MRI CHARACTERIZATIONS OF REGION SPECIFIC WHITE MATTER HYPERINTENSITIES AND VERTEBRAL ARTERY STENOSIS

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INTRODUCTION

White matter hyperintensities (WMHs) is one indicator of cerebrovascular diseases, which may contribute to the development of dementia and Alzheimer's disease (AD) [1]. Earlier reports have shown a greater severity of WMHs among patients with AD. WMHs is also associated with the reduction of white matter integrity which is linked to the cognitive decline [2]. While WMHs are commonly found in patients with symptomatic cerebrovascular disease, they can also be seen in individuals with cardiovascular risk factors, such as hypertension and atherosclerosis. Therefore, one specific interest is to examine the association between cerebral vascular abnormalities and carotid and/or vertebral artery (VA) stenosis. Several studies have assessed the relationship between WMHs and the risk of stroke, dementia, and carotid artery diseases [3-5]. However, the optimal management of VA stenosis has received limited attention, and is not well understood [6]. Unlike carotid diseases, the prognosis of symptomatic VA stenosis is also largely unknown [7]. This partly reflects difficulties in imaging of extracranial VA adequately. Here we report MRI examinations of individuals with cerebral vascular and cardiovascular risks to demonstrate the association between extracranial VA stenosis evidenced by obstructed artery and blood flow velocity and cerebral vascular comorbidities, particularly WMHs and reduction of cerebral blood flow in specific brain regions.

MATERIALS AND METHODS

Subjects: This study was approved by the local Institutional Review Board. Based on VA stenosis and the specific location of WMHs, 15 consecutive participants (3 men, 12 women; average age of 60.1 ± 9.1 years old) included: 1) left VA stenosis with bilateral asymmetric periventricular WMHs (n = 4), 2) right VA stenosis with bilateral asymmetric periventricular WMHs (n = 7), and 3) bilateral vertebral arteries stenosis with similar caliber with bilateral symmetric periventricular WMHs (n = 4). All participants did not have histories or findings suggestive of stroke as determined by reviewing their medical records and a neurologic exam.

MRI Acquisition and Data Analysis: All images were acquired on 3T MRI scanner (Siemens Tim Trio) using a standard 12-channel head coil and a four-element phased array carotid coil (Machnet, Maastricht, The Netherlands) when needed. Except routine T_2 weighted and FLAIR images to detect WMHs, a 3D TOF sequence was performed to provide bright blood signal, 60-slice region of interest (ROI) centered at the carotid bifurcation to evaluate the vessel lumen. Phase contrast magnetic resonance imaging (PCMR) images encoded for through-plane blood velocity were acquired at the internal carotid artery (ICA) at the same location as the proximal slice of the 3D-TOF image stack. The imaging parameters included 30 cardiac phases, pixel size = 1.1 X 1.1 mm^2, slice thickness = 6 mm, and VENC = 100 cm/s. The proximal extracranial vertebral arteries and the internal carotid arteries were processed offline using Segment (Medviso AB, Lund, Sweden) [8]. Vessel borders were drawn on magnitude images and contours were transferred directly to the corresponding phase images. Pixel-by-pixel velocity values were then integrated over the region of interest (ROI) to obtain flow rates for each time point. Net flow over the cardiac cycle was quantified from these time dependent flow rate data. Relative cerebral blood flow (relCBF) was generated inline on the scanner by the arterial spin labeling (ASL) sequence for assessing possible cerebral hypoperfusion [9].

RESULTS AND DISCUSSIONS

Among 15 cases collected in this study, seven presented right VA stenosis with asymmetric periventricular WMHs in the occipital horns, which was more pronounced in the ipsilateral occipital region. These WMHs observed in both T_2 weighted **(Figure 1A)** and FLAIR **(Figure 1B)** images appear as a hyperintense band with variable thickness located along the dorsolateral angles of the ventricles close to the ependymal surface. The reduction of relCBF was found in the bilateral occipital lobes, but predominantly in the right occipital lobe, as shown in **Figure 1C,** which was consistent with the significant narrowing of right extracranial VA(>80%) observed in 3D TOF MRA **(Figure 1D)**. However, the sizes of the bilateral carotid arteries were similar as shown in **Figure 1D, 1E**. The internal diameter of the right VAwas measured at 2.4 mm. In comparison, the internal diameters of the left vertebral artery, right ICA, and left ICA were 4.6 mm, 7.2 mm, and 8.4 mm, respectively **(Figure 1F)**. PCMR confirmed there was decreased blood flow velocity in the right VA **(arrow, Figure 1G)**, comparing to the left one **(Figure 1H)**.

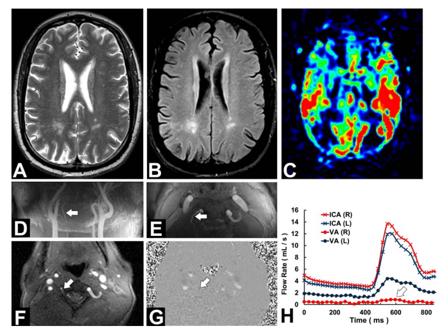

Fig. 1: Subject with right VA stenosis presented asymmetric periventricular WMHs which are more pronounced on the ipsilateral occipital.

Figure 2 presents another example about unilateral VA stenosis leading to ipsilateral periventricular WMHs. In four cases with left VA stenosis, they all exhibited unilateral VA stenosis that can be associated with bilateral asymmetrical periventricular WMHs, which was more pronounced in the left occipital horns in T_2 weighted imaging **(Figure 2A)**. Furthermore, the FLAIR image revealed such asymmetrical appearances of WMHs in the occipital horn along with punctuate and confluent lesion adjacent to the occipital horn of the anterior periventricular areas **(Figure 2B)**. In this case, the FLAIR image was found to have a better sensitivity to WMHs than T2 weighted imaging, especially for those at periventricular locations. Besides identifying infarcts from structural imaging, relCBF map calculated from the ASL images demonstrated decreased relCBF in the left rostral occipital cortex and parietal cortex, including angular gyrus, supramarginal gyrus, and postcentral gyrus **(Figure 2C)**. MRA of head and neck generated from 3D TOF MRI **(Figure 2D, 2E)** showed marked narrowing of the left proximal extracranial VA (>70%) with the internal diameter measured at 3.2 mm, comparing to 5.7 mm diameter of the right vertebral artery. The diameters of carotid arteries were 6.5 mm (left) and 7.7 mm (right), respectively **(Figure 2F)**. The flow velocity calculation based on PCMR **(Figure 2G)** suggested that there was a decrease in blood flow rate in the left proximal extracranial vertebral artery, but not in the right extracranial VA and bilateral ICA as shown in **Figure 2H**. These findings suggest that periventricular WMHs in the occipital horn might be caused by ipsilateral VA stenosis.

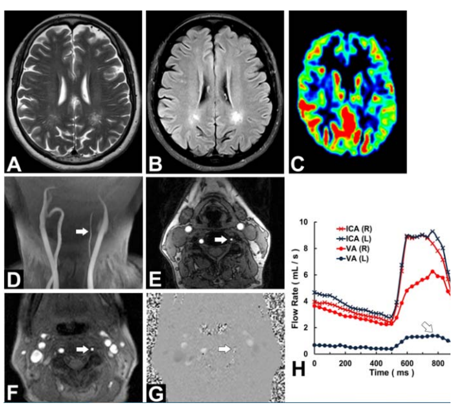

Fig. 2: Subject with left vertebral artery stenosis revealed ipsilateral periventricular WMHs.

We also found four cases that showed symmetrical minor WMHs in the areas of bilateral periventricular occipital horns seen in T_2 weighted images **(Figure 3A)**, which were more pronounced in the FLAIR image **(Figure 3B)**. The lesions mostly appeared as punctuate WMHs adjacent to the bilateral occipital horns. No juxtacortical or posterior fossa lesions were observed. The relCBF map revealed decreased CBF in bilateral occipital regions **(Figure 3C)**, although no significant major vessel stenosis or occlusion was observed in bilateral proximal extracranial VA **(Figure 3D, 3E)**. The internal diameter of the right vertebral artery, left vertebral artery, right ICA, and left ICA were 4.9 mm, 5.2 mm, 6.7 mm and 6.4 mm, respectively **(Figure 6F)**. However, blood flow velocity appeared to be slow in the bilateral proximal extracranial VA detected in PCMR **(Figure 3G).** The relevant changes were plotted in **Figure 3H.** These findings suggest that low blood flow velocity might contribute to the cause of WMHs in the periventricular occipital horns even though no apparent bilateral extracranial VA narrowing was observed. From the neuroimaging technique perspective, PCMR with information on flow velocity seems to provide more sensitive and specific detection of vasculature abnormalities in the extracranial vertebral arteries than 3D TOF MRI due to its quantitative capability.

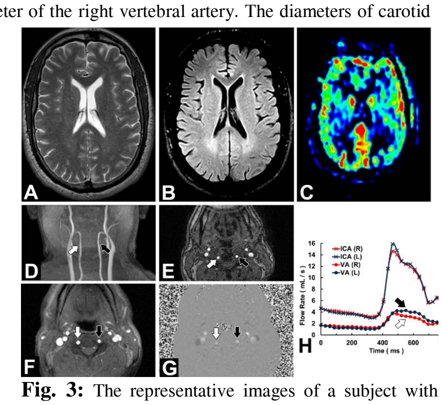

Fig. 3: The representative images of a subject with bilateral vertebral artery with similar caliber demonstrated periventricular WMHs on the bilateral occipital horns.

CONCLUSIONS

The comprehensive MRI protocol with functional and high resolution structural imaging sequences is capable of providing valuable information on blood flow supply in the VA and cerebrovascular ischemia in individuals having vertebral and cardiovascular abnormalities.

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