MR Protocols

Knee Imaging

Knee examinations commonly represent 10% to 15% of all MR procedures at most of outpatient clinics or centers. Therefore, any incremental improvement in workflow and scan efficiency becomes critical. In addition, recent technology developments made in improving brain MR exams can often be migrated to knee imaging, as both anatomies can be imaged under similar conditions in the magnet.

The additional challenge of the knee exam is that it requires sub-millimeter spatial resolution. This is possible on most up-to-date MR scanners, which typically achieve an in-plane resolution of 0.4 to 0.6 mm in 2D Fast Spin Echo scan protocols, with or without fat suppression. As the sequence is 2D, though, the slice thickness remains in the range of 3 mm to 4 mm, which still is a concern when trying to image small cartilage fissures or meniscal tears, for instance.

The 3D Cube sequence, first introduced for brain applications, has recently been optimized for use in knee imaging, and is now rapidly gaining popularity worldwide. Cube enables the acquisition of a quasi-isotropic data set with typically a 0.4 x 0.4 x 0.6 mm voxel size at 3T and 0.6 x 0.6 x 0.6 mm at 1.5T in a scan time of 7 minutes or less (depending on the knee size and resolution), providing a true Spin-Echo contrast, as opposed to conventional 3D gradient-echo based techniques.
The following protocol was provided by Eric Lévêque, senior radiographer at IRM Jardin Des Plantes, Paris, France. The clinical case was provided by Dr. Eric Pessis, Centre Cardiologique du Nord, St Denis, France.

HOW IT WORKS

Cube is a 3D Fast Spin Echo sequence, developed initially for brain imaging. Data are acquired using a relatively long echo train in a single slab or volume. The challenge in knee imaging comes from the much shorter T1 and T2 relaxations of the structures of interest, especially the articular cartilage, but also meniscus, bone marrow, and tendons and ligaments. Adjustments in the pulse sequence design relate particularly to shortening the echo spacing (the time interval between adjacent RF pulses in the echo train) thanks to an optimization of gradient and RF waveforms. This reduces the blurring that could occur when acquiring data from short T2 species.

SCAN PROTOCOL

Series	Acquisition	Resolution & Reconstruction	Scan Time
2DSSFSE, 3-pl.	TR=585, TE=85, BW=83.3, 0.5Nex	4 mm, FOV=21x21, 256x128	0:14 min
Cube, SAG	TR=1800, TE=50, ETL=30, BW=111.1, 0.5Nex, CV22=1 (MSK), CV12=90 (Center-k), Fat Sat Classic, ARC slice x2 (maxi), Phase x2 (maxi), 0.8 Phase FOV, Sat-rl	0.6 mm, FOV=21.1, 384x352, ED, Z512, Z2, 205 slices, Clariview filter “e” (prospective)	7:29 min
2D-FSE T1W, SAG	TR=380, TE=min-full, ETL=3, BW=50kHz, 2Nex, 0.8 Phase FOV	3.3 mm, 0.8 mm gap, FOV=18, 416x320, ED, TRF,	1:18 min

Table 1. FOV and matrix size are tailored to produce a true isotropic, 0.6 mm voxel size. Cube images are first retrospectively filtered with Clariview filter D, then reformatted in the 3 orthogonal standard planes, 2.1 mm thickness (average).

USEFUL TIPS

- Scan time can be optimized by slightly adjusting the ETL (30 to a maximum of 40), the number of slice locations depending on the actual knee size, and the ARC acceleration factors.
- Position lateral Sat bands near each lateral end of the axial localizer image.
- Use the option “Whole Volume Excitation.”
- On all Discovery MR450/750 and Optima MR450w/750w scanners, set up CV12 “Center-K-space refocusing flip angle” at 90 (1.5T) or 70 (3T). Note that this setting is not saved in the scan protocol database and has to be set up for the current exam from the default value at 30.
- At 1.5T, Cube reformation can benefit from running a retrospective Clariview filtering (D) prior to reformatting.

CUBE PROTOCOL

A scan protocol using Cube to visualize the entire knee may be applied at either 1.5T or 3T. (Cube is a proprietary technology available from GE Healthcare.) The differences in each step between 1.5T and 3T are noted.

- Limit the echo train length (ETL) to about 32, not more than 40 echoes. This will dramatically decrease the blurring that otherwise would prevail with short T2 species.
- Keep the echo spacing short, by using a high receive bandwidth. At 3T, it makes sense to use the higher SNR capability to increase the receive bandwidth further.
- In order to not increase the scan time too much because of the lower echo train, the TR should be reduced significantly, down to 1500ms at 1.5T, 1700 at 3T. The synovial fluid is still quite bright even in pure Proton Density, thanks to the Fast Recovery gradient and RF pulses applied at the end of the repetition time to eliminate T1 saturation.
- Last, but not least, Cube benefits from the latest development in parallel imaging and RF coils, allowing accelerated data acquisition in both slice and phase encoding directions, using either the HR T/R Knee Array coil or the new GEM-Flex Medium Phased Array coil.

CUBE RESULTS

Sample images from this optimized MRI protocol of the knee exam are shown below, at 1.5T and at 3T.

Field Strength: 1.5T

The following exam was completed using a Discovery MR 450 1.5T scanner, and the HR T/R Knee Array coil.

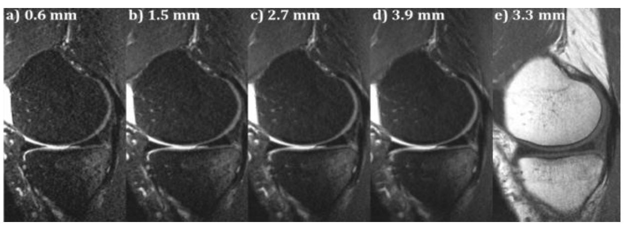

Figure 1. Cube, with variable reformat thickness (a-d). 2D-FSE T1W, sagittal (e).

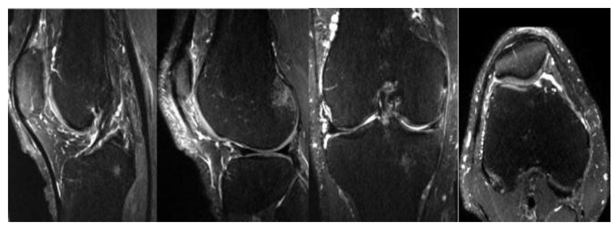

Figure 2. Cube: reformat, 2.1 mm thickness.

SAMPLE CASE

The following exam was performed on a Signa HDxt 3.0T, with the HR T/R Knee Array coil.

CUBE PROTOCOL USED IN THIS EXAM:

- TR=1740, TE=25, ETL=32, BW=50kHz, 0.5Nex, Phase FOV=1, Fat Sat Classic, Sat-rl.
- 0.6 mm slice thickness, FOV=16.5, 416x384, ED.
- Scan time = 7:18min for 190 slices.

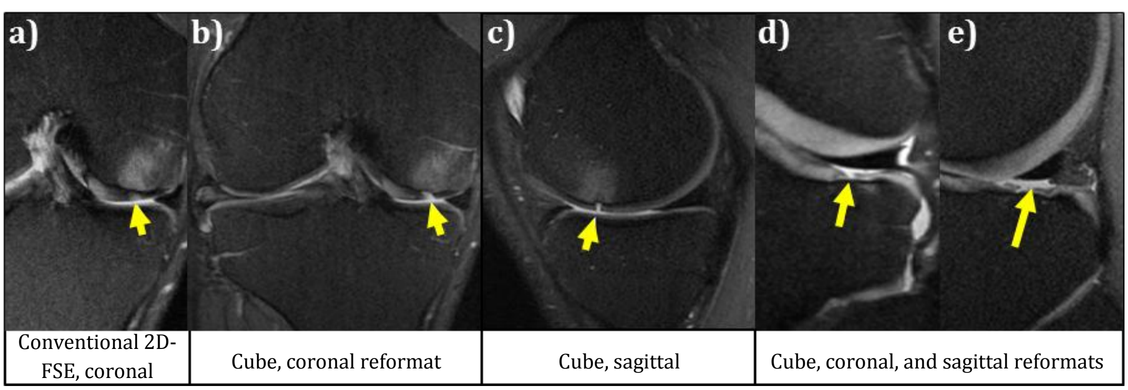

Figure 3. Small cartilage defect at the central weight-bearing medial femoral condyle (a-c). Fat-suppressed intermediate-weighted FSE image (a) of medial femoral condyle shows a full-thickness cartilage lesion (arrow) at the central weight-bearing medial femoral condyle. On the corresponding sagittal and coronal images reformatted from fat-suppressed 3D isotropic Cube intermediate-weighted MR data (b & c), the small cartilage defect (arrows) is better visualized. Cartilage defect at the central weight-bearing lateral femoral condyle (d & e). Sagittal and coronal images reformatted from the same Cube data set show an irregular articular surface of the lateral femoral condyle (d & e).