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Stress CMR Reduces Revascularization, Hospital Readmission, and Recurrent Cardiac Testing in Intermediate-Risk Patients With Acute Chest Pain

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OBJECTIVES The aim of this study was to determine the effect of stress cardiac magnetic resonance (CMR) imaging in an observation unit (OU) on revascularization, hospital readmission, and recurrent cardiac testing in intermediate-risk patients with possible acute coronary syndromes (ACS).

BACKGROUND Intermediate-risk patients commonly undergo hospital admission with high rates of coronary revascularization. It is unknown whether OU-based care with CMR is a more efficient alternative.

METHODS A total of 105 intermediate-risk participants with symptoms of ACS but without definite ACS on the basis of the first electrocardiogram and troponin were randomized to usual care provided by cardiologists and internists (n = 53) or to OU care with stress CMR (n = 52). The primary composite endpoint of coronary artery revascularization, hospital readmission, and recurrent cardiac testing at 90 days was determined. The secondary endpoint was length of stay from randomization to index visit discharge; safety was measured as ACS after discharge.

RESULTS The median age of participants was 56 years (range 35 to 91 years), 54% were men, and 20% had pre-existing coronary disease. Index hospital admission was avoided in 85% of the OU CMR participants. The primary outcome occurred in 20 usual care participants (38%) versus 7 OU CMR participants (13%) (hazard ratio: 3.4; 95% confidence interval: 1.4 to 8.0, p = 0.006). The OU CMR group experienced significant reductions in all components: revascularizations (15% vs. 2%, p = 0.03), hospital readmissions (23% vs. 8%, p = 0.03), and recurrent cardiac testing (17% vs. 4%, p = 0.03). Median length of stay was 26 h (interquartile range: 23 to 45 h) in the usual care group and 21 h (interquartile range: 15 to 25 h) in the OU CMR group (p < 0.001). ACS after discharge occurred in 3 usual care participants (6%) and no OU CMR participants.

CONCLUSIONS In this single-center trial, management of intermediate-risk patients with possible ACS in an OU with stress CMR reduced coronary artery revascularization, hospital readmissions, and recurrent cardiac testing, without an increase in post-discharge ACS at 90 days. (Randomized Investigation of Chest Pain Diagnostic Strategies; NCT01035047) (J Am Coll Cardiol Img 2013;6:785–94)

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Recent reports have demonstrated the adaptability of cardiac magnetic resonance (CMR) for testing emergency department (ED) patients with symptoms concerning for acute coronary syndromes (ACS) (1–5). Attributes of CMR making this modality appealing for use in ED patients are its abilities to diagnose myocardial infarction (MI) before troponin elevation (1), differentiate between new and old infarcts (6), and accurately determine prognosis (7). These strengths of CMR allow patients at intermediate risk for ACS, commonly managed as inpatients, to be evaluated in an observation unit (OU) setting.

In intermediate-risk patients, OU-based care with stress CMR testing reduced cost over the course of 1 year compared with an inpatient care strategy in a recent analysis of a single-center randomized trial (8). An ancillary finding of that trial was a reduction in coronary revascularization associated with OU CMR that did not reach statistical significance. Reducing revascularization procedures may be desirable because they are expensive, and up to two-thirds of coronary revascularization procedures in the United States are of uncertain appropriateness or do not meet appropriateness criteria (9). In addition, emerging evidence suggests that intervention in stable coronary lesions may not improve outcomes (10), and revascularization is associated with a high rate of readmissions and repeat revascularizations in the short term after the procedure (11). Together, these data suggest that efficiency gains could result from more carefully selecting patients for coronary revascularization procedures.

ABBREVIATIONS AND ACRONYMS

ACS = acute coronary syndromes

CMR = cardiac magnetic resonance

ED = emergency department

IQR = interquartile range

MI = myocardial infarction

OU = observation unit

TIMI = Thrombolysis In Myocardial Infarction

Evaluation of the efficiency of a cardiac-related care pathway must consider not only coronary revascularization but also the impact on other clinical events, such as the need for additional cardiac testing, hospital readmissions, and delayed cardiac events. We hypothesized that an OU CMR care strategy would provide a highly accurate, noninvasive, comprehensive assessment during the index visit, thereby allowing some patients to safely avoid revascularization while reducing hospital readmissions and recurrent cardiac testing. Accordingly, we conducted a single-center trial powered to detect a difference in the composite endpoint of coronary revascularization, hospital readmission, and recurrent cardiac testing 90 days after randomization between OU CMR and usual inpatient care strategies.

METHODS

Study design. We conducted a randomized, controlled, single-center clinical trial funded by grant 1 R21 HL097131-01A1 from the National Heart, Lung, and Blood Institute. The study was approved by the institutional review board of the Wake Forest School of Medicine and registered at ClinicalTrials.gov (NCT01035047) before enrollment. All participants provided written consent for study participation and were randomized to an OU CMR strategy or usual care, an inpatient-based strategy. In the OU CMR strategy, participants were managed in an OU setting, underwent serial troponin measurements at 4 and 8 h after arrival, and underwent stress CMR exams at the first available time. Participants in the usual care group were evaluated by the inpatient service for hospital admission and further diagnostic evaluation as determined by their care providers. Disposition decisions and subsequent testing in both groups were performed at the discretion of the care providers.

Setting. Participants were recruited from the ED of Wake Forest Baptist Medical Center. The study institution is a tertiary care academic medical center located in the Piedmont Triad area of North Carolina, serving urban, suburban, and rural populations. The ED volume in 2011 consisted of 103,000 patient encounters. This study population is distinct from other studies we have previously published from the OU setting.

At the study institution, patients with chest pain and related symptoms, but without definite

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ACS, are risk-stratified by attending emergency physicians in the ED as low risk (TIMI [Thrombolysis In Myocardial Infarction] risk score < 2) or elevated risk. Low-risk patients are managed in the OU, whereas elevated-risk patients are managed as inpatients. Cardiac imaging modalities available in the OU and inpatient settings include stress imaging with echocardiography, nuclear imaging, and CMR; coronary computed tomographic angiography; and invasive catheter coronary angiography. The OU is staffed by midlevel providers, and oversight is provided by attending emergency physicians. These care providers have been exposed to the clinical use of CMR imaging since 2008 and have managed intermediate-risk participants with CMR imaging in previous trials (4,8).

Participants. Patients at least 21 years old presenting with symptoms suggestive of ACS were screened, and those eligible were consecutively approached during enrollment hours (6 days excluding Saturday, 80 h/week). Eligibility criteria required an inpatient or OU evaluation of the patient's symptoms because of at least intermediate-risk chest pain, defined as either TIMI risk score (12) ≥ 2 (corresponding to 10% or greater risk for ACS at 30 days in patients with undifferentiated chest pain [13]) or a physician's global risk assessment based on the American College of Cardiology and American Heart Association guidelines (14) of intermediate or high risk. Additionally, at the time of enrollment, the ED attending physician had to declare the patient as being safe for OU care and that the patient could be discharged home if cardiac disease were excluded as the cause of symptoms. Patients were determined ineligible for the following reasons: definite ACS at the time of enrollment (elevated initial troponin, new ST-segment elevation [≥1 mm] or depression [≥2 mm]), known inducible ischemia, hypotension, contraindications to CMR, life expectancy <3 months, pregnancy, coronary revascularization within 6 months, and increased risk for nephrogenic systemic fibrosis (defined in the study as creatinine clearance <45 ml/min or <60 ml/min if concomitant chronic liver disease, clinical concern for acute kidney injury, hepatorenal syndrome, or solid organ transplantation).

Randomization. After obtaining written consent, participants were stratified on the basis of the presence of known coronary disease (≥50% stenosis, prior MI, or revascularization), and assigned within strata to 1 of the 2 treatment arms with equal probability using variably sized permuted block randomization. The randomization sequence was generated using nQuery Advisor 6.0 (Statistical Solutions, Saugus, Massachusetts) and integrated into a secure Web site that was used by the study coordinators to register participants and obtain the study group assignments. The clinical investigators and staff members were blinded to the randomization sequence.

Study procedures. After randomization, usual care participants underwent consultation in the ED by the admitting service in accordance with customary practice. Care delivery in this group was not directed by the study protocol. In the OU CMR group, orders were placed for serial troponin and electrocardiographic assessments at 4 and 8 h after the initial evaluation, for placement into observation status, and for a vasodilator CMR exam to be conducted at the first available time. CMR exams were integrated into the daily caseload of exams without special scheduling provisions for this study. Clinical reports from the CMR exams were interpreted by the care providers in the OU to make a decision to discharge the patient home or obtain a cardiology consultation. Interpretations, the need for cardiology consultation, and decisions to perform revascularization were not directed by the study protocol.

CMR imaging. Participants underwent CMR imaging in accordance with imaging protocols used in previous trials and for clinical care at the study site that have been previously described in detail (4,5). Imaging was performed using a 1.5-T Siemens Magnetom Avanto system (Siemens Healthcare, Erlangen, Germany). An initial order was placed for an adenosine vasodilator stress exam, with regadenoson and dobutamine available as alternatives. Participants underwent assessments of resting wall motion, T2 imaging for edema, stress perfusion, rest perfusion, and delayed enhancement. Images were interpreted by a reading pool of board-certified cardiology and radiology faculty members with at least level 2 training in CMR (15), with results entered into the electronic medical record.

Blinding. Per protocol, inpatient care providers in the usual care group were not informed of the subject's participation. Subjects were also asked to refrain from discussing their participation in a clinical trial with inpatient clinical staff members. Because care providers in the OU CMR group were integral to delivering the care pathway, these providers could not be blinded to the study intervention. Participants in both groups were not routinely made aware of the study endpoints during the consent or follow-up process.

Data collection and processing. The study was conducted in accordance with standards of good

clinical practice, standardized reporting guidelines (16), and key data elements and definitions (17). A detailed map of sources of data was created before study initiation. Medical records were used as the source for data elements reliably contained in the medical record. Data collection templates were implemented to prospectively collect data from patients and ED care providers that were not reliable or not present in the electronic medical record. Data were recorded in Web-based case report forms and transferred to a secure Structured Query Language relational database.

Follow-up was conducted during the index visit using a structured record review. At both 30 and 90 days, a structured record review was followed by a structured telephone interview. Outcome events reported at other health care facilities were confirmed using a structured review of those medical records. Incomplete telephone follow-up at 90 days was handled using the following algorithm: participants with ongoing visits in the electronic medical record were considered to have complete information and were classified on the basis of the data available in the medical record; participants with no ongoing visits were considered lost to follow-up at the point of last contact (index visit discharge or 30-day telephone interview) and were censored in the analysis. Separate analyses were conducted assuming that those participants with no telephone contact had no events, as evidenced by their lack of events on chart review.

Outcomes. The primary outcome was a composite of coronary revascularization, all-cause hospital readmission, and recurrent cardiac testing within 90 days of randomization. Coronary revascularization included percutaneous and surgical revascularization occurring any time after randomization. Hospital readmission was defined as an overnight stay or placement into observation or inpatient status for >8 h, for all causes, after the index visit. Recurrent cardiac testing was defined as receiving

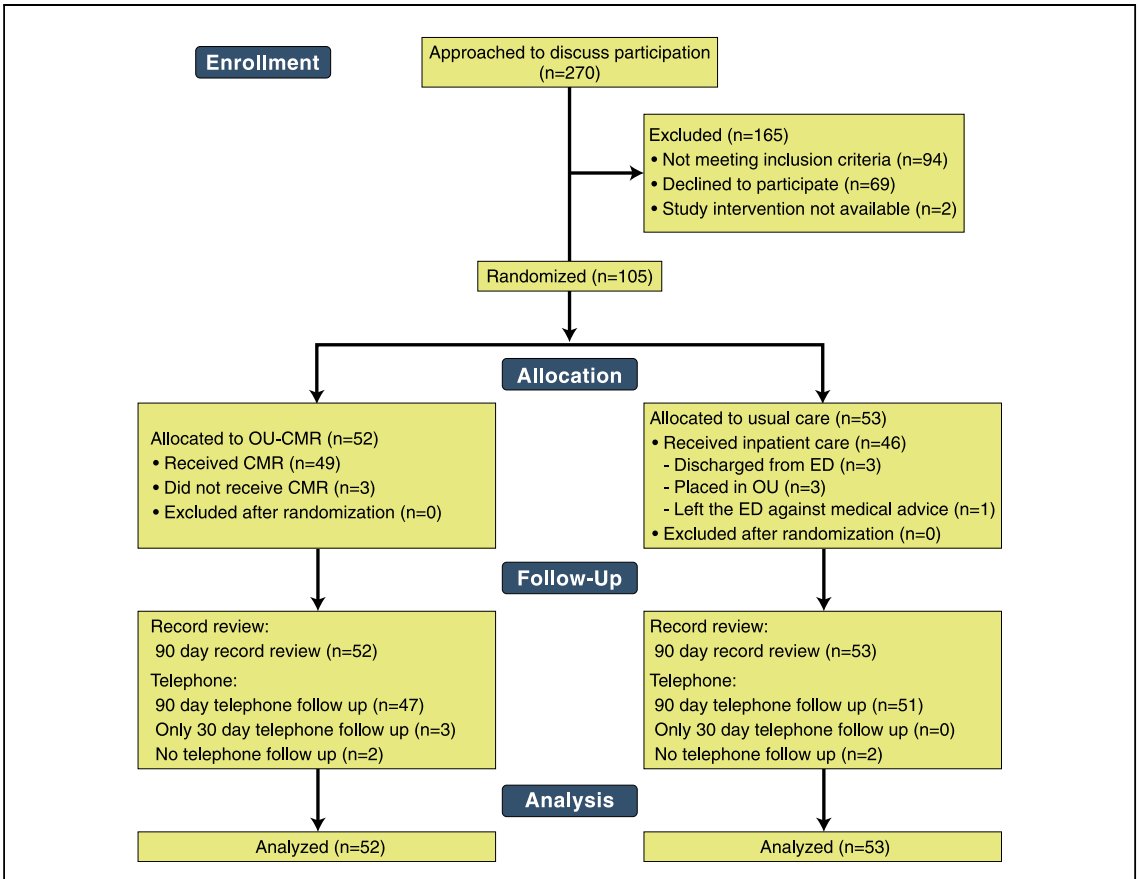

Figure 1. CONSORT Diagram

The study randomized 105 participants to observation unit (OU) cardiac magnetic resonance (CMR) imaging (n = 52) or usual care (n = 53). All were analyzed on the basis of intent to treat. CONSORT = Consolidated Standards of Reporting Trials; ED = emergency department.

1 or more of the following procedures after index visit discharge: cardiac echocardiography, CMR, nuclear imaging, coronary computed tomographic angiography, or invasive angiography.

The secondary outcome was index visit length of stay, defined as the time elapsed between randomization and discharge from the facility. Safety events were all-cause mortality within 90 days, adverse events related to index visit stress testing, and ACS after discharge and within 90 days of randomization, defined as 1 of the following: 1) acute MI according to the universal definition (18); 2) ischemic symptoms leading to revascularization; 3) death likely related to cardiac ischemia; and 4) discharge diagnosis of unstable angina with evidence of >70% coronary stenosis or inducible ischemia on stress testing if coronary angiography was not performed.

Sample size. A 3-stage, group sequential design was used to assess the difference in event rates of the primary outcome between the 2 groups. We calculated that 27 events were needed to provide 80% power for detecting a hazard ratio of 3.0 at the 5% 2-sided level of significance when data are analyzed 3 times according to the O'Brien-Fleming stopping rules (19) (S+ SeqTrial, TIBCO Spotfire, Somerville, Massachusetts). The anticipated effect size was based on preliminary data from another trial (8) demonstrating 28% versus 9% event rates (hazard ratio: 3.5) for the primary outcome favoring OU CMR. We anticipated that approximately 146 patients would be needed to achieve the required 27 events, on the basis of the estimate of the fraction of patients experiencing events.

Data analysis. For the primary outcome, the time to the composite outcome was the minimal time to any of the component events. Kaplan-Meier methods were used to estimate the time-to-event distributions for the 2 groups. Participants lost to follow-up were considered censored at their last contacts. The primary test for the group effect was accomplished using a Cox proportional hazards regression model for the time to the composite event. The primary model was based on intent to treat and included the assignment group and the stratification factor as covariates. The results of this analysis were compared with the O'Brien-Fleming stopping boundaries (19) during 2 interim analyses and the final analysis. At the final analysis, the null hypothesis was rejected if the p value was <0.045. Length of stay was measured as a continuous variable from the time of ED presentation to the time of hospital discharge. All participants were discharged; there were no index visit deaths. A Kruskal-Wallis test was used to assess the group difference in length of stay. Data analysis was conducted using SAS version 9.2 and SAS Enterprise Guide version 4.3 (SAS Institute Inc., Cary, North Carolina).

RESULTS

Over 67 weeks, 4,996 patients presented during the hours of screening and had either a chief symptom of chest pain or troponin plus electrocardiography ordered. Of these with available information, the median age was 56 years, 48% were men, and 24% had prior coronary disease. From this population, 270 patients were approached, and 105 consented and were enrolled (Fig. 1). After randomizing 105 subjects (53 inpatients, 52 OU CMR patients), the target number of participants with events (n = 27) was observed. No participants were removed from the study cohort after randomization, and analysis was

Table 1. Participant Demographics and Medical Histories

	Usual Care (n = 53)	OU CMR (n = 52)
Age, yrs	59 (40–76)	54 (35–91)
Age ≥65 yrs	15 (28)	9 (17)
Men	29 (55)	28 (54)
Race/ethnicity		
Hispanic	1 (2)	1 (2)
Black	15 (28)	20 (38)
White	37 (70)	29 (56)
Other	0 (0)	2 (4)
BMI, kg/m^2	29.6 (19.7–46.8)	30.7 (16.4–51.2)
Underweight	0 (0)	1 (2)
Normal	13 (25)	12 (23)
Overweight	16 (30)	10 (19)
Obese	24 (45)	29 (56)
Hypertension	45 (85)	37 (71)
Diabetes mellitus	16 (30)	16 (31)
Current smoking	20 (38)	21 (40)
Hyperlipidemia	39 (74)	33 (63)
Prior heart failure	1 (2)	3 (6)
Prior MI	7 (13)	9 (17)
Prior PCI	9 (17)	7 (13)
Prior CABG	1 (2)	0 (0)

Values are median (range) or n (%).
BMI = body mass index; CABG = coronary artery bypass graft; CMR = cardiac magnetic resonance; MI = myocardial infarction; OU = observation unit; PCI = percutaneous coronary intervention.

performed on the basis of intent to treat. Follow-up was conducted via chart review in all participants, and all but 6 completed the telephone interview for 90-day events (Fig. 1). To understand the likelihood of undetected events among these 6 participants, the proportion of participants experiencing events not referenced in the medical records of the study institution was calculated. In total, 26 of 27 participants (96%) with events had evidence of the events in the records of the study institution. The remaining event was confirmed by obtaining medical records from another institution.

The study cohort had a median age of 56 years (range 35 to 91 years), 54% were men, 30% had histories of diabetes mellitus, and 20% were known to have pre-existing coronary artery disease (Table 1). Chest pain was the chief symptom in 91% of participants, 89% had pain at rest, 65% had numerous episodes within 24 h, and 60% had normal electrocardiographic findings at presentation (Table 2). The TIMI risk score measured near the time of randomization did not differ among study groups and was most commonly 2 or 3 (range 0 to 5).

In subjects randomized to usual care, the disposition from the ED was inpatient admission for 46

Table 2. Presenting Characteristics and Physical Exam Findings

	Usual Care	OU CMR	p Value
Presenting characteristics			
Chest pain chief symptom*	47/50 (94)	46/52 (88)	0.488
Chest pain at rest*	43/50 (86)	48/52 (92)	0.353
Multiple episodes of symptoms within 24 h†	30/49 (61)	29/52 (56)	0.578
Chest pain present on arrival to the ED†	34/50 (68)	32/52 (62)	0.495
Chest pain pleuritic*	3/50 (6)	6/52 (12)	0.488
Physical exam			
Heart rate, beats/min‡	78 ± 12	78 ± 16	0.946
Systolic blood pressure, mm Hg‡	149 ± 21	146 ± 21	0.570
Diastolic blood pressure, mm Hg‡	87 ± 12	82 ± 14	0.058
Rales*	0/50 (0)	1/52 (2)	1.000
Chest pain reproducible*	4/47 (9)	5/47 (11)	1.000
Overall ECG classification*			0.213
Normal	34/53 (64)	29/52 (56)	
Nonspecific changes	12/53 (23)	8/52 (15)	
Early repolarization only	0/53 (0)	1/52 (2)	
Abnormal but not diagnostic of ischemia	3/53 (6)	6/52 (12)	
Infarction or ischemia known to be old	1/53 (2)	6/52 (12)	
Infarction or ischemia not known to be old	3/53 (6)	2/52 (4)	
Suggestive of acute MI	0/53 (0)	0/52 (0)	
Risk stratification			
ED physician assessment of % likelihood of ACS within 30 days§	5 (5–10)	5 (5–10)	0.852
TIMI risk score‖			0.873
0	1/53 (2)	1/52 (2)	
1	8/53 (15)	2/52 (4)	
2	21/53 (40)	29/52 (56)	
3	19/53 (36)	17/52 (33)	
4	3/53 (6)	2/52 (4)	
5	1/53 (2)	1/52 (2)	

Values are n/N (%), mean ± SD, or median (interquartile range). *Fisher exact test. †Chi-square test. ‡Data were analyzed using *t* tests. §Data were analyzed using Kruskal-Wallis tests. ‖Kruskal-Wallis test.

ACS = acute coronary syndromes; ECG = electrocardiographic; ED = emergency department; TIMI = Thrombolysis In Myocardial Infarction; other abbreviations as in Table 1.

patients (87%), discharge for 3 (6%), OU for 3 (6%), and leaving against medical advice for 1 (2%). In the OU CMR group, all subjects were placed in the OU, of whom 44 (85%) were discharged home; the remaining 8 participants (15%) were admitted. Median length of stay from randomization to final discharge from the hospital was 26 h (interquartile range [IQR]: 23 to 45 h) in the usual care group and 21 h (IQR: 15 to 25 h) in the OU CMR group ($p < 0.001$).

Cardiac imaging or angiography during the index visit was performed in 48 of 53 usual care participants (91%) and all OU-CMR participants. In the usual care group, the first test modalities were stress echocardiography in 33 (62%), catheterization in 8 (15%), stress CMR in 3 (6%), resting echocardiography in 3 (6%), coronary computed tomographic angiography in 1 (2%), and no testing in 5 (9%). Median time to completion of testing in the usual care group was 22 h (IQR: 19 to 26 h). The first cardiac test in the OU CMR group was CMR in 50 (96%) and stress echocardiography in 2 (4%) participants (Table 3). Median time to completion of the first test was 21 h (IQR: 16 to 23 h).

During the index visit, elevated troponin levels occurred in 8 participants (5 usual care and 3 OU CMR participants) after randomization and before invasive angiography (Table 4). On cardiac imaging, 6 OU-CMR participants (12%) had acute or inducible ischemia, all detected with vasodilator stress CMR, leading to invasive angiography in 5 and revascularization in 1; 2 had abnormal delayed enhancement, 1 from an acute MI and 1 from a prior MI. In the usual care group, 11 participants (21%) underwent invasive angiography during the index visit, leading to revascularization in 7 (13%).

The primary outcome composite at 90 days occurred in 20 participants (38%) in the usual care group and 7 (13%) in the OU CMR group (Table 5). In the Cox proportional hazards model, usual care was associated with a hazard ratio of 3.4 (95% confidence interval: 1.4 to 8.0, $p = 0.006$). In inpatient versus OU CMR participants, cardiac testing after discharge occurred in 9 (17%) versus 2 (4%) participants ($p = 0.03$), revascularization after randomization in 8 (15%) versus 1 (2%) participant ($p = 0.03$), and rehospitalization in 12 (23%) versus 4 (8%) participants ($p = 0.03$). Three protocol-defined safety events occurred, all due to ACS after discharge among usual care subjects.

Table 3. Cardiac Testing and Disposition During the Index Hospital Visit

	Usual Care (n = 53)	OU CMR (n = 52)	p Value
First cardiac test completed			—
None	5 (9)	0 (0)	
Stress CMR	3 (6)	50 (96)	
Stress echocardiography	33 (62)	2 (4)	
Resting echocardiography	3 (6)	0 (0)	
Stress nuclear imaging	0 (0)	0 (0)	
Cardiac catheterization	8 (15)	0 (0)	
Coronary computed tomographic angiography	1 (2)	0 (0)	
Elapsed time: ED arrival to first cardiac imaging test completed (h)*	22.3 (18.7–25.8)	20.9 (15.7–23.4)	0.028
Hospital admission from ED or observation unit	47 (89)	8 (15)	—

Values are n (%) or median (interquartile range). *Data were analyzed using Kruskal-Wallis tests. Abbreviations as in Tables 1 and 2.

DISCUSSION

We found that the OU CMR care pathway in elevated-risk participants is an efficient alternative to inpatient care and can shorten hospital length of stay and reduce revascularization, recurrent cardiac testing, and hospital readmissions, in agreement with trends observed in a prior trial (5,8). Participants in this trial were consistent with intermediate-risk patients enrolled in other trials in terms of age, prior cardiac event rates (Table 1) (5,20), and TIMI risk score (Table 2). Reflective of typical care delivered to these patients across the United States, the usual care group underwent a wide variety of initial testing modalities, most commonly stress echocardiography (51%) and cardiac catheterization (17%) (Table 3). In this context, an OU CMR pathway whereby nearly all participants underwent stress CMR as the first objective cardiac test appears to improve efficiency and did not incur any safety events through 90 days (Tables 3 and 4, Fig. 2).

Assessing the net clinical benefit of reducing revascularizations is complicated. Appropriateness criteria for coronary revascularization are intricate and vary on the basis of an individual patient's clinical data, including angina severity and results from biomarker, invasive, and noninvasive tests (21). Because all patients cannot receive all possible tests before revascularization, these decisions are made on the basis of available data. The findings from this trial suggest that the order in which tests are conducted, and perhaps the location of care delivery, influences decisions regarding the need for

Table 4. Participants With Troponin Levels Higher Than the Upper Limit of Normal or Undergoing Revascularization During the Index Visit

Age (yrs)	Sex	Group	Peak Troponin Before Cath (ng/ml)	Peak Troponin (ng/ml)	First Test	Target Vessel(s)	Maximal Target Vessel Stenosis	Notes
47	Male	OU CMR	—	0.06	CMR	—	—	
48	Male	OU CMR	1.99	214.30	CMR	Ramus	100	PCI
48	Female	OU CMR	—	0.41	CMR	—	—	—
40	Male	UC	0.14	56.90	Cath	RCA	20	RCA dissection during cath
58	Male	UC	0.00	0.06	CMR	Graft vessel	90	PCI
61	Female	UC	0.13	0.13	Cath	Distal RCA	90	PCI
61	Male	UC	0.02	0.14	Cath	Mid LAD and prox circ	80 and 98	PCI
63	Male	UC	0.02	0.02	Stress echo	Prox LAD	90	CABG
67	Female	UC	1.59	1.59	Cath	Second diagonal	80	PCI
67	Male	UC	—	1.63	Stress echo	—	—	Ischemic stroke
68	Male	UC	—	0.05	Stress echo	—	—	—
71	Male	UC	0.00	0.00	Stress echo	Prox LAD	90	CABG

cath = catheterization; circ = circumflex coronary artery; echo = echocardiography; LAD = left anterior descending coronary artery; mid = middle; prox = proximal; RCA = right coronary artery; UC = usual care; other abbreviations as in Tables 1 and 2.

revascularization. From 1 vantage point, it appears that some OU CMR participants avoided revascularization without compromising clinical outcomes. From another perspective, the patients receiving revascularization (Table 5) all appear to have had critical stenoses justifying intervention. It is unknown whether patients with similar coronary phenotypes were in the OU CMR group, but the randomized design makes that likely. One interpretation is that in patients with symptoms attributed to unstable angina, stenotic vessels thought to be the cause of the patients' symptoms may not actually cause inducible ischemia as measured by stress CMR. In these circumstances, appropriateness criteria would support a trial of medical therapy in some patients with single-vessel or 2-vessel disease and low-risk findings on noninvasive testing (21).

Table 5. Study Outcomes and Safety Events Through 90 Days

	Usual Care (n = 53)	OU CMR (n = 52)	p Value
Primary outcome			
Composite*	20 (38)	7 (13)	0.004
Revascularization†	8 (15)	1 (2)	0.031
Hospital readmission*	12 (23)	4 (8)	0.033
Recurrent cardiac testing*	9 (17)	2 (4)	0.028
Secondary outcome			
Index visit length of stay, h‡	26.3 (22.7–44.8)	21.1 (14.8–25.2)	<0.001
Safety events†			
Death (all cause)	0 (0)	0 (0)	—
ACS after discharge	3 (6)	0 (0)	0.24
Stress testing adverse events	0 (0)	0 (0)	—

Values are n (%) or median (interquartile range). *Chi-squared test. †Fisher exact test. ‡Kruskal-Wallis test. Abbreviations as in Tables 1 and 2.

A similar and related finding is the management of patients with small troponin elevations. Patients with elevated troponin values are often referred for revascularization because of a recognized benefit of an early invasive strategy in patients with non–ST-segment elevation ACS, with the largest benefit observed in patients with elevated serum troponin levels (14). Recently, troponin assays have become more sensitive, and MI has been redefined to include patients with smaller elevations in troponin (18). It remains unclear whether data supporting an early invasive strategy in "troponin-positive" patients extends to these lower-grade troponin elevations. Mills et al. (22) reported the impact of more sensitive troponin assays on mortality. In the 2 time periods during which low-grade elevations were blinded or revealed to care providers, patients benefited from improved outcomes when the low-grade elevations were revealed. However, the main benefit from the lower troponin threshold appeared to be derived from more aggressive medical therapy, with no significant difference in revascularization rates. In our trial, 5 participants had peak troponin values higher than the upper limit of normal and <1.0 ng/ml before any coronary intervention. Of these "small" elevations, 3 underwent vasodilator CMR or stress echocardiography as the first test, leading to uneventful discharge. These very

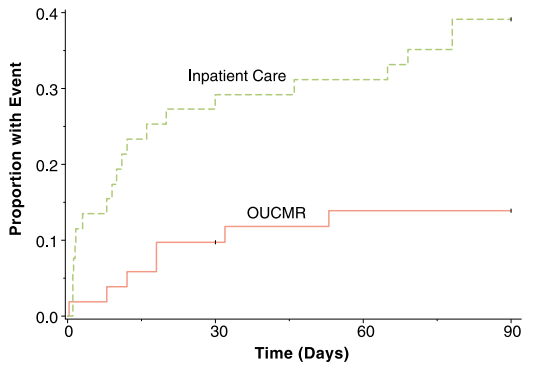

Figure 2. Cumulative Incidence Curves

Cumulative incidence curves demonstrate an early reduction in composite events that continued through 90 days in the observation unit cardiac magnetic resonance (OUCMR) group compared with the usual care group.

preliminary findings suggest that highly accurate noninvasive testing may aid in the selection of patients for invasive testing and revascularization.

Study limitations. The strengths of this analysis relate to the randomized design, high adherence to the OU CMR pathway, and rigorous data collection and follow-up procedures. In trade-off, our work had limitations. Because of the single-center design, these findings will need to be replicated across multiple centers to ensure external validity of the findings. We did not adjudicate the appropriateness of revascularization and therefore cannot comment on whether the reductions in revascularization would have been classified as appropriate. However, we submit that the absence of events in the short term makes it unlikely that patients in need of life-sustaining revascularization were deprived of this intervention. Longer term follow-up is being conducted to determine if revascularizations were required after the 90-day period; our prior investigation did not reveal an increase in post-discharge events through 1 year in a similar OU CMR group (8). It is possible that our findings relate to an imbalance in ischemic cardiac events among the study groups despite our randomized design. We believe that this is less likely, because predictors of adverse cardiac events such as the TIMI risk score and initial electrocardiographic findings did not differ among groups and because efficiency gains have now been observed in both of our studies. Additionally, incomplete blinding could have changed patients' or care providers' behavior, despite our attempts to prevent this source of bias. Finally, we cannot specifically comment on the safety of the 2 groups, given that events after discharge were rare. Given that most patients in both groups underwent serial cardiac biomarker assessments and objective cardiac testing, we believe that it is unlikely that the safety of the 2 approaches differs.

CONCLUSIONS

In this single-center trial, management of intermediate-risk patients with possible ACS in an OU with stress CMR reduced coronary artery revascularization, hospital readmissions, and recurrent cardiac testing, without an increase in post-discharge ACS at 90 days.

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