Correcting for structural distortions – Does it matter?

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Introduction

In Magnetic Resonance Imaging (MRI), scanner specific image artefacts and distortions may occur. Such distortions may reduce accuracy and precision in structural investigations of the human brain. Standardised processing streams should be applied to multi-centre data to reduce variance (Cannon, Sun et al. 2014). For longitudinal studies, such as investigating volumetric changes in brain regions due to ECT, corrections is important even for single-site studies, as the distortions may depend on the position of the head within the magnetic field itself (Jovicich, Czanner et al. 2009). Here we compare structural imaging data (3D T1 volumes) of the human brain acquired at two different scanners, and estimate the effects of correcting images for scanner specific gradient non-linearity.

Objective

The objective of this study was to evaluate:

1. The effect of distortion corrections on different scanners
2. If the variance in longitudinally acquired volumetric measurements can be reduced by applying distortion corrections to MRI data

Materials and Methods

Structural 3D T1 volumes of patients that underwent electroconvulsive therapy were acquired at 3 time intervals on a GE 3T Signa (n=6) or Discovery 750 (n=6) scanner.

The T1 volumes were corrected for scanner specific gradient non-linearity by a standardised processing stream implemented in magickbox (Bartsch) in an application running under Ubuntu (Ver 14.04 LTS. Osirix MD (Ver 6.5.1) was used for reading the images.

The distortions were estimated by comparing volumetric analysis of automated segmented regions of interest (ROI) with FreeSurfer before and after application of distortion corrections.
The ROIs that were analysed was: The Hippocampus formation, The Corpus Callosum, Subcortical Grey matter, Total Intracranial Volume (ICV) and the Superior Frontal Gyrus. ROIs used in the analysis were calculated as the sum of the values for the right and left hemispheres.

Longitudinal data (3 time points) from 2 scanners allowed evaluation of intra scanner variance (same patient scanned 3 times on the same scanner) as well as variance induced by using different scanners in the same project.

The ICV should not change over time, nor by ECT treatment. Therefore, in order to estimate the effect of distortion-correction on the variance (in longitudinal data) of FreeSurfer ROI quantification, the estimate of the ICV was used.

Scanner	ROI	Original (SD) (µl)	Corrected (SD) (µl)	Diff (%)	Sig (paired t-test)
	Hippocampus	7237 (518)	7095 (533)	141.33(2.0)	0.005
	Superior Frontal Gyrus	41255 (2568)	43613 (2625)	-2357.67(-5.8)	0.005
	White matter (Corpus Callosum)	3124 (490)	3119 (490)	5.13(0.2)	0.2
Signa (n=6)	Subcortical Grey	51564 (3266)	51955 (4188)	-391.00(-0.7)	0.5
	Total Intracranial Volume	1391911 (99801)	1426229 (81236)	-34318.74 (-2.6)	0.02
	Hippocampus	8024 (1501)	8061 (1446)	-37.33 (-0.6)	0.4
	Superior Frontal Gyrus	45210 (4688)	46027 (4591)	-816.83 (-1.9)	0.004
Discovery 750 (n=6)	White matter (Corpus Callosum)	3232 (551)	3234 (541)	-2.48 (-0.1)	0.7
	Subcortical Grey	58174 (6820)	57834 (6893)	340.50 (0.6)	0.3
	Total Intracranial Volume	1606977 (130060)	1613345 (127043)	-6368.83 (-0.4)	0.07

Table 1 - The mean, standard deviation, difference and significance based on a paired t-test of the automatic segmentations of ROIs done by FreeSurfer. The volumes are in µl

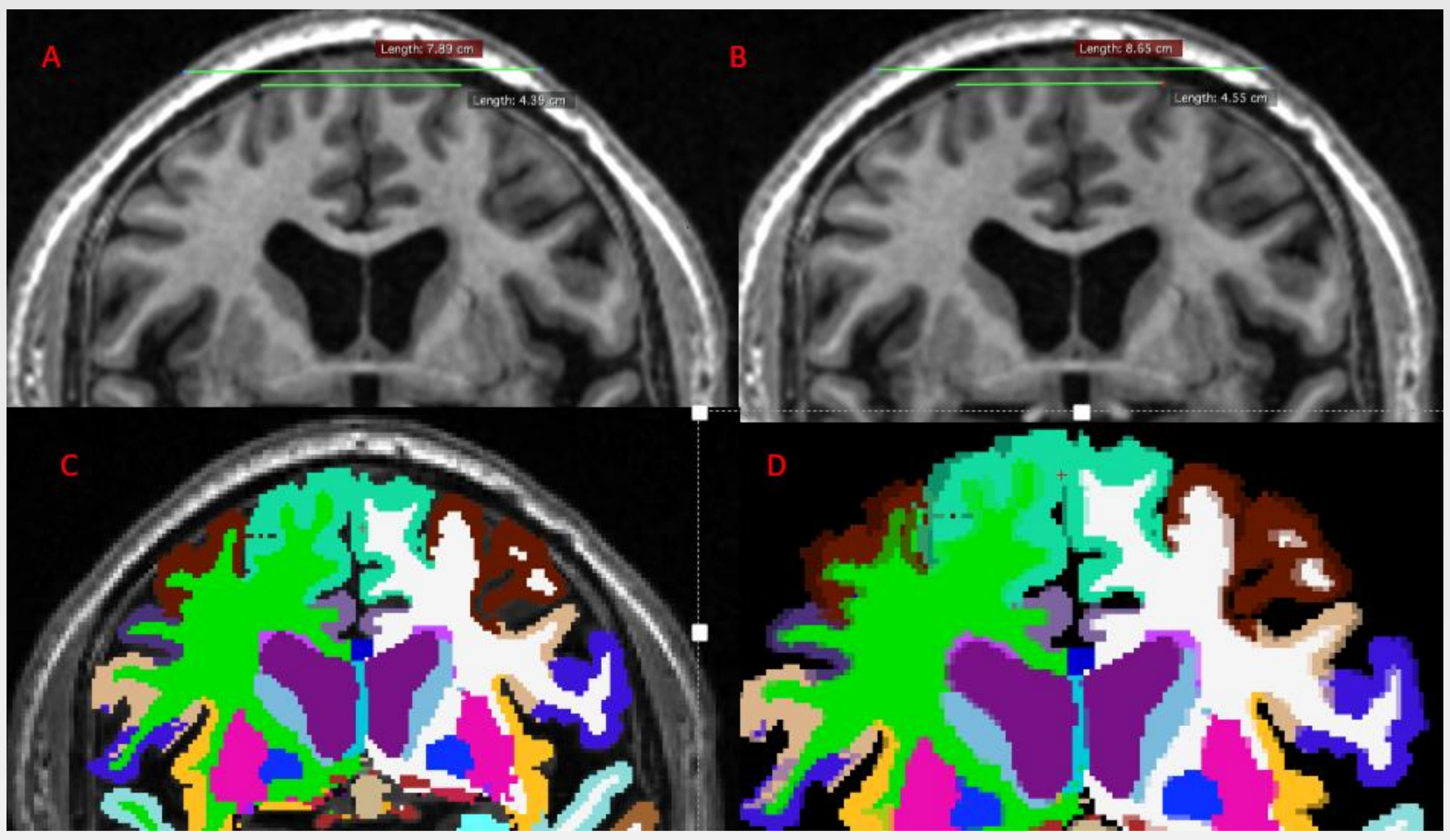

Figure 1 Effects of corrections: A, uncorrected scan, B, corrected scan. Notice difference in measurements. C, the T1 image and overlayed segmentation from the uncorrected data. D, segmented uncorrected (more intense) data overlayed the segmented corrected data (less intense).

Results

The visual effect of the distortions were confirmed by the freesurfer segmentations. The ROI that changed the most was the superior frontal gyrus by ~6% on the Signa scanner. Additionally, there was a change of ~3% and ~2% in the ICV and hippocampus formation respectively. On the discovery 750, only the superior frontal gyrus changed significantly at ~2%. These results are displayed in table 1.

The effects of the corrections were scanner-dependent

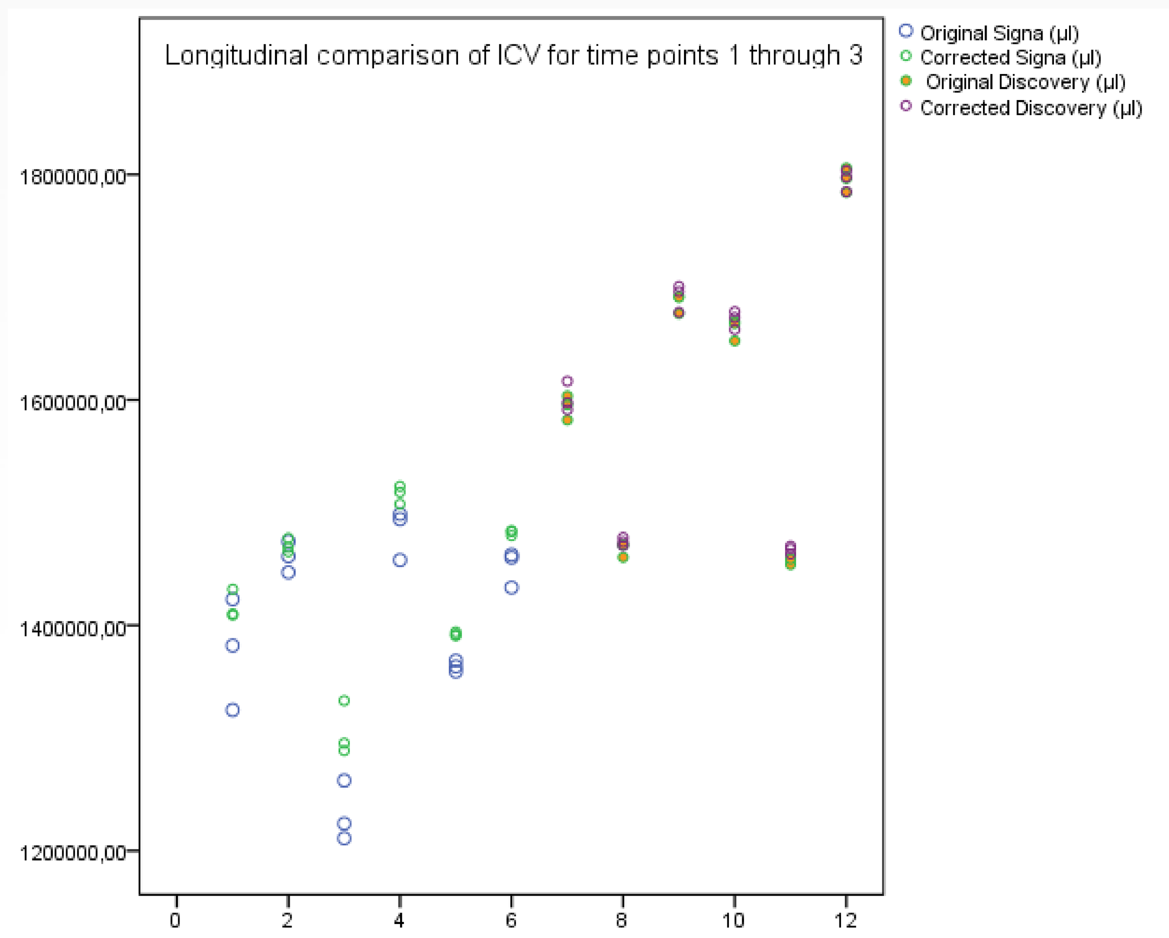

Figure 2 – A scatter plot that shows the ICV from time point 1 through 3 for all subjects. Subjects 1 through 6 were scanned on the Signa scanner and the remaining 6 subjects on the Discovery scanner. From this figure one can appreciate the reduction in variance due to the corrections.

Discussion

As seen visually by co-registering corrected and uncorrected T1-Volumes, the top of the head seems to flatten and become wider in general when corrections have been applied. This is supported by the change in volume of the superior frontal gyrus.

Additionally, Figure 2 shows a smaller spread in ICV between time points, both on the Signa and Discovery scanners. This would indicate that the corrections reduce variance on longitudinally acquired data.

Conclusion

In research using T1-weighted MRI volumes, correcting for scanner-specific gradient non-linearity could prove important for reducing variance in longitudinal and multi-centre studies. In addition it is important for precise and accurate measurements when evaluating structures in the human brain.

References

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