Deformable registration of abdominal mion-enhanced MR images for presurgical and radiotherapy planning of lymph nodes

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1 Introduction

Lymphotropic nanoparticles such as MION (monocrystalline iron oxide nanoparticle) have paved the way for MR in imaging lymph node metastasis. This highly sensitive and specific method has now been used on many patients with cancers of the prostate, bladder, kidney and breast to identify metastases as small as 1 mm in lymph nodes that have become cancerous. MION particles take advantage of the physiological behavior of some specialized white blood cells, which pick up foreign particles and carry them to the lymph nodes. These cells also pick up the similarly sized MION particles. Once the MION particles reach the lymph nodes, the nodes appear dark on MR images because of the effects of the iron oxide core of these particles. Since the white blood cells carrying the MION particles do not collect in cancerous tissue, normal lymph nodes can be distinguished from those that are cancerous.

In order to accurately determine the extent of metastasis in the lymph nodes, pre- and post- contrast images must to be accurately co-registered. By combining accurately the complementary information provided by these datasets, the physician can then manually or semi-automatically quantify the extent of metastatic lymph nodes in the image. In this initial patient study, we test the performance of a rigid and a non-rigid registration algorithm on an abdominal dataset.

2 Materials and Methods

Pre- to Post- Image alignment was performed using both a rigid and a non-rigid registration method. The rigid registration method uses maximization of mutual information between the two datasets, as described in [1]. The non-rigid registration technique described in [2] was initially proposed for the registration of brain images and was more recently applied to motion compensation problems in dynamic lung studies [3]. The dense transformation between the images is modeled as a mapping of the image domain. It is obtained by computing iteratively the steady state of an evolution equation of the form $\frac{\partial \Phi}{\partial t} = D\Phi \cdot v, \quad \Phi(0) = identity$, where v is a regularized velocity field induced by a local statistical similarity measure. In the context of MION enhanced data, we found the use of local statistics particularly effective to discriminate between the contrast agent intake and misalignment. To improve both the speed and the capture range of the method, this algorithm was implemented in combination with a multi-resolution strategy. Initial estimates of the deformation are obtained from coarse representations of the images and later refined at higher resolutions.

The patient dataset used in this study is an MR MION T_2 non-fat suppressed abdominal scan. Two Pre- and Post- datasets were acquired (512×512×60 voxels, with 0.5×0.5×3mm voxel size). The physician accurately identified the positions P_i of five structures, 4 lymph nodes and 1 cyst. The Pre- dataset was registered to the Post- dataset. Three distance measurements were performed on each structure: $\| P_{i\text{-}Pre} - P_{i\text{-}Post} \|$ before registration, after rigid registration, and finally after non-rigid registration. The results are shown in Figs 1, 2 and 3.

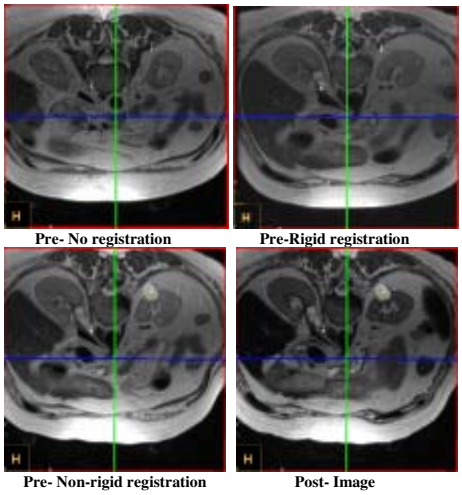

Fig. 1. Axial slices containing the cyst (1), and a lymph node (2) initially identified in the Post- Image.

3 Results

Fig.3 demonstrates some improvement in lymph node alignment using the rigid registration algorithm: the average error distance drops from 28mm to 13mm. However the non-rigid registration technique yields a pixel accurate alignment of all four lymph nodes and of the cyst.

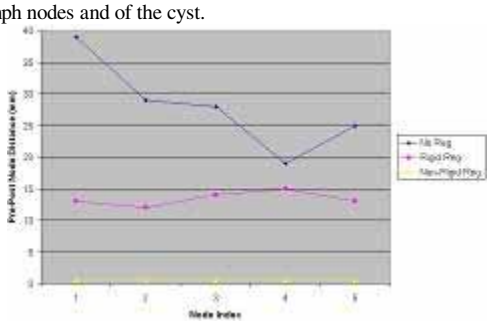

Fig. 3. Pre- to Post- error distances for all nodes (2-5) and the cyst (1).

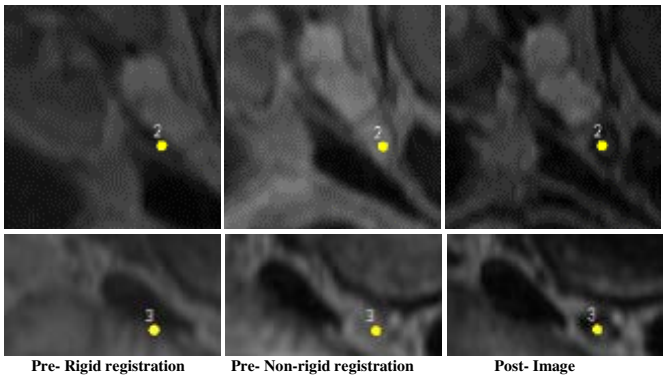

Fig. 2. Zoomed areas containing lymph nodes (2) and (3) initially identified in the Post- image.

4 Conclusion

This initial study shows that the joint analysis of MION enhanced Pre- and Post- data strongly benefits from the application of a robust and accurate non-rigid registration technique. This may enable significant improvement in detection rate of lymph node metastasis. In addition nodal information from pre-contrast images may be used to accurately identify nodal boundaries on post-contrast images. Finally precise registration of anatomical images with MRAs or CTs, will pave the way for precise surgical planning or radiotherapy.

References

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