Powerful detection of cerebral microbleeds on 7.0T MR phase gradient magnitude images using the radial symmetry transform

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Introduction: Interest in cerebral microbleeds (CMBs) is increasing rapidly since a few years. CMBs are commonly detected on MRI and are associated with vascular disease and dementia [1-6]. Currently, the standard for microbleed detection is visual rating with validated visual rating scales [5,7]. Identification and rating of CMBs on MR images may be facilitated by semi-automatic detection, particularly on high-resolution images acquired at ultra high field strength. Previous work showed that this can be done by using the radial symmetry transform (RST) on dual-echo 7.0T MR gradient echo magnitude images. The RST is a technique that utilizes image gradients and orientations to infer the center of mass of 3D spherical objects in a scan [15], corresponding to microbleeds. Although the RST outperforms other known semi-automatic methods for CMB detection [8-10], it still returns a number of false positives (FPs) that have to be censored manually. Manual censoring requires on average 2 minutes per patient, as opposed to 30 minutes for a full manual rating [8].

Up to date, CMBs are detected on the signal magnitude of a gradient echo acquisition, which shows a reduced signal as a function of the echo time. This signal loss is the result of a local susceptibility effect, caused by the paramagnetic hemosiderin deposits of which a CMB consists. Besides the blooming effect on the signal magnitude [17], an effect of the varying susceptibility can be observed in the signal phase [18,19].

In this study, a proof-of-principle experiment was performed to investigate the possibility to reduce the number of false positives by applying the RST on the phase gradient magnitude image [11,12]. At the location of CMBs, a characteristic dipole phase pattern is visible, which is not expected at the location of false positives. On the phase gradient magnitude image, this pattern has radial symmetry and can be detected by the RST.

Methods and materials: For this study, three participants with CMBs were included from the Second Manifestations of ARTerial disease (SMART) study [13]. Written informed consent was given by all participants. MRI acquisition was performed as described previously by Conijn *et al.* [14] on a 7.0T whole-body system. A dual-echo gradient echo sequence was acquired (first echo time: 2.5 ms, second echo time: 15.0 ms, repetition time: 20.0ms, and reconstructed voxel size: 0.35x0.35x0.3 mm^3).
Automatic CMB detection in magnitude images was performed as described in our previous study [8]. Potential CMBs were identified by combining the output of the RST on both echoes. Each potential CMB identified through the RST was visually checked by two experienced raters to identify probable CMBs.

On the second echo, where microbleeds are most prominent owing to the blooming effect [17], the phase gradient magnitude image was computed at each potential CMB location [11,12]. Figure 1 shows the typical spherical pattern that was visible at a CMB location, but not or less prominent at the location of FPs. Detecting this spherical shaped pattern in the phase gradient magnitude image was performed by applying the RST. By thresholding on the computed radial symmetry value, it was possible to significantly improve the distinction between true and false microbleeds.

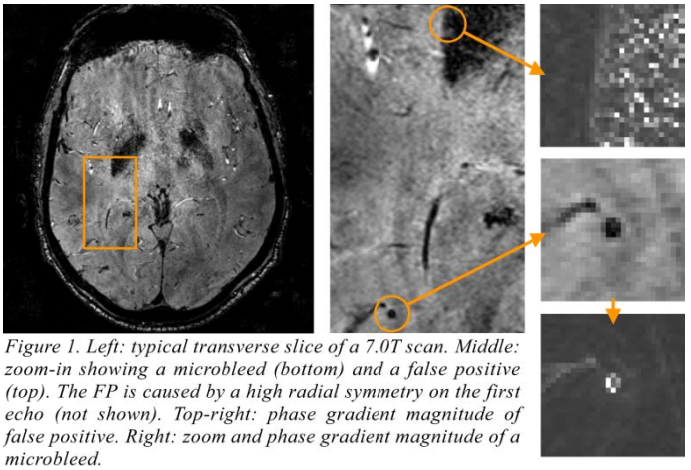

Figure 1. Left: typical transverse slice of a 7.0T scan. Middle: zoom-in showing a microbleed (bottom) and a false positive (top). The FP is caused by a high radial symmetry on the first echo (not shown). Top-right: phase gradient magnitude of false positive. Right: zoom and phase gradient magnitude of a microbleed.

Results: In total, the RST detected 13 true positive (TP) and 60 false positive (FP) microbleeds on the magnitude images. Figure 2 shows all 73 potential CMBs (the three patients combined), sorted on the radial symmetry value per CMB as computed on the phase gradient magnitude image.

As can be seen in the graph, nearly all true microbleeds have a high radial symmetry value on the phase gradient magnitude images. The dashed lines indicate two possible thresholds: the lower including all TPs, and the upper excluding all FPs at the cost of some false negatives. By applying a conservative threshold, it is possible to eliminate 47 of the 60 FPs.

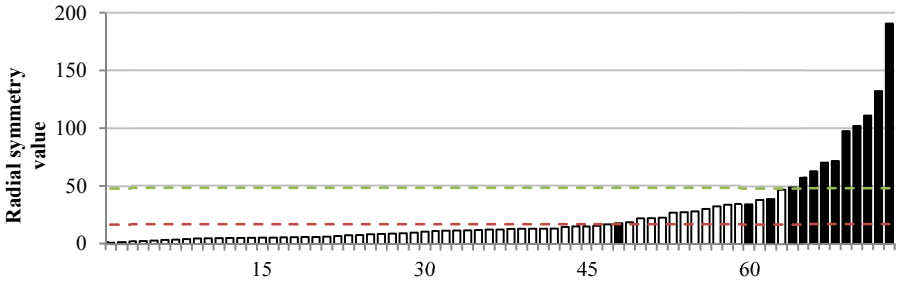

Figure 2: Graph showing radial symmetry values. Filled bars indicate true microbleeds and open bars indicate false positives. Dashed lines indicate possible thresholds.

Discussion: This experiment demonstrates the feasibility to improve automatic microbleed detection by including phase gradient magnitude images.

Computation was done within seconds and hence does not significantly add to the overall computation time of automatic CMB detection. The presented technique can likely be applied at lower field strength as well, since phase gradient magnitude images on 1.5T show a similar spherical pattern for CMBs. Since phase information is readily available with every gradient echo MRI scan, no extra steps during acquisition are needed.

We will extend this pilot study to further evaluate the added value of phase gradient magnitude images for automatic microbleed detection, in order to turn this proof of principle experiment into a general recommendation for automatic CMB detection.

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