Quantifying changes in breast tumour $K^{\text{trans}}/v_e$ parameters when reducing temporal resolution of contrast enhanced dynamic MRI

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INTRODUCTION

The trade-off between spatial and temporal resolution plays an important role¹ in clinical breast tumour studies using dynamic contrast enhanced MRI (DCE-MRI). Increasing the spatial resolution of the image requires a reduction in the temporal resolution and vice versa. An improved spatial resolution allows tumour heterogeneity to be investigated. Whereas, improving the temporal resolution increases the power of the model fitting procedure. In this study the Tofts’ pharmacokinetic model² has been chosen in order to test the effect of reducing a dynamic scan’s temporal resolution on the physiological parameters $K^{\text{trans}}$ and $v_e$. In order to simulate a lower temporal resolution a simple approach based on averaging the original samples has been developed.

MATERIALS AND METHODS

17 patients with invasive breast cancer have been scanned at 1.5 T before chemotherapy treatment by DCE-MRI at 10 seconds temporal resolution with a T1-weighted two dimensional fast spoiled gradient echo (FSPGR) sequence acquired in the coronal plane with 9 interleaved slices. The dynamic images are acquired after a double dose of Gd-DTPA bolus injection (0.2 mmol/Kg). The FSPGR sequence has a TR/TE setting of 8.4/4.2 ms and flip angle of 35°. To produce a single $K^{\text{trans}}$ measure for each tumour, the average of the “hot spot” of the most enhancing cluster of pixels (a 3x3x3 matrix) was found using a semi-automatic method and fitted. For simulating a lower resolution of 20 seconds two adjacent samples are averaged and the averaged value is placed in a time location which is in between the two original samples at 10 seconds; this process aims to simulate a linear k-space sampling approach and can be repeated at lower resolutions by averaging a higher number of points (3 points at 30 seconds, 4 at 40 seconds and so on). At each lower resolution the new samples are re-fitted into the Tofts’ model in order to give a new pair of $K^{\text{trans}}/v_e$ values and these are then compared with their original fitted values at a 10 seconds resolution. These results are compared against simulated data generated using IDL (Research Systems, Inc, Boulder, Colorado). This data has the same acquisition parameters, assumes a native T1 of the breast tissue equal to 1.1 sec, and considers a range of nominal $K^{\text{trans}}/v_e$ values ($K^{\text{trans}}$ equal to 0.5, 1.2, 2.0 min⁻¹ and $v_e$ equal to 30, 50 and 70%³) and uses a temporal resolution ranging from 10 to 70 seconds.

RESULTS

Figure 1a shows a plot of time resolution versus $K^{\text{trans}}$ for each of the 17 patients and Figure 1b shows a plot for their associated $v_e$. This shows that lowering the temporal resolution of the dynamic scan reduces $K^{\text{trans}}$ by an average value of 12% at 70 sec temporal resolution; the smallest measured reduction is of 6% for patient 4 and 6 and the greatest reduction is of 15% for patient 5, 6, 14 and 17. There is almost no change in $v_e$ estimation when the temporal resolution is lowered; one patient (patient 16) demonstrated a small decrease of about 1% at lower resolutions possibly due to the presence of noise on the enhancement curve. Figure 2a shows a plot of temporal resolution versus $K^{\text{trans}}$ for nine simulated enhancing curves. Figure 2b shows the plot of temporal resolution versus $v_e$ for the same dataset. As with the patients’ results the graph in Figure 2b shows little variation of $v_e$ in respect to the temporal resolution. However, there is a clear decrease in $K^{\text{trans}}$ which is more severe with reducing $v_e$. The reduction in $K^{\text{trans}}$ is proportional to its starting value at 10 seconds resolution. For example in Figure 2a for a $K^{\text{trans}}$ of 30%, $K^{\text{trans}}$ drops by 14% when its starting value is 0.5 min⁻¹, by 30% when its starting value is 1.2 min⁻¹ and by 41% when its starting value is 2 min⁻¹. These temporal resolution simulations replicate the trends demonstrated with the patients’ data.

DISCUSSION

Under-sampling the original dynamic signal enhancement curve the gradient of the initial slope is reduced because the original samples are substituted by averaged values, this has the effect of decreasing the fitted $K^{\text{trans}}$ and will have more pronounced effect at high $K^{\text{trans}}$ values. Concerning the $v_e$ analysis it can be observed that its value does not change at lower temporal resolutions because the height of the dynamic curve is left almost unchanged by the averaging process. A further investigation is needed to see how errors in $K^{\text{trans}}$ caused by imaging at poor temporal resolution relate to the clinical prognostic value of $K^{\text{trans}}$. However, this work suggests that it may be possible to decrease the temporal resolution of a dynamic scan to around 20 seconds and still maintain robust estimation of pharmacokinetic parameters. This in turn may allow higher spatial resolution images to be acquired.

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REFERENCES