Imaging of the Red and White Zones of the Meniscus Using a 3D Cones (UTE) Subtraction Pulse Sequence

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Introduction: Distinction between the red (vascular) and white (avascular) zones of the meniscus of the knee is of considerable clinical importance. Tears which are entirely in the red zone, or in both the red and white zones generally heal well, but those entirely in the white zone often do not heal and surgical resection of the torn region is usually performed (1). Because a tourniquet is generally used at surgery, and intra-articular fluid pressure is raised the red zone may not bleed and it may not be possible to determine whether a tear involves the red zone, or not. A method of determining this preoperatively might therefore be of considerable value. Direct measurement of T2 has only shown a small difference between the red and white zones and the most effective means of demonstrating them has been by use of an intravenous gadolinium chelate to show enhancement in the red zone and lack of it in the white zone (2). A critical component of this has been the use of subtraction of a second longer TE image from the first UTE image to reduce the signal from the adjacent peri-meniscal tissue which borders on the red zone and shows a greater degree of enhancement. This has only previously been done with 2D sequences, and only in the sagittal and coronal planes. In this study we employed a 3D Cones sequence to allow display of images in any plane, and followed the subjects for over two hours post injection to determine the time course of enhancement.

Materials and Methods: Examinations were performed on a patient with an oblique posterolateral tear of the medial meniscus. Imaging was performed using a radial out 3D Cones acquisition. The 3D cones sequence employed a unique data sampling trajectory scheme that samples MRI data along twisting paths along evenly spaced cone surfaces in 3D (Fig.1) (3). It samples data starting from the center of k-space and twist outwards from there with the data acquisition starting as soon as possible after the RF excitation. To minimize scan-time, anisotropic FOV encoding together with slab-selection was used to excite and encode an axial region around the meniscus (see Fig.2). Two fat suppressed echoes were obtained at TE = 30µs and TE =12ms, to allow dual echo subtraction. Scans were repeated for four cycles, one before gadolinium-DTPA injection (0.26mmol/kg) and three at different post injection time points.

Experimental Results: An example set of a dual echo images and the dual echo subtraction is shown in Fig.3, while Fig.4 shows several such dual echo subtraction images before and at different time-points after injection. Obvious enhancement was demonstrated in the periphery of the meniscus. In the subtraction scans the enhancement extended centrally over time. Enhancement was also apparent in the white zone adjacent to the tear.

Conclusion: Demonstration of the red and white zones was dramatic, as was progression of the extent of the enhancement over time. The availability of the oblique axial plane gave a better demonstration of the location and extent of enhancement than either of the coronal or sagittal planes and depicted the progression of contrast agent diffusing into the normal white zone. Demonstration of enhancement in the white zone adjacent to the tear was evidence of vascularization and attempted healing.

Increasing in T2 in the white zone region adjacent to the tear did not result in suppression of enhancement of the subtraction images.
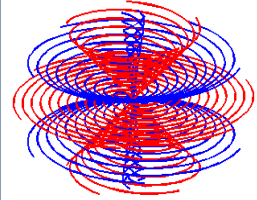

Fig.1: 3DCones k-space trajectory. K-space trajectories originate at the center and move outwards.

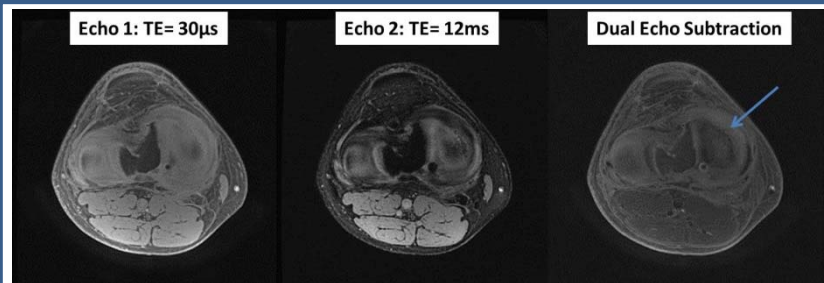Fig.2: Sagittal localizer image showing the approximate slab selection of the axial images.

Fig.3: Axial 3DCones images at TE = 30µs and TE =12ms. Their subtraction shown on the right shows positive contrast for the meniscus (arrow).

Ref: [1] McCarty, Clin Orthop Relat Res 402:122-34 (2002); [2] Gatehouse, Br J Radiol 920:641-7(2004); [3] Gurney, MRM 55:575-582 (2006)
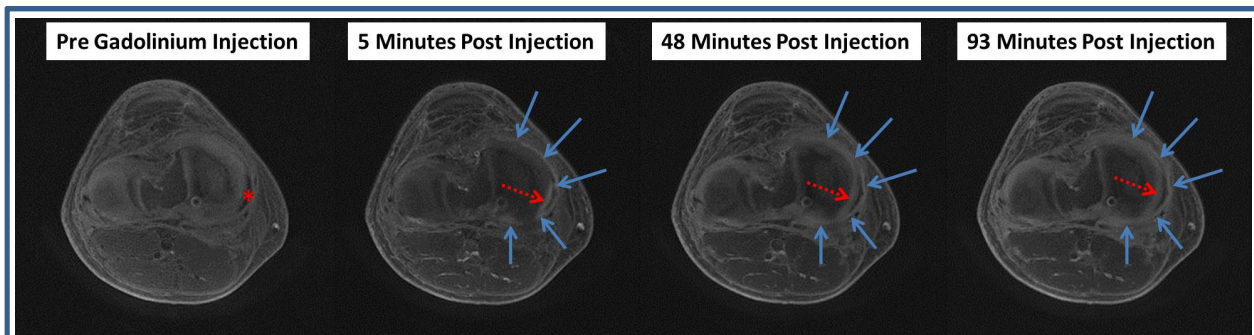

Fig.4: Four axial 3DCones dual echo subtraction images before gadolinium-DTPA injection and at three time-points after injection. An oblique tear is seen (*). Progressive enhancement of the red zone is readily seen (solid arrows) as well as in the vascularized region in the white zone (dashed arrows)