Magic Angle Phenomenon

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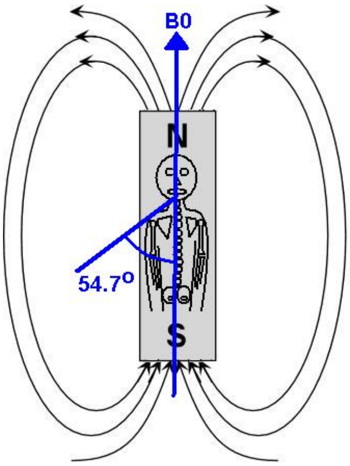
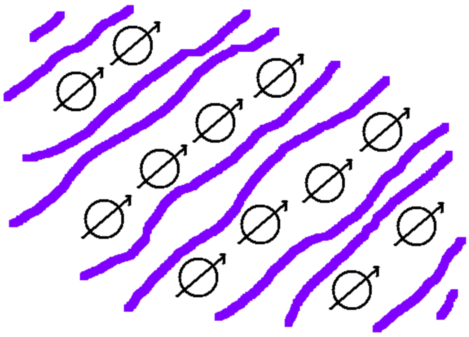


The Magic Angle Phenomenon is an artifactual increased signal seen in MRI imaging, in structures with ordered / organised collagen. This includes tendons, fibrocartilage, hyaline cartilage, ligaments and menisci. It happens when they lie at 54.7^{o} to the main magnetic field, B0.

Much of our image forming signal in MRI originates from water. In most body tissue, water protons are relatively free to move about. Therefore when a resonant RF signal is received proton re-alignment occurs readily.



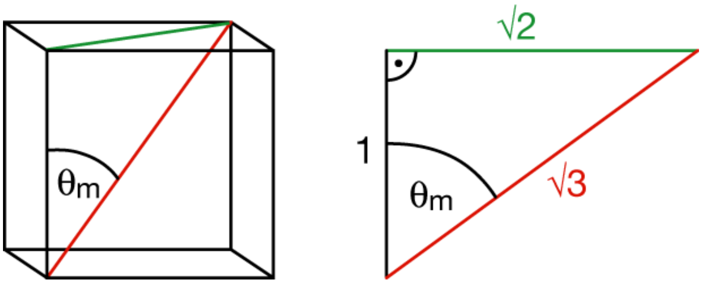
Water in collagen however is tigtly bound and as such, the collagen fibres restrict the movement and orientation of the water protons. This promotes dipolar interactions between the water protons, i.e. they tend to align with each other.

When the resonant RF frequency is introduced, the water protons within the collagen fibers will resist being re-aligned. The result of this is that there will be a reduction in the amount of transverse magnetization to decay once the RF signal is switched off. This causes a very rapid T2 decay time of around 250μs and gives us an extremely low signal intensity, such as in the Achilles tendon or the patellar tendons.

Low signal in tendons

So, organised collagen usually produces low signal in MR imaging.

At one peculiar angle, however, these dipole interactions between water protons disappear completely This is because the interaction between two adjacent water molecules is given by the formula $3 \cos^2 \theta - 1$.
When $\theta = 54.7^o$ you find that $3 \cos^2 54.7 - 1$ = zero, i.e. at this angle there is no resistance in molecule re-alignment, T2 relaxation is maximal at around 25 ms (~100x slower than before) and whilst still quicker than many other tissues, it is slow enough to produce an MR signal.



This is called the Magic Angle and is interestingly the angle made between the diagonal line corner to corner in a cube, and the upright wall of the cube.

The MRI appearance is a section of high signal within a collagen containing structure, at the point where it is lying at 54.7^o to B0.

Scanning sequences using short TEs such as T1 or PD sequences are more likely to be prone to magic angle artefact as these will emphasise the difference in T2 relaxation times. Sequences with longer TEs such as T2 will give enough time before the echo is sampled for both areas to have fully relaxed.
For similar reasons, the artefact will be more likely when using a high flip angle, so you are unlikely to see it with gradient echo imaging, and, spin echo will be more prone than fast spin echo. At higher field strengths T2 relaxation is quicker, and so with 3T scanners there is an increased likelihood of magic angle artefact compared with 1.5T scanners.

Look for it in in the outer portions of the rotator cuff, the supraspinatous tendon, the distal patellar tendon, tendons of the ankle, extensor & flexor pollicis tendons of the wrist or any part made of collagen that lies in a curve!
High signal within a tendon can mimic tendonopathy, so it is important that radiographers and radiologists are aware of the Magic Angle Phenomenon and how to overcome it, i.e. move the anatomy away from 54.7^o or repeat the scan with a T2 or gradient echo sequence and compare.