Effect of partial volume modeling, use of anatomical templates, and bias-field correction, on the repeatability of MRI regional volume quantification

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Objective: Two main acquisition factors may distort volume quantification from brain MRI: intensity non-uniformity and partial volume effects (PVE). Segmentation methods should be not only accurate but also highly repeatable, to reach the highest statistical power.
The aim of this work is to measure the repeatability of different segmentation strategies on regional volume estimates. We choose to focus on three possible alternatives of the most widely used segmentation method, the EM algoritlun. Thus, we have obtained regional volumetric data using raw EM, EM with PVE modeling, and EM using anatomical templates. To account for the most common sources of error, these methods have been evaluated under different conditions of patient positioning, MR scanner, and bias field correction.
Methods: The dataset used consisted of 24 MR images (T1-weighted 3D gradient echo; 0.9 x 0.9 x 1.5 mm thickness) of 4 different subjects, acquired in 2 different MR scanners of different static field (0.5 and 1.5 Tesla) and repeating the acquisition 3 times in each scanner, to account for patient repositioning. All of these images were then corrected for intensity in-homogeneities with the N3 algorithm (Sled et al. 1998). Both the corrected and uncorrected images were segmented using 3 different strategies: EM (Standard EM algorithm; Wells, 1996); PVE (EM algorithm and implementing partial volume modeling; Ruan et al.,2000); and SPM (EM algorithm and using anatomical templates, implemented by SPM; Ashburner et al., 2000).
Repeatability measurements were based on standard deviation values of volume data obtained with each method, for the sample of 12 images (4 subjects repeated three times). Inter-subject variation was left out by using residuals modeled in an ANOVA using subject as factor.

Repeatability values measured as standard deviation (Std. Dev.) of volume data obtained for each scanner and each segmentation method, both corrected (N3) and uncorrected (Unc) for bias field inhomogeneity. Left-most column shows the mean volume (in cc) for the sample of 12 images (4 subjects repeated three times). Regional volume measurements for whole brain, frontal, orbital, parietal, occipital, and temporal lobes, were obtained using a semiautomatic method based on the Talairach grid system (Desco et al. 2001).
Results & Discussion: Our results indicate that the inclusion of PVE always improves considerably the repeatability of the data, but SPM methods shows the most repeatable values for most of the variables (Table 1). Values for GM tissue seem to be more dependant than CSF or WM on the segmentation method used.Correction of bias field is critical to obtain minimally repeatable values. In all methods, repeatability of corrected images was more than twice that of uncorrected images (Table 1).
Conclusions: Even in the event of uncorrected data, the SPM method still achieves considerable repeatability. This conclusion is relevant for situations where uncorrected data is preferred over the uncertainty of biasing the results by using a bad correcting criteria or when the amount of bias field strength is unknown or too low (Gispert et al. 2004).
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