MR Scanner Geometry Changes: Phantom Measurements Compared to Intracranial Contents Calculations

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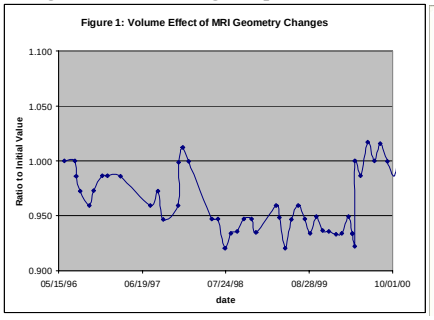
Introduction

The purpose of this study was to evaluate the degree to which total intracranial contents (ICC) measures could be used to track MRI scanner geometry changes during a longitudinal study of brain volumes measured with MRI over a span of four years. In adults, the size of the intracranial cavity is not expected to change significantly. While the brain may shrink, the lost material is replaced by CSF, thus changes in the ICC (the sum of brain and csf volumes), for a population in which there had been no cranial surgery or trauma, would be expected to reflect primarily scanner gradient calibration changes. While scanners are normally recalibrated periodically or after changes in hardware or software this is usually done only to an accuracy of 1%. This level of inaccuracy could lead to 11cm^3 variation in an 1100cm^3 brain volume which is twice the expected yearly change of 5.4cm^3 in a normal aging population [1]. If the ICC can be used to track scanner geometry changes the necessity for scanner geometry verification using separate phantom measurements can be reduced or eliminated.

Methods

While higher-order spatial mapping procedures could be considered, this work focused on the linear scale factors of the scanner under the assumption that those accounted for a major portion of changes over time. Scanner geometry measurements were made periodically over a period of 4 years by measuring landmarks in spin-echo images of a phantom that was scanned approximately monthly. A particular distance between two points separated by 72mm in the x, y and z directions was measured each time. The same MRI scanner and phantom was used throughout (1.5T, Signa echo-speed, GE Medical Systems) using the standard quadrature head rf coil. The phantom was a standard QA phantom (GE QA phantom) that had a rectangular region that was similar in the axial, sagittal and coronal planes. The width of this section was measured each time.

ICC was evaluated for 113 normal elderly subjects enrolled in an IRB approved longitudinal study of major depression in which volumetric MRI scanning was performed every two years. The ICC was determined using a semiautomated two contrast (proton density and T2-W) tissue identification computer program that involves a stage in which various tissue types (grey, white, csf, other) are sparsely identified by a trained operator (seeding) [2]. The semiautomated analysis was done as the data was collected and hence there can be slight 'method drifts' between analyses. ICCS (ICC semiautomated) is calculated as the sum of the gray, white and csf volumes. These results were compared to ICCA (automated) calculated using a fully automated, atlas driven tissue identification algorithm [3](for a subset of 83 of the 113 total subjects) and to the changes detected using the phantom measurements.



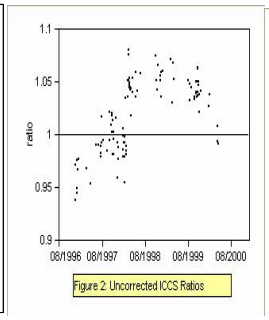


Figure 2: Uncorrected ICCS Ratios

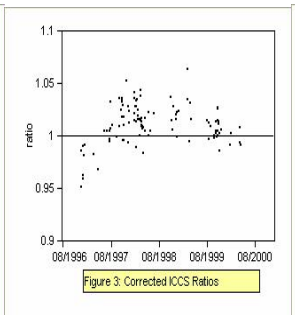


Figure 3: Corrected ICCS Ratios

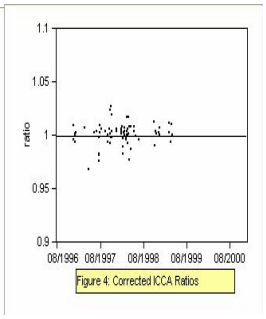


Figure 4: Corrected ICCA Ratios

Results

The product of the x, y, and z direction ratios of the phantom measurement at a particular time to the initial measurement were calculated to provide an estimate of the overall volume effect of scanner geometry changes. Changes of up to 5% in the volume were detected by the phantom measurements as shown in Figure 1. While the small changes probably reflect the variance of the method, the large changes correlate with events in the service logs of system such as gradient amplifier failure/replacement. The ratio of the ICC at the year 2 scan to the subject's baseline scan for subjects recruited throughout this time are shown in Figure 2 for ICCS. The average value is 1.015±0.036. If there had been no geometry changes this ratio should be unity. The same ratio is shown in Figure 3 after correction using factors derived from the phantom measurements. The ratio is improved to 1.009±0.019. Figure 4 shows the ICCA data after the same correction (fewer subjects available with automated processing at this analysis). This ratio averages 1.000±0.010.

Discussion

The fact that the correction factors derived from the phantom brought the ICC ratios close to unity is encouraging and indicates that it is possible to consider using the ICC in adults to 'self-calibrate' for scanner geometry changes. A clear limitation is that the ICC cannot be used to detect change in a single gradient, but only the product of the changes in all three directions, ie, the ICC can only detect volume changes, while phantom measurements can detect individual gradient direction scale changes. Comparison of the correction results in Figures 3, 4 for the semiautomated vs the automated method indicates that a potential second cause of geometry volume changes in an operator assisted tissue identification method is that of method drift. For two different scans it is possible that the operator could use a slightly different criterion during the seeding process as to which part of a tissue to sample, which can cause some of the gray, white or csf category to be shifted into the 'other' category, leading to an apparent change in ICC and thus the ratio of ICC's for scans of the same subject taken at different dates. We believe that this is the major reason the semiautomated method is not completely corrected to unity by the purely geometric corrections while the fully automated one (which has no method drift) is corrected. Thus the ICC self-calibration method may be limited in its utility to the automated tissue identification methods.

References

1. Resnick SM**,** The Journal of Neuroscience, 23(8):3295–3301, 2003.

2. Kikinis R, etal., J Magnetic Resonance Imaging, 2(6): 619-629, 1992.

3. Van Leemput, et al., IEEE Trans Med Imaging **22**(1): 105-19, 2003.