3D Late Gadolinium Enhancement CMR

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Introduction

Late gadolinium enhancement (LGE) CMR is widely used for myocardial scar assessment. Clinically, multi-slice two-dimensional (2D) imaging is used during multiple breath-holds to cover the entire ventricle. However, 2D breath-hold imaging requires patients to perform repeated breath-holds, limits spatial resolution and coverage. Free-breathing 3D LGE imaging is an alternative technique that allows a full LV coverage in free-breathing with improved spatial resolution. Despite its potential, 3D free-breathing LGE imaging is only performed in selected clinical sites. Our laboratory at Cardiac MR Center at Beth Israel Deaconess Medical Center is among a few selected sites where free-breathing 3D LGE imaging is routinely performed in all clinical patients for nearly a decade. In this article, we describe our current practice of LGE CMR in patient scans using a 3T MAGNETOM Vida scanner (Software version: NXVA20A). Specifically, 3D LGE is performed during free-breathing with navigator-based gating and slice-tracking for respiratory motion suppression. The images are acquired on a 4-chamber slab and are reformatted to other desired planes using on-scanner tools.

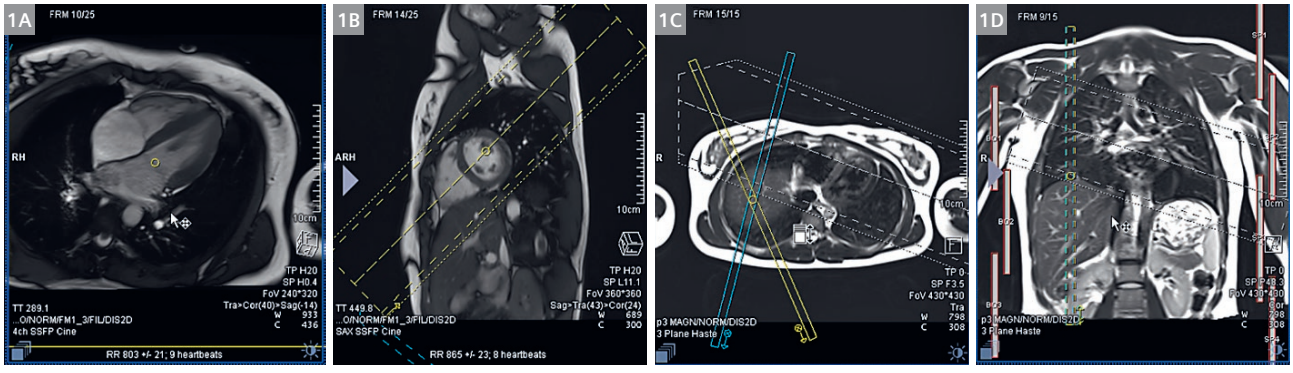
Workflow

LGE acquisition is performed after injection of contrast agent and can be planned without the need for any additional localizers. As show in Figure 1, we use multi-plane localizers, 4-chamber, and short-axis images to set up the imaging volume. The setup can be performed via the following steps:

1) Copying the slice location on the 4-chamber view (Panel A);
2) Adjusting the center of the slab on the short-axis images to cover the entire left ventricle (Panel B);
3) Placing the crossed-pair navigator on the liver dome using the multi-plane localizer (Panels C-D).

It is preferred to image on 4-chamber view rather than short-axis view as imaging at 4-chamber view usually results in fewer motion artifacts.

Like segmented 2D LGE imaging, non-selective inversion is performed for magnetization preparation during systole and data acquisition is performed with segmented cartesian trajectory. The inversion time is adjusted based on the TI scout scan for proper contrast. Figures 2 and 3 show screenshots of imaging parameters



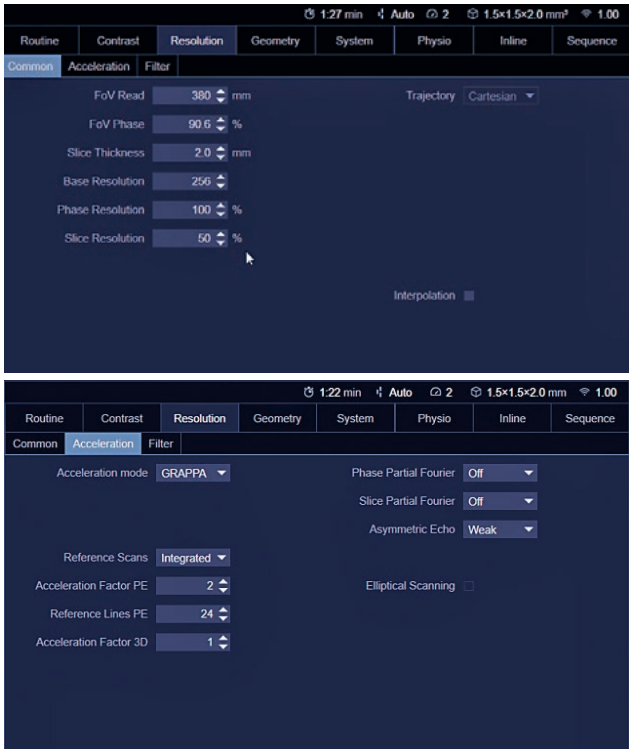
1 Illustration of image planning for 3D LGE.

in the Routine and Resolution tabs. We image a 3D slab with 40–45 slices per slab and a slice thickness of 2 mm. A large field-of-view (380 mm) is used to avoid folding artifacts in the 4-chamber plane. With an in-plane matrix size of 256 x 256, the spatial resolution is 1.5 x 1.5 x 2.0 mm^3. GRAPPA is used for an acceleration rate of two in the phase encoding direction.

The timing of acquisition is adjusted to place the read-outs during end-diastole, as shown in Figure 4. Typically, approximately 40 *k*-space lines are sampled per heartbeat depending on the heart rate. The crossed-pair navigator is used for gating and slice-tracking during the free-breathing acquisition with an acceptance window of ± 4 mm. Respiratory motion adaptation is also used to automatically locate the end-expiration position of the navigator. The acquisition time is approximately three minutes assuming a navigator efficiency of 40%.

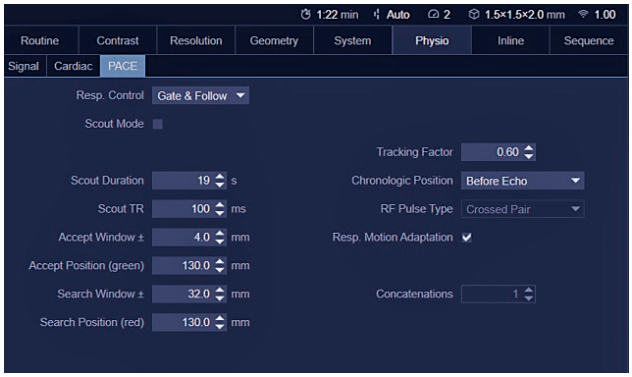
In addition, the protocol uses "Cardio" for matrix optimization and "Cardiac B0 Shim" with the adjustment volume on the heart.

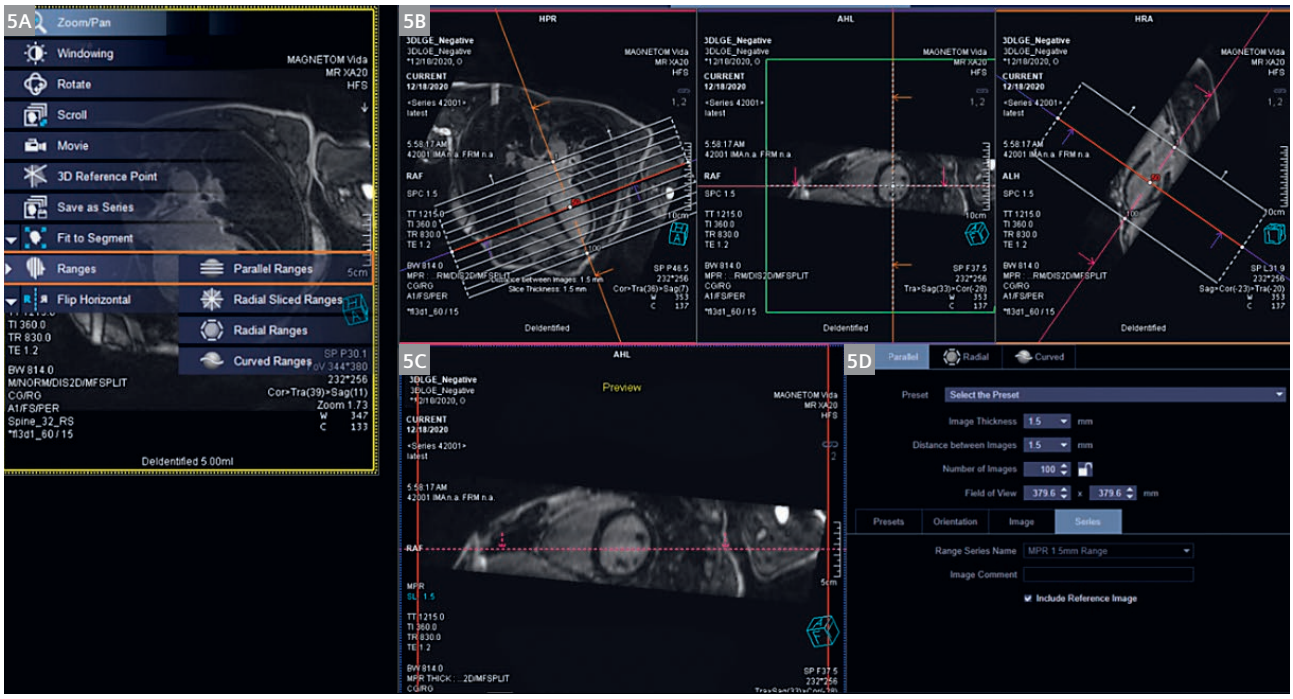
2 Screenshot shows Routine tab of the 3D LGE protocol.



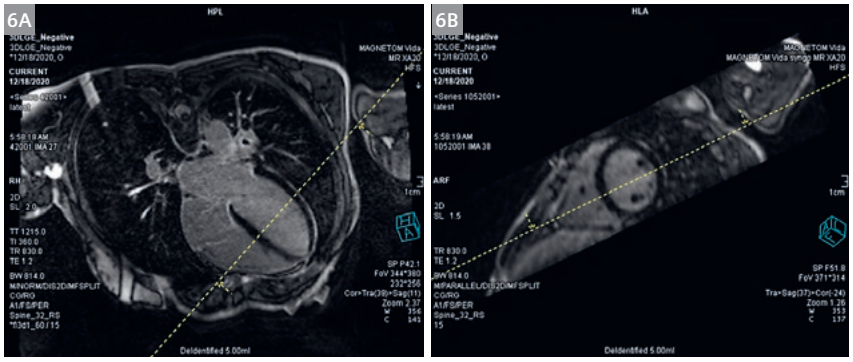
3 Screenshot shows Resolution tab of the 3D LGE protocol.

4 Screenshot shows Physio tab of the 3D LGE protocol.

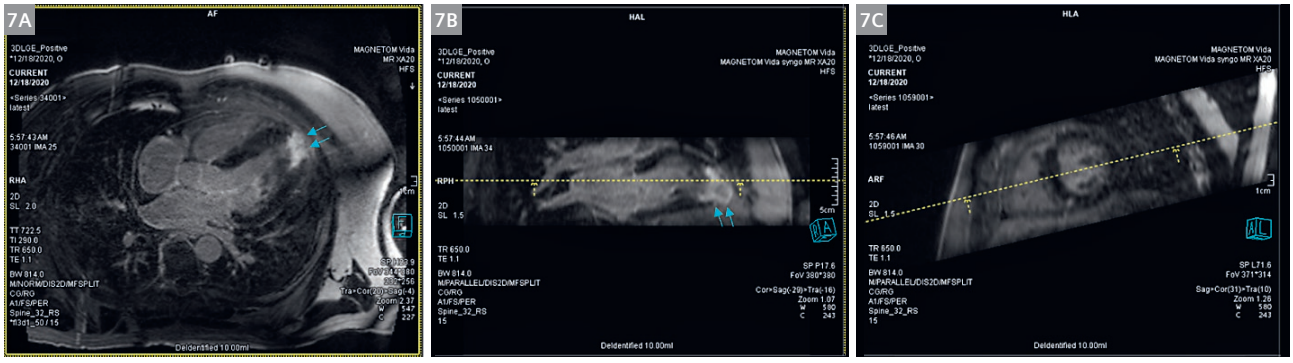




5 Illustration of reformatting the 3D LGE images to short-axis planes. **(5A)** Select "Parallel Ranges" on the source images. **(5B)** Adjust the orientation and location of the slices to be reconstructed. Short-axis views are set up in this example. **(5C)** Preview of the slices to be reconstructed. **(5D)** Parameters to adjust the coverage of the slices.



6 Exemplary images of 3D LGE acquisition in a subject with suspected cardiomyopathy. **(6A)** A 4-chamber slice. **(6B)** A short-axis slice reformatted from the 4-chamber 3D LGE images. No scar is present in this case.



7 Exemplary images of 3D LGE acquisition in another subject. **(7A)** A 4-chamber slice. **(7B)** A 2-chamber slice reformatted from the 4-chamber 3D LGE images. **(7C)** A short-axis slice reformatted from the same dataset. Scar is present in the apical segment (arrows).

Image reconstruction

The acquisition is reconstructed inline and the images can be reformatted to short-axis and/or 2-chamber views as desired using multiplanar reconstruction. As shown in Figure 5 the reconstruction can be done in the following steps:

1) Selecting the 3D LGE series as the source images in MR View&Go or opening the series with MR View&Go.
2) Selecting "Parallel Ranges" from the upper left corner menu of the source images (Fig. 5 Panel A).
3) Adjusting the orientation, position, and coverage of the slices to be reconstructed (Fig. 5 Panel B and D).
4) Scrolling through the slices in the Preview window to check if the results are satisfactory (Fig. 5 Panel C).
5) Clicking "Start" to start the reconstruction and then "Accept" to save the output images (Fig. 5 Panel D).

Clinical examples

Figures 6 and 7 show exemplary images of 3D LGE from two clinical cases. Both the original 4-chamber view and the reconstructed short-axis or 2-chamber views are included. The first case was LGE negative with no scar present. The second case was positive showing scar in the apical area.

Discussion

In this article, we described the workflow and set up of how 3D LGE is performed at our center. With the modified protocol, we can perform high-resolution LGE imaging of the ventricle within five minutes. The workflow has been simplified to one-time setup by using 3D and free-breathing acquisition. A higher through-plane resolution is achieved compared to multi-slice 2D LGE imaging. The 3D images are acquired on 4-chamber planes but can be conveniently reformatted to other planes for flexible interpretation.

The .exar1 protocol is available for download at:
www.siemens-healthineers.com/magnetom-world
> Clinical Corner > Protocols > Cardiovascular MRI

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