Effect of gain field inhomogeneity correction on automated segmentation of the intracranial cavity

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Introduction

Identifying the intracranial cavity (ICC) is an important initial step in many procedures for computer-assisted brain tissue segmentation of head MR images. Identification of the ICC was the only step in our image analysis procedures for the segmentation of white matter signal abnormalities (WMSA) that required operator interaction (1). While the operator effect on the reproducibility of WMSA volume measurement has been shown to be minimal (2), the necessity for even minimal human supervision introduces a disproportionate time penalty by the added need for data management.

Previously, an individual statistical classifier was generated for each MRI head study by manually selecting a few sample points in the image (1). The application of this classifier to all images, combined with a chain of automated morphological operators yielded a quasi-accurate identification of the ICC (Fig. c). Remaining misclassification (eg, inclusion of the periorbital fat and eyeballs Fig. c big arrow) required manual editing. In this work we have applied a self-adaptive tissue segmentation algorithm (EM segmentation), that includes gain inhomogeneity correction (3) to the identification of the ICC. We present a comparison of these two methods in terms of reproducibility and accuracy, and processing time.

Methods

Two groups of data were acquired from patients with multiple scrolesis (MS) on different MRI systems and similar yet different acquisition protocols. Fifteen double-echo data sets were obtained using a Siemens 1.5 T MRI system (The Cleveland Clinic Foundation, Cleveland ,OH), TR 2800ms, TE 20/80ms. Five double-echo data sets were acquired on a GE 1.5 T MRI system (Brigham and women's hospital, Boston, MA) with TR 3000ms and TE 30/80. Both data were obtained with 3mm contiguous sections; 256X192 acquisition matrix.

For each group of data, 15 cases from a Siemens scanner and 5 cases from a GE scanner, an a-priori tissue-conditional intensity model and the correction parameters were set up for the EM segmenter. The EM intensity inhomogeneity correction algorithm was applied to all twenty cases. One intensity based statistical classifier (Parzen map) was built for each group by manually selecting a few sample points for background, brain parenchyma, CSF, and facial tissues in an inhomogeneity-corrected image. Each map was then used to automatically generate an ICC for all cases in the respective group of image sets.

To test the reproducibility of each method the ICC extraction from one case was repeated ten times. A standard ICC for each method was built by selecting pixels identified as ICC by at least eight out of the ten runs. A pixel by pixel Dice similarity coefficient (DSC) was measured for each ICC with respect to the standard ICC (4).

The two methods' accuracy was similarly evaluated with respect to a single "gold standard" slice at the level of the orbits, which had been manually segmented 10 times by a single radiologist.

Results

In the new method, the EM corrected data yielded well distributed intensity image for all 20 cases. An intact and satisfactory ICC for each case was generated automatically from one Parzen map per group. In comparison the old method used on all 20 cases, yielded the ICC that was missing portion mostly of parietal region and posterior fossa, while some non-ICC tissues(ie, periorbital fat) were included(Fig. c big arrow), At least one manual Parzen map was needed for each case, in some cases needed more than one Parzen map. The misclassifications required manual editing.

For the reproducibility test, the average DSC was 100% for the new method vs. 99.52% for the older one.

In the accuracy evaluation the average DSC was 99.09% and 96.99% for the new and old methods respectively.

The average time for identifying an ICC with the old method was approximately 30 minutes (including the generation of Parzen maps), while only about 4 minutes were needed with the new method.

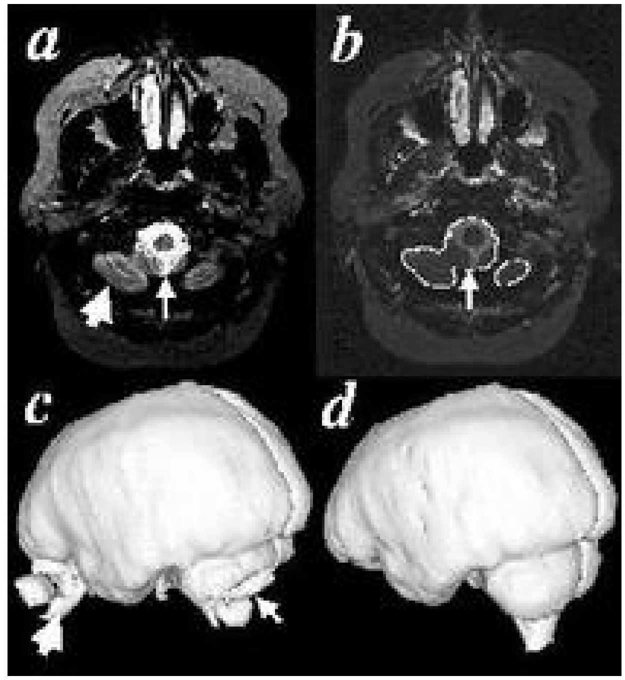

Figure a and b are from the same MRI image across the cerebellar hemispheres. (a) original T2WI overlaid with ICC from the old method (small arrow), the signal intensity is not well distributed due to intensity inhomogeneities. The cerebellar hemispheres with weak signal intensity are excluded from ICC (big arrow), (c)In the corresponding 3D rendering of the ICC, part of the posterior fossa is lost(small arrow). (b)EM segmentation inhomogeneity corrected image overlaid with the ICC from the new method (small arrow)the signal intensity is well distributed, the cerebellar hemispheres are correctly included into the ICC.(d)In the corresponding 3D rendering of the ICC, the posterior fossa appears intact.

Discussion

We have developed an ICC identification method that uses the EM segmentation algorithm to correct intensity inhomogeneities. With the old method,the intensity variations from scan to scan required a manual Parzen map for each case, while inter-plane intensity inhomogeneities occasionally necessitated the use of additional maps to cover the whole brain. In addition, in-plane inhomogeneities also lead to misclassifications with the old method. The EM segmenter compensates for intra- and inter-scan intensity inhomogeneities, gets a smooth intensity correction and brings the observed scan intensities into agreement with an a-priori tissue-conditional intensity model, thereby overcoming intensity variations from scan to scan. The same tissue-class conditional model of intensities can be used across scans, intensity corrected images can be saved for further processing with the property that a collection of scans will all have similar intensity properties. That allowed us to use one fixed intensity-based Parzen map to identify the ICCs in a whole group of similarly acquired image sets, without case-by-case operator interaction. The automated ICC generation reduces processing time, increases reproducibility and sensitivity, and benefits quantitive MRI follow-up studies.

References

1. Kikinis R, et al., J Magn Reson Imaging, 9(4), 519, 1999.
2. Guttmann CRG, et al.,J Magn Reson Imaging, 9(4), 509,1999.
3. Wells III WM, et al. IEEE Trans Med Imaging 15(4), 429,1996.
4. Warfield SK, et al. Med Image Anal. 4(1), 43, 2000.