Deformable image registration of PET-CT and MRI using a BSpline algorithm

T. C. Lauenstein[1], E. Schreibmann[2], D. M. Schuster[1], D. R. Martin[1], and T. Fox[2]

[1]Department of Radiology, Emory University Hospital, Atlanta, GA, United States, [2]Radiation Oncology Department, Emory University School of Medicine, Atlanta, GA, United States

Introduction

Image registration between modalities is necessary to more precisely replicate presentation of FDG-PET when analyzing FDG-PET-MRI. The aim of registration is to establish an exact point-to-point anatomic spatial correspondence (coordinate system transformation) between the voxels of images derived from the different modalities, making direct comparison possible. Transformations are either rigid or non-rigid. A rigid coordinate transformation allows only translations in three orthogonal directions and rotations in three directions. The use of rigid registration may not provide accurate results due to several reasons: the patient can be positioned differently between imaging scans; the internal organs may change position and shape; and respiration may change the diaphragm level and thus change the position of internal organs. Deformable or elastic registration methods can be employed for these situations (1). However, this technique is computationally more demanding. Deformable image registration considers each feature from one image and elastically deforms it to fit a second image. With deformable registration methods, posture changes are locally defined and calculated in small iterative steps using advanced optimization algorithms to mathematically represent the deformations. No commercially available systems are yet available for fusion of PET and MRI. Aim of this study was to evaluate a deformable BSpline approach technique for image registration of FDG-PET-CT and MRI and compare it to a rigid transformation.

Methods

FDG-PET-CT and MR images were subsequently acquired in a female patient with known breast cancer. A standard whole-body FDG-PET-CT examination was performed on a GE Discovery ST. The MRI examination was performed on a 1.5T MR whole-body MR scanner (Magnetom Avanto®, Siemens Medical Solutions) six days after the FDG-PET-CT scan. A combination of specialized surface phase-array coils was utilized for signal reception. T2-weighted half-Fourier acquisition single-shot turbo spin echo sequences (TR/TE/Flip: 1200ms/90ms/90°; slice thickness: 7 mm; matrix: 192x256) were acquired without fat saturation of the thorax, abdomen and pelvis in an axial plane.

Corresponding patient images taken from the FDG-PET-CT and the MRI were fused using rigid and non-rigid co-registration software available at our institution. Calculations were implemented using an open-source software toolkit named Insight Toolkit (ITK), which consists of template-based codes for a large number of image visualization, segmentation and registration classes. ITK offers standard tools for results evaluation such as checkerboards and image difference displays. A special filter permits connecting registration results to other medical software through the DICOM protocol. For the deformable registration a BSpline (2) approach was used due to it's multi-modality nature and ability to model local deformations. In the BSpline model, the deformation is defined on a grid with N^3 cells spanning the input image. The corner of a lattice cell is referred to as a node and is indexed by i (i=1, 2, …N^3). The displacement of a node i is specified by a vector X*i* and the displacement vectors, {X*i*}, of a collection of nodes characterize the tissue deformation. The displacement at a location X on the image is deduced by fitting a polynomial expressed using the basis spline to the grid nodes X*i*. In a first step, rigid registration of PET-CT and MRI axial images was assessed using a checkerboard tool. Secondly, a deformable registration of PET-CT to the MRI was performed.

Results

Comparison of rigid versus deformable registration of mosaic CT and MRI axial images revealed superior results for deformable registration. The deformable registration was feasible and showed exact anatomical correlation between CT and MR images on a checkerboard (Figure 1). Regarding the deformable registration of PET images and MRI, increased activity from the PET scan clearly corresponded to dedicated anatomical structures on the MR images. The patient showed increased FDG activity in the perirectal space on PET-CT, which was initially rated as possible tumor disease. Additional soft tissue information available from the MRI revealed a benign fibroid, which was not visible on CT. Image registration of PET and MRI revealed the complimentary information (Figure 2).

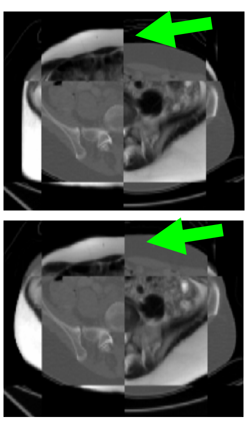

Figure1: Comparison between rigid (above) and deformable (below) image registration of CT and MRI. While the rigid algorithm led to partially poor registration (arrow), there was exact anatomical correlation for the deformable registration on the checkerboard.

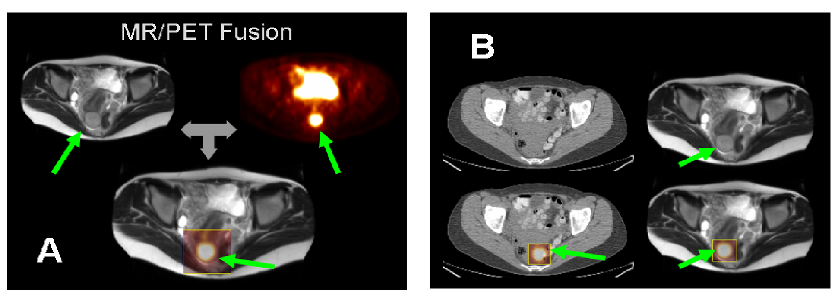

Figure 2: MRI and PET before and after deformable registration (A). The activity from the PET scan clearly corresponds to a benign fibroid on the MRI. Figure B represents the original CT (upper left) and PET-CT (lower left) compared to the MRI (upper right) and PET-MRI (lower right). Increased FDG activity in the perirectal space on PET-CT is of uncertain origin. Additional soft tissue information is available from the MRI showing a benign fibroid.

Discussion

Deformable image registration of PET-CT and MRI using a BSpline algorithm is feasible and provides exact anatomical overlay of both image modalities. Image fusion methodology for FDG-PET-CT and MRI images will help to detect and specify lesions, which may be particularly important for tumor imaging. Furthermore, this technology will provide guidance regarding utility and future engineering of combined PET-MRI systems.

References

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