Making the invisible visible: Magic Angle a source of artefact or a new technique for imaging?

Karyn E Chappell[1], Catherine Van De Straeten[1], Quentin Herreros[2], Donald W McRobbie[3], Wladyslaw Gedroyc[4] and Djordje Brujic[5]

[1]Surgery and Cancer, Imperial College London, United Kingdom, [2]Institut de Physique Nucléaire de Lyon, Lyon, France, [3]Medical Physics & Radiation Safety, Flinders Medical Centre, Adelaide, Australia, [4]Imperial College Healthcare NHS Trust, London, United Kingdom [5]Mechanical Engineering, Imperial College London, London, United Kingdom.

Background

How can we gain more information about collagen-rich structures of the knee? Can an artefact be used to make the invisible visible? In conventional pulse sequences collagen signal in tendons and ligaments decay faster than we can collect it. The structure appears dark and is inferred by the surrounding brighter soft tissue[1]. The magic angle artefact causes an increased signal intensity within tendons and ligaments when they are aligned at 55˚ to the main magnetic field B_0[2]. The artefact is caused by a minimization of the dipole-dipole interaction which lengthens the T2 in the part of the structure orientated at the magic angle (55˚)[3]. This allows more time to collect a signal directly from the collagen; e.g. using spin echo sequence the T2 decay is around five times longer[4]. A significant limitation to the further development of magic angle imaging in conventional MRI scanners is space; it is extremely difficult, often impossible, to adequately position the patient within the fixed diameter cylindrical bore[5].

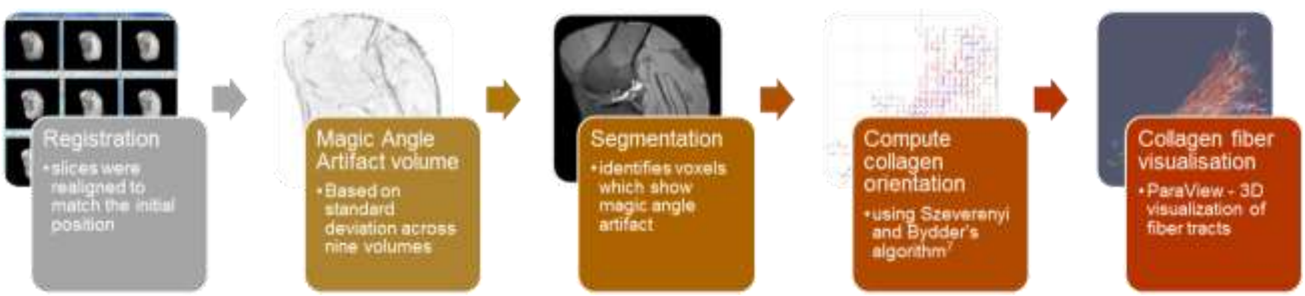
Purpose

We have developed a prototype rotating magic angle scanner[6] (**figure 1**) that allows B_0 to move around the patient so we can perform magic angle imaging *in-vivo.* We think it is possible to use the magic angle artefact as a contrast mechanism to differentiate between normal and ruptured ligaments, especially in the area in-between which includes partial tears. Here we present developmental work carried out on a conventional scanner.

Figure 1: A photograph of the prototype scanner - an open MRI system with the main field B_0 parallel to the poles (**red arrow**). Two motors rotate the magnet about two orthogonal axes allowing B_0 to move around the patient.

Methods

A caprine stifle was scanned in nine different positions relative to B_0 using a Siemens 3T Verio. The stifle was embedded in a test sphere with the nine positions marked on it. The sphere was placed in a holder positioned in the center of the 12 channel head coil. A 3D PD SPACE sequence optimized to cause the magic angle artefact was repeated in each position once the test sphere was rotated. Parameters were: TR1300ms, TE13ms, FOV256mm^2, BW434Hz, 1x1x1mm isotropic voxels. The raw data was saved in a DICOM format. The post processing steps are shown below.



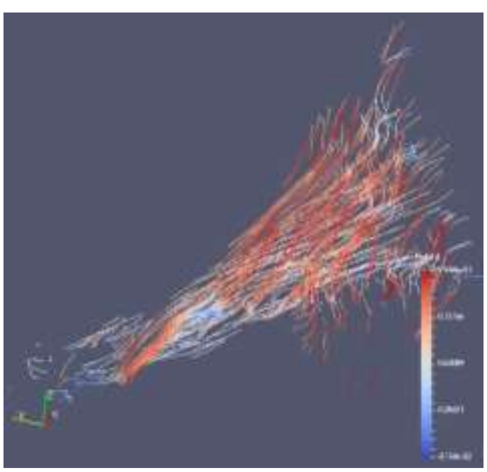


Figure 2: ParaView image of the ACL showing the two bundles anteromedial in-front (**pale red**) and posterolateral behind (**pale blue**)

Results

An image of the Anterior Cruciate Ligament (ACL) showing the collagen fiber bundles made up of the anteromedial portion to the front and the posterolateral portion underneath is shown in **figure 2**.

Conclusions

Development of the new magic angle scanner continues and we hope to start doing volunteer scans in the near future. The research presented here shows that even within the confines of a conventional scanner it is possible to use the magic angle artefact as a contrast mechanism to make invisible structures visible.

References

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