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The diagnostic accuracy and outcomes after coronary computed tomography angiography vs. conventional functional testing in patients with stable angina pectoris: a systematic review and meta-analysis

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Aims To systematically review and perform a meta-analysis of the diagnostic accuracy and post-test outcomes of conventional exercise electrocardiography (XECG) and single-photon emission computed tomography (SPECT) compared with coronary computed tomography angiography (coronary CTA) in patients suspected of stable coronary artery disease (CAD).

Methods and results We systematically searched for studies published from January 2002 to February 2013 examining the diagnostic accuracy (defined as at least ≥50% luminal obstruction on invasive coronary angiography) and outcomes of coronary CTA (≥16 slice) in comparison with XECG and SPECT. The search revealed 11 eligible studies ($N = 1575$) comparing the diagnostic accuracy and 7 studies ($N = 216.603$) the outcomes of coronary CTA vs. XECG or/and SPECT. The per-patient sensitivity [95% confidence interval (95% CI)] to identify significant CAD was 98% (93–99%) for coronary CTA vs. 67% (54–78%) ($P < 0.001$) for XECG and 99% (96–100%) vs. 73% (59–83%) ($P = 0.001$) for SPECT. The specificity (95% CI) of coronary CTA was 82% (63–93%) vs. 46% (30–64%) ($P < 0.001$) for XECG and 71% (60–80%) vs. 48% (31–64%) ($P = 0.14$) for SPECT. The odds ratio (OR) of downstream test utilization (DTU) for coronary CTA vs. XECG/SPECT was 1.38 (1.33–1.43, $P < 0.001$), for revascularization 2.63 (2.50–2.77, $P < 0.001$), for non-fatal myocardial infarction 0.53 (0.39–0.72, $P < 0.001$), and for all-cause mortality 1.01 (0.87–1.18, $P = 0.87$).

Conclusion The up-front diagnostic performance of coronary CTA is higher than of XECG and SPECT. When compared with XECG/SPECT testing, coronary CTA testing is associated with increased DTU and coronary revascularization.

Keywords Meta-analysis • Non-invasive diagnostic testing • Coronary computed tomography angiography • Exercise electrocardiography • single-photon emission computed tomography

Introduction

The role of non-invasive testing in the management of patients with suspected coronary artery disease (CAD) has gained increasing attention over the past decade. Particularly in patients with a low-to-intermediate pre-test likelihood of CAD, non-invasive modalities play an important role in detecting CAD, provide prognostic information, and guide therapy. Traditionally, functional testing (FTs) such as exercise electrocardiography (XECG) and myocardial perfusion imaging (MPI) with gated single-photon emission

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computed tomography (SPECT) have been used as clinical gatekeepers prior to invasive coronary angiography (ICA) in patients with stable CAD. Coronary computed tomography angiography (coronary CTA) has emerged as a non-invasive alternative method with high diagnostic performance when compared with ICA.[1,2] Moreover, several studies have demonstrated that coronary CTA provides prognostic information in patients suspected of stable CAD.[3,4] However, the introduction of coronary CTA as a frontline diagnostic test in patients suspected of stable CAD has been questioned as coronary CTA is an anatomical imaging modality and thus may identify more patients with CAD when compared with FT. It has been proposed that as a result, coronary CTA may lead to increased downstream test utilization of diagnostic procedures (DTU) and revascularization of non-ischemic CAD.[5] Currently, there is an ongoing debate regarding the diagnostic accuracy and outcomes after coronary CTA-based evaluation when compared with other methods, but the results of existing studies have not been systematically reviewed. Therefore, we conducted a systematic literature review and meta-analysis to evaluate both the diagnostic accuracy and post-test outcomes of coronary CTA when compared with XECG and SPECT in patients suspected of stable CAD.

Methods

Literature search

The electronic databases such as PubMed, EMBASE, and Cochrane were searched to find primary references, and the bibliographies of selected articles and relevant reviews were screened for potentially suitable references. The following search terms were used: computed tomography, angiography, coronary artery, exercise, stress, ECG, MPI, and SPECT. The search was restricted to literature published between January 2002 and February 2013.

Study eligibility

Two types of comparative studies were included. First, studies that examined the diagnostic accuracy of coronary CTA when compared with FT in patients suspected of stable CAD were assessed. We included a study if: (i) the diagnostic accuracy of coronary CTA was compared with XECG and/or SPECT (with ICA as a reference standard) and the results were reported so that a 2 × 2 table of results could be constructed. (ii) Significant coronary stenosis was defined as at least ≥50% luminal obstruction on ICA. Secondly, studies that evaluated the post-test outcomes defined as all-cause mortality, non-fatal myocardial infarction (MI), DTU (ICA, coronary CTA, SPECT, or XECG), and revascularization after coronary CTA vs. XECG and/or SPECT in patients with stable angina were evaluated. We included both randomized controlled trials and observational studies. Studies were considered eligible for both patients with and without previously known CAD. Studies that did not fully report relevant data, and studies using CT systems older than 16-slice CT, were excluded.

Data extraction

Three authors (L.H.N., N.O., and J,A,) independently extracted data and discrepancies were resolved by consensus and by the adjudicating author (J.A.). Methodological quality of the selected studies was assessed by the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2)[6] and the Newcastle Ottawa Scale (NOS).[7]

Statistical analysis

Analyses performed to compare the accuracy of coronary CTA, XECG, and SPECT with that of ICA incorporated sensitivity, specificity, negative predictive value, positive predictive value, likelihood ratios, and diagnostic odds ratios (ORs). The pooled diagnostic data are presented in summary receiver operating characteristic (SROC) curves. The differences between sensitivity and specificity were meta-analysed using ORs. Outcome analyses were performed by pooling events from each study to calculate OR and its *P*-value. All data were analysed by the DerSimonian–Laird random-effects model in case of heterogeneity and by Mantel–Haenzel fixed-effects model in case of homogeneity. To retain weights of the large-size studies, it was more relevant to analyse the data in the fixed-effects model. The homogeneity between studies was tested by the χ^2 test. The I^2 index was used to test study variation attributed to heterogeneity. Statistical heterogeneity was defined as $I^2 > 20\%$. All *P*-values <0.05 were considered significant. Analyses were performed using STATA version 12 MP (STATA Corporation, Lakeway Drive, College Station, TX, USA).

Results

Search results

The search strategy yielded 629 citations after duplications were removed (*Figure 1*). Of these, 595 were excluded by title or abstract, and 34 studies were retrieved for detailed evaluation. Thirteen studies were excluded as they did not provide sufficient data. Four studies were excluded as they used acute chest pain patients. This left 17 studies that met the inclusion criteria and were included in the analyses.

Study characteristics

Seven studies[8–14] of 1349 patients [weighted mean age = 58 ± 10 years, male = 803/1349 (59.5%)] compared the diagnostic accuracy of coronary CTA with XECG (*Table 1*). In two studies, ICA was clinically driven and not performed in all patients.[10,11] Five studies of 2884 patients [weighted mean age = 62 ± 10 years, male = 1788/2884 (62%)] compared SPECT with coronary CTA.[14–18] In three studies, ICA was clinically driven.[15,16,18]

Seven non-randomized studies[18,19–24] of 216 603 patients assessed the outcomes following coronary CTA vs. FT [weighted mean age = 73 ± 6 years, male = 127 796 (59%)] with a mean follow-up period of 20 months (*Table 2*). The higher weighted mean age was due to the large weight of the study by Shreibati *et al.*[20]

Diagnostic accuracy of coronary CTA vs. XECG and SPECT

The sensitivity of CCTA vs. XECG and SPECT was 98% [95% confidence interval (95% CI) 93–99%] vs. 67% (95% CI 54–78%) ($P <$ 0.001) and 99% (95% CI 96–100%) vs. 73% (95% CI 59–83%) ($P = 0.001$), respectively. The specificity of CCTA was 82% (95% CI 63–93%) vs. 46% (95% CI 30–64%) ($P < 0.001$) for XECG, and 71% (95% CI 60–80%) vs. 48% (95% CI 31–64%) ($P = 0.14$) for SPECT. The meta-analysed studies comparing coronary CTA and SPECT were homogeneous ($P = 0.86$, $I^2 = 0\%$). The studies comparing the sensitivity of coronary CTA with XECG were homogeneous ($P = 0.68$, $I^2 = 0\%$), whereas for specificity, analysis was significantly heterogeneous ($P = 0.0001$, $I^2 = 81\%$). The diagnostic

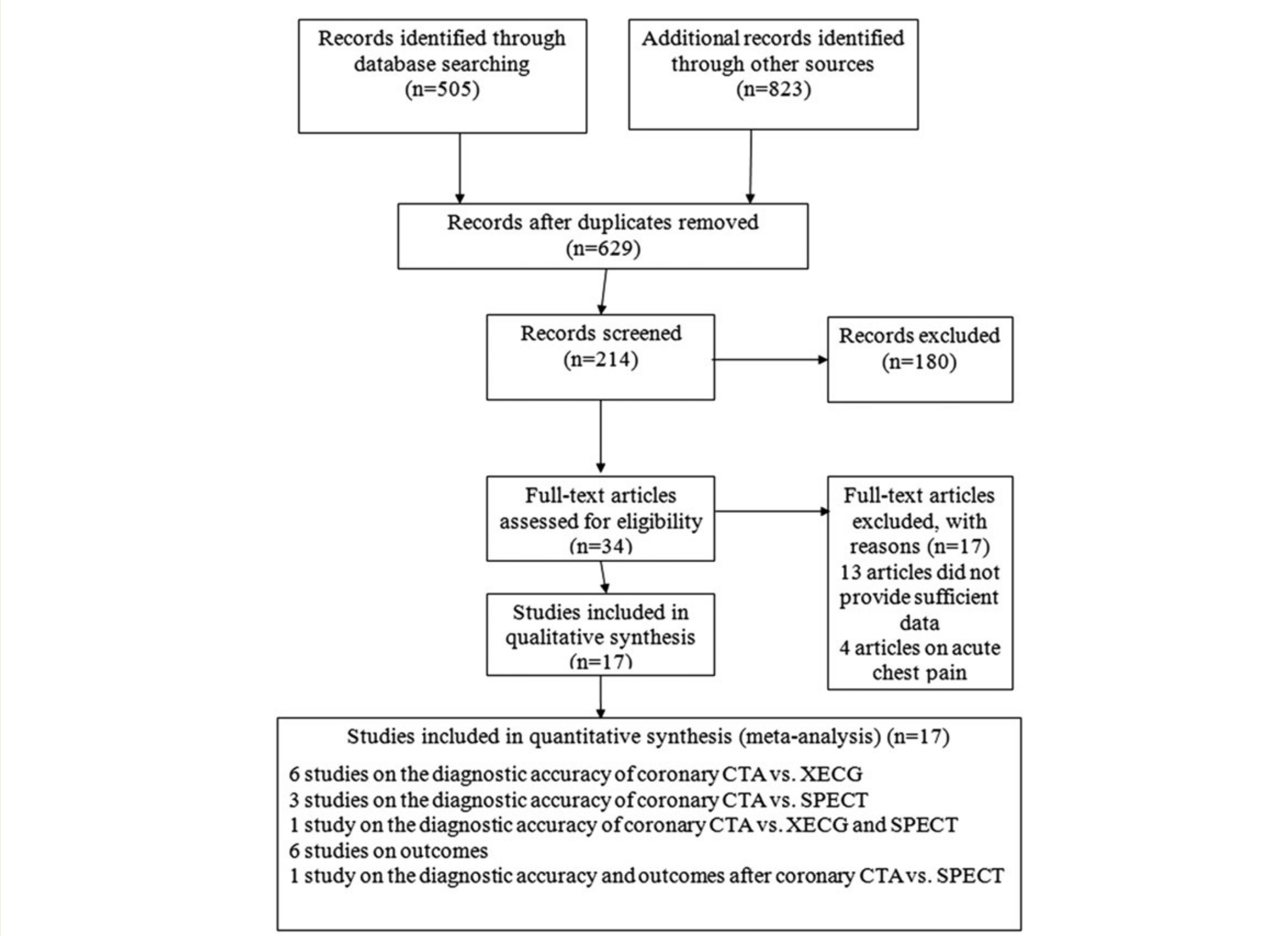

Figure 1: Flow chart of the searching process. Coronary CTA, coronary computed tomography angiography; SPECT, single-photon emission computed tomography; XECG, exercise electrocardiography.

performance of the tests is illustrated by SROC graphs (*Figure 2A* and *B*). A sub-analysis of the studies using conclusive results[8,10,11,15] or an intention-to-diagnose approach[9,12,13] influenced the diagnostic accuracy estimates (*Table 3*). To diminish the likely influence of verification bias, we did the analyses without the studies that performed ICA in subgroups of patients, and coronary CTA compared with ICA showed maintained significantly higher sensitivity, specificity, and diagnostic odds ratio (*Table 3*).

Results of outcome analyses

The pooled incidences of downstream testing were 24.4% after coronary CTA and 18.5% after FT with a pooled OR of 1.38 (95% CI 1.33–1.43, $P = 0.0001$). The included studies were heterogeneous ($P = 0.0001$, $I^2 = 99\%$). A subgroup analysis differentiating between XECG and SPECT did not significantly change the latter outcome (*Figure 3*). An analysis of downstream use of ICA alone showed that the incidence of ICA was 18% in the coronary CTA cohort vs. 11% in the FT cohort with an OR of 2.25 (95% CI 2.17–2.34, $P < 0.0001$) (*Figure 4*). There was evidence of significant statistical heterogeneity ($P = 0.0001$, $I^2 = 98\%$). A sub-analysis excluding the large-size study by Shreibati *et al.*[20] showed a significantly more frequent use of any downstream testing after coronary CTA compared with FT with an OR of 1.18 (95% CI 1.05–1.32, $P = 0.004$), but use of downstream ICA alone was not significantly different with an OR of 0.90 (95% CI 0.80–1.30, $P = 0.13$).

The pooled OR comparing the incidences of revascularization was significantly higher after coronary CTA than after FT with an OR of 2.63 (95% CI 2.50–2.77, $P < 0.0001$) (*Figure 5*). The combined studies were heterogeneous ($P = 0.0001$, $I^2 = 89\%$). A sub-analysis by the type of FT (XECG or SPECT) did not significantly alter the outcome (*Figure 5*). Excluding the study by Shreibati *et al.*[20] did change the overall result with an OR of 1.47 (95% CI 1.19–1.82, $P < 0.0001$).

Four studies[19–22] that reported incidences of MI showed significantly lower MI in favour of coronary CTA with an OR of 0.53 (95% CI 0.39–0.72, $P < 0.001$) (*Figure 6*). The included studies were homogeneous ($P = 0.52$, $I^2 = 0\%$). A sub-analysis that excluded the large-size study by Shreibati *et al.*[20] showed an OR of 0.64 (95% CI 0.31–1.32, $P = 0.23$). Three studies that reported all-cause mortality[19,20,22] showed no significant difference in total mortality between coronary CTA compared with FT with an OR of 1.01 (95% CI 0.87–1.18, $P = 0.87$).

Table 1 Characteristics of the studies that examined the diagnostic accuracy of coronary CTA vs. functional testing

Author [references]	Total/analysed populations	Mean age ± SD (years)	No. of men (%)	Pre-test probability of CAD	Type of stress test	CT imaging technique	Sensitivity (%) coronary CTA vs. FT	Specificity (%) coronary CTA vs. FT
Mollet *et al.*[8]	62/62	60 ± 9	45 (72.5)	–	XECG	16-slice scanner, retrospective gating	100 vs. 78	87 vs. 67
Dewey *et al.*[9]	80/80	63 ± 9	58 (74)	Intermediate–high (mean 75%)[a]	XECG	16-slice scanner	91 vs. 73	83 vs. 31
Nieman *et al.*[10]	471/98	56 ± 10	244 (52)	Low–intermediate (mean 52%)[b]	XECG	Dual-source CT, prospective gating	96 vs. 82	37 vs. 46
Pundziute *et al.*[11]	201/63	56 ± 11	100 (50)	–	XECG	64-slice scanner, prospective gating	91 vs. 34	75 vs. 82
Øvrehus *et al.*[12]	100/97	61 ± 9	50 (50)	Intermediate (55%)–high (35%)[b]	XECG	64-slice scanner and dual-source CT	96 vs. 71	84 vs. 38
Maffei *et al.*[13]	177/177	54 ± 8	88 (50)	Low (15%)–intermediate (85%)[b]	XECG	64-slice scanner, retrospective gating	100 vs. 46	99 vs. 17
Weustink *et al.*[14]	376/334/61	60 ± 10	254 (68)	Low-intermediate (mean 61%)[b]	XECG and SPECT (technetium-99m sestamibi)	64-slice scanner and dual-source CT	99 vs. 72 (XECG) 98 vs. 89 (SPECT)	71 vs. 57 (XECG) 82 vs. 76 (SPECT)
Schuijf *et al.*[15]	114/58	63 ± 10	64 (66)	Intermediate (85%)–high (9%)[b]	SPECT (technetium-99m sestamibi/tetrofosmin)	16- and 64-slice scanner, retrospective gating	100 vs. 59	81 vs. 48
Ravipati *et al.*[16]	145/47	67 ± 10	86 (59)	–	SPECT (technetium-99m sestamibi)	64-slice scanner, retrospective gating	100 vs. 69	73 vs. 36
Hamirani *et al.*[17]	122/122	66 ± 11	94 (77)	–	SPECT (technetium-99m sestamibi)	64-slice scanner, prospective and retrospective gating	99 vs. 56	74 vs. 39
Tandon *et al.*[18]	2442/254	58 ± 10	1221 (50)	Intermediate (score 10.7)[c]	SPECT (technetium-99m tetrofosmin)	64-slice scanner, retrospective gating	97 vs. 82	54 vs. 32

Coronary CTA, coronary computed tomography angiography; FT, functional testing; SPECT, single-photon emission tomography; SD, standard deviation; XECG, exercise electrocardiography; CAD, coronary artery disease.
[a]Prior risk model.
[b]Diamond–Forrester risk algorithm.
[c]Morise risk model.

Table 2 Characteristics of studies examining the outcomes after coronary CTA vs. functional testing

Author [references]	Study population	Patient no. coronary CTA vs. FT	Mean age ± SD (years)	Male (%)	Type of functional testing	CT imaging technique	Mean follow-up (months)	MI	ICA *n* (%) coronary CTA vs. FT	Any DTU *n* (%) coronary CTA vs. FT	Revascularization *n* (%) coronary CTA vs. FT
Nielsen *et al.*, 2013[19]	Retrospective study, patients without known CAD	251 vs. 247	56 ± 11	52	XECG	Dual-source CT	12	0 vs. 3 (1.2)	44 (18) vs. 56 (23)	55 (22) vs. 89 (36)	15 (6) vs. 12 (5)
Shreibati *et al.*[20]	Retrospective study of Medicare beneficiaries without known CAD 1 year prior to diagnostic test date	8820 vs. 61 063 (XECG) 132 343 (SPECT)	74 ± 2	47	XECG/SPECT	Multi-slice CT	6	17 (0.2) vs. 195 (0.3) (XECG) 575 (0.4) (SPECT)	2023 (22.9) vs. 5520 (9.0) (XECG) 16 058 (12.1) (SPECT)	2399 (27.2) vs. 16 265 (26.6) (XECG) 19 959 (15.1) (SPECT)	1006 (11.4) vs. 2632 (4.3) (XECG) 6078 (4.6) (SPECT)
Min *et al.*[21]	Retrospective study based on private insurance claims database, patients without known CAD 9 months prior to diagnostic test date	1938 vs. 7752	52 ± 8	57	SPECT	Multi-slice CT	9	8 (0.4) vs. 43 (0.6)	120 (6.2) vs.736 (9.5)	283 (14.6) vs. 899 (11.6)	41 (2.1) vs. 124 (1.6)
Cheezum *et al.*[22]	Retrospective study, patients without known CAD	252 vs. 241	53 ± 10	56	SPECT	64-slice CT scanner	30 ± 7	0 vs. 0	8 (3.3) vs. 19 (8.1)	28 (11.5) vs. 40 (17.0)	NA
Hachamovitch *et al.*[23]	Prospective study, patients without known CAD	509 vs. 565	62 ± 11	48	SPECT	64-slice CT scanner	3	NA	78 (13.2) vs. 24 (4.3)	NA	53 (9) vs. 11 (2)
Tandon *et al.*[18]	Prospective study	1221 vs. 1221	58 ± 10	50	SPECT	64-slice CT scanner	23 ± 9	NA	129 (10.6) vs. 124 (10.2)	NA	76 (6.2) vs. 72 (5.9)
Min *et al.*[24]	Randomized controlled trial, patients without known CAD	91 vs. 89	57 ± 9	51	SPECT	Multi-slice CT	55 ± 34	NA	12 (13.0) vs.7 (8.0)	3 (3.0) vs. 9 (10.0)	7 (8) vs. 1 (1)

CAD, coronary artery disease; coronary CTA, coronary computed tomography angiography; DTU, downstream test utilization; FT, functional testing; MI, non-fatal myocardial infarction; NA, not available; SPECT, single-photon emission tomography; SD, standard deviation; XECG, exercise electrocardiography.

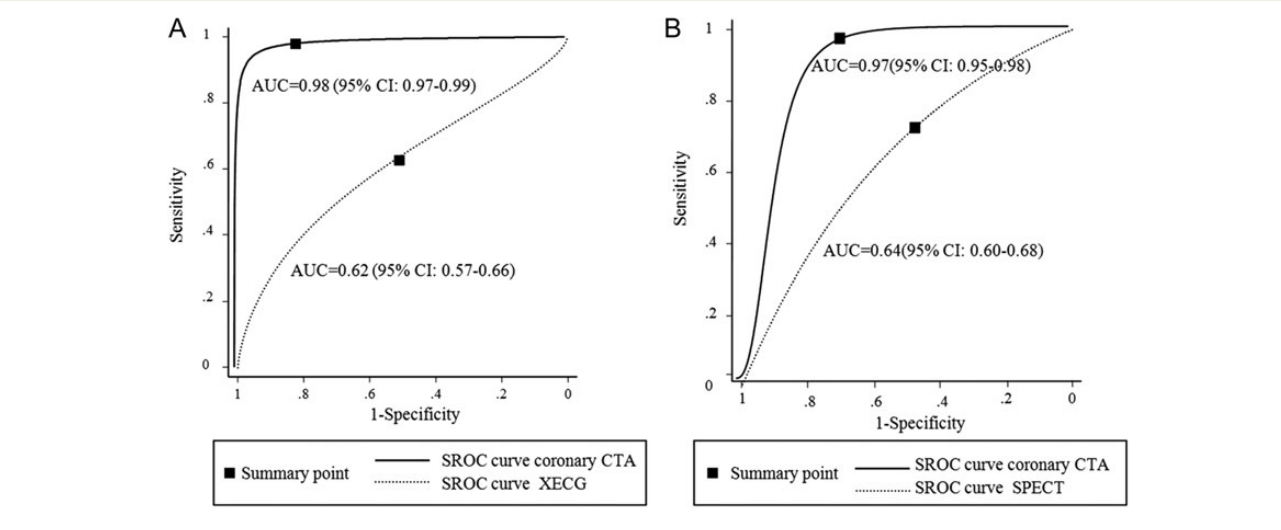

Figure 2: SROC curves of the per-patient meta-analyses of the diagnostic performance of coronary CTA vs. XECG (*A*) vs. single-photon emission computed tomography (SPECT) (*B*), compared with ICA as standard reference, in patients suspected of stable CAD. AUC, area under the curve; CI, confidence interval.

Table 3 Diagnostic performance of coronary CTA vs. XECG and SPECT, all values with 95% CI

	No. of studies	Sensitivity	Specificity	DOR	PPV	NPV
Coronary CTA vs. XECG	7					
Coronary CTA vs. ICA		98 (93–99)	82 (63–93)	221 (37–1316)	85 (71–93.5)	97.5 (87–99)
XECG vs. ICA		67 (54–78)	46 (30–64)	2 (1–4)	41 (30–55)	72 (53.5–84)
Coronary CTA vs. XECG (studies performed ICA in all patients)	5					
Coronary CTA vs. ICA		99 (91–100)	88 (74–95)	728 (54–9803)	89 (85–92)	99 (97–100)
XECG vs. ICA		68 (59–75)	39 (24–57)	1.2 (0.5–2.3)	50 (46–55)	51 (50–63)
Coronary CTA vs. XECG (studies with inconclusive results excluded)	4					
Coronary CTA vs. ICA		98 (93–100)	68 (47–83)	128 (18–919)	75 (61–86)	97 (83–100)
XECG vs. ICA		70 (65–75)	60 (51–68)	4 (2–6)	49.5 (44.5–54.5)	78 (72–83)
Coronary CTA vs. XECG (studies with intention to diagnose approach)	3					
Coronary CTA vs. ICA		95 (88–98)	93 (89–96)	192 (24–1556)	93 (90–95)	95 (92–97)
XECG vs. ICA		65 (55–75)	24 (19–30)	0.7 (0.17–2.7)	32 (28–37)	55 (48–62)
Coronary CTA vs. SPECT studies	5					
Coronary CTA vs. ICA		99 (96–100)	71 (60–80)	172 (48–615)	91 (88–94)	95.5 (88–99)
SPECT vs. ICA		73 (59–83)	48 (31–64)	2 (1–7)	80 (75–85)	33 (25–42)
Coronary CTA vs. SPECT studies (ICA performed in all patients)	2					
Coronary CTA vs. ICA		99 (96–100)	74 (58–86)	228 (39–1311)	91 (84–95)	96 (85–100)
SPECT vs. ICA		67 (58–74)	52 (37–66)	4 (0.15–126)	78 (69–85)	38 (27–50)

Coronary CTA, coronary computed tomography angiography; CI, confidence interval; DOR, diagnostic odds ratio; ICA, invasive coronary angiography; NPV, negative predictive value; PPV, positive predictive value; SPECT, single-photon emission tomography; XECG, exercise electrocardiography.

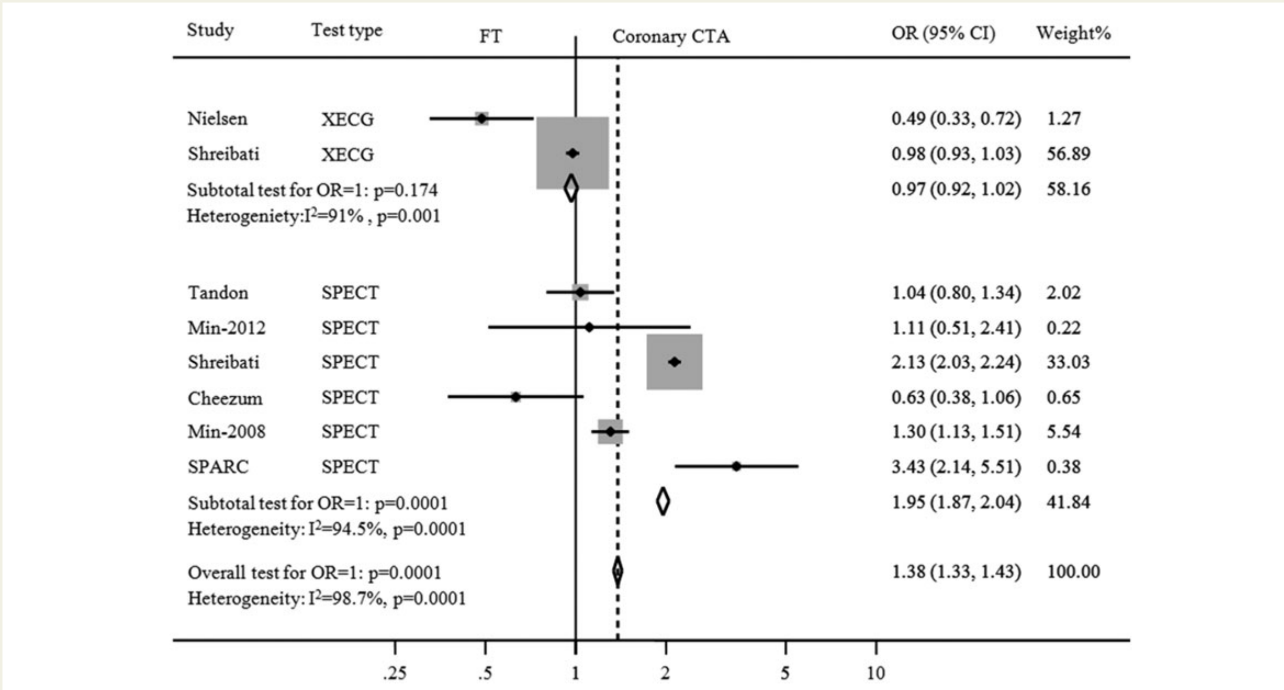

Figure 3: Meta-analyses of the risk of DTU in patients undergoing coronary CTA vs. FTs. Numbers in brackets are 95% CIs. OR, odds ratio; SPECT, single-photon emission computed tomography; XECG, exercise electrocardiography.

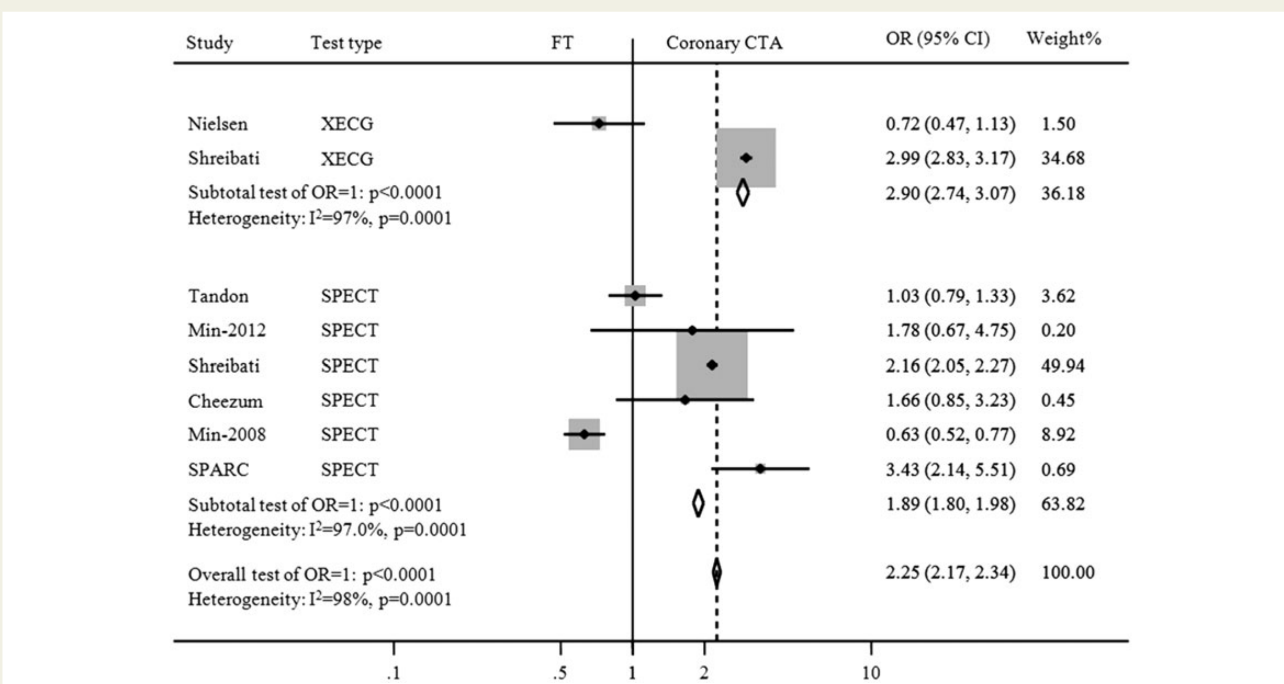

Figure 4: Meta-analyses of the risk of ICA in patients undergoing coronary CTA vs. FTs. Numbers in brackets are 95% CIs. OR, odds ratio; SPECT, single-photon emission computed tomography; XECG, exercise electrocardiography.

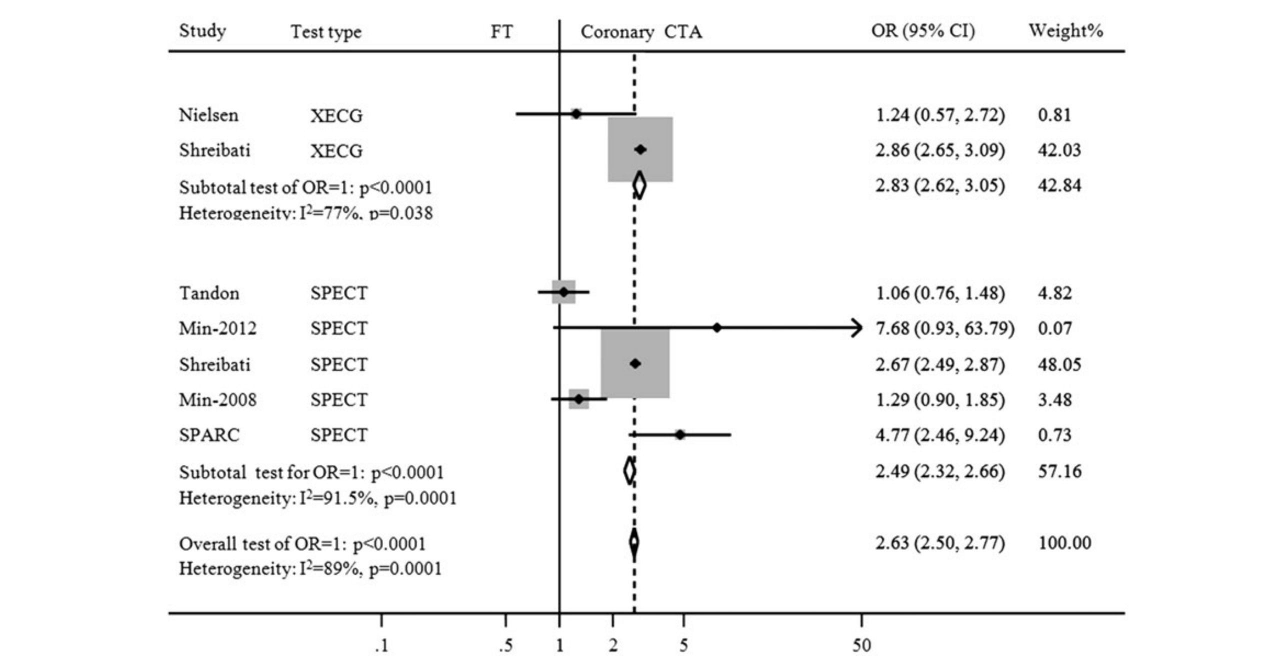

Figure 5: Meta-analysis of the risk of revascularization in patients undergoing coronary CTA vs. FTs. Numbers in brackets are 95% CIs. OR, odds ratio; SPECT, single-photon emission computed tomography; XECG, exercise electrocardiography.

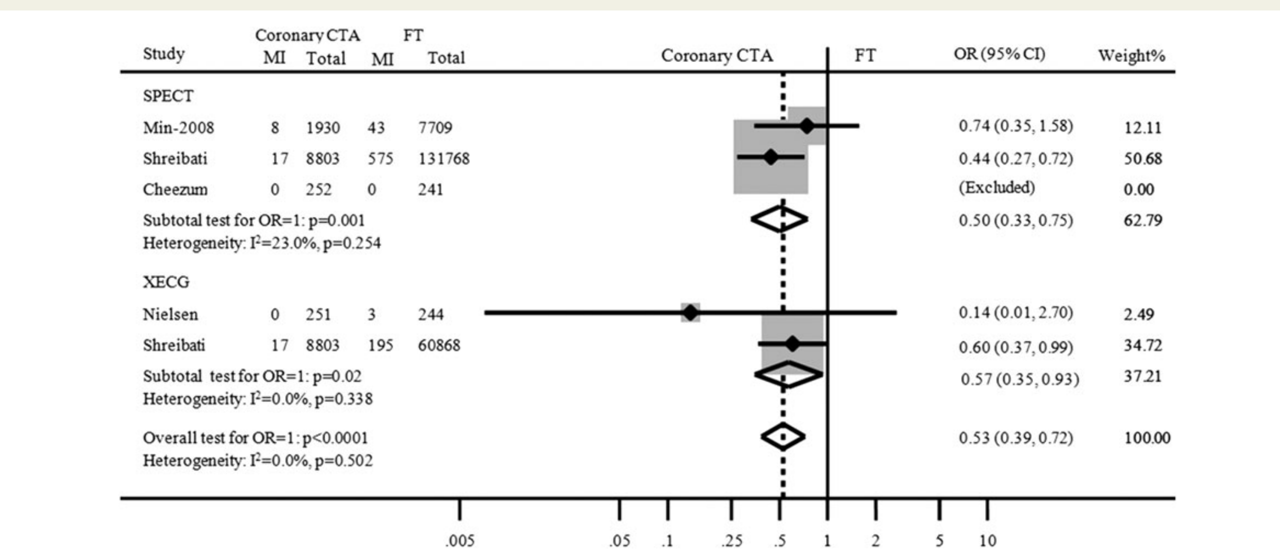

Figure 6: Meta-analysis of the risk of MI in patients undergoing coronary CTA vs. FTs. Pooled weighted incidences are reported. Numbers in brackets are 95% CIs. OR, odds ratio.

Study quality assessment and publication bias

The methodological quality of the included studies was generally good (*Tables 4 and 5*). Egger's test for the presence of potential publication bias in the diagnostic studies revealed no significant bias ($P = 0.24$).

Discussion

This systematic review and meta-analysis revealed important findings: (i) to detect significant CAD, the diagnostic performance of coronary CTA was substantially higher than both XECG and SPECT using ICA as the reference standard. (ii) Coronary CTA was associated with increased DTU and coronary revascularization.

Table 4 **Quality assessment results for bias risk and applicability of studies examining diagnostic accuracy**

Risk of bias					Applicability concerns		
Study	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Mollet *et al.*[8]	Low	Low	Low	Low	Low	Low	Low
Dewey *et al.*[9]	Low	Low	Low	Low	Low	Low	Low
Nieman *et al.*[10]	Low	Unclear	Low	Low	Low	Low	Low
Pundziute *et al.*[11]	High	Low	Low	High	Unclear	Low	Low
Øvrehus *et al.*[12]	Low	Low	Low	Low	Low	Low	Low
Maffei *et al.*[13]	Low	Low	Low	Unclear	Low	Low	Low
Weustink *et al.*[14]	Low	Low	Low	High	Low	Low	Low
Schuijf *et al.*[15]	Low	Low	Low	Low	Low	Low	Low
Ravipati *et al.*[16]	High	Unclear	Low	Unclear	High	Unclear	Low
Hamirani *et al.*[17]	Low	Low	Low	High	Low	Low	Low
Tandon *et al.*[18]	Low	Low	Low	High	Low	Low	Low

Table 5 **Quality assessment results for non-randomized studies examining outcomes**

Author [references]	Selection	Comparability	Outcome
Nielsen *et al.*, 2013[19]	****	**	***
Shreibati *et al.*[20]	***	**	***
Min *et al.*[21]	****	**	***
Cheezum *et al.*[22]	****	**	**
Hachamovitch *et al.*[23]	****	**	***
Tandon *et al.*[18]	****	**	**

A study can be awarded a maximum of four stars within the selection and outcome categories. A maximum of two stars can be given for comparability.

In the present meta-analysis, the sensitivity and specificity of coronary CTA were comparable with previously published findings,[1,2] whereas the observed specificity of XECG and SPECT were substantially lower than those presented in previously published meta-analyses.[25,26] The discrepancies in specificity between this and previous studies may reflect the fact that specificity of a diagnostic test tends to decline with time as the test is applied to a wider spectrum of patients.[27] Moreover, the pooled specificity in the meta-analysis of XECG by Gianrossi *et al.*[25] may have been inflated due to the fact that >80% of the enrolled studies excluded inconclusive test results from analyses. The demonstrated lower diagnostic specificity of SPECT in the present study when compared with previous findings[26] may be attributed to verification bias, i.e. inclusion of studies comprising patients undergoing clinically driven ICA.[15,16,18] Accordingly, excluding studies with a potential verification bias in this study resulted not surprisingly in a slightly higher specificity (52%) and a lower sensitivity (66%).

Although coronary CTA, based on the present results, seems an attractive alternative to FT, its modest specificity and positive predictive value remain a concern as it has been shown to result in increased downstream testing and potentially higher rates of ICA assessment with its inherent risks of complications and therapeutic interventions of non-ischaemic coronary lesions. In this study, patients undergoing coronary CTA vs. FT had more frequent any downstream testing performed; however, when the large-size study by Shreibati *et al.*[20] was excluded, no significant differences between the two groups regarding ICA utilization were found. From the three outcome studies in the present meta-analysis reporting results of subsequent catheterizations,[18,19,23] we found false-positive rates of coronary CTA ranging between 17 and 35%.[19,23] Thus, a relatively high number of unnecessary ICA's might have been avoided if these cases had been further non-invasively tested with FT providing higher specificities than obtained by coronary CTA, XECG, or SPECT, i.e. with positron emission tomography.[28] Moreover, it should be acknowledged that given the lower sensitivity of both XECG and SPECT when compared with coronary CTA, the proportion of false-negative results may be non-negligible. Accordingly, it has been shown that both XECG, stress-echocardiography, and SPECT misclassify a substantial proportion of patients as 'low risk'.[15,29]

In this meta-analysis, we observed that ICA after coronary CTA was more often associated with revascularization than following catheterization prompted by XECG and SPECT. Since the studies did not report whether the decision to perform revascularization was based on anatomical or functional CAD assessment, it can only be speculated that coronary CTA predisposes to subsequent revascularization *per se*, i.e. by 'stimulation' of the 'oculostenotic reflex' as described by Topol and Nissen.[30] Recently, fractional flow reserve which measures the ratio of pressure across a stenosis during ICA under conditions of maximal coronary hyperaemia recently has been accepted as the reference standard for assessing the haemodynamic significance of CAD, and to guide coronary revascularization (Evidence level 1A).[31]

In the present study, the risk of subsequent MI was almost twice following a diagnostic strategy comprising FT vs. coronary CTA.

However, the latter finding was not consistent following exclusion of the large-sized study by Shreibati *et al.*[20] Whether a potential association between the mode of non-invasive testing and outcome reflect differences in the use of revascularization between groups cannot be assessed by the results of studies included in this meta-analysis. This finding may reflect an increased tendency to initiate preventive medical treatment after coronary CTA, given its ability to reveal subclinical atherosclerosis. Accordingly, the SPARC investigators showed that the use of aspirin and lipid-lowering agents was higher following normal/non-obstructive coronary CTA findings when compared with SPECT.[23] Four studies reported separately that the overall use of aspirin and lipid-lowering drugs was higher following coronary CTA vs. a FT diagnostic strategy,[19,21,23,24] but due to major methodological heterogeneity between these studies this aspect was not included in the present meta-analysis. Overall, the finding of lower rates of MI following coronary CTA vs. FT needs delineation in future large-scaled prospective comparative outcome studies.

Limitations

The studies included in the meta-analyses demonstrated methodological heterogeneity. With respect to study populations, eight of the diagnostic accuracy studies included only patients without known CAD, while three studies included both patients with and without known CAD. These differences are reflected in the mean age varying from 54 to 63 years vs. 56 to 67 years. The majority of patients included in the diagnostic accuracy analysis were males; accordingly, the results cannot be generalized to women.

Four percent of the included patients underwent 16-slice coronary CTA,[8,9,15] but the sensitivity and specificity were comparable with those demonstrated in studies using $\geq$16-slice coronary CTA.[10–14]

Four studies included clinically driven ICA with likely verifications bias. To exclude potential verification bias, we performed sub-analyses, which showed maintained higher diagnostic performance of coronary CTA (*Table 3*).

The outcome results were dominated by the large-size study by Shreibati *et al.*;[20] therefore, sub-analyses without this study were performed and the main findings were still supportive of our conclusions. We used random-effects model in our pooled analyses, to account for variations in methodology between studies. However, methodological heterogeneity regarding the study population, technology, and design remains a limitation, and it is difficult to draw firm conclusions from the results, which need to be confirmed in future large-size studies.

Conclusion

The current meta-analysis demonstrated that a coronary CTA may serve as a more accurate and efficient alternative non-invasive front-line diagnostic method than XECG and SPECT in patients with a low-intermediate likelihood of CAD. The increased DTU and subsequent revascularization following a coronary CTA strategy may allow for decreased MI and mortality. However, the results should be investigated further in large-size prospective randomized trials with a long-term follow-up.

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IMAGE FOCUS

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Oesophageal dilatation due to gastric band detected by echocardiography: a 'chameleon tumour'

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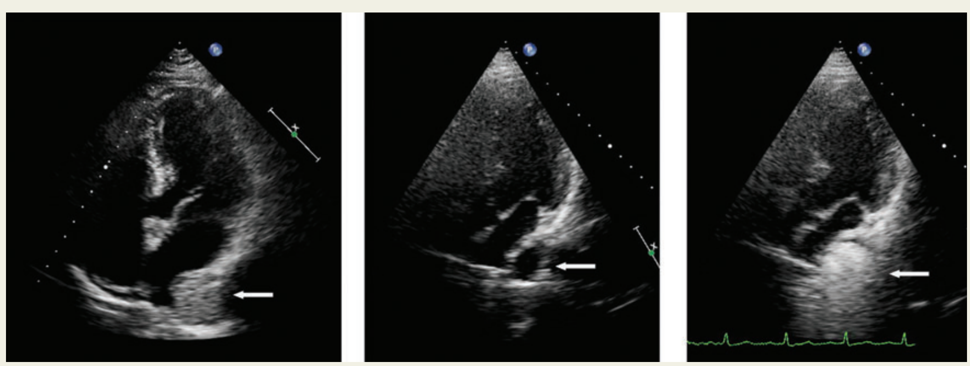

We present a case of a 53-year-old lady who was admitted in our hospital with a history of shortness of breath, palpitations, anaemia, and ankle oedema. On echocardiogram that was performed to investigate her breathlessness, a solid echo dense mass was visible posteriorly to the left atrium (LA) (*Panel —left*). The structure was well-delineated, solid with a granular appearance. A computed tomography of the chest revealed a gastric band, dilatation of oesophagus, and normal aorta. Subsequently, the patient was examined again with echocardiography. Surprisingly, the same structure was noted behind the LA, but it now appeared completely echo-free (*Panel—middle*). That raised the suspicion that the structure represented an empty dilated oesophagus, whereas in the first scan it was full of food remnants. Indeed, the patient confirmed that there had been 2–3 h since her last meal at the time of the second scan, while the first scan was done shortly after her breakfast. In order to confirm the hypothesis that the visualized structure was the oesophagus, the patient was asked to drink a few sips of commercially available carbonated beverage under continuous imaging of the structure. Immediately after ingestion, a significant amount of echo-bright gas bubbles appeared in the noted structure (*Panel—right*, see Supplementary data online, *Video S1*). Though oesophageal dilatation is not very uncommon after gastric band operation, echocardiographic demonstration has not been previously published. This case report suggests one more simple and easily available diagnostic tool for the difficult differentiation of extracardiac structures noted in echocardiography.

(*Panel—left*) Apical four-chamber view (A 4-C). Solid extracardiac mass (white arrow); (*Panel—middle*) Apical five-chamber view. The previously noted structure appears echo lucent (white arrow); (*Panel—right*) Apical five-chamber view after ingestion of carbonated beverage. The same structure (white arrow) appears full of echo-bright gas bubbles confirming that represents part of the oesophagus.

Supplementary data are available at *European Heart Journal – Cardiovascular Imaging* online.