Cardiac CARE MRI Scanning Guidance

This guidance is designed to be used alongside local policies and procedures in the acquisition and processing of cardiac MRI images for the CARE trial.

Technical considerations

- 3 Tesla (T) are preferred but if not available, 1.5T scanners may also be used for image acquisition.
- It is crucial to have a high quality ECG signal to ensure accurate cardiac triggering and optimal image quality.

Patient Positioning

Patients should be imaged using either a dedicated phased array cardiac/body coil with anterior and posterior elements, or alternatively using elements of the spine coil posteriorly and a phased array body coil anteriorly if a dedicated cardiac coil is unavailable.

The patient should be positioned supine with the heart over the middle of the posterior coil elements being used for imaging.

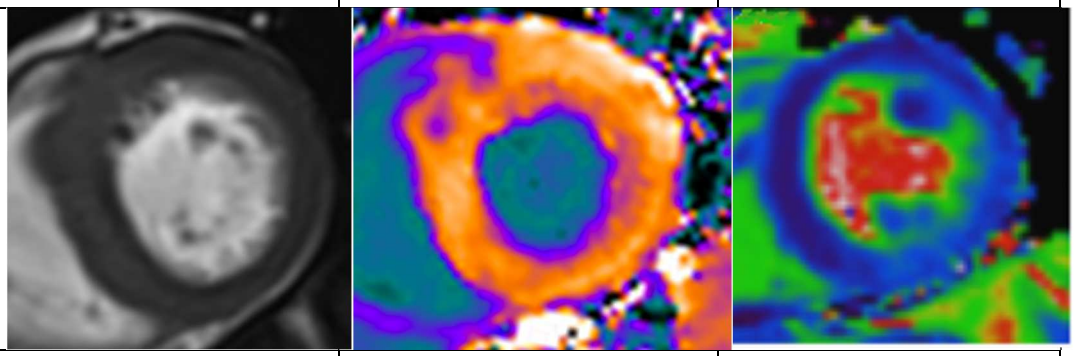
If the patient is male, the chest may need to be shaved prior to placement of ECG electrodes in order to establish optimal conduction of ECG-gating signal. Electrodes should be placed according to scanner manufacturer specifications. Only MRI-compatible ECG electrodes and gating equipment should be used. Once the electrodes are in place, the radiographer should view the ECG signal on the MR patient monitoring system and on the MR scanner console. The technologist should check that the MR system is detecting a gating signal from the ECG. If the MR system is gating reliably and correctly on the R-wave, the anterior cardiac or body coil should be placed over the patient chest, with the heart approximately in the middle of the coil.

The patient should then be moved to the bore aperture and the ECG-gating signal checked again. If the MR system is designed to run through a 'learning' phase for ECG-gating, this procedure should be followed at this stage.

If the ECG-gating signal is still reliable, the middle of the imaging coil (and therefore patient heart) should be moved to magnet isocentre. Once the patient is at isocentre, a final assessment of gating quality should be made. If the MR system is not reliably gating to the patient R-wave, the patient should be removed from the bore and the electrode placement procedure re-started.

Image acquisition

There are three main components to the CMR imaging protocol:

Major components	Structural imaging	T1 mapping (optional)	T2 mapping (optional)
Pulse sequence	Cine MRI	MOLLI	T2 prep acquisition
Typical images			
Rationale	Quantify LV size, mass and systolic function	To assess myocardial fibrosis	To assess myocardial oedema

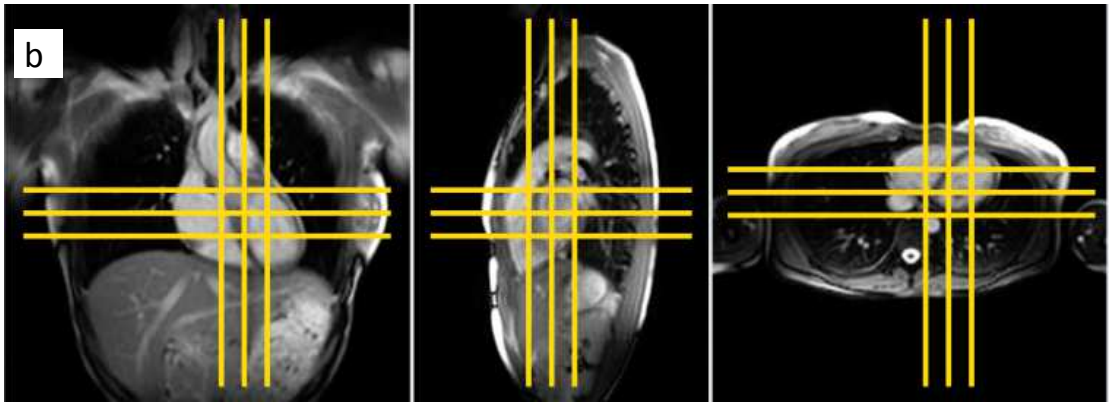
In brief the imaging protocol will consist of:

1. Localiser sequences
2. LV imaging I (4 chamber, 3 chamber and 2 chamber long axis cines + LV short axis stack)
3. *3 short axis slice T1 maps (Basal, mid-LV, and apical)*
4. *3 short axis slice T2 maps (Basal, mid-LV, and apical)*

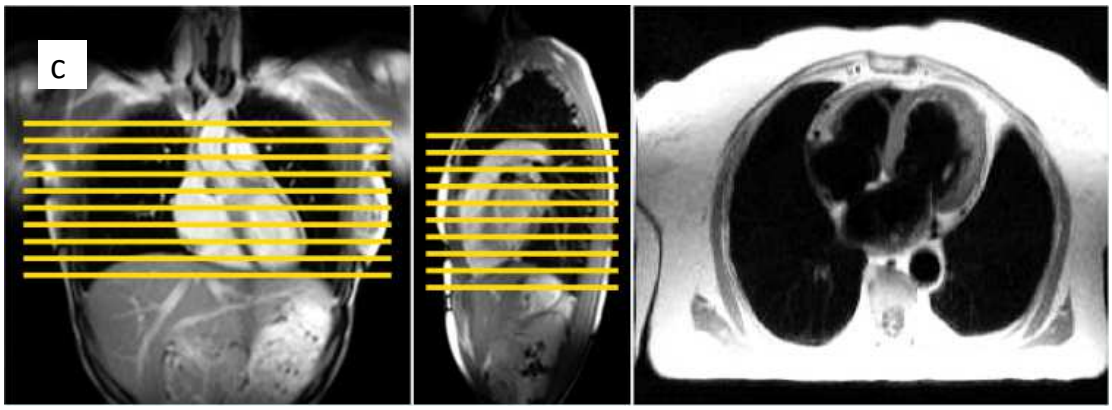
1. Localiser sequences

Note: all breath-holds should be acquired in expiration.

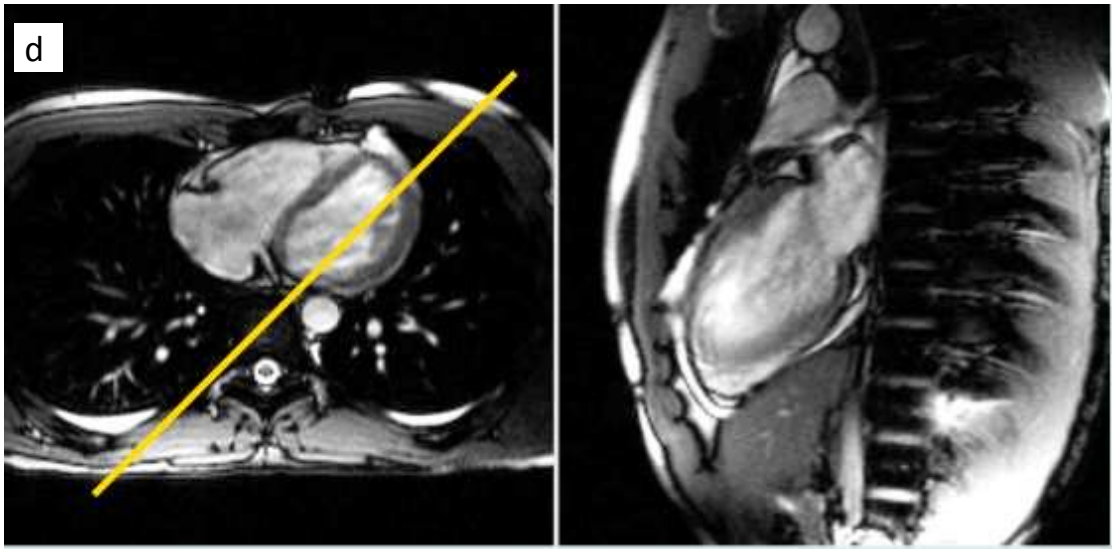
1. Cardiac plane localization
   a) 3-plane localizer: run automatically, untriggered free breathing to localize heart centre position.
   b) 3-plane isocentre localizer: adjust heart to isocentre of bore (run this acquisition in ISOCENTRE mode). Prescribe 3 axial, 3 coronal, 3 sagittal slices, single breath-hold, ECG-trigger on every heartbeat, capture cardiac cycle for diastole.



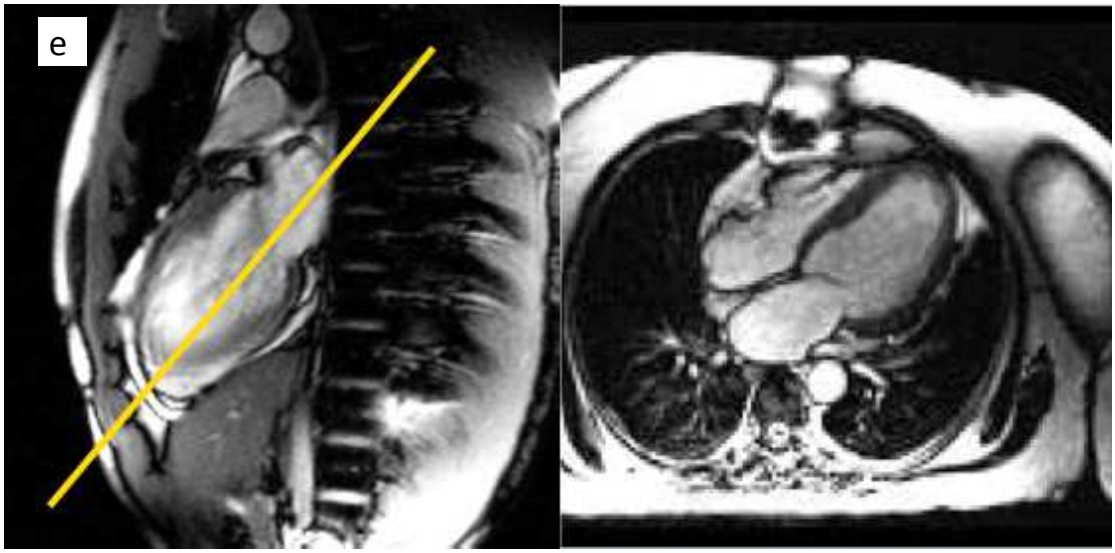
c) Axial dark blood half-fourier localizer: 20 or more slices for coverage prescribed from sagittal and coronal 1b) views, cover from above aortic arch to below apex, multiple breath-holds if required by MR system, trigger on every second heartbeat, capture cycle for diastole. Example image acquired is shown on right.



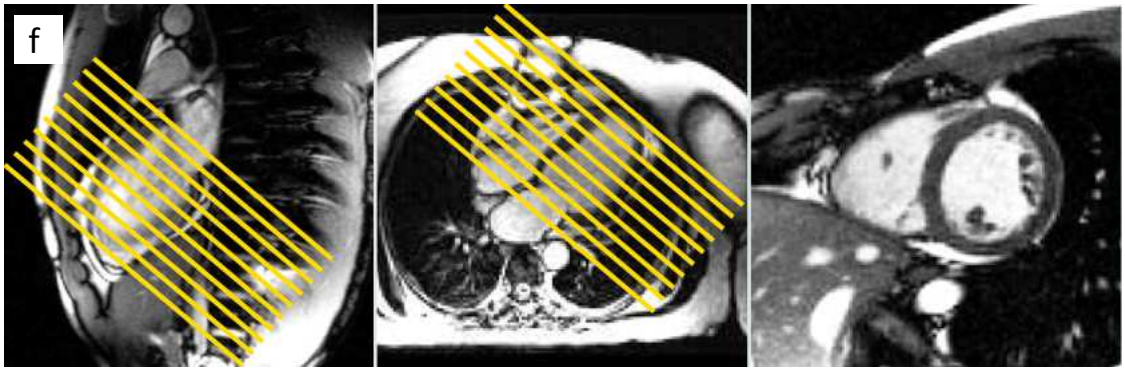
d) 2 chamber localizer: prescribe 1 slice from axial view (1c) parallel to ventricular septum, bisect left ventricle through mitral valve and apex, single breath-hold, trigger on every heartbeat, capture cycle for diastole.



e) 4 chamber localizer: prescribe 1 slice from two chamber view (1d), bisect left ventricle through mitral valve and apex, single breath-hold, trigger on every heartbeat, capture cycle for diastole.



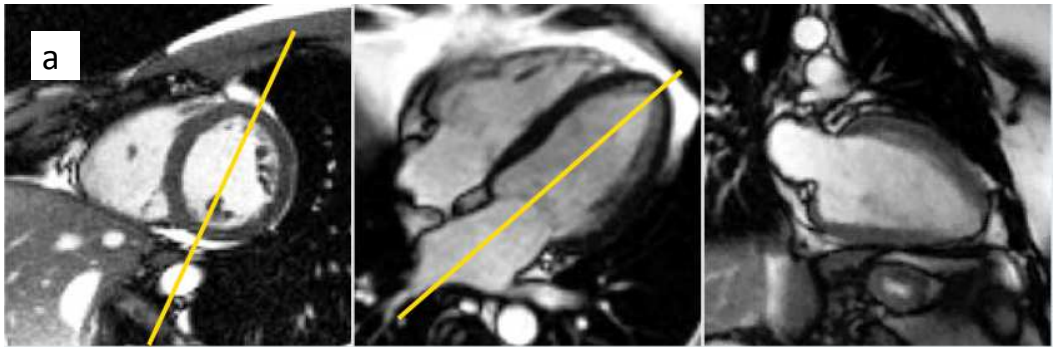
f) Short-axis localizer: prescribe 3 slices from LVOT towards apex (whole stack is shown in image below) from 2 chamber (1d) and 4 chamber (1e) views, perpendicular to long axis of left ventricle, single breath-hold, trigger on every heartbeat, capture cycle for diastole.



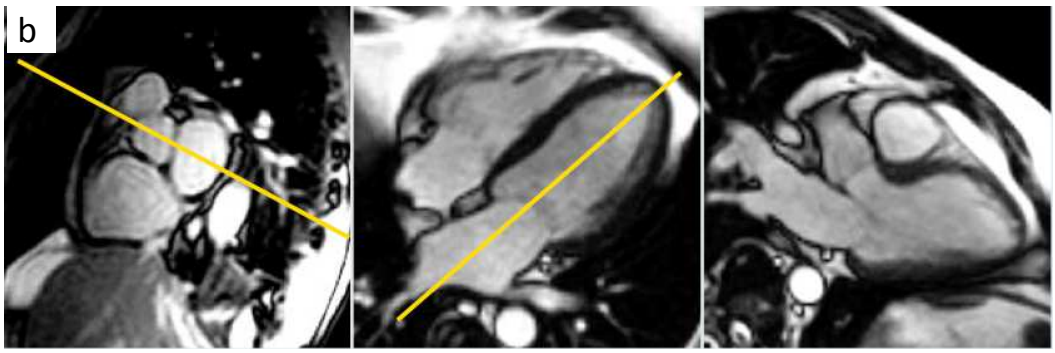
2. LV imaging I

CMR cine imaging will be performed using steady state free-precession (SSFP), breath-hold cines. The following sequences should be acquired:

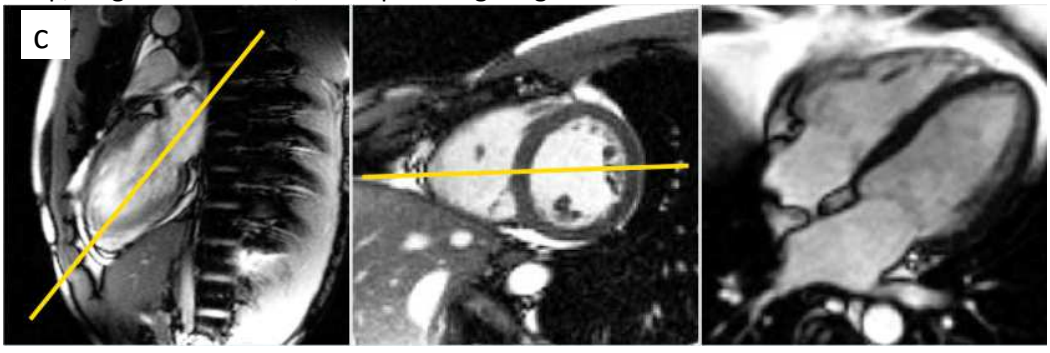
a) *2-chamber cine:* prescribe 1 slice, parallel to ventricular septum on a mid-ventricle short axis localiser (1f), bisect left ventricle through mitral valve and apex on four chamber localiser (1e), rotate FoV to avoid phase-wrap, single breath-hold, retrospective gating.



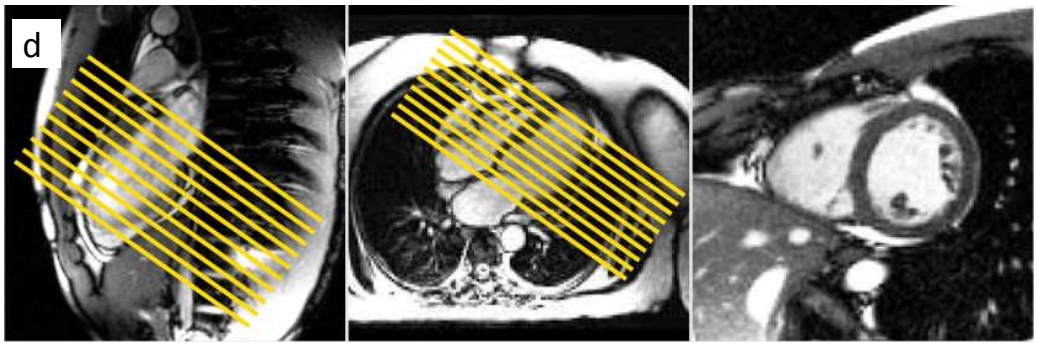
b) *3-chamber cine*: prescribe 1 slice, bisect the LVOT and posterolateral LV wall on the most basal short axis localiser (1f), and bisect the LV through the mitral valve and apex on a 4-chamber localiser (1e), rotate FoV to avoid phase-wrap, single breath-hold, retrospective gating.



c) *4-chamber cine*: prescribe 1 slice, bisect LV through the mitral valve and apex on 2-chamber localiser (3a), bisect left and right ventricles between anterior and posterior papillary muscle, on mid-ventricle short axis localiser (1f), rotate FoV to avoid phase-wrap, single breath-hold, retrospective gating.

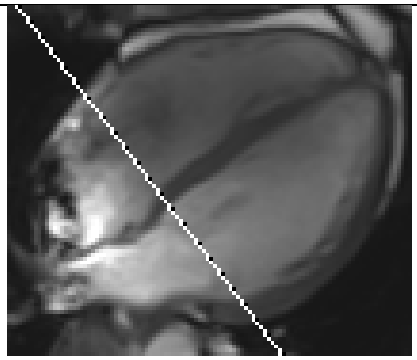
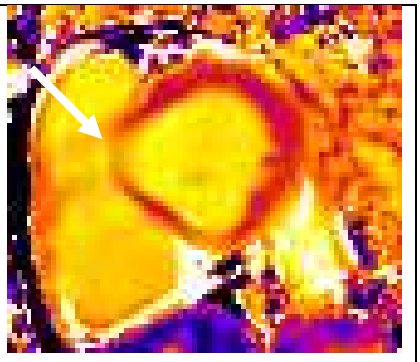
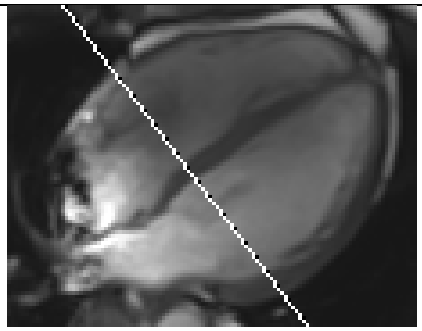
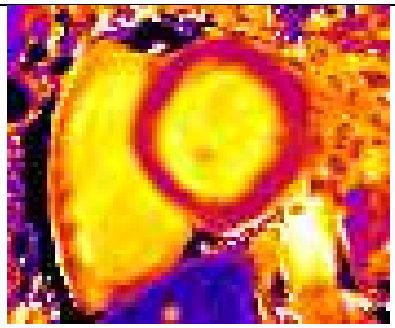
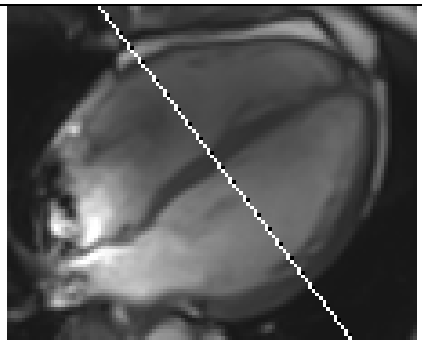
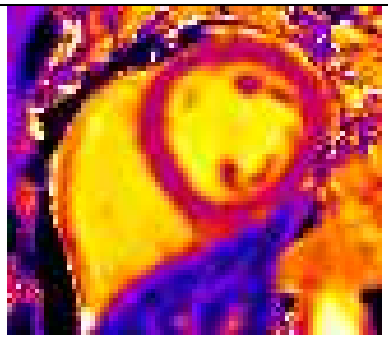


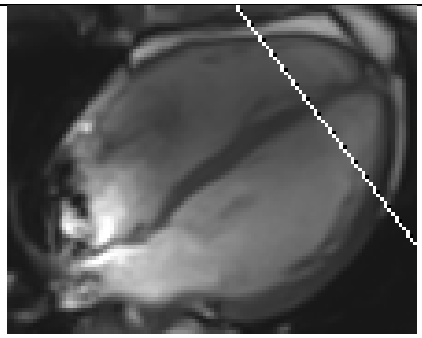
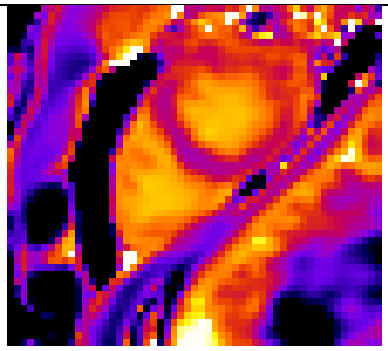
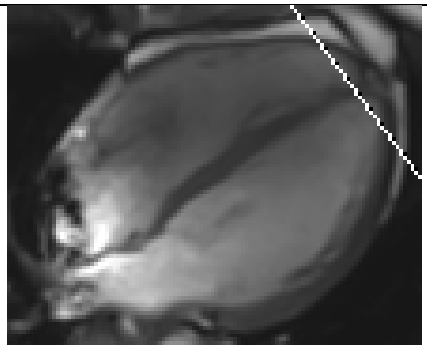
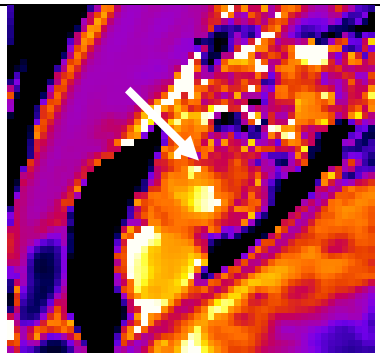
d) Short-axis cine stack: prescribe contiguous slices from 2-chamber cine diastolic view (2a) and 4-chamber cine (2c), perpendicular to long axis of LV, slices should be acquired with 8mm slice thickness and no gap, with enough slices selected to cover from mitral valve to apex. Rotate FoV to avoid phase-wrap, multiple breath-holds (depending on parallel imaging factor used), retrospective gating. Checking each slice for gating artefacts and repeat slice if required.



3. T1 mapping

For T1 mapping, a Modified Look Locker Inversion (MOLLI) sequence should be used (3-3-5 scheme, start 100ms, increment 80ms, and 160ms).
3 short axis T1 maps should be acquired which correspond to slice positions used during the short axis cine sequences. The three slices to be acquired are the **basal-LV** (the most basal slice with a full circle of myocardium that does not contain the LVOT in mid-diastole), **mid-LV** (two slices more apically from the basal LV slice, approximately half way from mitral valve to LV apex), and **apical-LV** (which is the most apical slice still containing left ventricle blood pool). This aims to minimise scan time whilst maximising usable data.
Selection of the basal slice is critical to enable image analysis. A complete ring of LV myocardium is necessary for accurate analysis. There should be no hint of LVOT visible on the septal wall to enable accurate T1 values to be calculated from this area (see below).

BASAL-LV SLICE Incomplete ring of myocardium (portion of LVOT is visible indicated by white arrow). This slice is too basal. **UNACCEPTABLE**		
BASAL-LV SLICE First (most basal) slice with complete ring of myocardium visible. **ACCEPTABLE**		
MID-LV SLICE Slice position chosen (from SA cine imaging) 2 slices more apical than selected basal-LV slice. **ACCEPTABLE**		

APICAL-LV SLICE Last (most apical) slice with myocardial ring and ventricle blood pool both visible. **ACCEPTABLE**		
APICAL-LV SLICE Neither myocardial ring or ventricle blood pool clearly visible (white arrow). This slice is too apical. **UNACCEPTABLE**		

4. T2 mapping

For T2 mapping, a T2 prepared TrueFISP sequence with a standard 3 different T2 preps (durations 0 ms, 25 ms and 55 ms) should be used. 3 short axis T2 maps should be acquired in the same slice positions as the T1 maps acquired in step 3.

Table of CMR sequences

	Number of acquisitions	Estimated time	Time post-contrast
Position subject within scanner, ensure high quality ECG signal		5 mins	
Sequence			
Localiser	1		
Site specific method of localisers to derive appropriate cardiac planes	1-5	1-3 mins	
4 chamber (horizontal long axis) cine	1	2 min	
2 chamber (vertical long axis) cine	1	2 min	
3 chamber cine	1	2 min	
LV short axis stack cine – 8mm slice thickness, no gap	14-15	6 mins	
T1 maps: MOLLI (basal, mid and apical ventricle slices)	3	3 mins	
T2 maps: TrueFISP (basal, mid and apical ventricle slices)	3	3 mins	