Diaphragm alignment of multiple breath-hold dynamic contrast-enhanced MRI of the liver for quantitative parameter estimation

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Introduction. Dynamic Contrast-Enhanced MRI of the liver provides information about blood flow [1] and can be used to monitor tumours during treatment by characterising changes in functional parameters. However, there are practical challenges related to respiratory motion. Short breath-holds, repeated separately for each frame of the dynamic sequence [2], offer a partial solution; but patients are typically unable to precisely reproduce the depth of breath-hold for each frame. Manual alignment of each frame at scan-time [3] obtains good results but sacrifices temporal resolution. Standard navigator triggering is available on many scanners and can align images well [4] but leads to a variable time-interval between frames, potentially troublesome for parametric analysis. In this study we apply simple post-processing techniques based on navigator methodology to align coronal images acquired at regular intervals during repeated breath-holds, and show the effect this has on parametric analysis.

Materials and Methods. Patients with colorectal cancer and metastases visible in the liver were scanned on a Siemens 1.5T Vision MR system. Coronal T1 weighted images were acquired using 2D FLASH (3 slices in 6s; res. 1.76mm, TR=10.2ms, TE=4.7ms, α=35^o). Dynamic acquisitions were every 13s starting before contrast injection; the patient was asked to breath-hold (on expiration) for 6s while the scan took place, then breathe freely for 7s before the next scan. Proton density weighted images were acquired similarly (TR=20ms, α=5^o).

Correction for variations in breath-hold position were applied by translating each image in the sup-inf direction such that the diaphragm was aligned; although liver tissue may deform non-rigidly, breath-hold depth variation can typically be characterised well across the liver by this rigid transform [5]. The required translation was estimated in three ways. Firstly, manual alignment of the diaphragm to a reference marker superimposed on the displayed images was performed. Secondly, the diaphragm was found by identifying a threshold crossing point between the dark lung and bright liver tissue along a certain profile (on the right hemidiaphragm peak, 5.3x44mm in size; see Figure 1). Thirdly, correlation along a similar profile between successive pairs of images was maximised over vertical offset. Proton density images were also registered to the main T1 series.

T1 weighted images were then divided by proton density images and converted to Gd concentration (after Hittmair [6]). Area under the curve (AUC) maps – integral of Gd concentration over time – were computed. AUC has been shown to correlate with extravascular volume [7].

Results. Patient breath-hold depth is typically fairly constant but in some cases variations of a centimetre or more were observed in the diaphragm position. Correlation and diaphragm thresholding produced near-identical results. Figure 1 shows the location of the diaphragm tracking profile on an example scan. In Figure 2 this 1D profile is shown over time from the uncorrected and correlation-registered series. Figure 3 shows AUC maps derived from the unregistered, manually registered and correlation-registered data. These maps are masked to the outline of the liver in the first image.

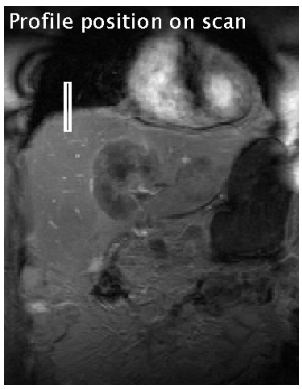

Figure 1

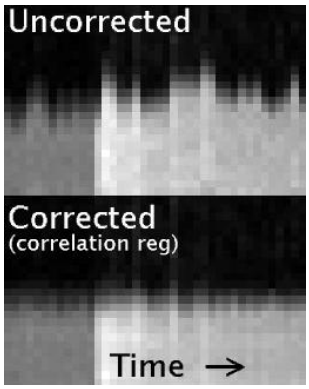

Figure 2

Discussion. Relatively short profiles, covering just the diaphragm boundary (Figure 1), showed better registration. Several features are noteworthy in Figure 3. Firstly, the bright motion artefact visible along the left inferior surface of the liver (arrows A), where extra-hepatic tissue moved inside the original liver outline, is reduced in the manually registered images and removed entirely in the correlation-registered images. Secondly, many blood vessels are visible *only* in the correlation-registered images (small, bright structures throughout liver; arrows B point to examples). These vessels are visible on individual dynamic frames, and thus their absence on AUC maps implies misregistration. Thirdly, more heterogeneity is seen within the tumour, and particularly within the central region, in the correlation registered images. Pixel-based analysis of uptake/washout curves also showed more pronounced peaks and more distinct washout at many points in this region.

Conclusions. This study demonstrates that even without correction the method of repeated breath-hold for dynamic imaging can produce good results. Simple vertical alignment using correlation of tracking profiles has been shown to recover features, particularly from studies with moderate to high variability in breath-hold position. This provides the basis of a simple, robust and computationally inexpensive methodology for dynamic studies of the liver.

References

[1] Totman J et al, Proc ISMRM 2003, 1433
[2] Feinberg DA et al, MRM 1995 34:905-909
[3] Feinberg DA et al, MRM 1995 34:770-774
[4] Taylor NJ et al, Proc ISMRM 2003, 1275
[5] White MJ et al, Proc 13th NMR Symp. 2003
[6] Hittmair K et al, MRM 1994 31:567-71
[7] Walker S et al, Proc ISMRM 2003, 1267

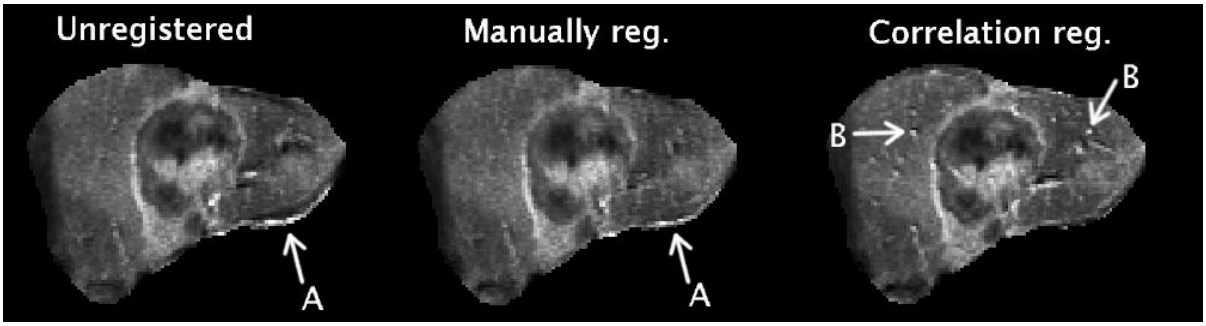

Figure 3