Acquisition and Artifacts

From CMR Pocket Guide First Edition 2013

Imaging
Poor Breath-Holders

Acceleration technique	Comment
• Reduce **number of slices** acquired per breath-hold	• Increases overall scan time
• Reduce **number of phases** for each breath-hold: - by reducing **acquisition matrix** (scan or phase percentage) - by reducing **FOV**	• Reduces SNR • Increases spatial resolution
• Increase **voxel size**	• Decreases spatial resolution
• Use **parallel imaging**	• Prone to artefacts
• Use **respiratory navigator**	• Increases overall scan time
• Acquire images in **inspiration**	• Varying slice position with each breath-hold
• Consider **general anaesthesia**	

Imaging
Patients With Arrhythmia

Technique	Comment
• **Heart rate** and/or **rhythm control** before scanning	• Use beta-blockers or other antiarrhythmic medication
• Use **Arrhythmia Rejection**	• Increases breath-hold time
• Use **Prospective triggering**	• Reduces SNR
• Use **Real-time imaging**	• Reduces temporal and spatial resolution as well as SNR

Anatomy, LV and RV Function Module

Anatomy Module

1. **T1w** axial black blood imaging (diaphragm to above aortic arch)

   Free breathing or breath-hold (high resolution)

   Slice thickness: 8-10mm (contiguous)

LV function Module

1. **Cine SSFP** pulse sequence (parallel imaging as required)
2. **2-ch, 4-ch, SA** and **LVOT** (2 orthogonal) cine images
3. **SA cine stack** (from mitral valve to apex)

   Slice thickness 6-10mm

   Inter-slice gap 0-4mm to equal 10mm
4. **Temporal resolution** ≤ 45ms

RV function Module

1. **Cine SSFP** pulse sequence (parallel imaging as required)
2. **Trans-axial cine stack** (from diaphragm to pulmonary bifurcation) or **SA cine stack as for LV module**

   Slice thickness 6-8mm, inter-slice gap 0mm
3. **Temporal resolution** ≤45ms

Tips & Tricks (Anatomy Module)

1. **Scan in diastole** to reduce motion artefacts

Tips & Tricks (LV / RV Function Module)

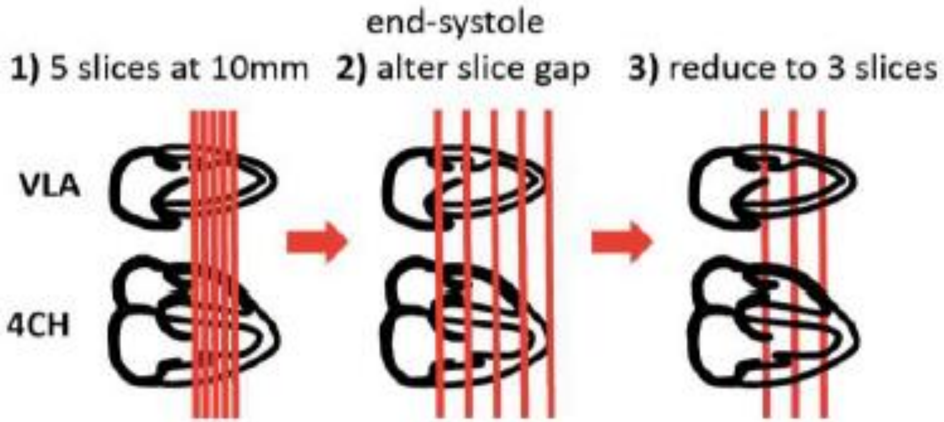
1. **To reduce breath-hold times use acceleration techniques**
2. **Contouring:**
   - In a healthy heart there is usually one less slice to contour in end-systole at the base of the heart (longitudinal LV shortening). Correlate SA to long axis view if available to identify mitral valve plane.
   - Use the movie function of the analysis software for correct alignments
   - Different methods have been proposed to deal with trabeculation and papillary muscles. Use a consistent approach and the correct normal values for the chosen method.
3. **RV volumes** are more reproducible when calculated from an axial imaging plane.

Perfusion Module

1. **Scout imaging** as per LV function module
2. **Saturation-recovery gradient echo pulse sequence** (GRE, gradient echo-echo planar (GRE-EPI), or SSFP readout)
3. **Parallel imaging** (twofold acceleration, if available)
4. **SA view imaging** (at least **three slices** per heartbeat);
   - **Slice thickness 8-10mm**
   - **In-plane resolution < 2.5mm**
   - Ideally obtain data **every heart beat**
5. **Contrast (0.05 - 0.1mmol/kg, rate: 3 - 7ml/s)** followed by 30ml saline flush (3-7ml/s)
6. **Breath-hold** starts during early phases of contrast infusion **before contrast reaches the LV cavity**
7. Image for **>40 heartbeats**

Tips & Tricks

1. "Dummy" scan to check
   - Correct slice positioning
   - Artefacts
   - ECG triggering at every single heartbeat
2. Switch to alternate heartbeat acquisition if HR is too high or reduce number of slices
3. **Field of View**
   - As small as possible
   - Parallel to the anterior chest wall
4. Use **"3 out of 5" technique to position slices**



Early and Late Gd Enhancement Module

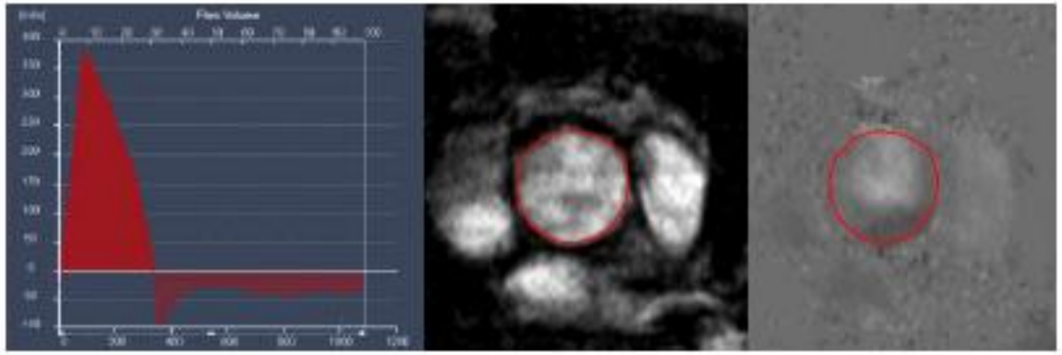
1. **2D-segmented IR GRE imaging during diastolic rest period**
2. **4-ch, 3-ch, 2-ch, SA** images
3. **In-plane resolution : <2mm**
4. **EGE**: image **1-3min** after contrast, **TI >400ms**
5. **LGE**: **≥10min** after **Gd injection (0.1 – 0.2mmol /kg)**
   - The delay may be shorter if lower Gd doses are used
   - The delay may be increased in a low output state
6. **TI set to null normal myocardium:**
   - TI scout or Look Locker sequence
   - Phase-sensitive sequence with fixed TI as alternative
7. **Readout**:
   - Usually every other heartbeat
   - Every heartbeat in the setting of bradycardia
   - Every third heartbeat in the setting of tachycardia

Tips & Tricks

1. **Scan in mid- or late-diastole** to minimize motion artefacts
2. Use **saturation bands** across the spinal column and the anterior chest wall to reduce ghosting artefacts
3. **Late enhancement on images:**
   - Use **"Phase Swap"** (changing the phase encoding direction) to confirm pathology/detect artefact
   - Always consider a different plane cross-cutting through the enhanced area
4. **Increase TI times by 10 – 15ms every couple of minutes**, because the correct TI for "nulling" of normal myocardium slowly changes over time
5. **To reduce breath-hold times use acceleration techniques**
6. Acquiring the images during every second or third heartbeat can help if there are problems with arrhythmia
7. Consider infiltrative disease (**amyloidosis)** if normal myocardium is hard to null despite correct technique

Phase Contrast Velocity Encoded Module

1. Choose the **appropriate imaging plane perpendicular to direction of flow**
2. **Consider orthogonal acquisition** to define peak velocity
3. Set required **direction of flow**
4. Choose **appropriate VENC:**
   - **Normal systemic flow: 150cm/s**
   - **Normal right-sided flow: 100cm/s**
   - Adjust in pathological situations (severe valve stenosis > 400cm/s)
5. Choose **adequate spatial resolution**
   - **minimum of 4-6 pixels per vessel diameter**



Volume time curve from flow velocity encoding through the ascending aorta in a patient with severe aortic regurgitation

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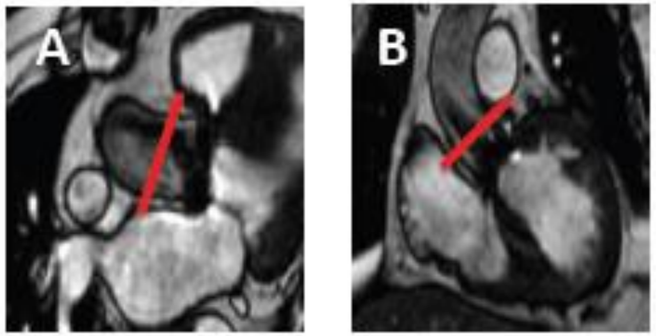
Phase Contrast
Velocity Encoded Module

Tips & Tricks

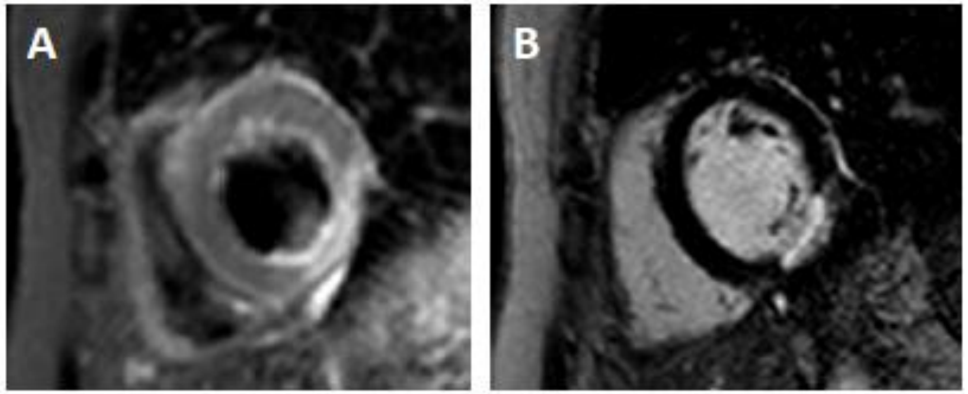
1. **VENC settings:**
   - Optimal within 25% of the true peak velocity
     - Too low: flow aliasing
     - Too high: underestimating velocity
   - Correct direction of flow (R-L, F-H)
   - Image plane distal from valve leaflet tips
   - Flow assessment: perpendicular to the vessel
   - Max. velocity assessment: perpendicular to the jet
2. **Avoid underestimation of velocities. Check:**
   - Adequate temporal resolution (phases)
     - Free-breathing acquisition: 30 phases
     - Breath-hold acquisition: 20-25 phases
3. Rotate FOV - orthogonal to the direction of flow
4. Slice thickness: <7mm



Sagittal (A) and coronal (B) slice positioning for aortic stenosis

Edema Module

1. **T2w imaging**
2. **Prior to contrast administration**
3 **Slice thickness:**
   - ≥ 10mm to ensure good SNR
   - **Slice thickness** of the dark blood pre-pulse should be greater than the longitudinal shortening of the LV
4. **Mid-diastolic readout**
5. Use **body coil** or alternatively **functional surface coil** intensity correction algorithms to correct for coli-related signal differences
6. Slow flow artefacts may cause high signal at endocardial border



Myocardial infarction with inferior edema on T2w images (A) and LGE (B)

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Angiography Module

1. Prepare **infusion pump** with contrast agent and flush

   Gd dose: 0.1–0.2mmol/kg

2. Define **3D target region** (usually a very large volume)
3. Define required **timing of acquisition** (arterial / venous)
4. Determine best **timing parameters** for data acquisition (pre-bolus or automatic triggering)
5. Perform a **dummy** acquisition
6. Perform **acquisition** with contrast administration

Tips & Tricks

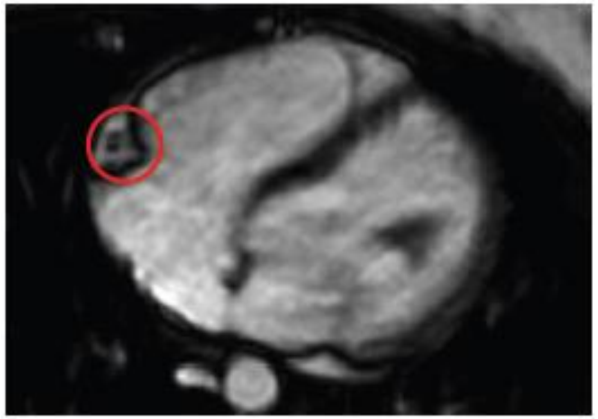
1. Optimize timing technique:
   - Ensure that the centre of k space is acquired at the same time as the bolus of contrast arrives in the vessel of interest
2. Ensure that the FOV covers the whole area of interest including any collateral or aberrant vessels

Coronary Artery Imaging Module

1. Determine coronary **rest period**
   - Acquire **HLA** with **high temporal resolution** (50 phases)
2. **Navigator-gated, free-breathing 3D pulse sequence:**
   - **Trans-axial slices** (from the proximal main pulmonary artery to the middle of the right atrium; entire cardiac coverage if desired).
   - **Slice thickness: 1-1.5 mm**
   - **Spatial resolution in-plane: 1.0** mm or less
   - **Slices**: typically **50 – 80**
   - **Adjust trigger** delay and **acquisition window** according to observed coronary artery rest period
   - **Parallel acquisition** preferred
   - Navigator placed over the right hemi-diaphragm
3. **Optional:**
   - Consider contrast to increase vessel conspicuity
   - Breath-hold techniques if poor image quality or if navigators are unavailable or are of poor quality
   - T2-prepared sequence may be useful

Tips & Tricks

1. **Problems identifying coronary rest period:**
   - repeat high temporal resolution 4-ch scan at the **correct HR**
   - **Consider cine scan during free-breathing** if HR changes significantly during breath-hold
   - **Check during systole** with a tight window (<50 ms)
   - As a compromise, scan **with longest trigger delay and a tight window** (<50 ms)
2. Coronary rest period may differ between LCA and RCA
3. **High HR** (≥ 90bpm): Use shortest scan window possible to minimize blurring
4. **Keep scan times to a sensible limit**
5. Higher spatial resolution equals longer scan times



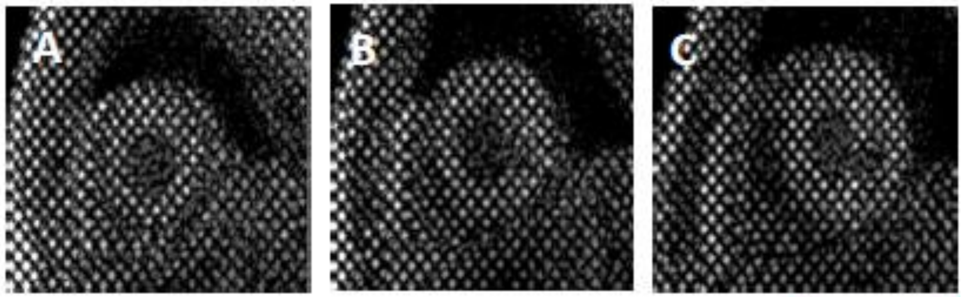
4-ch view showing the RCA in diastole

Tagging Module

1. **Scout imaging** as per LV function module
2. Choose **line tagging or grid tagging** pattern
3. Choose **slice orientation from cine study**
4. Acquire data in **breath-hold**

Tips & Tricks

1. Reference modality for evaluating multidimensional strain
2. **Temporal resolution about 15-20ms**
3. **Acceleration techniques** used to shorten the breath-hold time are the same as for cine imaging
4. Use a low **flip angle** to reduce tissue saturation and prolong the tagging pattern throughout the cardiac cycle
5. Mid-myocardial circumferential strain from SA is most reproducible



Apical (A), mid-ventricular (B) and basal (C) grid-tagging

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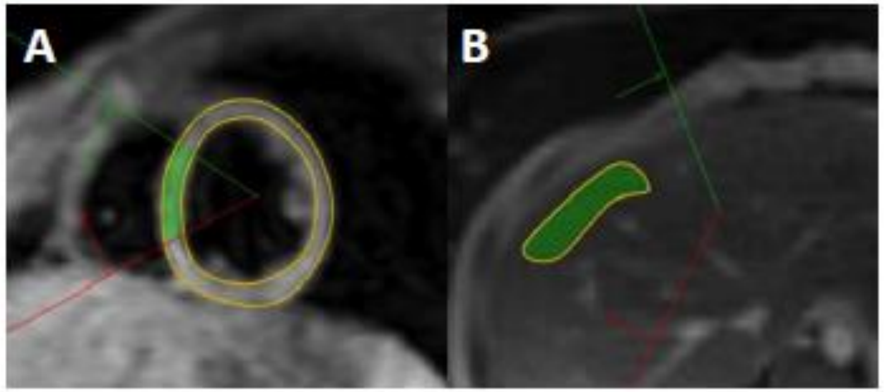
T2* Module

1. T2* quantitation is a standard CMR technique for **disease monitoring** and **guiding chelation therapy** in cardiac iron-loading conditions
2. **Single breath-hold, multi-echo, T2* sequence** (gradient echo or modified black blood sequence)
3. **Single mid-ventricular slice**
4. **Single transaxial slice of the liver**



ROIs are placed in the ventricular septum (A) and the liver (B)

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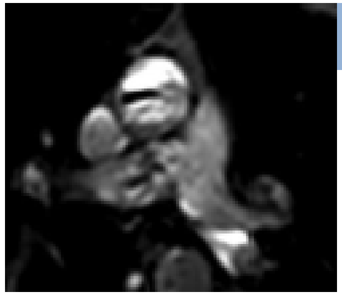
Tips & Tricks

1. **Ensure good** patient **breath-holding for the heart and the liver scans** by coaching as the scan duration is long
2. **Make sure the septum is of good image quality** as this is where quantification is most reproducible
3. Position the transverse liver slice correctly:
   - Avoid large hepatic vessels for correct T2* measurement in the liver tissue

Artefacts

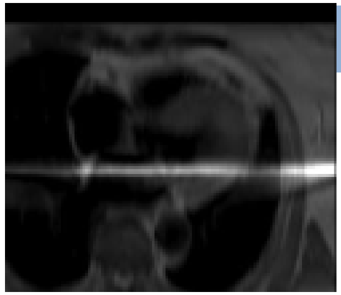
Ghosting artefact from motion (respiratory)

- Strict breath-holding plus acceleration techniques
- Respiratory gating or navigator echoes
- Swap phase and and frequency direction
- Use selective tissue saturation bands to suppress the signal from the anterior abdominal wall



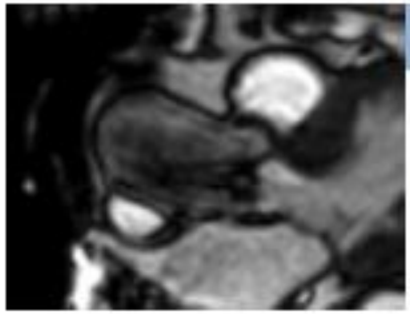
Ghosting artefact from motion (pulsatile flow)

- Use ECG triggering / gating
- Use flow compensation (gradient moment nulling, gradient motion rephasing)
- Use selective tissue saturation bands to suppress the blood signal
- Swap phase and frequency direction



Wrapping artefact (fold-over, back-folding)

- Increase FOV
- Add phase encoding (phase-oversampling, foldover suppression, no phase wrap)
- Swap phase and frequency direction
- Use selective tissue saturation bands
- Use a surface coil



Flow-related signal loss and flow jets

- Reduce echo time
- Use flow compensation
- Use bSSFP acquisition

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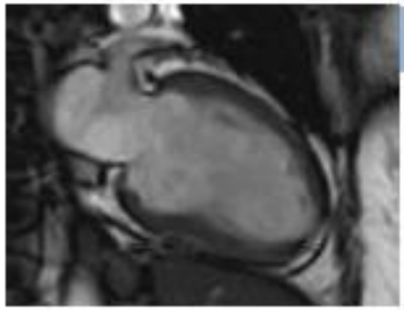
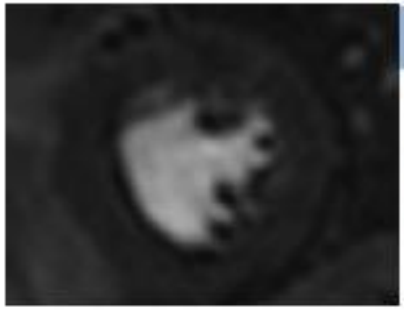
Artefacts



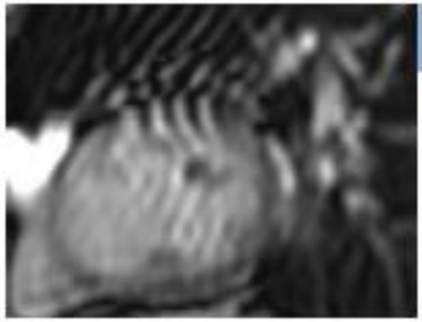
Chemical shift artefact

- Compare with other images as they are sequence dependent



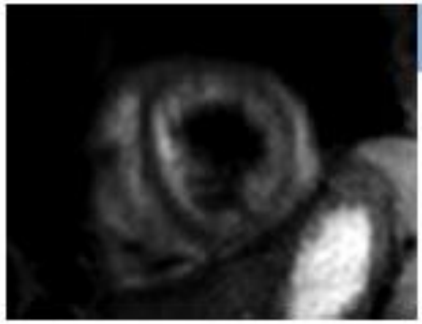
Dark rim artefact

- Often seen in perfusion imaging
- Reduce contrast dose/infusion speed
- Increase in-plane spatial resolution



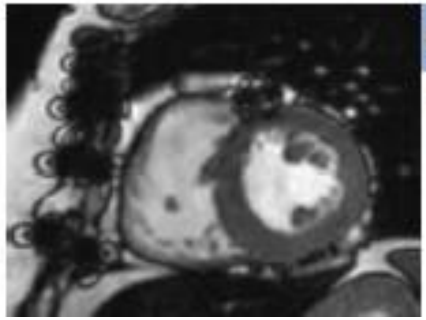
Radiofrequency interference artefact

- Check for sources of interference and eliminate (e.g. make sure scan room door is closed)



Slow flow artefact

- Usually in T2w images
- Increase black blood pre-pulse slice thickness



Metallic artefact

- Usually less prominent on spin echo images than gradient echo images