Improved segmentation of intracranial volumes using a combination of T1- and T2-weighted 3D MRI

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Introduction:

A reliable segmentation of the brain into different tissue classes is the key to further evaluation by volumetry or voxel-based morphometry. 'Non-brain' structures may be excluded to simplify the segmentation problem for automatic processing. This strategy of 'brain extraction' is pursued by the FMRIB's software library (FSL, University of Oxford, 1). T1-weighted 3D sequences at a resolution of about 1 mm are traditionally used for 'structural' MRI. Typical problems regarding segmentation with T1-contrast are bleed-over at the skull base, unreliable assignment of major vessels, and an underestimation of sulcal CSF-space. Here, we present an approach that overcomes these problems by exploiting features of T2-contrast.

Methods:

11 healthy adults were examined on a 3T clinical imager (Siemens Magnetom Trio) using an 8-channel receive head-coil. 3D-datasets of 1 mm isotropic resolution were acquired using prescribed signal evolution of a multiple spin-echo sequence with variable refocusing flip angle (SPACE) for T2-weighting (2) and a purpose-optimized M-DEFT sequence for T1-weighting (3). Postprocessing comprised rigid-body registration, brain extraction (4), segmentation (5), and volumetry over the whole brain region using FSL 3.2.

Results:

Brain extraction: T2-w contrast yielded a clean delineation of parenchyma and CSF space. Due to the large signal drop from CSF to bone, the borders to the skull were outlined with high precision. The outer draining sinuses were excluded (Fig. 1, top). Voxels at the borders of the mask contained connective tissue of the dura mater as identified on the T1-w dataset (Fig 1, bottom). Delineation of the peripontine regions was mildly affected by flow artifacts from the basilar artery, but problems occurred around the pituitary gland and at the sinus cavernosus. The M-DEFT sequence provided excellent delineation at the skull base. Delineation of the draining sinuses was inconsistent as only an arbitrary part of the rostral sagittal sinus was excluded. A considerable portion of CSF space could be excluded around slightly atrophic gyri. The net difference of the brain masks amounted to up to 136 ml or 8% of the T2-subarachnoidal volume.

Segmentation: Standard segmentation into 3 classes reliably identified major structures of WM, GM, and CSF on MDEFT images, except at sub-pontine levels, where the Markov random field algorithm yielded an arbitrary transgression from WM to GM (Fig. 2, top right). On SPACE, segmentation did not delineate motor and visual cortex. It failed in 2/11 subjects, where frontal WM and pixels at the margin of the brain mask were combined into one class of low signal. In these subjects, hypointense signal levels from bone, cavities, vessels, or connective tissue were identified as a fourth class of "non-brain" (shown in green in Fig. 1) being clearly separated in the intensity histogram. Although this class obviously lacks a consistent T1-w signal level; it was consistently identified by multispectral segmentation into 4 classes (Fig 2, bottom). It accounted for about 30% of extra-parenchymal volume.

Discussion:

This 4-class segmentation strategy combines the superior T1-contrast for GM/WM differentiation and the T2-contrast to identify CSF and non-brain structures. Mismatches between the GM/WM/CSF sub-volumes determined from one contrast only could be explained by the 4-class results by a large degree. The technique may be beneficial to assess cortical atrophy in dementia, normal ageing, and developmental disorders.

Figure 1: T2w (top) and T1w (bottom) structural MRI of a 40-y old male

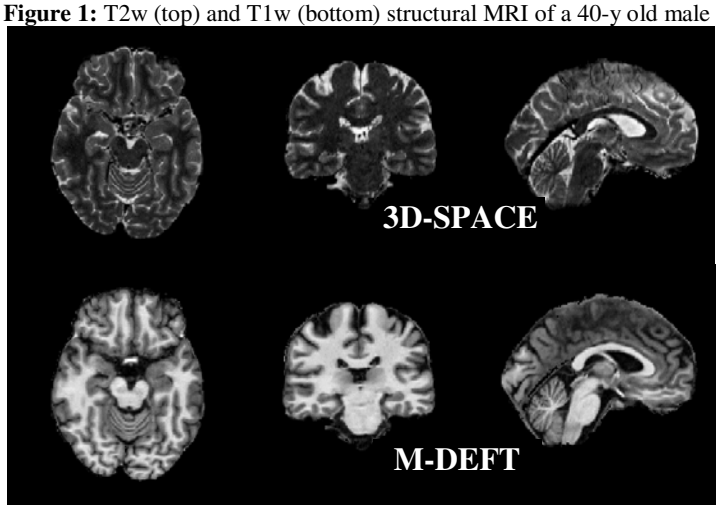
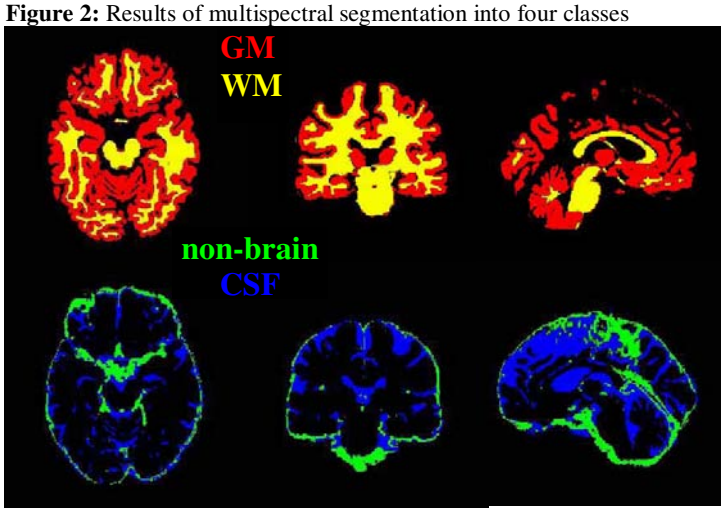


Figure 2: Results of multispectral segmentation into four classes



References:

(1) http://www.fmrib.ox.ac.uk/fsl (2) Mugler, Kiefer, Brookeman. *Proc. 8th ISMRM*, 2000. (abs 687) (3) Deichmann, Schwarzbauer, Turner. *NeuroImage* 2004:21:757-67. (4) Smith. *Human Brain Mapping* 2002:17:143-55. (5) Zhang, Brady, Smith. *IEEE Trans Med Imaging* 2001:20:45-57.

Acknowlegements:

The MDEFT sequence was provided by Dr. R. Deichmann (London); the SPACE sequence by Siemens. Grant sponsor: Volkswagen Foundation.