A Device to Facilitate the Performance of Magic Angle Studies on the Wrist and Elbow

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Introduction

It has been known since the earliest days of clinical MRI that dipolar coupling is an important relaxation mechanism in some body tissues – notably cartilage and tendon [1]. This phenomenon was explored to some degree in the development of MRI [2], but was regarded as an artifact to be avoided. It was not until recently that attempts were made to use the signal provided by the effect to improve images and develop useful contrast [3,4]. One of the main reasons why little attention has been given to the topic may be because the recovery of suitable data to study the effects can be tedious and awkward in a typical clinical MRI system. We describe here a unit designed to make this form of imaging easier in the wrist, arm and elbow. This device moves the region to be investigated round an arc, unlike previous systems which provided some of the same facilities which relied on motion parallel to, or transverse to, the machine axis [5].

The theory underlying the changes in relaxation time constants observed in some complex systems is well known [6]. The relevant result from the theoretical analysis is that, in a rigid lattice, the relaxation rate is minimized when the term $(3\cos^2\theta - 1)$ is equal to zero, where θ is the angle between the direction of the magnetic field (very predominantly B_0 in this instance) and the direction along which the spins are coupling in the tissue in which they are held. The maximum signal is detected when $3\cos^2\theta = 1$, or when $\theta = 54.74^o$.

Methods

A limb-positioning device actuated by rotary air-driven motors (see Figure 1) was developed as illustrated in Figure 2. The unit sits above the patient's body, and the drive moves a carriage along an arc of a circle. The carriage supports the part of the body to be studied, though in the case of the lower arm the carriage normally supports the subject's elbow. Movement of the carriage then moves the upper arm from its starting position roughly parallel to the magnet field in a standard machine so as to cause it to lie at an angle of at least 60^o to it. In the case of the forearm, which starts lying transverse to the main field it is only necessary to have an excursion of less than 40. The fact that the patient's arm is almost always significantly above the centre line of the magnet, means that the effective diameter of the region of good field is significantly smaller than it is nearer the machine centre. This restriction can be minimised by careful selection of starting positions.

The motor used, and the optical position feedback sensors were completely MR-compatible [5], and the assembled system was checked for its compatibility. It was not found not to affect imaging performance in any significant manner.

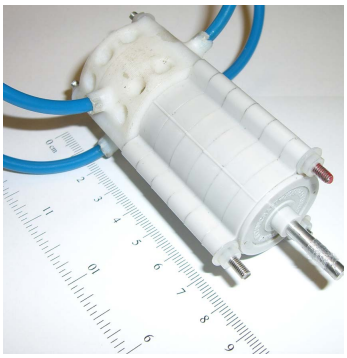

Figure 1. Pneumatic actuator developed for magic angle units.

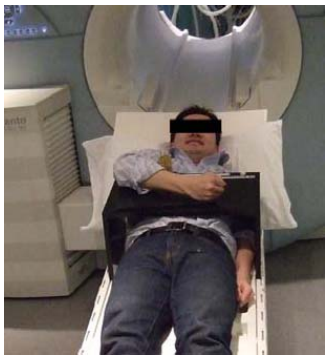

Figure 2: A volunteer in place in the magic angle platform.

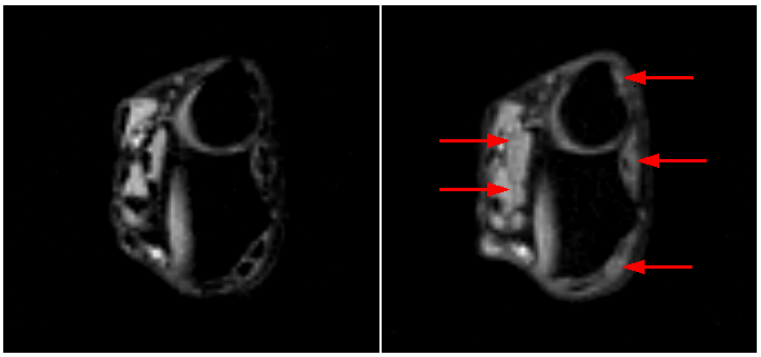

Figure 3: Axial images of the wrist taken at (Top) 0° and (Bottom) 55° to the static field. The red arrows point to structured tissue where signal changes are observed.

Results

There are no particular performance requirements for operating speed, as the device is moved by an operator who is seeking accuracy rather than speed. End to end traverse time was therefore about 15 seconds. Positional error was measured to be less than 1° in laboratory tests in which angular positions were entered into the control system and the final position achieved was measured. A typical pair of images obtained using the system are shown in Figure 3.

Discussion

A device which simplifies the acquisition of magic angle images from the arm has been developed and tested on human subjects prior to full clinical trials.

References

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