

Effects of fat saturation on perfusion parameter quantifications for the parotid glands in dynamic contrast-enhanced MRI

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Introduction

Non-fat-saturated (NFS) dynamic contrast-enhanced (DCE) MRI has been used to quantitatively characterize the parotid gland alteration after receiving radiotherapy [1]. The parotid gland contains as much as 50% of fat [2], which has been proven to influence the parotid ADC measurements. We hypothesize that the parotid fat may also have substantial effects on perfusion measurement using NFS DCE-MRI. The effects of fat saturation (FS) and its relationship with NFS DCE-MRI have not been reported. Therefore in this study, we perform FS and NFS T1-weighted DCE MRI with the Brix model [3] applied to investigate the influences of fat content on the perfusion parameters derived from DCE-MR images of the parotid glands.

Materials and methods

Our study included both phantom and in vivo studies. The phantom consisted of 18 bottles of 20ml fat-water emulsion solution at three fat contents (0%, 30%, and 50%) and six concentrations of Gd-DTPA (0, 0.5, 1.0, 1.5, 2.0, and 2.5 μM), which underwent both NFS and FS T1-weighted imaging at 1.5T (TR/TE = 400/6.3). Percentage signal enhancements at all concentrations were calculated with the zero-dose intensity as the baseline. 19 patients (17 men and 2 women, aged 51.0 ± 16.0 years) and 20 patients (14 men and 6 women, aged 46.8 ± 12.6 years) received single contrast-administered MRI using FS and NFS DCE head and neck fast spin-echo MR imaging, respectively, at 1.5T (FOV = 23cm, 256×256 matrix, 6 slices, TR/TE = 400/12.6, 20 dynamic phases with 12.3s interval). Gd-DTPA was manually injected as a bolus over a period of 3 s with the standard dose of 0.1 mmol/kg of patient weight. In addition, three healthy subjects (2 men and 1 woman, aged 30.3 ± 7.5 years) volunteered receiving two doses of Gd-DTPA injection for separate NFS and FS DCE-MRI scans with otherwise identical scanning parameters to compare the perfusion parameters derived from the two data sets.

For perfusion parameter analysis, the Brix model [3] was used for curve fitting on the percentage signal increase relative to the baseline signal before contrast injection [4]. Besides the three Brix model parameters A, k21, and Kel, three other parameters were also calculated. The peak enhancement (PE) is defined as the percentage increase at maximum value of the fit curve, the time-to-peak refers to the time when the curve reaches maximum, and the slope is defined as the ratio of PE to time-to-peak. Behavior of these parameters were compared on three regions-of-interest (ROIs) selected manually, including a pair of the parotid glands (which contain variable amount of fat) and the other one for skeletal muscle (which contains negligible fat).

Results

For the two groups of patients, parameters A, PE, and slope of the parotid glands exhibit statistically significant difference between NFS and FS DCE-MRI ($p < .001$; Fig.1 left), while the skeletal muscle shows no difference between non-fat-saturation and fat-saturation T1 weighted DCE-MRI ($p > 0.3$ for all; Fig.1 right).

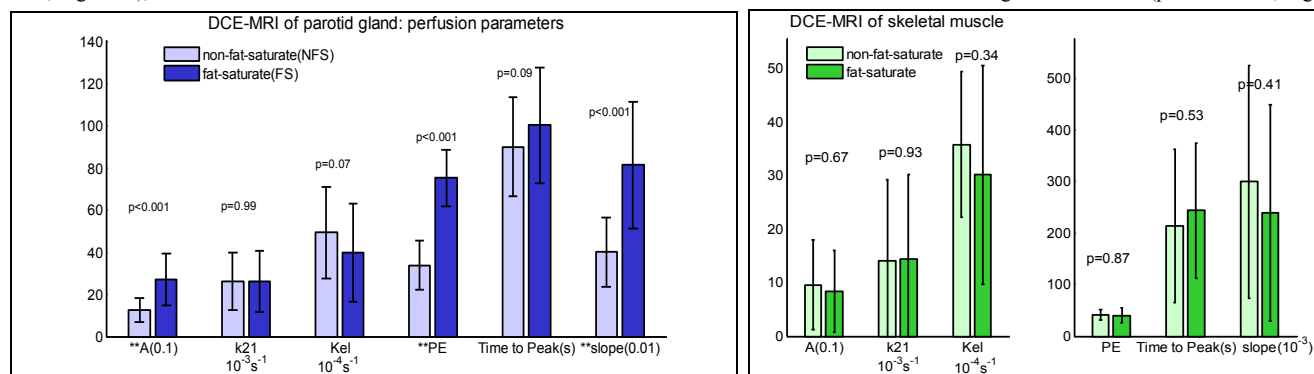


Figure 1. Comparison of perfusion parameters derived from FS and NFS DCE-MRI, where A, PE, and slope for the parotid glands (left) show statistically significant differences (** denotes significant differences with $p < 0.001$). The skeletal muscle shows no significant difference in any of the parameters.

Figure 2 from the phantom study shows that the percentage signal enhancement in FS scan is higher than the corresponding NFS scan. The higher fat content, the larger difference in percentage signal enhancement is found between FS and NFS scans. Figure 3 from the volunteer study (fat contents 65%, 48%, 60%) shows prominently higher A, PE, and slope in the FS scan for all three subjects consistently, in good agreement with the phantom and patient results.

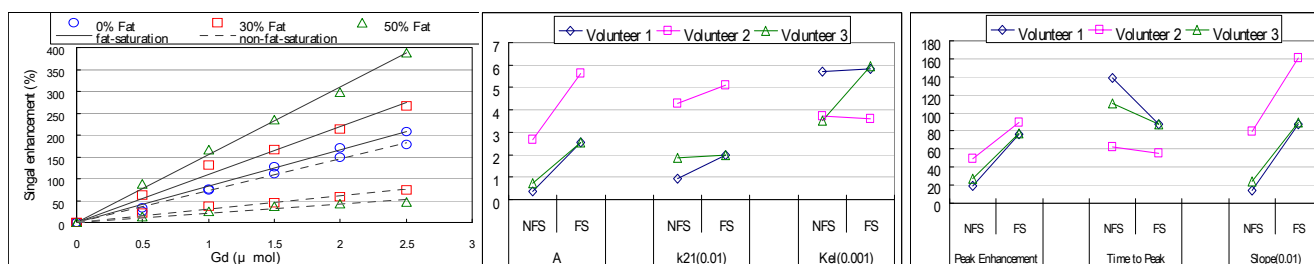


Figure 2. Phantom with 3 different fat contents

Figure 3. Volunteer perfusion measurements in the parotid glands

Discussion and Conclusion

Calculation of perfusion parameters from DCE-MRI is generally based on signal enhancement relative to the pre-contrast baseline signals [1,4]. In fat-containing tissues, the baseline signals consist of contributions from both water and fat protons. Note that water occupies one of the coordination sites of Gd³⁺ in the contrast agent complex, which exchanges rapidly with bulk water, leading to shortening of T1 and hence signal enhancement on T1-weighted images. Since there is no such mechanism involving fatty acid triglycerides, no T1-related enhancement is present for the fat signals. As a result, the inclusion of fat signals in the pre-contrast baseline causes an increase of the baseline intensity and a lowered value of the percentage signal enhancement. This mechanism is in good agreement with our study which shows that all amplitude-related perfusion parameters (A, PE, and slope) exhibit larger values in FS as compared with NFS DCE-MRI in the parotid glands but not in skeletal muscle. The phantom and volunteer experiments further confirm these findings on patients. It is therefore suggested that the use of FS or NFS should be explicitly specified for objective comparison of perfusion parameters with DCE-MRI on fat-containing tissues such as the parotid glands.

References [1] Juan CJ, Eur Radiol 2009;19:94. [2] Juan CJ, Radiology 2009;253:144. [3] Brix G, JCAT 1991;15:621. [4] Buckley DL, MRM 1994;32:646.