Multispectral Fusion-Based Detection of Virchow-Robin Spaces

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Purpose: Virchow-Robin spaces (VRS) are defined as fluid filled spaces that surround veins, venules, arteries and arterioles. Dilation of VRS is recognized as a biomarker of microvascular disease, vascular dementia, hypertension and multiple sclerosis[1]. VRS have cylindrical or spherical shape, are about 1mm to 4mm and are present predominantly in white matter. On MRI, VRS are iso-intense relative to cerebrospinal fluid (CSF): hyper-intense on T_2-weighted images and hypo-intense on T_1-weighted images. They are usually manually detected by a trained observer; few automated techniques have been suggested [2,3]. These techniques focus primarily on T_1-weighted images, where lacunar infarcts and depleted myelin lesions have similar intensities as VRS [1]. In order to minimize false positives, we present an automatic multispectral detection method utilizing both MPRAGE and T_2 -weighted images.

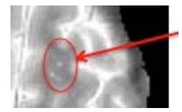

Figure 1 Virchow Robin spaces on a T_2-weighted image

Methods: Data from 10 neurologically healthy volunteers aged from 45 to 65 years were used for the study. After providing informed written consent, each volunteer underwent a brain MRI on a 3.0T Siemens Allegra head only scanner equipped with a quadrature coil. MRIs were inclusive of MPRAGE and T_2-weighted images. Following image acquisition the brain parenchyma was extracted from all the images using BET [4]. Since VRS appear as isolated peaks on images as shown in Fig. 1, we applied a top hat transform in the native space of T_2-weighted images using a 3-D median filter of size 7 [5]. The top hat transform isolates peaks by subtracting the original from the median filtered image. Region growing based counting was then performed on the images to detect and count the VRS; a size threshold was applied to the counting algorithm. Given that VRS are predominantly present in white matter [6], a white matter mask was generated using FSL [4], and used to isolate white matter VRS. Processing was repeated on the MPRAGE images, with the median filter size set to 11 to account for increased resolution. Resulting individual detection masks from the top-hat transform showed a high rate of false positives; therefore, all VRS masks were registered to a common space and subsequently combined to generate a final fused VRS mask for each subject. This mask contained only structures detected in both images. In order to assess the performance of the proposed technique, we compared VRS detected by our technique with manually marked VRS.

Results: The results below illustrate the original image and detected VRS overlaid on the original image. Fig. 2 and 3 illustrate detection on T_2-weighted image and MPRAGE image respectively. Figure 4 illustrates the fused VRS mask overlaid on a MPRAGE image. Table 1 represents the truth table generated by comparing the results of the automatic technique to manual detection. True positives represent manually marked VRS, which were detected by the technique. True negatives represent small structures or lesions or (non-VRS), which were not detected by the technique. The technique has a sensitivity of 92.1% and a specificity of 84.6%.

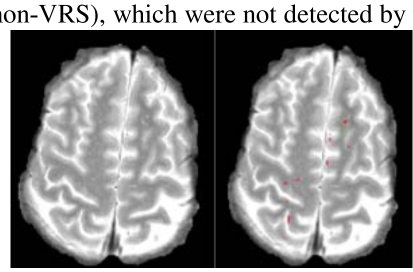

Figure 2 Original image (T_2-weighted - left), automatically detected VRS (red dots) overlaid on original image (right)

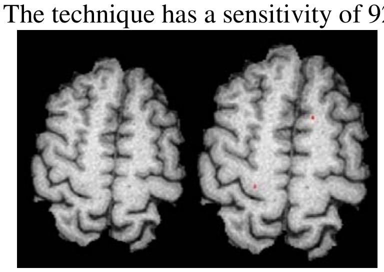

Figure 3 Original image (MPRAGE - left), automatically detected VRS (red dots) overlaid on original image (right)

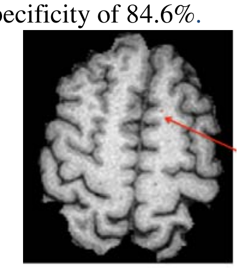

Figure 4 Detected VRS mask from fusion overlaid on original MPRAGE

Conclusions: We presented an automated technique for detection and counting VRS. The technique is fast and fully automated, and requires minimal user intervention in setting the thresholds for the region growing. The fusion step improves noise stability of the technique; additionally, it allows all processing to take place in the native space of each image, preventing registration-related blurring that would inhibit the detection of small structures like VRS. Due to the clinical significance, this approach can be useful in the characterization of neurological diseases with a vascular component.

	Present	Not present
Detected	86	8
Not Detected	7	44

Table 1 Truth table representing the performance of the technique

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References: [1] H. Bokura et al, *Journal of Neurology*, 245:116-122 (1998). [2] X. Descombes et al, *IEEE Transactions on Medical Imaging*, 23: 246-255(2004). [3] Y. Uchiyama et al, *IEEE EMBS*, 2008:3908-3911. [4] S. M. Smith et al., *NeuroImage*, 23:S208-219 (2004). [5] M. Sonka et al, *Image Processing: Analysis and Machine Vision*,1998. [6] Y.-C. Zhu et al.,*AJNR*, 32:709-713 (2011).