Vein classification using vesselness filters on SWI data acquired at 3T and 7T

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Introduction

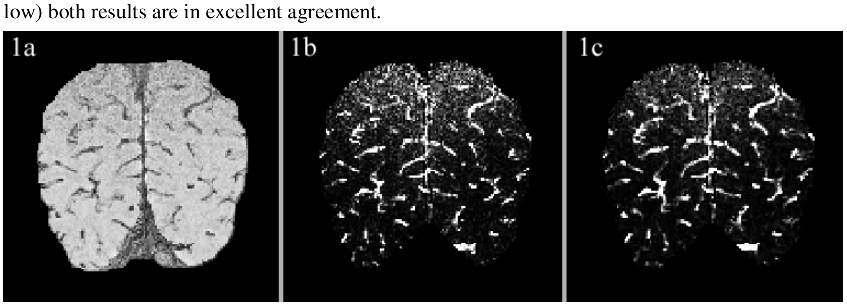
MR venography based upon susceptibility weighted imaging (SWI) can depict the venous vascular tree with excellent detail by using minimum intensity projections (mIP) over several slices [1]. While this visualisation works quite nicely, this approach does not classify veins, which can be necessary, e.g. to remove veins from high resolution functional MRI scans. To solve this it has been proposed to use filters known from angiography [2]. In this study we assessed the performance of two such filters: the Utrecht vesselness filter and Vessel Enhancing Diffusion (VED) in regions of high and low SNR. As higher field strengths are beneficial for SWI-venography the VED filter was used on SWI data acquired at 7T and compared with 3T data.

Methods

All experiments were performed on whole body MRI scanners (Siemens, Erlangen, Germany) at field strengths of 3T and 7T. SWI images were acquired using a first-order flow-compensated 3D gradient echo FLASH sequence with the following parameters: FA 15°, BW 120 Hz/pixel, acceleration factor 2 (GRAPPA). At 3T we used an echo time of 28 ms with a TR of 35 ms, at 7T these were 15 ms and 22 ms respectively. Whole brain sagittal acquisitions were performed on the same subject at both fields using a matrix size of 352x448x144 and a resolution of 0.57x0.57x1.25 mm^3. Acquisition times were 15 and 10 minutes at 3T and 7T respectively. To test the filters in regions of high and low SNR a dataset was acquired using an eight channel occipital surface coil array [3]. In order to increase SNR an average over 4 repetitions was used. Matrix size was 144x192x40 using an isotropic resolution of 0.75 mm. Acquisition time was 2 minutes per volume. All datasets were intensity-inhomogeneity corrected and veins were segmented using the Utrecht vesselness filter and VED which are described in detail in [4] and [5] respectively. In short, the Utrecht filter uses second order image information to distinguish dark tube-like structures (veins) from their surroundings and noise. The VED filter uses an iterative approach by alternately applying the Utrecht filter and a diffusion process to eliminate noise. However the shape/direction of the diffusion is dependent on the vessel likeliness found by the previous iteration of the Utrecht filter. For voxels that do not belong to the venous tree, the diffusion is isotropic, for venous voxels diffusion is applied in the direction of the vessel. This diffusion process improves the starting conditions for the next Utrecht filter step. In this study 5 iterations were used. In addition to the automated filters, manual segmentation was performed on the 0.75 mm resolution dataset to be compared with the VED result.

Results

Fig. 1a shows a mIP over 11 slices of the dataset acquired using the occipital coil. Fig. 1b shows the maximum intensity projection (MIP) of the output of the Utrecht filter, fig. 1c shows the MIP of the VED result. In the bottom part of the images, where SNR is relatively high, both filters perform very well. In the top part, where SNR is reduced due to the inhomogeneous coil profile, the VED method is better able to contrast veins with respect to the noisy background than the Utrecht filter. Fig. 2 shows the manual segmentation (a) and the VED result (b) overlaid on the mIP of the data. Apart from the very top part of the image (where SNR was extremely low) both results are in excellent agreement.



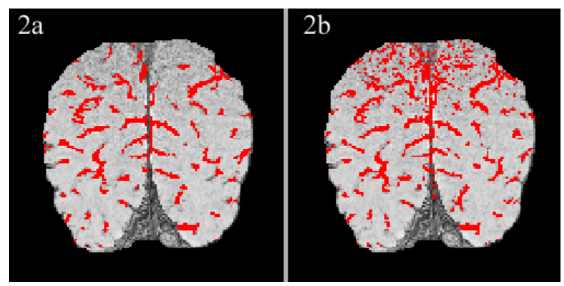
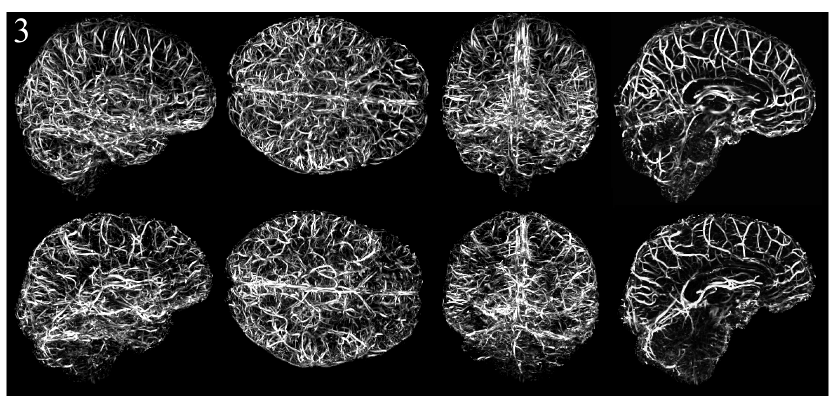


Fig. 3 shows projections of the VED output of 3T (top row) and 7T (bottom row) whole brain data. The first three columns show whole brain MIPs, the last column shows a MIP over a few slices surrounding the interhemisperic cleft. At both field strengths detailed venograms can be created without being compromised by the differences in shape of the brain across slices. Due to increased inhomogeneity problems at 7T details in the deeper regions of the brain are less well visible than at 3T. One should keep in mind however that the acquisition time at 3T was 50% longer than at 7T.



Conclusions

Two automated vein segmentation filters have been applied to SWI-venography data. In regions of high SNR the Utrecht vesselness filter and the vessel enhancing diffusion method both performed very well. In regions of low SNR the VED method outperformed the Utrecht filter and the result was in excellent agreement with manual segmentation results. The VED filter was applied to whole brain 3T and 7T data where – due to the huge amount of visible veins - manual segmentation can no longer be considered a possibility. Although the results at 3T were slightly better than at 7T due to increased SNR inhomogeneity at the latter field strength, 7T allows for a much shorter acquisition time and therefore shows good promise for future SWI-venography.

References

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This work was supported by NWO grant ALW2PJ/04064