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Rule-based semi-automated method to segment T1 black holes on 2D brain images in multiple sclerosis

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Introduction

- In multiple sclerosis (MS), a subset of the hyperintense lesions on T2-weighted images are visible as 'black holes' on T1-weighted images, appearing hypointense compared to the surrounding white matter (WM) and iso- to hypointense relative to the cortical gray matter (GM).
- Black holes correlate with clinical disability[1] and mostly represent neuronal tissue destruction and axonal loss[2].
- Because a lot of existing data has 2D T1-weighted images, the ability to (semi-)automatically obtain black hole measurements from these images could provide useful insights and new information about the disease.

Objectives

To develop and validate a semi-automated method to segment black hole lesions on 2D T1-weighted images in multiple sclerosis that follows radiological intensity rules for black hole identification using cortical gray matter intensity as a reference.

Methods

- Multi-center MRI scans of the REFLEXION study (NCT00813709) of suspected/early MS were used.
- The method was optimized on a training set (N = 40, 57.5% female, mean age 31.4 ± 8.7 [standard deviation] years).
- The remaining 274 patients formed the test set (61.3% female, age 31.8 ± 8.4 years).
- Performance was quantified by Dice (DSC) similarity coefficient (a similarity metric) and intraclass correlation coefficient (ICC) for absolute agreement compared to manual reference segmentations as ground truth.
- Lesion-wise sensitivity and specificity were also calculated.

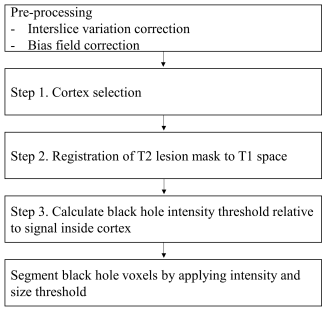

Figure 1. Overview of the pipeline used for the semi-automated method to segment black holes.

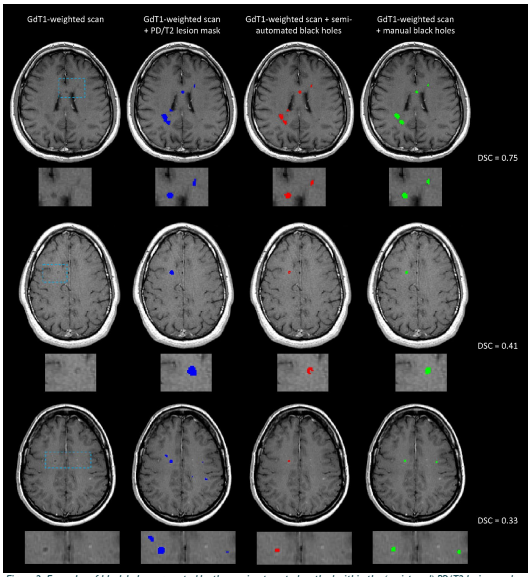

Figure 2. Examples of black holes segmented by the semi-automated method within the (registered) PD/T2 lesion mask on post-gadolinium T1 (GdT1)-weighted scans. The ground truth is also shown. DSC= Dice similarity coefficient (whole brain).

Conclusion

The proposed method to semi-automatically segment black holes shows acceptable performance. This method is recommended to be used to aid the radiologist to reduce the workload to obtain quantitative information on black hole lesions.

Results

Optimization

The optimized method consisted of:

(1) GM selection by adding WM and GM partial volume maps and imposing a 0.8 probability threshold using an MNI cortex mask.

(2) Linear co-registration of T2- to T1-weighted images with normalized mutual information as cost function, and interpolating T2 lesion masks to T1 space using trilinear interpolation and 0.6 threshold.

(3) Using the mean intensity inside the GM mask as upper intensity threshold.

Volume evaluation

- Spatial accuracy of the final optimized method was acceptable with a mean DSC of 0.39 ± 0.26. Volumetric accuracy was good with an ICC of 0.84, 95% CI [0.72, 0.90].

Lesion-wise evaluation

- The mean lesion-wise sensitivity was 0.91 ± 0.19 (determined in N = 227 patients with black holes) and the mean specificity was 0.62 ± 0.22 (N = 274 patients).

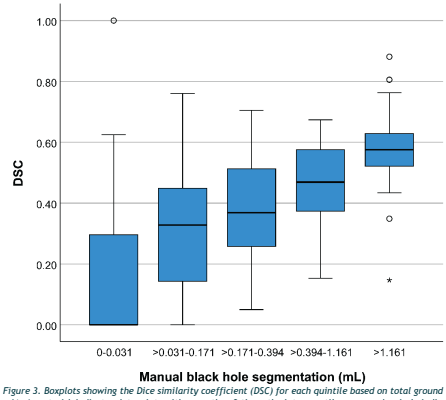

Figure 3. Boxplots showing the Dice similarity coefficient (DSC) for each quintile based on total ground truth black hole volume (in mL). An asterisk indicates datapoints with more than 3 times the interquartile range and a circle indicates datapoints between 1 and 3 times the interquartile range.

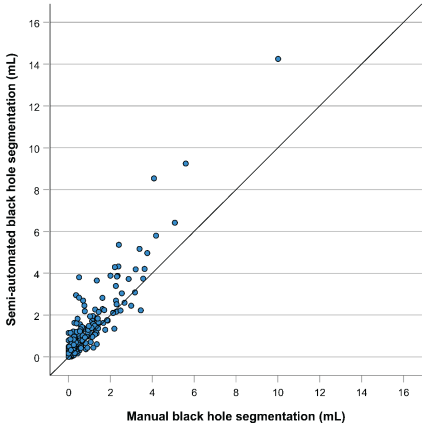

Figure 4. Scatterplot showing the agreement between the segmentation of black hole volumes (in mL) by the semi-automated method and the manual segmentation (ground truth; in mL). The identity line, reflecting perfect agreement, is shown for reference.

References:
[1]. Zivadinov R, Leist TP. Clinical-magnetic resonance imaging correlations in multiple sclerosis. J Neuroimaging. 2005;15(4, Suppl.):10S-21S.
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