Morphological and Quantitative Imaging of Iron Using MP-RAGE and UTE Sequences

Wen Hong[1], Qun He[2], Hongda Shao[2], and Jiang Du[2]
[1]*Radiology, China-Japan friendship hospital, Beijing, Beijing, China,* [2]*Radiology, UC, San Diego, San Diego, CA, United States*

INTRODUCTION

The presence of iron effects T1, T2 and T2* as well as phase of tissues seen on MR images allowing various forms of it to be detected and quantified. Previous studies have used GRE sequences to relate iron concentration to T2* or R2 * [1-3]. However, this approach is less effective in tissues with high iron concentration because this causes shortening of T2* which leads to significant signal loss and inaccurate measurement with conventional clinical sequences. Ultrashort echo time (UTE) sequences can detect signal from short T2 species with T2*s as short as a few hundred microseconds [4] and could potentially help overcome this problem. The three-dimension (3D) magnetization-prepared rapid gradient-echo (MP-RAGE) sequences have also been used to create contrast between tissues with distinct T1s [5]. They have the disadvantage of a longer TE, but the advantage of great sensitivity to T1 shortening effects. The purpose of this study was to compare 3D-MP-RAGE and UTE sequences for morphological and quantitative imaging of iron.

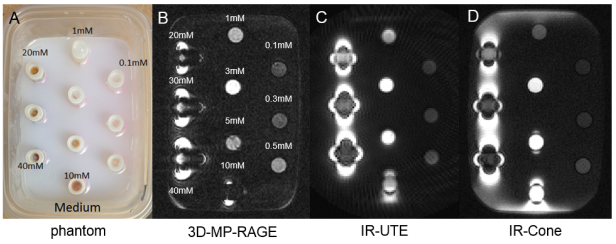

Fig 1 (A) phantom of different iron concentration tubes. (B), (C) & (D) are images using 3D-MP-RAGE (B), IR-UTE (C) and IR-CONE (D) in the presence of different iron concentrations. All sequences show all the tubes. 3D-MP-RAGE sequence show good image quality at 0.1, 0.3, 0.5, 1, 3, 5mM, IR-UTE at 0.1, 0.3, 0.5, 1, 3, 5, 10, 20mM and IR-CONE at 0.1, 0.3, 1, 3, 5, 10, 20, 30mM as well.

MATERIALS AND METHODS

A phantom composed of tubes filled with 2mL of Feridex .I.V solution with 10 different concentrations (0.1, 0.3, 0.5, 1, 3, 5, 10, 20, 30, 40 mM) was used. The tubes were fixed in 0.9% w/v agarose and the longitudinal direction of the tube was placed perpendicular to the B_0 field so that susceptibility artifacts were maximised (the worst case scenario).

MR imaging of the iron phantom was performed using a 3T Signa HDxt scanner (GE Healthcare Technologies, Milwaukee, WI).

Morphological and quantitative imaging sequences and data acquisition parameters included: 1) 3D-MP–RAGE: TR/TE = 6.79/1.92 ms, preparation time = 80 ms, flip angle = 12°, slice thickness = 2mm, bandwidth = 122 Hz/pixel, field-of-view (FOV) = 18 cm, 64 slices, matrix size = 512x512x32, in-plane resolution = 0.35 x 0.35mm^2, the total scan time = 1 minute 48 seconds; 2) 3D IR–Cones: TR/TE = 100/0.03 ms, inversion time (TI) = 45 ms, flip angle = 20°, slice thickness = 2mm, bandwidth = 1953 Hz/pixel, FOV = 15 cm, matrix size = 128x128x20, in-plane resolution = 1.17x1.17 mm^2, total scan time = 1 minute 49 seconds; 3) 2D IR-UTE: TR/TE = 300/0.03 ms, TI = 110 ms, flip angle = 60°, slice thickness = 3mm, bandwidth = 976.6 Hz/pixel, FOV = 16 cm, matrix size = 128x128, in-plane resolution = 1.25x1.25 mm^2, total scan time was 2 minute 02 seconds.

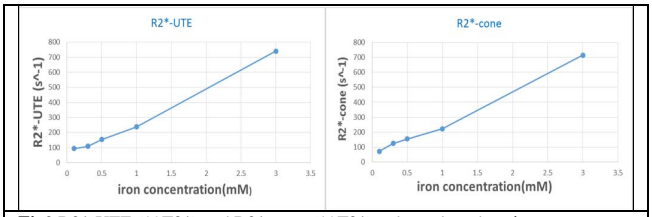

Fig2 R2*-UTE (1/ T2*) and R2*-cone (1/ T2*) values plotted against concentration of iron. R2* and iron concentration ranging from 0.1 to 3mM have a linear relationship.

RESULTS AND DISCUSSION

Figure 1 shows the iron phantom and representative images acquired with the 3D-MP-RAGE, 2D IR-UTE and 3D IR-CONE sequences. All sequences showed increased contrast for the iron containing tubes by suppressing the signal from agarose gel which had a longer T1 compared with those of the iron phantoms, whose T1s were significantly shortened. The 3D-MP-RAGE sequence showed high contrast images of the tubes with iron concentrations of 0.1, 0.3, 0.5, 1, 3 and 5mM. The 2D IR-UTE sequence detected higher iron concentration up to 30 mM. The 3D IR-CONE sequence detected the highest iron concentrations ranging up to 30 mM.

Figure 2 shows R2* values derived from the 2D UTE and 3D Cones sequences respectively, and their relationship to iron concentration. The data shows that the R2* and the iron concentrations in the range from 0.1 to 3mM have a linear relationship.

Figure 3 shows R2* derived from 2D IR-UTE and 3D IR-Cones sequences, respectively, and their relationship with iron concentration. The data also show a linear relationship between R2* and the iron concentration ranging from 0.1 to 30mM.

Figure 4 shows R1 measured with 2D UTE and 3D Cones using a variable TR approach. Again a general linear relationship was observed between T1 and the iron concentration ranging from 0.1 to 5 mM.

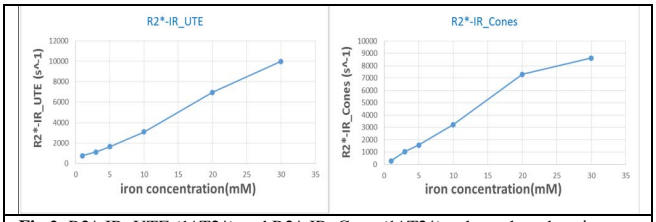

Fig 3 R2*-IR_UTE (1/ T2*) and R2*-IR_Cone (1/ T2*) values plotted against concentration of iron. R2* and the iron concentration ranging from 0.1 to 30mM have a generally linear relationship.

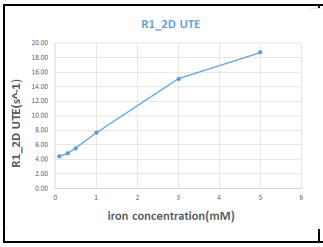

Fig 4 R1-UTE (1/T1), R1-3D_Cones (1/ T1) values plotted against concentration of iron by using 2D UTE and 3D Cones using a variable TR approach . R1 and the iron concentration ranging from 0.1 to 5mM have a generally linear relationship with all three approaches.

CONCLUSIONS

Our studies show that 3D MP-RAGE sequence can be used to generate high contrast for lower iron concentration (0.1 to 10 mM), while IR-UTE, especially 3D IR-Cones sequences can be used to imaging iron with higher concentration (0.1 to 30 mM) . Quantitative iron imaging is also feasible by measuring T2* and/or T1 using UTE based sequences. The clinical feasibility of these techniques will be investigated in follow-up studies.

REFERENCES:

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