

CARDIAC MRI

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INTRODUCTION

- MRI is a noninvasive imaging technique that came into clinical use in the early 1980s. It is based on the principles of nuclear magnetic resonance (NMR) that were developed in the 1930s. **Significant** advances were necessary to go from the basic principles of NMR to generating images of the human body. Techniques were developed to localize the small amount of radio frequency (RF) energy generated from spinning hydrogen protons when a patient is placed in a strong magnetic field. Image production today relies upon magnetic fields created by superconducting magnets and sophisticated electronics which manipulate and process the RF energy.

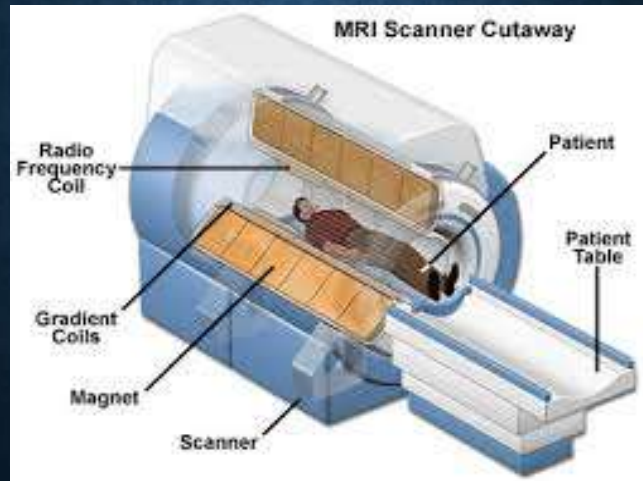
- MRI has revolutionized medical imaging for many organ systems. However, due to the motion of the heart, the development of cardiac MRI has been slow as compared to MRI for other organs due to the requirement for faster acquisition techniques. With advancements in technology, these obstacles have been overcome and cardiac MRI has become a validated tool for imaging the heart

MRI PHYSICS

- Magnetic resonance (MR) imaging relies on positively charged hydrogen protons in the body, most of which are located in water molecules. When a patient is placed in a magnetic field, these protons begin to spin at a frequency that is proportional to the strength of the magnetic field, called the Larmor frequency. Each proton is a spinning positive charge, and this moving charge generates a small magnetic field. The small magnetic fields of the protons align themselves with the large magnetic field generated by the superconducting magnet.

- A relatively small spatially varying magnetic field (gradient) is applied in addition to the large spatially constant magnetic field causing protons at different locations to rotate with slightly different frequencies. A radiofrequency (RF) energy pulse is then delivered by the RF coil to the protons. This RF pulse has the same frequency as the protons spinning in the desired imaging location. The RF pulse adds energy to only these protons by resonance; protons spinning at frequencies different from the RF pulse do not capture this energy. The energy from the RF pulse pushes the magnetization direction of the selected protons away from the direction of the large magnet field generated by the superconducting magnet.

- When the radiofrequency pulse is stopped, the selected protons relax back to their original alignment with the large magnetic field. While relaxing they release a signal in the form of RF energy. This energy can be captured by an RF receiver coil and processed to yield localized information about the protons in the patient's tissues. This process of disturbing selected protons and then collecting the energy released as the protons relax is the basis of MR imaging.



ADVANTAGE

- There are many advantages to Cardiac MRI when compared to other noninvasive imaging modalities such as ultrasound and CT. MRI does not have any ionizing radiation, thus permitting its use in children and pregnant women. It can produce high resolution and 3D images of the cardiac chambers and thoracic vessels. MRI gadolinium contrast media does not have as high a risk of allergic reaction or contrast media induced nephropathy as iodinated contrast media. Unlike echocardiography, MRI can produce images of cardiovascular structures without interference from adjacent bone or air which limits echocardiography. MRI is also less operator dependant than echocardiography. SSFP techniques can be used to assess global and regional ventricular contractile function, including the more difficult to assess right ventricle. Velocity encoded techniques permit measurement of blood flow. MRI does not have the weakness of geometric assumptions (as do angiography and 2-D echocardiography) in assessing ventricular volumes.

DISADVANTAGE

- However, Cardiac MRI has several disadvantages. MRI requires more patient cooperation than other tests and claustrophobic patients may be unable to undergo the exam. Examination times are significantly longer as compared with CT. This, in addition to the fact that the patient is physically isolated from direct care when in the scanner, makes MRI unsuitable for unstable patients. Installation and operation of MRI equipment is costly and as such is an important consideration both for hospitals and patients. MRI is incompatible with various medical and life support devices, limiting its use in acute trauma. Due to the forceful attraction of ferromagnetic objects to the magnet, most intracranial or intraocular metal or shrapnel, cardiac pacemakers or pacemaker wires, and cochlear implants are absolute contraindications to imaging with MRI. Most new aneurysm clips, stents and vascular filters are MR compatible. Finally, MRI has less spatial resolution than CT, which limits the evaluation of small structures such as the coronary arteries.

- Gadolinium can be toxic to patients with impaired kidney function, with haemodialysis recommended in some cases. Unlike ultrasound, an MRI is not portable to take to the patient's bedside. Patients with metallic objects such as pacemakers are unable to be scanned. R images are obtained through a process called "gating", whereby the an ECG is used to acquire images at each stage of the cardiac cycle over several heart beats. If a patient has an irregular rhythm this can reduce the image quality.

CONTRAST AGENTS

- MRI is sometimes performed with the use of intravenous contrast agents to enhance the signal of pathology or to better visualize the blood pool or vessels. Most MRI contrast agents are gadolinium. Contrast agent is used in Cardiac MRI for evaluation of myocardial perfusion, delayed enhanced imaging (myocardial infarctions, myocarditis, infiltrative processes), differentiation of intracardiac masses (neoplasm vs. thrombus) and to opacity blood vessels in MR angiography (MRA).

INDICATION

- The indications for cardiac MRI are ever expanding. At the moment they include:
 - 1) Coronary artery disease
 - A. Assessment of global ventricular function and mass
 - B. Detection of CAD
 - i. Regional LV function at rest and during dobutamine stress
 - ii. Assessment of myocardial perfusion (adenosine stress)
 - iii. Coronary MRA (anomalies)

- C. Acute and chronic myocardial infarction
 - i. Detection and assessment
 - ii. Myocardial viability

CARDIOMYOPATHIES

- 2
- A. Hypertrophic cardiomyopathy
- B. Dilated cardiomyopathy
- C. Arrhythmogenic Right Ventricular Cardiomyopathy
- D. Restrictive cardiomyopathies
 - i. Sarcoid
 - ii. Amyloid
 - iii. Eosinophilic
- E. Myocarditis

- 3) Cardiac and pericardiac masses
 - A. Primary cardiac
 - B. Pericardiac (including pericardial)
 - C. Thrombus

-) Pericardial disease
 - A. Pericardial effusion
 - B. Constrictive pericarditis
- 5) Valvular heart disease
 - A. Quantification of regurgitation

- 4
- 6) Congenital heart disease (CHD)
 - A. Assessment of shunt size
 - B. Anomalous pulmonary venous return
 - C. Pulmonary regurgitation
 - D Atrial septal defect
- 7) Diseases of the aorta and great vessels
 - A. Aortic aneurysm
 - B. Aortic dissection
 - C. Intramural hematoma

CARDIOMYOPATHIES

- Cardiomyopathies are chronic, progressive diseases of the myocardium which are classified into four categories: hypertrophic cardiomyopathy (HCM), dilated cardiomyopathy (DCM), restrictive cardiomyopathy (RCM) and arrhythmogenic right ventricular cardiomyopathy (ARVC). Cardiomyopathies are often due to genetic factors, but there is developing evidence that inflammation and injury may contribute to their development. While the cause of a given cardiomyopathy may be identifiable, many can only be classified as idiopathic. Cardiac MRI is able to characterize cardiomyopathies by their morphologic and functional phenotype as well as by tissue characterization. The previously described MRI techniques used to study myocardial function (cine imaging, delayed enhanced imaging) can also be put to use in studying cardiomyopathies.

ARRHYTHMOGENIC RIGHT VENTRICULAR CARDIOMYOPATHY

- Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a familial cardiomyopathy in which the right ventricular wall is progressively replaced with fibrosis and/or fat. The infiltration with fat/fibrotic tissue can interfere with electrical conductance in the myocardium resulting in ventricular arrhythmias and sudden death. Dilatation of the right ventricle and right sided heart failure can occur as well.
- Cardiac MRI is the primary imaging modality used to diagnose ARVC. The major imaging criteria for diagnosis of ARVC include severe global or local dysfunction of the RV (with no or only mild LV impairment), global RV dilatation, localized RV or right ventricular outflow tract (RVOT) aneurysm, and fatty infiltration of the RV myocardium (bright on T1, dark with fat saturation sequences). DHE of the right ventricle may suggest infiltration with fibrotic tissue, a finding that would be consistent with ARVC.

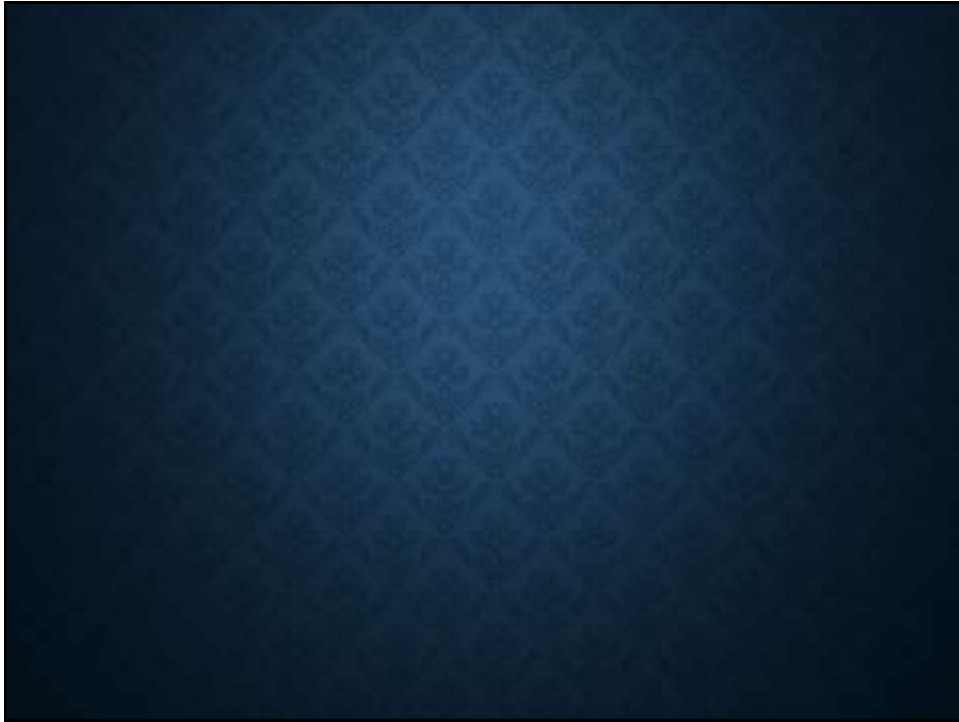
CMR in ARVC

Quake Institute
Electrophysiology



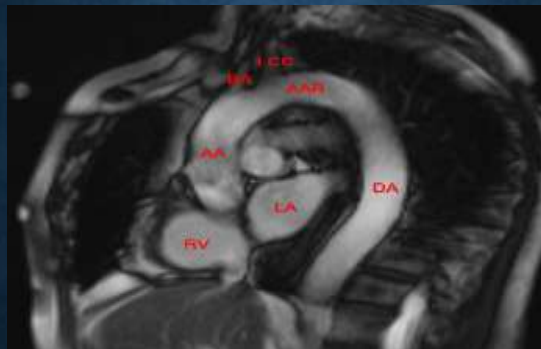
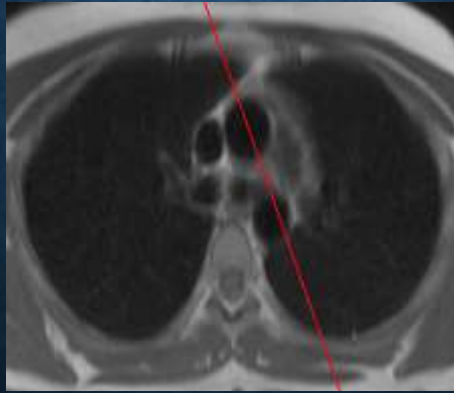
- Axial end-diastolic bright-blood image from a patient with ARVD showing RV dilatation. Note the diameter of RV is greater than LV at the mid-ventricular level.

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AORTIC VIEW

- The Aortic view ("Candy Cane" view) shows the aorta along its entire thoracic course along with some of its branches off the aortic arch. An axial image is selected and a plane is chosen that bisects both the ascending and descending aorta.
- Mouse over the aortic view image to display labels.



AA = Ascending Aorta, AAR = Aortic Arch, BA = Brachiocephalic Artery, DA = Descending Aorta, LA = Left Atrium, LCC = Left Common Carotid, RV = Right Ventricle

DETECTION AND ASSESSMENT OF ACUTE AND CHRONIC MYOCARDIAL INFARCTION

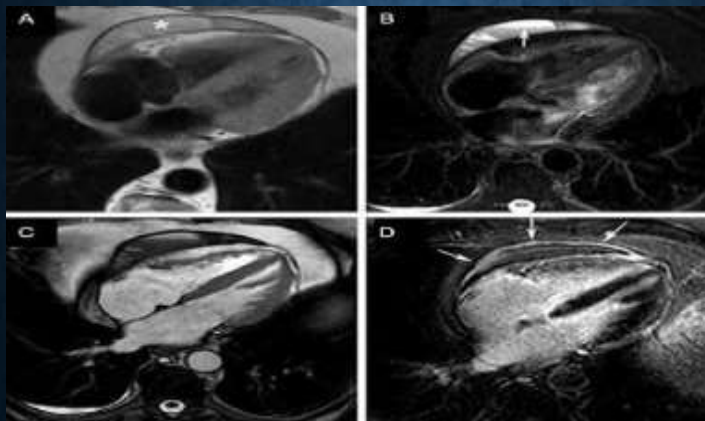
- Delayed Hyperenhanced Imaging
- The presence and extent of a myocardial infarction can be assessed with delayed enhanced imaging. Delayed hyperenhancement (DHE) is caused by delayed washout of contrast agent from the myocardium. In normal myocardium, contrast media quickly washes in and out of the myocardial interstitium. Abnormal myocardium, however, retains contrast agent which is demonstrated as enhancement on delayed imaging.

- Delayed enhanced imaging is performed 10-15 minutes after the intravenous administration of 0.15-0.2 mmol/kg of gadolinium contrast media. An inversion recovery sequence is used in which normal myocardium is nulled to accentuate the delayed enhancement.
- Delayed hyperenhancement may be seen in chronic infarcts as well as acute. In chronic infarcts, delayed washout is a result of scar tissue retaining contrast media. In acute infarcts, delayed washout is due to an increase in the volume of distribution of the interstitium due to destruction of myocytes and resultant edema

PERICARDIAL MASSES

- Pericardial cysts are congenital masses that are often located in the right cardiophrenic angle. These may appear as pericardiac masses on chest radiograph. Cardiac MRI can be useful in characterizing these lesions. On spin-echo imaging, they typically have a low intensity on T1-weighted imaging and homogenous high signal intensity on T2-weighted imaging. Lipomas are another benign lesion that sometimes arises from the pericardium; they typically have a high signal on T1-weighted imaging with loss of signal on fat saturated imaging

- Primary malignancies of the pericardium are rare. The most common is primary pericardial mesothelioma. The pericardium is more commonly a site of metastases from lung, colon, and breast cancer. All metastatic tumors will typically enhance.



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Thank
you

