ORIGINAL RESEARCH

Practice Pattern, Diagnostic Yield, and Long-Term Prognostic Impact of Coronary Computed Tomographic Angiography

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BACKGROUND: Although guidelines recommend the use of coronary computed tomographic angiography (CTA) in patients with stable pain syndromes, the clinical benefits of the use of coronary CTA in a broad spectrum of patients is unknown. We evaluated the contemporary practice pattern and diagnostic yield of coronary CTA and their impact on the subsequent diagnostic-therapeutic cascade and clinical outcomes.

METHODS AND RESULTS: We identified 39,906 patients without known coronary artery disease (CAD) who underwent coronary CTA between January 2007 and December 2013. The patients’ demographic characteristics, risk factors, symptoms, results of coronary CTA, the appropriateness of downstream diagnostic and therapeutic interventions, and long-term outcomes (death or myocardial infarction) were evaluated. The number of coronary CTAs had increased over time, especially in asymptomatic patients. Coronary CTA revealed that 6,108 patients (15.3%) had obstructive CAD (23.7% of symptomatic and 9.3% of asymptomatic patients). Subsequent cardiac catheterization was performed in 19.2% of symptomatic patients (appropriate, 80.6%) and in 3.9% of asymptomatic patients (appropriate, 7.9%). The 5-year rate of death or myocardial infarction was significantly higher in patients with obstructive CAD on CTA than those without (7.2% versus 3.0%; \( P < 0.001 \); adjusted hazard ratio [95% CI], 1.34 [1.17–1.54]). However, obstructive CAD on CTA had limited added value over conventional risk factors for predicting death or myocardial infarction.

CONCLUSIONS: Although the use of coronary CTA had substantially increased, CTA had a low diagnostic yield for obstructive CAD, especially in asymptomatic patients. The use of CTA in asymptomatic patients seemed to have led to inappropriate subsequent diagnostic or therapeutic interventions without clinical benefit.

Key Words: cardiovascular outcomes • coronary artery bypass grafting • coronary computed tomographic angiography • percutaneous coronary intervention

Because coronary artery disease (CAD) has a high prevalence and lacks specific diagnostic clinical signs and symptoms, guidelines recommend coronary computed tomographic angiography (CTA) in patients with stable pain syndromes who show moderate pretest risks of obstructive CAD.1,2 The goal of these recommendations is to prevent patients with low risks of obstructive CAD from undergoing unnecessary coronary CTA, thereby enhancing the diagnostic yield and clinical usefulness of coronary CTA as well as reducing test-related costs and risks. Because CTA provides a direct anatomic assessment of CAD with substantially higher accuracy compared with functional testing,3,4 the use of coronary CTA has substantially increased and is widely used as a frontline noninvasive diagnostic tool for the detection of obstructive CAD.

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Another potential benefit of CTA is the reduction in the need for invasive cardiac catheterization, which has a low diagnostic yield in routine clinical practice.5 On the basis of such usefulness and reliability of CTA, the recently updated guidelines recommend coronary CTA as the first-line test for obstructive coronary artery disease, low proportion of appropriate subsequent invasive procedures, and small additive effect on the prognosis for death or myocardial infarction.

METHODS

The data related to the findings of this study are available from the corresponding author on reasonable request.

Study Population

This study was conducted in the context of a prospective observational registry. We evaluated consecutive patients who underwent coronary CTA between March 1, 2007, and December 31, 2013, at Asan Medical Center, which is a large-sized tertiary referral hospital in Seoul, South Korea. To selectively analyze patients without known or documented heart diseases, we excluded those with a history of myocardial infarction (MI), percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), cardiac transplantation, or valvular surgery.

We collected information on the patients’ demographic characteristics, clinical risk factors, comorbid conditions, laboratory findings, and concomitant cardiovascular medications. Cardiac symptoms at the time of coronary CTA were categorized as symptomatic or asymptomatic (including no angina). The patients were considered symptomatic if they had symptoms related to CAD (eg, chest pain, chest tightness, chest discomfort, dyspnea, exertional dyspnea, and shortness of breath). To estimate the baseline cardiovascular risks of each individual, the Framingham risk score for hard coronary heart disease (https://www.framinghamheartstudy.org/fhs-risk-functions/hard-coronary-heart-disease-10-year-risk/) was calculated. In the subset of patients with missing values (n=4491; 11.2%), a modified Framingham risk score was calculated on the basis of available clinical data, with a moderate score (ie, 1 point) imputed for either a history of dyslipidemia or the use of statins, and for the presence of hypertension or a history of medication use for blood pressure control.5 The risk scores were categorized as low (<10%), intermediate (10%–20%), or high (>20%) according to the predicted risk of hard coronary heart disease. The institutional review board at Asan Medical Center approved the use of clinical data for
this study, and all patients provided written informed consent.

**Coronary CTA and Obstructive CAD**

Coronary CTA was conducted by using either a single-source 64-section computed tomography (CT) instrument (LightSpeed VCT; GE, Milwaukee, WI) or a dual-source CT instrument (Somatom Definition; Siemens, Erlangen, Germany). All coronary CTA scans were analyzed using a dedicated workstation (Volume Wizard; Siemens) by experienced cardiovascular radiologists. According to the guidelines of the Society of Cardiovascular Computed Tomography, a 16-segment coronary artery tree model was used. Obstructive CAD was defined as stenosis of ≥50% of the diameter of a major epicardial vessel. The contrast-enhanced portion of the coronary lumen was semiautomatically traced at the site of maximal stenosis. The diameter stenosis was then calculated by comparing with the mean value of the proximal and distal reference sites. The extent of the CAD (1-, 2-, or 3-vessel disease) and high-risk CAD (ie, left main disease or proximal left anterior descending artery disease) were also evaluated.

**Appropriateness of Subsequent Procedures and Long-Term Clinical Outcomes**

The rates of subsequent diagnostic coronary angiography (CAG) and coronary revascularization (PCI or CABG) were calculated, and their diagnostic and therapeutic appropriateness was determined using the recommendations from major cardiovascular societies. The information required for the assessment of the appropriateness of procedures, such as symptom status, disease extent, noninvasive test results, and medication status, was thoroughly reviewed. The appropriateness was independently judged by 2 cardiologists, and discordant cases were resolved by consensus with a third cardiologist. Patients were rated by the appropriate use criteria as appropriate, uncertain, and inappropriate for diagnostic or therapeutic procedures. Follow-up data were collected by a detailed review of all medical records. The cause and date of all deaths were confirmed by information gathered from the review of all available clinical records, together with the data from the national health insurance service.

The primary long-term clinical outcome was the composite of death from any cause or MI at 5 years after coronary CTA. All deaths were considered to be from cardiovascular causes, unless an unequivocal noncardiovascular cause could be established. MI was defined as either (1) an abnormal level of a cardiac biomarker (troponin or creatine kinase-MB) above the upper limit of the normal range and either ischemic discomfort lasting >10 minutes or ECG changes indicative of ischemia or infarction; or (2) new abnormal Q waves consistent with infarction. Procedure-related MI after PCI or CABG was disregarded in this study. All clinical outcomes of interest were confirmed by source documentation and were adjudicated by an independent group of clinicians.

**Statistical Analysis**

The baseline demographic characteristics, risk factors, results of coronary CTA findings, and subsequent diagnostic or therapeutic procedures and their appropriateness were compared between patients with clinical symptoms suggestive of CAD at the time of coronary CTA and those without. Continuous variables are presented as medians and interquartile ranges, and categorical variables are presented as percentages. Continuous variables were compared with the Wilcoxon-Mann-Whitney nonparametric test, and categorical variables were compared with the $\chi^2$ test. We assessed the temporal trends in the relative proportion of symptomatic or asymptomatic patients at the time of coronary CTA. For the comparison of temporal trends between symptomatic and asymptomatic patients, $\chi^2$ test for linear by linear association was used. We also examined the diagnostic yield of coronary CTA showing obstructive CAD, according to symptom characteristic and cardiovascular risk category.

We compared the cumulative 5-year incidence of death or MI according to the presence of obstructive CAD on CTA. Cumulative event curves were generated by the Kaplan-Meier method and compared using the log-rank test. Multivariable Cox proportional hazard analyses were used to determine whether the presence of obstructive CAD on CTA was a statistically significant predictor of the primary composite of death or MI at 5 years after adjustment of clinically relevant risk factors. The following covariates were included in the model: Framingham risk score, body mass index, diabetes mellitus, history of cerebrovascular disease, baseline renal insufficiency, and symptoms at CTA.

To estimate the relative prognostic value of obstructive CAD on CTA in predicting the primary composite outcome of death or MI at 5 years, we constructed 4 separate models: model 1 only included the Framingham risk score, and model 2 added other clinical risk factors (ie, diabetes mellitus, body mass index, baseline renal insufficiency [creatinine clearance <60 mL/min], and history of cerebrovascular disease) to model 1. Model 3 further added the presence of documented symptoms, and model 4 added the presence of obstructive CAD on CTA. The predictive value of each model was...
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RESULTS

Study Population and Baseline Characteristics

During the study period, 42,123 consecutive patients had undergone coronary CTA (Figure 1). Among them, 39,906 patients without known CAD who underwent coronary CTA and met inclusion/exclusion criteria were finally analyzed. The baseline characteristics of the overall population and according to the presence of clinical symptoms are shown in Table 1. Compared with patients who were asymptomatic at the time of CTA, symptomatic patients were older, had a lower proportion of men, and had a higher prevalence of hypertension, diabetes mellitus, current smoking, dyslipidemia, renal insufficiency, or history of cerebrovascular disease \( P < 0.001 \) for all comparisons). Accordingly, symptomatic patients had a higher prevalence of those in the high-risk category in the Framingham risk score and those who received concomitant cardiovascular medications.

Practice Pattern and Findings of Coronary CTA

Among the patients who were evaluated for suspicious CAD by coronary CTA, the proportion of asymptomatic patients had substantially increased over the study enrollment period \( P \) for trend \(<0.001\); Figure 2). The practice pattern and the coronary CTA findings are shown in Table 2. In patients with clinical symptoms, coronary CTA was most frequently performed in the outpatient clinics. A large proportion of asymptomatic patients (63.9%) underwent coronary CTA in health screenings at the patients’ own discretion, which was significantly less common in symptomatic patients (12.4%; \( P < 0.001 \)). Overall, obstructive CAD on CTA was identified in 15.3% of the patients,
of whom 45.3% had multivessel disease, 43.9% had proximal left anterior descending artery disease, and 8.5% had left main disease. The diagnostic yield for obstructive CAD on CTA increased with the presence of angina (23.7% of symptomatic patients and 9.3% of asymptomatic patients) and with a higher Framingham risk score ($P<0.001$ for both analyses) (Figure 3). As expected, the prevalence of multivessel, proximal left anterior descending artery and left main disease was significantly higher in symptomatic patients than in asymptomatic patients ($P<0.001$ for all comparisons).

### Subsequent Procedures and Appropriateness

The rate of subsequent diagnostic or therapeutic procedures and their appropriateness are summarized in Table 3. Invasive CAG was more frequently performed in symptomatic patients than in asymptomatic patients (19.2% versus 3.9%), and the rates of subsequent PCI (9.9% versus 1.5%) and CABG (2.4% versus 0.2%) were also significantly higher in symptomatic patients ($P<0.001$ for all comparisons). There was a substantial difference in the appropriateness of each diagnostic and therapeutic procedure according to the presence of clinical symptoms, as CAG was appropriate in most (80.6%) of patients with symptoms, but only in 7.9% of asymptomatic patients. This pattern was similar for subsequent therapeutic procedures of PCI and CABG.

### Long-Term Clinical Outcomes

During a median follow-up period of 5.4 years (interquartile range, 1.3–7.4 years), the primary composite outcome of death or MI occurred in 3.4% of patients (5.2% of symptomatic patients versus 2.1% of...
asymptomatic patients; \( P < 0.001 \) (Table 3). The 5-year rate of primary composite outcome was significantly higher in patients with obstructive CAD on CTA than in those without, regardless of clinical symptoms (Figure 4). Multivariable Cox regression analysis showed that the presence of obstructive CAD on CTA was independently associated with a higher risk of the primary composite of death or MI (adjusted hazard ratio, 1.34; 95% CI, 1.17–1.54), but to a lesser degree than the major clinical risk factors (Table 4).

### Incremental Value of Information Obtained at Clinical Risk Assessment and CTA Findings

The results of 4 separate models for predicting the primary composite of death or MI with the information obtained from clinical assessment and CTA findings are presented in Figure 5. Model 1, which only included the Framingham risk score, had a C-statistic value of 0.595 (95% CI, 0.579–0.610). By adding clinical factors that are not included in the Framingham risk score (model 2), we obtained a C-statistic value of 0.683 (95% CI, 0.667–0.700). Model 3, which further added the presence of clinical symptoms, had a slightly higher predictive ability (C-statistic, 0.711; 95% CI, 0.695–0.726). Finally, although the presence of obstructive CAD on CTA was associated with a higher risk of the primary composite outcome, the addition of information obtained from coronary CTA (model 4) had a limited effect on the model’s predictive ability over the effect achieved from the addition of clinical risk assessment (C-statistic, 0.716; 95% CI, 0.701–0.732), with a similar effect on patients with or without clinical symptoms. The calibration plot for the final model was depicted in Figure 6, which showed the agreement between predicted and observed outcomes.

### Table 2. Performing Site and Findings of Coronary CTA

| Variables                        | Total (n=39,906) | Symptomatic (n=16,571) | Asymptomatic (n=23,335) | \( P \) Value |
|----------------------------------|------------------|------------------------|--------------------------|---------------|
| Performing site of CTA           |                  |                        |                          | <0.001        |
| Outpatient clinic                | 17,212 (43.1)    | 10,345 (62.4)          | 6,867 (29.4)             |               |
| In hospital                      | 4,002 (10.0)     | 2,471 (14.9)           | 1,531 (6.6)              |               |
| Emergency department             | 1,734 (4.3)      | 1,700 (10.3)           | 34 (0.1)                 |               |
| Health screening                 | 16,958 (42.5)    | 2,055 (12.4)           | 14,903 (63.9)            |               |
| Coronary CTA findings            |                  |                        |                          | <0.001        |
| Obstructive CAD (>50%)           |                  |                        |                          |               |
| Absence                          | 33,798 (84.7)    | 12,638 (76.3)          | 21,160 (90.7)            |               |
| Presence                         | 6,108 (15.3)     | 3,939 (23.7)           | 2,175 (9.3)              |               |
| Extent of obstructive CAD*       |                  |                        |                          | <0.001        |
| 1 Vessel                         | 3343 (54.7)      | 1,954 (49.7)           | 1,389 (63.9)             |               |
| 2 Vessels                        | 1,661 (27.2)     | 1,121 (28.5)           | 540 (24.8)               |               |
| 3 Vessels                        | 1,104 (18.1)     | 858 (21.8)             | 246 (11.3)               |               |
| Proximal LAD disease             | 2,680 (43.9)     | 1,882 (47.9)           | 798 (36.7)               | <0.001        |
| Left main disease                | 521 (8.5)        | 377 (9.6)              | 144 (6.6)                | <0.001        |

Values are number (percentage). CAD indicates coronary artery disease; CTA, computed tomographic angiography; and LAD, left anterior descending artery. *Percentages denote the proportion of subjects among patients with obstructive CAD.
DISCUSSION

In this large-sized, contemporary observational cohort of patients without known CAD who underwent coronary CTA, we found that (1) the number of patients who were evaluated with coronary CTA for detecting obstructive CAD had substantially increased over time, a trend that was more evident in asymptomatic patients; (2) CTA had a low diagnostic yield (15.3%) for obstructive CAD, and the yield was much lower in asymptomatic patients (9.3%) than in symptomatic patients (23.7%); (3) downstream invasive angiography was performed in 10.3% of the patients, which was classified as appropriate in 80.6% of symptomatic patients and only in 7.9% of asymptomatic patients; and (4) although the presence of obstructive CAD on CTA was significantly associated with a higher risk of the primary composite of death or MI at 5 years, the incremental predictive value of obstructive CAD on CTA beyond the conventional risk score and clinical assessments was limited.

Recent advances in CT technology have significantly improved the diagnostic accuracy of coronary CTA, which led to substantial increases in its use for patients with suspected CAD. During the cohort period, a single-source 64-section CT or a dual-source CT instrument was used with a mean radiation dose of ≈7.58 mSv. Recently, second- or third-generation dual-source CT scanners with iterative reconstruction and high-pitch scans have been used, and technical improvements of CT (eg, prospective ECG gating, high-pitch helical acquisition, 256 or wider detector, and tube voltage reduction) have led to marked decreases in radiation exposure. With these technical advancements, several studies have reported substantial reductions in radiation dose without increases in nondiagnostic coronary CTAs. In addition, the newer generations of iterative reconstruction algorithms improve not only the image quality but also the diagnostic accuracy in heavily calcified coronary arteries, which have acted as a major obstacle in coronary CTA. Such advances of coronary CTA justify the widespread use of coronary CTA as a noninvasive alternative to CAG for the diagnosis of obstructive CAD.

Considering its high negative predictive value, CTA is commonly used to confidently rule out significant CAD in symptomatic patients with low-to-intermediate risks of CAD. Recently, with the widespread availability of coronary CTA and its high accuracy, the scope of coronary CTA has been expanded to low-risk populations. Our study showed that CTA was widely performed in a diverse spectrum of patients, including symptomatic patients with suspicious CAD, asymptomatic high-risk patients with type 2 diabetes mellitus, patients requiring preoperative cardiac evaluation for major high-risk surgery, and even asymptomatic patients for self-referral health screening.

The central theme of our study includes the inappropriate use of coronary CTA among asymptomatic patients. This increasing trend in the use of coronary CTA in asymptomatic patients might be an international phenomenon and is not in agreement with current guidelines and is a much larger proportion than those included in other registries or trials of coronary CTA. South Korea has a well-developed national health insurance and reimbursement system, and many hospitals therefore market health checkup programs that include CAD screening with technologically intensive cardiac CT. As a result,
CAD screening using cardiac CT or coronary CTA continues to grow in popularity. However, our study demonstrated that the benefit of routine CTA screening was poor (“pathognomonic for overdiagnosis and overtreatment”) and we did not find sufficient evidence that early detection of CAD led to improved outcomes. Specifically, coronary CTA in asymptomatic patients had a low diagnostic yield (9.3%) and a higher frequency of inappropriate or uncertain CAG (92.1%) and PCI (63.2%). The overt clinical benefit of coronary revascularization (ie, appropriate PCI or CABG) was observed in only 0.7% (165/23,335) of the overall asymptomatic patients. Considering the radiation hazard and potential complications related to CAG or PCI, the overall benefits of coronary CTA might not substantially overwhelm its potential risks; therefore, the low threshold for performing cardiac CT or coronary CTA in an asymptomatic and low-risk population cannot be readily justified. In this context, clinicians need to better adhere to the decision-making algorithms supported by established guidelines and the appropriate use criteria of coronary CTA.

In this contemporary clinical practice, the diagnostic yield of coronary CTA for revealing obstructive CAD was low. Specifically, <10% of patients without clinical symptoms had obstructive CAD. We also systematically assessed the appropriateness of the subsequent diagnostic-therapeutic procedures after coronary CTA. Among symptomatic patients, 19.2%, 9.9%, and 2.4% underwent subsequent CAG, PCI, and CABG, respectively, which were mostly deemed as appropriate (80.6%, 61.5%, and 85.9%, respectively). However, only a minor portion of subsequent CAG and PCI procedures in asymptomatic patients were regarded as appropriate (7.9% and 38.0%, respectively). Not surprisingly, we found that the rate of obstructive CAD on CTA was proportionally higher in patients with high Framingham risk scores than in those with intermediate or low risk scores. These findings suggest that a more adequate pretest clinical assessment is required and that adherence to the current guideline for appropriate use of coronary CTA is the best way to encourage “appropriate” diagnostic-therapeutic cascades.

The main clinical reasons for performing coronary CTA are to more accurately detect or exclude significant CAD and eventually reduce long-term negative clinical outcomes, such as death or MI. A prior observational study showed that although CTA was associated with a higher rate of subsequent invasive cardiac procedures and higher CAD-related medical costs compared with stress testing, patients who underwent CTA had a similar risk of death and a slightly lower risk of MI-related hospitalization. The PROMISE (Prospective Multicenter Imaging Study for Evaluation of Chest Pain) showed that compared with functional testing, the strategy of initial CTA did not significantly improve the primary end point events over 2 years. In contrast, the SCOT-HEART (Scottish Computed Tomography of the Heart) trial demonstrated that the use of CTA in addition to standard care in patients with stable chest pain resulted in a significantly lower rate of death from coronary

| Variables                      | Total (n=39,906) | Symptomatic (n=16,571) | Asymptomatic (n=23,335) | P Value |
|-------------------------------|-----------------|------------------------|-------------------------|---------|
| CAG                           | 4103 (10.3)     | 3183 (19.2)            | 920 (3.9)               | <0.001  |
| Appropriate                   | 2565 (80.6)     | 73 (7.9)               |                         | <0.001  |
| Uncertain                     | 558 (17.5)      | 457 (49.7)             |                         |         |
| Inappropriate                  | 60 (1.9)        | 390 (42.4)             |                         |         |
| PCI                            | 1986 (5.0)      | 1636 (9.9)             | 350 (1.5)               | <0.001  |
| Appropriate                   | 1006 (61.5)     | 133 (38.0)             |                         | <0.001  |
| Uncertain                     | 272 (16.6)      | 130 (37.1)             |                         |         |
| Inappropriate                  | 272 (17.4)      | 70 (26.1)              |                         |         |
| CABG                           | 448 (1.1)       | 403 (2.4)              | 45 (0.2)                | <0.001  |
| Appropriate                   | 348 (85.9)      | 32 (71.1)              |                         | 0.02    |
| Uncertain                     | 43 (10.7)       | 8 (17.8)               |                         |         |
| Inappropriate                  | 14 (3.5)        | 5 (11.1)               |                         |         |

Long-term clinical outcomes (over a median follow-up of 5 y)

| Variables                  | Total (n=39,906) | Symptomatic (n=16,571) | Asymptomatic (n=23,335) | P Value |
|----------------------------|-----------------|------------------------|-------------------------|---------|
| Primary composite outcome of death from any cause or MI | 1370 (3.4)     | 869 (5.2)             | 501 (2.1)            | <0.001  |
| Death from any cause       | 1125 (2.8)      | 688 (4.2)             | 437 (1.9)            | <0.001  |
| MI                         | 275 (0.7)       | 205 (1.2)             | 70 (0.3)              | <0.001  |

Values are number (percentage). CAG indicates coronary angiography; CTA, computed tomographic angiography; MI, myocardial infarction; and PCI, percutaneous coronary intervention.
heart disease or MI at 5 years than standard care alone. To better understand the relationship between the current decision-making processes for the need for coronary CTA and its clinical impact, we explored the relative usefulness of well-known risk scores, major cardiac risk factors, symptoms,

Figure 4. Kaplan-Meyer curves of the primary outcome of death or myocardial infarction (MI) according to the presence of obstructive coronary artery disease (CAD) on coronary computed tomographic angiography (CTA).

Obstructive CAD was defined as >50% stenosis in a major epicardial coronary artery on coronary CTA. Results are presented among the overall patients (A), symptomatic patients (B), and asymptomatic patients (C).

| Variables                              | Univariable Analysis | Multivariable Analysis |
|----------------------------------------|----------------------|------------------------|
|                                        | HR (95% CI)          | P Value                | HR (95% CI)          | P Value                |
| Framingham risk score (vs low)         |                      |                        |                      |                        |
| Intermediate                           | 1.55 (1.37–1.76)     | <0.001                 | 1.42 (1.25–1.61)     | <0.001                 |
| High                                   | 2.90 (2.43–3.47)     | <0.001                 | 1.80 (1.49–2.17)     | <0.001                 |
| Body mass index (vs normal)*           |                      |                        |                      |                        |
| Underweight (<18.5 kg/m²)              | 2.71 (1.97–3.73)     | <0.001                 | 2.28 (1.61–3.07)     | <0.001                 |
| Overweight (≥25.0 kg/m²)               | 0.96 (0.85–1.09)     | 0.53                   | 0.99 (0.87–1.12)     | 0.83                   |
| Diabetes mellitus                      | 2.09 (1.85–2.35)     | <0.001                 | 1.64 (1.45–1.86)     | <0.001                 |
| Cerebrovascular disease                | 1.72 (1.38–2.14)     | <0.001                 | 1.06 (0.85–1.33)     | 0.60                   |
| Estimated GFR <60 mL/min               | 3.37 (2.96–3.84)     | <0.001                 | 2.31 (2.01–2.65)     | <0.001                 |
| Symptoms at coronary CTA               | 2.63 (2.33–2.96)     | <0.001                 | 2.09 (1.84–2.37)     | <0.001                 |
| Obstructive CAD on coronary CTA        | 2.40 (2.12–2.71)     | <0.001                 | 1.34 (1.17–1.54)     | <0.001                 |

CAD indicates coronary artery disease; CTA, computed tomographic angiography; GFR, glomerular filtration rate; HR, hazard ratio; and MI, myocardial infarction.

*Body mass index was classified into 3 groups: underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), and overweight (≥25.0 kg/m²).
and CTA results for predicting the composite outcome of death or MI. Although the presence of CAD on CTA had a significant association with the occurrence of death or MI, the additional prognostic value of coronary CTA findings over the conventional clinical risk assessment was limited, increasing the C-statistic from 0.711 to 0.716. The predictability of future major cardiovascular events, as assessed before coronary CTA, was generally estimated by considering the traditional risk factors and the presence of symptoms. Our findings are in line with those of recent reports that routine CTA screening was not associated with better clinical outcomes in symptomatic subjects or even high-risk diabetic patients. These results emphasize the need for further refinement of coronary CTA indications with a Bayesian approach to maximize its clinical benefit over invasive tools or indirect functional testing in daily clinical practice.

Our study has several limitations. First, this study was a nonrandomized observational cohort study. Therefore, the observed findings should be considered hypothesis generating. Second, because of the observational nature of the study, the exact reasons for the decision to proceed with coronary CTA are unclear. Third, to reduce ascertainment bias, we excluded patients with a known history of CAD. Therefore, our population mainly consisted of relatively healthy subjects and thus the number of clinical events was lower than those in prior studies.
stenosis and did not evaluate the status of nonobstructive CAD, leading to the initiation of therapeutic procedures without a substantial improvement in the rates of inappropriate diagnostic or therapeutic procedures. Nonobstructive CAD accounted for >50% of subsequent MI. Last, given that the study population was relatively heterogeneous and included asymptomatic patients who were self-referred or tested for preoperative evaluation, the low diagnostic yield and limited prognostic value of CTA might lack external validity and therefore must be interpreted in the context of the population studied.

**CONCLUSIONS**

In this contemporary clinical-practice study, the number of coronary CTAs had substantially increased over time. However, the diagnostic yield of coronary CTA for obstructive CAD was low. The incremental use of coronary CTA in asymptomatic patients had led to increases in the rates of inappropriate diagnostic or therapeutic procedures without a substantial improvement in the prediction for death or MI. The decision-making for performing coronary CTA, including assessment of clinical factors and symptoms, needs to be substantially improved to increase the diagnostic yield and clinical benefit of coronary CTA in contemporary clinical settings.

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**ARTICLE INFORMATION**

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**Disclosures**

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