DUAL-ENERGY COMPUTED TOMOGRAPHY (DECT) FOR CHARACETRIZING TISSUE IRON OVERLOAD. COMPARISON TO MRI T2*

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INTRODUCTION: Iron toxicity plays a key role in tissue damage and organ failure in patients with iron overload. T2*-weighted MRI has been established as a reliable and non-invasive technique for evaluating iron overload with strong correlation with biopsy [1]. Specifically, T2* of 20 and 10 ms at 1.5T were used as cutoffs for identifying iron overload and severe iron overload, respectively, in the heart [2]. Despite its advantages, MRI has some limitations, including long scan time and inability to quantify large iron concentrations. Computed tomography (CT) can detect iron overload due to the increase in x-ray absorption caused by high iron density. However, CT has limited capability for quantifying iron due to the energy-dependent variation in CT attenuation. Dual-energy CT (DECT) scanners have recently been introduced with the capability of simultaneously acquiring two images at different energy levels [3], which makes it possible to evaluate iron overload without being affected by energy-dependent CT attenuation or tissue fat [4]. The aim of this study is to investigate the diagnostic performance of DECT for evaluating myocardial iron overload (from images acquired at four different diagnostic imaging energies of 80, 100, 120, and 140 kVp) and compare the results to MRI T2* measurements based on experiments on phantoms with calibrated iron concentrations.

METHODS: Ten 50-mL vials were filled with a mixture of distilled water, 0.5% agarose, and 0.085 mM $MnCl_2$ to produce T1 and T2 values similar to those of myocardium. Different amounts of iron sulphate were added to the vials to simulate iron concentrations from 0 to 225 μmol/g. The phantom was imaged on a Siemens 1.5T MRI scanner using multi-echo T2*-weighted gradient-echo (GRE) pulse sequence with the following imaging parameters: repetition time (TR) = 200 ms; TE (12 echoes) = 1-16 ms in equal increments; slice thickness = 10 mm; resolution = 2.8 × 2.8 mm^2; flip angle = 20°; and scan time = 19 s. The phantom was then imaged on a Siemens FLASH DECT scanner equipped with a tin filter for improved energy separation. Two DECT scans were conducted with 80/140 and 100/140 kVp energy settings. The imaging parameters were as follows: pitch = 0.6; gantry rotation time = 0.5 s; collimation = 32 × 0.6 mm; exposure time = 500 ms; tube current = 18-28 mA; slice thickness = 5 mm; resolution = 0.3 × 0.3 mm^2; and scan time = 2 s.

The images were transferred to a workstation provided by the manufacturer for analysis. A circular ROI of about 2 cm^2 was placed in the center of each vial to measure average signal intensity in MRI and HU in DECT. The values from the MRI images at different TEs were fitted to a mono-exponential curve to measure T2* (in ms) and R* (= 1000/T2*; in 1/s). Two vials resulted in T2* of 21 and 10 ms, which were used as the cutoff values for iron overload and severe iron overload, respectively. The DECT results were used to study the relationship between CT energy level and HU and to construct a map for evaluating the degree of iron overload severity. Regression and correlation analyses were conducted between iron concentration, R2*, and HU values (HU) / HU differences (ΔHU) / HU ratios (rHU) at different energies (the image at 120kVp was automatically calculated by the scanner from the 100/140 kVp scan).

RESULTS: Figure 1(a) shows the MRI-generated T2* map, where T2* (R2*) ranged from 36 ms to 6 ms (28 s^{-1} to 167 s^{-1}) for iron concentrations between 25 and 225 μmol/g, respectively. Figure 1(b) shows the exponential curve fitting for calculating T2* of the vials with T2* of 21 and 10 ms. The results showed a strong linear correlation ($r > 0.95$ and $P < 0.0001$) between iron concentration and R2*. Figure 2 shows the DECT images at 80 and 140 kVp, with varying CT attenuation depending on iron concentration and energy level. Figure 3(a) shows the relationship between HU values and iron concentration at different energy levels, which showed strong linear correlations ($r > 0.95$ and $P < 0.0001$). The results showed strong linear correlation ($r > 0.95$ and $P < 0.0001$) between iron concentration and all ΔHU; and moderate linear correlations ($0.42 < |r| < 0.76$ and $0.02 < P < 0.2$) between iron concentration and rHU (except for the 140/80 ratio). Finally, R2* showed a strong linear correlation with HU values at all energy levels ($r > 0.95$ and $P < 0.001$). The HU values of the vials with R2* between 21 and 10 ms showed perfect linear relationships with the energy level (Figure 3(b)), where the resulting map can be used to evaluate the severity of iron content (normal, iron overload, and severe iron overload) by dividing the figure into three regions based on the energy level and HU value.

CONCLUSIONS: This study showed the capability of DECT for evaluating iron overload in the clinical setting with similar accuracy to MRI T2*. Therefore, DECT might help in patient staging and treatment monitoring based on the severity of iron overload, independent of the implemented imaging energy. The low radiation dose of the new imaging protocols, very short scan time, capability of identifying large iron concentrations, and high resolution of DECT make it a promising tool for evaluating iron overload. Future work includes implementing the developed technique on a large number of patients with wide range of iron overload to optimize the imaging parameters for clinical implementation and investigate its clinical importance for evaluating iron overload.

REFERENCES: [1] Eur Heart J, 22:2171-2179; [2] Annals New York Academy Sciences, 1054:373-378; [3] Eur J Radiol, 68:362-368; [4] Eur J Radiol, 68:442-445.

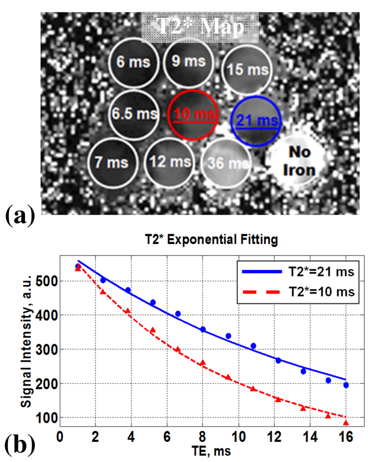

Figure 1. MRI results. (a) T2* map. (b) T2* measurement for the cutoff values of 21 and 10 ms.

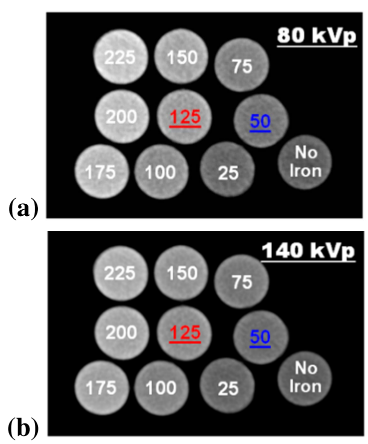

Figure 2. DECT images. Images at (a) 80 kVp and (b) 140 kVp. Numbers show iron concentr. (μmol/g).

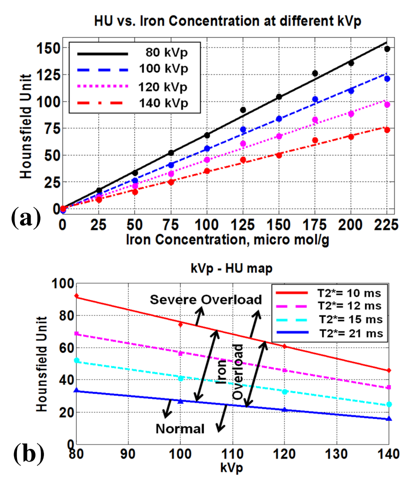

Figure 3. DECT analysis. (a) HU vs. iron concentration. (b) Iron overload map based on HU and imaging energy.