Using Registration to Quantify the Consistency of Whole Liver Position during Patient Breath-hold in Dynamic Contrast-Enhanced MRI

A. Melbourne[1], D. Atkinson[1], M. J. White[1], D. J. Collins[2], M. O. Leach[2], and D. J. Hawkes[1]

[1]Centre for Medical Image Computing, University College London, London, United Kingdom, [2]Cancer Research UK, Clinical Magnetic Resonance Research Group, The Institute of Cancer Research, Sutton, Surrey, United Kingdom

Abstract: Motion of a patient during an imaging scan or therapy can compromise the quality of the diagnosis or treatment. If the patient is instructed to lie supine with arms raised above the level of the head, we can acquire a dynamic contrast-enhanced MR scan during full-exhale breath-holds with very little motion. Analysis of this residual motion using image registration reveals that the patient's whole liver moves less than ±1mm in the medial-lateral direction and ±3mm in the superior-inferior direction between breath-holds in 90% of successfully registered images. This technique for limiting motion of the patient should therefore be of interest, particularly to therapeutic groups.

Introduction: The liver is a common site for the formation of secondary cancers. It is widely believed that treatments such as surgery, radiotherapy and radio-frequency ablation can substantially extend lifespan provided all diseased tissue is removed. Motion of the patient during a pre-operative image acquisition can compromise this process, so we must restrict patient movement by training a patient to breathe in a repeatable way. Here we look at the consistency of repeated breath-hold position when a patient lies supine with their arms raised above the level of their head. Images are acquired at successive full exhale breath-holds for use in a dynamic contrast-enhanced MR study of the liver - this method is useful in the diagnosis of tumours and in assessing response to therapy. Previous work ([1] and [2]) has found variation in diaphragm position (and hence liver position) to vary by less than 3mm at full-inhale and under active breathing control. This work re-enforces this conclusion for motion of the entire liver at end-exhale.

Methods: To find how much the liver has moved position between breath-holds we use an image registration method. In this case the registration will tell us how much the liver has moved between two images at different breath-holds. This will allow us to analyse to what extent we can restrict motion of a patient without recourse to active breathing control methods and by only simple training. Twenty-nine datasets (covering 7 patients returning at intervals between 2-5 visits) are examined; each with between 34-40 triplets of coronal slices taken at 13s intervals. Three 7mm spatially separated slices are acquired sequentially at the start of each 13s interval (1-2-3 Anterior to Posterior). The patient breathes under instruction during the interval between scans (6s), but is asked to hold their breath at full expiration whilst the scanner is acquiring images. Mis-registration between scans represents a measure of the inconsistency of the breath-holds. The liver is analysed by implementing a non-rigid registration method based on a fluid equation [3]. Evaluation is performed by independent visual inspection of the images. Images for which the registration scores well (excluding registrations that fail due to rapid contrast changes) are selected for further analysis. The liver is segmented, and the mean & standard deviation of the displacement field calculated over this region.

Results: Registration shows that movement of the liver is well described by bulk rigid motion, manifested by a large mean displacement and small standard deviation of the local displacement field. The distribution of this bulk motion is found to have standard deviation, σ=0.52mm, in the medial-lateral direction and σ=1.53mm in the superior-inferior direction over a range –1.84mm & 1.90mm in the medial-lateral direction and –10.3mm & 4.77mm in the superior-inferior direction.

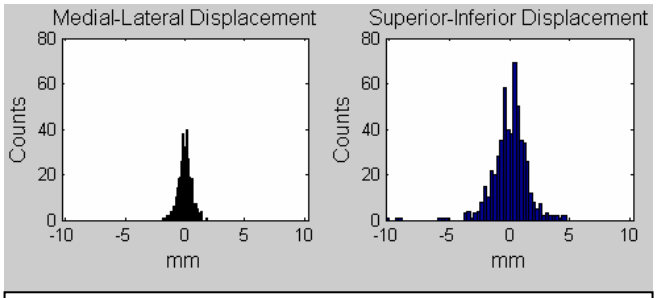

Fig 1) Distribution of displacement in *mm* of the liver in medial-lateral (left-hand histogram) & superior-inferior (right-hand histogram) directions.

Conclusion: The extent of motion is similar in magnitude to the description of the diaphragm position found in previous work, though here we measure the position of the entire liver. The use of supine, arms back patient positioning to consistently maintain the liver position reduces the requirement for registration. At breath-hold, tumours can be localised to a few millimetres, which is of interest to radiotherapy groups. The important results of the registrations presented here demonstrate the ease at which the liver can be held constant for the length of an MR scan between successive breath-holds and this is vital for successful treatment and clinical evaluation using DCE-MRI.

[1] Kim, D.J. *et al*. Held-breath self-gating technique for radiotherapy of non-small-cell lung cancer: a feasibility study. *Int J Radiat Oncol Biol Phys,* **2001***, 49*, 43-49.

[2] Eccles, C. *et al*. Reproducibility of liver position using active breathing coordinator for liver cancer radiotherapy. *Int J Radiat Oncol Biol Phys,* **2006***, 64*, 751-759.

[3] Crum, W.R.; Tanner, C. & Hawkes, D.J. Anisotropic multi-scale fluid registration: evaluation in magnetic resonance breast imaging. *Phys Med Biol,* **2005***, 50*, 5153-5174.