The Venous Volume Portion within Multiple Sclerosis Lesions Compared to Healthy Tissue - an Atlas Based Approach

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Introduction:

The purpose of this work was to create a group specific vein-atlas based on healthy control subjects in order to visualize the variability of the venous system under normal conditions and to compare the venous volume portion within Multiple Sclerosis (MS) lesions of individual patients to that atlas. The vein-atlas is based on automatic vessel segmentation on high resolution Susceptibility-Weighted-Imaging (SWI) images. The vein-atlas was created by using the approach presented by [1]. In this approach a T1 weighted model is created with images which are in the same image space as the segmented veins. After the T1 weighted model, the vein-atlas is created by using the final non-linear transforms created during the process of the T1 weighted model development. The purpose of our study was to evaluate the vein-atlas by comparing normal-appearing white matter (NAWM) regions within MS patient datasets with corresponding regions within the atlas. Subsequently, we compared the venous volume portion within MS lesions to corresponding regions in the vein-atlas.

Materials and Methods:

SWI as well as T1 weighted imaging was performed at 7 Tesla (T) on 9 healthy controls and 8 age matched MS patients. Additionally all patients were examined using a turbo spin-echo sequence with variable flip-angle echo trains. This sequence was used in order to acquire images with the radiologically known FLAIR contrast (hyperintense definition of MS lesions), which cannot be achieved by the standard 2D inversion recovery FLAIR sequence because of SAR limitations at 7 T. SWI images were acquired with a TE of 15 ms; other sequence parameters were: TR = 28 ms; resolution = 0.3x0.3x1.2mm. FLAIR-SWI images [3] were created and automatic vein segmentation on the SWI data was performed by using the approach presented by [2]. After the development of the T1 weighted model, the vein segmentation results were subsequently non-linearly transformed into the model space by using the transformations created during the T1 model development. Finally, the segmentation results were averaged in order to create the vein-atlas. Eighteen MS lesions and 13 corresponding NAWM regions (contralateral hemisphere if available) were manually segmented and used in order to calculate the venous volume portion within individual MS patient data and corresponding regions within the vein-atlas.

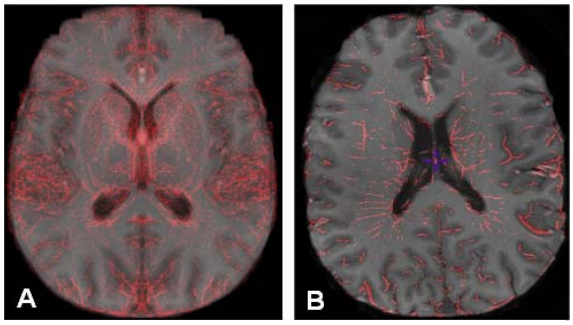

Figure 1: The average venous system represented by the vein-atlas (**A**) and the segmented veins of a randomly chosen control subject (**B**). The large variability of the individual venous networks can be seen by comparing (**A**) and (**B**). The veins are overlaid to the corresponding T1 data.

Results:

The analysis of the venous volume portion in MS lesions (18 MS lesions; eight MS patients) showed a significant difference (Wilcoxon signed rank; $p = 0.029$) to the corresponding regions within the vein-atlas. The mean venous volume portion in the 18 MS lesions was 1.94% (median 1.8%; range 0.4 – 6 %) and 1% (median 1%; range 0.08 – 2.3 %) within the vein-atlas (corresponding regions). The analysis of the 13 NAWM-ROIs showed no significant difference (U test; $p > 0.05$) between the mean venous volume portion of 1.1% (median 0.7%; range 0 – 3.6 %) within the individual datasets (MS patients) and 0.9% (median 0.7%; range 0.17 – 2.3 %) within the vein-atlas (corresponding regions).

The difference between the mean venous fraction within the 13 individual MS lesions (mean 2.2%; median 2.1%; range 0.4 – 6.1%) and the corresponding NAWM-ROIs was significant (U-test; $p = 0.033$). Fig. 1 shows the vein-atlas and Fig. 2 gives an example for automatic vessel segmentation.

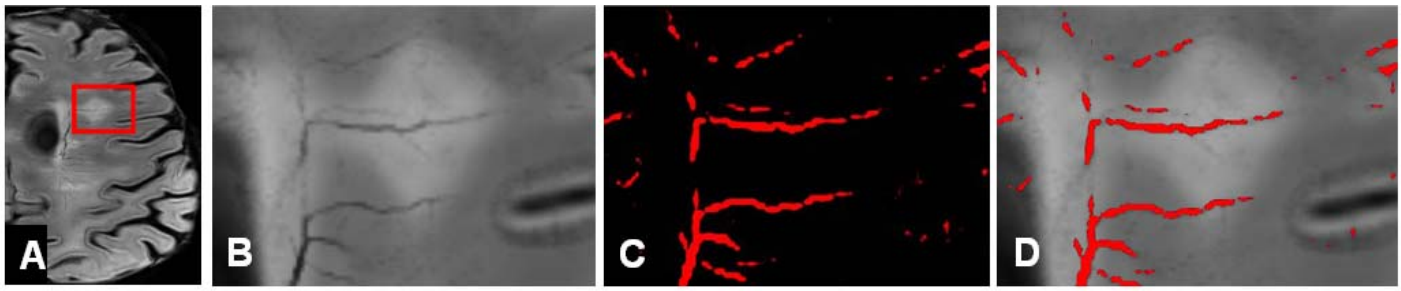

Figure 2: Venous vessel centered MS lesion: (**A**) FLAIR-SWI, (**B**) represents the subsection of the area marked with the red rectangle in (**A**). The automatically segmented veins are shown in (**C**) and (**D**) shows the MS lesion overlaid with the segmented vessels.

Discussion and Conclusion:

The developed vein-atlas shows the mean venous system of the group being studied and can serve as evaluation tool in order to analyze the venous system of individual subjects.

References:

1) Grabner G. et al. J Magn Reson Imaging 2010, 31(1):215-20
2) Frangi A.F. et al. LNCS, 1998, 130-137
3) Grabner G. et al. J Magn Reson Imaging 2011, 33(3):543-9