MRI Cardiac

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Indications

1. Assessment of chamber dimensions, mass and function
2. Assessment of congenital heart disease
3. Diagnosis and evaluation of cardiomyopathies – e.g. sarcoid, amyloid, hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy
4. Evaluation of pericardial disease
5. Evaluation of:
   - myocardial viability
   - extent of myocardial necrosis/fibrosis
   - inducible ischaemia to guide revascularization strategies
6. Imaging and quantification of flow:
   (a) to assess valvular disease – stenosis and incompetence
   (b) to assess shunts – ASD/VSD/PDA/PAPVR
   (c) to assess coarctation of the aorta.

Patient preparations

- Fast for at least 4 hours.
- Avoid caffeine, tea, smoking 24 hours prior examination
- Withold beta blocker day prior procedure (in perfusion study)
- Standard MRI safety screening.
- Allergy – covered.
- Patient able to lie flat.
- Patient able to breath hold.
- Placement of MRI-compatible ECG electrodes for gating of sequences.
- Insert IV cannula at antecubital fossa;
  - 1 for gadolinium
  - 1 for adenosine (in perfusion study)
- Contrast – Gadolinium (0.2mmol/kg)

Techniques

Duration of scan 1-2 hours, repeated hold breath.

Cardiac coil

Machine 3T and 1.5T - With its higher SNR (signal-to-noise ratio) and contrast, leading to better quality, 3T delivers better images and superior clarity along with better parallel and faster imaging.

ECG and Respiratory gating

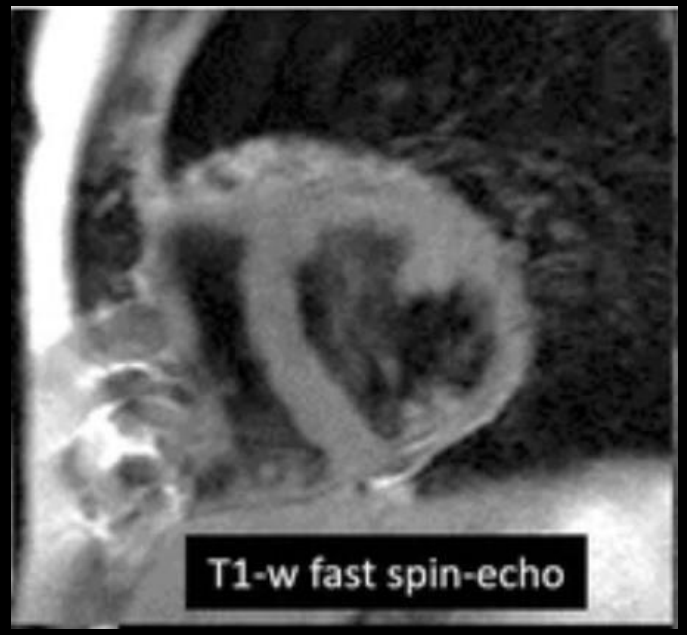
- ECG gating – retrospective or prospective gating

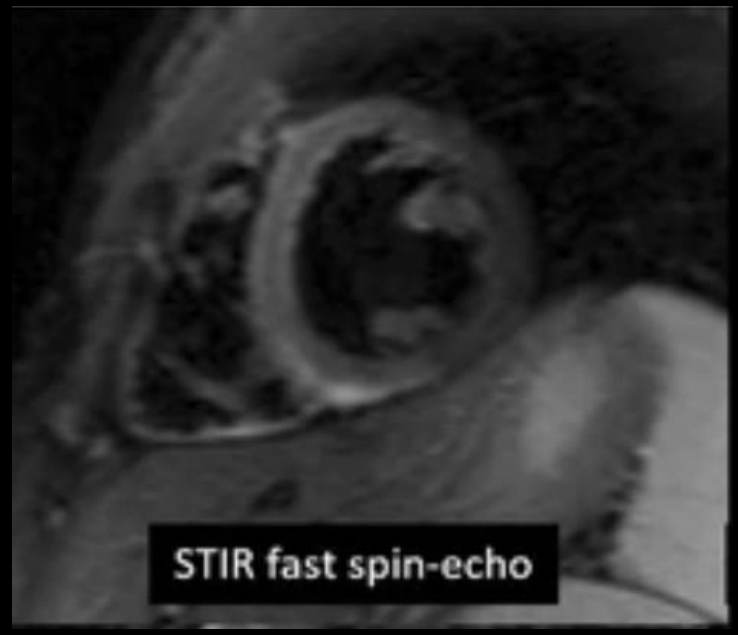
Sequence

- Dark Blood Imaging
- Bright Blood Imaging
- Inversion recovery
- Phase contrast imaging
- Contrast enhanced
    - Perfusion (early gadolinium)
    - Viability (late gadolinium)

Dark Blood Imaging

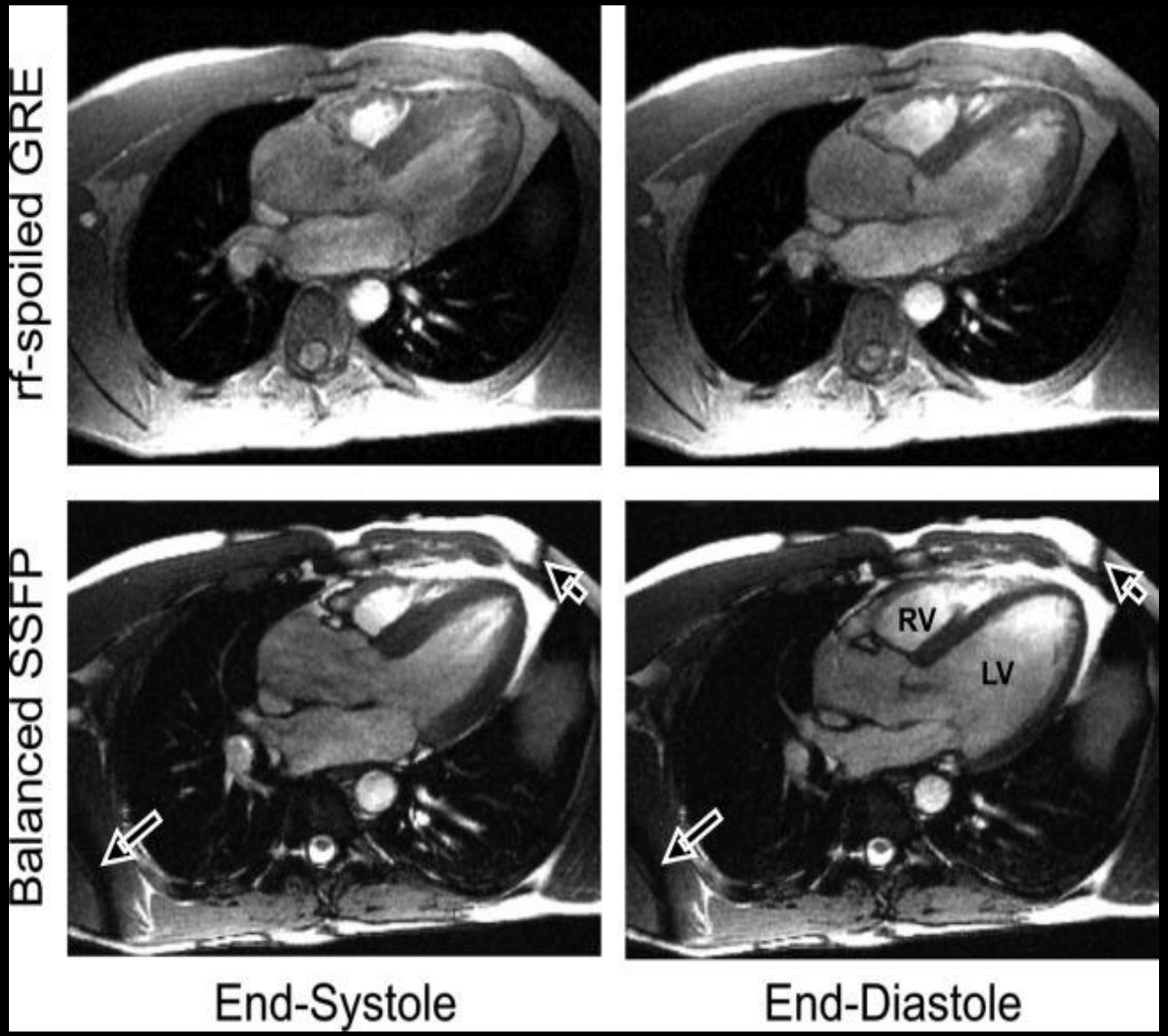
- Vascular imaging technique in which the signal from flowing blood is suppressed, rendering it “black”. Purpose mainly to is mainly used to delineate anatomic structures.
- Fast/Turbo Spin Echo (FSE/TSE) technique in cardiac imaging . It enable rapid imaging, which minimizes the effects of respiratory and cardiac motion.
- Sequence T1, T2-weighted short-tau inversion recovery (T2-STIR)





Bright Blood Imaging

- Bright blood imaging describes the high signal intensity of fast-flowing blood and is typically used to evaluate cardiac function.
- Main pulse sequences used for bright blood imaging include gradient echo (GRE) and steady-state free precession (SSFP).
- SSFP are similar but incorporate a short TR with gradient refocusing that is less vulnerable to T2* effects compared with standard GRE
- SSFP sequences can be executed rapidly while providing greater contrast-to-noise and signal-to-noise ratios than GRE sequences

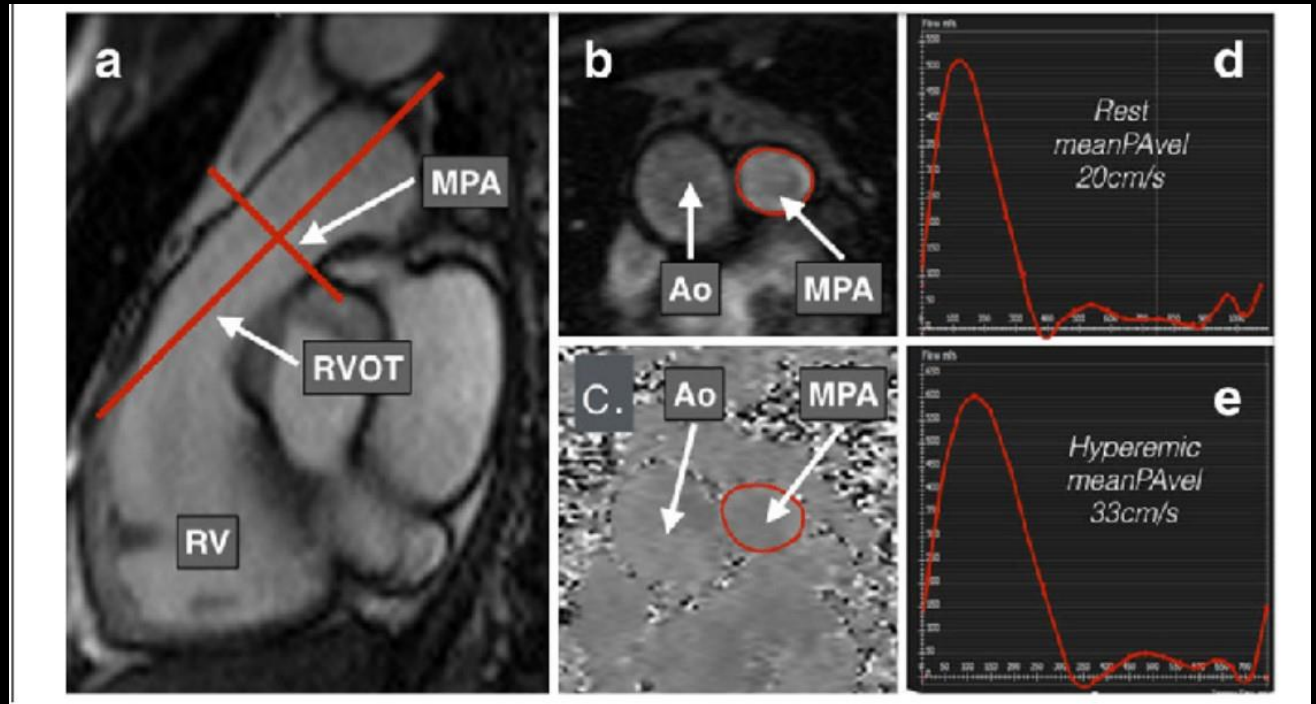

rf-spoiled GRE
Balanced SSFP
RV
LV
End-Systole
End-Diastole

Inversion Recovery

- Inversion recovery (IR) consists of applying additional 180° pulses.
- Double or triple IR can be used to further null signal from blood for black blood imaging, thereby improving contrast between the cardiac tissues and blood pool.

Phase Contrast

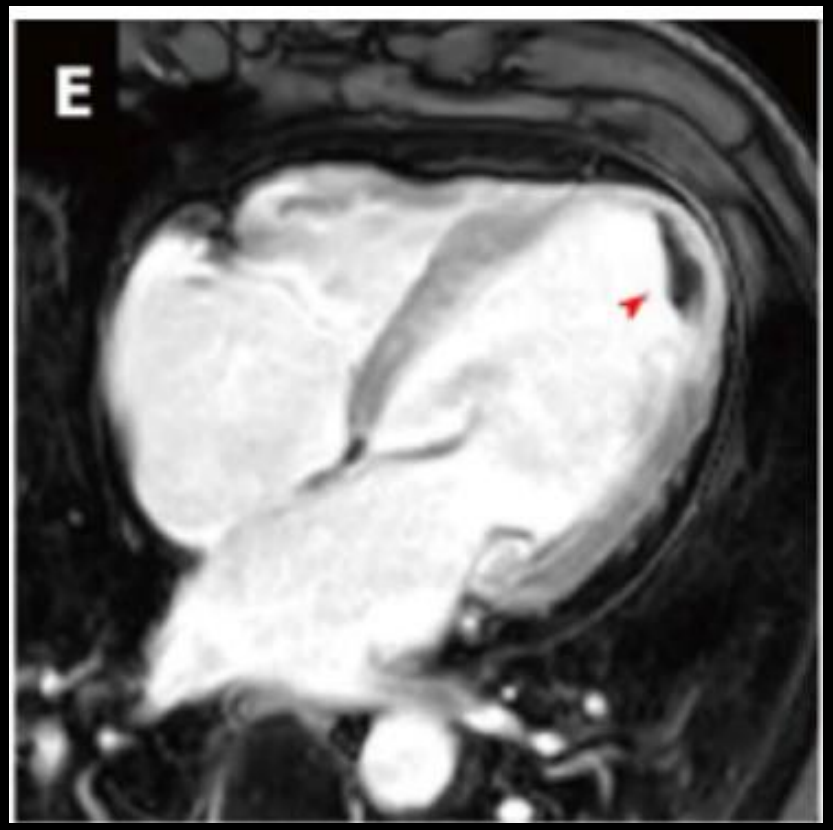
- Phase-contrast imaging with velocity-encoded imaging is a non contrast technique that is frequently used to estimate pulmonary blood flow and systemic blood flow to calculate the pulmonary-to-systemic flow ratio to determine shunt fraction.
- Can also be used to calculate regurgitant fractions and valve area using the continuity equation.



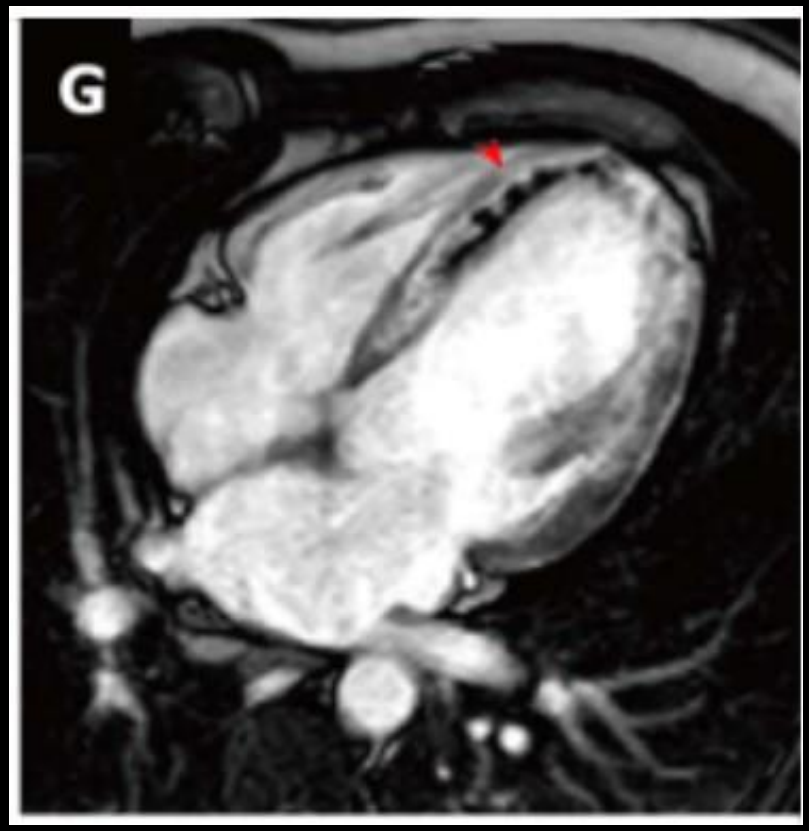
Reference sequences for main pulmonary arterial (MPA) phase contrast imaging were two double-oblique orthogonal views along the main axis of the pulmonary trunk (a). The endocardial border of the MPA was manually outlined at all 20 reconstructed cardiac phases (b and c) permitting flow velocity profiles to be generated at rest and hyperemia (d and e respectively: flow velocity in ml/s on y axis and time in milliseconds on x axis). MeanPAvel was calculated as the average blood flow velocity across all cardiac phases. Ao = aorta, RV = right ventricle, RVOT = right ventricular outflow tract

Contrast Enhanced

- Early Gadolinium Enhancement:
- 3-5 minutes.
- reference for assessment of capillary leakage and microcirculatory disturbance



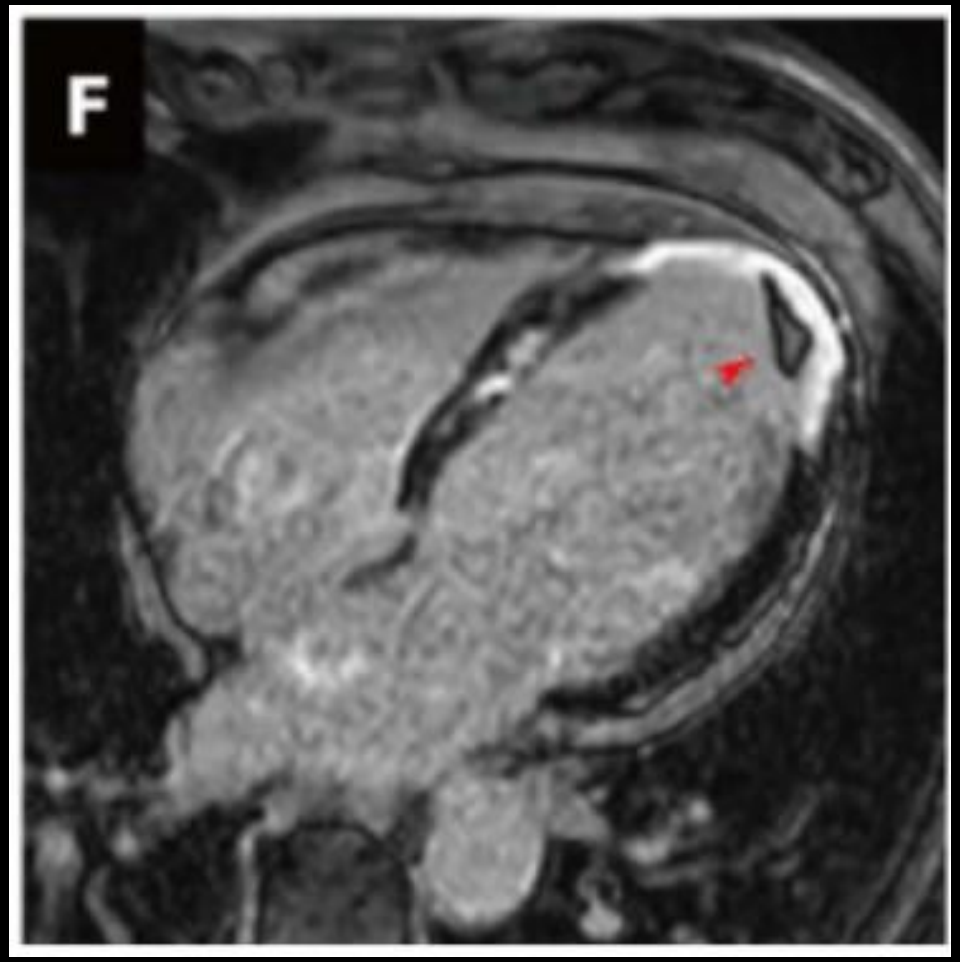
Aapical thrombus appearing black (highlighted by red arrow)



An extensive acute antero-apical infarction with a core of microvascular obstruction visible within the hyperenhancement on EGE (red arrow)

Late Gadolinium Enhancement

- After 10 minutes contrast given.
- Identifies areas of myocardial infarct, fibrosis or infiltration
- Differentiate between ischaemic and non-ischaemic pathology
- Gadolinum – confines to extracellular & interstitial space. It does not penetrate intact myocardial cell membranes.
- Images 10 min following administration of gadolinium in the standard cardiac planes are taken. Infarct region will be enhanced.



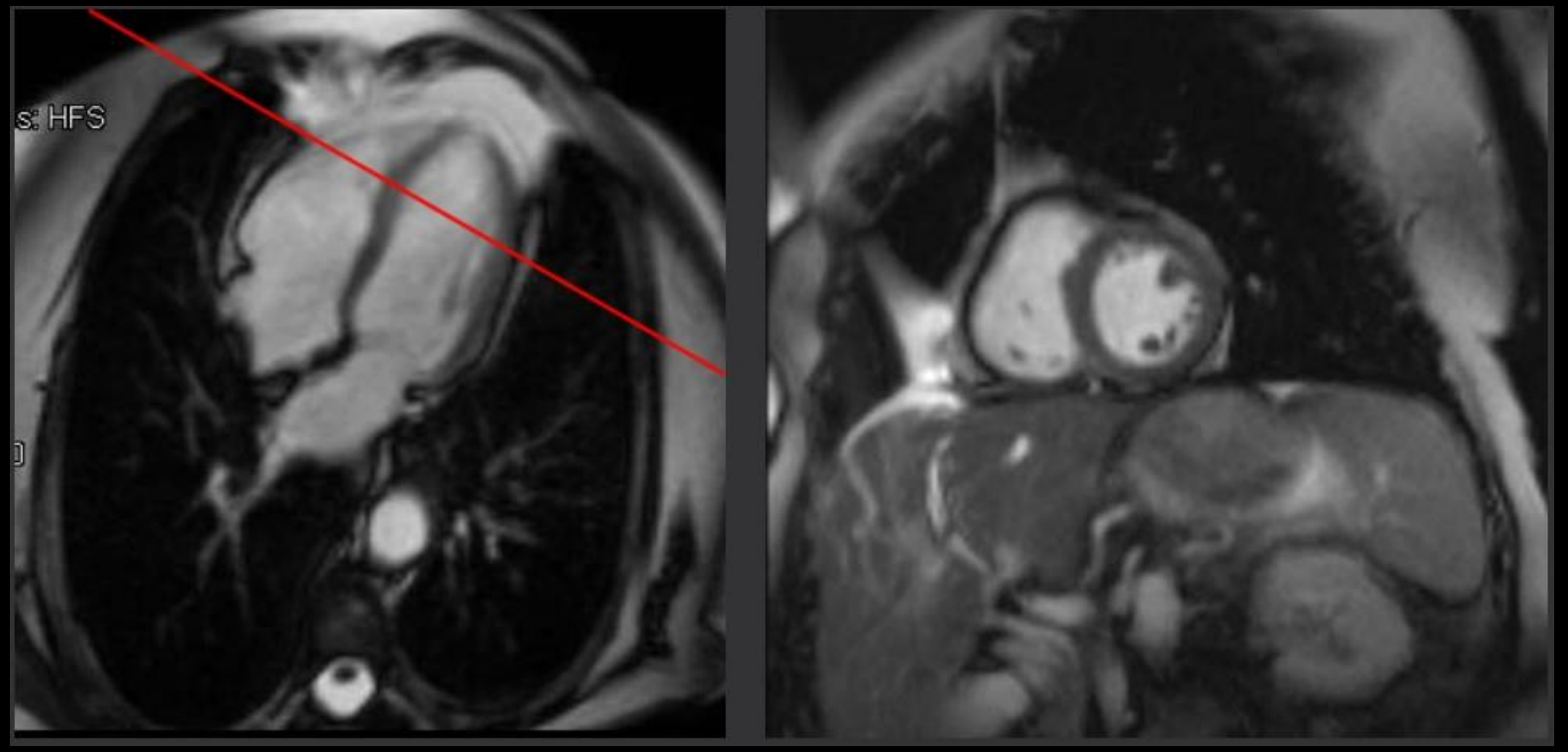
LGE showing full thickness apical infarction

Cardiac Axes

- Short axis
- Long axis
  - 2 chamber view
  - 3 chamber view
  - 4 chamber view
  - 5 chamber view

Short axis view

- The short axis view shows cross-sections of the left and right ventricle that are useful for volumetric measurements.
- The short axis view is chosen such that a series of slices are perpendicular to the long axis of the LV.

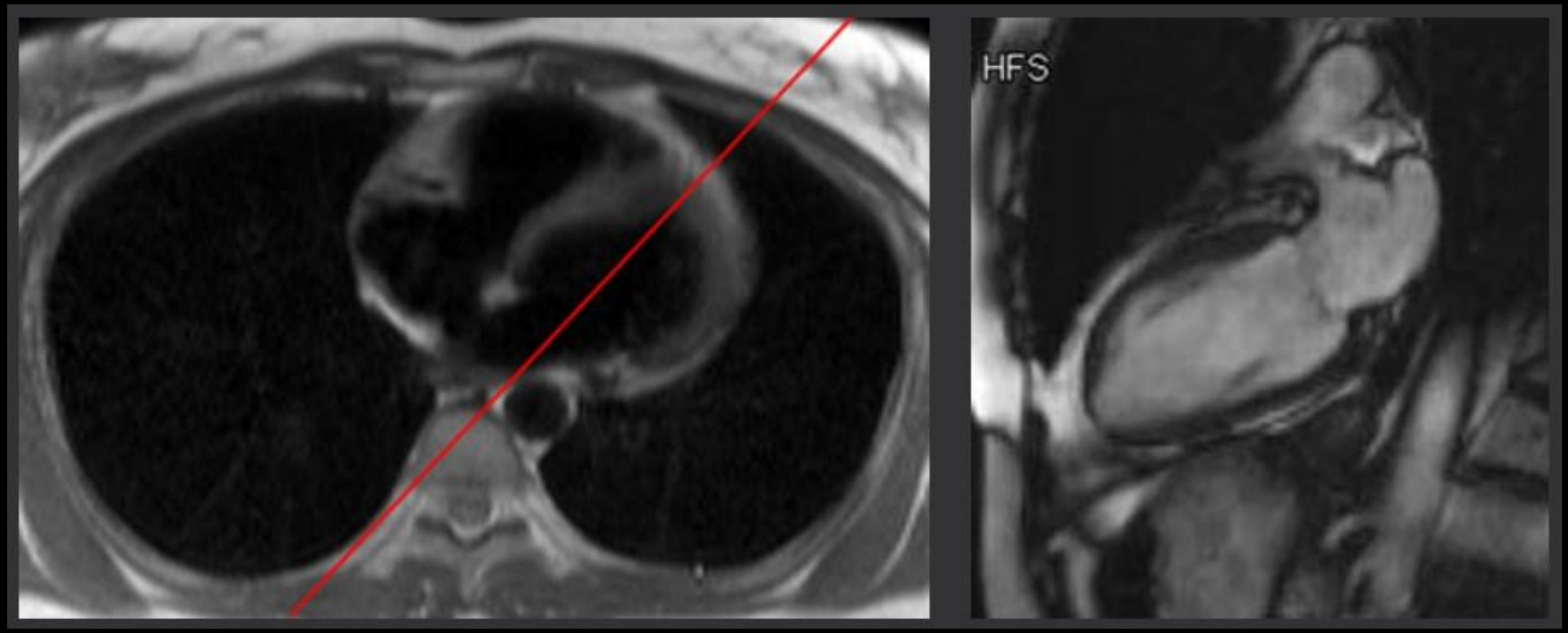


The red line in the figure on the left represents the plane through which the short axis image on the right is obtained.

https://introductiontoradiology.net/courses/rad/CardiacMR/Anatomy/Short.html

2 Chamber/Vertical long axis view

- Vertical long axis is for evaluating the anterior, inferior walls and apex of the left ventricle

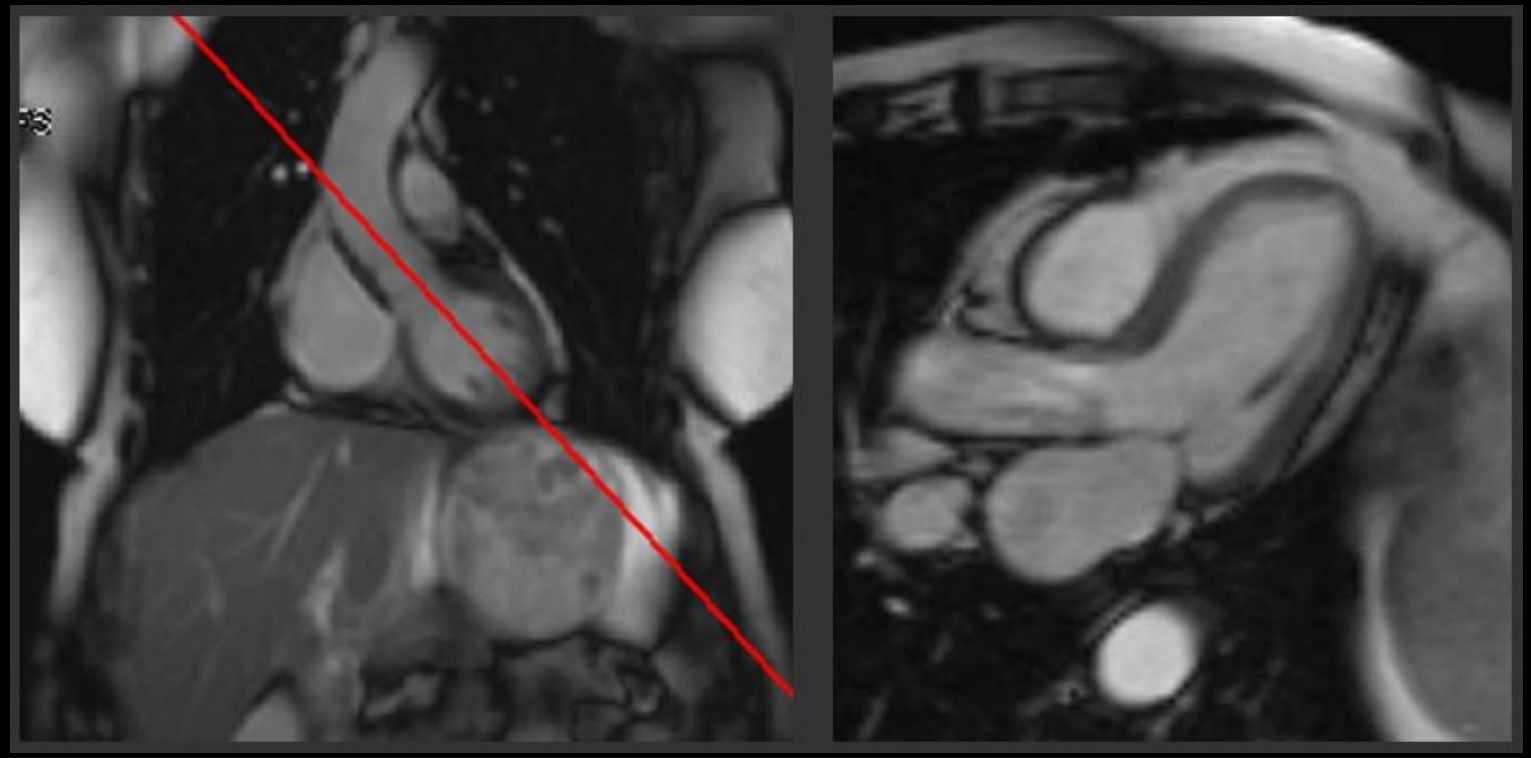


The red line in the figure on the left represents the plane through which the vertical long axis image on the right is obtained.

https://introductiontoradiology.net/courses/rad/CardiacMR/Anatomy/Vertical.html

3 chamber view/LVOT

- The three chamber view shows the aortic root and aortic valve, left ventricular outflow tract, mitral valve, and the anteroseptal and inferolateral walls of the left ventricle.
- A true coronal image is chosen through the aortic root and a plane is chosen that is perpendicular to the aortic valve plane.

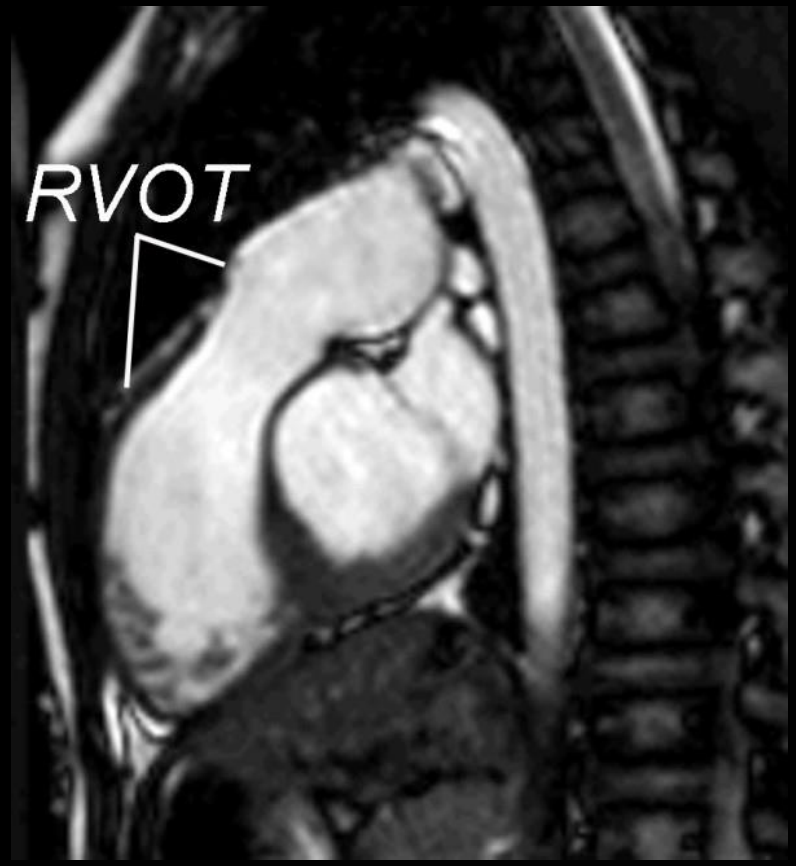


The red line in the figure on the left represents the plane through which the three chamber image on the right is obtained.

https://introductiontoradiology.net/courses/rad/CardiacMR/Anatomy/Three.html

RVOT

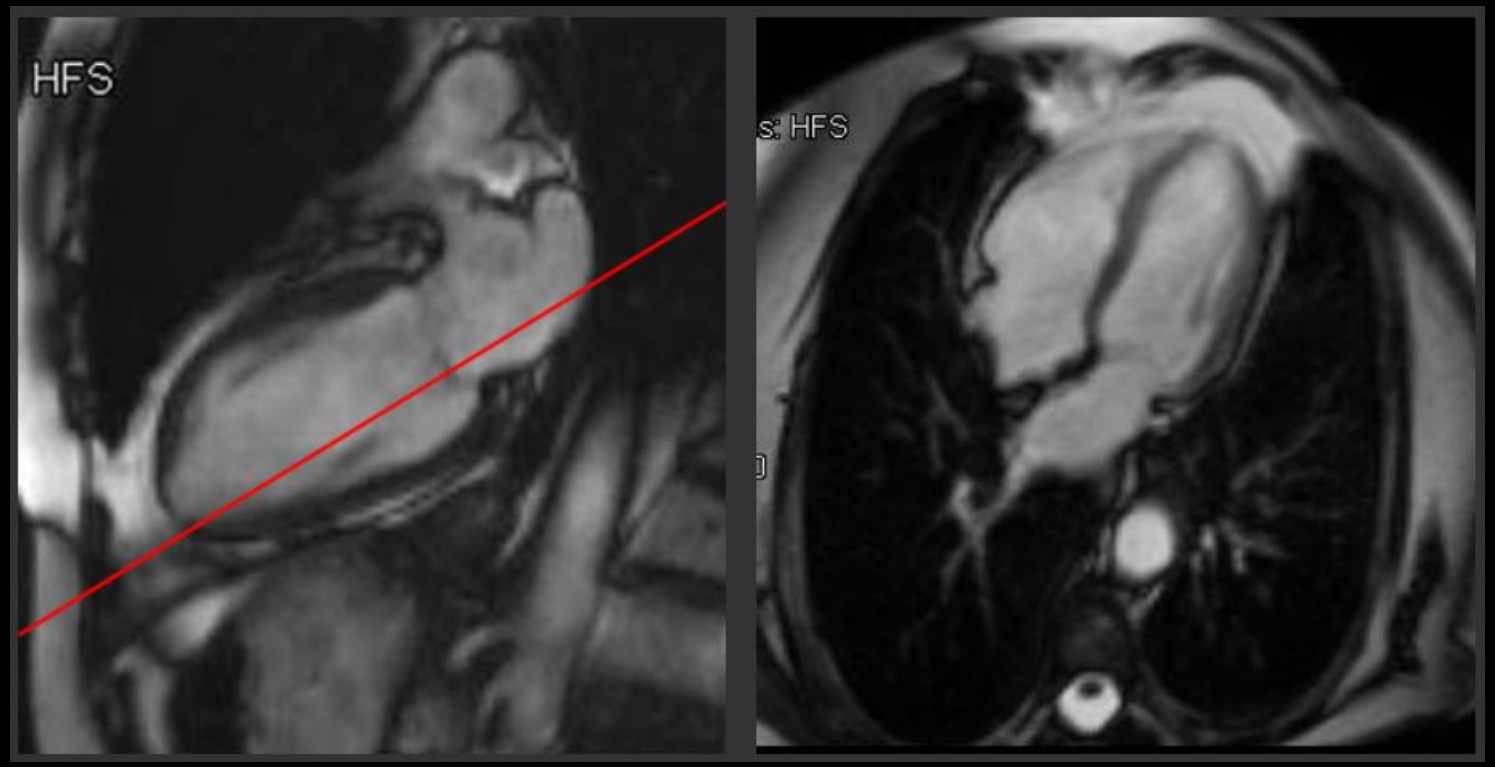
- Visualized the right ventricle, right ventricular outflow tract and pulmonary artery



https://www.researchgate.net/figure/Evaluation-of-the-right-ventricular-outflow-tract-RVOT-long-axis-by-ECG-gated-cine-SSFP_fig13_49770934

4 chamber/Horizontal long axis view

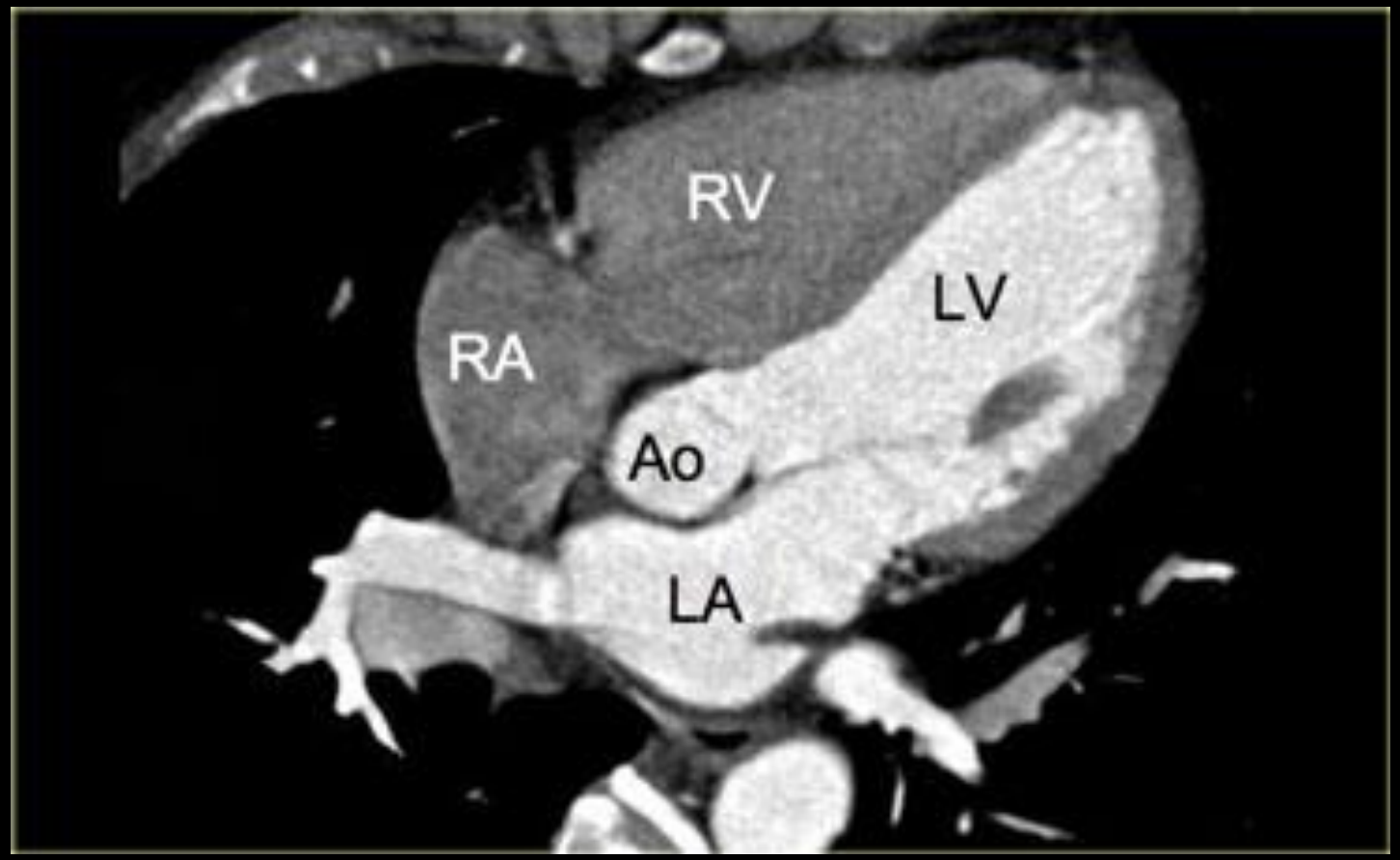
- Best for evaluating the septal and lateral walls and apex of the left ventricle, the right ventricular free wall, and chamber size.
- The mitral and tricuspid valves are also well visualized in this plane. A perpendicular plane to the vertical long axis image is chosen which intersects the lower third of the mitral valve and the LV apex



The red line in the figure on the left represents the plane through which the horizontal long axis image on the right is obtained.

https://introductiontoradiology.net/courses/rad/CardiacMR/Anatomy/Horizontal.html

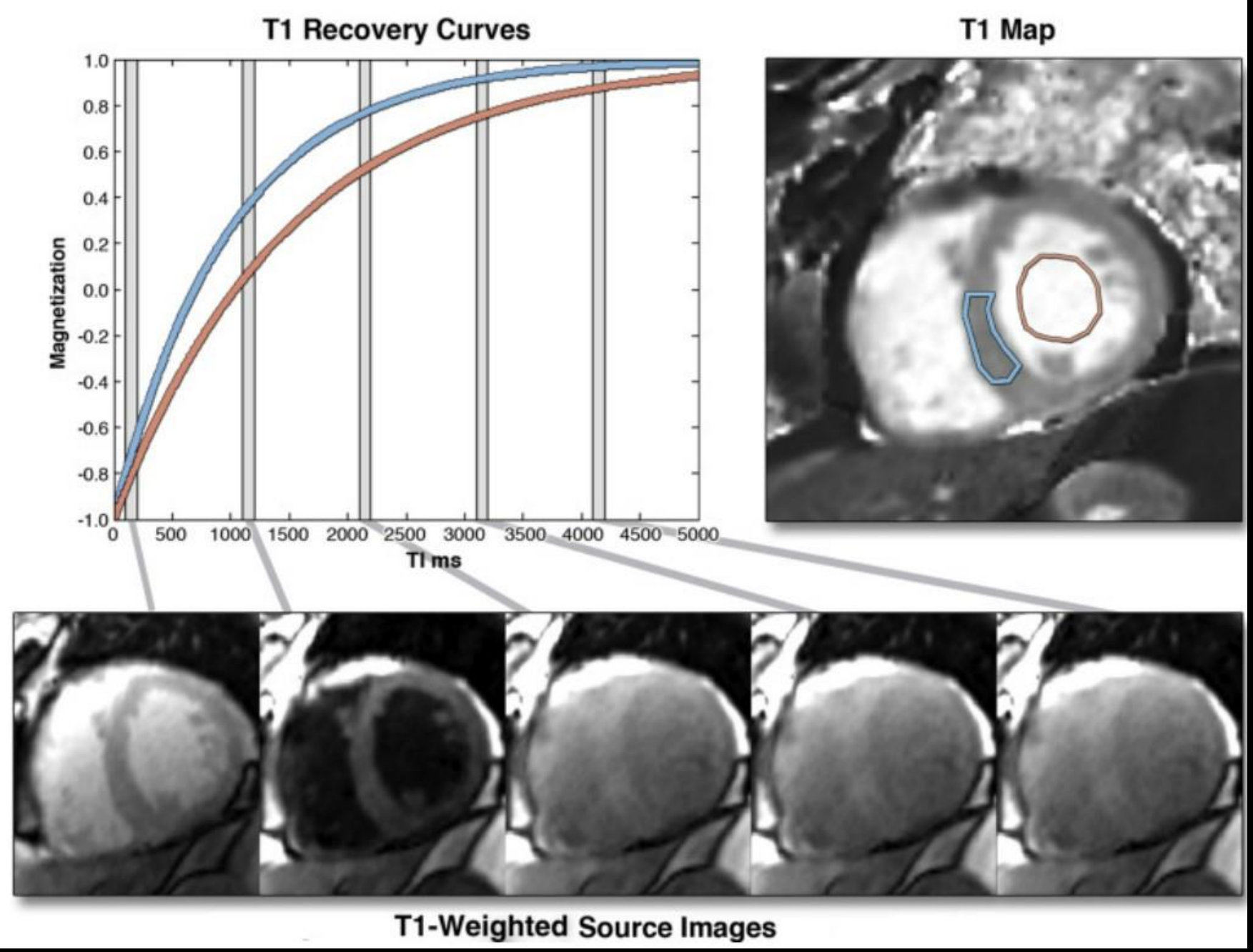
5 chamber view



https://radiologyassistant.nl/cardiovascular/anatomy/cardiac-anatomy

Imaging Techniques for T1 Mapping

- The general principle for T1 mapping is to acquire multiple images with different T1 weightings and to fit the signal intensities of the images to the equation for T1 relaxation (Figure 1).
- For T1 measurements, the equilibrium magnetization is either inverted or nulled with RF pulses, and T1-weighted images are acquired at different times after the inversion (TI) or time after saturation pulse.
- In both cases, the data can be fit to an equation of the form $A-B\cdot\exp(-t/T1)$, where A and B are fitting parameters related to the equilibrium magnetization and type of preparation, t is the time after the preparation (i.e., either TI or time after saturation pulse), and T1 is the T1 relaxation time.
- T1 times can be determined for regions of interest, myocardial segments, or at each pixel location to form a T1 map; in the latter case, pixel intensities in the images correspond to the fitted T1 values (Figure 2).



The graph on the left shows 2 inversion recovery curves for a septal region of interest (blue) and the blood pool, generated from images, shown in the bottom row, taken at different times after an inversion pulse at time t = 0. Similar inversion recovery curves can be generated for each pixel location if the images are all acquired during a breath-hold and for the same cardiac phase. The T1 for each pixel location can be used to generate a T1 map, as shown in the top-right image. T1 maps represent arguably the most succinct and informative summary of the spatial and temporal changes during an inversion recovery.

Figure 1 - Magnetization Inversion Recovery for T1 Mapping

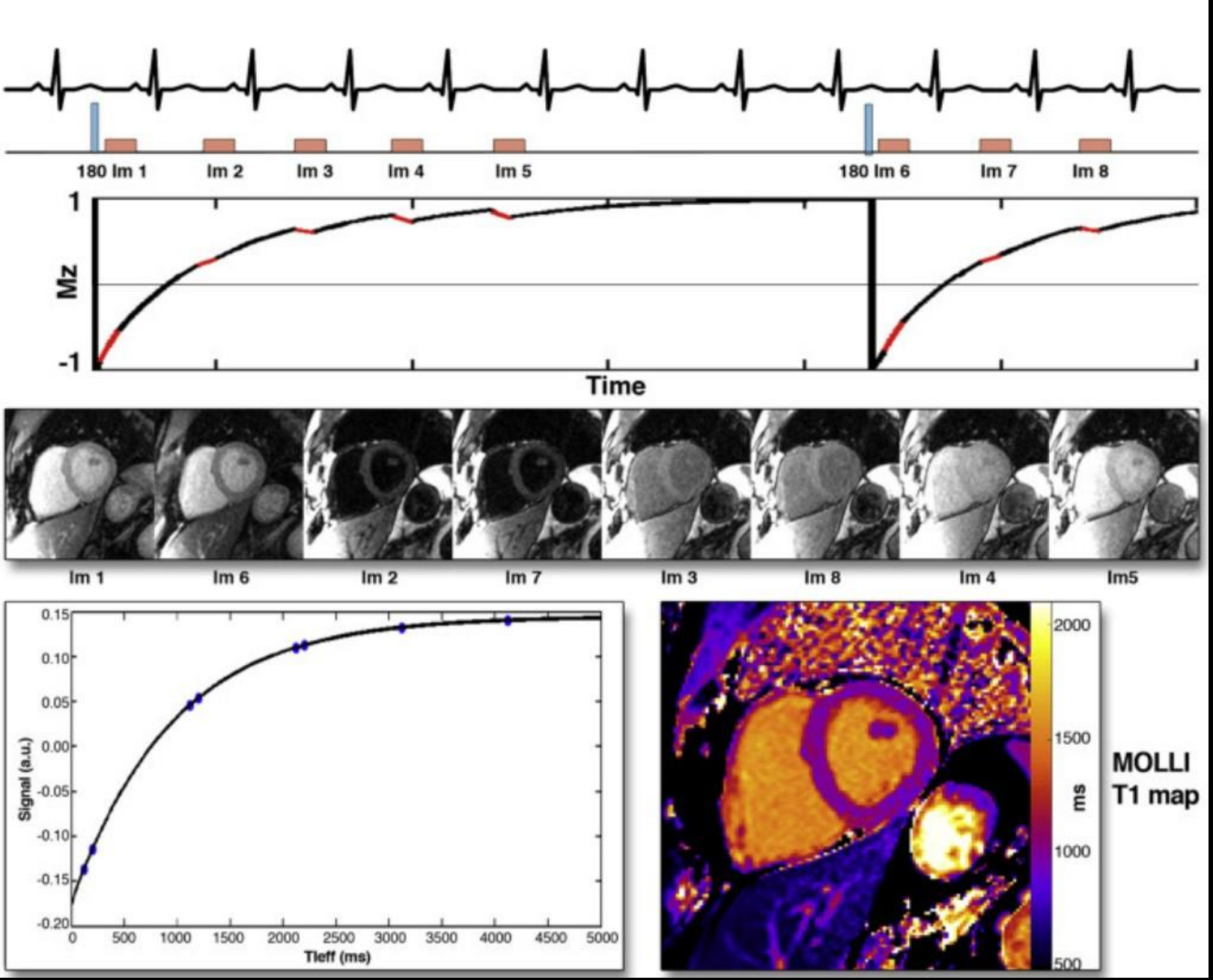


Figure 2 – MOLLI T1 Mapping

Acquisition strategy for the modified Look-Locker sequence (MOLLI). In this particular example, and after an 180° inversion pulse, images are acquired in diastole over 5 heartbeats, followed by a rest period of 3 heartbeats. After another inversion, another 3 image are acquired with slightly offset TIs to sample more points along the inversion recovery curves. Based on the number of heartbeats for acquiring images after each inversion pulse, and a rest period of 3 heart beats between the 2 cycles, this MOLLI acquisition scheme is termed 5(3)3. Images are sorted in order of increasing TI, and the signal intensity in each pixel is fit to the T1 recovery curve. Performing this technique for all pixels in the image yields a T1 map (bottom right).

Extracelullar Volume (ECV)

Estimation of the ECV (interstitium and extracellular matrix) requires measurement of myocardial and blood T1 before and after administration of contrast agents as well as the patient's hematocrit value according to the formula:

$$\mathrm{ECV} = (1 - haematocrt)\,\frac{1/T1_{myocardial\,post} - 1/T1_{myocardial\,pre}}{1/T1_{blood\,post} - 1/T1_{blood\,pre}}$$

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THANK YOU