Magnetic Resonance Imaging of Body Calcification *In Vitro* and *In Vivo* Using Ultra Short Echo Time (UTE) Sequence

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Purpose:

The purpose of this study was to measure T_1 and T_2 relaxation times of hydroxyapatite and calcium oxalate *in vitro* and to apply it *in vivo* using an ultra short echo time (UTE) sequence [1]. Since those crystals make up 85% of the constituents of renal stones [2], the approach is well suited towards our ultimate goal in providing an MR strategy for imaging patients with known or suspected renal stones.

Materials and methods:

In vitro imaging:

We measured the T_1 and T_2 of calcium oxalate and hydroxyapatite crystals using MRI (GE Signa HDx 1.5 T scanner) with a 6-cm diameter coil and a UTE sequence. To measure the T_1, we imaged two samples of calcium oxalate and hydroxyapatite at different TR values ranging from 0.1 sec up to 4 sec with fixed TE=0.1msec. The T_2 was measured by imaging the crystals at TE values ranging from 0.1ms up to 7 ms at TR=2sec. Since the crystals showed bright signal on both imaging sequences, ROIs were drawn on each image. The averaged results for two separate acquisitions at 3 different sections were calculated from the signal intensities obtained. The results for T_1 were plotted on a scatter graph and then fitted for the exponential recovery curve by the equation $y = M_0(1-\exp^{(-x/T1)})$. The results for T_2 were also plotted on a scatter graph and then fitted for the exponential decay curve and the T_2 was measured by the equation $y = M_0(\exp^{(x/T2)})$.

In vivo imaging:

Knowledge gained from the *in vitro* experiments guided us to use appropriate imaging parameters with a UTE sequence to optimally visualize renal stones *in vivo*. A volunteer patient with a known right renal stone, based on a non-enhanced CT study obtained <1 hour prior to the MRI, was imaged on a 1.5T MR scanner (same as for in vitro imaging) using a body phased array coil. The UTE sequence was done with the following parameters: TR: 300 msec, TE: 0.1 msec, 2 echoes, BW=±31.3 kHz, FOV: 34 × 34 cm^2, 8.0 mm slice thickness, gap 1mm, 256 × 499 and 2.00 NEX .Number of slices=20

Later echo images at TE=6.7 msec were also obtained and difference images were produced by subtracting the later echo image from the first echo image. UTE imaging was acquired from the upper pole of the highest kidney to the symphysis pubis in the axial plane.

An expert radiologist correlated the findings with the non-enhanced CT findings of the patient.

Results:

The T_1 relaxation values of calcium oxalate and hydroxyapatite were as follows; 1.86 and 1.69 sec with error = 0.11 and 0.17, respectively; the T_2 relaxation values were 15.2 and 9.2 msec with error = 0.83 and 0.53 respectively (see Figures 1 and 2).

In vivo, as shown in Figure 3, the stone was demonstrated as bright signal on the UTE difference image that matched with the CT image with regards the location and size.

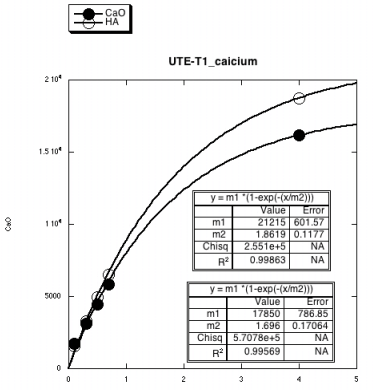

Figure 1. Signal intensity changes with TR. Note the fitted curves.

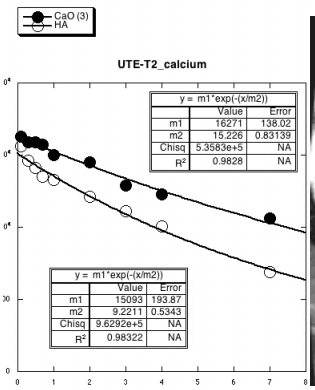

Figure 2. Signal intensity changes with TE. Note the fitted curves.

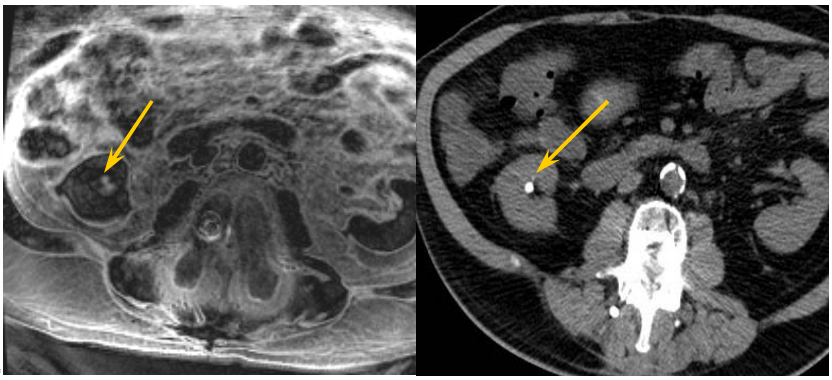

Figure 3. MR difference image shown on the left compared with the CT image on the right. The arrow indicates the renal stone. Note the excellent agreement.

Conclusion:

UTE MR imaging can be used to demonstrate calcium oxalate and hydroxyapatite (calcium apatite), the main constituents of renal stones (85%). The idea was successfully applied in imaging a patient with a renal stone and will provide the basis for further technical and clinical studies of renal stones. An MR imaging strategy to visualize renal stones is particularly important in children, women of child bearing age and pregnant females, patients in whom radiation exposure from CT is undesirable.

References:

1. Robson, M.D., and Bydder, G.M., NMR in Biomed, 2006, 19: 765-780.
2. Charles Y.C. Pak, MD, John R.Poindexter et al. Predictive Value of Kidney Stone Composition in the Detection of Metabolic Abnormalities, The American Journal Of Medicine, 2003, 115: 28-32