In-vivo flow territory mapping of major brain feeding arteries: a population study with selective arterial spin labeling MRI.

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Introduction

The ability to visualize the perfusion territories of major feeding arteries in the brain is important for many clinical applications. Knowledge of the relationship between collaterals and regional perfusion may explain differences in clinical outcome and expand treatment options for acute stroke, arteriovenous malformation and chronic cerebrovascular disorder. Since the pioneering work of Duret in 1874 on cerebral vascularisation of the brain, many textbooks and atlases have shown schematic drawings of these territories (Duret H, *Arch Physiol Norm Pathol 1874; 60-91:316-353*). Recent post-mortem studies by Van der Zwan et al. demonstrated that the variability of the cerebral vascular territories is significantly greater than previously assumed (Van der Zwan A, et al. *Stroke 1992;77:827-940*). Until now, it was not possible to measure flow territories *in-vivo.* Using selective arterial spin labelling MRI, this is the first study that determines individual perfusion territories *in-vivo* in a large population (n=115).

Methods and material

The aim of the present study was to investigate the variability of flow territories in the brain *in-vivo*. In 115 subjects (58 ± 9 years) without abnormalities on MRI and MRA images of the brain and without hemodynamically significant internal carotid artery (ICA) obstruction on duplex were included in the study. The MRI investigations were performed on a 1.5-T whole body system. Separate flow territory mapping of the left ICA, right ICA and posterior circulation (vertebral arteries and basilar artery) was performed with selective arterial spin labeling MRI (Hendrikse J, et al. *Stroke 2004;35:882-887*). The inversion is achieved by applying two consecutive slice-selective 90° RF pulses. Subsequently, three saturation pulses are applied on the imaging slices to remove the effects of labelling pulses. A delay of 1200 ms was used to allow the blood to flow to the tissue. Other MRI parameters of the RPI scans were: TR = 3000 ms; TE = 5.6 ms; 62% half Fourier acquisition; number of slices = 5; slice thickness = 8 mm; time between slices = 25 ms; FOV = 240 x 240 mm; matrix = 74 x 63; zero filling to 128 x 128 matrix; averages = 30 ms. To quantify cerebral blood flow (CBF) non-selective turbo-tilt arterial spin labelling was used (Hendrikse J, et al. Magn Res Med. 2003;30:429-433).

Results

Flow territory maps for the entire population indicated high variation in flow territories of the individual ICAs and posterior circulation (figure 1). Subanalyses showed that this variation is mainly causes by differences in anatomy of the circle of Willis. Subcategories of subjects with a complete circle of Willis, with a missing A1 segment or with a unilateral or bilateral foetal type posterior cerebral artery showed a considerably lower variation within groups (figure 2.a; figure 2.b). No significant difference was found in CBF between the various anatomical variants of the circle of Willis.

Conclusion

With non-invasive selective arterial spin labelling MRI, we demonstrated that the flow territories of the cerebral arteries are considerably fixed. The wide inter-individual variation in flow territories is caused by anatomical variants of the circle of Willis. These anatomical variants are not associated with difference in cerebral perfusion.

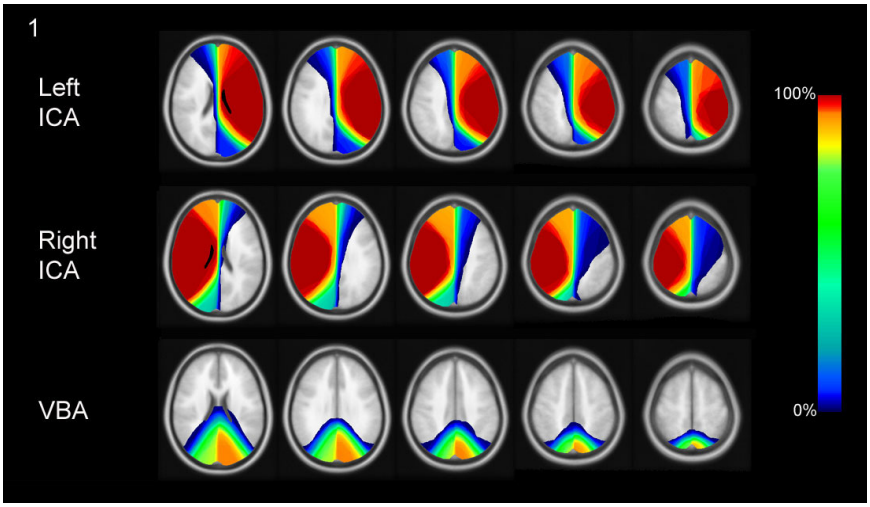

Figure 1. Flow territory maps of the left ICA, right ICA and posterior circulation for the *total population* (n=115) projected on a standard brain. Colours correspond to the colour bar, with percentage scale indicating the percentage of subjects with overlap of the flow territories.

Figure 2.a. Flow territory maps for subjects with a circle of Willis with a *missing A1 segment right* (n=8). When applying selective labelling of the left ICA, perfusion weighted signal is present in the left MCA flow territory and both the left and right ACAs flow territory. Colours correspond to colour bar in figure 1.

Figure 2.b. Significant differences in flow territory between the complete circle of Willis and the circle of Willis with a *missing A1 segment*. Colours correspond to the colour bar, indicating p-values.