



2017 Multimodality Appropriate Use Criteria for Noninvasive Cardiac Imaging: Expert Consensus of the Asian Society of Cardiovascular Imaging

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In 2010, the Asian Society of Cardiovascular Imaging (ASCI) provided recommendations for cardiac CT and MRI, and this document reflects an update of the 2010 ASCI appropriate use criteria (AUC). In 2016, the ASCI formed a new working group for revision of AUC for noninvasive cardiac imaging. A major change that we made in this document is the rating of various noninvasive tests (exercise electrocardiogram, echocardiography, positron emission tomography, single-photon emission computed tomography, radionuclide imaging, cardiac magnetic resonance, and cardiac computed tomography/angiography), compared side by side for their applications in various clinical scenarios. Ninety-five clinical scenarios were developed from eight selected pre-existing guidelines and classified into four sections as follows: 1) detection of coronary artery disease, symptomatic or asymptomatic; 2) cardiac evaluation in various clinical scenarios; 3) use of imaging modality according to prior testing; and 4) evaluation of cardiac structure and function. The clinical scenarios were scored by a

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separate rating committee on a scale of 1–9 to designate appropriate use, uncertain use, or inappropriate use according to a modified Delphi method. Overall, the AUC ratings for CT were higher than those of previous guidelines. These new AUC provide guidance for clinicians choosing among available testing modalities for various cardiac diseases and are also unique, given that most previous AUC for noninvasive imaging include only one imaging technique. As cardiac imaging is multimodal in nature, we believe that these AUC will be more useful for clinical decision making.

Keywords: *Appropriate use criteria; Multimodality; Noninvasive cardiac imaging*

INTRODUCTION

Noninvasive cardiac imaging procedures provide essential information for the detection, diagnosis, and management of cardiovascular diseases and serve a vital role in risk assessment and clinical decision making. The range of diagnostic tools used to evaluate cardiovascular disease has expanded over the past decade; in particular, computed tomography (CT) and magnetic resonance (MR) have emerged as alternatives to echocardiography, exercise electrocardiography (ECG), and invasive angiography.

Guidelines developed in the United States and Europe are often not applicable in Asian countries because of differences in healthcare systems, medical expenses, body habitus, and disease prevalence between Asian and Western countries. For this reason, the Asian Society of Cardiovascular Imaging (ASCI) separately developed ASCI appropriate use criteria (AUC) for cardiac CT and MR in 2010. Since the introduction of ASCI AUC in 2010, there has been further accumulation of scientific evidence and advances in imaging technology.

Currently, there are many guidelines published by different cardiovascular societies led by various expert groups; as a consequence, there are various AUC for different modalities and diseases and from different countries. The American College of Cardiology Foundation (ACCF), along with key specialty and subspecialty societies, published AUC for cardiac CT and cardiac MR (CMR) in 2006 (1). In 2010, AUC for CT were published by the Society of Cardiovascular Computed Tomography (SCCT) as well as the ASCI (2, 3). More recently, in 2015, the Korean Society of Radiology (KSR) also published AUC for CT (4). AUC for CMR were also published by the ASCI in 2010 (5) and by the KSR in 2015 (6). As for radionuclide imaging (RNI), the ACCF, along with key specialty and subspecialty societies, published AUC in 2009 (7), although they were limited to coronary artery disease only. Moreover, the ACCF and key specialty and subspecialty societies published AUC for echocardiography in 2011 (8). There are also many guidelines for specific

clinical scenarios, such as for appropriate utilization of various cardiac imaging modalities in the diagnosis and treatment of heart failure (9, 10), hypertrophic cardiomyopathy (11), and stable ischemic heart disease (12, 13). However, few guidelines encompass various clinical scenarios, and to the best of our knowledge, there have been no multimodality AUC in Asia. Thus, we believe that multimodality AUC for different clinical scenarios would be relevant as an update for the previous ASCI CT and MR guidelines. The purpose of this document is to delineate the appropriate use of various noninvasive testing modalities for the diagnosis and evaluation of heart disease, as well as to update the previous 2010 ASCI AUC for cardiac CT and MR.

MATERIALS AND METHODS

Plans and Approval for ASCI Guideline Update

In March 2016, the need for an update of ASCI AUC was discussed at the ASCI Administration office-presidential office meeting. A steering committee was appointed among the board of directors in order to establish plans and a budget for the AUC update. In addition, a writing committee was to be appointed from the Korean members, a rating committee to be comprised of major speakers and researchers among the ASCI members, and a review committee to be comprised of previous presidents, vice-presidents, and congress presidents of the ASCI. The plan was approved at the annual ASCI meeting held in Singapore in August 2016.

The working group consisted of the following committees:

Steering Committee

Yeon Hyeon Choe, Jongmin Lee, Yun Hyeon Kim, Bin Lu, Tae Hoon Kim

Writing Committee

Young Jin Kim, Jeong A Kim, Sung Mok Kim,

Kyongmin Sarah Beck, Hwan Seok Yong, Dong Hyun Yang,
Yoo Jin Hong

Rating Committee

The number of technical panel members on the rating committee from each country was decided by the working group according to participation in the ASCI executive committee and ASCI annual meetings, as well as academic credentials of the investigators in the field. Thirty-three experts were nominated for the technical panel, taking into account the members' nationalities and areas of expertise, and all were approved by the working group in consensus. Twenty-two of the 33 technical panel members responded and participated in the consensus process according to the modified Delphi method.

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Review Committee

Yeon Hyeon Choe, John Hoe, Sachio Kuribayashi,
Tae-Hwan Lim, Zhaoqi Zhang, Shihua Zhao, Lilian Leong,
Sim Kui Hian, Jae Hyung Park, Hajime Sakuma,
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Determining the Methods for Establishing AUC of Multimodality Cardiac Imaging: Adaptation and Consensus Methodology

Because the ASCI CT and MR AUC were last published in 2010, we searched online databases for guidelines on noninvasive imaging published since 2010; if such guidelines were unavailable for certain modalities, we then searched for the most recently published guidelines instead. The following online databases were searched: Ovid-Medline, Ovid-Embase, National Guideline Clearing, and Guideline

International Network. For development of this consensus document, we reviewed pre-existing utilization guidelines from countries worldwide. Eight pre-existing guidelines (3-9, 13) were finally selected for guideline adaptation: 1) ACCF cardiac radionuclide imaging guideline 2009 (7), 2) ASCI CMR guideline 2010 (5), 3) ASCI cardiac computed tomography angiography (CCTA) guideline 2010 (3), 4) ACCF echocardiography guideline 2011 (8), 5) ACCF multimodality guideline for stable ischemic heart disease 2013 (9), 6) ACCF cardiovascular imaging in heart failure 2013 (13), 7) Korean CMR guideline 2014 (6), 8) Korean CCTA guideline 2014 (4).

The key questions were developed by the writing committee. To establish the key questions, the writing committee reviewed the previously published guidelines for each imaging modality as well as multimodality guidelines for ischemic heart disease and heart failure. After collecting all of the existing clinical questions from the guidelines, the writing committee classified the questions into four sections as follows: 1) detection of coronary artery disease, symptomatic or asymptomatic; 2) cardiac evaluation in various clinical scenarios; 3) use of imaging modality according to prior testing; and 4) evaluation of cardiac structure and function. Since questions in the previous guidelines varied by imaging modality, the writing committee selected questions common to each imaging method. Questions limited to a specific imaging method were changed or combined, conforming to more general clinical situations. Each question was modified based on feedback from independent reviewers who were cardiovascular experts. Finally, the writing committee established four sections comprised of 95 clinical scenarios for various noninvasive modalities.

The appropriateness use criteria were defined with three ratings: appropriate (A), uncertain (U), and inappropriate (I). A questionnaire was emailed to the rating committee and then collected by the ASCI office after completion. The questionnaires were collected between December 2016 and February 2017 (22 of the 33 nominated members of the rating committee responded to the survey).

The questionnaire had four sections with 95 clinical scenarios. A total of two rounds of consensus survey were conducted; for each round, the appropriateness of utilization was categorized with a 9-point response scale: 1-3 points as I, 4-6 points as U, and 7-9 points as A. For each round, different imaging modalities were separately scored for their appropriateness in a given scenario. When

more than 50% of the panelists agreed on a category, the panel was considered to have reached a consensus for that particular clinical scenario. The questionnaire form included appropriateness criteria from other guidelines for each category and each noninvasive test modality (exercise ECG, echocardiography, positron emission tomography, single-photon emission computed tomography [SPECT], RNI, CMR, and CCTA), the 9-point response scale, and space for additional comments. In the second round, the median scores from the previous round and the scores originally given by the answering panelist were shown for the questions for which agreement had not been reached. The questions with agreement reached in the previous round were not shown in the following round.

Of the 95 clinical scenarios-comprised of a total of 455 questions for different modalities-sent for the first round, consensus was reached on all modalities in 42 scenarios (197 questions). Of the other 53 scenarios (258 questions), 86 questions for which consensus was not reached were sent for the second round. The results of the consensus voting are included in the Supplementary (in the online-only Data Supplement).

When interpreting the score, several specific assumptions should be considered. Presumably, each test is performed in compliance with published criteria for quality cardiac diagnostic testing, locally available, and interpreted by experts who are qualified to do so. For exercise ECG, it should be assumed that the patient can exercise to a symptomatic endpoint or 85% of their age-predicted maximal heart rate. For echocardiography, SPECT, and CMR in evaluation of coronary artery disease, it is assumed that pharmacological stress test is performed to identify the presence of myocardial ischemia. Each modality has inherent risks such as radiation exposure, contrast

sensitivity, and interpretation error. It is assumed that each modality should be chosen after weighing the risks and benefits in the specific clinical scenario. It should be assumed that CCTA and SPECT are performed using contemporary dose-saving techniques conforming to the As Low As Reasonably Achievable (ALARA) principle. For reasonable use of cardiovascular modality, the As High As Reasonably Achievable (AHARA) principle was considered.

The review committee, consisting of past-presidents, vice-presidents, and congress presidents, reviewed the AUC selected by consensus.

The development of the current AUC was funded by the ASCI. However, the activities of the writing committee, the rating committee, and the review committee were independent of one another, and none of the three committees were influenced in any way by any of the funding for guideline development.

These guidelines should be revised as needed, following advances in technology, changes in the healthcare environment, and further accumulation of scientific evidence.

RESULTS

The final AUC ratings for multimodality cardiac imaging are divided into four sections and listed by clinical scenarios sequentially (Tables 1-17).

Section 1

Detection of CAD: symptomatic or asymptomatic (Tables 1-4).

Section 2

Cardiac evaluation in various clinical scenarios (Tables 5-9).

Table 1. Symptomatic: Non-Acute Chest Pain Suspected of Stable Coronary Artery Disease

1-1. Symptomatic: Non-Acute Chest Pain Suspected of Stable Coronary Artery Disease					
	Exercise ECG	ECHO	SPECT	CMR	CCTA
ECG interpretable AND able to exercise					
1. Low pretest probability	A	I	I	I	U
2. Intermediate pretest probability	A	A	A	A	A
3. High pretest probability	A	A	A	A	A
ECG uninterpretable OR unable to exercise					
4. Low pretest probability	I	U	U	U	A
5. Intermediate pretest probability	I	A	A	A	A
6. High pretest probability	I	A	A	A	A

A = appropriate, CCTA = cardiac computed tomography angiography, CMR = cardiac magnetic resonance, ECG = exercise electrocardiography, I = inappropriate, SPECT = single-photon emission computed tomography, U = uncertain

Section 3

Use of imaging modality according to prior testing (Tables 10-12).

Section 4

Evaluation of cardiac structure and function (Tables 13-17).

DISCUSSION

These new ASCI multimodality AUC were developed in order to reflect the current status of noninvasive cardiac imaging in Asia. In the current document, we present a synthesis of clinical experience for all commonly employed

Table 2. Symptomatic: Acute Chest Pain Suspected of Acute Coronary Syndrome

1-2. Symptomatic: Acute Chest Pain Suspected of Acute Coronary Syndrome						
	Exercise ECG	ECHO	SPECT	CMR	CCTA	
Normal ECG AND cardiac biomarker						
7. Low global CAD risk	U	A	A	U	A	
8. Intermediate global CAD risk	U	A	A	U	A	
9. High global CAD risk	I	A	A	U	A	
Non-diagnostic ECG OR equivocal cardiac biomarker						
10. Low global CAD risk	I	A	A	U	A	
11. Intermediate global CAD risk	I	A	A	A	A	
12. High global CAD risk	I	A	A	A	A	
13. Abnormal ECG (ischemic nature)	I	A	A	U	A	
14. Acute chest pain of uncertain cause in emergency department ("triple rule out")	I	A	I	U	A	

CAD = coronary artery disease

Table 3. Asymptomatic (1)

1-3. Asymptomatic (1)						
	Exercise ECG	ECHO	SPECT	CMR	CAC	CCTA
Framingham CHD risk						
15. Low	I	I	I	I	I	I
16. Intermediate	U	I	I	I	U	U
17. High	A	U	U	U	U	A
Abnormal or uncertain prior testing						
18. Abnormal rest ECG (potentially ischemic)	A	A	A	A	U	A
19. Abnormal prior exercise ECG test	U	A	A	A	A	A
20. Zero CAC > 5 years ago	I	I	I	I	I	I
Positive CAC > 2 years ago						
21. CAC < 100	I	I	I	I		U
22. CAC 100-400	U	I	U	I		A
23. CAC 401-1000	A	U	A	U		U
24. CAC > 1000	A	U	A	U		U
25. Abnormal prior stress SPECT	I	U	U	U		A

CAC = coronary artery calcification, CHD = coronary heart disease

Table 4. Asymptomatic (2): Post-Revascularization (PCI or CABG)

1-3. Asymptomatic (2): Post-Revascularization (PCI or CABG)						
	Exercise ECG	ECHO	SPECT	CMR	CCTA	
Post-revascularization (PCI or CABG)						
26. Incomplete revascularization (additional revascularization feasible)	U	U	A	A	A	
27. Prior left main coronary stent	U	U	U	U	A	
28. < 5 years after CABG	I	U	U	U	A	
29. ≥ 5 years after CABG	U	U	U	U	A	
30. < 2 years after PCI	I	I	I	I	A	
31. ≤ 2 years after PCI	U	U	U	U	A	

CABG = coronary artery bypass graft, PCI = percutaneous coronary intervention

Table 5. Newly Developed or Suspected Heart Failure

2-1. Newly Developed or Suspected Heart Failure					
	ECHO	Stress ECHO	SPECT	CMR	CCT
32. Initial evaluation of cardiac structure and anatomy	A	U	I	A	A
Evaluation of ischemic etiology					
33. Angina/ischemic equivalent symptom	U	A	A	A	A
34. WITHOUT angina/ischemic equivalent symptom	A	A	A	A	A
35. Evaluation of ventricular function	A	A	A	A	U
36. Evaluation of myocardial viability (after ischemic etiology determined)	U	A	A	A	U

CCT = cardiac CT

Table 6. Cardiac Evaluation Prior to Surgery

2-2. Cardiac Evaluation Prior to Surgery					
	Exercise ECG	ECHO	SPECT	CMR	CCT
37. Moderate-to-good functional capacity (≥ 4 METs) or no clinical risk factor	I	I	I	I	I
Poor or unknown functional capacity (< 4 METs)					
38. Low-risk surgery	I	I	I	I	I
39. Intermediate-risk surgery	U	U	U	U	U
High-risk surgery					
40. Vascular surgery	U	A	A	A	A
41. Non-coronary cardiac surgery	U	A	A	A	A
42. Kidney or liver transplant	U	A	A	U	A

MET = metabolic equivalent of task

Table 7. Evaluation of Arrhythmia or Syncope without Ischemic Etiology

2-3. Evaluation of Arrhythmia or Syncope without Ischemic Etiology					
	Exercise ECG	ECHO	SPECT	CMR	CCT
43. Initial evaluation of cardiac structure and anatomy	I	A	I	A	U
44. Evaluation of ventricular function	I	A	U	A	U
45. Evaluation of myocardial scar or fibrosis	I	A	A	A	U

Table 8. Coronary Revascularization

2-4. Coronary Revascularization					
	Exercise ECG	ECHO	SPECT	CMR	CCT
Before revascularization					
46. Evaluation of complex lesions before PCI (i.e., chronic total occlusions, bifurcation lesions)	I	U	U	U	A
47. Myocardial viability	I	U	A	A	U
After revascularization					
48. Suspected post-PCI myocardial infarction	I	A	A	A	U
49. Suspected ischemic chest pain after coronary revascularization	U	U	A	A	A

Table 9. Kawasaki Disease

2-5. Kawasaki Disease					
	Exercise ECG	ECHO	SPECT	CMR	CCT
Asymptomatic					
50. No previous definitive test available	I	I	I	U	A
51. Previous tests documented coronary aneurysm/stenosis, for follow up	U	U	U	A	A
Symptomatic					
52. No previous definitive test available	U	A	A	A	A
53. Previous tests documented coronary aneurysm/stenosis, for follow up	U	U	A	A	A

Table 10. Prior Exercise ECG

	3.1. Prior Exercise ECG				
	ECHO	SPECT	CMR	Calcium Scoring	CCTA
Normal exercise ECG					
54. Stable symptom	I	I	I	I	U
55. New onset or worse symptom	U	A	U	I	A
Equivocal- or uninterpretable exercise ECG					
56. Stable symptom	U	A	A	U	A
57. New onset or worse symptom	A	A	A	I	A
Abnormal exercise ECG					
58. Stable symptom	A	A	A	U	A
59. New onset or worse symptom	A	A	A	I	A

Table 11. Prior SPECT

	3.2. Prior SPECT		
	ECHO	CMR	CCTA
60. Discordant exercise ECG and SPECT	U	A	A
Prior normal SPECT			
61. Stable symptom	I	U	A
62. New onset or worse symptom	U	A	A
Equivocal- or uninterpretable SPECT			
63. Stable symptom	U	A	A
64. New onset or worse symptom	A	A	A
Abnormal SPECT			
65. Stable symptom	A	U	A
66. New onset or worse symptom	A	A	A

Table 12. Prior CCTA

	3.3 Prior CCTA		
	ECHO	SPECT	CMR
67. Equivocal- or uninterpretable CCTA	U	A	A
Non-obstructive lesion			
68. Stable symptom	U	A	U
69. New onset or worse symptom	A	A	A
Obstructive lesion			
70. Stable symptom	A	A	A
71. New onset or worse symptom	A	A	A

Table 13. Congenital Heart Disease

	4-1. Congenital heart disease				
	TTE	TEE	RNI	CMR	CCT
72. Evaluation of coronary anomaly	A	U	I	A	A
73. Assessment of complex congenital heart disease	A	A	I	A	A
74. Anatomic assessment before percutaneous management of congenital heart disease (ASD, PDA, etc.)	A	A	I	A	A
75. Assessment of post-operative congenital heart disease	A	A	I	A	A

ASD = atrial septal defect, PDA = patent ductus arteriosus, RNI = radionuclide imaging, TEE = transesophageal echocardiography, TTE = transthoracic echocardiography

noninvasive imaging procedures for diagnosis of various cardiovascular diseases.

This document covers the same or similar clinical scenarios as the prior ASCI AUC for CT and MR and other modality guidelines for individual procedures. Overall, the

AUC ratings for CT are higher than those of the previous guidelines. This difference might be attributable to advances in CT technology, which have resulted in reduced radiation exposure and more accurate evaluation of small structures with improvement in temporal resolution.

Table 14. Valvular Heart Disease (Native Valve AND Prosthetic Valve)

4-2. Valvular Heart Disease (Native Valve AND Prosthetic Valve)					
	TTE	TEE	RNI	CMR	CT
76. Initial evaluation of valvular heart disease	A	A	I	A	U
77. Evaluation of native cardiac valves -Inadequate information from TTE		A	I	A	A
78. Initial postoperative evaluation of prosthetic valve	A	A	I	U	U
79. Evaluation of prosthetic cardiac valves -Inadequate information from TTE		A	I	A	A
80. Evaluation before transcatheter valve replacement	A	A	I	A	A

Table 15. Cardiomyopathy (after Ischemic Etiology Ruled Out)

4-3. Cardiomyopathy (after Ischemic Etiology Ruled Out)					
	TTE	TEE	SPECT	CMR	CT
81. Suspected infiltrative cardiomyopathy	A	U	I	A	U
82. Suspected myocarditis	A	I	I	A	U
83. Suspected ARVD/C	A	A	I	A	U
84. Suspected cardiomyopathy due to cardiotoxic agent	A	I	I	A	U
85. Suspected hypertrophic cardiomyopathy	A	U	I	A	U

ARVD/C = arrhythmogenic right ventricular dysplasia/cardiomyopathy

Table 16. Electrophysiology Study, Ablation, ICD/CRT

4-4. Electrophysiology Study, Ablation, ICD/CRT					
	TTE	TEE	SPECT	CMR	CT
86. Evaluation prior to RF ablation for AF	A	A	I	A	A
Implantable cardioverter-defibrillator therapy					
87. Evaluation determine patient candidacy	A	A	I	A	A
88. Follow-up after placement	A	A	I	I	U
Cardiac resynchronization therapy					
89. Evaluation determine patient candidacy	A	A	I	A	A
90. Follow-up after placement	A	A	I	I	U

AF = atrial fibrillation, RF = radiofrequency ablation

Table 17. Cardiac Mass, Pericardial Disease, and Aorta

4-5. Cardiac Mass, Pericardial Disease, and Aorta					
	TTE	TEE	PET	CMR	CT
Mass					
91. Initial evaluation of suspected cardiac mass		A	A	I	A
92. Evaluation of cardiac mass, inadequate information from echocardiography		U	A	A	A
Pericardial disease					
93. Initial evaluation of suspected pericardial disease		A	U	U	A
94. Evaluation of pericardial disease, inadequate information from echocardiography		U	U	U	A
Aorta					
95. Evaluation of suspected aortic dissection, aneurysm, or inflammation		A	A	I	A

PET = positron emission tomography

In addition, wide availability of CT in Asian countries compared to CMR, which is less accessible, could be another cause of the improved rating of CT.

These rating differences might also reflect the changing practice environment and evolution in cumulative clinical experience with these procedures, as well as maturation of the field since publication of the original documents.

These new AUC are intended to provide guidance for clinicians when choosing among available testing modalities for various cardiac diseases. Each test was rated individually for each scenario based on the quality of the published evidence as well as the expert opinion of the rating panel. In the absence of robust evidence of comparative effectiveness, a comparative rating approach would be both premature and misleading. In addition, a larger number of radiologists in the writing and rating committees might have resulted in somewhat skewed ratings for certain modalities. Thus, although these ratings reflect existing evidence-based practice supplemented by expert consensus, further research is needed to identify not only when to use any given modality, but also when to favor one over another.

Supplementary Materials

The online-only Data Supplement is available with this article at <https://doi.org/10.3348/kjr.2017.18.6.871>.

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