Technical Aspects 2

2.1 Cardiac Magnetic Resonance Imaging Techniques

Each cardiac magnetic resonance imaging (CMR) sequence must be adapted to the patient in terms of heart rate and duration of apnea. Cardiac gating is a prerequisite in a CMR study. Electrocardiogram leads have to be MR compatible and positioned to provide a clear, strong electrocardiogram signal. Peripheral vein access must be available to inject contrast medium during the scan session. Different CMR techniques at 1.5T, proposed for the evaluation of a cardiac mass, are described further on [1–6].

Cine Sequences

Steady-state free precession cine sequences are considered as the gold standard for assessing left ventricular volume, ejection fraction and chamber anatomy [7]. The high contrast between the myocardium (low signal) and the blood (high signal) is excellent on cine sequences and gives an accurate delineation of the endocardial wall, showing the intracavity border of a cardiac mass. Temporal resolution is also excellent, providing high resolution cine sequences, and single shot images covering the whole chest in the axial plane in one or two breath-holds. The examination should include cine sequences in the two-chamber, four-chamber and short axis views, with the option of measuring left and right ventricle volumes, ejection fraction and mass.

T1- and T2-Weighted Sequences

These are mainly used to image the great vessels and they can also be used to delineate anatomical features and characterize different types of tissue. These sequences are very sensitive to flow artifact and a black blood pulse is usually performed before acquisition to null the signal of flowing blood. They can also be used with a fat-suppressed pre-pulse and are of great interest in assessing differential diagnoses for thrombus such as lipoma, fatty infiltration or anatomic variations.

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First Pass Perfusion Imaging

Gradient echo, steady-state free precession and echo planar imaging based sequences can be used to assess first pass myocardial perfusion. These sequences are T1-weighted, have a high temporal resolution and provide images on three or four different slice levels (usually three different short axis views, and one long axis view) in one RR interval. These MR techniques are used to measure myocardial perfusion [8] after gadolinium chelate injection, but can be used to assess cardiac mass perfusion [5].

Look-Locker Sequences

Look-locker sequences consist in performing electrocardiogram-synchronized look-locker trains in one breath hold on consecutive heart beats (echo planar imaging with slice selective inversion recovery pulse). These sequences have the advantage of setting the inversion time of normal myocardium that is subsequently used for the delayed contrast-enhanced MR images [9]. Look-locker [10, 11] and, more recently, MOLLI sequences have also been used to measure T1 of the myocardium before and after contrast injection to assess the presence of enhancement within a mass [12].

Delayed Contrast Enhancement

Gradient echo with inversion recovery in 2D and, more recently, in 3D is the gold standard sequence for assessing myocardial enhancement [9]. This sequence must be performed 5–20 min after the administration of an extracellular contrast medium for measuring myocardial infarcts [13–15]. Delayed contrast-enhanced MR images can also be performed to assess myocardial mass enhancement [1] and earlier acquisitions should be made (at 1–5 min) to assess the quality of mass enhancement. With gradient echo inversion recovery, inversion time must be set to null normal myocardium before each acquisition to provide a high contrast to noise ratio [9]. Phase sensitive inversion recovery images can now be used to assess late enhancement without the need to set inversion time [16, 17].

2.2 Multidetector Computed Tomography Image Acquisition

Multidetector computed tomography (MDCT) yields high temporal resolution isotropic voxel images. Other benefits include improved quality of multiplanar and 3D reconstruction and the ability to combine other protocols with coronary CT angiography while still using a single dose of contrast medium. Thin slices give this imaging modality the capacity to visualize the cardiac and coronary anatomy in any spatial orientation with equal resolution. The same acquisition also provides both morphological and functional information.

Images Acquisition

Cardiac MDCT is a technical challenge because image acquisition must be synchronized with the heart rate using the minimum dose of radiation. The scanning parameters must be adapted to the patient's heart rate and morphology in order to achieve perfect image quality with the lowest possible radiation exposure for the patient. In clinical protocols, images are acquired in two different phases [18].

The arterial phase is synchronized with the arrival of the contrast bolus in the cardiac chambers and aortic roots. This acquisition is used to assess the coronary anatomy and myocardial perfusion and to differentiate early perfusion defects that are picked up as hypoenhanced areas in the normal myocardial tissue and to measure left ventricular (LV) volume and ejection fraction [19, 20].

The delayed enhancement phase is performed 5 min after contrast injection and image parameters must be adapted to show delayed myocardial enhancement [21–25].

Acquisition Parameters

For the arterial phase, the acquisition parameters (detector collimation, tube voltage and tension) are set to assess the coronary anatomy and require the highest technical potential of the CT hardware and software. These acquisitions demand a high radiation dose, although the dose required may decrease as the technology progresses [26]. Acquisition parameters for the arterial rule-out phase depend on the available scan hardware and are described in detail in several papers [25, 27–29].

For the delayed enhancement phase the acquisition parameters must be adapted to show myocardium enhancement and most investigators set the tube voltage around 80 kV [21, 25, 30–32] in human studies assessing delayed myocardial enhancement. The tube voltage is adjusted to a low setting (80 kV) to decrease radiation exposure and increase contrast to noise ratio. The tube voltage should be set at 100 kV to assess delayed myocardial enhancement in patients with a body weight above 80 kg [30]. Detector collimation can be increased to 1.2 or 1.5 mm because the spatial definition required for assessing delayed myocardial enhancement is not the most essential aspect of this acquisition [25, 30, 32]. Increasing the detector collimation decreases the noise and subsequently increases the signal to noise ratio (SNR) and the control to noise ratio (CNR) thus allowing dose reduction [21]. The medium kernel convolution used for late enhancement reconstruction must be selected to enhance the contrast resolution [25].

Contrast Injection

MDCT assessment of delayed myocardial enhancement requires an increased dose of iodinated contrast medium – between 120 and 140 mL compared to the dose used in coronary anatomy assessment (70–80 mL for 64-slice technology) [21, 25, 31, 32]. In the studies mentioned above, the concentrations of contrast media vary from 300 to 400 mg of iodine per mL and the total amount of iodine injected varies from 44 to 56 g per patient,

which means a quantity between 0.44 and 0.77 mg of iodine per kg of body weight for a body weight of 80 kg. MDCT has advantages over CMR including a direct proportionate linear relationship between enhanced X-ray absorption and the concentration of the contrast agent [33]. An increase in the dose of iodine injected will increase the CNR, SNR and the contrast resolution. There is no recommended dose for MDCT in the literature but a dose of iodine around 0.6–0.7 mg of iodine per kg of body weight yields images of good diagnostic value.

The delay between injection and image acquisition varies substantially in the literature for the delayed enhancement phase, ranging from 5 [32] to 15 min [25] after intravenous injection; this delay can increase to 24 ± 11 min if the iodine is injected directly into the coronary tree during coronarography with revascularization [30]. Lardo et al [20] measured the enhancement kinetics of iodine contrast media in vivo in a pig infarct model. Investigators showed that the infarct area was clearly delineated and reached peak enhancement 5 min after injection and then washed out showing the progressive renal clearance of the contrast medium. It was recently shown in humans that a delayed enhancement acquisition 5 min after contrast medium injection provided a higher CNR and SNR compared with the 10 min time point. This is explained by the rapid decrease in iodine concentration in the blood due to renal clearance. This study shows that delayed enhancement acquisitions should be performed 5 min after contrast injection to improve image quality [15].

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