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EuroCMR (European Cardiovascular Magnetic Resonance) Registry

Results of the German Pilot Phase

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Objectives During its German pilot phase, the EuroCMR (European Cardiovascular Magnetic Resonance) registry sought to evaluate indications, image quality, safety, and impact on patient management of routine CMR.

Background CMR has a broad range of applications and is increasingly used in clinical practice.

Methods This was a multicenter registry with consecutive enrollment of patients in 20 German centers.

Results A total of 11,040 consecutive patients were enrolled. Eighty-eight percent of patients received gadolinium-based contrast agents. Twenty-one percent underwent adenosine perfusion, and 11% high-dose dobutamine-stress CMR. The most important indications were workup of myocarditis/cardiomyopathies (32%), risk stratification in suspected coronary artery disease/ischemia (31%), as well as assessment of viability (15%). Image quality was good in 90.1%, moderate in 8.1%, and inadequate in 1.8% of cases. Severe complications occurred in 0.05%, and were all associated with stress testing. No patient died during or due to CMR. In nearly two-thirds of patients, CMR findings impacted patient management. Importantly, in 16% of cases the final diagnosis based on CMR was different from the diagnosis before CMR, leading to a complete change in management. In more than 86% of cases, CMR was capable of satisfying all imaging needs so that no further imaging was required.

Conclusions CMR is frequently performed in clinical practice in many participating centers. The most important indications are workup of myocarditis/cardiomyopathies, risk stratification in suspected coronary artery disease/ischemia, and assessment of viability. CMR imaging as used in the centers of the pilot registry is a safe procedure, has diagnostic image quality in 98% of cases, and its results have strong impact on patient management. (J Am Coll Cardiol 2009;54:1457–66) © 2009 by the American College of Cardiology Foundation

Cardiovascular magnetic resonance (CMR) is a rapidly emerging noninvasive imaging technique providing high-resolution images of the heart in any desired plane without application of radiation (1). Rather than a single technique, CMR consists of several protocols that can be performed in various combinations during a single examination. For example, cine-CMR can provide cardiac morphology, function, and contractile reserve (2), perfusion CMR with and without vasodilators can provide myocardial perfusion

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Abbreviations and Acronyms

CAD = coronary artery disease

CMR = cardiovascular magnetic resonance

HCM = hypertrophic cardiomyopathy

SCMR = Society for Cardiovascular Magnetic Resonance

SPECT = single-photon emission tomography

(3–6), and contrast CMR can be used for infarct detection, as well as for tissue characterization (7).

CMR has a broad range of appropriate clinical applications, and is increasingly used in daily clinical practice. However, detailed information on the general use of this technique in the clinical routine, its safety, and its impact on patient management is currently not available. Thus, the German pilot phase of the EuroCMR (European Cardiovascular Magnetic Resonance) registry sought to evaluate indications, image quality, safety, and impact on patient management of routine CMR imaging in a large number of cases to: 1) substantiate the clinical value of CMR; and 2) help define clinical questions to be investigated as specific protocols on a European multicenter level (Fig. 1).

Methods

Study population and data management. The basis of the current paper is the German pilot phase of the EuroCMR registry. This registry includes 11,040 consecutive patients who underwent CMR in 1 of 20 participating sites (see Acknowledgments in the Online Appendix) according to the American College of Cardiology Foundation/American College of Radiology/Society of Cardiovascular Computed Tomography/Society for Cardiovascular Magnetic Resonance (SMCR)/American Society of Nuclear Cardiology/North American Society for Cardiac Imaging/Society for Cardiovascular Angiography and Interventions/Society of Interventional Radiology consensus appropriateness criteria for CMR imaging (8). All procedures were performed in compliance with the standardized SCMR-recommended protocols (9). All data were prospectively collected by trained personnel, manually entered in online case record forms based on database elements provided by the "Institut für Herzinfarktforschung," University of Heidelberg, Germany via a secure sockets layer internet connection, and stored on a central server. Each participating center appointed a senior investigator (either SCMR Level 3 trained, or licensed for CMR by the German Chamber of Physicians, which has stricter requirements than SCMR Level 3 [2 years' full-time training]) as local investigator responsible for data quality of each patient entered. If necessary, this local investigator contacted all sources of information necessary in order to determine more complex variables, such as the impact of CMR on patient management. A plausibility check was carried out after submitting the data to minimize further queries. Benchmarking reports were regularly made available to the local investigators for quality control. The reports were compiled for each participating center relating all data of the center with those of other centers. Data collection and management were approved by the ethics committee of the Institut für Herzinfarktforschung.

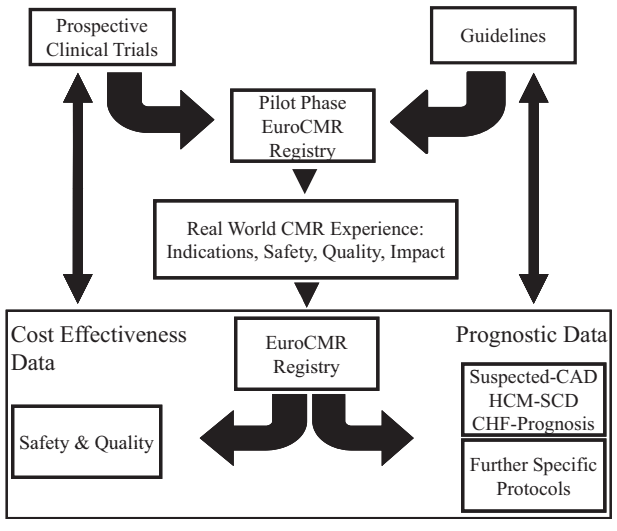

Figure 1 Registry Goals

Illustration of the role and importance of imaging registry data in the continuous circle of optimizing patient management and prognosis, as well as short-term goals and future plans for the EuroCMR (European Cardiovascular Magnetic Resonance) registry. CAD = coronary artery disease; CHF = congestive heart failure; HCM = hypertrophic cardiomyopathy; SCD = sudden cardiac death.

Analysis cohort. All 11,040 patients enrolled between April 2007 and January 2009 were included in the analysis. During online documentation pre-specified plausibility checks were performed. The completeness of the analysis dataset was higher than 98%. For some types of analysis, the cohort was divided in patients that underwent CMR stress testing (n = 3,475), and patients that did not undergo stress CMR (n = 7,565).

Variables and definitions. All variables assessed were predefined, and were collected directly from patients, and/or from medical records. Variables include anonymous demographic data, history, indication for CMR, procedural parameters, complications, results of CMR, as well as the impact of CMR on clinical management. Most fields are self-explanatory; all other fields are defined in the following paragraphs.

COMPLICATIONS OF CMR. Severe complications were defined as death, resuscitation, or any other condition related to the CMR procedure that required monitoring as an inpatient for at least 1 night after the CMR scan (e.g., allergic shock, arrhythmias, and so on). Mild complications were defined as any complications related to CMR that did not fulfill the criteria for severe complications (e.g., dyspnea, chest pain, allergic reactions without shock, problems related to intravenous lines, and so forth).

CMR IMAGE QUALITY. Images that did not allow answering the question of the referrer were graded as poor. Images that did allow complete answering of the question of the referrer,

but some doubts on the findings remained due to artefacts, were graded as moderate. Images with optimal quality that allowed complete answering of the question the CMR was ordered for were graded as good.

A change of patient management was reported if CMR resulted in a new diagnosis that was not suspected before (e.g., amyloidosis found during workup of suspected aortic valve stenosis). Furthermore, a change of patient management was also reported if the results of CMR initiated a direct therapeutic consequence, such as a change in medication (e.g., start of secondary prevention after detection of a myocardial infarction), ordering of invasive procedures, such as coronary angiography or surgery, immediate hospital admission (e.g., new aortic dissection), or discharge from the hospital (risk stratification in suspected coronary artery disease [CAD] revealed low risk for cardiovascular events).

Statistics. Since the objectives of this registry are descriptive in nature, no formal hypothesis testing was done. Absolute numbers and percentages were computed to describe the patient population. Medians (with quartiles) or means (with standard deviation) were computed as appropriate. Categorical values were compared by chi-square test or Fisher exact test, and continuous variables were compared by 2-tailed Wilcoxon rank sum test. Values of $p < 0.05$ were considered significant. All p values were results of 2-tailed tests. The tests were performed using the SAS statistical package version 9.1 (SAS Inc., Cary, North Carolina).

Results

General use of CMR in the clinical routine and most important indications. The most important indications for CMR in this cohort were: 1) workup of myocarditis and cardiomyopathies (31.9%); 2) risk stratification in suspected CAD/ischemia (30.8%); followed by 3) the assessment of myocardial viability (14.7%). Dividing the analysis cohort in subgroups of internal referrals (46.7%) and external referrals (53.3%), the 3 most important indications remain: 1) workup of myocarditis and cardiomyopathies; 2) risk stratification in suspected CAD/ischemia; and 3) assessment of myocardial viability in each of the 2 subgroups. Case examples illustrating the capabilities of CMR regarding the most important indications can be viewed in Figures 2 to 4. Eighty-eight percent of all patients received a gadolinium-based contrast agent. The median contrast dose was 1.28 mmol/kg [bodyweight] (1.16 − 1.56 mmol/kg). Baseline characteristics can be viewed in Table 1.

Imaging procedures before CMR. Before undergoing CMR, 64.1% of patients had undergone transthoracic echocardiography, 25.1% had undergone cardiac catheterization, 1.9% had undergone transesophageal echocardiography, 1.8% had undergone cardiac computed tomography, and 0.3% had undergone single-photon emission tomography (SPECT) imaging. In 23.1% of patients, CMR was the first imaging procedure ordered.

Procedural safety in the clinical routine. Nearly 99% of all CMR procedures (n = 10,896) were performed without complications. Mild complications occurred in 1.1% of patients (n = 124), and severe complications in 0.05% only (n = 5). In the group with mild complications, most events (e.g., dyspnea, chest pain, extra systoles, and so on) occurred during dobutamine or adenosine infusion (76%), followed by mild allergic reactions after injection of contrast (e.g., mild urticaria or exanthema) in 22% of cases.

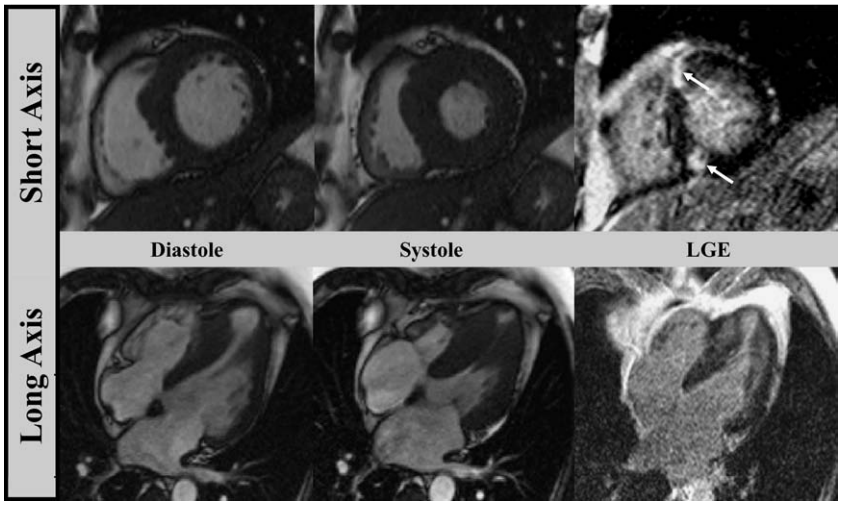

Figure 2 Cardiomyopathies

Steady-state free precession (**left 2 columns** [systole and diastole]), and contrast cardiovascular magnetic resonance images (**right column**, late gadolinium enhancement [LGE]) of a 51-year-old male patient presenting for workup of myocardial disease after aborted sudden cardiac death. Short- and long-axis images clearly show eccentric septal hypertrophy as a typical feature of hypertrophic cardiomyopathy (systolic steady-state free precession). Myocardial scarring, which is suspected to be an important arrhythmogenic substrate, can be visualized and quantified noninvasively by contrast cardiovascular magnetic resonance (**white arrows**, **right column**, LGE).

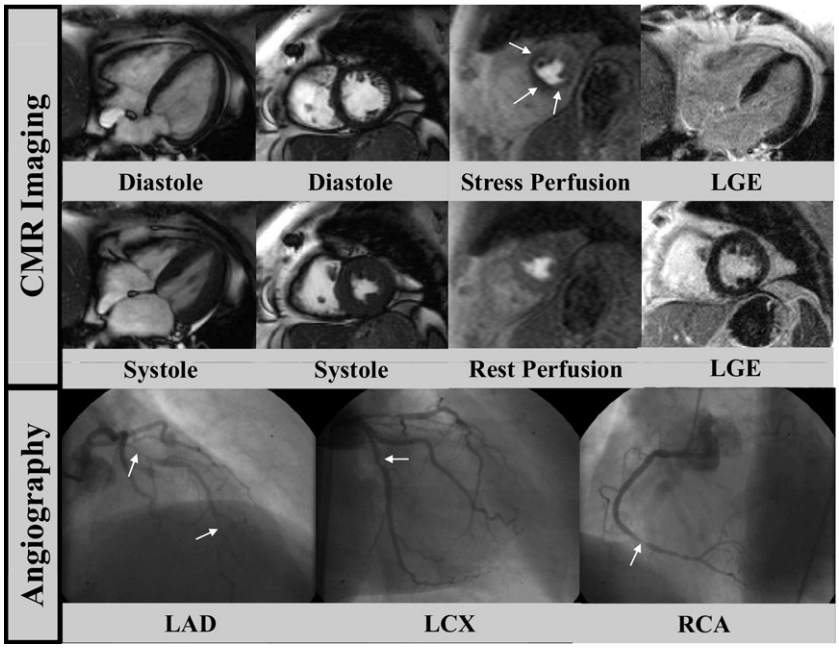

Figure 3 **Risk Stratification in Suspected CAD**

Steady-state free precession cine (diastole and systole), fast gradient echo perfusion (stress and rest), as well as contrast-enhanced cardiovascular magnetic resonance (CMR) late gadolinium enhancement (LGE) images of a 65-year-old woman presenting for workup of atypical chest pain and diabetes mellitus as her only cardiovascular risk factor. She was referred to adenosine stress CMR after a normal stress electrocardiogram up to 125 W and normal echocardiography at rest. Adenosine perfusion CMR revealed stress-induced ischemia in several coronary artery territories **(top and middle)** without myocardial scarring or wall motion abnormalities. Based on the CMR results, invasive angiography was performed demonstrating triple-vessel coronary artery disease **(bottom)**. The patient underwent subsequent surgical revascularization. Note the stress perfusion defects in the perfusion areas of the left anterior descending (LAD), and the right coronary artery (RCA) **(top, white arrows)**, matching significant stenosis of the corresponding coronary vessels **(bottom, white arrows)**. CAD = coronary artery disease; LCX = left circumflex artery.

In the 5 patients with severe complications, we found nonsustained ventricular tachycardia (n = 1) and ventricular fibrillation (n = 1) during dobutamine infusion, as well as overt heart failure (n = 2) and unstable angina (n = 1) related to adenosine stress. No patient died during or due to CMR. All severe complications were related to stress testing (Table 2). Procedural safety was not dependent on race, sex, or age of the patient.

Image quality in the clinical routine. Good image quality was achieved in 90.1% (n = 9,938) of all patients. In 8.1% (n = 897), image quality was moderate but still diagnostic. Poor image quality (nondiagnostic) was present in 1.8% of patients only (n = 189). No difference was found comparing stress to no stress CMR (good image quality in 89.9% without stress vs. 90.7% with stress, p = 0.22).

Image quality was not dependent on race or sex of the patients. However, there was a significant trend toward poorer image quality in older patients (>75 years vs. <45 years; p < 0.0001). Despite this decrease of image quality with age, the ability of CMR to derive a diagnosis and the impact on patient management was not affected (Table 3). In fact, the percentage of therapeutic consequences was even significantly higher in older patients compared with younger patients (age >75 years vs. <45 years; p < 0.0001).

Impact of CMR on patient management in the clinical routine. In nearly two-thirds of all patients (61.8%), we could demonstrate direct impact of CMR on the clinical management by providing an unsuspected new diagnosis (16.4%) and/or resulting in therapeutic consequences as described in Tables 4 and 5.

A typical example for a completely unsuspected new diagnosis can be viewed in Figure 5. A retired man presented at our emergency room due to overt heart failure. A few weeks earlier, he had been seen with the same symptoms at another hospital, where the diagnosis of severe aortic valve stenosis was made, and aortic valve replacement was recommended. However, the patient did not consent to surgery at that time and was discharged after medical treatment. Emergency room assessment demonstrated global hypertrophy accentuated at the ventricular septum, a slightly elevated transaortic pressure gradient, and mild aortic stenosis only. CMR was performed for workup of the discrepancies between the actual and the previous external findings. Based on CMR planimetry, the aortic stenosis was ruled to be mild. However, contrast CMR revealed circular subendocardial late gadolinium enhancement in the entire left ventricular myocardium, which is characteristic for cardiac amyloid-

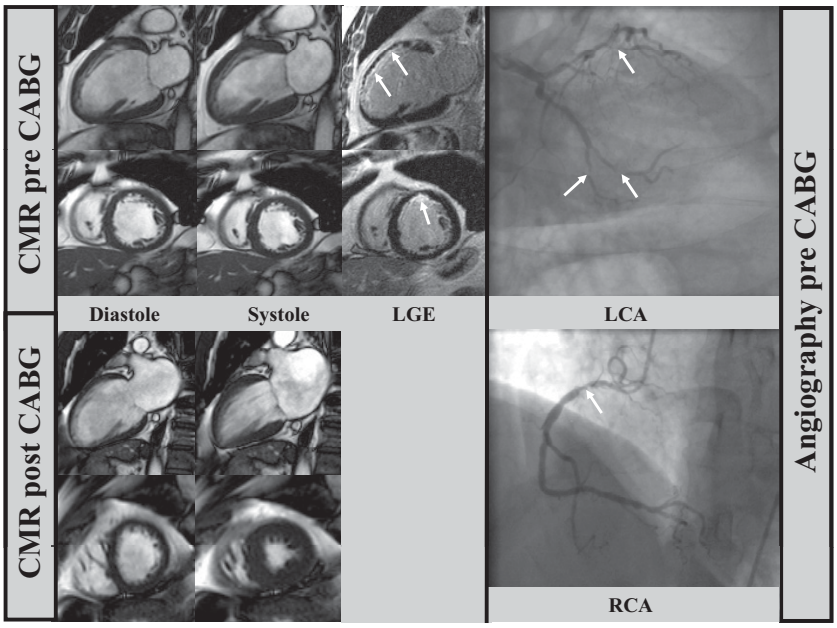

Figure 4 **Myocardial Viability**

Steady state free precession cine (diastole and systole), as well as contrast-enhanced CMR images of a 69-year-old man with known triple-vessel disease (see coronary angiography in the **right row**), and severely impaired left ventricular function presenting for workup of myocardial viability before planned surgical revascularization. Note that only a small nontransmural anterior wall myocardial infarction is present (LGE, **white arrows**), whereas the remaining myocardium is dysfunctional but viable. Thus, after surgical revascularization, the left ventricular function significantly improved (**bottom panels**, 6 months after surgery). CABG = coronary artery bypass grafting; LCA = left circumflex artery; other abbreviations as in Figure 3.

osis (10). This diagnosis was confirmed by endomyocardial biopsy.

In our analysis cohort, CMR was capable of satisfying all imaging needs in more than 86% of patients so that no further noninvasive imaging procedure was required after CMR (Table 4). In the subgroup of patients in whom CMR was the first imaging procedure ordered (23.1%), CMR satisfied all imaging needs in 80.3%, and also no further noninvasive imaging procedure was required in those patients. Furthermore, in this subgroup 74.2% of CMR scans resulted in a direct therapeutic consequence as described in the preceding text.

Focusing on the group of patients that underwent stress CMR for workup of suspected CAD or suspected ischemia in known CAD reveals that in nearly one-half of the cases (45%) invasive angiography could be avoided based on the results of CMR (Table 6).

Discussion

This dataset is unique in that it describes the clinical use, including indications, image quality, procedural safety and impact on patient management of CMR in a large number of cases in an interdisciplinary, multicenter, and multivendor setting (Online Appendix). Our data indicate that CMR is frequently performed in clinical routine, is a safe procedure, has diagnostic image quality in more than 98% of cases, and its results have strong impact on patient management.

General use of CMR in the clinical routine and most important indications. In our analysis, more than 88% of CMR procedures involved the use of contrast media. This may relate to the unique capabilities of CMR providing noninvasive tissue characterization (7), allowing the detection of small subendocardial infarcts (11,12), prediction of recovery of ventricular function before revascularization (13), risk stratification in suspected CAD (14,15), evaluation of myocardial ischemia (4), as well as assessment of cardiomyopathies (7,16–18) and myocarditis (19–21), respectively. Pharmacologic stress testing using adenosine or dobutamine was applied in about one-third of cases (Table 1) underscoring that CMR stress testing is not a research application anymore, but is widely used in clinical routine.

CMR case reading and reporting was mostly done by cardiologists (78.2%), or a team of cardiologists and radiologists (20.1%), respectively. However, this finding may be influenced by a selection bias, since the registry was initiated and is run by a cardiologist society.

Although promising results have been reported for 3.0-T imaging, especially to improve speed (e.g., CMR perfusion), and/or spatial resolution (e.g., CMR coronary angiography) (22,23), CMR imaging at 3.0-T still plays a minor role in general clinical practice (0.8% of studies).

Since the 3 most important CMR indications are not different in the subgroups of internal and external referrals, a relevant bias of the registry data reflecting the

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Table 1 Baseline Characteristics

All	100 (11,040)
Male	63.7% (7,020/11,017)
Female	36.3% (3,997/11,017)
Age (yrs)	60 (47–70)
BMI (kg/m^2)	26.2 (23.7–29.4)
Field	
1.0-T	1.1% (116/11,002)
1.5-T	98.2% (10,801)
3.0-T	0.8% (85)
Stress	
No stress	68.5% (7,565/11,040)
Adenosine	20.9% (2,309)
Dobutamine	10.6% (1,166)
Reader	
Cardiologist	78.2% (8,619)
Team of cardiologist and radiologist	20.1% (2,215)
Radiologist	1.7% (187)
Primary indication for CMR	
Myocarditis/cardiomyopathies	31.9% (3,511/11,026)
Suspected CAD/ischemia in known CAD	30.8% (3,399)
Myocardial viability	14.7% (1,626)
Valvular heart disease	4.8% (531)
Aortic disease	3.4% (372)
Congenital heart disease	1.6% (181)
Ventricular thrombus	1.4% (154)
Cardiac masses	1.2% (129)
Pulmonary vessels	1.1% (126)
Coronary vessels	0.2% (25)
Other than above	8.8% (972)

Values are % (n) or median (quartiles).
BMI = body mass index; CAD = coronary artery disease; CMR = cardiovascular magnetic resonance.

priorities of the authors driven by self-referrals seems to be unlikely.

Imaging procedures before CMR. About two-thirds of patients had a prior echocardiography before undergoing CMR, which reflects the importance of echocardiography as a first-line imaging technique in the clinical routine. However, in 23.1% of patients CMR was the first imaging test ordered, giving us a unique subgroup for evaluation of the diagnostic capabilities of CMR.

Procedural safety in the clinical routine. Mild complications occurred in 1.1%, and severe complications in only 0.05% of patients. No patient died during or due to CMR, indicating that CMR as used in the centers participating in the registry is safe, when performed in a routine clinical setting. All severe complications were related to stress testing (Table 2). Thus, resting CMR may be as save as resting echocardiography, despite the fact that more than 88% of CMR studies involved the administration of contrast media. Importantly, the procedural safety of CMR is not dependent on race, sex, or age of patients.

However, one important limitation of our data concerning CMR safety may be that patients did not undergo systematic clinical follow-up, and, thus, theoretically possible cases of nephrogenic systemic fibrosis may have been missed despite the fact that our mean dose of contrast media was low (1.28 mmol/kg), and we did repeatedly contact the participating centers but did not receive any reports of nephrogenic systemic fibrosis. Nevertheless, serum creatinine and glomerular filtration rate should be evaluated and taken into account before any gadolinium contrast administration.

Since most complications of stress CMR are not related to CMR imaging itself, but to stressing the patient, stress CMR is likely to be as safe as stress echocardiography (24), stress nuclear testing (25), or even as safe as obtaining a simple treadmill electrocardiogram (about 1 fatal complication or myocardial infarction in 2,500 cases) (26).

Image quality in the clinical routine. To our knowledge, this is the first dataset on clinical routine image quality of CMR in a multicenter and multivendor setting (Online

Table 3 Indications, Image Quality, and Complications Related to Patient Age

	Age			
	−44 Yrs	45–59 Yrs	60–74 Yrs	75 Yrs
Indication				
Ischemia/CAD	10.1%	32.3%	39.6%	36.9%
Myocarditis/CMP	58.2%	32.5%	21.2%	14.5%
Viability	4.5%	15.5%	17.9%	21.5%
Stress CMR	22.2%	22.7%	40.2%	37.7%
Image quality				
Good	94.6%	92.8%	88.5%	81.3%
Moderate	4.5%	6.0%	9.5%	15.2%
Poor	0.9%	1.2%	2.0%	3.6%
Ectopy	72.2%	37.1%	42.1%	28.9%
Atrial fibrillation	27.8%	62.9%	57.9%	71.1%
Complications*				
None	99.2%	98.9%	98.6%	98.5%
Mild	0.8%	1.0%	1.4%	1.3%
Severe	0%	0.2%	0%	0.1%
New diagnosis	18.3%	17.1%	15.8%	12.9%
Therapeutic consequence	29.2%	42.4%	49.3%	53.2%

*See definitions section for details.
CMP = cardiomyopathy; other abbreviations as in Table 1.

Table 2 Complications Related to No Stress Versus Stress Cardiovascular Magnetic Resonance

Complications*	All (n = 1,027)	No Stress (n = 7,553)	Stress (n = 3,474)	p Value
None	98.8% (n = 10,896)	99.5% (n = 7,516)	97.7% (n = 3,380)	<0.0001
Mild	1.1% (n = 124)	0.5% (n = 35)	2.5% (n = 89)	<0.0001
Severe	0.05% (n = 5)	0.0% (n = 0)	0.2% (n = 5)	<0.0001

*See definitions section for details.

Table 4 Impact of CMR on Patient Management

All	100% (11,040)
Completely new diagnosis not suspected before	16.4% (1,748/10,672)
Therapeutic consequences	
Change in medication	23.5% (2,462/10,464)
Intervention/surgery	8.7% (912)
Invasive angiography/biopsy	8.7% (909)
Hospital discharge	2.2% (231)
Hospital admission	0.3% (36)
Impact on patient management (new diagnosis and/or therapeutic consequence)	61.8% (6,589)
Noninvasive imaging ordered after CMR	
Transthoracic echocardiography	11.9% (1,228/10,346)
Transesophageal echocardiography	0.9% (97)
Computed tomography	0.9% (96)

Values are % (n).
CMR = cardiovascular magnetic resonance.

Appendix). Our data demonstrate that CMR was capable of answering the relevant clinical questions in more than 98% of cases. This indicates that current CMR utilization yields a high number of valuable studies, which is related to the good image quality. Only 1.8% of studies were inadequate in quality, allowing no diagnosis.

Importantly, this was shown in a clinical routine setting, since patients with dyspnea at rest, atrial fibrillation, obesity (body mass index quartiles 23.7 to 29.4 kg/m^2), or other frequent cardiac conditions affecting image quality were not excluded. Thus, the average image quality of CMR may be better than the average image quality of other noninvasive imaging techniques, such as echocardiography (27), cardiac computed tomography (28,29), or SPECT (30). In addition, no ionizing radiation needs to be applied during CMR, so it can therefore be repeated as often as necessary for follow-up purposes.

However, we found a significant decrease of image quality in older patients, which interestingly was associated with an increased impact on patient management in this group (Table 3). This can most probably be explained by the increased morbidity in older patients causing more gating or breathing problems, but also yielding more abnormal findings requiring an altered management (Table 3).

Impact of CMR on patient management in the clinical routine. We found that CMR was capable of satisfying all imaging needs in more than 86% of patients so that no further noninvasive imaging procedure was required after completion of CMR. Interestingly, in the subgroup of patients with no other imaging test before CMR (23.1%), all imaging needs were also satisfied by CMR in the majority of cases (80.4%). This finding underscores that the low rate of additional tests ordered after completed CMR is not due to the fact that CMR is the last test in a long row of diagnostic procedures, but rather can answer multiple important questions within 1 exam. Furthermore, CMR had direct impact on the clinical management of the majority of patients (Tables 4 and 5). Importantly, in patients in whom CMR was the only imaging test performed, nearly three-quarters (74.2%) of CMR procedures had direct impact on patient management. Thus, based on the pilot data of the EuroCMR registry, the potential of CMR imaging in the clinical routine is now well documented in a multicenter and multivendor setting.

In patients undergoing CMR stress testing for workup of suspected CAD (Table 6), invasive angiography could be avoided in nearly one-half of the patients (n = 1,509). Consequently, CMR stress testing for risk stratification in suspected CAD may have the potential to significantly bring down the number of diagnostic coronary angiographies that do not result in intervention or surgery in the future (31–33). In addition, nearly 700 noninvasive procedures involving the use of ionizing radiation, such as SPECT imaging, could also be avoided on the basis of the CMR results (Table 6).

Table 5 Impact of CMR on Patient Management by Indication

	Myocarditis/CMP	Suspected CAD/Ischemia	Viability
All (from n = 11,040)	31.8%	30.8%	14.7%
Completely new diagnosis not suspected before	21%	19.6%	7.9%
Therapeutic consequences			
Change in medication	22.7%	25.9%	34.4%
Intervention/surgery	2.9%	6.7%	17.7%
Invasive angiography/biopsy	6.3%	15.6%	6.1%
Hospital discharge	1.7%	3.6%	2.2%
Hospital admission	0.4%	0.2%	0.3%
Impact on patient management (new diagnosis and/or therapeutic consequence)	55.0%	71.2%	68.6%
Noninvasive imaging ordered after CMR			
Transthoracic echocardiography	16.9%	6.3%	10.9%
Transesophageal echocardiography	0.4%	0.4%	0.3%
Computed tomography	0.6%	0.8%	1.1%

Abbreviations as in Tables 1 and 3.

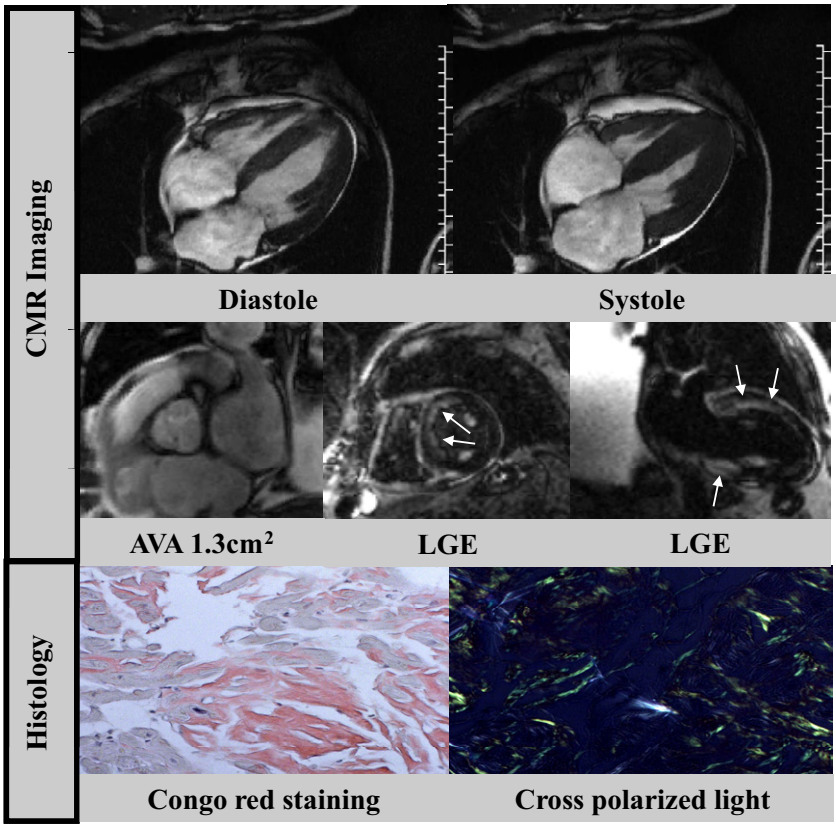

Figure 5 **Completely New Diagnosis by CMR**

Steady state free precession cine (diastole, systole, and aortic valve area [AVA]), as well as contrast-enhanced CMR (LGE) images of a 78-year-old man presenting for workup of heart failure, and discrepant previous findings regarding possible aortic stenosis. Whereas steady-state free precession CMR sufficiently assessed the AVA to be 1.3 cm^2, contrast CMR (LGE) revealed diffuse subendocardial enhancement in the large parts of the left ventricle **(white arrows)**, which is typical for cardiac amyloidosis. After CMR, this diagnosis was confirmed by endomyocardial biopsy **(bottom row)**. Abbreviations as in Figure 3.

We did not perform a cost analysis of integrating CMR into the clinical routine. However, given the reduced need for further imaging, or other diagnostic procedures in combination with the large percentage of altered patient management after CMR, it is likely that integrating CMR into the clinical routine does not increase the overall costs of patient care.

Clinical implications. On the basis of the registry findings, one could speculate that an increased routine use of CMR could have an effect on the number of invasive procedures, as well as on the numbers of SPECT scans in the future. Echocardiography with its flexibility, speed, and low associated costs will probably remain the imaging technique of first choice in most patients as recommended by current guidelines (34), which is also reflected by the fact that the majority of registry patients underwent echocardiography before CMR. However, CMR can add to echocardiographic findings, especially in the workup of cardiomyopathies and myocarditis (17,35), suspected CAD (14), as well as myocardial viability (13).

Despite our promising results, however, it is important to keep in mind that most of the parameters describing the impact of CMR on patient management collected during the pilot phase of the EuroCMR registry are all more or less

Table 6 **Additional Diagnostic Procedures Avoided Due to Results of CMR**

	All (n = 10,284)	No Stress (n = 6,933)	Stress (n = 3,351)	p Value
Invasive angiography	21.5% (2,213)	10.2% (704)	45.0% (1,509)	<0.0001
Nuclear (SPECT/PET)	9.0% (928)	4.6% (319)	18.2% (609)	<0.0001
Coronary CT	2.0% (204)	1.9% (131)	2.2% (73)	0.32

Values are % (n).

CMR = cardiovascular magnetic resonance; CT = computed tomography; PET = positron emission tomography; SPECT = single-photon emission tomography.

precise surrogate parameters for the impact of CMR imaging on a patients prognosis. Thus, an important next step is to expand the EuroCMR registry to collect prognostic data on a European multicenter, and multivendor level (Fig. 1), beginning with the most important indications based on the results of this pilot data. As soon as sufficient prognostic data is available, CMR may hold promise to reshape cardiovascular patient management in the future. Thus, in April 2009 we have started to implement the following 3 first specific protocols on a European level.

SUSPECTED CAD. Using the combined information from wall motion, ischemia, and scar detection, CMR yields a diagnostic performance for the detection of CAD similar to SPECT or stress echocardiography (2,4). However, compared with SPECT and stress echocardiography, there is only limited evidence on the prognostic impact of this combined CMR information in the setting of suspected CAD (5,36). Thus, the main aim of the first specific protocol initiated by the European CMR registry is to demonstrate that patients presenting for workup of suspected CAD that have a completely normal CMR scan will have a low risk for cardiovascular events during follow-up.

HYPERTROPHIC CARDIOMYOPATHY (HCM)—SUDDEN CARDIAC DEATH. Another clinical problem of high socioeconomic concern is HCM, because the average loss of individual lifetime caused by an HCM-induced lethal event is much higher than that caused by most other heart diseases, due to the common early manifestation of HCM and the fact that, especially in young patients, sudden cardiac death sometimes is the first symptom of the disease (37). Recently, it has been described that the amount of myocardial scarring detected by CMR is related to the long-term clinical outcome, and may thus be a much better predictor of lethal events than individual clinical markers (38), which are limited by low positive predictive values (39,40). Consequently, the main aim of the second specific protocol initiated by the European CMR registry will be to evaluate CMR for risk stratification in HCM patients.

CONGESTIVE HEART FAILURE—PROGNOSIS. Ischemic as well as nonischemic heart failure are major health burdens in Western countries. CMR can differentiate etiologies of heart failure and (7), thus, guide therapy. It has a high accuracy and reproducibility for the assessment of left ventricular volumes, function, and mass and might, thus, be a superior tool for guiding therapeutic strategies than echocardiography (2). In addition, the presence and extent of scar tissue have been shown to be important and independent parameters for cardiac events (18). However, it is currently unclear which parameters are best for the prediction of events, how often CMR abnormalities are found in "normals," and which of these findings are of clinical importance. The main aim of the third specific protocol initiated by the European CMR registry will be to evaluate CMR for risk stratification in patients with reduced ejection fraction.

Study limitations. The grading of image quality was based on the ability of CMR to answer the clinical question the scan was ordered for. This definition may rather describe the overall quality of the CMR study than the actual quality of images with regard to artefacts.

The sample reported in this report may not be representative to the medical community since all sites participated in the registry on a voluntary basis. In addition, despite the fact that following the American College of Cardiology Foundation/American College of Radiology/Society of Cardiovascular Computed Tomography/SMCR/American Society of Nuclear Cardiology/North American Society for Cardiac Imaging/Society for Cardiovascular Angiography and Interventions/Society of Interventional Radiology consensus appropriateness criteria for CMR (8) was regarded mandatory for all sites, there was no monitoring comparable to a controlled multicenter trial if those criteria were followed in every patient.

Furthermore, the current registry data do not include a head-to-head comparison of CMR to other imaging modalities with regard to diagnostic performance or prognostic implications. Thus, the current data cannot be used to make clinical recommendations on these topics.

Conclusions

CMR is frequently performed in daily clinical practice in many participating centers. The most important indications are workup of myocarditis and cardiomyopathies, risk stratification in suspected CAD/ischemia, and assessment of myocardial viability. CMR imaging as used in the centers of the pilot registry, is a safe procedure, has diagnostic image quality in more than 98% of cases, and its results have strong impact on patient management.

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Key Words: cardiovascular magnetic resonance ■ registry ■ patient management ■ therapeutic implications.

APPENDIX

For detailed information about the participating sites and acknowledgments, please see the online version of this article.