORE-64 multicenter international trial. AJR Am J Roentgenol. 2010;194:93–102.
20. Fuchs A, Kühl JT, Chen MY, et al. Subtraction CT angiography improves evaluation of significant coronary artery disease in patients with severe calcifications or stents. Eur Radiol. 2018;28:4077–4085.
21. Tanaka R, Yoshioka K, Muranaka K, et al. Improved evaluation of calcified segments on coronary CT angiography: a feasibility study of coronary subtraction CT angiography. Int J Cardiovasc Imaging. 2013;29(Suppl 2):75–82.
22. Rønning M, Sartoretti T, Rossi A, et al. Photon-counting CT versus energy-integrating detector CT for coronary artery imaging: a systematic review. Eur Radiol. 2025.
23. Nitta K, Akiba T, Uchida K, et al. Assessment of coronary artery calcification in hemodialysis patients using multi-detector spiral CT scan. Hypertens Res. 2004;27:527–533.
24. Daniel WT, Weber C, Bailey JA, et al. Prospective analysis of coronary calcium in patients on dialysis. J Surg Res. 2013;185:498–503.

Figures

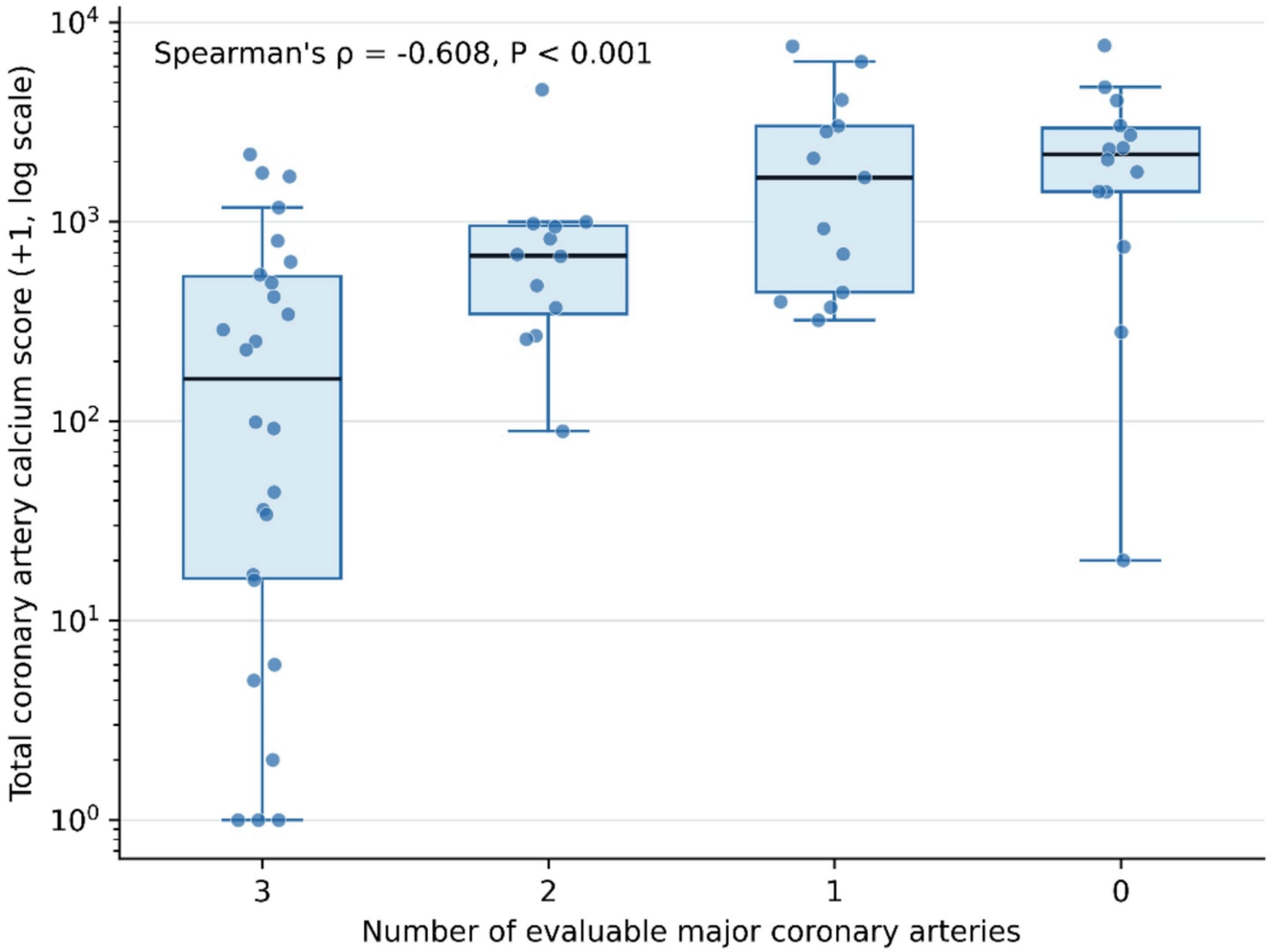


Figure 1

Total coronary artery calcium scores according to the number of evaluable major coronary arteries. Boxes indicate the interquartile range, horizontal lines indicate the median, and dots represent individual patients. The vertical axis is logarithmic. The calcium score was inversely correlated with the number of evaluable arteries (Spearman's ρ = −0.608, P < 0.001).

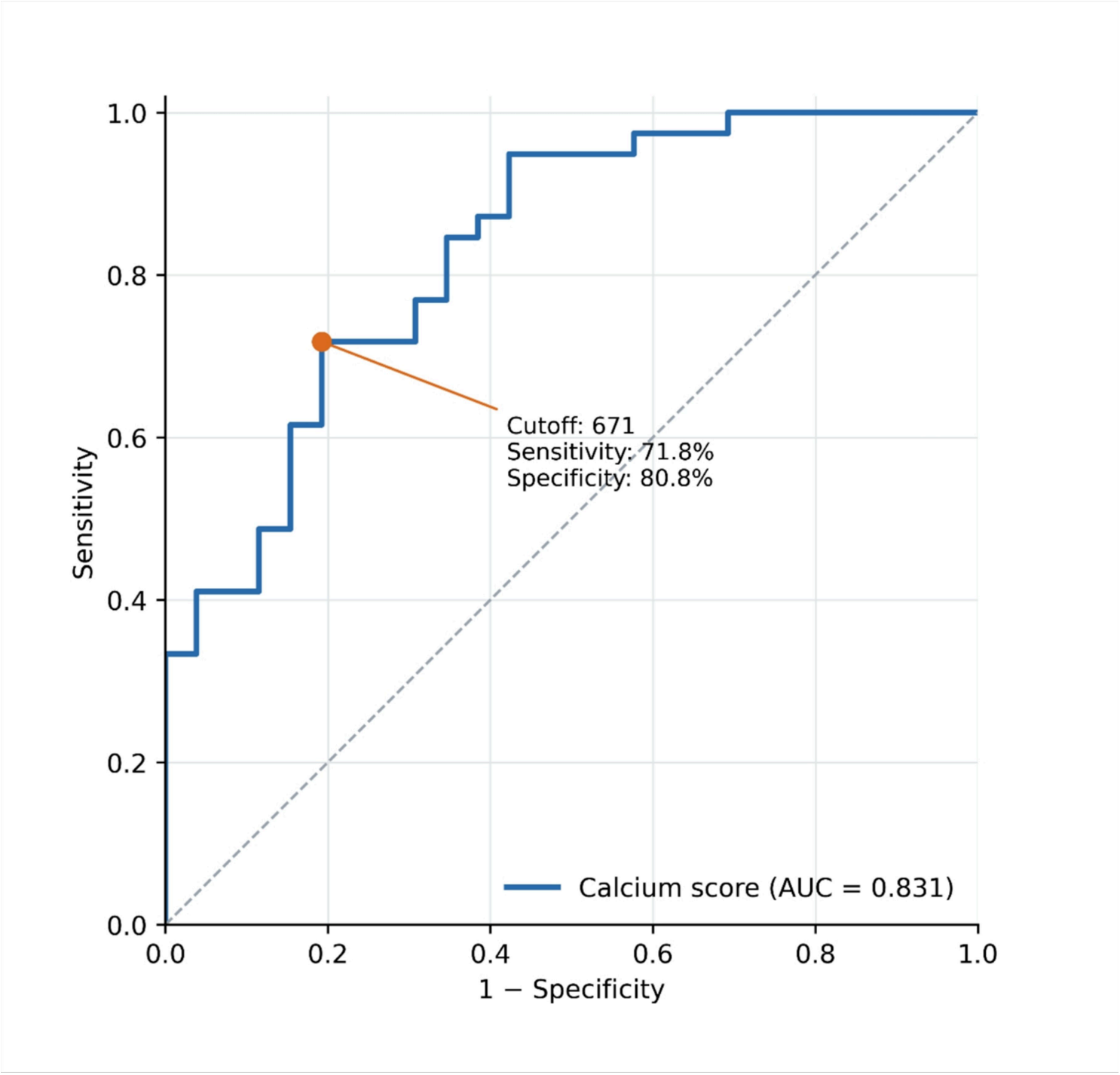


Figure 2

Receiver operating characteristic curve for identifying limited coronary artery evaluability. The area under the curve was 0.831 (bootstrap 95% confidence interval, 0.723–0.925). The exploratory cutoff value of 671 yielded a sensitivity of 71.8% and specificity of 80.8%.