MRI derived CT substitute

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Introduction

The voxel intensities in computed tomography (CT) images are directly related to the electron density. CT is therefore used for attenuation correction of SPECT and PET, and as a basis for the dose calculations in external radiotherapy. There is however an emerging interest in methods for replacing the CT information with magnetic resonance (MR) information (1, 2, 3). Such methods also have the potential of reducing the radiation exposure in applications involving children. The main challenge is the extremely short T2 relaxation time of bone, 0.4–0.5 ms (4), making discrimination between bone and air difficult using traditional MR sequences. Therefore, ultra short echo time (UTE) sequences can be used to acquire signal from bone.

Aim

To develop a voxel based method for generating a substitute CT image from an MRI examination.

Method

In the current study we made retrospective use of five clinical datasets with MRI and CT data of the head, originally acquired for treatment planning purposes for radiotherapy. Each of the five patients was imaged with CT (Siemens Emotion 6) and three MR sequences: two dual echo UTE sequences (TE = 0.07 and 3.76 ms) with different flip angles (10° and 60°), and one conventional T2 weighted sequence. All MR images were acquired on a Siemens Espree 1.5 T scanner using a standard 4 segment head coil and corrected for geometrical distortions and inhomogeneous coil-sensitivity. For each patient the MR and CT images were coregistered and a binary mask covering the head was created using morphological image processing methods. For each MR image two new images were derived by calculating the mean value and standard deviation of the voxels in a 27-voxel neighborhood around each voxel. The distribution of voxels in this 16-dimensional (5 MR images × 3 + CT) intensity space was approximated by a mixture of 15 multivariate Gaussians using the Expectation Maximization (EM) algorithm with k-means initialization. For a new set of five MR images and their 10 filtered counterparts a substitute CT image can be generated by calculating the expectation value of the CT number conditional upon the 15 observed variables for each voxel. The model was trained on the MR and CT data from four patients at a time and applied to the MR data of the remaining patient to generate a substitute CT image. This procedure was repeated for all five combinations of training and validation data in a leave-one-out cross-validation (LOOCV) procedure. The substitute CT was compared to the real CT for each patient by calculating the mean absolute error (MAE) in Hounsfield units (HU) for all voxels inside the binary mask.

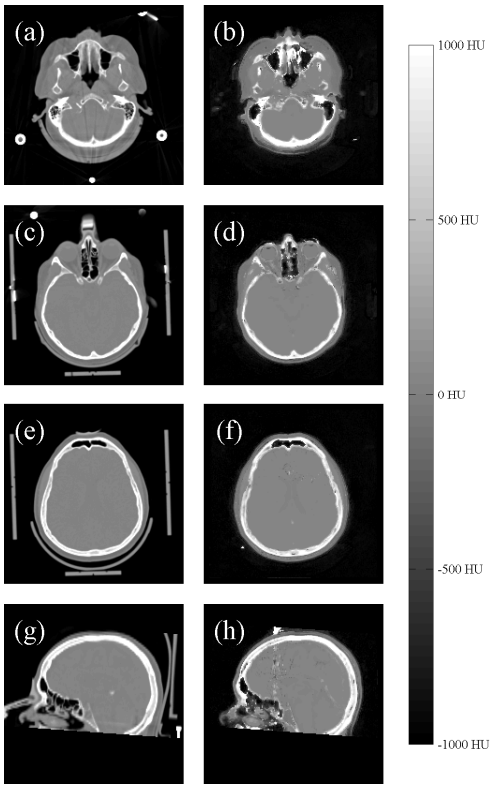

Fig. 1. A real CT (a, c, e, g) and a substitute CT derived from MR images of the same patient (b, d, f, h). The fixation used during CT imaging is also seen in the real CT images.

Results

The LOOCV MAE for the all the substitute CT images was 141 HU which is 14 percent of the difference in CT number between air (–1000 HU) and water (0 HU). A real CT is seen along with a substitute CT in fig. 1. Differences between real and substitute CT images were primarily found at the patient surface and at bone–tissue and air–tissue interfaces inside the head.

Conclusions

The agreement between the real CT images and the substitute CT images makes the above described method a feasible option both for attenuation correction in PET/MR and for dose calculations in external radiotherapy. The results also motivate an evaluation for pediatric purposes.

References

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