MEASUREMENT OF CONCENTRATIONS OF METAL IONS IN PSEUDOTUMOURS CLOSE TO METAL-ON-METAL HIPS

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Introduction: We present a method to use Magnetic Resonance Imaging (MRI) to measure concentrations of metal ions in fluid-filled pseudotumours near metal-on-metal (MoM) hips. The method uses standard imaging sequences which are available on clinical MRI scanners. The acquisition time is sufficiently short to use in routine clinical examinations.

MoM hips have been associated with pain and soft tissue reactions [1-3] and with elevated levels of Cr and Co ions in the joint fluid, blood and tissues [4, 5]. It has been suggested that soft tissue lesions may be reactions to wear debris from MoM hips [1-3]. A study of patients undergoing revision surgery found median concentrations of Cr and Co in the joint fluid of 4.8 μM and 3.4 μM respectively, measured using mass spectrometry. Cr and Co levels up to 559 μM and 87 μM were reported in the joint fluid from some of the patients in the study [4].

In the UK the Medicines and Healthcare products Regulatory Agency (MHRA) issued a Medical Devices Alert for all MoM hip replacements [6]. The MHRA recommended that all patients implanted with MoM hips should be followed up for at least five years after implantation and that painful MoM hips should be investigated using measurements of concentrations of chromium and cobalt ions in the patients' blood and cross-sectional imaging [6, 7]. Metal Artefact Reduction Sequence (MARS) MRI has been used to study the prevalence of pseudotumours in painful and well-functioning MoM hips. No significant difference was found in the prevalence of pseudotumours between the two groups [2]. The significance of high concentrations of metal ions is also unknown.

Figure 1: Plan view of phantom containing plastic vials of $CrCl_3$ solutions in a plastic rack with a metal hip at the centre of the phantom.

Method: Phantoms containing solutions of $CrCl_3$ and $CoCl_2$ at concentrations 0.1 M to 1 μM were scanned at 1.5 T (Siemens Avanto). The phantoms were scanned with and without metal hips (Figure 1). T1 relaxation times were measured using 3D gradient echo images acquired at two different flip angles (3° and 19°) [8]. 3D gradient echo images exhibited only moderate metal artefacts when a high receive bandwidth per pixel (650 Hz/pixel) was used.

Results: T1 relaxation times of water protons are reduced due to the presence of paramagnetic ions. Measurements of T1 can be used to determine concentrations of Cr^{3+} between 10 mM and 10 μM (Figure 2) and Co^{2+} between 0.1 M and 1 mM. The concentrations measured are within the range of clinically significant concentrations of Cr. The phantoms were also scanned with metal hips (ASTM75 CoCr). The T1 values measured in samples located 10-15 cm from the head of the hip were not significantly different to the values measured without the metal hip. At locations close to the head of the hip (2-3 cm) the metal artefacts introduced errors of 500 ms samples with T1~2000 ms.

Conclusions: T1 relaxation times can be used to measure clinically-significant concentrations of Cr and Co close to metal hips. The method could be used to place upper limits on concentrations of metal ions in fluid-filled lesions in patients with MoM hips. Our phantom measurements show that a T1 of 2500 ms or higher in a fluid-filled lesion indicates that the concentration of Cr^{3+} is less than 10 μM. We have demonstrated the method to produce T1 maps of the hips of a healthy volunteer and are beginning to acquire T1 images of patients with well-functioning and painful MoM hips. Results will be compared with concentrations measured using mass spectrometry of aspirated samples. The study forms part of the long-term follow-up of patients with painful and well-functioning MoM hips in order to investigate the clinical significance of pseudotumours and elevated levels of metal ions.

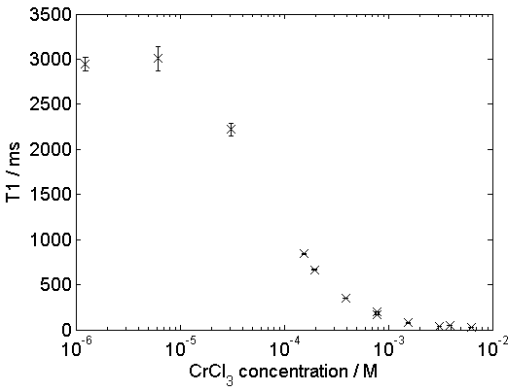

Figure 2 : T1 relaxation times of water containing $CrCl_3$ (10 mM to 1 μM).

References:

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