Int J Cardiovasc Imaging (2010) 26:173–186
DOI 10.1007/s10554-010-9687-z

ORIGINAL PAPER

ASCI 2010 appropriateness criteria for cardiac magnetic resonance imaging: a report of the Asian Society of Cardiovascular Imaging cardiac computed tomography and cardiac magnetic resonance imaging guideline working group

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Received: 10 August 2010 / Accepted: 11 August 2010 / Published online: 24 August 2010

Abstract There has been a growing need for standard Asian population guidelines for cardiac CT and cardiac MR due to differences in culture, healthcare system, ethnicity and disease prevalence. The Asian Society of Cardiovascular Imaging, as the only society dedicated to cardiovascular imaging in Asia, formed a cardiac CT and cardiac MR guideline working group in order to help Asian practitioners to establish cardiac CT and cardiac MR services. In this ASCI cardiac MR appropriateness criteria report, 23 Technical Panel members representing various Asian countries were invited to rate 50 indications that can frequently be encountered in clinical practice in Asia. Indications were rated on a scale of 1–9 to be categorized into 'appropriate' (7–9), 'uncertain' (4–6), or 'inappropriate' (1–3). According to median scores of the 23 members, the final ratings for indications were 24 appropriate, 18 uncertain and 8 inappropriate with 22 'highly-agreed' (19 appropriate and 3 inappropriate) indications. This report is expected to have a significant impact on the cardiac

Technical Panel Members of ASCI 2010 Cardiac MR Appropriateness Criteria have been processed in Appendix.

Electronic supplementary material The online version of this article (doi:10.1007/s10554-010-9687-z) contains supplementary material, which is available to authorized users.

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MR practices in many Asian countries by promoting the appropriate use of cardiac MR.

Keywords Appropriateness criteria · Cardiac magnetic resonance · Guideline · Asia

Abbreviations

ACCF	American College of Cardiology Foundation
ARVD	Arrhythmogenic right ventricular dysplasia
ASCI	Asian Society of Cardiovascular Imaging
ASD	Atrial septal defect
CABG	Coronary artery bypass graft
CAD	Coronary artery disease
CCT	Cardiac CT
CHD	Coronary heart disease
CMR	Cardiac MR
CT	Computed tomography
CTCA	CT coronary angiography
ECG	Electrocardiogram
JCCT	Journal of Cardiovascular Computed Tomography
LV	Left ventricle
MR	Magnetic resonance
MRA	MR angiography
MRCA	MR coronary angiography
MRI	MR imaging
PCI	Percutaneous coronary intervention
RV	Right ventricle
TEE	Transesophageal echocardiography
VSD	Ventricular septal defect

Introduction

Due to differences in culture, healthcare systems, ethnicity [1], socioeconomic status [2] and disease prevalence [3, 4], existing guidelines for cardiac computed tomography (CT) and cardiac magnetic resonance (MR) developed by western professional societies are often not applicable in Asian countries. In March 2009, the Asian Society of Cardiovascular Imaging (ASCI), as the only society in Asia dedicated solely to cardiovascular imaging, nominated 7 representatives from different Asian countries to form a working group to provide recommendations on cardiac CT and cardiac MR. Detailed background of this project has previously been described in the ASCI cardiac CT criteria report, the first publication from the working group, which summarized the opinions of leading cardiac CT practitioners in Asia on 51 indications [5]. As the second step, we present here the ASCI cardiac MR appropriateness criteria. The purpose of this report is to serve as a reference for Asian practitioners to promote and improve their use of cardiac MR by providing appropriateness ratings for common clinical indications.

Methods

ASCI cardiac MR appropriateness criteria were developed through the same process as used for ASCI CT appropriateness criteria published earlier this year [5]. Briefly, we employed the modified Delphi method with one-round data collection to evaluate the cardiac MR appropriateness [6, 7]. A total of 25 panelists were nominated [Japan 6, Korea 5, Taiwan 4, China 3, Hong Kong (China) 3, Singapore 2, Thailand 2] by Working Group members, and approved by the Working Group with consensus.

In the development of the cardiac MR indications, the Working Group members agreed to use the 33 cardiac MR indications provided by the ACCF 2006 appropriateness criteria as the framework [8]. Indications considered for the ASCI 2010 cardiac CT appropriateness criteria were added and integrated to derive 50 indications which were approved by the Working Group. Among the 50 indications, 28 were in common with ACCF 2006 appropriateness criteria and 39 were in common with ASCI 2010 CT appropriateness criteria. Three indications [risk assessment in general populations with low, moderate and high coronary heart disease risk using coronary magnetic resonance angiography (MRA)] were original indications of ASCI cardiac MR appropriateness criteria.

A questionnaire was emailed to the 25 Technical Panel members. After completion, the questionnaires were collected by the ASCI office. The questionnaires were collected during a period between October 13 and November 11, 2009. Please refer to the online supplement for the complete questionnaire (Online Supplement 1).

Definition of cardiac MR

There are a variety of techniques used for cardiac MR [9]. Basic protocols might include cine magnetic

resonance imaging (MRI) for wall motion and delayed gadolinium enhancement MRI for the assessment of scar [10–19]. However, some may perform stress tests routinely using either perfusion MRI with adenosine [20, 21] or cine MRI with dobutamine [22, 23], while others may consider coronary and non-coronary MRA [24, 25] as important parts of cardiac MR examinations. Moreover, different techniques can be utilized to assess certain aspects of cardiac morphology and function [26–29]. Since cardiac MR is still an intense field of research and development, it is also possible for appropriateness to be influenced by the availability of newer scanners and more sophisticated imaging techniques [30]. Thus, the Working Group decided to leave the definition of cardiac MR to the judgment of the Technical Panel members. Resulting variations in definitions might be an important reflection of the current perspectives of the leading Asian cardiac MR practitioners. In the questionnaire, the term "cardiac MR" was defined as including motion, stress and rest perfusion, delayed gadolinium enhancement, flow measurement, black blood T2-weighted imaging, and coronary MRA.

Rating system

The rating system used in this Asian survey is the same as previously used in other appropriateness criteria reports and ASCI CT appropriateness criteria. The panelists were asked to assess whether the use of cardiac MR for various indications was appropriate, uncertain or inappropriate. The Technical Panel scored each indication as follows:

Score 7–9: *Appropriate* test for the specific indication. Test is generally acceptable and a reasonable approach for the listed indication.
Score 4–6: *Uncertain* for specific indication. Test may be generally acceptable and may be a reasonable approach for the indication. Uncertainty also implies that more research or patient information or both are needed to classify the indication definitively.
Score 1–3: *Inappropriate* test for specific indication. Test is not generally acceptable and is not a reasonable approach for the indication.

In a panel with 23–25 members, 'highly agreed' was defined as 7 or fewer panelists rating outside the three-point region containing the median. 'Disagreement' was defined as at least 8 panelists rating in either extreme (1–3 and 7–9). Median values for each indication served as the final scoring if there was no disagreement among Technical Panelists [5, 7, 8]. If there was disagreement, the final appropriateness score was set as uncertain regardless of the median.

Results

The questionnaires were emailed to the Technical Panel members on October 13, 2009. Completed questionnaires were returned from 23 members [Japan 6, Korea 5, Taiwan 4, China 2, Hong Kong (China) 2, Singapore 2, Thailand 2] by November 11. Their specialties were radiology in 17 and cardiology in 6. The years of experience in the cardiovascular field ranged from 4 to 26 years while the experience of cardiac MR interpretation ranged from 300 to 3,000 examinations. For the cardiologists, the number of percutaneous coronary interventions performed range from 0 to 700 cases. The hospitals they were working in included city hospitals, medical centers, and university hospitals, with in-patient bed numbers ranging from 440 to 5,600. The complete list of Technical Panel members is provided at the beginning of this report.

Among the indications rated by Technical Panel, none showed disagreement. There were 24 appropriate, 18 uncertain and 8 inappropriate indications. Technical Panel members highly agreed in 22 indications, including 19 appropriate and 3 inappropriate indications. The 'highly agreed' inappropriate indications were: use of cardiac MR for evaluation of chest pain syndrome in patients with low pre-test probabilities of CAD, interpretable ECGs and ability to exercise; use of cardiac MR for detection of CAD in asymptomatic patients with low coronary heart disease risk; and use of coronary MRA for risk assessment in patients with low coronary heart disease risk. A detail appropriateness rating result is provided as an online supplement (Online Supplement 2).

Compared with the ACCF 2006 report [8], only 4/28 (14%) indications changed their category. Indication no. 38 ("evaluation of LV function following myocardial infarction or in heart failure patients") and no. 49 ("to detect post PCI myocardial necrosis") were shifted from uncertain to appropriate. Indication no. 30 ("evaluation of bypass grafts and coronary

anatomy") and no. 31 ("history of percutaneous revascularization with stents") were shifted from inappropriate to uncertain.

Compared with the ASCI cardiac CT appropriateness criteria report [5], 29/39 (74%) were in the same appropriateness category. In 7 indications, cardiac CT received a more favorable category than cardiac MR: indication no. 2 ("detection of CAD: symptomatic, intermediate pre-test probability of CAD. ECG interpretable and able to exercise"), no. 27 ("use of MRI for CAD evaluation before valve surgery"), no. 29 ("evaluation of complex lesions before PCI"), no. 30 ("evaluation of bypass grafts and coronary anatomy"), no. 31 ("history of percutaneous revascularization with stents"), no. 33 ("evaluation of bypass grafts and coronary anatomy greater than or equal to 5 years after CABG"), and no. 34 ("evaluation for in-stent restenosis and coronary anatomy after PCI"). On the other hand, cardiac MR received a more favorable category than cardiac CT in 3 indications; indication no. 38 ("evaluation of LV function following myocardial infarction or in heart failure patients"), no. 48 ("to determine the location and extent of myocardial infarction including 'no-reflow' regions, post-acute myocardial infarction"), and no. 50 ("to determine viability prior to revascularization").

The final ratings for cardiac MR are listed by indication sequentially (Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11) and by appropriateness category (Tables 12, 13, 14).

Discussion

This ASCI cardiac MR appropriateness criteria report was developed in order to reflect the current status of cardiac MR in Asia and the opinions of Asian cardiac MR leaders about appropriate indications for cardiac MR. This report should prove useful in clinical

Table 1 Detection of CAD: symptomatic

	Indication	Appropriateness criteria (median score)	Note
Evaluation of chest pain syndrome			
1	Low pre-test probability of CAD ECG interpretable AND able to exercise	I (2)	Highly agreed ACCF indication no. 1
2	Intermediate pre-test probability of CAD ECG interpretable AND able to exercise	U (4)	ACCF indication no. 2 ASCI CT indication no. 1
3	Intermediate pre-test probability of CAD ECG uninterpretable OR unable to exercise	A (7)	ACCF indication no. 3 ASCI CT indication no. 2
4	High pre-test probability of CAD	U (6)	ACCF indication no. 4 ASCI CT indication no. 3
Evaluation of intra-cardiac structures			
5	Evaluation of suspected coronary anomalies	A (8)	Highly agreed ACCF indication no. 8 ASCI CT indication no. 4
Acute chest pain			
6	Low pre-test probability of CAD No ECG changes and serial enzymes negative	U (4)	ASCI CT indication no. 5
7	Intermediate pre-test probability of CAD No ECG changes and serial enzymes negative	U (5)	ACCF indication no. 9 ASCI CT indication no. 6
8	High pre-test probability of CAD No ECG changes and serial enzymes negative	U (5)	ASCI CT indication no. 7
9	High pre-test probability of CAD ECG—ST-segment elevation and/or positive cardiac enzymes	I (2)	ACCF indication no. 10 ASCI CT indication no. 8

Table 2 Detection of CAD: asymptomatic (without chest pain syndrome)

Indication		Appropriateness criteria (median score)	Note
Asymptomatic			
10	Low CHD risk (Framingham risk criteria)	I (1)	Highly agreed ASCI CT indication no. 10
11	Moderate CHD risk (Framingham)	U (4)	ASCI CT indication no. 11
12	High CHD risk (Framingham)	U (6)	ASCI CT indication no. 12

Table 3 Risk assessment: general population

Indication		Appropriateness criteria (median score)	Note
Asymptomatic (use of coronary MRA)			
13	Low CHD risk (Framingham)	I (3)	Highly agreed
14	Moderate CHD risk (Framingham)	I (3)	
15	High CHD risk (Framingham)	U (5)	

practice in Asia, especially for institutes starting cardiac MR services for the first time.

Among the 50 indications evaluated in this report, 28 were in common with the ACCF 2006 appropriateness criteria report [8], 39 were also included in the ASCI 2010 cardiac CT appropriateness criteria report [5] and 3 indications were unique to this report. In contrast to the ASCI cardiac CT appropriateness criteria report in which an upward shift of appropriateness category was demonstrated in 51.3% (20/39) of the indications as compared with ACCF 2006 appropriateness criteria report, such a shift was seen in only 14.3% (4/28) of the indications in this cardiac MR appropriateness criteria report. The rapid advancement of CT technology [31] and associated accumulation of evidence of its clinical usefulness [32–34] as well as reduction of its radiation levels [32] may explain the faster expansion of appropriate indications for cardiac CT compared to the expansion seen for cardiac MR, which has seen comparatively few technical advances over the past 5 years.

One of the most significant features of the ASCI cardiac CT and cardiac MR appropriateness criteria reports is the high number of indications evaluated for both CT and MR. Although cardiac CT was originally developed for visualization of coronary anatomy, recent studies have demonstrated the potential usefulness of one-stop shop cardiac examination in assessment of function, myocardial ischemia and myocardial viability [35, 36]. Meanwhile, the introduction of whole heart coronary MRA has enabled routine imaging of coronary anatomy which is completely noninvasive and without the need for radiation exposure and contrast medium [24, 37, 38]. Given the similarities in information obtainable, it is inevitable that CT and MR share many indications. In our questionnaire surveys, different panelists were selected for CT and MR. The panelists were not aware that similar surveys were being performed for the other modality, thus minimizing the extent to which their ratings were based on comparison to the other modality. Our survey demonstrated that CT received higher ratings than MR in the morphological assessment of native coronary arteries and bypass grafts before and after revascularization therapy. On the other hand, assessment of myocardial viability and fibrosis can be performed better with MR. However, most appropriateness ratings were similar for CT and MR, indicating that modality choice should be based on the technology and expertise available at each individual medical center.

"Use of coronary MRA in the risk assessment of general population" was evaluated in this survey. This indication was evaluated because coronary MRA has been gaining popularity as a screening tool in recent years, since the introduction of whole-heart coronary MRA [37, 39]. We found that experts in Asia consider this indication inappropriate in populations with low to intermediate coronary heart disease risk. Future research is needed to determine whether risk assessment of population with high coronary heart disease risk is appropriate or not.

This survey had several limitations. As was the case with the ASCI cardiac CT appropriateness criteria report, the Technical Panel in this study was dominated by experts from Eastern and Southeastern

Table 4 Detection of CAD with prior test results

Indication	Appropriateness criteria (median score)	Note
Evaluation of chest pain syndrome		
16 Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)	A (8)	Highly agreed ASCI CT indication no. 16
17 Evidence of moderate to severe ischemia on stress test (exercise, perfusion, or stress echo)	U (5)	ASCI CT indication no. 17

Table 5 Risk assessment with prior test results

Indication	Appropriateness criteria (median score)	Note
Asymptomatic		
18 Normal prior stress test (exercise, nuclear, echo, MRI) High CHD risk (Framingham)	I (3)	ACCF indication no. 11
19 Equivocal stress test (exercise, stress SPECT, or stress echo) Intermediate CHD risk (Framingham)	U (6)	ACCF indication no. 12
20 Coronary angiography (catheterization or CT) Stenosis of unclear significance	A (7)	ACCF indication no. 13

Table 6 CAD detection in pediatric patients with kawasaki disease

Indication	Appropriateness criteria (median score)	Note
Asymptomatic		
21 No previous definitive test (invasive angiography, MRCA or CTCA) available	U (5)	Asian characteristic indication ASCI CT indication no. 21
22 Previous tests (invasive angiography, CMR or CCT) documented coronary aneurysm/stenosis, for follow up	A (7)	Highly agreed Asian characteristic indication ASCI CT indication no. 22
Symptomatic		
23 No previous definitive test (invasive angiography, MRCA or CTCA) available	A (7)	Asian characteristic indication ASCI CT indication no. 23
24 Previous tests (angiography, CMR or CCT) documented coronary aneurysm/stenosis, for follow up	A (7)	Asian characteristic indication ASCI CT indication no. 24

Asia reflecting the current academic contribution and participation in ASCI. We hope to see active participation in ASCI from Asian countries outside the Asia–Pacific region in the future. Secondly, many Technical Panelists proposed further clarification of the scan protocol. Although the importance of correct choice of MR scan protocol cannot be underestimated, this aspect is considered too complicated to be included in this questionnaire survey because of the diversity and rapid innovation of MR scan techniques

Table 7 Risk assessment: preoperative evaluation for non-cardiac surgery

Indication		Appropriateness criteria (median score)	Note
Low-risk surgery			
25	Intermediate perioperative risk	I (3)	ACCF indication no. 14 ASCI CT indication no. 25
Intermediate- or high-risk surgery			
26	Intermediate perioperative risk	U (5)	ACCF indication no. 15 ASCI CT indication no. 26

Table 8 Risk assessment: preoperative evaluation for cardiac surgery or endovascular intervention

Indication		Appropriateness criteria (median score)	Note
Preoperative evaluation			
27	Use of MRI for CAD evaluation before valve surgery	U (6)	JCCT 2009 proposed indication ASCI CT indication no. 27
28	Anatomic assessment before percutaneous device closure of ASD or VSD or percutaneous aortic valve replacement	A (7)	JCCT 2009 proposed indication ASCI CT indication no. 28
29	Evaluation of complex lesions before PCI (i.e., chronic total occlusions, bifurcation lesions)	U (5)	JCCT 2009 proposed indication ASCI CT indication no. 29

Table 9 Detection of CAD: post-revascularization (PCI or CABG)

Indication		Appropriateness criteria (median score)	Note
Evaluation of chest pain syndrome			
30	Evaluation of bypass grafts and coronary anatomy	U (5)	ACCF indication no. 16 ASCI CT indication no. 30
31	History of percutaneous revascularization with stents	U (4)	ACCF indication no. 17 ASCI CT indication no. 31
Asymptomatic			
32	Evaluation of bypass grafts and coronary anatomy Less than 5 years after CABG	U (4)	ASCI CT indication no. 32
33	Evaluation of bypass grafts and coronary anatomy Greater than or equal to 5 years after CABG	U (4)	ASCI CT indication no. 33
34	Evaluation for in-stent restenosis and coronary anatomy after PCI	I (3)	ASCI CT indication no. 34

Table 10 Structure and function

Indication	Appropriateness criteria (median score)	Note
Morphology		
35 Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves	A (8)	Highly agreed ACCF indication no. 18 ASCI CT indication no. 35
36 Assessment of post-operative congenital heart disease, such as residual pulmonary stenosis, ventricular septal defect and patency check for Blalock-Taussig shunt	A (8)	Highly agreed ASCI CT indication no. 36 Asian characteristic indication
37 Evaluation in patients with new onset heart failure to assess etiology	A (8)	Highly agreed ASCI CT indication no. 37
Evaluation of ventricular and valvular function		
38 Evaluation of LV function following myocardial infarction OR in heart failure patients	A (8)	Highly agreed ACCF indication no. 19
39 Evaluation of LV function following myocardial infarction OR in heart failure patients Patients with technically limited images from echocardiogram	A (9)	Highly agreed ACCF indication no. 20
40 Quantification of LV function Discordant information that is clinically significant from prior tests	A(9)	Highly agreed ACCF indication no. 21
41 Evaluation of specific cardiomyopathies (infiltrative [amyloid, sarcoid], HCM, or due to cardiotoxic therapies)	A(9)	Highly agreed ACCF indication no. 22
42 Characterization of native and prosthetic cardiac valves Patients with technically limited images from echocardiogram or TEE	A (7)	Highly agreed ACCF indication no. 23
43 Evaluation for arrhythmogenic right ventricular cardiomyopathy (ARVC) Patients presenting with syncope or ventricular arrhythmia	A (8)	Highly agreed ACCF indication no. 24
44 Evaluation of myocarditis or myocardial infarction with normal coronary arteries Positive cardiac enzymes without obstructive atherosclerosis on angiography	A(9)	Highly agreed ACCF indication no. 25
Evaluation of intra- and extra-cardiac structures		
45 Evaluation of cardiac mass (suspected tumor or thrombus) Patients with technically limited images from echocardiogram or TEE	A (9)	Highly agreed ACCF indication no. 26 ASCI CT indication no. 42
46 Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery) Patients with technically limited images from echocardiogram or TEE	A (8)	Highly agreed ACCF indication no. 27 ASCI CT indication no. 43
47 Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation Left atrial and pulmonary venous anatomy including dimensions of veins for mapping purposes	A (7)	Highly agreed ACCF indication no. 29 ASCI CT indication no. 44

used for cardiac examinations. Third, the comparison of CT and MR in the discussion section was done based on separate surveys. Since the panelists were not aware of the potential comparison, the comparison is not a 'head-to-head' comparison. Rather, the comparison is actually 'what indications cardiac CT

Table 11 Detection of myocardial scar and viability

Indication		Appropriateness criteria (median score)	Note
Evaluation of myocardial scar			
48	To determine the location and extent of myocardial infarction including 'no-reflow' regions	A (9)	Highly agreed ACCF indication no. 30
	Post-acute myocardial infarction		
49	To detect post PCI myocardial necrosis	A (8)	Highly agreed ACCF indication no. 31
50	To determine viability prior to revascularization	A (9)	Highly agreed ACCF indication no. 32

experts think are appropriate for cardiac CT' vs 'what indications cardiac MR experts think are appropriate for cardiac MR'. Although such comparison still gives us some reasonable insights on the appropriate choice of modality, 'head-to-head' comparison might be more desirable for appropriate use of cardiac CT and cardiac MR. However, in order to perform a 'head-to-head' comparison, we would need to subdivide the indications based on the patient's age, sex, renal function, allergy to the contrast medium etc., which would run the risk of making the guidelines overly lengthy and complicated.

We expect that this ASCI 2010 cardiac MR appropriateness criteria report will serve as a timely and useful guide for the establishment of clinical cardiac MR services in Asian countries. ASCI will continue to pay close attention to this field and keep Asian practitioners updated about developments in cardiac MR and new indications as they arise.

Appendix

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Table 12 Appropriate indications (median score 7–9)

Indication		Appropriateness criteria (median score)
Detection of CAD: symptomatic—evaluation of chest pain syndrome		
3	Intermediate pre-test probability of CAD	A (7)
	ECG uninterpretable OR unable to exercise	
Detection of CAD: symptomatic—evaluation of intra-cardiac structures		
5	Evaluation of suspected coronary anomalies	A (8)
Detection of CAD with prior test results—evaluation of chest pain syndrome		
16	Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo)	A (8)
Risk Assessment with prior test results—asymptomatic		
20	Coronary angiography (catheterization or CT)	A (7)
	Stenosis of unclear significance	
CAD detection in pediatric patients with kawasaki disease—asymptomatic		
22	Previous tests (invasive angiography, CMR or CCT) documented coronary aneurysm/stenosis, for follow up	A (7)
CAD detection in pediatric patients with kawasaki disease—symptomatic		
23	No previous definitive test (invasive angiography, MRCA or CTCA) available	A (7)
24	Previous tests (angiography, CMR or CCT) documented coronary aneurysm/stenosis, for follow up	A (7)
Risk Assessment: preoperative evaluation for cardiac surgery or endovascular intervention—preoperative evaluation		
28	Anatomic assessment before percutaneous device closure of ASD or VSD or percutaneous aortic valve replacement	A (7)
Structure and function—morphology		
35	Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers and valves	A (8)
36	Assessment of post-operative congenital heart disease, such as residual pulmonary stenosis, ventricular septal defect and patency check for Blalock-Taussig shunt	A (8)
37	Evaluation in patients with new onset heart failure to assess etiology	A (8)
Structure and function—evaluation of ventricular and valvular function		
39	Evaluation of LV function following myocardial infarction OR in heart failure patients	A (9)
	Patients with technically limited images from echocardiogram	
38	Evaluation of LV function following myocardial infarction OR in heart failure patients	A (8)
40	Quantification of LV function	A(9)
	Discordant information that is clinically significant from prior tests	
41	Evaluation of specific cardiomyopathies (infiltrative [amyloid, sarcoid], HCM, or due to cardiotoxic therapies)	A(9)
42	Characterization of native and prosthetic cardiac valves	A (7)
	Patients with technically limited images from echocardiogram or TEE	
43	Evaluation for arrhythmogenic right ventricular cardiomyopathy (ARVC)	A (8)
	Patients presenting with syncope or ventricular arrhythmia	
44	Evaluation of myocarditis or myocardial infarction with normal coronary arteries	A(9)
	Positive cardiac enzymes without obstructive atherosclerosis on angiography	
Structure and function—evaluation of intra- and extra-cardiac structures		
45	Evaluation of cardiac mass (suspected tumor or thrombus)	A (9)
	Patients with technically limited images from echocardiogram or TEE	

Table 12 continued

Indication	Appropriateness criteria (median score)
46 Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery)	A (8)
Patients with technically limited images from echocardiogram or TEE	
47 Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation	A (7)
Left atrial and pulmonary venous anatomy including dimensions of veins for mapping purposes	
Structure and function—evaluation of myocardial scar	
48 To determine the location and extent of myocardial infarction including 'no-reflow' regions	A (9)
Post-acute myocardial infarction	
49 To detect post PCI myocardial necrosis	A (8)
50 To determine viability prior to revascularization	A (9)

Table 13 Uncertain indications (median score 4–6)

Indication		Appropriateness criteria (median score)
Detection of CAD: symptomatic—evaluation of chest pain syndrome		
2	Intermediate pre-test probability of CAD	U (4)
	ECG interpretable AND able to exercise	
4	High pre-test probability of CAD	U (6)
Detection of CAD: symptomatic—acute chest pain		
6	Low pre-test probability of CAD	U (4)
	No ECG changes and serial enzymes negative	
7	Intermediate pre-test probability of CAD	U (5)
	No ECG changes and serial enzymes negative	
8	High pre-test probability of CAD	U (5)
	No ECG changes and serial enzymes negative	
Detection of CAD: asymptomatic—asymptomatic		
11	Moderate CHD risk (Framingham)	U (4)
12	High CHD risk (Framingham)	U (6)
Risk Assessment: general population—asymptomatic (use of coronary MRA)		
15	High CHD risk (Framingham)	U (5)
Detection of CAD with prior test results—evaluation of chest pain syndrome		
17	Evidence of moderate to severe ischemia on stress test (exercise, perfusion, or stress echo)	U (5)
Risk Assessment with prior test results—asymptomatic		
19	Equivocal stress test (exercise, stress SPECT, or stress echo)	U (6)
	Intermediate CHD risk (Framingham)	
CAD detection in pediatric patients with kawasaki disease—asymptomatic		
21	No previous definitive test (invasive angiography, MRCA or CTCA) available	U (5)
Risk assessment: preoperative evaluation for non-cardiac surgery		
Intermediate- or high-risk surgery		
26	Intermediate perioperative risk	U (5)
Risk assessment: preoperative evaluation for cardiac surgery or endovascular intervention—preoperative evaluation		
27	Use of MRI for CAD evaluation before valve surgery	U (6)

Table 13 continued

Indication		Appropriateness criteria (median score)
29	Evaluation of complex lesions before PCI (i.e., chronic total occlusions, bifurcation lesions)	U (5)
Detection of CAD: post-revascularization (PCI or CABG)—evaluation of chest pain syndrome		
30	Evaluation of bypass grafts and coronary anatomy	U (5)
31	History of percutaneous revascularization with stents	U (4)
Detection of CAD: post-revascularization (PCI or CABG)—asymptomatic		
32	Evaluation of bypass grafts and coronary anatomy Less than 5 years after CABG	U (4)
33	Evaluation of bypass grafts and coronary anatomy Greater than or equal to 5 years after CABG	U (4)

Table 14 Inappropriate indications (median score 1–3)

Indication		Appropriateness criteria (median score)
Detection of CAD: symptomatic—evaluation of chest pain syndrome		
1	Low pre-test probability of CAD ECG interpretable AND able to exercise	I (2)
Detection of CAD: symptomatic—acute chest pain		
9	High pre-test probability of CAD ECG—ST-segment elevation and/or positive cardiac enzymes	I (2)
Detection of CAD: asymptomatic (without chest pain syndrome)—asymptomatic		
10	Low CHD risk (Framingham risk criteria)	I (1)
Risk assessment: general population—asymptomatic (use of coronary MRA)		
13	Low CHD risk (Framingham)	I (3)
14	Moderate CHD risk (Framingham)	I (3)
Risk assessment with prior test results—asymptomatic		
18	Normal prior stress test (exercise, nuclear, echo, MRI) High CHD risk (Framingham)	I (3)
Risk assessment: preoperative evaluation for non-cardiac surgery—low-risk surgery		
25	Intermediate perioperative risk	I (3)
Detection of CAD: post-revascularization (PCI or CABG)—asymptomatic		
34	Evaluation for in-stent restenosis and coronary anatomy after PCI	I (3)

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