

Intra-operative ultrasound based correction of brain-shift

I. Reinertsen^{1,3}, D. H. Iversen^{1,2,3}, F. Lindseth^{1,2,3}, W. Wein⁵, G. Unsgård^{4,2,3}

¹ SINTEF, Dept. Medical technology, Trondheim, Norway

² Norwegian university of Science and Technology (NTNU), Trondheim

³ Norwegian National Advisory Unit for ultrasound and Image Guided Therapy

⁴ St. Olav University Hospital, Dept. of Neurosurgery, Trondheim, Norway

⁵ ImFusion GmbH, Munich, Germany

Ingerid.Reinertsen@sintef.no

Introduction

Accurate mapping between pre-operative MR images and the patient is key to reliable neuro-navigation, however difficult to achieve due to errors introduced by patient-to-image registration and brain-shift. Consequently, pre-operative MR images can not always be trusted for accurate neuro-navigation. In order to correct for these effects, intra-operative ultrasound imaging is an attractive solution. However, interpretation of the ultrasound images may present an important obstacle in the efficient use of this modality, as most neurosurgeons are not specifically trained in ultrasound anatomy of the brain. Automatic MR-to-ultrasound registration has the potential to correct the MR data for inaccuracies due to initial mapping and brain-shift. The MR images can then be used actively during tumor resection.

In this work, we have combined the open-source intra-operative navigation platform CustusX [1] and automatic image registration software [2] to test the hypothesis that correction for brain-shift can be automatically performed in the operating room, and be accurate enough for brain tumor resection guidance. The results were evaluated both intra-operatively and post-operatively.

Methods

Ten glioma patients were prospectively included in the study. The study was approved by the Regional committee for medical and health research ethics and all patients provided written informed consent. The pre-operative MR images (T1 and FLAIR) were registered to the patient using five fiducial markers. The intraoperative setup consisted of a navigation rack with our open-source platform CustusX [1]. The navigation system was connected to an optical position tracker (NDI Polaris Spectra; Northern Digital, Canada) and a GE Vingmed E9 ultrasound scanner with a GE 11L linear array transducer (GE Vingmed Ultrasound, Norway). The image registration software (ImFusion Suite, ImFusion GmbH, Germany) automatically aligns MR and ultrasound based on a robust image-based algorithm which is invariant to the different appearance between the modalities. It was run as an independent package called from the navigation system interface, and the result was automatically loaded.

Immediately after image registration, the surgeon evaluated the rigid registration result by inspection of the correspondence between the MR and

ultrasound volumes. Post-operatively, the results were evaluated by placing ten landmarks in the image volumes and computing the distance between points before and after registration.

Results

In six out of ten cases, the correction was judged sufficiently accurate to continue the resection based on the corrected images. In three cases, the rigid registration was unable to accurately correct the images due to non-rigid deformation of brain-tissue. In one case, the navigation setup failed causing the mismatch between the images to be larger than the capture range of the algorithm. In the six successful cases, the mean distance between corresponding landmarks was reduced from 6.46 mm to 2.68 mm.

Discussion

We have shown that automatic correction of brain-shift is feasible in the operating room. The registration improved navigation accuracy in six of ten cases. The method should be further extended to non-rigid registration for increased accuracy, and also applied to other datasets such as fMRI and DTI.

References

- [1] C. Askeland et al. "CustusX: an open-source research platform for image-guided therapy," *IJCARS*, 2015.
- [2] W. Wein et al. "Global Registration of Ultrasound to MRI using the LC2 Metric for Enabling Neurosurgical Guidance", *MICCAI 2013 Proceedings*