Non-rigid motion compensation in MR prostate perfusion imaging

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Introduction: Prostate cancer (PCa) is currently the most frequently diagnosed non-cutaneous cancer and the second most important reason for cancer mortality in men. Early diagnosis is imperative as cure can often be established. Dynamic Contrast enhance MRI (DCE-MRI) has been established as accurate method in detection and localization of PCa. DCE-MRI is performed by obtaining repeated, fast T1-weighted images before and up to a few minutes after intravenous injection of a gadolinium containing contrast agent. Three-dimensional datasets of the prostate are obtained every few seconds. This allows obtaining a per-voxel signal-intensity vs. time curve. From this, different pharmacokinetic parameters are modeled and used to differentiate cancerous from non-cancerous tissue. Drawbacks are that rectal peristalsis and patient movement often result in spatial-mismatching of serial 3D datasets and therefore incorrect enhancement curves and pharmacokinetic parameters. Hence, a definite need exists to correct these movement related inaccuracies. Therefore, in this work we present a new algorithm that exploits temporal movement patterns to compensate for this movement and enable a more reliable and automatic analysis of the pharmacokinetic data.

Material and Methods: In six patients with biopsy proven prostate cancer, a 3T MRI (TrioTim, Siemens, Erlangen, Germany) was performed. A pelvic phased-array coil and an endorectal coil (Medrad Pittsburgh, USA) were used for signal acquisition. For peristalsis suppression, 40 mg of butylscopolamine (Buscopan, Bayer, Leverkusen, Germany) was administered intramuscularly directly before the MRI scan. 3D T1-weighted spoiled gradient echo images were acquired directly before and during an intravenous bolus injection of 15 ml paramagnetic gadolinium chelate (Dotarem, Guerbet, Paris, France) using a power injector (Spectris, Medrad, Pittsburgh, USA) with an injection rate of 2.5 ml/second followed by a 15 ml saline flush. This dynamic series had a temporal resolution of 3 seconds and was acquired for 300 seconds, resulting in 100 3D datasets of the whole prostate. In order to compensate for misalignment due to motion between acquisitions, we designed a three step image registration scheme: First, a subset of images of the series that are already well aligned (same movement amplitude) are selected based on the values of an image similarity measure derived from Normalized Gradient Fields [1]. In the second step, one of these images, chosen to have a high general contrast, is selected as the global sequence reference, and all the other images of this subset are registered non-rigidly to it by minimizing the same similarity measure. Finally, in the third step, and similar to what it was proposed in Milles et al. [2], for each of the remaining images, a synthetic reference is generated based on the already aligned subset. This image will exhibit a similar intensity distribution to its unregistered counterpart and non-rigid registration is achieved by optimizing the Sum of Squared Differences. In order to validate the registration results, we compared intensity profiles from manually defined and tracked regions of the prostate to those obtained by propagating a static mask defined in the global reference image before (original) and after registration (registered) (Fig. 1).

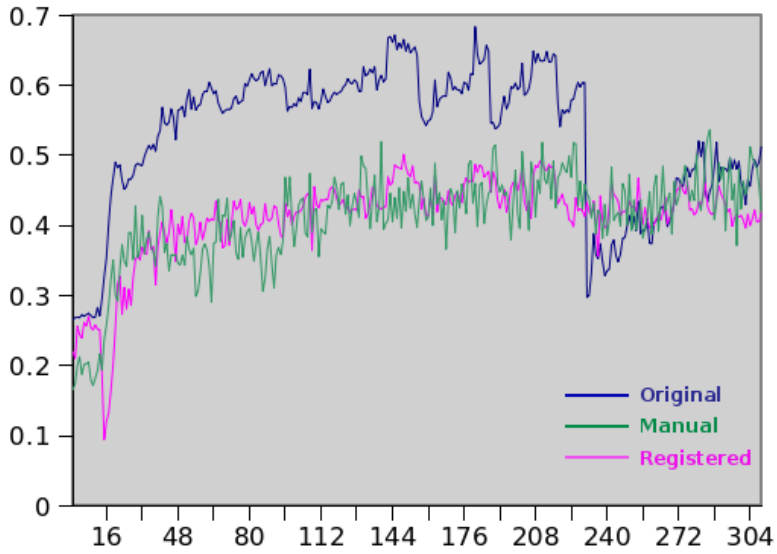

Figure 1: Intensity time curve before and after registration vs. the manual obtained curve.

Results: Full registration of a series of 100 images can be achieved in approximately 4 minutes on an up-to-date workstation class computer. In all series, a good motion compensation was achieved. As it can be seen from Fig. 1, after registration, the time-intensity curve resembles the manually obtained one quite well, making an automatic analysis of the perfusion possible. In this case, we assessed the improvement of the registration process measuring the Normalized Mean Squared Errors between the manually obtained profiles and the original profiles (18.6%), and between the manually obtained curve and the one obtained after registration (2.4%).

Conclusions: We proposed a fully automatic registration scheme to compensate motion in a series of prostate MR perfusion image series. Good motion compensation was achieved in all six cases and we were able to preliminary evaluate the registration scheme by comparing manually obtained intensity-time curves to automatically obtained ones before and after registration.

References

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