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PHYSICS CONTRIBUTION

RESULTS OF A MULTI-INSTITUTIONAL BENCHMARK TEST FOR CRANIAL CT/MR IMAGE REGISTRATION

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Purpose: **Variability in computed tomography/magnetic resonance imaging (CT/MR) cranial image registration was assessed using a benchmark case developed by the Quality Assurance Review Center to credential institutions for participation in Children's Oncology Group Protocol ACNS0221 for treatment of pediatric low-grade glioma.**
Methods and Materials: **Two DICOM image sets, an MR and a CT of the same patient, were provided to each institution. A small target in the posterior occipital lobe was readily visible on two slices of the MR scan and not visible on the CT scan. Each institution registered the two scans using whatever software system and method it ordinarily uses for such a case. The target volume was then contoured on the two MR slices, and the coordinates of the center of the corresponding target in the CT coordinate system were reported. The average of all submissions was used to determine the true center of the target.**
Results: **Results are reported from 51 submissions representing 45 institutions and 11 software systems. The average error in the position of the center of the target was 1.8 mm (1 standard deviation = 2.2 mm). The least variation in position was in the lateral direction. Manual registration gave significantly better results than did automatic registration ($p = 0.02$).**
Conclusion: **When MR and CT scans of the head are registered with currently available software, there is inherent uncertainty of approximately 2 mm (1 standard deviation), which should be considered when defining planning target volumes and PRVs for organs at risk on registered image sets.** © **2010 Elsevier Inc.**

Image registration, Image fusion, Image correlation.

INTRODUCTION

Imaging has become an essential and routine part of defining target volumes and critical normal structures in radiation therapy. Multiple techniques and modalities are often used for the same patient. Computed tomography (CT) scans with and without contrast, magnetic resonance imaging (MRI) scans with different echo sequencing, and positron emission tomography scans are often required to define adequately the volumes to be treated and the volumes to be avoided. Accurate target definition is increasingly important because the ability to closely conform the dose has increased with technologies such as intensity-modulated radiation therapy and tomotherapy.

Modern treatment planning is usually based on a CT scan acquired with the patient immobilized in the treatment position. The CT scans allow accurate calculation of dose in heterogeneous material, which is not currently possible for other imaging modalities. Target volumes and organs at risk are defined on the CT planning scan so that conformal treatments may be devised. Software is often provided to allow registration and visualization of other three-dimensional imaging sets, which may better show the extent of disease. The importance of image registration for accurate target definition is now widely acknowledged (1–3).

Planning systems provide various tools for performing this registration. Typical options include matching DICOM (Digital Imaging and Communication in Medicine) coordinates, manual selection of the same anatomic points on both imaging sets, manual translation and rotation, and various ''automatic'' algorithms that look at matching similar pixel patterns and gradients.

To evaluate the accuracy of the registration, visualization tools usually include overlay of the imaging sets with variable degrees of transparency and/or split images. Assessment of the success of the registration is usually a subjective judgment by the individual performing the registration, usually a radiologist, radiation oncologist, physicist, or dosimetrist.

Several studies have attempted to assess the accuracy of image registration in a systematic way (4–11). Sarkar *et al.* (4) compared the use of match points vs. two algorithms

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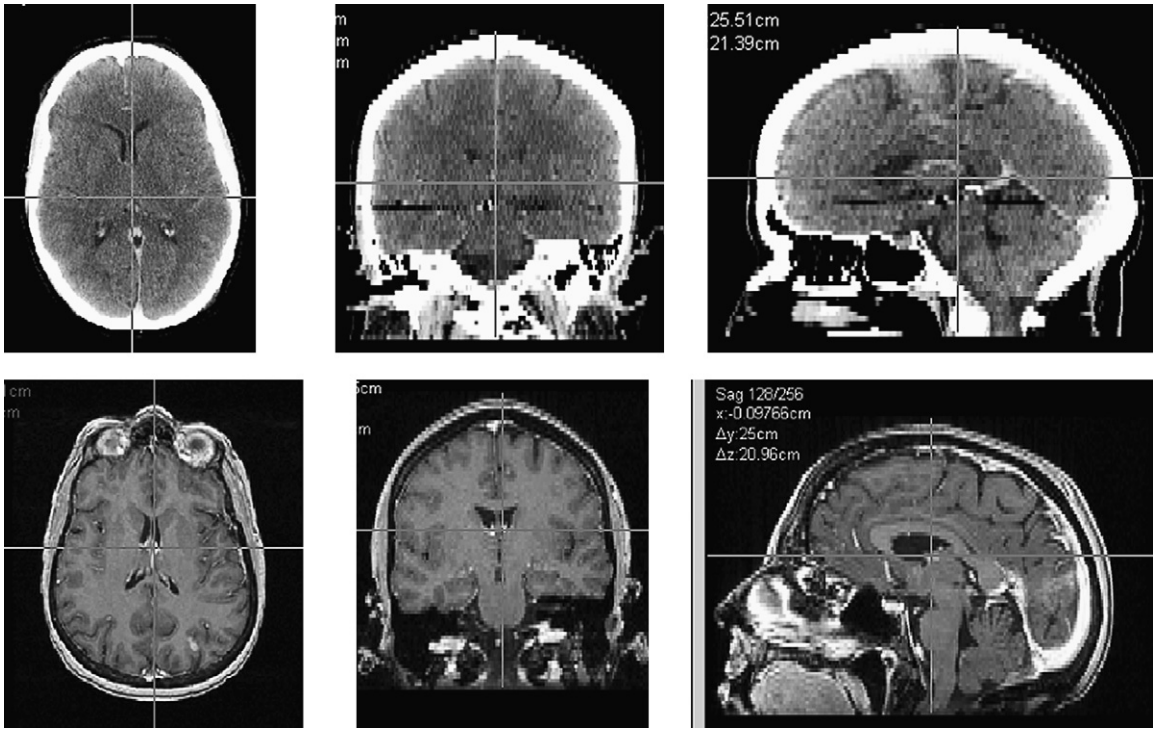

Fig. 1. Transverse, coronal, and sagittal slices of the computed tomography and magnetic resonance imaging sets used for the registrations.

for ''automatic'' registration of cranial CT and MR image sets. Veninga *et al*. (5) assessed the accuracy of the normalized mutual information method for cranial CT/MR image registration. Dean *et al*. (8) developed an analytic method for comparing results for CT/MR image registration from two software systems used in radiotherapy. Phantoms have been used to assess the accuracy of image registration (9–11), but phantoms lack the anatomic complexity needed for a complete test of the process.

The Children's Oncology Group has developed a protocol for the treatment of pediatric low-grade glioma (COG ACNS0221). Many of these tumors can be visualized on MRI but not on CT. To verify that institutions could accurately perform image registration, the Quality Assurance Review Center (QARC) was asked to develop a test case. The QARC is an organization funded by the National Cancer Institute to provide quality assurance of the radiation therapy of patients treated on protocols sponsored by the Children's

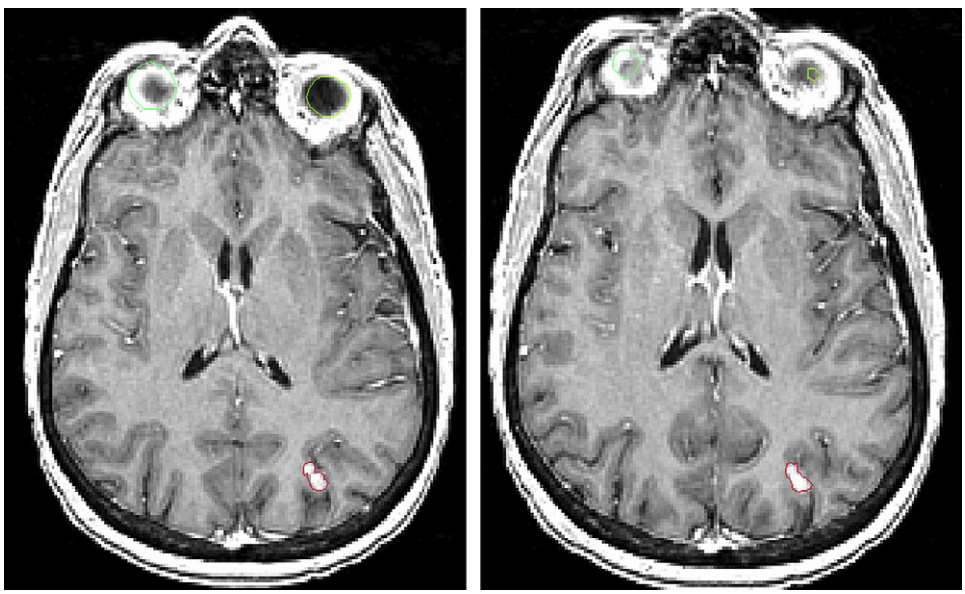

Fig. 2. Magnetic resonance imaging sections on which the target volume, the contrast-enhancing lesion in the posterior occipital lobe, was to be outlined.