American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Nonischemic Myocardial Disease with Clinical Manifestations (Ischemic Cardiomyopathy Already Excluded)**

Variant 1: **Suspected arrhythmogenic cardiomyopathy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI heart function and morphology without and with IV contrast	9		O
US echocardiography transthoracic resting	8		O
MRI heart function and morphology without IV contrast	7		O
CT heart function and morphology with IV contrast	6	This procedure is an alternative to MRI if the patient has a pacemaker or other contraindication.	☢☢☢☢
Arteriography coronary with ventriculography	3		☢☢☢
CT chest without IV contrast	2		☢☢☢
MRI chest without and with IV contrast	2		O
MRI chest without IV contrast	2		O
Tc-99m V/Q scan lung	2		☢☢☢
X-ray chest	1		☢
FDG-PET/CT heart	1		☢☢☢☢
CT coronary calcium	1		☢☢☢
US echocardiography transesophageal	1		O
Arteriography pulmonary	1		☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Nonischemic Myocardial Disease with Clinical Manifestations (Ischemic Cardiomyopathy Already Excluded)**

Variant 2: **Suspected myocardial infiltrative disease.**

Radiologic Procedure	Rating	Comments	RRL*
MRI heart function and morphology without and with IV contrast	9		O
US echocardiography transthoracic resting	8		O
X-ray chest	7		☢
FDG-PET/CT heart	7	This procedure is as good as MRI for initial diagnosis of sarcoidosis and better than MRI for follow-up.	☢ ☢ ☢ ☢
MRI heart function and morphology without IV contrast	6		O
US echocardiography transesophageal	5	Perform this procedure for associated valve disease.	O
CT heart function and morphology with IV contrast	4	This procedure is an alternative to MRI if the patient has a pacemaker or other contraindication to MRI.	☢ ☢ ☢ ☢
CT coronary calcium	2		☢ ☢ ☢
Tc-99m V/Q scan lung	2		☢ ☢ ☢
Arteriography coronary with ventriculography	2		☢ ☢ ☢
CT chest without IV contrast	1		☢ ☢ ☢
MRI chest without and with IV contrast	1		O
MRI chest without IV contrast	1		O
Arteriography pulmonary	1		☢ ☢ ☢ ☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Nonischemic Myocardial Disease with Clinical Manifestations (Ischemic Cardiomyopathy Already Excluded)**

Variant 3: **Suspected hypertrophic cardiomyopathy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI heart function and morphology without and with IV contrast	9		O
US echocardiography transthoracic resting	9		O
Arteriography coronary with ventriculography	8	Perform this procedure prior to alcohol septal ablation or to assess left ventricular pressure and gradients.	☢ ☢ ☢
US echocardiography transesophageal	7	Perform this procedure to assess left atrial appendage for thrombus prior to cardioversion or in patients with implantable devices and poor acoustic windows.	O
MRI heart function and morphology without IV contrast	7		O
CT heart function and morphology with IV contrast	3	This procedure is an alternative to MRI if the patient has a pacemaker or other contraindication.	☢ ☢ ☢ ☢
FDG-PET/CT heart	3		☢ ☢ ☢ ☢
CTA chest with IV contrast	2		☢ ☢ ☢
MRI chest without IV contrast	2		O
X-ray chest	1		☢
CT chest without IV contrast	1		☢ ☢ ☢
Tc-99m V/Q scan lung	1		☢ ☢ ☢
CT coronary calcium	1		☢ ☢ ☢
MRI chest without and with IV contrast	1		O
Arteriography pulmonary	1		☢ ☢ ☢ ☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Nonischemic Myocardial Disease with Clinical Manifestations (Ischemic Cardiomyopathy Already Excluded)**

Variant 4: **Suspected acute/subacute myocardial disease.**

Radiologic Procedure	Rating	Comments	RRL*
MRI heart function and morphology without and with IV contrast	8		O
US echocardiography transthoracic resting	8		O
X-ray chest	7	Perform this procedure to assess systemic inflammation.	☢
MRI heart function and morphology without IV contrast	6	Perform this procedure if contrast cannot be given or if right disease is suspected.	O
US echocardiography transesophageal	4	Perform this procedure primarily to assess left atrial thrombus.	O
Arteriography coronary with ventriculography	3		☢ ☢ ☢
CT heart function and morphology with IV contrast	2		☢ ☢ ☢ ☢
CTA chest with IV contrast	2		☢ ☢ ☢
MRI chest without and with IV contrast	2		O
MRI chest without IV contrast	2		O
FDG-PET/CT heart	2	This procedure may be considered in select cases to look for inflammatory causes of myocarditis-like disorders.	☢ ☢ ☢ ☢
CT chest without IV contrast	1		☢ ☢ ☢
CT coronary calcium	1		☢ ☢ ☢
Tc-99m V/Q scan lung	1		☢ ☢ ☢
Arteriography pulmonary	1		☢ ☢ ☢ ☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

NONISCHEMIC MYOCARDIAL DISEASE WITH CLINICAL MANIFESTATIONS (ISCHEMIC CARDIOMYOPATHY ALREADY EXCLUDED)

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Summary of Literature Review

Introduction/Background

Symptomatic myocardial disease, which is not the result of flow-limiting coronary artery disease or prior myocardial infarction, is commonly referred to as nonischemic myocardial disease or cardiomyopathy (CM). Clinical manifestations of nonischemic myocardial disease include arrhythmia, palpitations, heart failure, shortness of breath, dyspnea, lower extremity edema, ascites, syncope, and chest discomfort. At times, the symptoms are so generalized and/or nonspecific that it may be difficult to identify myocardial disease as the etiology of the illness. Early and accurate detection and characterization of myocardial disease therefore becomes critical for appropriate patient treatment and management and to potentially avoid disease progression.

Nonischemic CM is more common in women and younger individuals. In general, the prognosis of nonischemic myocardial disease or CM is better than in ischemic myocardial disease or CM [1], although specific therapy such as revascularization may improve symptoms in the latter. Cardiac dysfunction can further be classified as systolic or diastolic or a combination of both. Most commonly the left ventricle (LV) is affected, but the right ventricle (RV) can also be affected in certain disease states. Systolic heart failure is diagnosed when there is reduction in the ventricular ejection fraction. Symptoms of heart failure occur when the degree of myocardial dysfunction exceeds compensatory mechanisms that occur to maintain adequate cardiac output and oxygenation. An LV ejection fraction (LVEF) less than 50% is below normal range, but some patients are asymptomatic with even lower ejection fractions. Nonischemic myocardial disease can also be secondary to other cardiac or systemic disease processes, such as valvular disease or recurrent tachyarrhythmia.

Conversely, heart failure with normal systolic function, also referred to as diastolic heart failure, is an increasingly recognized illness. There is a growing body of literature regarding diastology, which is the study of relaxation of the myocardium. Various diseases produce diastolic dysfunction and result in inadequate relaxation and filling of the ventricle(s). Myocardial fibrosis and infiltrative diseases such as amyloid and sarcoid are examples. Alternatively, there may be pericardial disease causing constriction of the cardiac chambers, resulting in inadequate diastolic filling. Symptoms of diastolic abnormality may be typical for congestive heart failure as well as symptoms of right heart failure, which include ascites, hepatic congestion, and lower extremity edema.

Overview of Imaging Modalities

In most cases of systolic heart failure, ischemic CM should be considered and excluded prior to assessment for nonischemic CM. Echocardiography (echo) is the mainstay of evaluating left ventricular function due to ease of access and widespread use [2]. Valvular function and diastolic function can also be evaluated. Advanced echo techniques such as pulsed tissue Doppler imaging and 3-D imaging have added diagnostic and prognostic value in the evaluation of nonischemic CM [3-5]. Stress physiology assessment via treadmill exercise, rest and stress radionuclide myocardial perfusion imaging (SPECT MPI), or stress echo are also commonly used in the evaluation of CM primarily to exclude ischemic etiologies [6]. Dobutamine and adenosine stress functional cardiac magnetic resonance imaging (MRI) provide high sensitivity and specificity for ischemia. If these studies are inconclusive, coronary angiography with ventriculography may be considered. In cases of low-to-intermediate likelihood for coronary artery disease, coronary computed tomography angiography (CCTA) can be performed for

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direct coronary artery evaluation to differentiate ischemic versus nonischemic CM [7,8]. Since elevated pulmonary arterial pressure is a predictor of death in patients with heart failure, echo and/or right heart catheterization may be considered [9]. Evaluating right heart pressures is also useful in evaluating restrictive cardiomyopathies.

Recent advances in technology allow further reduction of radiation dose from CCTA; newly available dose-reducing techniques include prospective triggering, adaptive statistical iterative reconstruction, and high-pitch spiral acquisition [10-14]. These new lower-dose techniques are appropriate in patients with low heart rates (<65 bpm) who are in sinus rhythm. If function evaluation is desired, the retrospective gating technique must be utilized. If chronic pulmonary embolism is being considered, a chest CTA can be performed [15]. Alternatively, a ventilation perfusion examination can be done if a patient has contraindication to iodinated contrast [16]. The role of positron emission tomography (PET) in the assessment of cardiac sarcoidosis is well established, and its role in cardiomyopathies has been studied to a limited extent for the localization of scar for cardiac resynchronization therapy [17].

Coronary calcium scoring (CCS) is most commonly used for risk stratification in asymptomatic patients. In a large study of 10,377 subjects it has been shown that CCS provides independent incremental information in addition to traditional risk factors in the prediction of all-cause mortality [18].

Cardiac MR (CMR) imaging has emerged as a powerful tool for the diagnosis of ischemic and nonischemic cardiomyopathies [19]. It is now considered the reference standard imaging technique to assess myocardial anatomy, regional and global function, and viability—and often reveals the underlying etiology of heart failure [20,21]. CMR allows a multifaceted approach for the evaluation of new onset heart failure [22]. Advanced MRI techniques with tissue imaging and delayed myocardial enhancement can provide information beyond echo for tissue characterization in CM [23].

In nonischemic CM, delayed myocardial enhancement usually does not occur in a coronary artery distribution and is often mid wall or subepicardial rather than subendocardial or transmural [24]. Localization of pathology can also guide myocardial biopsy to the affected area, increasing its yield [25]. In addition, MRI is increasingly being used for evaluation of genetically positive, phenotypically negative patients for risk stratification [26,27], and the prognostic value of delayed enhancement in CMR has been described [28-30].

Variant: Suspected Arrhythmogenic Cardiomyopathy

A patient may suffer from palpitations, and ECG/Holter monitoring may reveal a pattern of arrhythmias, which may indicate a need to exclude underlying structural heart disease. Arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) is caused by genetic mutations, which result in fibrofatty infiltration of the myocardium, most often the RV. RV dilation and dysfunction are hallmarks of ARVC/D and set the stage for life-threatening arrhythmias [31]. Morphologic and genetic variants of this disease have been investigated [32]. Advances in echo techniques have aided evaluation of the right heart [33]. CT can also provide a significant role in morphologic evaluation of the RV, particularly in patients with implantable cardioverter-defibrillators (ICD) who cannot have MRI examinations [34]. MRI has significant contribution in evaluating the morphology and function of the RV. This is a significant advantage for ARVC/D and also for other diseases such as decompensated RV function from pulmonary hypertension in the setting of chronic pulmonary embolism. Another advantage of MRI is the ability to evaluate RV fibrous tissue, which enhances in a delayed fashion, and RV fat [35].

Variant: Suspected Myocardial Infiltrative Disease

Sarcoid and amyloid are the most common infiltrative diseases involving the myocardium [36]. Sarcoid is a granulomatous disease that can affect any organ and has a wide spectrum of clinical manifestations. Cardiac sarcoid may be symptomatic or asymptomatic. The most common clinical presentations are heart block, dilated CM, and ventricular arrhythmias. Because the yield of endomyocardial biopsy for the suspected diagnosis is low from patchy disease, noninvasive imaging is often pursued. Echo and MRI are the most commonly used imaging modalities, although CT is often used in search of mediastinal adenopathy and lung abnormalities [37]. PET using 18-F-fluoro-2-deoxyglucose (FDG-PET) may offer earlier detection of cardiac sarcoidosis and indicate areas of active disease [38]. MRI with late gadolinium enhancement has shown higher sensitivity in the detection of cardiac sarcoidosis than standard clinical evaluations (ECG, thallium scintigraphy, and echo) [39-41]. Early treatment is crucial in improving symptoms and prognosis[42].

Amyloidosis is a systemic condition characterized by the extracellular deposition of amyloid into one or more organ systems. Cardiac deposition leads to an infiltrative/restrictive CM [43]. On imaging, the LV is hypertrophied, the valves and the interatrial septum are often thickened, and the LV exhibits diastolic dysfunction [44]. MRI has an increasing role in the diagnosis of amyloid with characteristic patterns of myocardial delayed enhancement [45].

Chagas disease is rare in the United States but may be seen in the southern states and in California, especially in immigrants and visitors from Central and South America. Migratory movements can raise the suspicion of this parasitic infiltrative myocardial disease. CMR has emerged as the noninvasive tool to evaluate the myocardial fibrosis typical of Chagas disease [46].

Iron overload CM is considered an infiltrative cardiomyopathy, which results in diastolic and systolic dysfunction. It may be primary with a genetic basis as in hemochromatosis. It may also be secondary due to various transfusion dependent anemias [47,48]. Advances in cardiac MRI have allowed not only the diagnosis but also the quantification of myocardial iron with T2* evaluations for the purposes of early diagnosis and guiding chelation therapy [49-51].

Variant: Suspected Hypertrophic Cardiomyopathy

Hypertrophic CM (HCM) is a genetically based myocardial disease with a wide spectrum of genotypic abnormalities and phenotypic presentations. The distribution of the hypertrophy may be concentric, involving the entire LV, or may asymmetrically affect the LV. Most commonly, the septum or apex is hypertrophied if the distribution is asymmetric. Although echo remains the mainstay modality for diagnosis, diagnostic imaging can be performed with CT and MRI as well [52,53]. LV outflow obstruction and systolic anterior motion of the mitral valve are characteristic features of hypertrophic obstructive cardiomyopathy (HOCM) and can be evaluated by echo and CMR. True short-axis views of the LV by CMR can be helpful in obtaining accurate measurement of LV wall thickness, one of several criteria for ICD placement. MRI may be particularly useful in distinguishing hypertensive CM from symmetric HCM by characteristic enhancement patterns [54]. Fabry disease can be considered when there is symmetric hypertrophy, and MRI may also be helpful in differentiating Fabry disease and HCM [55].

Variant: Suspected Acute/Subacute Myocardial Disease

Acute and subacute nonischemic myocardial diseases can cause troponin elevation and mimic ischemic causes of chest pain. Myocarditis is inflammation of the myocardium and may have a viral etiology or be idiopathic. Echo might show global or regional wall motion abnormalities, which may be concerning for ischemia. CMR provides additive information with the ability to image tissue edema and characteristic midwall or subepicardial patterns of delayed enhancement. This can be very useful in differentiating troponin elevation in acute myocardial infarction [56,57]. In addition, associated pericardial thickening or inflammation can be evident.

Stress CM, also known as takotsubo CM, produces transient myocardial dysfunction, which resolves in a period of days to weeks [58]. The wall motion abnormalities are regional, dyskinetic, and in a non-coronary distribution. The most common variant is apical ballooning, with occasional variations of basal and mid-ventricular ballooning. The patient may present with acute chest pain worrisome for myocardial infarction, and imaging is helpful to diagnose this condition in the absence of flow-limiting coronary artery disease [59,60]. Cardiotoxic medications such as chemotherapeutic agents can have either temporary or permanent effect on myocardial function and should also be considered in acute/subacute development of systolic cardiac dysfunction.[61].

Suspected Familial or Genetically Transmitted Cardiomyopathy

Familial and/or genetically transmitted cardiomyopathies are increasingly recognized, and several have been described in the text above. Heart failure in complex congenital heart diseases is multifactorial and may have a genetic basis, but this is beyond the scope of this document. The imaging for these cardiomyopathies is quite varied depending on the particular disease and therefore will not be covered in the variant tables. The most commonly recognized myocardial diseases with a genetic basis are HCM, dilated CM, and ARVC/D. Less common are deposition diseases such as Fabry disease and hemochromatosis. Isolated left ventricular noncompaction is a rare but increasingly recognized congenital CM characterized by prominent trabecular, deep intertrabecular recesses, and thickened myocardium with 2 distinct layers (compacted and noncompacted) [62-65].

Summary

- Imaging plays an important role in the diagnosis of nonischemic cardiomyopathies.
- Newer technologies involving CT and MRI have shown promise in improving earlier detection and improved accuracy of diagnosis of several cardiomyopathies.
- Although it is expected that traditional imaging modalities such as echo will continue to play a primary role in nonischemic cardiomyopathies, MRI in particular is expected to play an increasing role in both diagnosis and management.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢ ☢	0.1-1 mSv	0.03-0.3 mSv
☢ ☢ ☢	1-10 mSv	0.3-3 mSv
☢ ☢ ☢ ☢	10-30 mSv	3-10 mSv
☢ ☢ ☢ ☢ ☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

1. Follath F. Nonischemic heart failure: epidemiology, pathophysiology, and progression of disease. *J Cardiovasc Pharmacol.* 1999;33 Suppl 3:S31-35.
2. Cheitlin MD, Armstrong WF, Aurigemma GP, et al. ACC/AHA/ASE 2003 guideline update for the clinical application of echocardiography--summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/ASE Committee to Update the 1997 Guidelines for the Clinical Application of Echocardiography). *J Am Coll Cardiol.* 2003;42(5):954-970.
3. Ballo P, Guarini G, Simioniuc A, et al. Prognostic value of pulsed tissue Doppler imaging for the assessment of left ventricular systolic function in patients with nonischemic dilated cardiomyopathy. *Echocardiography.* 2012;29(3):291-297.
4. Cabell CH, Trichon BH, Velazquez EJ, et al. Importance of echocardiography in patients with severe nonischemic heart failure: the second Prospective Randomized Amlodipine Survival Evaluation (PRAISE-2) echocardiographic study. *Am Heart J.* 2004;147(1):151-157.

5. Okura H, Fuyuki H, Kubo T, et al. Noninvasive diagnosis of ischemic and nonischemic cardiomyopathy using coronary flow velocity measurements of the left anterior descending coronary artery by transthoracic Doppler echocardiography. *J Am Soc Echocardiogr.* 2006;19(5):552-558.
6. Berman DS, Hachamovitch R, Shaw LJ, et al. Roles of nuclear cardiology, cardiac computed tomography, and cardiac magnetic resonance: assessment of patients with suspected coronary artery disease. *J Nucl Med.* 2006;47(1):74-82.
7. Jain A, Shehata ML, Stuber M, et al. Prevalence of left ventricular regional dysfunction in arrhythmogenic right ventricular dysplasia: a tagged MRI study. *Circ Cardiovasc Imaging.* 2010;3(3):290-297.
8. Bhatti S, Hakeem A, Yousuf MA, Al-Khalidi HR, Mazur W, Shizukuda Y. Diagnostic performance of computed tomography angiography for differentiating ischemic vs nonischemic cardiomyopathy. *J Nucl Cardiol.* 2011;18(3):407-420.
9. Abramson SV, Burke JF, Kelly JJ, Jr., et al. Pulmonary hypertension predicts mortality and morbidity in patients with dilated cardiomyopathy. *Ann Intern Med.* 1992;116(11):888-895.
10. Dalal D, Nasir K, Bomma C, et al. Arrhythmogenic right ventricular dysplasia: a United States experience. *Circulation.* 2005;112(25):3823-3832.
11. Tandri H, Rutberg J, Bluemke DA, Calkins H. Magnetic resonance imaging of arrhythmogenic right ventricular dysplasia. *J Cardiovasc Electrophysiol.* 2002;13(11):1180.
12. Husmann L, Valenta I, Gaemperli O, et al. Feasibility of low-dose coronary CT angiography: first experience with prospective ECG-gating. *Eur Heart J.* 2008;29(2):191-197.
13. Heilbron BG, Leipsic J. Submillisievert coronary computed tomography angiography using adaptive statistical iterative reconstruction - a new reality. *Can J Cardiol.* 2010;26(1):35-36.
14. Achenbach S, Marwan M, Ropers D, et al. Coronary computed tomography angiography with a consistent dose below 1 mSv using prospectively electrocardiogram-triggered high-pitch spiral acquisition. *Eur Heart J.* 2010;31(3):340-346.
15. Tardivon AA, Musset D, Maitre S, et al. Role of CT in chronic pulmonary embolism: comparison with pulmonary angiography. *J Comput Assist Tomogr.* 1993;17(3):345-351.
16. Schwickert HC, Kauczor HU, Piepenburg R, et al. [CT compared with SPECT in chronic recurrent pulmonary embolism: hyperdensities as signs of pulmonary artery hyperperfusion?]. *Rofo.* 1995;162(3):199-203.
17. O'Neill JO, McCarthy PM, Brunken RC, et al. PET abnormalities in patients with nonischemic cardiomyopathy. *J Card Fail.* 2004;10(3):244-249.
18. Shaw LJ, Raggi P, Schisterman E, Berman DS, Callister TQ. Prognostic value of cardiac risk factors and coronary artery calcium screening for all-cause mortality. *Radiology.* 2003;228(3):826-833.
19. Jiji RS, Kramer CM. Cardiovascular magnetic resonance: applications in daily practice. *Cardiol Rev.* 2011;19(5):246-254.
20. Karamitsos TD, Francis JM, Myerson S, Selvanayagam JB, Neubauer S. The role of cardiovascular magnetic resonance imaging in heart failure. *J Am Coll Cardiol.* 2009;54(15):1407-1424.
21. Kumar A, Patton DJ, Friedrich MG. The emerging clinical role of cardiovascular magnetic resonance imaging. *Can J Cardiol.* 2010;26(6):313-322.
22. Kim YJ, Kim RJ. The role of cardiac MR in new-onset heart failure. *Curr Cardiol Rep.* 2011;13(3):185-193.
23. Karamitsos TD, Francis JM, Neubauer S. The current and emerging role of cardiovascular magnetic resonance in the diagnosis of nonischemic cardiomyopathies. *Prog Cardiovasc Dis.* 2011;54(3):253-265.
24. Kim DH, Choi SI, Chang HJ, Choi DJ, Lim C, Park JH. Delayed hyperenhancement by contrast-enhanced magnetic resonance imaging: Clinical application for various cardiac diseases. *J Comput Assist Tomogr.* 2006;30(2):226-232.
25. Gottlieb I, Macedo R, Bluemke DA, Lima JA. Magnetic resonance imaging in the evaluation of non-ischemic cardiomyopathies: current applications and future perspectives. *Heart Fail Rev.* 2006;11(4):313-323.
26. Bluemke DA. MRI of nonischemic cardiomyopathy. *AJR Am J Roentgenol.* 2010;195(4):935-940.
27. Caliskan K, Szili-Torok T, Theuns DA, et al. Indications and outcome of implantable cardioverter-defibrillators for primary and secondary prophylaxis in patients with noncompaction cardiomyopathy. *J Cardiovasc Electrophysiol.* 2011;22(8):898-904.
28. Bello D, Shah DJ, Farah GM, et al. Gadolinium cardiovascular magnetic resonance predicts reversible myocardial dysfunction and remodeling in patients with heart failure undergoing beta-blocker therapy. *Circulation.* 2003;108(16):1945-1953.

29. Masci PG, Barison A, Aquaro GD, et al. Myocardial delayed enhancement in paucisymptomatic nonischemic dilated cardiomyopathy. *Int J Cardiol.* 2012;157(1):43-47.
30. Wu KC, Weiss RG, Thiemann DR, et al. Late gadolinium enhancement by cardiovascular magnetic resonance heralds an adverse prognosis in nonischemic cardiomyopathy. *J Am Coll Cardiol.* 2008;51(25):2414-2421.
31. Marcus FI, McKenna WJ, Sherrill D, et al. Diagnosis of arrhythmogenic right ventricular cardiomyopathy/dysplasia: proposed modification of the Task Force Criteria. *Eur Heart J.* 2010;31(7):806-814.
32. Dalal D, Tandri H, Judge DP, et al. Morphologic variants of familial arrhythmogenic right ventricular dysplasia/cardiomyopathy a genetics-magnetic resonance imaging correlation study. *J Am Coll Cardiol.* 2009;53(15):1289-1299.
33. Prakasa KR, Wang J, Tandri H, et al. Utility of tissue Doppler and strain echocardiography in arrhythmogenic right ventricular dysplasia/cardiomyopathy. *Am J Cardiol.* 2007;100(3):507-512.
34. Bomma C, Dalal D, Tandri H, et al. Evolving role of multidetector computed tomography in evaluation of arrhythmogenic right ventricular dysplasia/cardiomyopathy. *Am J Cardiol.* 2007;100(1):99-105.
35. Deyell MW, Andrade JG, McManus BM, Leipsic J. The other side of arrhythmogenic right ventricular cardiomyopathy. *Can J Cardiol.* 2011;27(2):263 e213-266.
36. Stather D, Ford S, Kisilevsky R. Sarcoid, amyloid, and acute myocardial failure. *Mod Pathol.* 1998;11(9):901-904.
37. Syed J, Myers R. Sarcoid heart disease. *Can J Cardiol.* 2004;20(1):89-93.
38. Ohira H, Tsujino I, Sato T, et al. Early detection of cardiac sarcoid lesions with (18)F-fluoro-2-deoxyglucose positron emission tomography. *Intern Med.* 2011;50(11):1207-1209.
39. Patel MR, Cawley PJ, Heitner JF, et al. Detection of myocardial damage in patients with sarcoidosis. *Circulation.* 2009;120(20):1969-1977.
40. Smedema JP, Snoep G, van Kroonenburgh MP, et al. The additional value of gadolinium-enhanced MRI to standard assessment for cardiac involvement in patients with pulmonary sarcoidosis. *Chest.* 2005;128(3):1629-1637.
41. Smedema JP, Snoep G, van Kroonenburgh MP, et al. Evaluation of the accuracy of gadolinium-enhanced cardiovascular magnetic resonance in the diagnosis of cardiac sarcoidosis. *J Am Coll Cardiol.* 2005;45(10):1683-1690.
42. Bargout R, Kelly RF. Sarcoid heart disease: clinical course and treatment. *Int J Cardiol.* 2004;97(2):173-182.
43. Falk RH, Dubrey SW. Amyloid heart disease. *Prog Cardiovasc Dis.* 2010;52(4):347-361.
44. Nicolosi GL, Pavan D, Lestuzzi C, Burelli C, Zardo F, Zanuttini D. Prospective identification of patients with amyloid heart disease by two-dimensional echocardiography. *Circulation.* 1984;70(3):432-437.
45. Maceira AM, Joshi J, Prasad SK, et al. Cardiovascular magnetic resonance in cardiac amyloidosis. *Circulation.* 2005;111(2):186-193.
46. Regueiro A, Garcia-Alvarez A, Sitges M, et al. Myocardial involvement in Chagas disease: Insights from cardiac magnetic resonance. *Int J Cardiol.* 2013;165(1):107-112.
47. Kremastinos DT, Farmakis D. Iron overload cardiomyopathy in clinical practice. *Circulation.* 2011;124(20):2253-2263.
48. Pennell DJ. T2* magnetic resonance: iron and gold. *JACC Cardiovasc Imaging.* 2008;1(5):579-581.
49. Anderson LJ, Holden S, Davis B, et al. Cardiovascular T2-star (T2*) magnetic resonance for the early diagnosis of myocardial iron overload. *Eur Heart J.* 2001;22(23):2171-2179.
50. Tanner MA, Galanello R, Dessi C, et al. A randomized, placebo-controlled, double-blind trial of the effect of combined therapy with deferoxamine and deferiprone on myocardial iron in thalassemia major using cardiovascular magnetic resonance. *Circulation.* 2007;115(14):1876-1884.
51. Westwood MA, Wonke B, Maceira AM, et al. Left ventricular diastolic function compared with T2* cardiovascular magnetic resonance for early detection of myocardial iron overload in thalassemia major. *J Magn Reson Imaging.* 2005;22(2):229-233.
52. Nagueh SF, Bierig SM, Budoff MJ, et al. American Society of Echocardiography clinical recommendations for multimodality cardiovascular imaging of patients with hypertrophic cardiomyopathy: Endorsed by the American Society of Nuclear Cardiology, Society for Cardiovascular Magnetic Resonance, and Society of Cardiovascular Computed Tomography. *J Am Soc Echocardiogr.* 2011;24(5):473-498.
53. Syed IS, Ommen SR, Breen JF, Tajik AJ. Hypertrophic cardiomyopathy: identification of morphological subtypes by echocardiography and cardiac magnetic resonance imaging. *JACC Cardiovasc Imaging.* 2008;1(3):377-379.

54. Puntmann VO, Jahnke C, Gebker R, et al. Usefulness of magnetic resonance imaging to distinguish hypertensive and hypertrophic cardiomyopathy. *Am J Cardiol.* 2010;106(7):1016-1022.
55. van Dalen BM, Caliskan K, Soliman OI, et al. Diagnostic value of rigid body rotation in noncompaction cardiomyopathy. *J Am Soc Echocardiogr.* 2011;24(5):548-555.
56. Mavrogeni S, Dimitroulas T, Kitas GD. Multimodality imaging and the emerging role of cardiac magnetic resonance in autoimmune myocarditis. *Autoimmun Rev.* 2012;12(2):305-312.
57. Danti M, Sbarbati S, Alsadi N, et al. Cardiac magnetic resonance imaging: diagnostic value and utility in the follow-up of patients with acute myocarditis mimicking myocardial infarction. *Radiol Med.* 2009;114(2):229-238.
58. Crean A, Greenwood JP, Plein S. Contribution of noninvasive imaging to the diagnosis and follow-up of Takotsubo cardiomyopathy. *JACC Cardiovasc Imaging.* 2009;2(4):519-521.
59. Andersson H, Atharovski KA, Christensen TE, et al. How to distinguish takotsubo cardiomyopathy from acute myocardial infarction using multimodal cardiac imaging. *Int J Cardiol.* 2012;159(1):73-74.
60. Kanjanauthai S, Ananthasubramaniam K. Integral role of cardiovascular magnetic resonance imaging in the diagnostic workup of suspected takotsubo cardiomyopathy: Avoiding misdiagnosis. *Cardiol J.* 2007;14(6):592-594.
61. Nagy AC, Cserep Z, Tolnay E, Nagykalnai T, Forster T. Early diagnosis of chemotherapy-induced cardiomyopathy: a prospective tissue Doppler imaging study. *Pathol Oncol Res.* 2008;14(1):69-77.
62. Stanton C, Bruce C, Connolly H, et al. Isolated left ventricular noncompaction syndrome. *Am J Cardiol.* 2009;104(8):1135-1138.
63. Guntheroth WG. Left ventricular noncompaction cardiomyopathy. *J Am Soc Echocardiogr.* 2012;25(7):806.
64. Caliskan K, de Visser RN, van Geuns RJ, Ten Cate FJ, Serruys PW. Left ventricular angiogram in a patient with noncompaction cardiomyopathy. *EuroIntervention.* 2007;2(4):533-534.
65. Paterick TE, Gerber TC, Pradhan SR, Lindor NM, Tajik AJ. Left ventricular noncompaction cardiomyopathy: what do we know? *Rev Cardiovasc Med.* 2010;11(2):92-99.