Who said fat is bad? Skull-stripping benefits from additional fat image.

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Introduction

Being a preliminary step for many clinical applications and analyses, accurate skull-stripping is a key challenge in MR brain imaging [1-3]. One of its major difficulties arises from the contrast similarities at brain/non-brain tissue interfaces, in particular between grey matter (GM), veins, the dura mater and fat tissue. Multispectral imaging may help to mitigate this problem [4]. Specifically, the acquisition of multiple echoes in a MP-RAGE sequence (MEMPR) as shown in the work of van der Kouwe et al. [5] can be used for this purpose. Pursuing their approach, we combine MEMPR with the Dixon method [6] to obtain an additional contrast depicting only the fat signal. This work investigates whether the thus generated additional information can improve the outcome of an unsupervised intensity-based skull-stripping algorithm.

Material and Methods

A multi-echo MP-RAGE sequence (TI/TR=900/2200ms, 2 bipolar echoes, TE_1=2.56 ms, TE_2=6.02ms, FOV=256x256x160mm^3, 1mm isotropic, GRAPPA=2, pre-scan normalise, TA=5:16 min) was used to scan three young healthy volunteers providing informed written consent. The experiments were performed on a TIM Trio 3T MR system (Siemens Healthcare Sector, Erlangen, Germany) equipped with a 32-channel head coil. The length of the GRE readout amounted to 1552 ms in the MEMPR compared to 1008 ms in a normal MP-RAGE with similar bandwidth. The fat and water images were created by applying the classical Dixon equation [6] on the magnitude and phase data of both echoes. A third volume "mprContrast" was created by taking the mean of the magnitude of the two echo volumes. The mprContrast hence corresponds to a single-echo MP-RAGE image acquired with TE=(TE_1+TE_2)/2.

The in-house skull-stripping technique applied to test our hypothesis uses a variational expectation-maximisation algorithm combined with pre-aligned prior probability maps of grey and white matter, cerebrospinal fluid and non-brain tissue [7]. It is able to segment single- and multispectral MR images and incorporates contextual information by means of Markov Random Fields. The outcome of the algorithm using only mprContrast was qualitatively compared with the one using both mprContrast and the fat image as input.

Results and Discussion

In regions with similar brain/non-brain contrast, e.g. in the inferior part of the temporal and occipital lobes, the algorithm decides on the bases of the aligned prior probability maps, which may, however, be subject to misregistration. The additional information provided by the fat images mitigates this problem, as it can be seen in Fig. 1A. Skull-stripping results improved similarly in the other two subjects, showing analogue difference patterns (see Fig. 1B).

Compared to a standard MP-RAGE, the acquisition of the second echo does not prolong the overall scan time. The longer GRE readout, however, worsens the point-spread-function, whereas the combination of the two echoes (mprContrast) should recover most of the SNR lost due to the higher bandwidth. No image co-registration is needed, since the two echo image volumes are acquired simultaneously, preventing introduction of further partial volume effects.

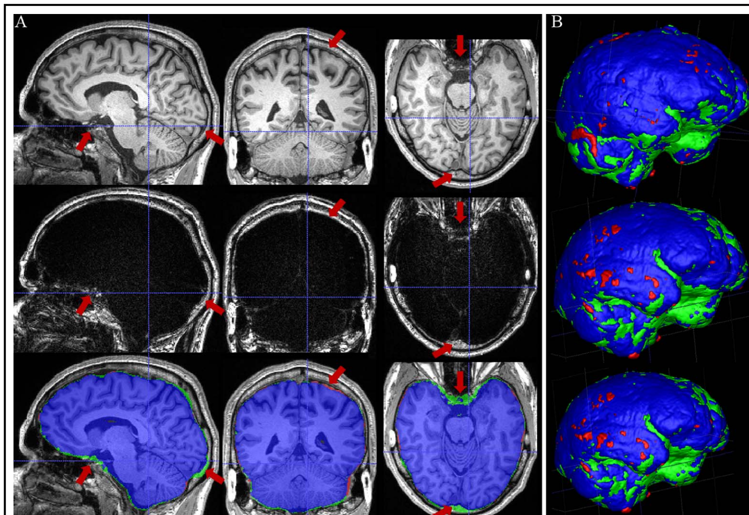

Fig. 1 Overlap (blue) and differences in skull-stripping results using mprContrast only (green) and both mprContrast and the fat image (red). (A) Exemplary case (top: mprContrast, middle: fat image, bottom: comparison result). Arrows show regions of better separation, primarily in posterior and inferior regions. (B) All three cases show similar difference patterns.

The presented method has the potential of ameliorating skull-stripping results without extending scan time. The additional information is inherently co-registered and does hence not significantly affect the algorithm's performance. These features make it an interesting subject for further investigations.

References

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