Evaluation of quantitative dynamic contrast enhanced pharmacokinetic parameters with and without postprocessing alignment

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Introduction

Dynamic contrast enhanced (DCE-) MRI is a powerful technique for the non-invasive monitoring of tumour vasculature. The ability to monitor the progression and regression of tumour vascularity and angiogenesis would assist assessment of drug response particularly if these changes precede any change in morphology. Dynamic imaging in the liver is a major challenge particularly in accounting for mis-alignments and deformation of the liver. Acquisition of dynamic data in the coronal orientation during successive breath-holds on expiration effectively minimizes this effect [1]. Previous work has evaluated the performance of this method of dynamic acquisition by measuring the displacements of the whole liver between successive dynamic images [2]. In this paper, the effects of mis-alignment effects in a clinical DCE-MRI liver protocol which involved successive full-exhale breath-holds was evaluated by analyzing the pharmacokinetic (PK) parameters with and without post-processing alignment.

Materials & Methods

The patient cohort consisted of neuroendocrine cancer patients with liver metastases. Imaging was performed on a Siemens Avanto 1.5T system with a phased array body coil. Dynamic contrast-enhanced (iv. Magnevist® 0.1mmol/kg body weight) 3D coronally acquired breath-hold MR imaging was performed using PD and T1-weighted gradient-echo sequences (TR/TE = 4.36/1.32 ms, $\alpha = 2°/24°$, NSA = 3/1, 350mm^2 FOV, 256x256 matrix, 20 partitions, 5mm thick). Images were acquired during 5.32s of breath-hold at expiration followed by ~6s of free breathing. This sequence was repeated 20 times during the dynamic acquisition. To assess the effects of mis-alignment, the images were registered using a technique based on navigator methodology [3]. All images were assessed by a radiologist with more than 10 years experience in body MRI. Regions of interest (ROI) were drawn encompassing the index lesions using the T1-weighted images in each patient. A total of 7 index lesions were chosen for the analysis. Both the original and the registered T1 signal intensity-time course curves of the ROIs were converted to gadolinium concentration-time course curves using native T1 and dynamic T1 calculated using the variable flip angle technique [4] and a single-input raised cosine form of a population-averaged AIF [5]. PK parameters evaluated were K^{trans}, v_e, k_{ep} and IAUGC-60. Bland-Altman analysis was performed to compare the agreement between median PK parameters calculated using unaligned and aligned datasets [6].

Results

Visual inspections of the original dynamic series showed good alignment of the liver between the dynamic images. Bland-Altman coefficients which represent twice the standard deviations of the difference in the two sets of PK parameters calculated using unaligned and aligned datasets are shown in table 1. These high degrees of agreement are also illustrated in the Bland-Altman scatter plots. An example plot for K^{trans} is shown in figure 1. PK parametric maps and their histogram distributions calculated from the unaligned (black solid lines) and aligned datasets (red solid lines) are shown in figure 2.

Parameters	Bland-Altman coefficient (%)
K^{trans}	6.76
v_e	8.41
k_{ep}	4.80
IAUGC-60	7.08

Table 1: Bland-Altman coefficients of the PK parameters are lower than commonly reported reproducibility values which indicate that there is no significant difference between the parameters calculated from unaligned and aligned datasets.

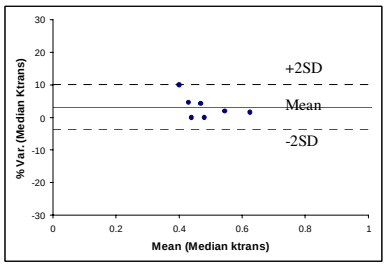

Figure 1: An example Bland-Altman scatter plot of median K^{trans} calculated from unaligned and aligned datasets shows good correlation between the two sets of parameters. There was a variation of 6.8% in the median K^{trans} value within 2 standard deviations of the mean difference of the two measurements, which was 3%.

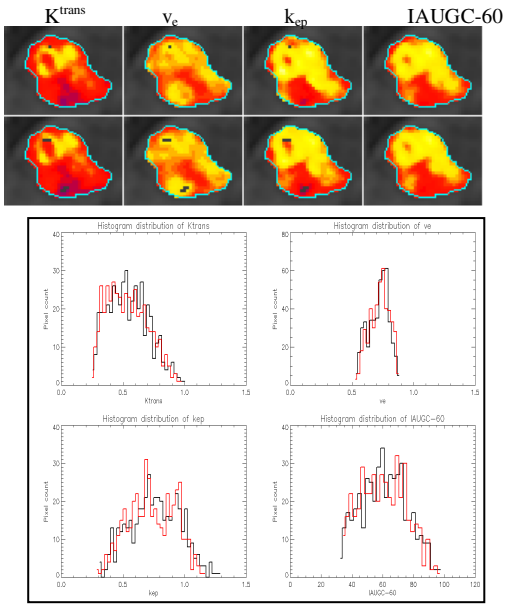

Figure 2: PK parametric maps, scaled to the same level, calculated from unaligned (1st row) and aligned (2nd row) datasets which show little difference. Corresponding histogram distributions show a high degree of overlap between parameters calculated from the unaligned (black) and aligned (red) datasets.

Discussions

Bland-Altman analysis of the PK parameters calculated from the unaligned and aligned dynamic datasets showed there is no significant difference between the two sets of parameters, indicating the alignment process had no significant effect on the PK analysis and that our dynamic data acquisition protocol was effective in minimizing mis-alignments of the liver. The statistical results were also supported qualitatively by the PK parametric maps, where little difference was observed between those calculated from unaligned and aligned datasets. High degrees of overlap in the histogram distributions of the unaligned and aligned PK parameters also confirm the results of the Bland-Altman analysis.

Conclusions

This study shows that acquisition of dynamic data in the liver during successive full-exhale breath-holds is effective in minimizing mis-alignments and deformations of the liver. It has been validated by analyzing DCE-MR calculated PK parameters with and without post-processing alignment. This finding is consistent with previously reported results [2]. DCE-MR protocols which are robust to mis-alignments in the organs would assist accurate derivation of quantitative PK parameters which are increasingly used in several clinical setting to monitor disease progression and regression.

References

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