Assessment of Non–ST-Segment Elevation Acute Coronary Syndromes With Cardiac Magnetic Resonance Imaging

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OBJECTIVES
The goal of this study was to determine: 1) if the presence of significant coronary stenosis in patients presenting with non–ST-segment elevation acute coronary syndromes (NSTE-ACS) can be predicted by cardiac magnetic resonance (CMR) imaging; and 2) if the analysis of several CMR methods improves its diagnostic yield compared with analysis of individual methods.

BACKGROUND
With modern acquisition techniques, several CMR methods for the assessment of coronary artery disease (CAD) can be combined in a single noninvasive scanning session. Such a multicomponent CMR examination has not previously been applied to a large patient population, in particular those with a high prevalence of CAD in an acute situation.

METHODS
Sixty-eight patients presenting with NSTE-ACS underwent CMR imaging of myocardial function, perfusion (rest and adenosine-stress), viability (by late contrast enhancement), and coronary artery anatomy. Visual analysis of CMR was carried out. First, all CMR data were reviewed in combination (“comprehensive analysis”). In further separate analyses, each CMR method was analyzed individually. The ability of CMR to detect coronary stenosis ≥70% on X-ray angiography was determined.

RESULTS
Comprehensive CMR analysis yielded a sensitivity of 96% and a specificity of 83% to predict the presence of significant coronary stenosis and was more accurate than analysis of any individual CMR method; CMR was significantly more sensitive and accurate than the Thrombolysis In Myocardial Infarction risk score (p < 0.001).

CONCLUSIONS
Cardiac magnetic resonance imaging accurately predicts the presence of significant CAD in patients with NSTE-ACS. In this study, a comprehensive analysis of several CMR methods improved the accuracy of the test. (J Am Coll Cardiol 2004;44:2173–81) © 2004 by the American College of Cardiology Foundation

Cardiac magnetic resonance (CMR) imaging can provide a wide range of information that is relevant to the clinical management of patients with known or suspected coronary artery disease (CAD). Among others, CMR methods have been established for assessment of global and regional cardiac function, myocardial perfusion, myocardial viability, and proximal coronary anatomy (1–11). Individually, these methods have shown promise as alternatives to the established tools for the noninvasive detection of obstructive coronary stenosis and myocardial infarction (3,4,6,9,10). A unique advantage to CMR imaging is that several of its methods can be combined in a single scanning session (12). The diagnostic accuracy provided by such a comprehensive multicomponent CMR study has not previously been evaluated in a wider patient population. Importantly, it is also not known if the combined analysis of several CMR methods increases the diagnostic performance over analysis of individual methods.

Patients who could benefit particularly from noninvasive assessment with CMR are those presenting with non–ST-segment elevation acute coronary syndromes (NSTE-ACS). One of the most important clinical decisions in these patients is to determine which patients require early revascularization because of the presence of flow-limiting coronary stenosis. Current guidelines recommend that patients at high or intermediate risk of future vascular events should undergo early invasive testing (13). Several risk-stratification tools such as the Thrombolysis In Myocardial Infarction (TIMI) risk score have been proposed to guide this decision process (14). However, in clinical trials, between a quarter and a half of patients presenting with NSTE-ACS had no obstructive CAD that required revascularization (15–19).

Kwong et al. (20) have recently shown that CMR is more accurate than the TIMI score to predict the diagnosis of acute coronary syndromes (ACS) in a low-risk group of
patients presenting with chest pain in the emergency room. However, the important clinical question as to whether CMR can predict the need for revascularization in patients with known or suspected ACS has not yet been addressed. Furthermore, the applicability of CMR to patients at the high end of the risk spectrum, who are most likely to require early invasive investigation, has not yet been studied.

In this study we hypothesized that CMR imaging would be an accurate tool to detect the presence of flow-limiting coronary stenosis in patients with a clinical diagnosis of NSTE-ACS. We further speculated that the combined analysis of several CMR methods would have an incremental benefit on the diagnostic accuracy of CMR compared with the assessment of any single component.

**METHODS**

**Subjects.** A total of 72 patients (56 men and 16 women, mean age 57 years, range 37 to 75 years) with a clinical diagnosis of NSTE-ACS who were listed for coronary angiography during their index admission were recruited for the study. The diagnosis of NSTE-ACS was based on the presence of one or more of the following: suspected cardiac chest pain, a rise in the serum troponin-I levels (by a single measurement 12 h after presentation), and/or ischemic changes on the electrocardiogram (ST-segment depression, T-wave abnormalities, or transient ST-segment elevation). Patients were placed supine in a 1.5-T scanner (Philips Medical Systems, Best, the Netherlands) equipped with “Master” gradients (30 mT/m, 150 mT/s slew rate) and a five-element cardiac phased-array receiver coil. Heart rate, blood pressure, and the electrocardiogram were monitored continuously. The CMR protocol was shown schematically in Figure 1. Except for coronary imaging, all acquisitions were performed during short breath-hold periods. The study commenced with the acquisition of survey images to determine the true left ventricular short axis and a reference image of the receiver-coil sensitivity. Resting myocardial perfusion was then assessed. For this, a bolus of 0.05 mmol/kg dimeglumine gadopentetate followed by a 10-ml saline flush was administered at 6 ml/s into an antecubital vein by a power injector (Spectris, Medrad, Pittsburgh, Pennsylvania). A dynamic sequence of images was acquired over 40 s with a T1-weighted saturation recovery segmented k-space gradient echo pulse sequence combined with sensitivity encoding (echo time, 1.6 ms; repetition time, 3.3 ms; flip angle 15°, four parallel short-axis slices, spatial resolution 2.5 to 3.0 x 3.0 to 4.0 x 8 mm) (21). For measurements of ventricular function, cine imaging covering the whole heart in 10 to 12 parallel short-axis slices was then performed using a steady-state free precession pulse sequence (echo time, 1.4 ms; repetition time, 2.8 ms; flip angle 55°, spatial resolution 2 x 2 x 7 mm, 18 phases per cardiac cycle) (22). This was followed by a coronary localizer scan and the first of two targeted, high-
resolution coronary CMR acquisitions. The first coronary image plane was aligned in the path of the right coronary artery (RCA) and also covering, where possible, that of the left circumflex artery (LCX). Acquisition used a T2-prepared three-dimensional free-breathing technique with prospective respiratory gating based on navigator echoes acquired through the right hemidiaphragm (echo time, 2.1 ms; repetition time, 7 ms; flip angle 25°, 16 overlapping slices, reconstructed spatial resolution 0.78 × 1.04 × 1.5 mm) (23). Stress perfusion was then assessed during a 6-min intravenous administration of adenosine (140 μg/kg/min) and the data obtained with identical parameters as for the resting perfusion acquisition. This was followed immediately by injection of a further 0.1 mmol/kg of contrast in preparation of viability imaging. Then the second coronary CMR data set was obtained aligned to cover the left main and proximal and mid-left anterior descending (LAD) and LCX arteries. Finally, late contrast-enhanced imaging for the assessment of viability was carried out using an inversion recovery segmented k-space gradient echo pulse sequence with a nonselective 180° prepulse (echo time, 3.8 ms; repetition time, 7.5 ms; flip angle 15°, inversion time adjusted individually to suppress signal from normal myocardium, 8 to 10 short-axis slices, spatial resolution 1.8 × 1.8 × 10 mm).

CMR analysis—comprehensive analysis. Two separate analyses of CMR data were carried out on a commercially available workstation (Philips Easyvision Version 4.0, Philips, Best, the Netherlands). In a first analysis, which aimed to reflect the likely clinical use of a comprehensive CMR protocol, two observers (S.P., J.P.G.) who were blinded to clinical data were given unrestricted access to all CMR images of each patient and analyzed these in combination (this analysis will be referred to as the “comprehensive analysis”). The presence of significant CAD (i.e., flow-limiting or ≥70% luminal narrowing) was reported for the three coronary artery territories as per the American Heart Association definition (24) and in individual patients. Cardiac magnetic resonance was interpreted as abnormal if one or more components of the study showed an abnormality in a coronary artery territory, but, in this analysis, the observers were allowed to discard components with poor image quality or significant artifacts and base their evaluation on the remaining data.

CMR analysis—individual components. In order to assess the performance of the individual CMR components, a separate second analysis session was carried out in which the four CMR components (function, perfusion, viability, and coronaries) were analyzed individually. At least two weeks separated the comprehensive and each of the individual analyses of the same patient. For this analysis, the observers had access to data from only one CMR component at a time. For each component, abnormalities in the three coronary artery territories as per American Heart Association definition (24) and in individual patients were reported. From the cine images, left ventricular function was graded as normal or impaired. Rest and stress perfusion data were analyzed as a single component and were reviewed in the movie-mode and by scrolling through the series of dynamic images. Perfusion was considered abnormal if the first pass of the contrast was delayed or the peak signal intensity was lower than in other parts of the myocardium. Both fixed (present at rest and stress) or inducible (present only at stress) perfusion defects were reported as abnormal. Late contrast-enhanced images were regarded as abnormal if any hyperenhancing myocardium was present. Coronary CMR images were analyzed by scrolling through the slices of the three-dimensional data sets, and stenoses that appeared to be ≥70% were reported as abnormal. For presentation purposes, coronary CMR images were reformatted after the analysis using SoapBubble software (Philips Medical Systems, Best, the Netherlands) (25).

X-ray coronary angiography. X-ray coronary angiography was performed within 24 h after the CMR study using a standard technique (26). Two experienced cardiologists (the treating physician and M.U.S.) carried out qualitative analysis of the coronary angiograms independently and without knowledge of the CMR data. They reported the presence of significant CAD if one or more coronary stenosis of ≥70% luminal narrowing was seen in a main coronary vessel or
major side branch of >2 mm diameter. In case of disagreement between the two observers, a consensus decision was made.

**Statistical analysis.** The sensitivity, specificity, overall diagnostic accuracy, negative and positive predictive values, together with their corresponding 95% confidence intervals for the ability of visual CMR analysis to detect the presence of significant CAD were calculated using standard methods. This analysis was carried out for patients as a whole and for individual coronary territories. The sensitivity, specificity, and overall diagnostic accuracy of the comprehensive analysis in comparison with each CMR component were compared using McNemar’s chi-square test. These analyses were repeated for the comparisons of a TIMI score ≥3 with the combined analysis. All statistical tests were two-sided and performed at the 5% significance level. Analysis was conducted using SAS version 8.2 (SPSS Inc., Chicago, Illinois).

Exploratory analyses were then conducted on combinations of several of the CMR components. For this, the results of individual CMR components were combined and derived as abnormal if one or more components were abnormal and normal if all components were normal. All possible combinations of two CMR components were analyzed as well as the three-way combinations of perfusion/wall motion/late contrast enhancement and coronaries/wall motion/late contrast enhancement. The resulting combined scores were compared with the comprehensive analysis using the methods described in the preceding text.

Finally, logistic regression modeling was used to assess the ability of each individual CMR component to predict the presence of significant CAD. A multivariate logistic regression model was constructed using a forward selection procedure, with a p value <0.05 for model entry, to assess the incremental predictive value of including each CMR component in the model.

**RESULTS**

**CMR imaging.** Results of 68 patients are reported. Three CMR studies were not completed; two patients were claustrophobic, and one patient was intolerant to adenosine (transient breathlessness and chest tightness). One patient was found to have asymmetric left ventricular hypertrophy on CMR and was, therefore, excluded from the analysis.

No adverse events occurred, and all 68 patients tolerated the CMR study well, including the pharmacologic stress component. The mean CMR imaging time was 62.5 ± 7.7 min.

Example images of one study patient, which illustrate the comprehensive range of information provided by CMR, are shown in Figure 2. Cardiac magnetic resonance suggested a large amount of viable myocardium at risk from a significant LAD stenosis, which was confirmed by X-ray angiography. Further examples of abnormalities detected by CMR are shown in Figures 3 to 5.

**Figure 2.** Selected cardiac magnetic resonance (CMR) images from one study patient. Cardiac magnetic resonance findings in a 49-year-old male patient (presented with anterolateral ST-segment depression, troponin 0.2 mg/l). Only one short-axis image of selected CMR acquisitions is shown. Cine images demonstrate anteroseptal hypokinesia, diastolic frame at midventricular level in (a), systolic frame in (b), white arrows. Stress perfusion imaging (c) shows an anteroseptal perfusion defect. Late contrast-enhanced images (d) show no hyperenhancement, indicating that the entire myocardium is viable. Coronary CMR shows a lesion in the mid-left anterior descending coronary artery (LAD) (e, dotted arrow), with normal left circumflex coronary artery (LCX) and right coronary artery (RCA) (f). The combined CMR analysis thus suggested significant coronary artery disease with a stenosis of the LAD and a large area of viable myocardium at ischemic risk. X-ray angiography, (g and h), confirmed a proximal high-grade lesion in the LAD (dotted arrow), with a normal LCX and RCA. LV = left ventricle; RV = right ventricle.
X-ray angiography. Of the 68 patients who were analyzed, 56 had significant CAD on X-ray angiography. A total of 30 patients had single-vessel disease, 19 two-vessel disease, and 7 patients had three-vessel disease; 39 lesions were located in the left main/LAD, 22 in the LCX, and 28 in the RCA. A total of 36 patients were treated by percutaneous coronary angioplasty to 44 vessels, and 10 patients underwent coronary artery bypass grafting. In 10 patients with significant CAD, immediate revascularization was not carried out. The reasons for not proceeding to immediate revascularization were: poor surgical targets for coronary artery bypass grafting (n = 3), presumed chronic coronary occlusions (n = 2), significant comorbidity resulting in unjustifiable risk for coronary artery bypass grafting (n = 2), and patients refusing coronary artery bypass grafting (n = 2).

Detection of significant CAD—comprehensive CMR analysis. The sensitivity, specificity, positive and negative predictive values, and overall accuracy for CMR analysis are provided in Table 2. Sensitivity and specificity are also presented in Figure 6. The comprehensive analysis of all CMR data correctly identified the presence of significant CAD in 54 patients (sensitivity 96%). A total of 10 of the 12 patients without significant CAD on X-ray angiography were identified as normal (specificity 83%). The overall diagnostic accuracy of the analysis was 94%, the negative predictive value 83%, and the positive predictive value 96%.

Detection of significant CAD—individual CMR components. Of the individual CMR components, perfusion yielded the highest sensitivity, specificity, and overall accuracy. Wall motion and late contrast enhancement yielded low sensitivities but high specificities (Table 2 and Fig. 6).

Compared with the comprehensive analysis, the sensitivity of perfusion showed no statistically significant difference (p = 0.13). The sensitivity of coronaries (sensitivity 84%), wall motion (sensitivity 68%), and late contrast enhancement (sensitivity 57%) were significantly lower than the sensitivity of the comprehensive analysis (p = 0.039, p < 0.001 and p < 0.001, respectively). There were no statistically significant differences between the specificities of the comprehensive analysis and each individual CMR component.

The overall diagnostic accuracy of wall motion (accuracy 69%) and late contrast enhancement (accuracy 62%) were significantly lower than the overall diagnostic accuracy of
the comprehensive analysis ($p < 0.001$ for both). There was no statistically significant difference between the overall accuracy of the comprehensive analysis and perfusion (accuracy $87\%$, $p = 0.18$) or coronaries (accuracy $82\%$, $p = 0.11$).

**Detection of significant CAD—combinations of individual CMR components.** Results of the exploratory analyses of combinations of individual CMR components are given in Table 3. Of the two-component combinations, analysis of perfusion plus coronary data showed the highest sensitivity ($98\%$), which was significantly higher than the sensitivity of either perfusion (sensitivity $88\%$, $p = 0.03$) or coronaries alone (sensitivity $84\%$, $p = 0.008$). The combination of wall motion and late enhancement had the lowest sensitivity of the two-component combinations ($77\%$) and was significantly less sensitive than the comprehensive analysis ($96\%$, $p < 0.001$). There were no statistically significant differences between the sensitivities of either of the other two component combinations and the comprehensive analysis. All combinations had similar specificities with no statistically significant differences compared with the comprehensive analysis.

There were no statistically significant differences between either of the three-way combinations (perfusion/wall motion/late enhancement and coronaries/wall motion/late enhancement) and the comprehensive analysis in terms of sensitivity, specificity, or overall accuracy.

**Logistic regression analysis for the prediction of significant CAD.** From the logistic regression analysis, perfusion was the most significant individual predictor ($p < 0.0001$) of the presence of significant CAD. The inclusion of coronaries significantly increased the predictive power of the logistic regression model containing perfusion alone (chi-square $[8.29]$, $p = 0.004$). The inclusion of wall motion or late enhancement did not add any incremental predictive power to the model.

**TIMI score ≥3.** A total of 38 patients had a low TIMI risk score (0 to 2), 27 had an intermediate risk score (3 to 4), and 3 patients had a high TIMI score (5 to 7). In comparison with the comprehensive analysis, a TIMI

Table 2. Comprehensive CMR Analysis and Analysis of Individual CMR Components for the Detection of the Presence of Significant CAD*

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Overall Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive analysis</td>
<td>96 (92–100)</td>
<td>83 (62–100)</td>
<td>96 (91–100)</td>
<td>83 (62–100)</td>
<td>94 (88–100)</td>
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<tr>
<td>Individual component analysis</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Perfusion</td>
<td>88 (79–96)</td>
<td>83 (62–100)</td>
<td>96 (91–100)</td>
<td>59 (35–82)</td>
<td>87 (79–95)</td>
</tr>
<tr>
<td>Coronaries</td>
<td>84 (74–94)</td>
<td>75 (51–100)</td>
<td>94 (87–100)</td>
<td>50 (27–73)</td>
<td>82 (73–92)</td>
</tr>
<tr>
<td>Wall motion</td>
<td>68 (56–80)</td>
<td>75 (51–100)</td>
<td>93 (85–100)</td>
<td>50 (27–73)</td>
<td>69 (58–80)</td>
</tr>
<tr>
<td>Late contrast enhancement</td>
<td>57 (44–70)</td>
<td>83 (62–100)</td>
<td>94 (86–100)</td>
<td>42 (25–58)</td>
<td>62 (50–73)</td>
</tr>
</tbody>
</table>

*Results are given as percentages with 95% confidence intervals. CAD = coronary artery disease; CMR = cardiac magnetic resonance; NPV = negative predictive value; PPV = positive predictive value.
Our results show that: 1) CMR imaging is feasible and safe in patients with NSTE-ACS; 2) CMR can accurately identify patients within this high-risk population who have significant coronary stenosis; 3) combining several CMR components increases the diagnostic yield of the study; and 4) CMR is more accurate than the TIMI risk score in this context.

This is the first report of CMR imaging with pharmacologic stress in patients presenting with ACS. We encountered no complications in our study, and 68 of 72 patients completed the whole examination. Failure rates due to claustrophobia and adenosine intolerance were comparable to previous reports in other patient groups (10,11). Our results, therefore, suggest that CMR imaging with adenosine stress can be safely applied to patients with NSTE-ACS.

Our results further suggest that CMR can be used to noninvasively detect the presence of significant CAD and, thus, determine the need for invasive assessment in patients presenting with NSTE-ACS. Although X-ray angiography would still be needed for those patients who undergo revascularization, CMR could provide a safe screening tool to select appropriate patients for invasive testing. At the level of accuracy reported here for the comprehensive CMR analysis, approximately one-third of X-ray angiograms could potentially be avoided (15–19). Importantly, the wide range of information provided by a comprehensive CMR study would also then complement the X-ray angiogram and guide appropriate clinical management, particularly of patients who require revascularization. Current guidelines emphasize that the decision to proceed to coronary revascularization in patients with CAD should not be based on the coronary anatomy alone, as is often the case in clinical routine, but should also consider ventricular function, the quantity of viable myocardium, and myocardium at ischemic risk (13). Only then can informed decisions regarding the appropriateness and benefits versus the risks of revascularization be taken. In current practice, this information is often not sought, because several different diagnostic modalities would have to be used. As we have shown and as illustrated in our figures, CMR could provide all the relevant data from a single noninvasive investigation.

The results of individual CMR components in our study were comparable to previous reports in other patient groups (3,4,9,10,12). In our population, perfusion imaging yielded the highest sensitivity and overall accuracy of any individual component and was the best individual predictor of the need for revascularization, followed by coronary CMR angiography. Interestingly, our visual perfusion analysis method yielded accuracy similar to previously reported semiquantita-

**DISCUSSION**

**Table 3.** Combinations of Separate Analyses of CMR Components in the Detection of the Presence of CAD Requiring Revascularization (as Confirmed by X-Ray Angiography)*

<table>
<thead>
<tr>
<th>Combinations of two CMR components</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Overall Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfusion/coronaries</td>
<td>98 (95–100)</td>
<td>67 (40–94)</td>
<td>93 (86–99)</td>
</tr>
<tr>
<td>Perfusion/wall motion</td>
<td>93 (87–100)</td>
<td>75 (51–100)</td>
<td>90 (82–97)</td>
</tr>
<tr>
<td>Perfusion/late contrast enhancement</td>
<td>95 (89–100)</td>
<td>75 (51–100)</td>
<td>91 (85–98)</td>
</tr>
<tr>
<td>Coronaries/wall motion</td>
<td>93 (87–100)</td>
<td>67 (40–93)</td>
<td>88 (81–96)</td>
</tr>
<tr>
<td>Coronaries/late contrast enhancement</td>
<td>91 (84–99)</td>
<td>67 (40–93)</td>
<td>87 (79–95)</td>
</tr>
<tr>
<td>Wall motion/late contrast enhancement</td>
<td>77† (66–88)</td>
<td>75† (51–100)</td>
<td>77† (66–87)</td>
</tr>
<tr>
<td>Combinations of three CMR components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfusion/wall motion/late contrast enhancement</td>
<td>95 (89–100)</td>
<td>75 (51–100)</td>
<td>91 (85–98)</td>
</tr>
<tr>
<td>Coronaries/wall motion/late contrast enhancement</td>
<td>95 (89–100)</td>
<td>67 (40–94)</td>
<td>90 (82–97)</td>
</tr>
</tbody>
</table>

*Results are given as percentages with 95% confidence intervals; †statistically significant difference to comprehensive analysis.
The combinations of two or three individual components were derived as abnormal if one or more component was abnormal and normal if all components were normal.

CAD = coronary artery disease; CMR = cardiac magnetic resonance.
In the present report, are most likely to require and benefit from invasive management and that it was, therefore, highly relevant to demonstrate that CMR can be used in patients with established or high-risk ACS. Although the role of CMR in the diagnostic pathway for CAD has yet to be established, the study by Kwong et al. (20) and our results taken together show that CMR can be applied across a wide range of disease prevalence.

Our results have shown for the first time that the combined analysis of several CMR methods increases its diagnostic yield compared with analysis of individual methods. The separate analysis of individual CMR components can be limited by technical and practical problems such as imaging artifacts due to registration errors or poor patient breath-holding. Also, some measures such as viability imaging have a limited sensitivity by their very nature, as they only detect areas of completed infarction. In this study, and in our specific patient population, combining perfusion and coronary analyses significantly increased the sensitivity of CMR analysis and increased the predictive power in the logistic regression model. The best overall accuracy was achieved by the comprehensive analysis in which the observers had unrestricted access to all CMR data. Importantly, this did not come at the expense of a lower specificity compared with the analysis of single components. The main reason for this increased accuracy is that myocardial function, perfusion, viability, and coronary anatomy each assess a different manifestation of CAD and together provide a wide range of complementary information. Having access to data from other CMR methods is especially useful when one component shows a borderline result or is affected by image artifacts. This allows the observers to come to a more confident conclusion and, as we have shown, reduces false negative reports without increasing the false positives.

When we combined the results of individual CMR components in further exploratory analyses, the three-way combination of perfusion/wall motion/late contrast enhancement and coronaries/wall motion/late contrast enhancement yielded accuracies comparable to the comprehensive analysis of all CMR data. In clinical practice, the former of these combinations would be particularly attractive because it avoids the need for time-consuming coronary CMR imaging and still provides a wide range of complementary information. Having access to data from other CMR methods is especially useful when one component shows a borderline result or is affected by image artifacts. This allows the observers to come to a more confident conclusion and, as we have shown, reduces false negative reports without increasing the false positives.

We have studied a patient population at the high end of the risk spectrum, in whom a diagnosis of NSTE-ACS and the decision to proceed to X-ray angiography had already been taken by the treating physician. Although it is a limitation of our work that the number of patients without significant CAD was low given the high-risk group we have studied, our population complements a recent report by Kwong et al. (20) that demonstrated the ability of CMR to identify ACS in patients at the opposite lower end of the risk spectrum. We suggest that patients with a high risk of future clinical events and a high prevalence of CAD, studied in the present report, are most likely to require and benefit from invasive management and that it was, therefore, highly relevant to demonstrate that CMR can be used in patients with established or high-risk ACS. Although the role of CMR in the diagnostic pathway for CAD has yet to be established, the study by Kwong et al. (20) and our results taken together show that CMR can be applied across a wide range of disease prevalence.

In our study as well as in the report by Kwong et al. (20), CMR was more sensitive and accurate than the TIMI risk score to detect ACS and the need for revascularization, respectively. The TIMI risk score and other similar tools are designed to determine the risk of future cardiovascular events rather than to detect ACS or the need for revascularization, but are often used in clinical practice to select patients for early X-ray angiography in accordance with current guidelines (6). Cardiac magnetic resonance appears to be superior to the TIMI risk score to identify patients who will benefit from early invasive management. We suggest that the most important reason for the higher sensitivity of CMR compared with the TIMI risk score is that, rather than relying on indirect measures such as the electrocardiogram and biochemical markers, CMR allows a direct visual assessment of the pathologic processes that occur in NSTE-ACS and, in particular, detects myocardial ischemia. Another reason why the TIMI risk score may be a relatively weak predictor of the presence of significant CAD is that it includes a number of nonspecific and common risk factors. The current study could not formally compare the ability of CMR and the TIMI risk score to predict future clinical events, because only six cardiovascular end points occurred during follow-up. However, all end points occurred in patients with abnormal CMR studies, which suggests that CMR may offer prognostically relevant information. This will need to be confirmed in larger studies and compared with conventional methods of risk stratification.

We used the presence of significant CAD in patients rather than in individual vascular territories as the main end point of this study. The main reason for this is that, in the clinical context of suspected NSTE-ACS, we regarded the detection of CAD in a patient as the most important potential role for a noninvasive screening test to identify those patients who should be referred for invasive testing. The localization of disease to an individual coronary artery, while also possible as we have shown, is less important in this scenario. Another reason for our choice of this end point was that we wanted to compare CMR with the TIMI risk score, which, of course, does also not allow localization of disease.

In conclusion, this study has shown that CMR imaging is safe and accurate in patients presenting with NSTE-ACS. It can be used for the triage of patients to early invasive management or to provide important additional information in combination with X-ray angiography for a fully informed treatment of patients with NSTE-ACS.
REFERENCES


