Synergies of High-Resolution Multi-Channel Lesion Segmentation in Multiple Sclerosis: MPRAGE, 3D FLAIR, 3D T2WI and 3D DIR

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Introduction

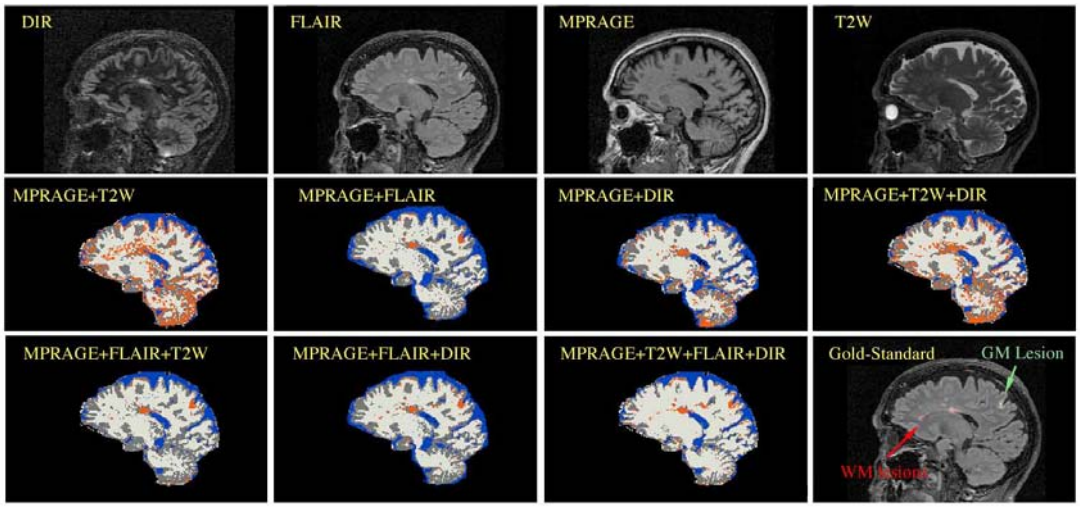
Multiple sclerosis (MS) has been long regarded as a white matter (WM) disease, even though it affects the cerebral grey matter (GM) to a very large extent, as well. In fact demyelinating lesions in the cortical GM have received renewed attention as they may provide a key to understanding different pathogenic pathways leading to neurodegeneration and demyelination (1). Until recently, however, GM demyelination was not well accessible through standard MRI techniques. With the availability of new high-resolution imaging sequences, in particular single-slab 3DFSE FLAIR and Dual-Inversion-Recovery (DIR) (2,3), the detection of GM disease and quantification of GM lesion burden appears feasible. In this work we present a preliminary analysis addressing the combined sensitivity of high-resolution multi-contrast imaging protocols and automated segmentation with respect to WM and GM lesions. The synergistic effects of multi-contrast protocols are evaluated. Specifically, the added value of the DIR protocol and the suppression of normal WM signal is assessed in the context of raising the sensitivity of automated lesion segmentation toward WM and GM lesions.

Methods

High-resolution sagittal single-slab 3D MPRAGE (TR/TE/TI, 2700/5/950 ms), FLAIR (TR/TE/TI, 6500/349/2200 ms), DIR (TR[p1]/TE/TI1/TI2, 6500/355/2350/350 ms) and T2W (TR/TE, 4300/349 ms) images were obtained from a single MS patient, with image size 1.2 x 1.2 x 1.3 mm^3 voxel size, on a 1.5 T MRI instrument (Siemens Sonata, Erlangen, Germany). The sequences were co-registered and intensity inhomogeneities were corrected. Manual consensus-based lesion delineation was performed by two experienced analysts and classified as GM and WM lesion, respectively. The intracranial cavity was also segmented for masking and reference. Subsequently, 2-, 3-, and 4-channel automated tissue-classification (kNN-classifier) was performed using all sequence combinations. Tissue classification maps were constructed from the same set of sample points to exclude selection bias. Automated segmentation results were compared to the manual delineation in terms of true and false positives and negatives (TP, FP, TN, FN). Sensitivity, specificity and accuracy were computed as sens=TP/(TP+FN), spec=TN/FP+TN, accu=(TN+TP)/(TN+TP+FN+FP). Lesions smaller than 4 pixels were excluded from analysis.

Results

The figure shows an example slice of the 4 channels (top row) and combinations of multi-channel segmentations, as well as the expert delineation of WM and cortical GM lesions (bottom right). Strong synergies are apparent from combinations of the DIR and FLAIR sequences. The best 2-channel results were obtained from the MPRAGE+FLAIR combination. The added value of the DIR sequence is strongest in combination with the FLAIR also. The T2W sequence yielded many false positives and contributed positively only in the 4-channel version in combination with FLAIR and DIR (Table).



Discussion

Multi-contrast MRI is becoming increasingly attractive in routine assessment of neurodegenerative disease, especially with the advent of parallel imaging. The choice of which MRI sequence and image contrasts provide the most synergy for automated disease detection is not straightforward. It is also not necessarily the case that more channels are always beneficial. Combinations without the MPRAGE sequence (not shown), for example, did not yield good results. 4-channel segmentation (MPRAGE+T2W+FLAIR+DIR) showed the highest sensitivity toward cortical GM lesions as well as overall lesion burden, but not necessarily for healthy GM (Figure). The applied segmentation did not consider spatial priors or anatomical constraints, because the objective was to evaluate the added value and synergistic effect of the additional MRI contrast toward tissue class separation. For example, the strong false-positive trend of the T2W is apparent. Enhanced specificity can be expected in combination with atlas or template-driven segmentation approaches.

MRI Sequence	*Sens*	*Spec*	*Accu*	*Sens GML*	*Sens WML*
MPR+DIR	33.3%	93.9%	93.6%	19.9%	34.5%
MPR+FLR	63.4%	99.0%	**98.9%**	56.3%	64.0%
MPR+T2W	41.8%	82.2%	82.1%	25.0%	43.2%
MPR+FLR+DIR	64.8%	**99.1%**	98.9%	50.4%	66.1%
MPR+FLR+T2W	62.5%	98.6%	98.5%	48.4%	63.7%
MPR+T2W+DIR	40.4%	87.1%	86.9%	20.7%	42.2%
MPR+FLR+T2W+DIR	**74.4%**	97.0%	96.9%	**68.4%**	**74.9%**

References

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