Exercise 8: Cine Imaging of the Heart

Teaching Points:

• How to do cardiac gating?

• What is Steady State Free Precession (SSFP)?

• What are the basic cardiac views and how to prescribe these images?
Cardiac MRI Imaging is used to evaluate morphology and function of the myocardium, pericardium, valves, coronary arteries, and surrounding structures. It can show the extent of the damage caused by heart attack, valve disease, hypertension, and shunts. It can evaluate cardiac function by measuring cavity volume and ejection fractions. It aids in the diagnosis and management of several cardiovascular diseases and can be used to monitor patient’s recovery following treatment.

**Step 1: Patient Prep**

Your volunteer should sign the safety screening form (see exercise 2), consent form, and the HIPPA research privacy form.

Review the information on the safety screening form and interview your volunteer to verify the information on the form and to make sure that nothing was overlooked. Ask him/her for any concerns and also explain the nature of exam so that your volunteer knows what to expect.

**Step 2: Prepare the scanner room**

Place the posterior element of the 8 channel cardiac coil on the scanner table and cover the table with a clean sheet and the pillow with clean pillowcase. Lay down the respiratory bellows so the volunteer can lie on top of it.
**Step 3: Placement of the ECG electrodes**

Volunteer should be supine and feet first. Make sure that upper edge of the posterior coil is above the cranial edge of scapula. Prepare the skin of the volunteer for lead placement by cleaning it using alcohol swab to remove oil and shave chest hair if necessary. Note that leads can also be applied on the back which can be more convenient to the volunteer. Dry the area completely before placing the electrodes. Position the leads in configuration avoiding breast tissue.

Position the ECG leads (RA, LA, RL and LL) on the chest of the volunteer as shown in Fig 8.2. The leads should not be placed more than 10 to 15 cm apart. Raise the left breast to position the LL lead, for women with large breasts. Proper placement ECG leads is important in any cardiac gated acquisition.

To display the waveforms, click Gating control on the Rx Manager. Turn on Vector Gating (ECG) and Respiratory Gating to display the waveform on the screen (Fig 8.3a). Make sure that R waves are detected, at least 16 heart cycles before you start scanning (Fig 8.4). Reposition the leads if R waves are not detected properly or the R wave amplitude is low (<1mV). If some of the R waves are missing trigger marks, go back to the Gating Control window and reduce Cardiac Trigger Level to 50%. The Cardiac Trigger Level allows adjustment, expressed as a percent of the QRS complex, where the signal amplitude must rise about the defined threshold to be detected.
**What is Cardiac Gating?**

Cardiac Gating is the technique which allows the same data to be collected at the same points of the cardiac cycle for each repetition of the pulse sequence. It monitors the cardiac cycle prospectively to initiate RF application and retrospectively determine when data were acquired in the R-R interval for creating cine images.

The ECG waveform represents the electrical activity of the heart that correlates to heart motion (Systole is cardiac contraction & Diastole is cardiac relaxation):

- **P wave** - atrial depolarization/systole of atria
- **QRS complex** - ventricular depolarization/systole of ventricles
- **R wave** - has strong signal and correlation of the heart muscle activity
- **ST segment** - end of the QRS complex and beginning of the T wave, represents period of slow repolarization of the ventricles
- **T wave** - ventricular repolarization/diastole of ventricles
- **QT interval** - both ventricular depolarization and repolarization; estimates the duration of the ventricular action potential
Step 4: Positioning the coil

Make sure the respiratory bellows is secured tightly around the abdomen before placing the anterior cardiac coil on the volunteer. You can place a pad or cushion on the chest before putting the anterior cardiac coil. The upper edge of the coil should be above the clavicle level. Arms are on the side or placed above the head. To relieve back pressure, place a cushion under the knees. Give your volunteer earplugs and squeeze ball and cover them with a blanket.

Step 5: Landmarking

Landmark at the volunteer’s mid-sternum (mid-chest).
Step 6: Set your own Three Plane Localizer

Click New Series in Rx Manager, Select INRX, and then click View Edit. We suggest the following parameter for your 3 plane localizer (Fig 8.7). Be sure to select Cardiac as the coil type. Click Save series, Download, Prep Scan, give instructions for breath holding, then Scan.
**Step 7: ASSET Calibration**

Array spatial sensitivity encoding technique (ASSET) is a parallel imaging single breath hold technique done to accelerate data acquisition and determine the sensitivity of all coils in the phased array coil. Copy and Paste 3 Plane loc on your Rx Manager then click View Edit. Set your parameters and fill up the Patient Position, Imaging Parameters, Acquisition Timing, and Scan Timing (Fig 8.8). Click Graphic Rx and be sure to prescribe enough slices to cover the whole heart. Click Save Series, Download, Prep Scan, give instructions for breath holding, and then click Scan.

Fig 8.8 Calibration sequence parameter
What is Steady-State Free Precession (SSFP) Imaging?

This is a gradient-echo sequence which has revolutionized cardiac MRI by increasing SNR with steady state echo magnetization. Normally left over signal at the end of a pulse is spoiled to avoid interfering with the next echo (e.g. spoiled gradient echo). With SSFP, left over signal is re-phased to align and superimposed on the next echo so that signal becomes stronger and stronger with every pulse until reaching steady state. It uses a high flip angle with short repetition time (< 4 ms). FIESTA or Fast Imaging Employing Steady State Acquisition is GE version of SSFP.

Fig 8.9 MR signal becomes a superimposition of free induction decays, spin echoes, and stimulated echoes after applying a series of closely spaced RF pulses.
Step 8: Two Chamber, Vertical Long Axis Fiesta (SSFP)

Vertical long axis (2C view) shows the anterior and inferior walls clearly, as well as the apex of the left ventricle. Copy and Paste 3 Plane loc on the Rx Manager then click View Edit. Set the parameters (Fig 8.10). Go to Graphic Rx, click Select Series, choose 3-Plane, then click Ok (Fig 8.11). Scroll through the images and choose an axial image to prescribe the localizer. Prescribe one slice parallel to ventricular septum, bisecting the left ventricle through mitral valve and apex (Fig 8.12). Adjust the Shim volume to 12 (Fig 8.11) and place it properly on the image. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.

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**Fig 8.10 2 Chamber, Vertical long axis Fiesta sequence parameter**
Fig 8.11 & 8.12 Graphic Rx for 2 Chamber, Vertical Long Axis Fiesta

Fig 8.11 Position small FOV shim volume on heart

Fig 8.12 Prescribe 2 Chamber, Vertical long axis view

Fig 8.13 2 Chamber, Vertical Long Axis Fiesta

Diastole 55 msec 92 msec 127 msec Systole 200 msec
Step 9: Short Axis (SA) Fiesta

Short Axis (SA) Fiesta is good for volumetric measurements because it shows the cross sections of the left and right ventricle. Copy and Paste Scout 2C Fiesta on the Rx Manager then click View Edit. Set the Parameters (Fig 8.14). Go to Graphic Rx, click Select Series, choose 2C Scout Fiesta, and then click Ok. Multiple slices are positioned perpendicular to the long axis of the left ventricle from the two-chamber view and make sure to cover from atria to apex (Fig 8.15). Set shim vol to 12. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan. This is a series of breath holding in expiration.
Step 10: 4 Chamber Long Axis Fiesta

Horizontal Long axis (4C view) shows mitral and tricuspid valves and it is best for evaluating the septal and lateral walls and apex of the left ventricle, right ventricular free wall, and chamber size. Copy and Paste SA Fiesta on the Rx Manager, click View Edit, and set the parameters (Fig 8.17). Go to Graphic Rx, click Select Series, choose Scout 2C Fiesta, then click Ok. Click the box on the upper left hand, click Select Series, choose SA Fiesta, and then click Ok. Prescribe one slice bisecting the left ventricle through mitral valve and apex on the two-chamber view and one slice in the middle of the left ventricle to the furthest corner of the right ventricle making a horizontal plane on the SA view (Fig 8.18). Set shim vol to 12. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.
Fig 8.17 4 Chamber, Horizontal Long Axis Fiesta sequence parameter
Step 11: 3 Chamber

The three chamber view is a good to see the aortic root and aortic valve, left ventricular outflow tract, mitral valve, and both the anteroseptal and inferolateral walls of the left ventricle. Copy and Paste 4 CH on the Rx Manager, click View Edit and set the parameters (Fig 8.20). Go to Graphic Rx, click Select Series, choose Scout 2C Fiesta, and then click Ok. Click the upper left hand box, click Select Series, choose SA Fiesta, and then click Ok. Prescribe a slice bisecting the left ventricle through the mitral valve and apex on the two-chamber view and bisect the left ventricular outflow tract, cutting through the aortic root on the most basal short axis view (Fig 8.21). Set shim volume to 12 and position it on the image correctly. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.
Fig 8.22 3 Chamber

T = 45 msec  T = 110 msec  T = 130 msec  T = 185 msec

Fig 8.23 Imaging planes that can be aligned from the SA Fiesta slice
**Step 12: Aortic Outflow Tract**

Copy and Paste 3 CH on the Rx Manager, click View Edit and set the parameters (Fig 8.24). Go to Graphic Rx, click Select Series, choose 3 CH, and then click Ok. Prescribe a slice bisecting the ascending aorta and aortic valve on the 3C view (Fig 8.25). Adjust the shim vol to 12. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.

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**Fig 8.24 Aortic Outflow Tract Sequence Parameter**

### Scan Timing
- **# of TE(s) per scan**: Min. 1.0 Max 2.0
- **TE Minimum**: 1.1
- **TE2**: 1.0
- **TR**: 15000.0
- **Inv. Time**: 0
- **T2**: 50
- **Flip Angle**: 60
- **Echo Train Length**: 1
- **Bandwidth**: 125.00
- **Bandwidth2**: 0.0

### Additional Parameters
- **Graphic RX**: OFF
- **Image Enhance**: 
- **Users CVs Screen**: 
- **Gating/Triggering**: 

### Acquisition Timing
- **Freq**: 256
- **Freq DIR**: S/I
- **Phase**: 192
- **Flow Comp Direction**: 
- **NEX**: 1.00
- **Shim**: Auto
- **Phase FOV**: 1.00
- **Acqs Before Pause**: 
- **Amf**: 
- **Agent**: ml

### Scanning Range
- **FOV**: 32.0
- **Slice Thickness**: 8.0
- **Spacing**: 0.0
- **Min. Slices**: 1
- **Max Slices**: 26
- **Start**: L31.6
- **End**: L31.6
- **S/I**: A12.5
- **R/L**: A12.5
- **A/P**: $39.4$
- **Table Delta**: 0.0

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Step 13: Aortic Valve

Copy and Paste Aortic Outflow Tract on the Rx Manager, click View Edit and set the parameters (Fig 8.27). Go to Graphic Rx, click Select Series, choose 3 CH, and then click Ok. Click the upper left box, click Select Series, choose Aortic Outflow Tract, and then click Ok. Change the spacing to 0. Prescribe three slices across aortic valve on both the 3C and Aortic Outflow Tract view as shown on Fig 8.28. Adjust the shim vol to 12. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.
Fig 8.27 Aortic Valve Sequence Parameters

**Patient Information**
- Accession Number: 0000
- Patient ID: 0000
- Patient Name:

**Patient Protocols**
- Patient Position: Supine
- Patient Entry: Feet First
- Coil: SCARDIAC
- Series Description: AORTIC VALVE
- Plane: Oblique
- Pulse Seq: Fiesta
- Imaging Options: Gate, Seq, Fast
- Pd Name: Protocol

**Scan Timing**
- # of TE(s) per scan: 1.0 (Min), 2.0 (Max)
- TE Minimum: 1.1
- TE Maximum: 1.1
- TR Minimum: 1.0
- TR Maximum: 1.0
- Inr. Time: 3.4
- TI: 0 (Min), 15000 (Max)
- Flip Angle: 90
- Echo Train Length: 60
- Bandwidth: 125.00
- Bandwidth2: 0.0

**Additional Parameters**
- Graphic Rx: OFF
- Image Enhance: Users CVS Screen
- Gating/Triggering:

**Acquisition Timing**
- Freq: 256
- Freq DIR: 51
- Phase: 192
- Flow Comp Direction:
- NEX: 1.00
- Shim: Auto
- Phase FOV: 7.00
- Acqs Before Pause:

**Scanning Range**
- FOV: 32.0
- Slice Thickness: 0.0
- Spacing: 0.0
- Min: 129.0
- Max: 450.0
- # of Slices: 1
- End:

**Fig 8.28 Graphic Rx for Aortic Valve**

- Erase Selected
- Erase All
- Reset Center
- Feedback to SD
- Loc Ref Lines
- Report Cursor
- Update All
- Keep W/L
- Display Normal
- Reverse Slice Order
- Localized image 11, 10
- Accel. Bar
- Cardiac/Resp
- Name of Radial Slices: 1
- Radial Direction: CW
- Partial Radial Spacing:

- Zoom
- Copy Rx...
- Select Series
- Select image
- Localized image 11, 10
- Cardiac/Resp
- Name of Radial Slices: 1
- Radial Direction: CW
- Partial Radial Spacing:

- Start:
- End:

- Table: Delta 0.00
**Step 14: Right Ventricular Outflow Tract**

Copy and Paste Aortic Valve on the Rx Manager, click View Edit and then set the parameters (Fig 8.30). Go to Graphic Rx, click Select Series, 3 plane loc, and then click Ok. Prescribe a slice bisecting the main pulmonary artery on the coronal view (Fig 8.31). Set shim vol to 12. Click Save Series, Download, Prep Scan, give instructions for breath holding, then Scan.

![Patient Information](image1)

**Fig 8.30 Right Ventricular Outflow Tract**

**Sequence Parameter**

<table>
<thead>
<tr>
<th>Accession Number</th>
<th>0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient ID</td>
<td>0000</td>
</tr>
<tr>
<td>Patient Name</td>
<td></td>
</tr>
</tbody>
</table>

**Patient Protocols**

- **Patient Position**: Supine
- **Patient Entry**: Feet First
- **Series Description**: RIGHT VENTRICULAR OUTFLOW TRACT

**Patient Subtract**

- **Plane**: Oblique
- **Mode**: 2D
- **Pulse Seq**: Fiesta
- **Gating/Triggering**: Scan

**Image Options**

- **Contrast**: Phase Correct
- **Linear Mode**: S44.2
- **Amplitude**: A21.6
- **Cardiac Phases**: 10
- **Scan Time**: 2.0
- **Sequence Parameter**

**Additional Parameters**

- **Graphic Rx**: OFF
- **Image Enhance**: On
- **Gating/Triggering**: On

**Acquisition Timing**

- **Freq**: 256
- **Freq DIR**: 5.8
- **Flow Comp**: Direction
- **Shim**: Auto
- **NEX**: 192
- **Phase**: 1.00
- **Phase FOV**: Apparent
- **Pause Before**: A21.6

**Scanning Range**

- **S/I**: R16.3
- **R/L**: A21.6
- **A/P**: $44.2$

**Acquisition Timing**

- **Min.**: 1.0
- **Max.**: 2.0
- **TE**: 1.1
- **TR**: 3.2
- **Inv. Time**: 50
- **T2**: 1
- **Flip Angle**: 60
- **Echo Train Length**: 125.00
- **Bandwidth**: 62.5
- **Bandwidth2**: 0.0

**Additional Parameters**

- **S/I**: 25
- **R/L**: 48
- **A/P**: 20
- **Table Delta**: 0.0

**Scan Timing**

- **Min.**: 1.0
- **Max.**: 2.0
- **TE**: 1.1
- **TR**: 3.2
- **Inv. Time**: 50
- **T2**: 1
- **Flip Angle**: 60
- **Echo Train Length**: 125.00
- **Bandwidth**: 62.5
- **Bandwidth2**: 0.0
Step 15: Clean up