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Prognostic Value of Stress Cardiac Magnetic Resonance Imaging in Patients With Known or Suspected Coronary Artery Disease:

A Systematic Review and Meta-Analysis

Michael J. Lipinski, MD, PhD[*], **Courtney M. McVey, BA**[*], **Jeffrey S. Berger, MD, MS**[†], **Christopher M. Kramer, MD**[*,‡], and **Michael Salerno, MD, PhD**[*,‡]

[*]Department of Medicine, Division of Cardiology, University of Virginia Health System, Charlottesville, Virginia

[†]Department of Medicine, Division of Cardiology, New York University, New York, New York

[‡]Department of Radiology and the Cardiovascular Imaging Center, University of Virginia Health System, Charlottesville, Virginia

Abstract

Objectives—This study sought to perform a systematic review and meta-analysis to understand the role of stress cardiac magnetic resonance imaging (CMR) in assessing cardiovascular prognosis in patients with known or suspected coronary artery disease (CAD).

Background—Although stress CMR is excellent for the diagnosis of obstructive CAD, the prognostic value of stress CMR has been less well described.

Methods—PubMed, Cochrane CENTRAL, and metaRegister of Controlled Trials were searched for stress CMR studies with >6 months of prognostic data. Primary endpoints were cardiovascular death, myocardial infarction (MI), and a composite outcome of cardiovascular death or MI during follow-up. Summary effect estimates were generated with random-effects modeling, and annualized event rates were assessed.

Results—Nineteen studies (14 vasodilator, 4 dobutamine, and 1 that used both) involved a total of 11,636 patients with a mean follow-up of 32 months. Patients had a mean age of 63 ± 12 years, 63% were male, and 26% had previous MI; mean left ventricular ejection fraction was 61 ± 12%; and late gadolinium enhancement was present in 29% and ischemia in 32%. Patients with ischemia had a higher incidence of MI (odds ratio [OR]: 7.7; $p < 0.0001$), cardiovascular death (OR: 7.0; $p < 0.0001$), and the combined endpoint (OR: 6.5; $p < 0.0001$) compared with those with a negative study. The combined outcome annualized events rates were 4.9% for a positive versus 0.8% for a negative stress CMR ($p < 0.0001$), 2.8% versus 0.3% for cardiovascular death ($p < 0.0001$), and 2.6% versus 0.4% for MI ($p < 0.0005$). The presence of late gadolinium enhancement was also significantly associated with a worse prognosis.

Conclusions—A negative stress CMR study is associated with very low risk of cardiovascular death and MI. Stress CMR has excellent prognostic characteristics and may help guide risk stratification of patients with known or suspected CAD.

Reprint requests and correspondence: Dr. Michael Salerno, University of Virginia Health System, Department of Medicine, Cardiovascular Division, 1215 Lee Street, Box 800158, Charlottesville, Virginia 22908. ms5pc@virginia.edu.
Drs. Lipinski and McVey contributed equally to this work.

Keywords

late gadolinium enhancement; myocardial perfusion; prognosis; stress cardiac MRI

Stress cardiac magnetic resonance imaging (CMR), either with vasodilator or dobutamine stress, has been shown to have excellent diagnostic accuracy for detection of significant coronary artery disease (CAD) (1–4). In addition, CMR provides valuable clinical data, including details on left ventricular function, the presence of late gadolinium enhancement (LGE), and whether there is structural or valvular heart disease. As a result, stress CMR is increasingly being used to assess chest pain in patients with known or suspected CAD. In addition, stress CMR may have a role after ST-segment elevation myocardial infarction (MI) to assess for residual ischemia due to coronary stenoses in noninfarct-related arteries (5,6). Furthermore, stress CMR can be used in patients with dilated cardiomyopathy to assess for ischemia and myocardial scar burden with LGE (7,8). Given the increasing health care costs associated with cardiovascular imaging, it is critical to validate the prognostic utility of stress CMR (9,10).

Over the past several years, multiple studies have been published regarding stress CMR assessment of prognosis. However, many of these studies are limited because they are small and single centered. Prognostic validation of stress CMR is critical because a negative stress CMR can be reassuring that the patient has a very low risk for major adverse cardiovascular events (MACE). Alternatively, patients with stress-induced wall motion abnormalities, abnormal perfusion, and/or LGE are at higher risk of MACE. In the current environment of escalating medical costs, the prognostic performance of stress CMR may also help justify its use compared with more commonly used stress modalities such as stress echocardiography and stress nuclear perfusion imaging. Given the multiple small and single-centered studies, we performed a systematic review and meta-analysis of studies reporting prognostic data from patients undergoing stress CMR to assess for myocardial ischemia in those with known or suspected CAD.

Methods

Eligibility criteria

We included any of the following: 1) study assessing for myocardial ischemia with stress CMR; 2) with ≥6 months of prognostic follow-up data, including cardiac death and/or MI; and 3) excluding populations composed of patients with cardiomyopathy or acute MI within the last 14 days.

Search strategy

To identify eligible studies for inclusion in the current systematic review and meta-analysis, 2 independent reviewers (M.J.L. and C.M.M.) systematically searched (October 2012) Cochrane CENTRAL, meta-Register of Controlled Trials, and PubMed for studies assessing prognosis in patients with known or suspected CAD after undergoing stress CMR. Key words used were “prognosis” OR “outcome” AND “stress magnetic resonance imaging” or “dobutamine magnetic resonance imaging” or “adenosine magnetic resonance imaging.” In addition, we consulted experts, reviewed citations from eligible studies, and explored “see related articles” for key publications in PubMed. The search was limited to studies published in peer-reviewed journals and thus excludes trials presented in abstract form only. We restricted the review to studies that enrolled adults only. No language restriction was applied. The current systematic review and meta-analysis was performed in accordance with guidelines of the MOOSE (Meta-analysis of Observational Studies in Epidemiology) and

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) groups (11,12).

Study selection

Two investigators (M.J.L. and C.M.M.) independently and in duplicate scanned all abstracts and obtained full-text reports of articles that indicated or suggested eligibility. After obtaining full reports, the same reviewers independently assessed eligibility from the full-text articles, with divergences resolved after consensus. Study quality was evaluated by the Newcastle-Ottawa Quality Assessment Scale for Cohort Studies (13), in which the quality of the selected trials was determined on the basis of selection of the study groups (0 to 4 points), comparability of the study groups (0 to 2 points), and ascertainment of the outcome of interest (0 to 3 points).

Data collection

Data abstraction and study appraisal were performed by the same 2 aforementioned investigators. Clinical outcomes of interest were cardiovascular death, MI, or the composite outcome of cardiovascular death or MI during follow-up. Clinical outcomes data were directly abstracted when reported. Unadjusted hazard ratios were used to determine the number of events if not provided for each group, and annualized event rates (AERs) for studies were calculated by dividing the number of events by the follow-up duration.

Data analysis

Dichotomous variables are reported as proportions (percentages); continuous variables are reported as mean ± SD or median (range). Binary outcomes from individual studies were combined with a random-effects model, leading to computations of odds ratios (ORs) with 95% confidence intervals (CIs). I^2 was calculated as a measure of statistical heterogeneity, with I^2 values of 25%, 50%, and 75% representing mild, moderate, and severe inconsistency, respectively. Small study or publication bias was explored with funnel plots, Egger's test (14), and Peters' test (15). Finally, meta-regression and sensitivity analyses (including exclusion of 1 study at a time) were conducted to explore heterogeneity.

Statistical analysis was performed by using Review Manager (RevMan) 5 version 5.1.7 freeware package (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) and NCSS 2007 (NCSS LLC, Kaysville, Utah), with statistical significance for hypothesis testing set at the 0.05 two-tailed level. AERs were compared by using weighted comparison of means in which we provide SD and SE of the difference of the means to provide significance by the Student's *t* test (16).

Results

Results of the literature search

Our literature search identified 2,019 relevant abstracts of full-text articles; of these, 58 unique articles were abstracted for review. Forty-five of these articles warranted full-text review. Twenty-six articles (5–9,17–37) were excluded for various reasons, including cohort overlap with other articles or lack of our prespecified outcomes, leaving 19 articles for detailed study (38–56). The details of our flow diagram can be found in Figure 1, and study characteristics are presented in Table 1. Only 1 study included patients undergoing stress CMR at 3.0-T and 1.5-T; the rest of the studies were performed at 1.5-T.

The 19 studies with a weighted mean follow-up of 32 months (median 25 months; range 9 to 72 months) included a total of 11,636 patients with known or suspected CAD undergoing stress CMR (14 vasodilator stress [38–44,46–52]; 4 dobutamine stress [53–56]; and 1 using

both vasodilator and dobutamine stress [45]) (median 362 patients; average 612 patients [range: 27 to 1,722]). Patients had a weighted mean age of 63 ± 12 years, and 63% of patients were male. The population also had a typical distribution of cardiovascular risk factors: 42% with CAD, 26% with previous MI, 66% with hypertension, 60% with hyperlipidemia, 24% with diabetes mellitus, and 25% with a history of smoking. With regard to stress CMR, the weighted mean left ventricular ejection fraction was 61 ± 12%, LGE was present in 29% of patients when reported, and 32% of patients had a positive stress CMR. Baseline patient characteristics are demonstrated in Table 2.

Evidence of ischemia in stress CMR and cardiovascular outcome

Of the 19 studies reporting the combined outcome of cardiovascular death and MI during follow-up (Fig. 2A), patients with a positive stress CMR had a greater incidence of the combined outcome compared with patients who had a negative stress CMR (OR: 6.5 [95% CI: 4.41 to 9.58]; $p < 0.00001$, $I^2 = 74\%$). There was no significant difference between the prognostic characteristics of vasodilator and dobutamine stress CMR. Patients with a positive stress CMR had a significantly greater AER of the combined outcome (Table 3, Fig. 3) than patients with a negative stress CMR (4.9 ± 3.1% vs. 0.8 ± 0.7%, respectively; T score = 5.69, $p < 0.000002$). There was no significant difference in the combined outcome AERs for patients undergoing vasodilator stress CMR versus dobutamine stress CMR in patients with a positive stress CMR (4.9 ± 3.5% vs. 4.7 ± 2.4%, respectively; T score = 0.15, $p = 0.89$) or in patients with a negative stress CMR (0.9 ± 0.8% vs 0.7 ± 0.7%; T score = 0.58, $p = 0.57$).

Of the 13 studies reporting cardiovascular death during follow-up (Fig. 2B), patients with a positive stress CMR had a significantly greater risk of cardiovascular death during follow-up compared with patients who had a negative stress CMR (OR: 6.96 [95% CI: 4.13 to 11.74]; $p < 0.00001$, $I^2 = 36\%$). When comparing the cardiovascular death AERs (Table 3, Fig. 3), patients with a positive stress CMR had significantly greater risk of cardiovascular death during follow-up than patients with a negative stress CMR (2.8 ± 1.6% vs. 0.3 ± 0.3%, respectively; T score = 5.58, $p < 0.00002$).

Of the 13 studies reporting nonfatal MI during follow-up (Fig. 2C), patients with a positive stress CMR had a significantly higher incidence of MI during follow-up compared with patients who had a negative stress CMR (OR: 7.73 [95% CI: 3.28 to 18.23]; $p < 0.00001$, $I^2 = 73\%$). When comparing the MI AERs (Table 3, Fig. 3), patients with a positive stress CMR had a significantly higher incidence of MI during follow-up than patients with a negative stress CMR (2.6 ± 2.0% vs. 0.4 ± 0.3%, respectively; T score = 4.1, $p < 0.0005$).

Meta-regression analysis was performed to determine whether any clinical variables were associated with the combined cardiovascular outcome, cardiovascular death, or nonfatal MI. All variables from Table 2 were included in the meta-regression. Meta-regression analysis demonstrated that only previous MI (correlation −0.64; $R^2 = 0.41$; $p < 0.04$) was associated with an increased incidence of combined cardiovascular outcomes. Among the studies reporting LGE, there was a significant correlation between previous MI and LGE (correlation 0.98; $R^2 = 0.96$; $p < 0.0001$).

LGE during stress CMR and cardiovascular outcomes

Of the 10 studies reporting the combined outcome of cardiovascular death and MI during follow-up and presence of LGE (Fig. 4A), patients with evidence of LGE had a worse outcome than patients without LGE (OR: 3.82 [95% CI: 2.56 to 5.71]; $p < 0.00001$, $I^2 = 46\%$). When comparing the combined outcome AERs (Table 4, Fig. 5), patients with LGE had significantly worse outcomes than patients without LGE (4.6 ± 4.0% vs. 1.4 ± 1.0%,

respectively; T score = 2.45, $p < 0.03$). Of the 6 studies reporting cardiovascular death during follow-up and presence of LGE (Fig. 4B), patients with evidence of LGE had a higher incidence of cardiovascular death during follow-up than patients without LGE (OR: 2.71 [95% CI: 1.66 to 4.41]; $p < 0.0001$, $I^2 = 0\%$). When comparing cardiovascular death AERs, patients with LGE had a significantly greater risk than patients without LGE (2.4 ± 1.4% vs. 0.8 ± 0.5%, respectively; T score = 2.54, $p < 0.04$). Of the 5 studies reporting nonfatal MI during follow-up and presence of LGE (Fig. 4C), patients with LGE had a trend toward a higher incidence of MI during follow-up than patients without LGE (OR: 3.29 [95% CI: 0.55 to 19.76]; $p = 0.19$, $I^2 = 59\%$). However, when comparing MI AERs, patients with LGE had a significantly higher incidence of MI during follow-up than patients without LGE (1.9 ± 0.3% vs. 0.8 ± 0.5%, respectively; T score = 3.66, $p < 0.008$).

Assessment of publication bias

Funnel plots were visually inspected for all outcomes for both assessment of ischemia and LGE. There was no significant asymmetry of the funnel plots for the different outcomes though heterogeneity, with an elevated I^2 value noted in some outcomes (Figs. 2A and 2C). However, Peter's test could not rule out the presence of publication bias ($R^2 = 0.16$; $p = 0.15$). Exclusion of 1 study at a time from the outcomes analysis did not affect the findings (data not shown).

Discussion

The findings of this systematic review and meta-analysis show that stress CMR provides excellent prognostic stratification of patients with known or suspected CAD. The data demonstrate that patients with a stress CMR negative for evidence of ischemia have <1% AER of either cardiovascular death or nonfatal MI, whereas patients with ischemia on stress CMR have a 5% AER of either cardiovascular death or nonfatal MI. Furthermore, there was no significant difference between vasodilator stress CMR and dobutamine stress CMR in terms of prognostic characteristics. This finding is important because vasodilator stress CMR is being used more frequently and has favorable characteristics given its ease of performance. In addition, the presence of LGE during CMR suggested an increased risk of MACE. Further studies are necessary to determine whether LGE provides incremental prognostic information in patients undergoing stress CMR. The findings of this meta-analysis in a large number of patients with a median follow-up of 25 months support the role of stress CMR for identifying patients at either low or high risk for future MACE.

Stress CMR has evolved into a powerful tool to provide comprehensive cardiac assessment. This imaging modality not only provides assessment of ischemia but can also identify the presence of LGE and valvular heart disease and can assess cardiac structure and function. Our data suggest that patients with a negative stress CMR have a prognosis comparable to those patients who have a negative stress myocardial perfusion imaging or stress echocardiogram (57–60). The combined event rate of the included studies in our meta-analysis was 5.1% during follow-up (AER 1.9%) with 2.0% for cardiovascular death (AER 0.9%) and 1.9% for nonfatal MI (AER 0.8%) in studies providing the individual outcomes. The total cardiovascular death AER was also comparable to that seen in patients undergoing coronary computed tomographic angiography in the CONFIRM (Coronary CT Angiography Evaluation for Clinical Outcomes: An International Multicenter Registry) trial (1.06%) (61). The robust prognostic data for stress CMR suggest that this imaging modality should be considered as an excellent alternative to stress nuclear myocardial perfusion imaging and stress echocardiography in patients who cannot exercise. This is especially true given the excellent diagnostic characteristics of stress CMR for CAD (1–4). Furthermore, research is currently underway to explore the possibility of performing exercise stress CMR to assess for myocardial ischemia (62), which may provide further valuable exercise and

electrocardiography data. Large multicenter trials are currently accruing longer-term follow-up data that will provide further valuable prognostic data for stress CMR (CE-MARC [Cardiovascular Magnetic Resonance and Single-Photon Emission Computed Tomography for Diagnosis of Coronary Heart Disease] [4], EuroCMR Registry [63], and MR-IMPACT-II [Magnetic Resonance Imaging for Myocardial Perfusion Assessment in Coronary Artery Disease] [3]). In the current financial environment, these findings provide justification for prospective randomized trials to assess the comparative effectiveness of stress CMR compared with alternative stress-testing modalities.

Study limitations

Limitations of systematic reviews pertinent to the current study include lack of raw and uniform data from included studies, inclusion of different stress modalities, variable censoring of data for patients that underwent revascularization after stress CMR, estimation of events from hazard ratios in some studies, which assumes a linear event rate, and differences in length of follow-up (for which we attempted to adjust for by using AERs). Another limitation was the inability to assess prognosis and the degree of ischemia on stress CMR. We also included single-center, retrospective studies, as well as studies that only reported data on patients with negative stress tests. The studies in this systematic review used magnets with a field strength of 1.5-T, but the data regarding 3.0-T imaging were limited. Another limitation is the lack of information regarding the adequacy of medical therapy after stress CMR. In addition, there is the possibility of publication bias, as small studies may have been performed that did not show a significant difference in prognosis and were not published. Although the random-effects pooling method adjusts for it, another limitation of this meta-analysis was the heterogeneity observed between studies. Overall pooling can be fraught with significant heterogeneity and inconsistency. Finally, meta-regression techniques are limited because we did not have access to all the raw patient information and therefore can only assess the correlation between the variable prevalence in a study and the outcome, and the results should thus be viewed with caution and as hypothesis-generating.

Conclusions

Stress CMR seems to provide excellent prognostic risk stratification for patients with known or suspected CAD. In addition, patients with the presence of LGE on CMR are at increased risk of cardiovascular death or nonfatal MI. Stress CMR seems comparable to other stress-testing modalities for assessment of prognostic risk.

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Abbreviations and Acronyms

AER	annualized event rate
CAD	coronary artery disease
CMR	cardiac magnetic resonance imaging
LGE	late gadolinium enhancement
MACE	major adverse cardiovascular event(s)

MI	myocardial infarction
OR	odds ratio

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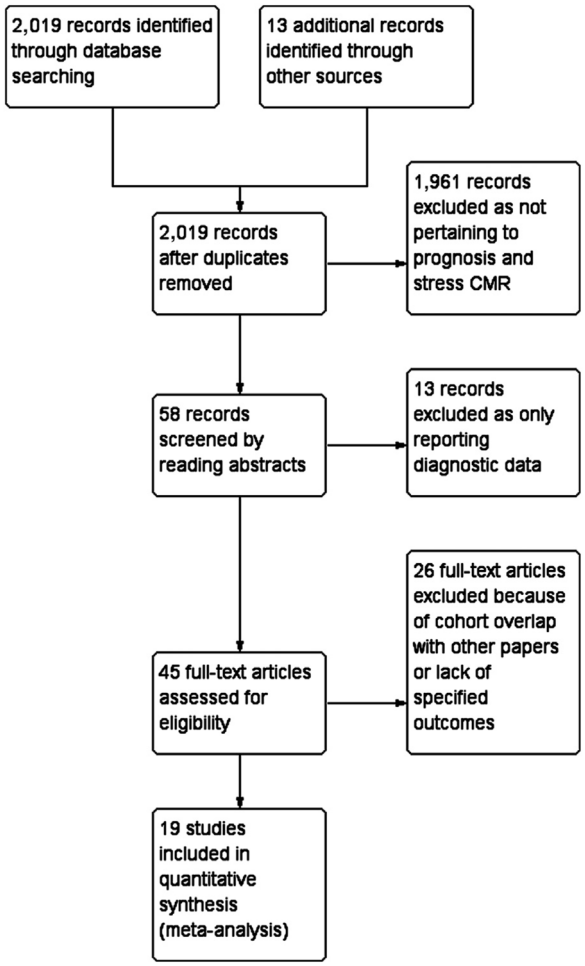

Figure 1. Flow Diagram of the Review Process
CMR = cardiac magnetic resonance imaging.

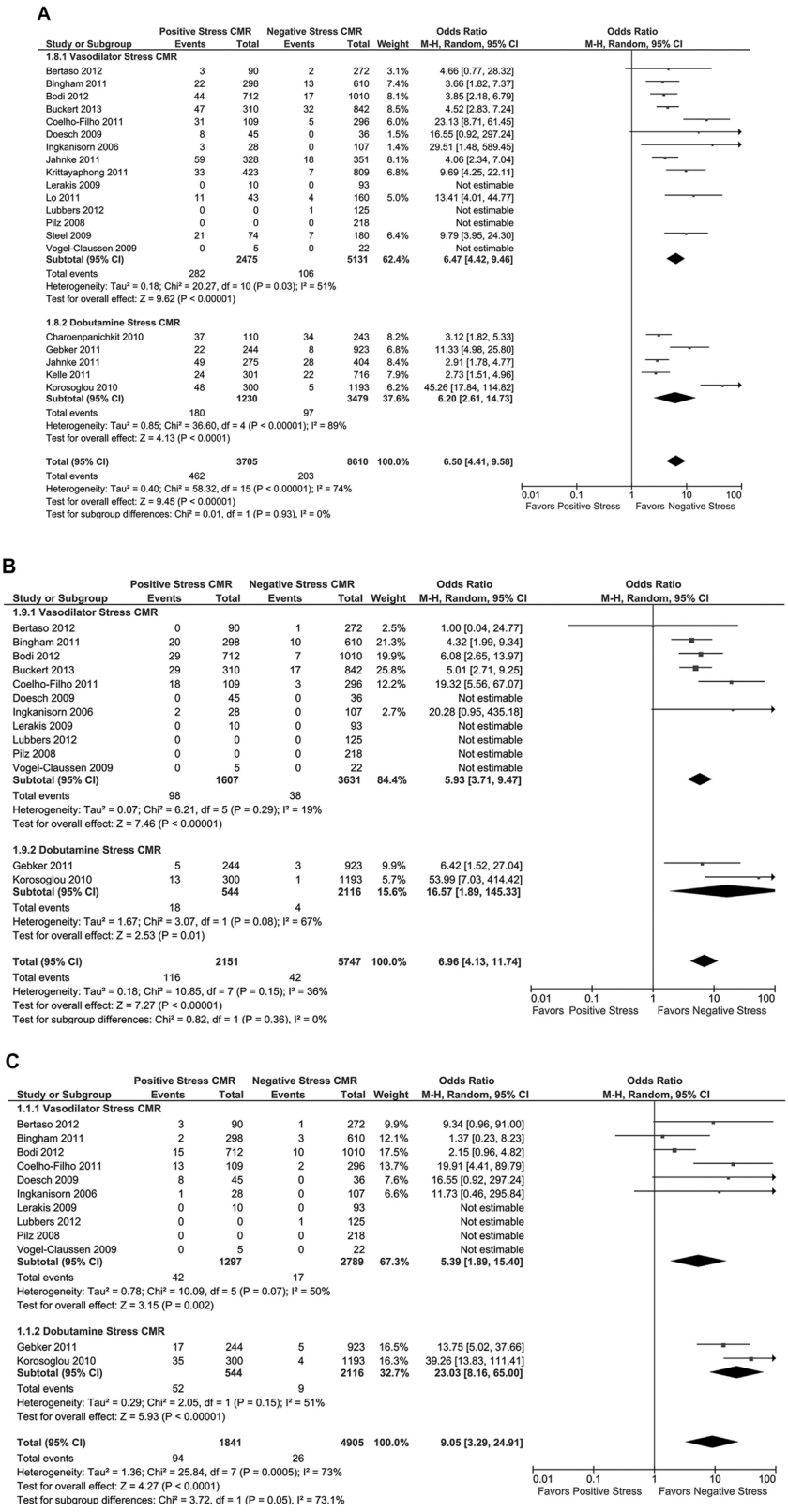

Figure 2. Individual and Pooled Risk of Cardiovascular Outcomes for Stress CMR

Forest plots comparing clinical outcomes of patients with known or suspected coronary artery disease (CAD) with positive stress cardiac magnetic resonance imaging (CMR) and negative stress CMR. Outcomes included **(A)** combined cardiovascular outcomes including cardiovascular death and nonfatal myocardial infarction (MI), **(B)** cardiovascular death, and **(C)** nonfatal MI. CI = confidence interval.

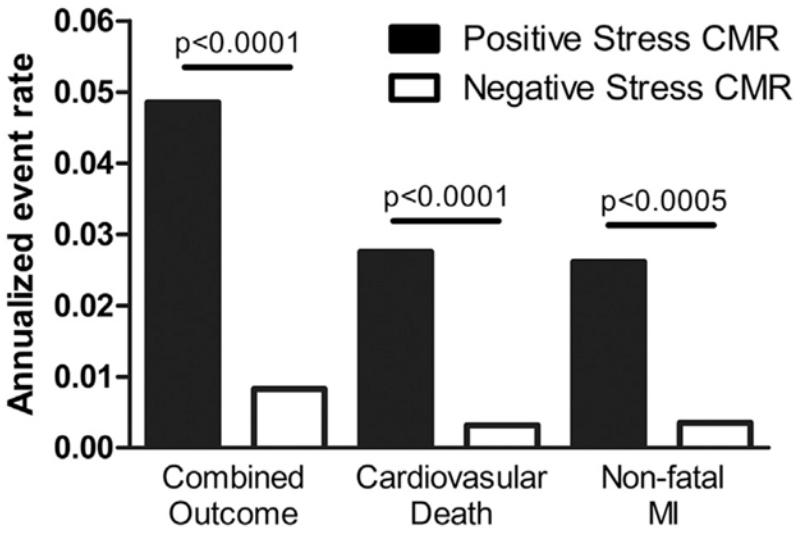

Figure 3. AERs of Cardiovascular Outcomes for Stress CMR

Weighted mean annualized event rates (AERs) for combined cardiovascular outcome of cardiovascular death and nonfatal MI, cardiovascular death, and non-fatal MI comparing patients with positive stress CMR **(solid bars)** and patients with a negative stress CMR **(open bars)**. Abbreviations as in Figure 2.

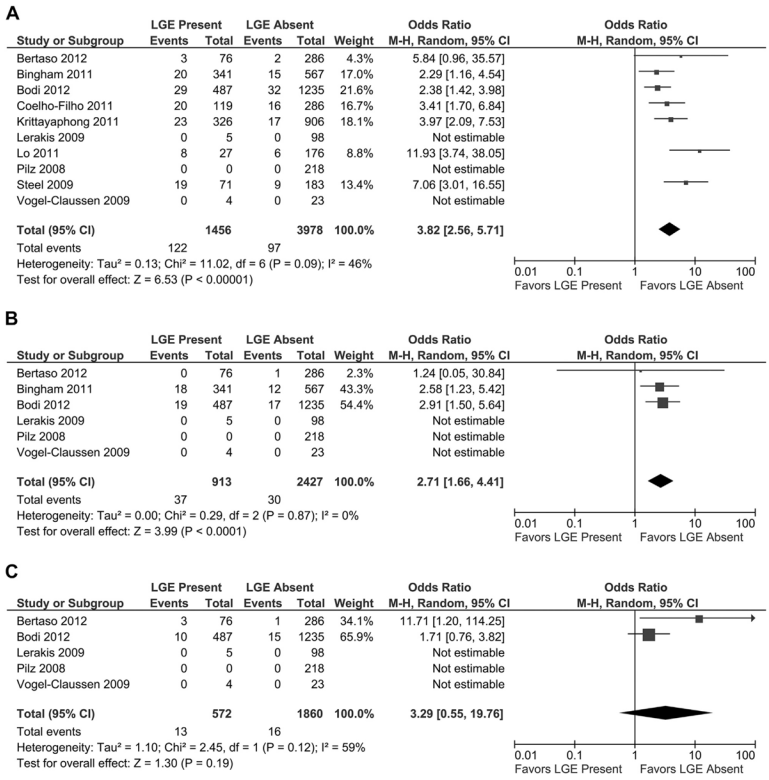

Figure 4. Individual and Pooled Risk of Cardiovascular Outcomes Based on the Presence of LGE

Forest plots comparing clinical outcomes of patients with known or suspected CAD with late gadolinium enhancement (LGE) on CMR and without LGE on CMR. Outcomes included **(A)** combined cardiovascular outcomes including cardiovascular death and nonfatal MI, **(B)** cardiovascular death, and **(C)** nonfatal MI. Abbreviations as in Figure 2.

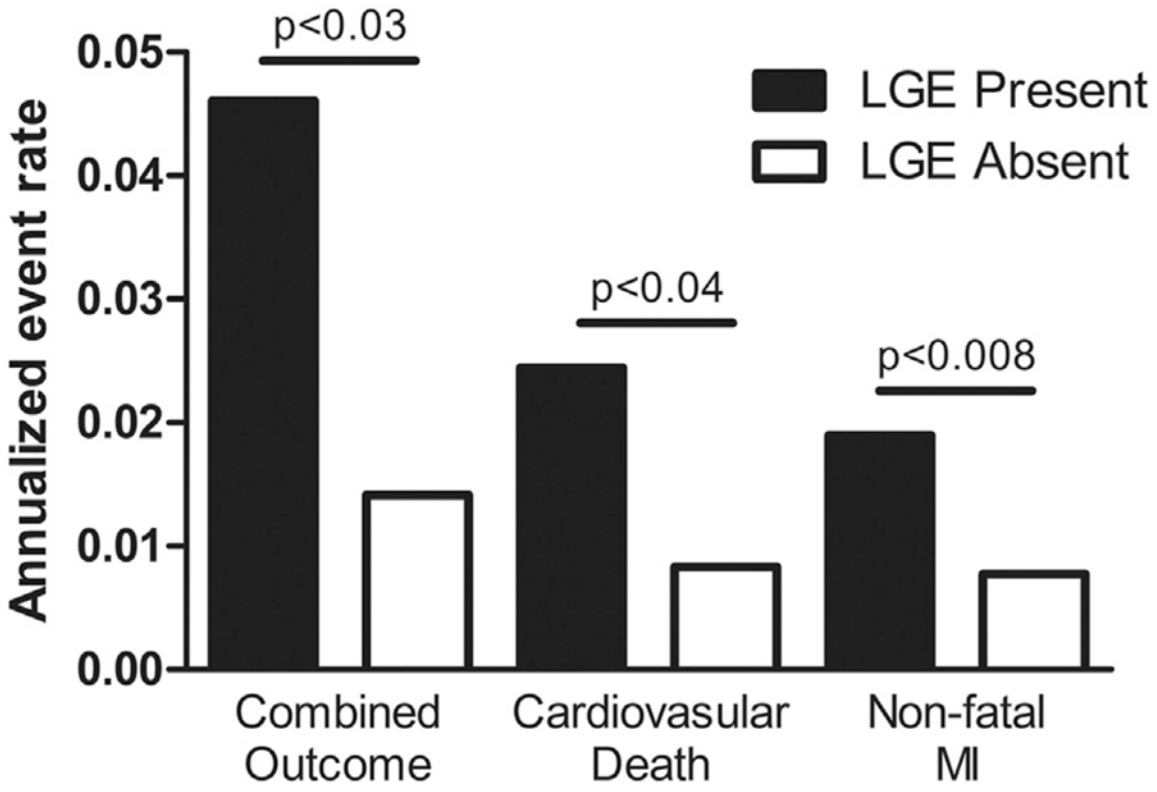

Figure 5. AERs of Cardiovascular Outcomes Based on the Presence of LGE

Weighted mean AERs for combined cardiovascular outcome of cardiovascular death and nonfatal MI, cardiovascular death, and nonfatal MI comparing patients with LGE on CMR **(solid bars)** and patients without LGE on CMR **(open bars)**. Abbreviations as in Figures 2 to 4.

Table 1

Study Characteristics

Stress CMR Studies First Author (Ref. #)	Year Published	No. of Patients Included	Follow-Up (Months)	Stress Agent	Study Design	Quality Assessment Score	Field Strength (T)	Definition of Positive Stress CMR	Population
Bertaso et al. (38)	2012	362	22	Adenosine	Retrospective, single-center	3/2/3	1.5	Reversible perfusion defect	Consecutive patients referred for stress CMR
Bingham et al. (39)	2011	908	31 ± 14	Adenosine	Prospective, single-center	4/2/3	1.5	Stress perfusion defect. No resting perfusion performed	Consecutive patients referred for stress CMR
Bodi et al. (40)	2012	1,722	13 ± 11	Dipyridamole	Prospective, multicenter	4/2/3	1.5	Reversible perfusion defect in at least one segment	Patients with chest pain or to assess ischemia in intermediate coronary stenoses
Buckert et al. (41)	2013	1,152	50 ± 25	Adenosine	Prospective, single-center	4/2/3	1.5	Reversible perfusion defect extending beyond any area of LGE	Patients with stable angina referred for stress CMR
Coelho-Filho et al. (42)	2011	405	30	92% Adenosine 8% Dipyridamole	Prospective, single-center	4/2/3	1.5 or 3.0	Stress perfusion defect without matching segmental LGE	Consecutive patients referred for stress CMR
Doesch et al. (43)	2009	81	30 ± 8	Adenosine	Prospective, single-center	4/2/3	1.5	Reversible perfusion defect extending beyond any area of LGE	Assessment of ischemia in patients with intermediate coronary stenoses
Ingkanisorn et al. (44)	2006	135	16	Adenosine	Prospective, single-center	4/2/3	1.5	Reversible perfusion defect in >1 segment	Patients with chest pain and negative troponins referred from the ED
Jahnke et al. (45)	2011	679	57 ± 26	Adenosine and dobutamine	Retrospective, single-center	3/2/3	1.5	Reversible perfusion defect	Consecutive patients to assess chest pain or dyspnea for combined stress adenosine or dobutamine CMR
Krittayaphong et al. (46)	2011	1,232	35 ± 16	Adenosine	Retrospective, single-center	3/2/3	1.5	Reversible perfusion defect extending beyond any area of LGE	All patients age >18 years referred for stress CMR
Lerakis et al. (47)	2009	103	9 (5–15)	Adenosine	Retrospective, single-center	3/1/3	1.5	Perfusion defect at rest or stress, resting wall motion abnormality, or LGE	Patients with low-risk chest pain referred from the ED
Lo et al. (48)	2011	203	38 ± 19	Adenosine	Retrospective, single-center	3/2/3	1.5	Reversible perfusion defect	Patients with known or suspected CAD to assess for ischemia
Lubbers et al. (49)	2012	125	22 (11 to 43)	Adenosine	Prospective, single-center	3/2/3	1.5	Perfusion defect in >2 segments (or 1 segment at apex)	Consecutive patients referred from outpatient cardiology clinic to assess for ischemia
Pilz et al. (50)	2008	218	12	Adenosine	Prospective, single-center	3/2/3	1.5	Only negative tests included	Patients with suspected CAD but adenosine CMR negative for ischemia or LGE
Steel et al. (51)	2009	254	17 (8–56)	89% Adenosine 11% Dipyridamole	Retrospective, single-center	3/2/3	1.5	Reversible perfusion defect in at least 1 segment.	Patients with chest pain referred for stress CMR
Vogel-Claussen et al. (52)	2009	27	14 ± 5	Adenosine	Prospective, single-center	4/1/3	1.5	Reversible perfusion defect	Patients with low-risk chest pain referred from the ED
Charoenpanichkit et al. (53)	2010	353	72 ± 24	Dobutamine	Prospective, single-center	4/2/3	1.5	New or worsening stress-induced wall motion abnormality in >1 segment	Consecutive patients referred for stress CMR
Gebker et al. (54)	2011	1,167	25 ± 10	Dobutamine	Prospective, single-center	4/2/3	1.5	New or worsening stress-induced wall motion abnormality in >1 segment, or a biphasic response	Consecutive patients to assess chest pain or dyspnea
Kelle et al. (55)	2011	1,017	44 ± 24	Dobutamine	Retrospective, single-center	3/2/3	1.5	New or worsening stress-induced wall motion abnormality in >1 segment or a biphasic response	Patients with known or suspected CAD to assess for ischemia
Korosoglou et al. (56)	2010	1,493	24 ± 12	Dobutamine	Retrospective, single-center	3/2/3	1.5	New or worsening stress induced wall motion abnormality in >1 segment	Consecutive patients with known or suspected CAD to assess for ischemia

CAD = coronary artery disease; CMR = cardiac magnetic resonance imaging; ED = emergency department; LGE = late gadolinium enhancement.

Table 2

Baseline Patient Characteristics

Stress CMR Studies First Author (Ref. #)	Age (yrs)	Male (%)	Known CAD (%)	Prior Revascularization (%)	Prior PCI (%)	Prior CABG (%)	Prior MI (%)	Hypertension (%)	Hyperlipidemia (%)	Diabetes Mellitus (%)	Smoking history (%)	LVEF (%)	LGE Present (%)	Positive Stress (%)
Bertaso et al. (38)	62 ± 12	58	43	NR	NR	0	NR	58	60	24	24	67 ± 12	21	25
Bingham et al. (39)	65	59	49	NR	33	15	35	64	NR	25	6	63	38	33
Bodi et al. (40)	64 ± 11	62	NR	NR	14	7	23	62	55	28	22	62 ± 13	28	41
Buckert et al. (41)	62 ± 12	72	NR	NR	41	12	36	63	57	21	24	64 ± 13	41	27
Coelho-Filho et al. (42)	57 ± 14	59	NR	NR	16	8	20	56	57	22	15	57 ± 13	30	31
Doesch et al. (43)	64 ± 10	83	100	35	27	7	30	72	58	28	40	56 ± 10	NR	56
Ingkanisorn et al. (44)	56 ± 14	56	17	12	NR	NR	7	42	53	10	30	65 ± 11	10	21
Jahnke et al. (45)	61 ± 10	69	54	48	NR	NR	24	78	74	23	35	57 ± 8	NR	48/41
Krittayaphong et al. (46)	65 ± 11	48	12	11	NR	NR	NR	63	62	35	15	64 ± 17	27	34
Lerakis et al. (47)	57 ± 12	37	13	NR	NR	NR	NR	64	39	29	19	NR	5	10
Lo et al. (48)	62 ± 12	59	16	NR	12	3	10	70	46	30	29	65 ± 13	13	21
Lubbers et al. (49)	61 ± 11	54	NR	NR	NR	NR	0	46	86	15	63	NR	NR	10
Pilz et al. (50)	63 ± 13	56	0	0	0	0	0	68	37	9	35	61 ± 9	0	0
Steel et al. (51)	58 ± 13	59	NR	26	18	11	22	57	61	25	11	58 ± 11	28	29
Vogel-Claussen et al. (52)	56 ± 13	56	19	19	4	15	NR	78	78	33	67	NR	15	19
Charoenpanichkit et al. (53)	64 ± 12	54	NR	NR	NR	NR	36	69	55	36	42	55 ± 13	NR	31
Gebker et al. (54)	63 ± 10	67	48	NR	40	18	31	74	65	23	31	57 ± 7	NR	40
Kelle et al. (55)	61 ± 11	68	52	43	NR	NR	25	73	70	17	44	57 ± 10	NR	30
Korosoglou et al. (56)	65 ± 13	74	55	NR	40	12	NR	71	53	19	18	60 ± 12	NR	20
Median	62	59	43	23	18	10	24	64	58	24	29	61	24	29
Weighted mean	63 ± 12	63	42	28	29	11	26	66	60	24	25	61 ± 12	29	32

CABG = coronary artery bypass graft surgery; LVEF = left ventricular ejection fraction; MI = myocardial infarction; NR = not reported; PCI = percutaneous coronary intervention; other abbreviations as in Table 1.

Table 3

AERs of Studies for Combined Outcome of Cardiovascular Death and MI, Cardiovascular Death, and MI Comparing Patients With Positive Stress CMR and Patients With a Negative Stress CMR

	Combined Event AER		Cardiovascular Death AER		Nonfatal MI AER	
Studies First Author (Ref. #)	**Positive Stress CMR**	**Negative Stress CMR**	**Positive Stress CMR**	**Negative Stress CMR**	**Positive Stress CMR**	**Negative Stress CMR**
Vasodilator stress CMR studies						
Bertaso et al. (38)	1.8	0.4	0	0.2	1.8	0.2
Bingham et al. (39)	2.9	0.8	2.6	0.6	0.3	0.2
Bodi et al. (40)	5.7	1.6	3.8	0.6	1.9	0.9
Buckert et al. (41)	3.6	0.9	2.2	0.5	1.4	0.4
Coelho-Filho et al. (42)	12.2	0.7	6.7	0.4	5.5	0.3
Doesch et al. (43)	7.1	0	0	0	7.1	0
Ingkanisorn et al. (44)	8.0	0	5.4	0	2.7	0
Jahnke et al. (45)	3.8	1.1	NR	NR	NR	NR
Krittayaphong et al. (46)	2.7	0.3	NR	NR	NR	NR
Lerakis et al. (47)	0	0	0	0	0	0
Lo et al. (48)	8.1	0.8	NR	NR	NR	NR
Lubbers et al. (49)	NR	0.4	NR	0	NR	0.4
Pilz et al. (50)	NR	0	NR	0	NR	0
Steel et al. (51)	19.0	4.2	NR	NR	NR	NR
Vogel-Claussen et al. (52)	0	0	0	0	0	0
Dobutamine stress CMR studies						
Charoenpanichkit et al. (53)	5.6	2.3	NR	NR	NR	NR
Gebker et al. (54)	4.3	0.4	1.0	0.2	3.3	0
Jahnke et al. (45)	3.8	1.5	NR	NR	NR	NR
Kelle et al. (55)	2.2	0.8	NR	NR	NR	NR
Korosoglou et al. (56)	8.0	0.2	2.2	0.04	5.8	0.2

Values are %.

AER = annualized event rate; CMR = cardiac magnetic resonance imaging; NR = not reported; MI = myocardial infarction.

Table 4

AERs of Studies for Combined Outcome of Cardiovascular Death and Nonfatal MI, Cardiovascular Death, and Nonfatal MI Comparing Patients With LGE on CMR and Patients Without LGE on CMR

	Combined Event AER		Cardiovascular Death AER		Nonfatal MI AER	
Stress CMR Studies First Author (Ref. #)	**LGE Present**	**LGE Absent**	**LGE Present**	**LGE Absent**	**LGE Present**	**LGE Absent**
Bertaso et al. (38)	2.2	0.4	0	0.2	2.2	0.2
Bingham et al. (39)	2.0	0.9	1.4	0.7	NR	NR
Bodi et al. (40)	5.5	2.4	3.6	1.3	1.9	1.1
Coelho-Filho et al. (42)	6.7	2.2	NR	NR	NR	NR
Krittayaphong et al. (46)	2.4	0.6	NR	NR	NR	NR
Lerakis et al. (47)	0	0	0	0	0	0
Lo et al. (48)	9.4	1.1	NR	NR	NR	NR
Pilz et al. (50)		0	NR	0	NR	0
Steel et al. (51)	18.9	3.5	NR	NR	NR	NR
Vogel-Claussen et al. (52)	0	0	0	0	0%	0

Values are %.

AER = annualized event rate; CMR = cardiac magnetic resonance imaging; LGE = late gadolinium enhancement; NR = not reported; MI = myocardial infarction.