Imperial College London

MRI but not as you know it!

Karyn E Chappell[1], Donald McRobbie[2], Wladyslaw Gedroyc[3], Quentin Herreros[4], John VM McGinley[5], Mihailo Ristic[5], and Djordje Brujic[5]

[1]MSK Lab, Imperial College London, United Kingdom, [2]University of Adelaide and Flinders Medical Centre, Adelaide, Australia [3]St Mary's Hospital MRI Unit, Imperial College Healthcare NHS Trust, London, United Kingdom [4]Institut de Physique Nucléaire de Lyon, Villeurbanne Cedex, France, [5]Mechanical Engineering, Imperial College London, United Kingdom

QUESTIONS

- How can we gain more information about collagen-rich structures of the knee?
- Can the magic angle effect be used to make the invisible visible?

BACKGROUND

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 artifact causes an increased signal intensity within tendons and ligaments when they are aligned at 55˚ to the main magnetic field B_0[2].

The artifact 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]

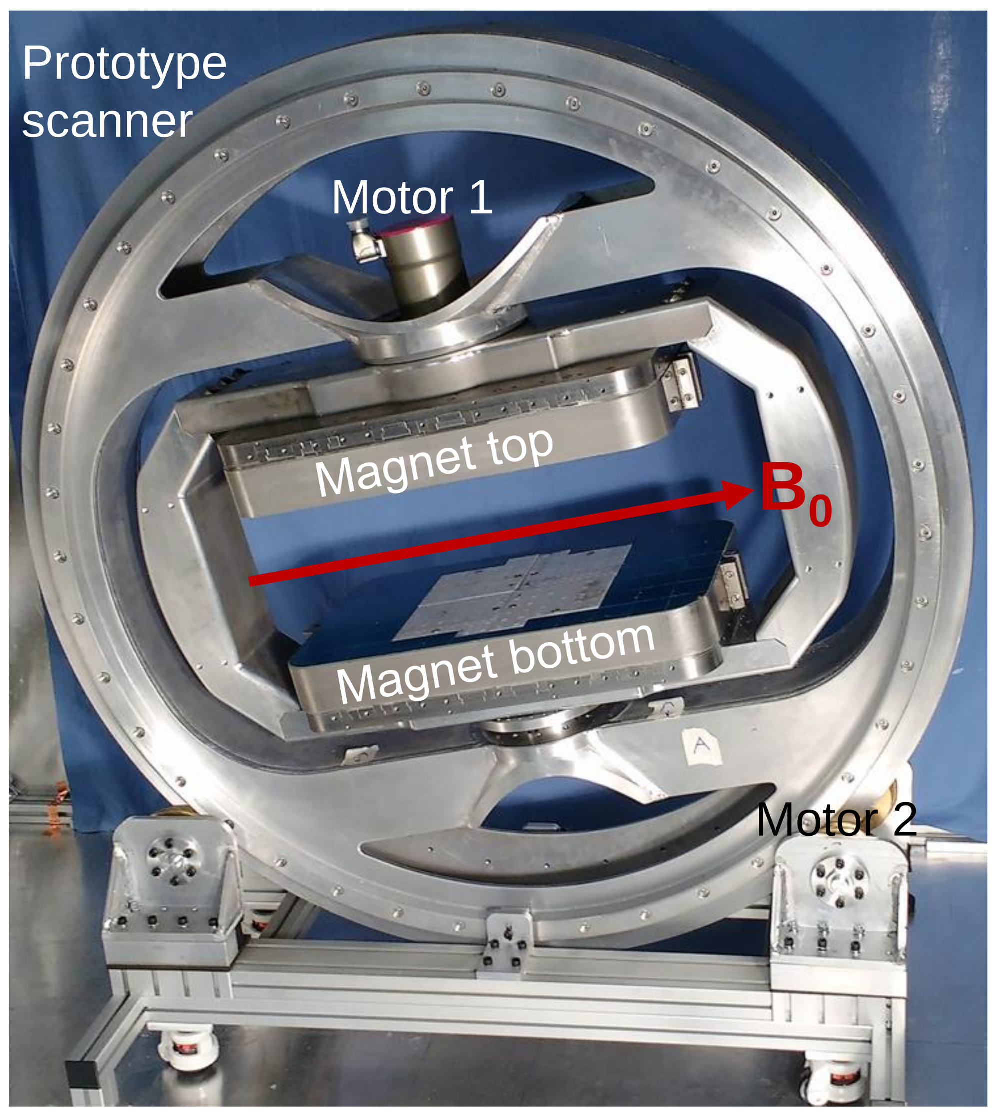
PURPOSE

A prototype rotating magic angle scanner[6] (**figure 1**) is being developed that allows B_0 to move around the patient's extremity to perform *in-vivo* magic angle imaging.

It may be possible to use the magic angle effect to differentiate between normal and ruptured ligaments, especially in partial tears by showing collagen fiber alignment.

Here we present developmental work carried out on a conventional wide-bore scanner.

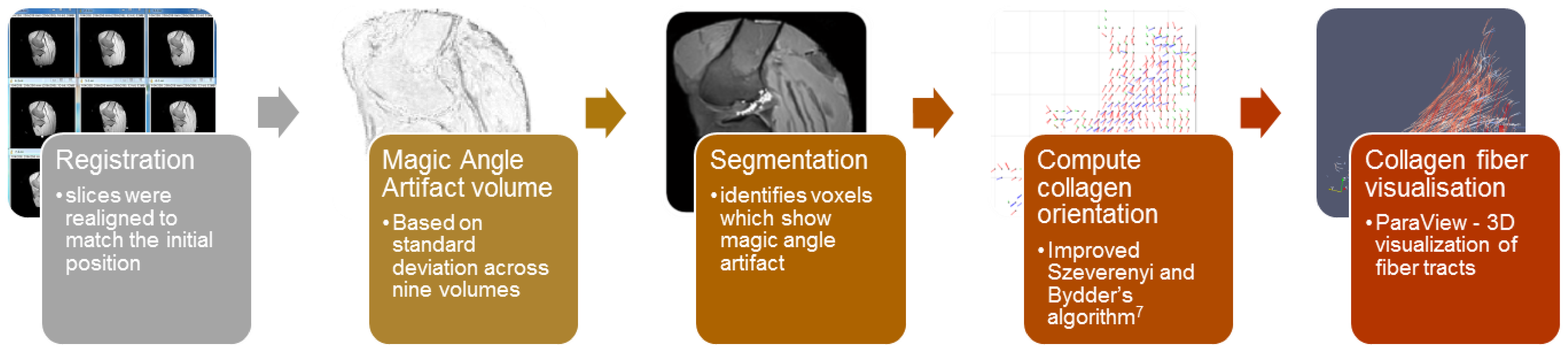
FIGURE 1



The open MRI system with the main field B_0 parallel to the magnet poles (**red arrow**).
Two motors rotate the magnet about two orthogonal axes allowing B_0 to move around the patient.

METHODS

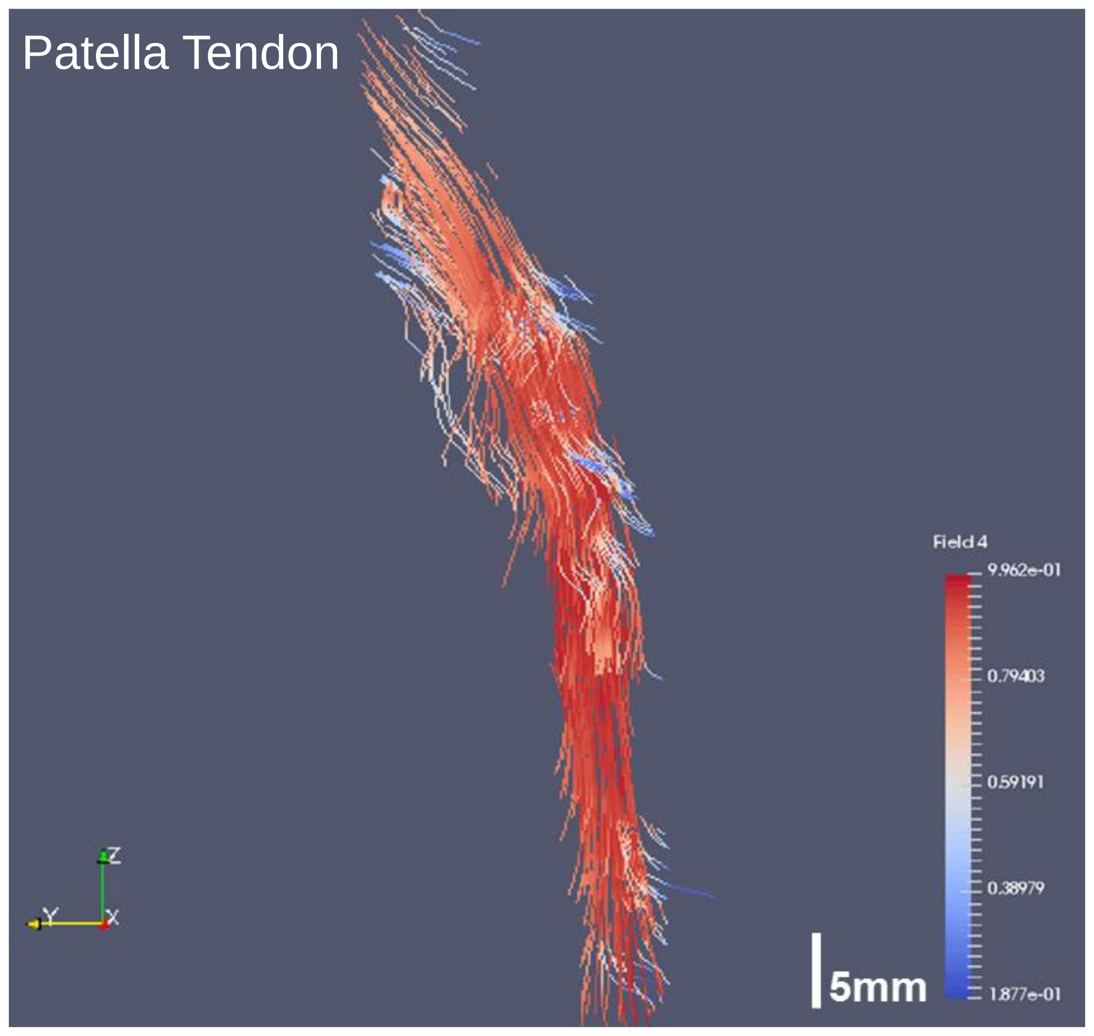
- A caprine stifle (knee) was scanned in nine different positions relative to B0 using a Siemens 3T Verio.
- The stifle was embedded in a test sphere with the nine positions marked on it.
- The sphere was placed in a holder positioned in the center of the 12 channel head coil.
- A 3D PD SPACE sequence optimized to cause the magic angle effect was repeated in each position once the test sphere was rotated.
- Parameters were: TR1300ms, TE13ms, FOV256mm2, BW434Hz, 1x1x1mm isotropic voxels.
- The raw data was saved in a DICOM format. The post processing steps are shown below.



RESULTS

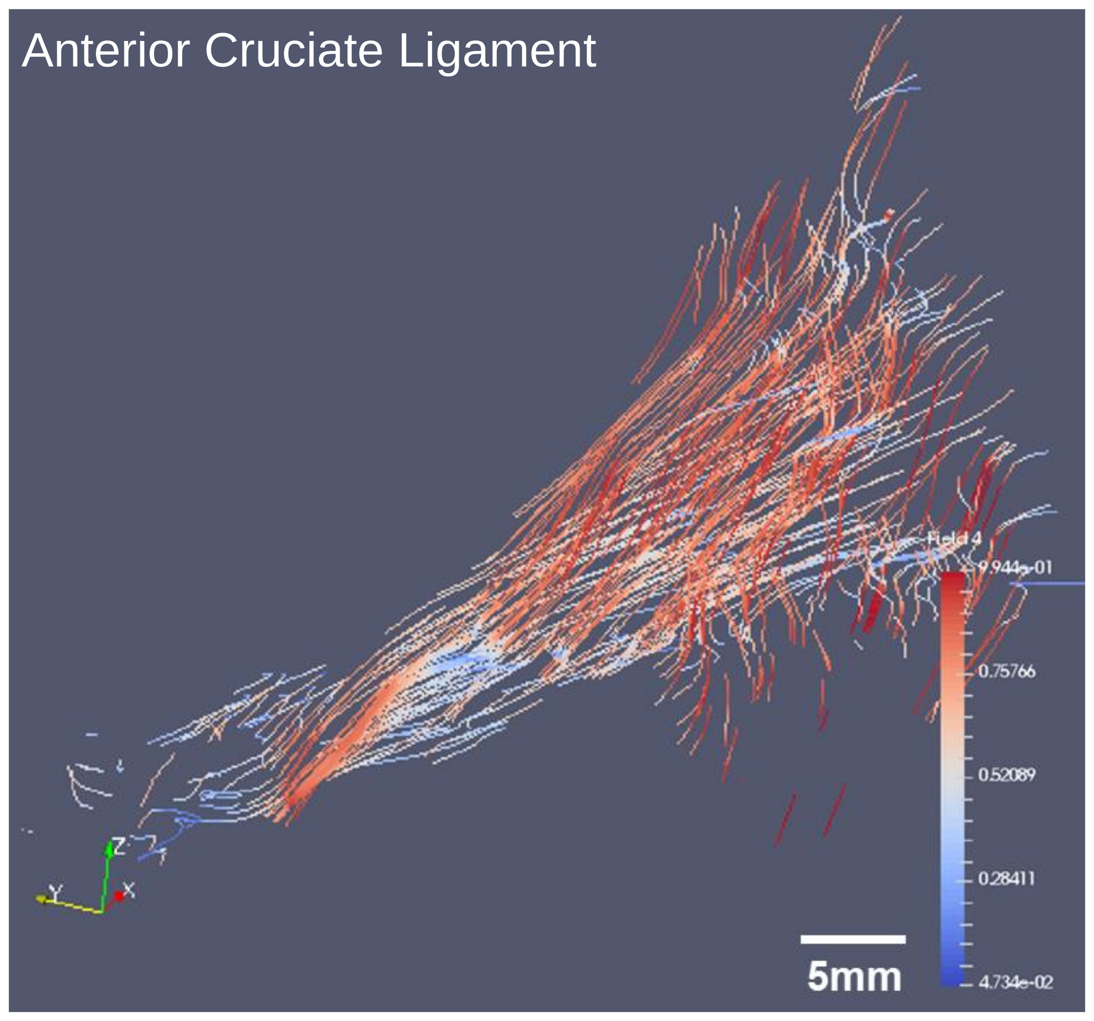
An image of the patella tendon in **figure 2** shows highly aligned **red** collagen fiber tracts running parallel along the length of the tendon.

FIGURE 2



An image of the Anterior Cruciate Ligament (ACL) in **figure 3** shows the collagen fiber bundles made up of the anteromedial portion in **red/orange** to the front and the posterolateral portion in light blue underneath**.**

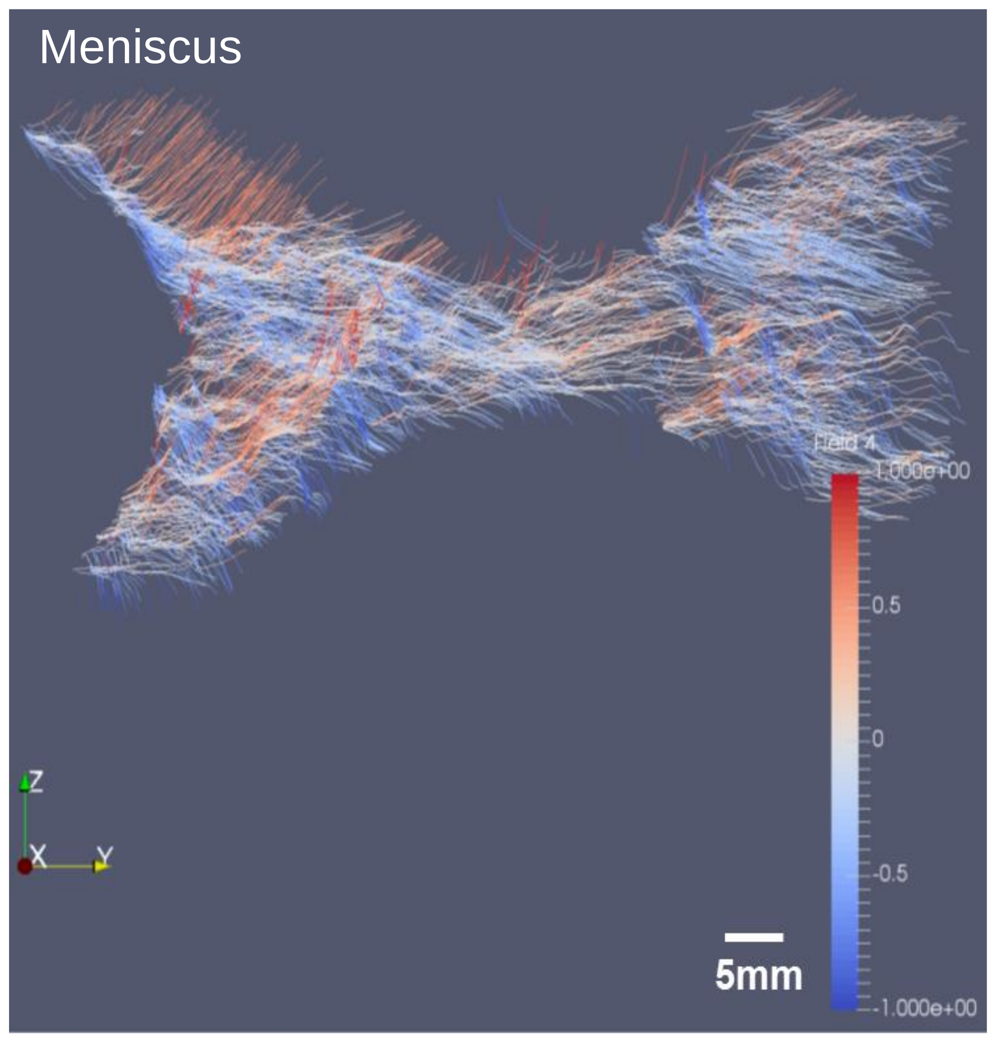
FIGURE 3



RESULTS continued

An image of the meniscus in **figure 4** shows the more variable collagen tracts with horizontal and circumferential fibres light blue and light red.

FIGURE 4



CONCLUSION

- Our findings show that even within the confines of a conventional scanner it is possible to use the magic angle effect as a contrast mechanism to make invisible structures visible.
- Development of the prototype magic angle scanner continues and the first *in-vivo* volunteer scans will begin shortly.

ACKNOWLEDGEMENTS

- This work was supported by the National Institute for Health Research (NIHR) Invention for Innovation (i4i) under Grant II-LA-1111-20005.
- We are grateful to Charing Cross MRI Department and Imaging Committee for the use of the Siemens 3T Verio.

REFERENCES

[1] Oatridge *et al*. Clinical Radiology (2003) 58: 384-388.
[2] Bydder *et al*. J. Magn. Reson. Imaging (2007) 25: 290-300.
[3] Erickson *et al*. Radiology (1993)181: 389-392
[4] Peh & Chan. Br J Radiol (1998)71: 31-6
[5] Rea *et al*. Magnetic Resonance Engineering (2010) 37B: 220-225
[6] McGinley *et al*. Journal of Magnetic Resonance (2016) 271: 60-67
[7] Szeverenyi & Bydder. MRM (2011) 65: 463-470

CONTACT

k.chappell@imperial.ac.uk