CARDIAC MR IN THE LITERATURE

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GENERAL


This is a comprehensive document and useful guideline on the clinical role of MRI and spectroscopy in the diagnosis and assessment of cardiovascular diseases. The task force, composed of cardiologists, pediatric cardiologists, and radiologists, based its recommendations on evidence from published literature and from clinical experience of its members. A total of 234 references on various aspects of cardiovascular MR were provided.

MYOCARDIUM


Microvascular obstruction determined by contrast-enhanced MRI predicted more frequent cardiovascular complications after infarction. The MRI-determined infarct size was also directly related to long-term prognosis in acute myocardial infarction. The microvascular status remains a strong prognostic marker even after control of the infarct size.


MRI and spectroscopy showed that left ventricular hypertrophy in cyclists was not associated with significant abnormalities of cardiac function or metabolism. These findings suggest that training-induced left ventricular hypertrophy in cyclists is predominantly a physiological phenomenon.


Patients with poor ventricular function and severe coronary artery disease underwent thallium scanning and MRI to predict regions of normally perfused, reversibly ischemic, or hibernating myocardium. Progressive reduction and disruption of connexin43 gap junctions in reversible ischemia and hibernation was demonstrated. Abnormal impulse propagation resulting from such changes may contribute to the electromechanical dysfunction associated with hibernation.


In patients with congestive heart failure, plasma atrial natriuretic peptide levels were shown to have a stronger relation with atrial volumes measured by MRI than with atrial pressures. These data suggest that increased right heart volume with subsequent increased atrial stretch is
the major determinant for atrial natriuretic peptide release in these patients.


MRI tissue tagging shows a small but significant decrease in posterior wall circumferential shortening after surgery for aortic insufficiency. The authors conclude that MRI tissue tagging is a sensitive and clinically applicable method of quantifying regional ventricular wall function before and after intervention for aortic insufficiency.


3D echocardiography was shown to be accurate for calculating left ventricular volumes and systolic function in patients with left ventricular aneurysm when compared with MRI. Unlike 2D echocardiographic methods, this technique requires no geometric assumptions that limit accuracy.


MRI. 123I-MIBG, and fluorescent microspheres showed that in the mechanically dysfunctional noninfarcted regions adjacent to chronic transmural myocardial infarction in a sheep model, blood flow and blood flow reserve were preserved but sympathetic innervation was reduced. These findings suggest that chronic sympathetic denervation may contribute to LV remodeling after infarction.


The value of cardiac MRI for assessment of myocardial motion and for measurement of intramyocardial strain was reviewed. Evaluation of myocardial dynamics was shown to be greatly enhanced by MRI but the resulting large data sets pose a challenge for visualization.


Breathhold cine MRI at rest and during dipyridamole infusion was used for qualitative wall motion analysis and quantitative wall thickening measurement in patients with severe coronary artery stenosis. The results were compared with SPECT. The quantitative method had higher performance than the qualitative one in identifying the diseased vessels territories.


A baseline and a serial follow-up cine MRI studies were performed to measure left ventricular myocardial mass, volumes, and ejection fraction in patients receiving antihypertensive therapy (isradipine). Cine MRI was able to depict small yet statistically significant reductions in left ventricular volumes in response to antihypertensive therapy.


Rapid MRI techniques provided comprehensive assessment of left ventricular structure and function, infarct artery patency, and regional myocardial contrast uptake in patients early after acute myocardial infarction. This information can be safely obtained by magnetic resonance techniques in less than 1 hr.


The clinical application, the advantages, and limitations of various imaging techniques, including MRI, are...
reviewed in relation to the determination of ventricular ejection fraction.


MRI was used to assess the presence, the degree, and the distribution of apical hypertrophic cardiomyopathy in patients of European descent diagnosed with hypertrophic cardiomyopathy on 2D echocardiography. A wide morphological spectrum of apical hypertrophy was demonstrated, including myocardial hypertrophy exclusively localized at the true apex.

Kudelka AM, Turner DA, Liebson PR, Macioch JE, Wang JZ and Barron JT. Comparison of cine magnetic resonance imaging and Doppler echocardiography for evaluation of left ventricular diastolic function. *Am J Cardiol, 1997; 80:384–386*

Cine MRI of the heart detected evidence of left ventricular diastolic filling abnormality in patients with left ventricular wall thickening but normal systolic function and normal diastolic function by routine Doppler echocardiography. Cine MRI may be more sensitive than routine echocardiography in detecting abnormalities of left ventricular diastolic function.


Ultrafast contrast-enhanced MRI was used to distinguish open and closed infarct-related arteries. An open artery is characterized by a faster rise and fall in signal intensity.


The authors showed that myocardial perfusion reserve can be quantified with first-pass MRI. In patients with microvascular dysfunction, myocardial perfusion reserve matches the reduced coronary flow reserve.


Improved reproducibility of myocardial motion trajectories calculated from cine phase-contrast velocity data was shown when presaturation of flowing blood. Presaturation was recommended for myocardial motion studies using cine phase-contrast velocity data.


Early after infarction, regions with dysfunction, normal function, and hyperfunction can be delineated using cine MR tagging and strain analysis. The compensatory increased contraction in the remote region shown in this study was possibly triggered by the Frank–Starling mechanism.


The authors show that left ventricle contraction and myocardial perfusion can be represented conjointly in one single fused MR image. The clinical relevance of this approach in assessing coronary artery disease needs to be established.

**RIGHT VENTRICLE**

Vogel M, Gutberlet M, Dittrich S, Hosten N and Lange PE. Comparison of transthoracic three dimensional echocardiography with magnetic resonance imaging in the assessment of right ventricular volume and mass. *Heart, 1997; 78:127–130*

Transthoracic 3D echocardiography was shown to have an acceptable accuracy for end-diastolic right ventricular volumes in normal and enlarged right ventricles but was less accurate for end systolic volumes. This method was unsatisfactory for right ventricular mass measurements. MRI was the standard of reference.

Vonk-Noordegraaf A, Marcus JT, Roseboom B, Postmus PE, Faes TJ and de Vries-PM. The effect of right ventricular hypertrophy on left ventricular ejection

MRI showed significantly larger right ventricular wall volume, thickness, and right ventricular-to-left ventricular wall thickness ratio in patients with pulmonary emphysema than in the controls. Flattening of the interventricular septum, shown in this study, was suggested as a possible explanation for the relatively normal left ventricular ejection fraction in emphysematous patients.

ARRHYTHMOGENIC RIGHT VENTRICULAR DYSPLASIA


MRI demonstrated mild structural abnormalities in 70% of patients including focal thinning, fatty infiltration, and wall motion abnormalities of the right ventricle. The most common site of MRI abnormalities was the right ventricular free wall, but there was a poor correlation between the site of MRI abnormalities and the origin of ventricular tachycardia.


In patients with idiopathic right ventricular outflow tract premature contractions, MRI revealed a higher rate of morphological and functional abnormalities of the right ventricular outflow tract than in the normal subjects. Large studies and long follow-up are needed to confirm whether these findings could help identify a localized form of arrhythmogenic cardiomyopathy and its clinical significance.


This study compares myocardial $^{125}$I-MIBG, $^{203}$TlCl, MRI, and ultrafast computed tomography for the early detection of left ventricular involvements in patients with arrhythmogenic right ventricular dysplasia. Myocardial imaging with $^{125}$I-MIBG sensitively detected myocardial damage in the early stage when cardiac systolic function is still preserved.

AORTA


Aortic distensibility, LV mass index, abdominal fat (subcutaneous and visceral), and free magnesium levels in the brain and skeletal muscle were assessed by MRI and spectroscopy. In patients with essential hypertension, the following were concluded: systolic hypertension and increased LV mass index may result from arterial stiffness, arterial stiffness may be one mechanism by which abdominal visceral fat contributes to cardiovascular risk, and decreased magnesium contributes to arterial stiffness in hypertension.


MRI was used to determine the aortic cross-sectional area/aortic pressure relationship in nine premenopausal women before and after menotropin therapy. In premenopausal women, a short-term rise in estrogen induced by menotropin treatment is associated with an increase in aortic compliance. Aortic size is not significantly increased within this time frame.


TEE, transthoracic (TTE) echocardiography, and MRI were used to predict bioprosthetic valve size. MRI of the aortic annulus correctly predicted valve size but could not reliably identify the sinotubular junction. The combi-
nation of TTE and TEE improve the accuracy of prediction of stentless bioprosthesis size.


Patients with acute traumatic rupture of the thoracic aorta may have a better fighting chance if aortic operation is postponed to the most favorable moment after undergoing life-sustaining measures and management of the major associated lesions. Evolution should be closely monitored by computed tomographic scans and MRI.

FLOW


This study shows that slice location is important in quantifying aortic regurgitant volume accurately by magnetic resonance velocity mapping. The higher accuracy achieved with the slice placed between the aortic valve and the coronary ostia suggests that this slice location should be considered and thoroughly examined as the preferred measurement site clinically.


Fast cine phase-contrast MR flow quantification may prove to be a useful adjunct to routine MR studies for measurements of peak flow velocity. However, estimates of volume flow rate using this fast MR method is limited because of increased noise during low diastolic flow and edge artifacts.

MAGNETIC RESONANCE ANGIOGRAPHY

Vliegen, Doornbos J, de Roos A, Jukema JW, Bekedam MA and van der Wall EE. Value of fast gradient echo magnetic resonance angiography as an adjunct to coronary arteriography in detecting and confirming the course of clinically significant coronary artery anomalies. Am J Cardiol, 1997; 79:773–776

Coronary MRA using two-dimensional fast gradient echo images and fat suppression were acquired to detect or confirm the course of coronary arteries. MRA provided conclusive diagnosis in some patients in whom x-ray coronary arteriography was not conclusive and confirmed the x-ray arteriography findings in the others.


3D contrast-enhanced breathhold angiography was shown to be a noninvasive, rapid, and useful diagnostic technique for detecting grafts patency in patients who have undergone CABG surgery.


The contrast travel time from injection site to the vascular system under consideration cannot be predicted based on physiologic parameters. This time interval can be reliably and accurately determined by a test bolus injection of a small volume of contrast agent followed by a saline flush during normal breathing.


Dynamic gadolinium-enhanced 3D spoiled gradient-recalled MR angiography was highly sensitive for revealing proximal renal artery stenosis when compared with x-ray arteriography.


3D breathhold contrast-enhanced MRA was able to detect and grade lesions in the abdominal aorta and renal
arteries when compared with intraarterial digital subtraction angiography as a standard of reference.


Nonbreathhold, 3D, gadolinium-enhanced MRA was shown to be less accurate than TOF imaging for evaluation of stenosis at carotid artery bifurcation. The standard of reference was digital subtraction angiography. Timing the injection of gadolinium and masking of the carotid bifurcation by the venous jugular system were the main suggested problems.


The use of an automatic MR power injector was shown to be superior to manual injection of contrast material. The optimal injection rate was 2 ml/sec for 3D breathhold MR angiography of the abdominal vessels.


Subtracted contrast-enhanced MRA was shown to be superior to cardiac-synchronized time-of-flight MR angiography for imaging of iliac and upper femoral arteries providing higher contrast-to-noise ratio, fewer artifacts, and easier image interpretability than nonsubtracted MR angiography.

CARDIOVASCULAR TUMORS


The morphological features of cardiac tumours demonstrated by MRI were used to differentiate malignant from primary benign tumors.

Mousseaux E, Meunier P, Azancott S, Dubayle P and Gaux JC. Cardiac metastatic melanoma investigated by magnetic resonance imaging. Magn Reson Imaging, 1998; 16:91-95

MRI was shown to be superior to transthoracic echocardiogram in the management of patients with cardiac involvement in malignant melanoma.

CONGENITAL HEART DISEASE


MRI replaced other techniques in the diagnosis and follow-up of some congenital heart diseases.


A follow-up study to evaluate the role of balloon angioplasty in the treatment of discrete coarctation of the aorta in adolescents including results of cardiac catheterization and MRI. The authors showed that balloon angioplasty was safe and effective alternative to surgery for treatment of discrete coarctation of the aorta in adolescents and adults.


Magnetic resonance bolus tagging method showed that a substantial amount of pulmonary blood flow in patients who have undergone a total cavopulmonary connection type of Fontan operation has a cardiac component. The authors suggest that this information may help in designing the systemic venous pathway and optimizing medical management.

Amodeo A, Galletti L, Marianeschi S, Picardo S, Giovanni S, Di Renzi P and Marcelletti C. Extracardiac Fontan operation for complex cardiac anomalies:
Seven years’ experience. *J Thorac Cardiovasc Surg*, 1997; 114:1020–1030

Serial MRI studies showed that total extracardiac cavopulmonary connection provides good early and midterm results and may reduce the prevalence of late arrhythmias in patients undergoing the Fontan operation.


Follow-up angiography and/or MRI after balloon angioplasty of surgically repaired aortic recoarctation was shown to be feasible, safe, and effective with good long-term results. It was recommended as the procedure of choice in the management of postsurgical recoarctation with hypertension and/or congestive heart failure.

**TECHNIQUES**


Two methods of artifact reduction for motion in the phase-encode direction were evaluated. First, the k-space trajectory was evaluated by comparing centric with top-down ordered sequences. Next, velocity gradient moment nulling of the phase-encode direction was evaluated for each trajectory. Computer simulations and experiments in flow phantoms and rabbits in vivo show that uncompensated centric ordering produces the highest image quality.


This article describes a technique that can be used to remove induced MRI gradient interference from an ECG recorded on a patient inside the bore of a MRI scanner. Induced signal from an external loop is subtracted from the ECG to minimize the low-frequency interference. The gradient-induced low-frequency interference was reduced to approximately 20% of its magnitude when using conventional ECG amplifiers.

**SAFETY**


The author questioned the recommendations previously published by Hartnell et al (AJR 1997; 168: 1157–1159) regarding the safety of MRI in patients with retained epicardial electrodes.


The author disagreed with Dr Kanal’s conclusion and continue to believe that patients with retained epicardial electrodes examined for clinical indications using conventional MRI scanners at the reported field strengths can be safely imaged.


The effects of MRI on pacemakers and electrodes were investigated in phantom studies using 1.5T scanner. Pacemaker malfunctions were not observed in asynchronous pacing mode (VOO/DOO) but inhibition and rapid pacing were observed during spin-echo imaging in VVI or DDD mode. Pacemaker function was not impaired during gradient-echo imaging but electrodes heating was significant.


The authors concluded that MRI at 0.5 Tesla should not be regarded as absolutely contraindicated in patients with implanted new generation cardiac pacemakers. However, knowledge of the behaviour of the specific pacemakers model in static and pulsed magnetic fields is required, changes of the pacemaker program prior to the MRI may be necessary and continuous ECG monitoring and cardiological stand-by is important.

Dujovny M, Alp MS, Dujovny N, Zhao YJ, Gundamraj NR, Misra M and Dobben G. Aneurysm clips:

The magnetic properties of different types of aneurysm clips was quantified in electromagnetic units by using a vibrating sample magnetometer. The authors concluded that aneurysm clips with a magnetic moment less than 1 EMU/g may be safely used during MR imaging.


This article described active noise control techniques that introduce antiphase noise to interfere with the MRI noise. The combination of standard passive ear protection and active attenuation of acoustic noise at both low and high frequencies may lead to improved patient comfort.

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**SPECTROSCOPY**


The results of this study demonstrate normal myocardial PCr/ATP ratios in patients with myocardial stunning after reperfusion and suggest that relative cardiac high energy phosphates are not depleted in stunned human myocardium.


High work-loads alter myocardial high-energy phosphate metabolism of the normal human heart.

Conway MA, Bottomley PA, Ouwerkerk R, Radda G and Rajagopalan B. Mitral regurgitation, impaired systolic function, eccentric hypertrophy and increase severity are linked to lower phosphocreatine/ATP ratios in human. *Circulation*, 1998; 97:1716–1723

Abnormalities in the PCr/ATP are demonstrated in patient with mitral regurgitation and are related to the severity of the disease suggesting PCr/ATP as a marker for both heart failure and hypertrophy.


Regional human heart total creatine non-invasively assessed by spatially localized 'H-MRS could be a means to distinguish healthy from infarcted non-viable myocardium.


The RV is less well preserved than in the LV during retrograde continuous normothermic blood cardioplegia as assessed by energy metabolism. A combination of antegrade continuous normothermic blood cardioplegia and retrograde continuous normothermic blood cardioplegia is indicative of good cardiac protection as measured by the recovery of cardiac energetics and pH.