

Indications for cardiac MRI

For the assessment of heart failure

- > Determination of etiology - ischemic vs. non-ischemic cardiomyopathy
- > Assessment of right and left ventricular function and size with precise quantification

For the evaluation of ischaemic heart disease

- > Viability assessment prior to treatment (e.g. revascularisation)
- > Assessment of location and extent of infarct

For the assessment of cardiac masses

- > For the characterisation, extent and invasion masses
- > For the assessment of pericardial disease
- > Constrictive pericarditis
- > Pericardial effusion

For the assessment of cardiomyopathies

- > Hypertrophic cardiomyopathy
- > Dilated cardiomyopathy
- > Arrhythmogenic right ventricular cardiomyopathy
- > Eosinophilic cardiomyopathy
- > Restrictive cardiomyopathies
- > Myocarditis

For the assessment of valvular disease

- > Detection, quantification, serial effect on ventricular function
- > Valve masses

For the assessment of congenital heart disease

- > Diagnosis and treatment monitoring
- > Cardiac and great vessel morphology
- > Coronary artery origin evaluation for anomalies
- > Intracardiac shunts with shunt fraction quantification

For the assessment of aorta and great vessels diseases

- > Aortic aneurysm
- > Aortic dissection
- > Intramural haematoma

For the assessment of myocardial infarction complications

- > Aneurysms
- > Thrombus formation

For the assessment of ventricular function

For the assessment of atrial arrhythmias

For anomalous coronary arteries

Clinical research

Heart anatomy and physiology

The heart is a muscular pump that receives deoxygenated blood and propels oxygenated blood to different parts of the body. It is composed of four chambers; the right atrium, right ventricle, left atrium and left ventricle.

Blood flow through the heart

On the right side deoxygenated blood from the superior and inferior vena cava enter the atrium whilst it is relaxed. At the same time, oxygenated blood from the pulmonary vein empties into the relaxed left atrium. The two atria then contract forcing the blood into the respective relaxed ventricles. On the right side deoxygenated blood flows through the right atrioventricular/tricuspid valve and on the left side oxygenated blood flows through the left atrioventricular/bicuspid/mitral valve. Next, the ventricles contract and the valves close. From the right ventricle the deoxygenated blood is forced through the semilunar/pulmonary valve into the pulmonary trunk and from the left ventricle oxygenated blood is forced through the semilunar/aortic valve into the aorta.

Valves

There are 4 valves of the heart:

1. The right atrioventricular valve/tricuspid valve separates the right atrium and right ventricle
2. The left atrioventricular valve/mitral valve separates the left atrium and left ventricle
3. The right semilunar/pulmonary valve lies between the right ventricle and pulmonary trunk
4. The left semilunar/aortic valve lies between the left ventricle and the aorta

Structure and function of the valves

The right atrioventricular valve/tricuspid valve has three cusps. The left atrioventricular valve/bicuspid valve/mitral valve has two cusps. These valves open on relaxation of the ventricles and close on contraction of the ventricles to

prevent the flow of blood back up into the atria. Their cusps point into the ventricles at all times with their free edges attached to fibrous strands called chordae tendineae. These chordae tendineae are in turn attached to papillary muscles from the ventricular wall.

The semilunar valves are composed of three cusps and their aim is to prevent the flow of blood back into the ventricles after ventricular contraction. At the centre of each valve is a fibrous nodule and ballooning of the cusps under back pressure simply presses their opposing surfaces together shutting off any backflow.

Pericardium

The pericardium is a double walled sac that contains the heart and the roots of the great vessels. The pericardium is composed of three layers:

1. Fibrous pericardium is the outer layer which attaches to the diaphragm, vena cava, aorta and sternum
2. Parietal pericardium is the middle serous layer
3. Visceral pericardium forms the outer layer of the heart, the epicardium

The pericardial cavity lies between the parietal and visceral pericardium and contains serous fluid which acts to prevent friction during movements of the heart.

Layers of the heart

The heart is composed of three layers:

1. Epicardium is the outer layer of the heart formed by the visceral pericardium
2. Myocardium is the middle layer composed of cardiac muscle
3. Endocardium is the inner layer composed of simple squamous epithelium

Blood supply to the heart

The coronary arteries supply the myocardium and epicardium of the heart. The right and left coronary arteries arise from the ascending aorta.

The right coronary artery arises from the right aortic sinus and gives off two major branches. The marginal branch supplies blood to the right ventricle and atrium and the posterior interventricular branch supplies blood to both

ventricles.

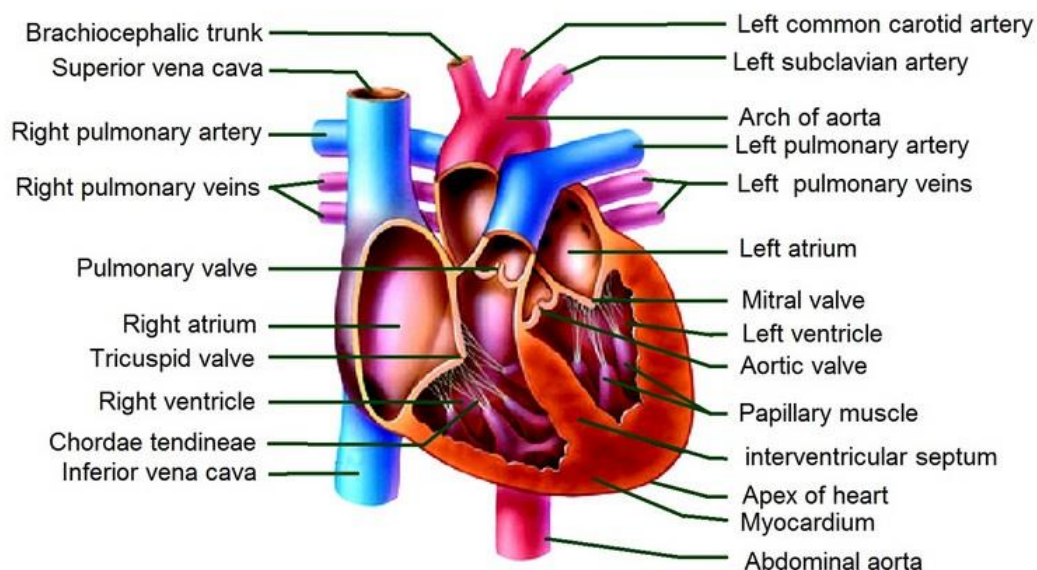
The left coronary artery arises from the left aortic sinus and also gives off two major branches. The anterior interventricular branch supplies blood to the walls of the ventricles and the circumflex branch supplies blood to the left ventricle and atrium.

Venous drainage of the heart

Deoxygenated blood which has supplied the heart itself is carried by the cardiac veins which follow a similar pathway to the coronary arteries. The main four cardiac veins are: the great cardiac vein, anterior cardiac vein, middle cardiac vein and posterior cardiac vein. These veins drain into the coronary sinus, the main vein of the heart. The coronary sinus runs in the posterior atrioventricular groove and then opens into the right atrium.

Innervation of the heart

The sinoatrial (SA) node generates an electrical impulse which passes through the atrial musculature on both sides causing them to contract. Atrial contraction causes the discharge of blood into the relaxed ventricles. Electrical impulses eventually reach the atrioventricular (AV) node situated in the interatrial septal region. These impulses from the AV node travel onward through the atrioventricular bundle (bundle of His) and arrive at the interventricular septum. In the interventricular septum the bundle divides into right and left bundle branches which pass to their respective ventricles and send out many branches called Purkinje fibres. These Purkinje fibres carry and spread the electrical impulses eventually causing the ventricles to contract.



Cardiac MRI technique

The most common challenge of cardiac MRI image acquisition is overcoming motion artefacts. Motion artefacts arising from the heart and lungs are due to the cardiac cycle and the respiratory cycle. Respiratory motion can be eliminated by breath holding or respiratory navigator technique. Artefacts from cardiac motion however can only be eliminated by ECG gating. ECG gating acquires data during diastole when the heart is at rest.

Respiratory artefact reduction

The most commonly used techniques to eliminate respiratory artefacts are breath holding and respiratory navigation.

Breath holding technique

Cardiac scans are normally performed under expiration. This is because during inspiration there is an increased tendency of the diaphragm to move and cause changes in anatomical positioning. It is therefore very important to give proper coaching to the patients before placing them into the scanner.

1. Instruct the patient to breathe in, but not too deeply
2. Instruct the patient to breathe out and then stop breathing
3. Ask the patient to breathe normally after the scan (usually under 20s)

It is important that the patient inhale and exhale approximately the same amount of air during each breath-hold as the position of the diaphragm is an important factor in ensuring anatomical positioning reproducibility.

Navigator technique

Navigator technique is used for patients who are not able to hold their breath. During free breathing the motion of the diaphragm changes the position of the heart, greater vessels and liver causing inconsistent image quality. This is because the same anatomical position is not found for each sampled k-space point. A navigator consists of an intermittent two-dimensional pulse that excites a cylinder of spins, followed by a readout gradient in the direction of the long axis of the cylinder to acquire a 1-dimensional profile of the area of interest.

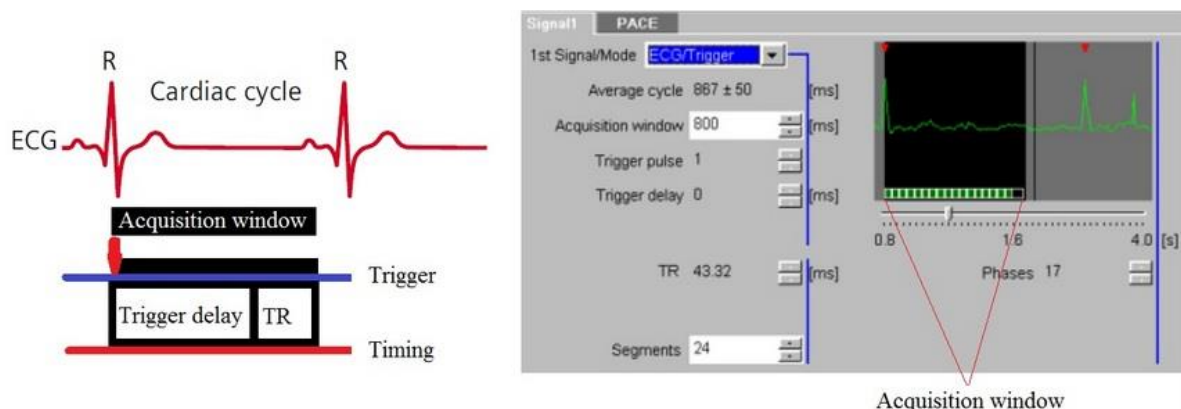
The sequence employs a low flip angle (10) to minimize saturation. The sharp change in the signal intensity of the lungs and liver along the axis of the box is used to determine the position of the diaphragm. The navigator pulse is about 20ms long and is executed every 200ms. A scan acceptance window is calculated from the preliminary pre-scan data after which the actual scan acquisition starts. The navigation box detects the position of the diaphragm during each slice acquisition and imaging only occurs when the diaphragm falls within the acceptance window.

ECG gating

Artefacts from cardiac motion can be suppressed using ECG (electrocardiographic) gating/triggering where image acquisition is synchronised with the cardiac rhythm. This can be done with either prospective or retrospective triggering.

Prospective Triggering

This technique is most commonly used for single slice or multi-slice single-phase cardiac imaging. Prospective triggering avoids cardiac motion artefact by acquiring images when the heart is at rest during mid-diastole. Image acquisition is triggered after the R-peak and subsequently at the same stage in each R-R interval. Data acquired at phases other than the cardiac rest period may be degraded by motion artefact.

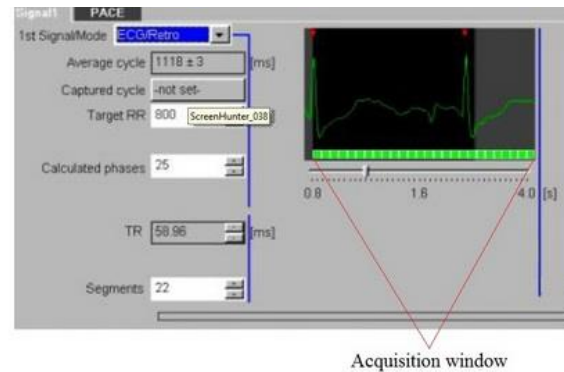
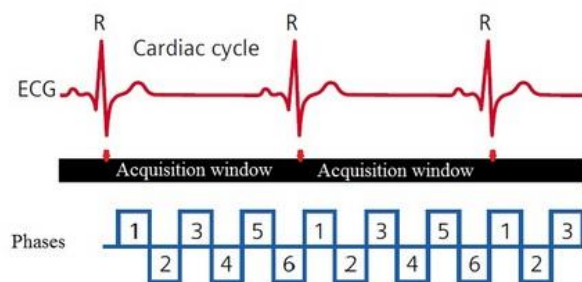


Retrospective Triggering

This method involves continuous acquisition of data to produce images from all phases of the cardiac cycle to construct a cine movie. Images of myocardial

contraction and relaxation can be used to detect myocardial dysfunction and undertake cardiac chamber quantification.

In retrospective triggering R-tops are automatically detected and data is acquired over an entire R-R interval for each specific K-profile. This is repeated until all K-profiles are acquired. ECG data and acquisition timings are then matched during reconstruction to construct images of all cardiac phases and construct the cine scan.



Triggering parameters

RR interval

This is interval from one QRS complex peak to the next peak on an ECG scan. The number of slices that can be acquired in a package is dependent on the RR interval. If more slices are required the sequence can be acquired in two packages (ie. 2 RR intervals).

Cardiac Frequency

RR interval is dependent on cardiac frequency i.e. number of heart beats per minute.

Trigger Delay

The delay from detection of the R-peak to start of acquisition.

RR Window

The RR window sets an acceptable lower and upper limit for the RR-interval and determines the permitted percentage variation in the interval length. The RR-interval lower limit determines the fastest accepted heart rate and the upper limit determines the slowest accepted rate. An RR window of 10 and 15 sets an acceptable RR interval of between 90% (110 minus 10%) and 115% (110+15%).

Arrhythmia Rejection

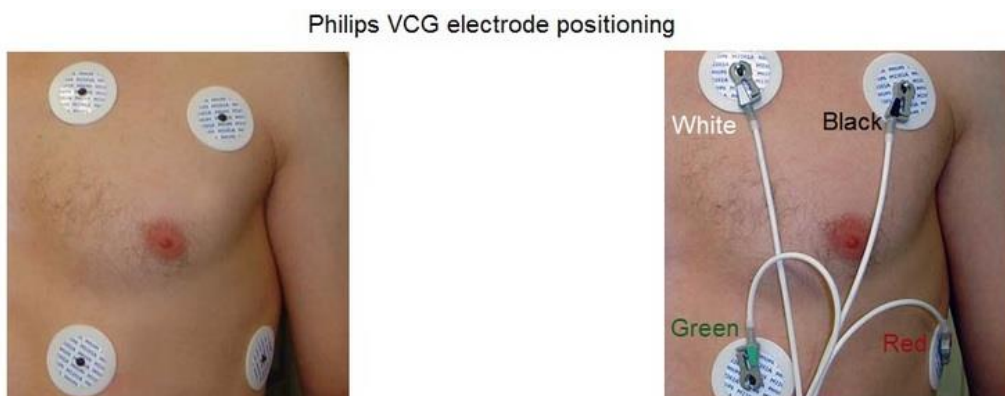
Useful in cases of patients with marked cardiac arrhythmia. Data acquired outside the permitted R-R window is rejected. In prospective triggering, arrhythmia rejection skips two R-R intervals (i.e. one R-R interval after the irregular beat). The system then resumes data acquisition after the next R-peak.

Positioning the electrodes in a Philips and GE scanner

The wireless VCG sensor has dual lead VCG monitoring capabilities based on 4 electrodes:

1. Position the first electrode (green) approximately 1 cm left of the xiphoid.
2. Position the second (white) and third (red) electrode to form a triangle around the nipple. The distance between the electrodes should be approximately 15 cm.
3. Position the fourth (black) electrode to the left of the top electrode, near the axilla.

Connect the green, white, red and black leads to the VCG electrodes as shown in the diagram.



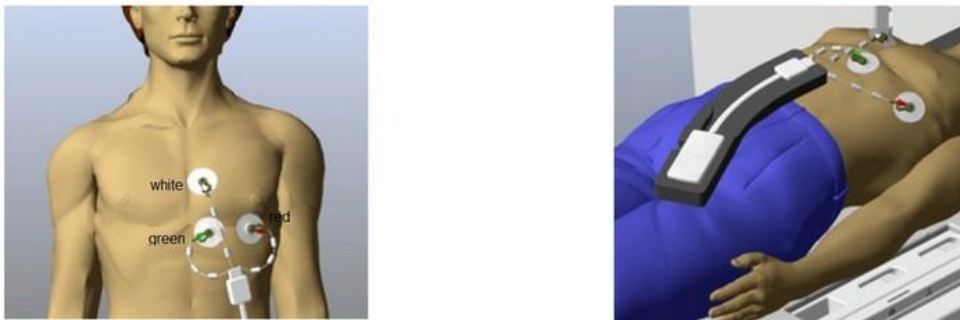
Positioning the electrodes in a Siemens scanner

The wireless ECG sensor has a monitoring capability based on 3 electrodes:

1. Position the first electrode (green) approximately 1 cm left of the xiphoid.
2. Position the second (white) and third (red) electrode to form a triangle around the nipple. The distance between the electrodes should be approximately 15 cm.

Connect the green, white and red leads to the ECG electrodes as shown in the diagram.

Siemens ECG electrode positioning



Warnings

Do not use the ECG signal for patient monitoring or diagnostic purposes.

Electrocardiograms acquired in the MR environment are useful only for cardiac triggered imaging. Such ECGs are NOT suitable for patient monitoring as the ECG signal is distorted when the patient is inside the magnet. ECG uses electrical measurements which can be corrupted by interference with electromagnetic fields and by magneto-hydrodynamic (MHD) effects.

Only use MR safe ECG electrodes.

Non MRI-safe ECG electrodes can cause severe skin burns.

Ensure proper ECG skin contact

A skin burn may develop if electrodes are not in complete contact with the skin. Ensure there are no air gaps and excess hair has been removed.

Do not use expired ECG electrodes.

Old electrodes can be dried out causing insufficient skin contact.

Do not reposition or reuse ECG electrodes.

Repositioning or the reuse of ECG electrodes may result in a heating effect due to worn down surfaces. Always use new electrodes.

Do not use paediatric ECG electrodes on adults and vice versa.

This may result in skin burns.

Do not place the ECG battery module directly on the patient's skin.

Direct contact may cause heating and skin burns. Keep away from the patient's skin by using pads under the battery.

Do not place the battery module close to the imaging volume.

Placing the battery close to the heart can lead to image artefacts and distortion

Contraindications

- > Any electrically, magnetically or mechanically activated implant (e.g. cardiac pacemaker, insulin pump biostimulator, neurostimulator, cochlear implant, hearing aids)
- > Intracranial aneurysm clips (unless made of titanium)
- > Pregnancy (risk vs benefit ratio to be assessed)
- > Ferromagnetic surgical clips or staples
- > Metallic foreign body in the eye
 - Metal shrapnel or bullet

Patient preparation

- > A satisfactory written consent form must be taken from the patient before entering the scanner room
- > Ask the patient to remove all metal object including keys, coins, wallet, any cards with magnetic strips, jewellery, hearing aid and hairpins
- > Ask the patient to undress and change into a hospital gown
- > **Instruct the patient to hold their breath for the breath hold scans and breathe gently for the gated scans (its advisable to coach the patient two to three times before starting the scan)**
- > Request the patient to use the rest room before procedure
- > Follow the appropriate manufacturer's instructions for the ECG electrodes and the blue tooth receiver placement
- > If the chest is covered with hair it is necessary to shave the required area before placing the ECG electrodes
- > Thoroughly clean the ECG contact area with an abrasive gel
- > Claustrophobic patients may be accompanied into the scanner room e.g. by staff member or relative with proper safety screening
- > Offer headphones for communicating with the patient and ear protection
- > Explain the procedure to the patient and answer questions
- > Note down the weight of the patient

Positioning

- > Position the patient in a supine position with head pointing towards the magnet (head first supine)
- > Position the patient over the spine coil and connect the ECG electrodes as specified above and in accordance with the specific manufacturer's instructions
- > Check the quality of the ECG in the integrated ECG display on the scanner terminal. If the signal is not satisfactory and consistent,
- > change the location of the electrodes
- > Place the body coil or the dedicated cardiac coil over the chest
- > Securely tighten the coil using straps to prevent respiratory artefacts
- > Give cushions under the head and legs for extra comfort
- > Centre the laser beam localiser over mid chest (i.e. over the nipples)

Positioning in Siemens scanner



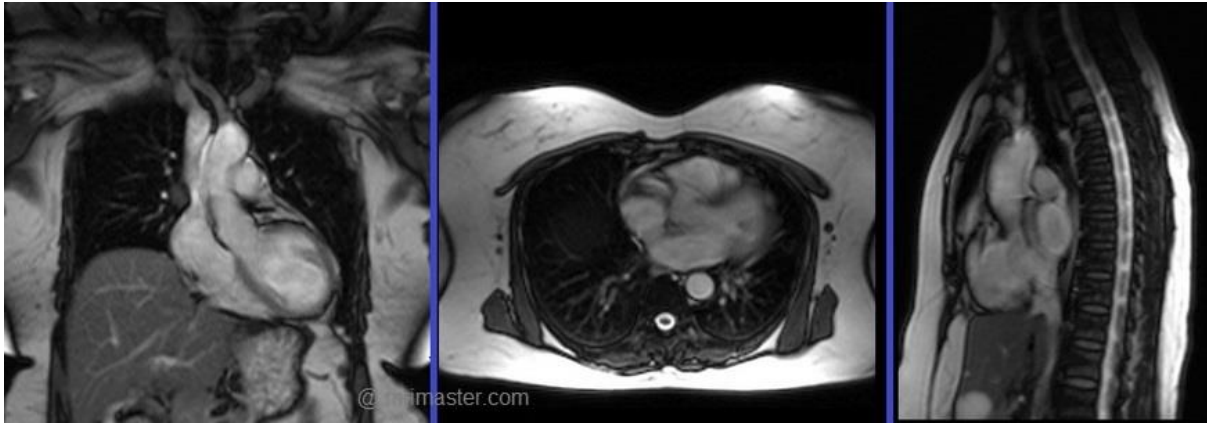
Positioning in Philips scanner



Suggested protocols, parameters and planning

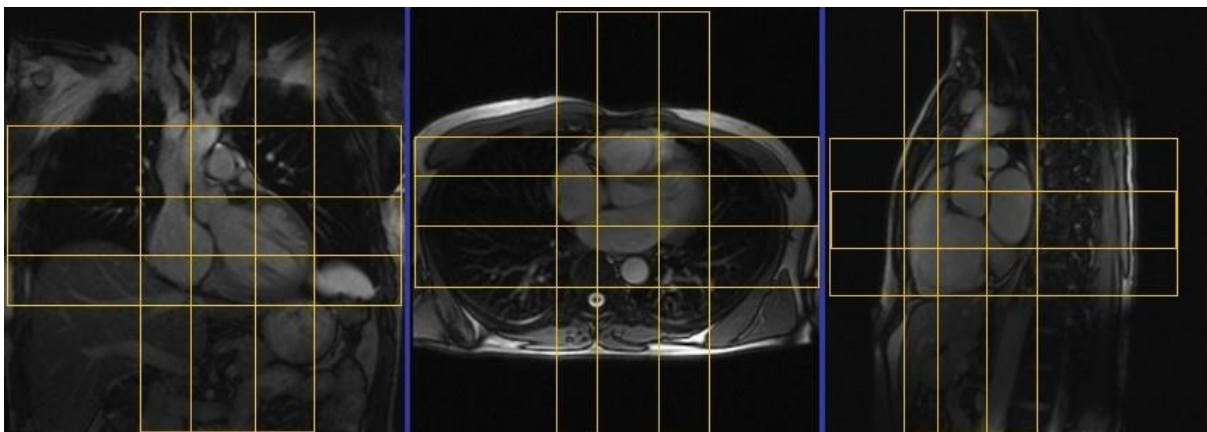
localiser

A three plane SSFP (TrueFISP, B-FFE or FIESTA) localiser must be taken initially to localise and plan the sequences. These are fast single shot localisers with an acquisition time of under 25s which are excellent for localising chest structures.



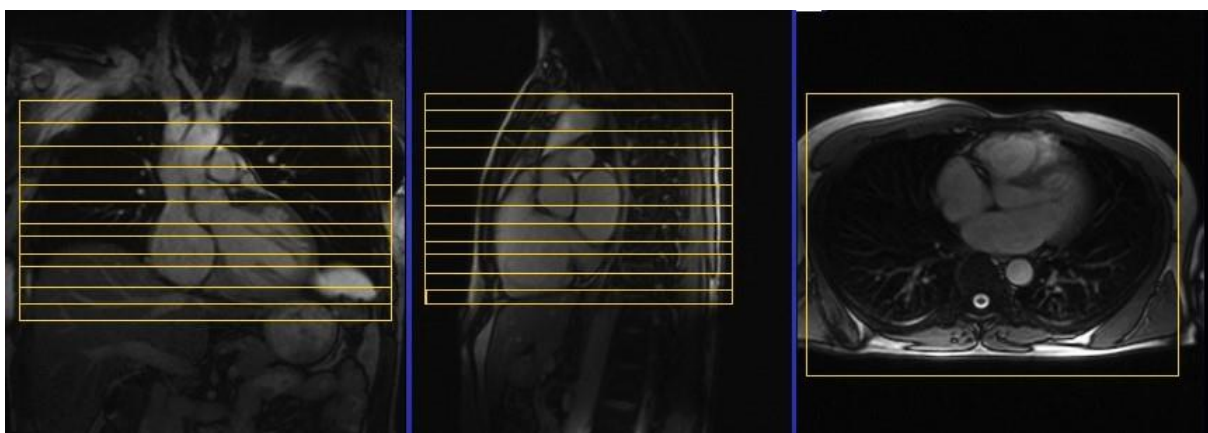
Cardiac planning localiser

Plan the axial localiser on the coronal plane and position the block across the chest as shown. Slices must cover the whole heart from aortic arch to the diaphragm (usually 3-4 slices). Check the position in the other two planes. Plan the sagittal localiser on the coronal plane and position the block parallel to the chest as shown. Slices must cover the whole heart from right to left (usually 3-4 slices). Check the position in the other two planes. Plan the coronal localiser on the axial plane and position the block across the chest as shown. Slices must cover the whole heart from sternum to thoracic aorta (usually 3-4 slices). Check the position in the other two planes. All three blocks must be ISO centred to the magnetic bore to avoid any inhomogeneity artefacts. These localizers are performed with a combination of ECG gating and a breath-hold. Scans should be performed under expiration breath-hold with an ECG trigger on every heartbeat (In our department we instruct the patients to breathe in and out twice before the “breathe out and hold” instruction).



Dark or bright blood axial

Plan the axial T2 scans on the coronal localizer. Plan the position block straight across the chest as shown. Check the position in the other two planes. An appropriate angle must be given in the sagittal plane (perpendicular to the thoracic spine). Slices must be sufficient to cover the heart from aortic arch to the apex (usually 18-20 slices). These axial slices are performed with a combination of ECG gating and breath-holds. Scans should be performed under expiration breath-hold with ECG triggers on every second heartbeat. Axial bright blood scans use a multiple breath-hold technique which acquires 8-10 slices with each breath hold. In our department the cardiologist prefers to do bright blood axials.



What are Dark Blood Sequences?

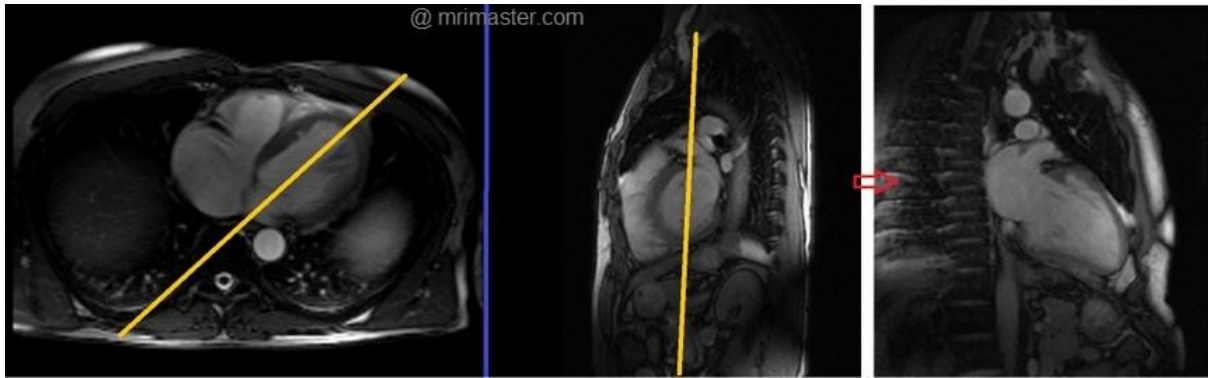
Dark blood sequences use a double preparation pulse. Signal from blood and myocardium inside and outside the slice area is inverted using the first pulse. The second pulse is a reinversion pulse affecting signal within the measurement slice only. As blood with an inverted signal flows into the measurement slice during data acquisition it will appear dark. Data acquisition must be carried out during the diastole to ensure this effect. Reinversion and data acquisition must take place in the heart in the same position to ensure that the tissues in the slice are successfully reinverted.

Recommended Protocol

Dark blood axial	Recommended Protocol	Siemens	Philips
Sequence Name	Single-Shot TSE/FSE	HASTE Dark Blood	
TR (ms)		1000	
TE (ms)		27	
Flip Angle (degrees)		160	
Field of View (mm)		400	
Resolution		256 X 104	
Slice Thickness (mm)		8	
Number of slices		20	
Inversion time (ms)	Dual-inversion pre-pulse	Dual-inversion	
Band width (Hz/pixel)		781	
Trigger		2 Pulse	
Parallel Imaging		Grappa 2	
Number of segments			
Gating		ECG/ Trigger	
Breath-hold	Multiple breath hold	Dual	
Dark Blood flip angle		200	
Phases		1	

Two chamber localiser

Plan the 2 chamber localiser on the axial plane and angle the position block parallel to the interventricular septum. Move the position block to the centre of the left ventricle parallel to the line along the centre of the mitral valve and left ventricular apex (in most patients these structures are not seen on the same image so scroll through the axial images to spot both structures). Check the position in the other two planes. An appropriate angle must be given in the sagittal plane (parallel to the interventricular septum). This single slice (non-cine) 2 chamber localiser is performed with a combination of ECG gating and a breath-hold. Scans should be performed under expiration breath-hold with ECG trigger on every heartbeat.



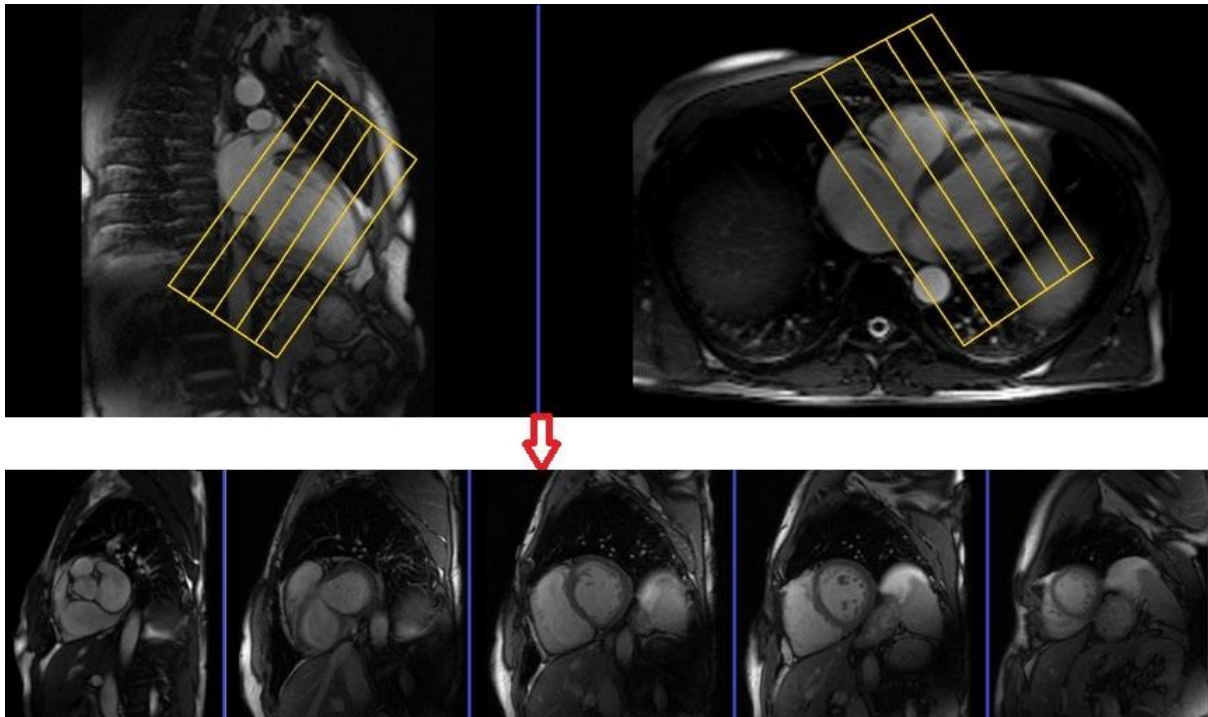
Recoended Protocol

2 chamber localiser	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP	B-FFE
TR (ms)	Minimum	345	Minimum
TE (ms)	Minimum	1.3	Minimum
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	256 x 224	256 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	1	1	1
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	1000-1200	1149	1180
Trigger	Every heartbeat	1 Pulse	Every heartbeat
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	<100	98	
Gating	Prospective	ECG/Trigger	Prospective
Breath-hold	Yes	Yes	Yes
Phases	1	1	

Short axis localiser

Plan the short axis localiser on the 2 chamber localiser and angle the position block perpendicular to the line along the centre of the mitral valve and left

ventricular apex (i.e. perpendicular to long axis of left ventricle). Check the position in the other two planes. An appropriate angle must be given in the axial plane (perpendicular to the interventricular septum). Slices must be sufficient to cover the heart from middle of left atrium to left ventricular apex (usually 8-10 slices). This multi-slice (non-cine) short axis localiser is performed with a combination of ECG gating and a breath-hold. Scans should be performed under expiration breath-hold with an ECG trigger on every heartbeat.

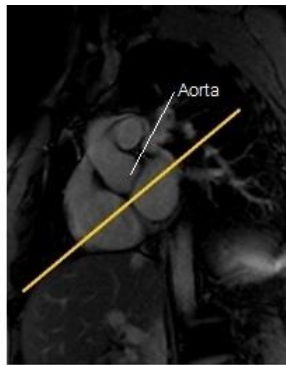
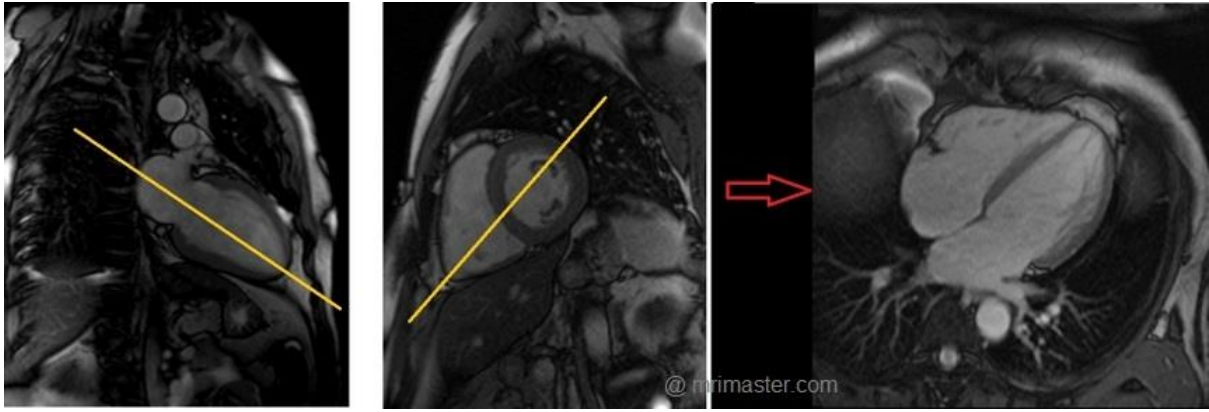


Recommended Protocol

Short axis localiser	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP	B-FFE
TR (ms)	Minimum	324	Minimum
TE (ms)	Minimum	1.46	Minimum
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	256 x 224	256 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	8-10	8	8
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	1000-1200	1149	1180
Trigger	Every heartbeat	1 Pulse	Every heartbeat
Parallel Imaging	YES, Acceleration factor: 2	Grappa 2	SENSE
Number of segments	<100	84	
Gating	Prospective	ECG/Trigger	Prospective
Breath-hold	Yes	Yes	Yes
Phases	1	1	

Four chamber view localiser

Plan the 4 chamber localiser on the 2 chamber localiser and angle the position block parallel to the line along the centre of the mitral valve and left ventricular apex. Check the position in the other two planes. An appropriate angle must be given in the short axis localiser (parallel to the line along the right ventricular apex and left anterolateral papillary muscle). While planning in the short axis, localiser care should be taken to avoid the aorta in the resulting 4 chamber view (please check the planning diagram for the appropriate planning). This single slice (non-cine) 4 chamber localiser is performed with a combination of ECG gating and a breath-hold. Scans should be performed under expiration breath-hold with ECG trigger on every heartbeat.



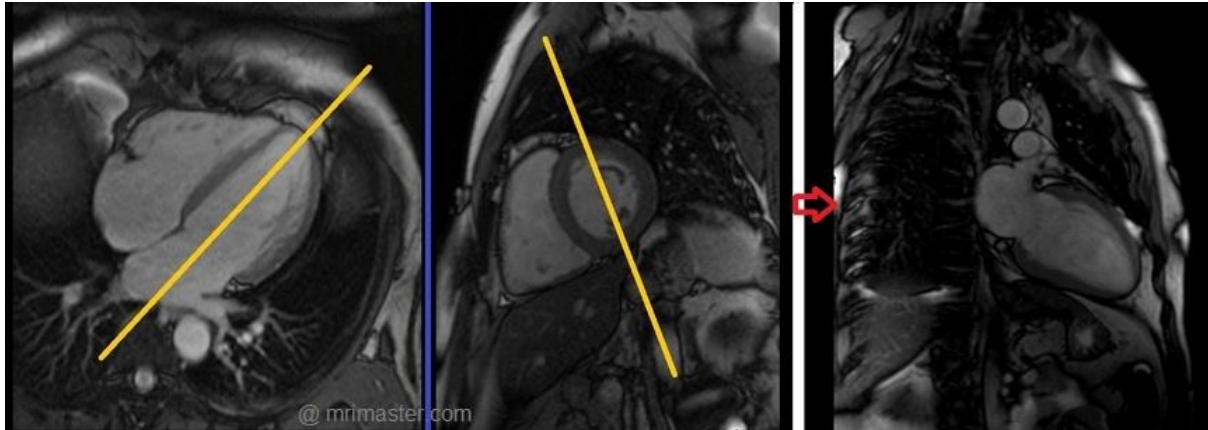
Recommended Protocol

4 chamber localiser	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP	B-FFE
TR (ms)	Minimum	324	Minimum
TE (ms)	Minimum	1.46	Minimum
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	256 x 224	256 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	1	1	1
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	1000-1200	1149	1180
Trigger	Every heartbeat	1 Pulse	Every heartbeat
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	<100	84	
Gating	Prospective	ECG/Trigger	Prospective
Breath-hold	Yes	Yes	Yes
Phases	1	1	

LEFT VENTRICULAR (LV) FUNCTION

Left two chamber cine

Plan the 2 chamber cine on the 4 chamber localiser and angle the position block parallel to the interventricular septum. Move the position block to the centre of the left ventricle parallel to the line along the centre of the mitral valve and left ventricular apex. Check the position in the other two planes. An appropriate angle must be given in the short axis localiser (parallel to the interventricular septum). This Retrospective 2 chamber cine scan is performed with a combination of ECG gating and breath-holds. Scans should be performed under expiration breath-hold.



What are cine Sequences?

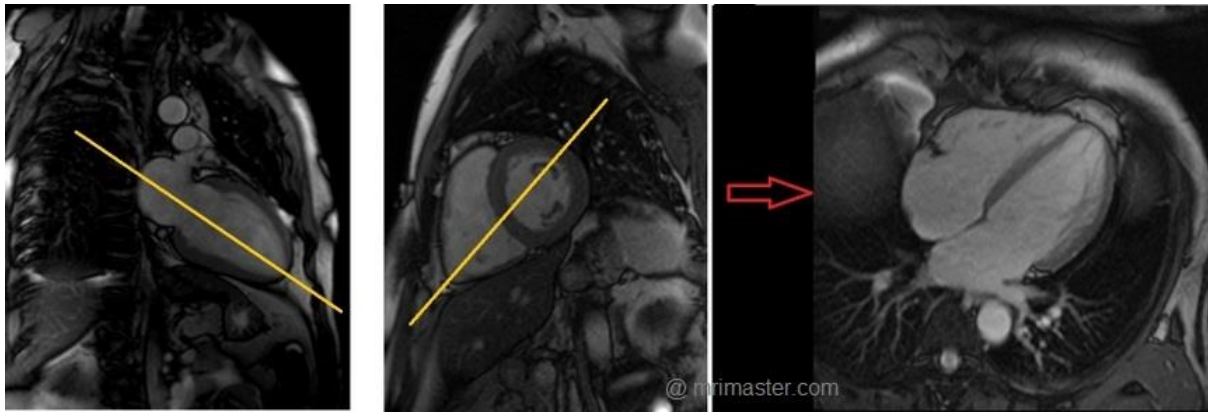
Cine sequences are used for the assessment of cardiac function. During cine acquisition several individual images are acquired in different phases of the cardiac cycle. These are then played as a movie to provide the user with a 'video' of the cardiac activity. TrueFISP sequences are highly recommended for cine imaging due to high temporal and spatial resolution and improved blood- tissue contrast. For cardiac cine imaging TrueFISP is used in combination with i-pat technology to reduce the acquisition time.

Recommended Protocol

2 chamber cine	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP 2d	B-FFE
TR (ms)	Minimum	49	50
TE (ms)	Minimum	1.3	1.3
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	224 x 224	224 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	1	1	1
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	900-980	930	960
Trigger	N/A	N/A	
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	10-20	15	
Gating	Retrospective	ECG/retro	Retrospective
Breath-hold	Yes	Yes	Yes
Phases	> 25	25	

Four chamber cine

Plan the 4 chamber cine on the 2 chamber localiser and angle the position block parallel to the line along the centre of the mitral valve and left ventricular apex. Check the position in the other two planes. An appropriate angle must be given in the short axis localiser (parallel to the line along the right ventricular apex and anterolateral papillary muscle). While planning in the short axis, localiser care should be taken to avoid the aorta in the resulting 4 chamber view (please check the planning diagram for the appropriate planning). This Retrospective 4 chamber cine scan is performed with a combination of ECG gating and breath-holds. Scans should be performed under expiration breath-holds.

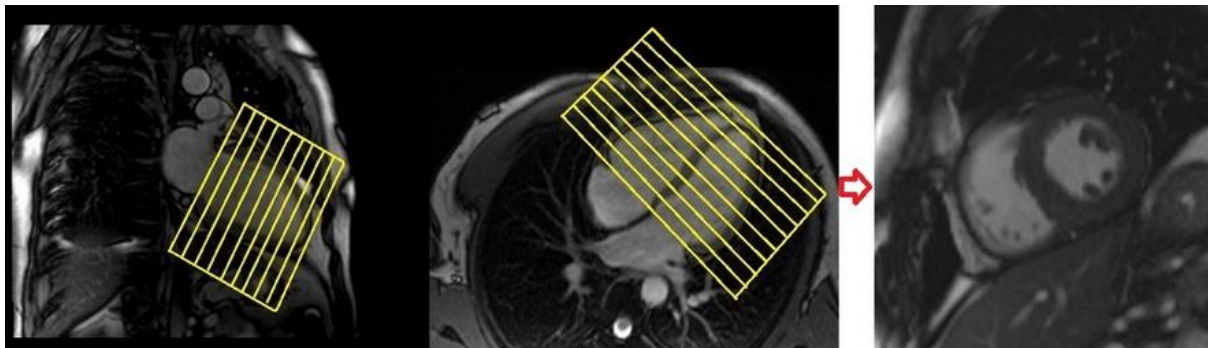


Recommended Protocol

4 chamber cine	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP 2d	B-FFE
TR (ms)	Minimum	49	50
TE (ms)	Minimum	1.3	1.3
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	224 x 224	224 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	1	1	1
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	900-980	930	960
Trigger	N/A	N/A	
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	10-20	15	
Gating	Retrospective	ECG/retro	Retrospective
Breath-hold	Yes	Yes	Yes
Phases	> 25	25	

Short axis cine

Plan the short axis cine scans on the 2 chamber cine and angle the position block perpendicular to the line along the centre of the mitral valve and left ventricular apex (i.e. perpendicular to long axis of left ventricle). Check the position in the other two planes. An appropriate angle must be given in the four chamber cine (perpendicular to the interventricular septum). Slices must be sufficient to cover the heart from mitral valve to left ventricular apex (usually 10-12 slices). This multi-slice retrospective short axis cine scans are performed with a combination of ECG gating and multiple breath-holds. Scans should be performed under expiration breath-hold with one slice on every breath hold. **Short axis cine scans must be planned on the end-systole (maximum ventricular expansion) slice on 2chamber and 4 chamber cine.**

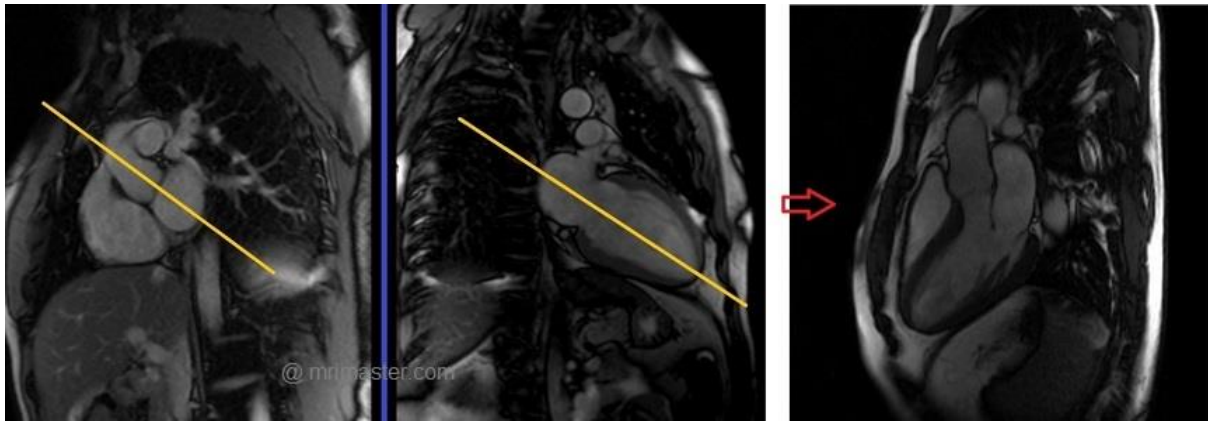


Recommended Protocol

Short axis cine	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP 2d	B-FFE
TR (ms)	Minimum	82	83
TE (ms)	Minimum	1.25	1.3
Flip Angle (degrees)	Maximum	70	65
Field of View (mm)	300-360	340	340
Resolution	256 x 192	192 x 192	256 x 128
Slice Thickness (mm)	6-8	8	8
Number of slices	15-20	15	15
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	900-980	930	960
Trigger	N/A	N/A	
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	<30	28	
Gating	Retrospective	ECG/retro	Retrospective
Breath-hold	Yes	Yes	Yes
Phases	> 25	25	

Three chamber (Left Ventricular Outflow Tract LVOT)cine

Plan the 3 chamber cine on the short axis localizer and angle the position block parallel to the line along the centre of the aortic valve and left ventricle (i.e. perpendicular to the posterolateral left ventricle wall). Check the position in the other two planes. An appropriate angle must be given in the 2 chamber localiser (parallel to the line along the centre of the mitral valve and left ventricular apex). This retrospective 3 chamber cine scan is performed with a combination of ECG gating and breath-hold. Scans should be performed under expiration breath-hold.



Recommended Protocol

3 chamber cine	Recommended Protocol	Siemens	Philips
Sequence Name	SSFP	TrueFISP 2d	B-FFE
TR (ms)	Minimum	49	50
TE (ms)	Minimum	1.3	1.3
Flip Angle (degrees)	Maximum	80	65
Field of View (mm)	300-360	340	340
Resolution	224 x 224	224 x 224	256 x 192
Slice Thickness (mm)	6-8	8	8
Number of slices	15-20	1	1
Inversion time (ms)	N/A	N/A	
Band width (Hz/pixel)	900-980	930	960
Trigger	N/A	N/A	
Parallel Imaging	YES, Acceleration factor: 2	Garappa 2	SENSE
Number of segments	10-20	15	
Gating	Retrospective	ECG/retro	Retrospective
Breath-hold	Yes	Yes	Yes
Phases	> 25	25	

Arrhythmia is a disturbance of the heart's usual rhythm. In patients with arrhythmia the heart beats too quickly, too slowly, or with an irregular pattern.

The main types of arrhythmia are;

Atrial fibrillation (AF): The most common type of arrhythmia where the heart beats irregularly and faster than normal.

Supraventricular tachycardia: The heart beats faster than normal, usually between 140 and 240 beats per minute.

Bradycardia: The heart beats more slowly than normal

Heart block: This occurs when the electrical impulses are blocked between the atria and the ventricles causing the heart to beat more slowly than normal.

Sick sinus syndrome: This condition is usually occurs due to the damage of SA node. In this type of arrhythmia the heart beat slowly or misses a few beats.

Ventricular fibrillation: This type of arrhythmia occurs when the heart's electrical activity becomes disordered causing a rare, rapid and disorganized cardiac rhythm.

Arrhythmia correction in cardiac imaging

Arrhythmia correction is a method that enables the MRI system to reject the unwanted data, achieving high quality scans in patients with irregular heart rhythm. Arrhythmia correction will allow the technologist to enter the expected average RR interval and tolerance range into the system. During the data acquisition if an R-peak is not within the RR-window, the acquired data will be rejected. The system will wait till the next R-peak occurs.