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Low-Risk Patients With Chest Pain in the Emergency Department: Negative 64-MDCT Coronary Angiography May Reduce Length of Stay and Hospital Charges

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Abstract

OBJECTIVE—The current standard-of-care workup of low-risk patients with chest pain in an emergency department takes 12–36 hours and is expensive. We hypothesized that negative 64-MDCT coronary angiography early in the workup of such patients may enable a shorter length of stay and reduce charges.

MATERIALS AND METHODS—The standard-of-care evaluation consisted of serial cardiac enzyme tests, ECGs, and stress testing. After informed consent, we added cardiac CT early in the standard-of-care workup of 53 consecutive patients. Fifty patients had negative CT findings and were included in this series. The length of stay and charges were analyzed using actual patient data for all patients in the standard-of-care workup and for two earlier discharge scenarios based on negative cardiac CT results: First, CT plus serial enzyme tests and ECGs during an observation period followed by discharge if all were negative; and second, CT plus one set of enzyme tests and one ECG followed by discharge if all were negative. Comparisons were made using paired Student's *t* tests.

RESULTS—For standard of care and the two CT-based earlier discharge analyses, the mean lengths of stay were 25.4, 14.3, and 5.0 hours; mean charges were \$7,597, \$6,153, and \$4,251. Length of stay and charges were both significantly less ($p < 0.001$) for the two CT-based analyses.

CONCLUSION—In low-risk patients with chest pain, discharge from the emergency department based on negative cardiac CT, enzyme tests, and ECG may significantly decrease both length of stay and hospital charges compared with the standard of care.

Keywords

chest pain; cost analysis; CT coronary angiography; emergency department; length of stay

Each year in the United States, more than 6 million patients present to emergency departments with chest pain [1]. These patients can be divided into categories of low, moderate, and high risk for acute coronary syndrome using the thrombolysis in myocardial infarction (TIMI) risk criteria [2–4]. Up to 79% of emergency department chest pain patients fall into the low-risk category (TIMI 0–2). About 5% of TIMI low-risk patient have acute coronary syndrome, compared with 20% for intermediate risk, and 40% for high risk [5]. Morbidity from missed acute coronary syndrome in the emergency department is high, resulting in a cautious and thorough evaluation of chest pain [6].

Current emergency department standard-of-care (SOC) workup for low-risk chest pain patients often involves serial cardiac enzyme tests, serial ECGs, and a cardiac stress test. Such a workup can take up to 30 hours and is expensive [7–11]. If low-risk patients could be ruled out for coronary artery disease earlier in their emergency department evaluation, both length of stay and overall charges might be reduced. With increasing congestion and cost in the practice of emergency medicine, such reductions may have an important effect.

ECG-gated coronary 64-MDCT angiography (coronary CTA) has a negative predictive value of 97–99% for significant coronary artery stenosis [12–16]. We hypothesized that a negative coronary CTA combined with negative ECG and negative cardiac enzyme tests in low-risk patients with chest pain might enable a shorter length of stay and decrease overall charges compared with the current SOC. The purpose of this study was to perform three analyses of the length of stay and of the charges incurred in a sequential group of low-risk patients with chest pain evaluated in the emergency department. The first of these three analyses was the SOC received by these patients. The second and third analyses involved earlier discharge scenarios based on negative coronary CTA results.

Materials and Methods

This HIPAA-compliant study was approved by the university institutional review board. Written informed consent was obtained from each patient by a trained and experienced research associate who recruited patients in this urban academic emergency department between the hours of 7:00 am and 6:00 pm, Monday through Friday. The consent allowed the addition of cardiac coronary CTA to the SOC workup and also allowed the researchers access to electronic medical and billing records related to the emergency department visits.

Patients

Qualifying patients all had chest pain and a low TIMI risk score of 0–2. Patients were excluded if they had positive initial cardiac enzyme tests, new ischemic ECG changes, TIMI risk score greater than 2, known cardiac disease, or inability to achieve a heart rate below 75 beats per minute (bpm) with the use of β -blockers. Clinical exclusion criteria for coronary CTA included severe allergy to iodine-containing contrast material, history of compromised renal function (calculated glomerular filtration rate < 40 mL/min/1.73 m²), pregnancy, a nonsinus rhythm, severe respiratory or cardiac failure, women under the age of 45 years, men under the age of 30, or a body mass index (BMI) greater than 40. Between September 2006 and December 2007, we enrolled 53 sequential patients who met these criteria.

Tests

At admission, as part of the SOC for chest pain, all patients underwent initial 12-lead ECG, a cardiac troponin I test, and chest radiography. In addition, each patient also had blood laboratory work and received drugs tailored to the presenting symptoms (Fig. 1). After the initial negative ECG and negative cardiac enzyme results were made available to the emergency department physician, in addition to the SOC, all patients consented to undergo

64-MDCT coronary CTA with retrospective ECG gating and tube current modulation or with prospective ECG triggering (LightSpeed VCT XT, GE Healthcare). Circulation time was determined with a timed bolus of 20 mL of iodixanol (Visipaque 320, GE Healthcare). Contrast enhancement was achieved using a three-phase bolus (70 mL of iodixanol followed by 50 mL of a 70:30 blend of iodixanol and saline, followed by 50 mL of saline) injected at 5 mL/s. Coronary CTA was acquired with detector collimation of 64×0.625 mm at 0.625-mm increments and with a gantry rotation time of 0.35 second. A negative coronary CTA examination was defined as no greater than 30% luminal stenosis in any coronary artery segment as interpreted by two experienced reviewers working independently at separate times on a dedicated workstation (AW 4.4, GE Healthcare) [10]. One reviewer was a radiologist and one a cardiologist, both with 5 years' experience with coronary CTA.

After the coronary CTA examination, patients were transferred to an emergency department observation unit, and SOC testing was continued, which included serial 12-lead ECG examinations and serial cardiac enzyme tests every 6 hours for 12 hours. After the negative results were available from this serial testing, the patient stayed in the observation unit until a stress test (^{99m}Tc -tetrofosmin SPECT or stress echocardiography) was performed as soon as possible during regular business hours (8:00 am to 5:00 pm).

Follow-Up

Forty-six patients were contacted by telephone 3 months after their emergency department visit, and 48 were contacted at 6 months. Using this combination, 49 of the 50 patients were contacted and questioned about evidence of subsequent major adverse cardiovascular events. One patient was lost to follow-up.

Data Collection and Processing

Test results and time course for this analysis were obtained from each patient's electronic medical record. Patient admitting time, time of tests and results, and patient discharge times were all entered into the study database. All hospital charges associated with each patient's emergency department course were obtained from the hospital electronic billing program (Horizon Performance Manager 10.2, McKesson Corporation) (Appendix 1). Professional fee charges were obtained from the academic medical practice electronic billing program (EPIC 1.0, EPIC Corporation). The charge profile of each patient was unique, based on clinical course and care decisions made by health care providers.

Outcome measures included total charges and length of stay. These were first analyzed for the SOC based on the actual course of events experienced by the patient, including an observation period with serial enzyme tests (two or three sets spaced 6 hours apart as determined by the emergency department providers), serial ECGs, and a stress test. For this SOC analysis, the actual emergency department discharge time was the end point (Fig. 1); coronary CTA results or charges were not included. The second analysis (coronary CTA with observation) for the same patient encounter included coronary CTA performed as soon as possible after admission (within 90 minutes) and encompassed the time from admission through a subsequent period of observation, serial cardiac enzyme tests, and serial ECGs. This second analysis ended one hour after the negative results from the final of the serial cardiac enzyme tests were reported to the emergency department physician and did not include a stress test. The third analysis (coronary CTA without observation) for the same patient encounter included initial admission enzyme tests plus ECG and coronary CTA performed as soon as possible after admission. This third analysis involved only the period of time from admission until 1 hour after the negative coronary CTA results were reported to the emergency department physician and did not include an observation period, serial enzyme tests, serial ECGs, or a stress test. The three analyses were compared using paired

Student's *t* tests between SOC and the two earlier discharge scenarios using SPSS 16.0 for Windows.

Results

Of the 53 patients enrolled, three had a positive coronary CTA that showed evidence of coronary artery disease with greater than 30% stenosis in a coronary artery segment; these patients were excluded from this series. Fifty patients had negative coronary CTA findings and were included. These patients were 31 men and 29 women with a mean age of 53 ± 8 (SD) years and a mean BMI of 28 ± 5 .

For all patients, serial enzyme tests and serial ECGs remained negative throughout the SOC. Subsequently, each patient had negative stress test results with no evidence of cardiac ischemia. At both 3 and 6 months, none of the patients in this series contacted by telephone reported a subsequent major adverse cardiac event.

The SOC mean length of stay was 25.4 hours. The mean length of stay for coronary CTA with observation was 14.3 hours, and for coronary CTA without observation was 5.0 hours. Both were significantly shorter than the SOC ($p < 0.001$). The SOC mean charges were \$7,597. The mean charges for coronary CTA with observation were \$6,153 (19% < the SOC), and for coronary CTA without observation were \$4,251 (44% < the SOC). Both differences were statistically significant ($p < 0.001$) (Table 1).

Discussion

With the present focus on emergency department congestion and cost containment, new methods to reduce length of stay and charges may have a positive effect [17]. We hypothesized that using coronary CTA in the large proportion of chest pain patients who have negative serum cardiac enzyme tests and negative ECG results might enable an earlier discharge and incur fewer charges than the current SOC if the coronary CTA results were also negative [12]. In this study, we tested that hypothesis using patient data and charges from actual patient emergency department experience. Although the two coronary CTA-based earlier discharge scenarios in this study did not occur, each of the three analyses was based on actual charges and time periods experienced by these patients as they received SOC evaluation in the emergency department. We found that both earlier discharge scenarios based on negative coronary CTA resulted in a statistically significant reduction in length of stay and a reduction in charges compared with the SOC.

We emphasize that this was not a cost-effectiveness study. Rather, this charge minimization study had a limited specific objective of analyzing only the potential savings that might result from inclusion of negative coronary CTA test results based on actual emergency department patient experience. Such savings from negative coronary CTA results, if present, might warrant undertaking a randomized controlled study of cost-effectiveness, including the implications of positive coronary CTA results.

Cost-effectiveness in emergency department patients with chest pain has been studied most often through modeling [7, 8, 18]. Such a modeling approach is typically based on preselected decision pathways and estimations from literature about cost, test accuracy, time to diagnosis, and disease prevalence. Modeling is limited by potential unknowns, such as actual patient experience, by publication bias in test performance parameters, by the accuracy of key assumptions, by the impact of variables not included in the model (e.g., incidental findings), and by multiple treatment thresholds in the clinical environment. Because of these limitations of modeling, some authors have called for validation using data from actual patient experience [7, 8]. Three small randomized controlled trials with actual

patient experience data have been published, and each has suggested decreased length of stay and decreased cost from adding coronary CTA to the evaluation of acute chest pain in the emergency department [10, 19, 20]. Our results tend to agree with these articles. In addition, three other published series reported that patients discharged from the emergency department on the basis of a negative initial evaluation and negative coronary CTA had no subsequent major adverse cardiac events at the 1-month follow-up [16, 21, 22].

This study has several important limitations. First, we did not look at charges stemming from positive, false-negative, or incidental coronary CTA findings. This study design was limited to identification of the potential savings from the use of coronary CTA in the large fraction of low-risk emergency department patients with chest pain in whom the high negative predictive value of coronary CTA might have the most impact [23]. Second, this study population was from a single institution; the results may not be applicable to other patient populations. Other institutions may have different charges, may practice a different SOC for low-risk patients with chest pain, and may not have rapid availability to cardiac CT for emergency department patients. Third, we did not look at cost but only at charges. However, the rate of payment discounts and write-offs at our institution is relatively constant, suggesting a good correlation between cost and charges.

In conclusion, discharge based on negative coronary CTA, negative cardiac enzyme tests, and negative ECG may significantly decrease both length of stay and hospital charges compared with SOC for low-risk emergency department patients with chest pain. These results suggest that a large randomized study of the cost-effectiveness of coronary CTA in the emergency department may be warranted.

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APPENDIX 1: Charge Categories Encountered in Clinical Care of Low-Risk Patients With Chest Pain Presenting to the Emergency Department

APPENDIX 1

Charge Categories Encountered in Clinical Care of Low-Risk Patients With Chest Pain Presenting to the Emergency Department

Laboratory	Pharmacology
Amylase	Acetaminophen
Basic metabolic panel	Aluminum magnesium hydroxide
Bilirubin, direct	Amlodipine
Blood culture	Atenolol
Blood glucose	Hydration, IV infusion per hour
β-Natriuretic peptide	Ibuprofen
CBC, differential, smear	Ketorolac injection
CBC, hemogram	Lidocaine, 2% solution
Complete blood panel	Lorazepam injection
Complete metabolic panel	Metoprolol IV
Creatine kinase-MB fraction	Metoprolol tablets

Laboratory	Pharmacology
Creatine kinase	Morphine IV
D-dimer	Nitroglycerine
Free thyroxine	Ondansetron injection
HGC pregnancy serum	Ramipril
Magnesium, blood	Ranitidine
Partial thromboplastin	Sodium chloride, 0.9%
Phosphorus, blood	^{99m} Tc tetrofosmin
Prothrombin	Thallium-201 chloride
Thyroid stimulating hormone	Visipaque (iodixanol, GE Healthcare)
Troponin I	Zolpidem
Urinalysis, complete	
Diagnostic Tests and Monitoring	Professional Charges
12-lead ECG	Radiologist
Chest radiography, 1-view (posteroanterior) or 2-view (posteroanterior and lateral)	Chest radiography
Coronary CT angiography	Coronary CT angiography
Echocardiography	Cardiologist
Myocardial perfusion scanning	ECG
Stress test for stress/echocardiography	Stress testing
Emergency department visit, level 4, level 5	Echocardiography
Observation unit admission and discharge	Emergency department physician
Initial observation unit care, levels 1–3	Level 4
Observation unit charges/hour	Level 5
Supervision for stress test	
Venipuncture	
IV administration, initial drug	
IV administration, each additional drug	

Note—Not all patients had all charges. CBC = complete blood count.

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Fig. 1.
Temporal sequence of events in three analyses of emergency department length of stay and charges.

TABLE 1**Mean Length of Stay and Charges**

Analysis of Workups	Emergency Department	
	Length of Stay (h)	Charges (U.S. \$)
Standard of care	25.4 ± 6.3	7,597 ± 2,216
Coronary CTA with observation	14.3 ± 5.0 ^a	6,153 ± 1,196 ^a
Coronary CTA without observation	5.0 ^a	4,251 ± 420 ^a

Note—Data are mean ± SD.

^a $p < 0.001$ when compared to standard of care.