ORIGINAL ARTICLE

CT Angiography for Safe Discharge of Patients with Possible Acute Coronary Syndromes

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ABSTRACT

BACKGROUND

Admission rates among patients presenting to emergency departments with possible acute coronary syndromes are high, although for most of these patients, the symptoms are ultimately found not to have a cardiac cause. Coronary computed tomographic angiography (CCTA) has a very high negative predictive value for the detection of coronary disease, but its usefulness in determining whether discharge of patients from the emergency department is safe is not well established.

METHODS

We randomly assigned low-to-intermediate-risk patients presenting with possible acute coronary syndromes, in a 2:1 ratio, to undergo CCTA or to receive traditional care. Patients were enrolled at five centers in the United States. Patients older than 30 years of age with a Thrombolysis in Myocardial Infarction risk score of 0 to 2 and signs or symptoms warranting admission or testing were eligible. The primary outcome was safety, assessed in the subgroup of patients with a negative CCTA examination, with safety defined as the absence of myocardial infarction and cardiac death during the first 30 days after presentation.

RESULTS

We enrolled 1370 subjects: 908 in the CCTA group and 462 in the group receiving traditional care. The baseline characteristics were similar in the two groups. Of 640 patients with a negative CCTA examination, none died or had a myocardial infarction within 30 days (0%; 95% confidence interval [CI], 0 to 0.57). As compared with patients receiving traditional care, patients in the CCTA group had a higher rate of discharge from the emergency department (49.6% vs. 22.7%; difference, 26.8 percentage points; 95% CI, 21.4 to 32.2), a shorter length of stay (median, 18.0 hours vs. 24.8 hours; P<0.001), and a higher rate of detection of coronary disease (9.0% vs. 3.5%; difference, 5.6 percentage points; 95% CI, 0 to 11.2). There was one serious adverse event in each group.

CONCLUSIONS

A CCTA-based strategy for low-to-intermediate-risk patients presenting with a possible acute coronary syndrome appears to allow the safe, expedited discharge from the emergency department of many patients who would otherwise be admitted. (Funded by the Commonwealth of Pennsylvania Department of Health and the American College of Radiology Imaging Network Foundation; ClinicalTrials.gov number, NCT00933400.)

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Patients who present to the emergency department with signs and symptoms consistent with a possible acute coronary syndrome pose a diagnostic dilemma.[1-6] Despite the introduction of clinical decision rules[6-15] and the improved sensitivity of cardiac markers,[15-17] most patients are admitted to the hospital so that an acute coronary syndrome can be ruled out, even though for most of these patients, the symptoms are ultimately found not to have a cardiac cause.

The absence of evidence of coronary disease on invasive coronary angiography is associated with a low risk of future cardiac events.[18,19] Coronary computed tomographic angiography (CCTA) is a noninvasive test with a negative predictive value of nearly 100% for the detection of coronary artery disease.[20]

Prior studies[21-30] have shown that the rate of cardiac events among patients with minimal or no coronary artery disease is very low. However, these studies were not large enough to clarify whether a CCTA-based strategy, as compared with traditional approaches, allows the safe discharge of patients after a negative test. We conducted a trial to determine the safety and efficiency of a CCTA-based strategy.

METHODS

STUDY DESIGN

The study was a randomized, controlled, multicenter trial comparing a CCTA-based strategy with traditional "rule out" approaches for low-to-intermediate-risk patients presenting to the emergency department with chest pain and possible acute coronary syndrome. Our primary hypothesis was that patients without clinically significant coronary disease on CCTA (i.e., no coronary-artery stenosis ≥50%) would have a 30-day rate of cardiac death or myocardial infarction of less than 1%. Secondary aims included comparisons of the two groups with respect to the rate of discharge from the emergency department, the length of stay during the index visit, and the 30-day rates of death, myocardial infarction, revascularization, and resource utilization.

In the CCTA group, the first evaluation that was performed was CCTA; in the traditional-care group, the patient's health care provider decided which tests, if any, were to be performed. In both groups, decisions about admission or discharge, further diagnostic testing, and treatment were made by the clinical team. The study was approved by the institutional review board at each participating site. The protocol, including the statistical analysis plan, is available with the full text of this article at NEJM.org. The first, second, and last authors vouch for the accuracy and completeness of the data and for the fidelity of the study to the protocol.

STUDY PATIENTS

Patients were enrolled in the emergency department at five sites. At three sites, patients were also enrolled after admission to an observation unit. Patients 30 years of age or older with signs or symptoms that were consistent with a possible acute coronary syndrome were eligible if the treating physician determined that they would require admission or objective testing to rule out an acute coronary syndrome, if the electrocardiogram (ECG) at presentation did not reveal acute ischemia, and if the patient had an initial Thrombolysis in Myocardial Infarction risk score of 0 to 2. All the patients provided written informed consent.

Patients were excluded if they had symptoms that were clearly noncardiac in origin, had a coexisting condition that necessitated admission regardless of whether they might have an acute coronary syndrome, had had normal findings on CCTA or invasive angiography in the previous year, or had contraindications to CCTA. These criteria are consistent with the 2010 Appropriate Use Criteria for Cardiac Computed Tomography.[31]

RANDOMIZATION PROCESS

Patients who provided informed consent underwent computer-based randomization, in a 2:1 ratio, to CCTA or to traditional care. Randomization was performed after the initial ECG had been obtained but could be performed before the results of serum creatinine and cardiac troponin measurements were available. Patients who were subsequently found to have a creatinine clearance of less than 60 ml per minute or who underwent computed tomographic (CT) scanning for the diagnosis of a pulmonary embolism, rather than CCTA, were withdrawn from the study.

DATA COLLECTION AND PROCESSING

Initial Evaluation

Structured collection of data was performed prospectively in accordance with standardized reporting guidelines for studies evaluating risk among

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patients admitted to emergency departments with possible acute coronary syndrome[32] and in accordance with key definitions from the American College of Cardiology for measuring the management and outcome of acute coronary syndromes.[33] We obtained data on the demographic and clinical characteristics of the patients and information on ECG results, the treatment received, diagnostic testing, and admission to or discharge from the hospital or observation unit.

CCTA

CCTA was performed with the use of a 64-slice or greater multidetector CT scanner that could be used to perform ECG-synchronized cardiac studies. The examination included a noncontrast ECG-triggered acquisition for calcium scoring and a postcontrast ECG-synchronized acquisition from the tracheal carina to the base of the heart. Patients received beta-blockers for control of their heart rate and nitroglycerin for dilation of coronary arteries, according to the protocol at the institution at which they were being treated. Techniques for reducing the radiation dose were used when available. Results were reported according to the Society of Cardiovascular Computed Tomography guidelines, with the use of the American Heart Association coronary segment model, and included the calcium score and both cardiac and noncardiac findings.[34] Readers had to meet the criteria for level 3 cardiac CT training.[35] Although local interpretations of CT studies were used for "real time" clinical decision making, for the purposes of our analysis, stenoses were quantified as no coronary-artery stenosis, stenosis of less than 50%, stenosis of 50 to 69%, or stenosis of 70% or more.

Hospital Course

Follow-up data that were collected included admission to the hospital or discharge from the emergency department, the details of the diagnostic testing, the treatment received, and the final diagnosis. To prevent the inappropriate discharge of patients who may have had a myocardial infarction despite minimal or no coronary disease, a second measurement of troponin levels in patients in the CCTA group was obtained 90 to 180 minutes after their arrival in the emergency department. When stress testing was performed, graded exercise testing or pharmacologic stress testing was used, according to the protocol at the local institution.

Follow-up

At the time of enrollment, all the patients were asked to provide multiple telephone numbers. Patients were contacted at least 30 days after presentation[32] and were questioned about whether they had had a myocardial infarction, had been hospitalized for a subsequent cardiovascular presentation, had undergone revascularization or cardiac testing, or had seen a cardiologist, and what medications they were taking. If a patient reported a hospitalization that was possibly related to cardiac causes, the hospital records were reviewed. Adverse events were confirmed by means of a review of the records. If the patients or secondary contacts were unavailable, records at the presenting and neighboring hospitals were reviewed to determine whether there had been repeat visits. When these methods failed to provide information on vital status, we searched the Social Security Death Master File (www.ssdmf.com) for vital status (date last accessed for all patients, January 25, 2012).

MAJOR OUTCOMES AND DEFINITIONS

The primary outcome of the study was safety, as indicated by the rate of major cardiac events (cardiac death or myocardial infarction) within 30 days after presentation among patients who were found not to have had clinically significant coronary artery disease on CCTA. All myocardial infarctions were reviewed by an adjudication committee to confirm the diagnosis.[36] Clinically significant coronary artery disease was defined as stenosis of 50% or more of the left main, left anterior descending, left circumflex, or right coronary artery or a first-order branch. A CCTA examination with any inadequately visualized coronary segments was considered to be indeterminate if clinically significant coronary artery disease was not present elsewhere. We chose a conservative definition for the absence of clinically significant coronary disease in an effort to be cautious, since, if this approach were to be adopted, physicians would use the results in practice. A positive stress test was defined as a test showing ST-segment elevation or depression of more than 1 mm or reversible ischemia on imaging. The algorithm used for the diagnosis of coronary artery disease is shown in Figure S1 in the Supplementary Appendix, available at NEJM.org. An acute coronary syndrome was defined as a myocardial infarction or objective confirmation of unstable angina (reversible ischemia on provocative testing or coronary angiography showing stenosis of 70% or more in a coro-

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nary artery).[32] Patients were considered to have been discharged if they were not designated to be assigned an inpatient bed or formal observation status. The length of stay in the hospital was defined as the interval from presentation until discharge.

STATISTICAL ANALYSIS

The study was powered to test the null hypothesis that the rate of major cardiac events among patients who did not have clinically significant coronary artery disease as assessed by CCTA would exceed 1%. We expected that up to 10% of the patients would have clinically significant coronary disease and that the true rate of major cardiac events would be 2 cases or fewer per 1000 patients without coronary disease.[23-25] Under these assumptions, with a sample of 860 patients in the CCTA group who could be evaluated, the study would have at least 90% power to reject the null hypothesis, with the use of an exact one-sided test at a significance level of 0.05. Allowing for a 5% attrition rate, we calculated that we would need to enroll 910 participants in the CCTA group and 455 participants in the traditional-care group, for a total of 1365 patients.

We estimated the rate of major cardiac events in each group and the rate among the patients in the CCTA group who were found not to have clinically significant coronary disease. Comparisons were made according to the intention-to-treat principle. We used exact confidence intervals and hypothesis tests to estimate the rate of cardiac events and to make comparisons either with a predetermined threshold for the null hypothesis or between groups. Nonparametric testing was used for the between-group comparison of the length of stay in the hospital. We used exact procedures to estimate and perform the between-group comparison of the rate of detection of clinically significant coronary disease, as well as the rate of resource use over the course of 30 days. Statistical computations were performed with the use of SAS software, version 9.2 (SAS Institute).

RESULTS

PATIENTS

During the period from July 7, 2009, through November 3, 2011, we enrolled 1392 patients. A total of 22 patients were withdrawn because they met predetermined criteria for withdrawal; the most common reason was renal insufficiency that was diagnosed after randomization (Fig. 1). Thus, the final sample included 1370 patients. Randomization was performed in the emergency department in the case of 1231 patients (90%). The remaining patients underwent randomization after admission to an observation unit. A total of 908 patients were randomly assigned to CCTA, and 462 to traditional care. The baseline characteristics were balanced between the study groups (Table 1).

DIAGNOSTIC TESTING DURING INDEX VISIT

Of the 908 subjects who were randomly assigned to the CCTA-based strategy, 767 (84%) underwent the CCTA examination. The likelihood of undergoing the test varied according to the institution, with the percentage of patients undergoing the test ranging from 67 to 93%. The most common reason for not undergoing the examination was persistent elevation of the heart rate (in 27% of patients). Of the patients who underwent CCTA, 640 (83%) had maximal coronary-artery stenosis of less than 50% (Table 2). Of the total number of patients in the CCTA group, 124 (14%) underwent stress testing, of whom 15 (12%) were found to have reversible ischemia. A total of 37 patients (4%) underwent cardiac catheterization; 28 (76%) were found to have coronary-artery stenosis of 50% or more. In the case of 80 patients in the CCTA group (9%), no imaging or provocative testing was performed.

In the traditional-care group, 295 patients (64%) underwent diagnostic testing, usually a stress test, either with imaging (258 patients) or without imaging (9 patients) (Table 2); 16 of the 267 patients who underwent stress testing (6%) were found to have reversible ischemia. Coronary-artery stenosis of 50% or greater was found in 8 of the 18 patients in this group (44%) who underwent invasive angiography. CCTA was performed in 26 patients (6%), of whom 4 (15%) were found to have stenosis of 50% or more. A total of 167 patients (36%) did not undergo an objective assessment for ischemia or coronary artery disease.

SAFETY

With respect to the primary outcome, none of the 640 subjects who had a negative CCTA examination died or had a myocardial infarction within 30 days after presentation (0%; 95% confidence interval [CI], 0 to 0.57); thus, the results met the prespecified safety threshold (upper limit of the confidence interval, <1%). With respect to the secondary out-

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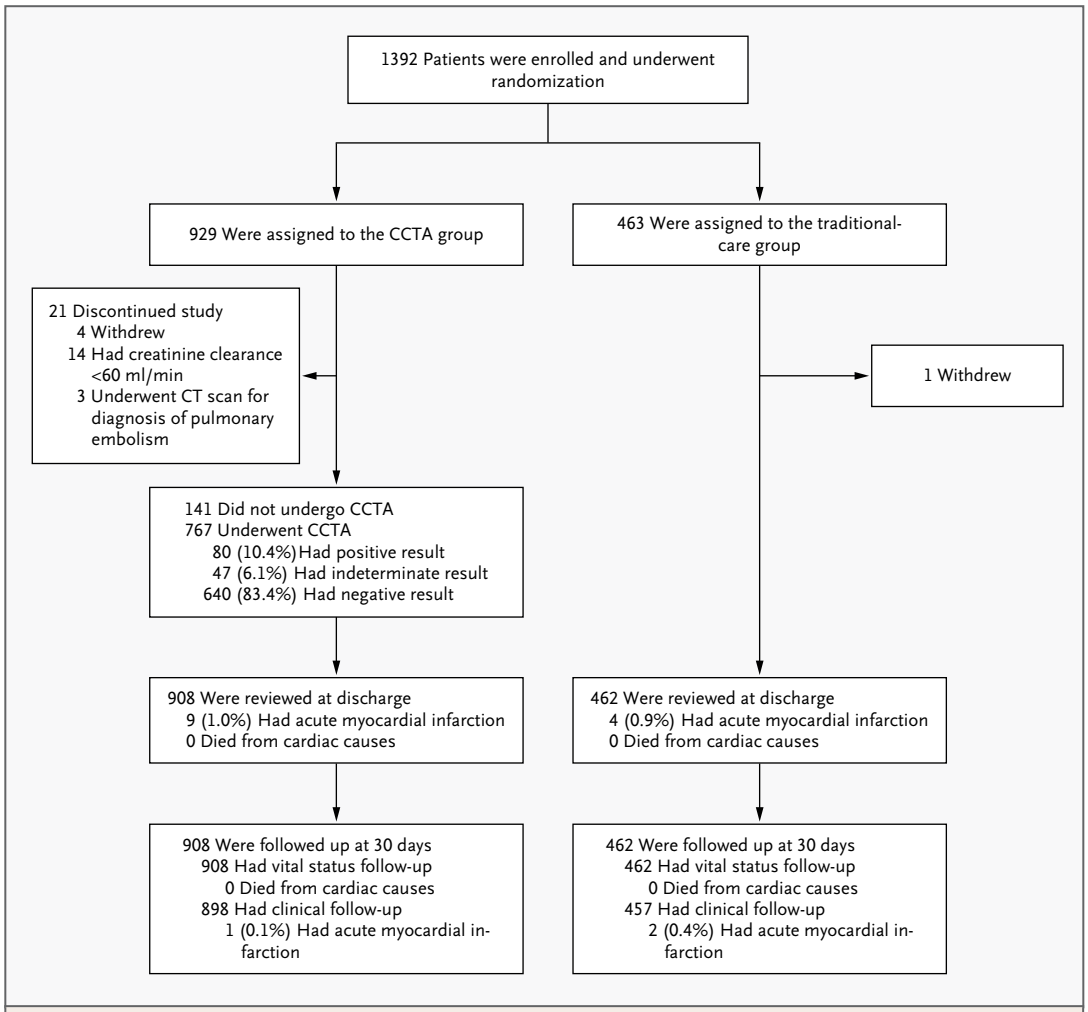

Figure 1. Enrollment, Randomization, Treatment, and Follow-up of the Study Patients.

comes (Table 3), there were no cardiac deaths among the patients in the CCTA group; 10 of the 908 patients in that group (1%) had a myocardial infarction within 30 days after presentation. There were also no cardiac deaths among the patients in the traditional-care group; 5 of the 462 patients in that group (1%) had a myocardial infarction (a difference of 0.02 percentage points for the comparison of the CCTA group with the traditional-care group; 95% CI, −5.6 to 5.7). There was one serious adverse event (bradyarrhythmia) in each group; in both cases, the event was considered by the investigators to be probably related to medications for control of the heart rate.

EFFICIENCY AND USE OF RESOURCES

As compared with patients in the traditional-care group, patients in the CCTA group were more likely to be discharged from the emergency department (49.6% vs. 22.7%; difference, 26.8 percentage points; 95% CI, 21.4 to 32.2); in addition, patients in the CCTA group, especially those with negative tests, had a shorter length of stay (Table 4). Coronary disease was more likely to be diagnosed in patients in the CCTA group than in patients in the traditional-care group (9.0% vs. 3.5%; difference, 5.6 percentage points; 95% CI, 0 to 11.2).

Over the course of 30 days after presentation, there was no significant difference between the CCTA group and the traditional-care group in the use of invasive angiography (5.1% and 4.2%, respectively; difference, 0.9 percentage points; 95% CI, −4.8 to 6.6) or in the rate of revascularization (2.7% and 1.3%, respectively; difference, 1.4 percentage points; 95% CI, −4.3 to 7.0). Patients in the CCTA group tended to be less likely than pa-

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tients in the traditional-care group to have negative findings on invasive angiography (29% vs. 53%; difference, –23.7 percentage points; 95% CI, –48.8 to 3.3). There was no significant between-group difference in the likelihood of a repeat emergency department visit, hospitalization, or cardiologist office visit. The results of a per-protocol analysis are provided in Table S1 in the Supplementary Appendix.

DISCUSSION

In this large, "real world" clinical trial, we found that the upper limit of the confidence interval for the rate of death or myocardial infarction within 30 days after presentation among patients with a negative CCTA examination was less than 1%. As compared with traditional care, the CCTA-based strategy was associated with an increased rate of

Table 1. Baseline Characteristics of the Study Patients.*

Characteristic	CCTA-Based Strategy (N=908)	Traditional Care (N=462)
Age — yr		
Mean	49±9	50±10
Range	30–78	30–83
Sex — no. (%)		
Male	443 (49)	202 (44)
Female	465 (51)	260 (56)
Race or ethnic group — no. (%)†‡		
Black	525 (58)	288 (62)
White	361 (40)	162 (35)
Asian	11 (1)	7 (2)
American Indian or Alaska Native	5 (1)	6 (1)
Native Hawaiian or other Pacific Islander	2 (<1)	0
Unknown	9 (1)	4 (1)
Hispanic or Latino ethnic group — no. (%)†		
Yes	21 (2)	11 (2)
No	867 (95)	439 (95)
Unknown	20 (2)	12 (3)
Cardiac history and risk factors — no. (%)‡		
Hypertension	463 (51)	232 (50)
Hypercholesterolemia	249 (27)	118 (26)
Family history of CAD	268 (30)	126 (27)
Diabetes mellitus	130 (14)	64 (14)
Current tobacco use	291 (32)	156 (34)
Cocaine use in previous week	49 (5)	20 (4)
Myocardial infarction	10 (1)	6 (1)
Heart failure	10 (1)	9 (2)
Pulse at presentation — no. (%)		
≥80 beats/min	519 (57)	250 (54)
60–79 beats/min	356 (39)	197 (43)
<60 beats/min	33 (4)	15 (3)

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Table 1. (Continued.)

Characteristic	CCTA-Based Strategy (N=908)	Traditional Care (N=462)
Electrocardiographic findings at presentation — no. (%)		
Normal	584 (64)	299 (65)
Nonspecific	208 (23)	111 (24)
Early repolarization	24 (3)	14 (3)
Nondiagnostic abnormalities	68 (7)	24 (5)
Ischemia		
Known to have been present previously	11 (1)	6 (1)
Not known to have been present previously	10 (1)	7 (2)
ST elevation consistent with previous acute myocardial infarction	2 (<1)	0
Other or unknown	1 (<1)	1 (<1)
TIMI risk score — no. (%)		
0	461 (51)	234 (51)
1	325 (36)	166 (36)
≥2	122 (13)	62 (13)

* Plus–minus values are means ±SD. There were no significant differences between the groups with respect to any of the characteristics listed. CAD denotes coronary artery disease, CCTA coronary computed tomographic angiography, and TIMI Thrombolysis in Myocardial Infarction.
† Race or ethnic group was determined by the investigator.
‡ Percentages may not add up to 100 because some patients had more than one disorder or risk factor or may have indicated more than one race.

discharge from the emergency department and a reduced overall length of stay. In addition, with the CCTA strategy, fewer patients had negative invasive angiograms and more patients were identified as having coronary disease.

This study supports findings from prior, smaller investigations suggesting a benefit of CCTA-based strategies for the evaluation of low-to-intermediate-risk patients whose symptoms warranted admission or further evaluation. Observational trials suggested similar safety and efficacy profiles but were limited by the lack of a comparison group[23-25] or by the fact that the results of diagnostic testing were concealed from the clinicians.[25] In previous randomized, controlled trials,[29,30] the statistical power to show the safety of a CCTA-based strategy for low-to-intermediate-risk patients (i.e., that CCTA was a reliable test on which to base decisions) was not sufficient to justify the widespread incorporation of this strategy into practice. The current study was powered to provide adequate statistical precision for determining whether the safety of the CCTA-based strategy was within a

Table 2. Diagnostic Testing Performed during Index Visit.

Test and Result	CCTA-Based Strategy (N=908)	Traditional Care (N=462)
	no./total no. (%)	
CCTA	767/908 (84)	26/462 (6)
Maximal stenosis <50%	640/767 (83)	20/26 (77)
Maximal stenosis 50–69%	52/767 (7)	2/26 (8)
Maximal stenosis ≥70%	28/767 (4)	2/26 (8)
Indeterminate or nondiagnostic	47/767 (6)	2/26 (8)
Stress testing, with or without imaging	124/908 (14)	267/462 (58)
Normal	98/124 (79)	245/267 (92)
Reversible ischemia	15/124 (12)	16/267 (6)
Indeterminate or nondiagnostic	11/124 (9)	6/267 (2)
Cardiac catheterization	37/908 (4)	18/462 (4)
Maximal stenosis <50%	9/37 (24)	10/18 (56)
Maximal stenosis ≥50%	28/37 (76)	8/18 (44)
None of the above tests	80/908 (9)	167/462 (36)

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Table 3. Outcomes and Use of Resources within 30 Days after Presentation.

Variable	CCTA-Based Strategy (N=908)	Traditional Care (N=462)	Difference, CCTA-Based Strategy – Traditional Care (95% CI)
	no./total no. (%)		*percentage points*
Cardiovascular event			
Death	0	0	0
Acute myocardial infarction*	10/908 (1)	5/462 (1)	0.02 (–5.6 to 5.7)
Composite of death or acute myocardial infarction	10/908 (1)	5/462 (1)	0.02 (–5.6 to 5.7)
Revascularization	24/893 (3)	6/457 (1)	1.4 (–4.3 to 7.0)
Resource used			
Cardiologist office visit	62/878 (7)	17/451 (4)	3.3 (–2.4 to 9.0)
Emergency department revisit	71/885 (8)	34/452 (8)	0.5 (–5.2 to 6.2)
Hospital admission after index visit	28/889 (3)	11/456 (2)	0.7 (–4.9 to 6.4)
Diagnostic testing			
CCTA			
Test performed	767/905 (85)	27/454 (6)	Not applicable†
Results showed maximal stenosis ≥50%	80/767 (10)	4/27 (15)	–4.4 (–23.6 to 14.8)
Stress test without imaging			
Test performed	11/886 (1)	10/454 (2)	Not applicable†
Results showed reversible ischemia	0	1/10 (10)	–10 (–48.8 to 32.2)
Stress test with imaging			
Test performed	140/891 (16)	264/458 (58)	Not applicable†
Results showed reversible ischemia	15/140 (11)	18/264 (7)	3.9 (–6.4 to 14.1)
Cardiac catheterization			
Test performed	45/887 (5)	19/454 (4)	0.9 (–4.8 to 6.6)
Results showed maximal stenosis ≥50%	32/45 (71)	9/19 (47)	23.7 (–3.3 to 48.8)
Resting echocardiogram			
Test performed	55/888 (6)	30/454 (7)	–0.4 (–6.1 to 5.2)
Results showed focal wall-motion abnormality	5/55 (9)	4/30 (13)	–4.2 (–26.1 to 18.0)
Medication use at 30 days			
Aspirin	196/884 (22)	113/452 (25)	–2.8 (–8.5 to 2.8)
Thienopyridines	31/884 (4)	8/452 (2)	1.7 (–3.9 to 7.4)
Statins	120/885 (14)	48/452 (11)	2.9 (–2.7 to 8.6)

* One patient in the CCTA group who had been found to have coronary artery disease on the initial test had an acute myocardial infarction after discharge from the hospital.
† Calculation of the between-group difference is not applicable, since testing disparities were dictated by the study design.

threshold that most emergency department physicians would find acceptable (i.e., an upper limit of the confidence interval of <1% for the occurrence of death or myocardial infarction within 30 days after a negative test).[1,3,4,6,8,10,11,15,23,24] In addition, the management of the patient's condition and the decision regarding admission or discharge after diagnostic testing were at the discretion of the treating clinician, thereby reflecting real-world practice.

A safe and efficient clinical decision rule or diagnostic test for patients with a possible acute coronary syndrome is highly desirable. Acute chest-pain syndromes are the second most common reason for emergency department visits, with more than 6 million such visits occurring annually in the

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Table 4. Outcomes during the Index Visit.

Outcome	CCTA-Based Strategy (N=908)	Traditional Care (N=462)	Difference, CCTA-Based Strategy – Traditional Care (95% CI)
			percentage points
Disposition — no. (%)			
Discharge	450 (50)	105 (23)	26.8 (21.4 to 32.2)
Admission or observation	458 (50)	357 (77)	
Length of stay — hr			
Overall*			
Median	18.0	24.8	
Interquartile range	7.6 to 27.2	19.2 to 30.5	
Patients with negative test*			
Median	12.3	24.7	
Interquartile range	7.0 to 24.3	19.7 to 29.6	
Medications prescribed at discharge — no. (%)			
Aspirin	233 (26)	110 (24)	1.9 (–3.8 to 7.5)
Thienopyridines	24 (3)	7 (2)	1.1 (–4.5 to 6.7)
Statins	153 (17)	75 (16)	0.6 (–5.0 to 6.2)
Cardiovascular events — no. (%)			
Death	0	0	0
Acute myocardial infarction	9 (1)	4 (1)	0.1 (–5.5 to 5.7)
Acute coronary syndrome without acute myocardial infarction	28 (3)	7 (2)	1.6 (–4.0 to 7.2)
Diagnosis of coronary disease	82 (9)	16 (3)	5.6 (0 to 11.2)
Revascularization	23 (3)	4 (1)	1.7 (–3.9 to 7.3)

* P<0.001 for the comparison between the two groups.

United States.[37] Although an acute coronary syndrome is ultimately diagnosed in only 10 to 15% of patients who present with chest pain, the majority of these patients are admitted to hospitals, at an estimated cost of over $3 billion annually.[38] We found that 50% of patients whose symptoms were evaluated with the use of a CCTA-based strategy were discharged home from the emergency department. This was more than double the rate of discharge among patients in the traditional-care group and exceeds typical rates in this patient population.[4,5,7-11,13-15] Since low-to-intermediate-risk patients account for 50 to 70% of presentations with a possible acute coronary syndrome,[10,11] we believe that a CCTA-based strategy can safely and efficiently redirect many patients home who would otherwise be admitted.

There are several limitations to our study. Studies of diagnostic procedures in which the event rates are very low cannot reasonably be powered to show between-group differences in safety. Therefore, we powered our study on the basis of a conservative safety estimate that would be acceptable to clinicians evaluating similar patients.

Because some clinicians believe that many low-risk patients should not undergo diagnostic testing, we carefully focused enrollment on patients who were being admitted or who were expected to undergo objective testing. As occasionally occurs with transitions of care, some patients did not undergo testing by the team that was assuming responsibility for their care. The median age and risk-factor profile of the patients in our study, as well as the prevalence of coronary disease among our patients, are consistent with those in other studies of low-to-intermediate-risk patients who present with chest pain.[10,11,23-30] Our results should not be extrapolated to groups with a higher pre-

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test probability of clinically significant coronary disease.

CCTA does result in radiation exposure. Recent technological advances have reduced radiation exposure[39] to the point that the average exposure is typically less than that from nuclear myocardial perfusion imaging.[40] We found that 16% of patients who were randomly assigned to CCTA did not undergo the test, owing most often to persistent elevation of their heart rate (27%). As CT technology improves, high-quality studies can be performed with less need for control of the patient's heart rate.

Finally, CCTA is an anatomical rather than a functional test. Thus, some patients may be found to have coronary artery disease that might not have been related to the presenting symptoms. Longer-term follow-up will be needed to better answer the question of whether detection of disease by CCTA leads to improved preventive interventions or, conversely, starts a diagnostic cascade of further testing that might otherwise not have been indicated.

In conclusion, a strategy in which CCTA is used as the first imaging test for low-to-intermediate-risk patients presenting to the emergency department with a possible acute coronary syndrome appears to allow the safe discharge of patients after a negative test. Increased rates of discharge home and a reduced length of stay make this strategy more efficient than traditional care. Whether earlier identification of coronary disease will lead to preventive therapies that improve long-term outcomes requires further study.

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