Validation of a simple anatomical classification method of the circle of Willis: a MR angiographical and selective arterial spin labeling MRI study at 3 Tesla

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Introduction: Numerous classification methods of the circle of Willis have given rise to widespread confusion both in radiological reports and communicating with clinicians. Here, we introduce a simple classification method and evaluated its hemodynamic relevance in terms of flow contributions to the anterior and posterior cerebral arteries. Five variants are based on MR angiographic diameter comparisons on the posterior side of the circle of Willis: P1 absent, P1<PCoM, P1=PCoM, P1>PCoM, PCoM absent and on the anterior side: A1 absent, A1<ACoM, A1=ACoM, A1>ACoM, ACoM absent. In a series of subacute stroke patients we correlated the results of our circle of Willis classification method with the perfusion territory contributions of the carotid and vertebrobasilar arteries measured with selective arterial spin labeling (ASL) MRI. With selective ASL MRI we show the quantitative contributions of the internal carotid artery and vertebrobasilar arteries to the anterior cerebral artery and posterior cerebral artery for each variant.

Methods: The ethics committee of our institution approved the study protocol. A total of 159 patients with clinical symptoms of cerebral ischemia lasting for more than 24 hours and no history of previous cerebro-vascular disease were included in the study. All MRI studies were performed on a 3.0 T Philips Achieva System. For ASL perfusion territory MRI we used the recently developed QUAntitative STAR labeling of Arterial Regions (QUASAR) pulse sequence. Scan parameters: 7 slices; thickness = 8 mm; gap = 1 mm; matrix = 64×64; FOV = 240 mm; α = 35°; TR/TE = 4000/23 ms; TI1/ΔTI = 50/390 ms; time points = 10, SENSE = 3; 96 averages (32 for each territory); scan time 6:40 min. For both the anterior and posterior circle of Willis the classification is based on the comparison of the relative size of the A1 segment of the anterior cerebral artery and the P1 segment of the posterior cerebral artery with the connected anterior and posterior communicating artery on MR angiographical images.

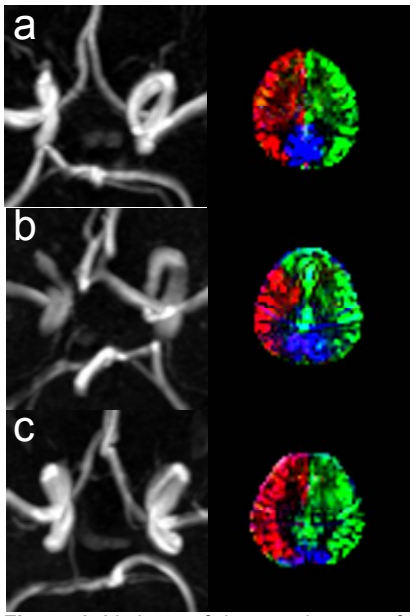

Figure 1. Variants of the anterior part of the circle of Willis. Time of flight MR angiography (TOF MRA) images and corresponding selective arterial spin labeling (ASL) perfusion territory images. The upper row shows absence of the anterior communicating artery (ACoM) with the perfusion territory of both anterior cerebral arteries (ACAs) fed from the ipsilateral internal carotid artery (ICA) (a). The middle row shows absence of the A1 segment on the right side with the left sided ICA feeding the perfusion territories of both ACAs (b). The bottom row shows a late cross-over of the blood supply of the perfusion territory of the left ICA (in green) to the right hemisphere. In the same slice the more anterior region of the right ACA is still fed from the right ICA (red). The TOF MRA in this patient shows an ACoM with a smaller size compared to both A1 segments.

Results Data of 238 posterior and anterior cerebral arteries in 119 patients contributed to this comparison. In patients with an absent PCoM the magnetization contribution of the vertebrobasilar arteries was 83±10%, with PCoM<P1 77±13%, with PCoM=P1 59±11%, with PCoM>P1 34±13% and with absent P1 25±12%. The respective contributions of the ipsilateral ICAs for the 5 variants were: 17±10%, 23±13%, 41±11%, 66±13% and 75±12%. In patients with an absent ACoM the magnetization contribution of the ipsilateral ICAs was 71%±16, with ACoM<A1 76±13%, with ACoM=A1 61±19%, with ACoM>A1 23±12% and with absent A1 27±13%. The respective contributions of the contralateral ICAs for the 5 variants were: 29±16%, 24±13%, 39±19%, 77±12% and 73±13%.

Conclusion: We evaluate an anatomical classification method of the anterior and posterior circle of Willis based on distinction of 5 variant types with comparisons of the size of the A1 segments with the ACoM and the P1 segments with the connected PCoM. For the posterior circle of Willis a graded increase in contributions from the ipsilateral ICA to the PCA are found for the variants: absent PCoM, P1>PCoM, P1=PCoM, P1<PCoM and absent P1. For the anterior circle of Willis the two variants with a dominant A1 relative to the ACoM (ACoM absent or A1>ACoM) and the two variants with a dominant ACoM relative to the A1 (A1 absent or A1<ACoM) showed comparable contributions of the ipsilateral and contralateral ICA. In a subgroup of patients a peripheral cross-over of blood supply to the ACA territory of the contralateral hemisphere was observed.

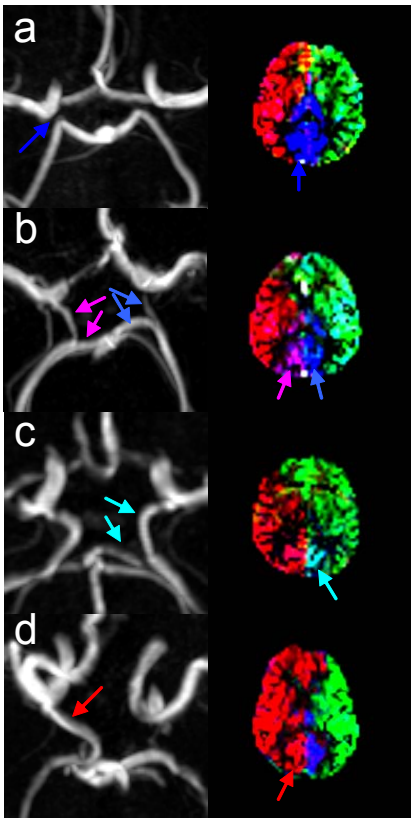

Figure 2. Variations of the posterior part of the circle of Willis. Time of flight MR angiography (TOF MRA) images and corresponding selective arterial spin labeling (ASL) perfusion territory images. The upper row shows absence of the posterior communicating artery on both sides with the perfusion territory of both posterior cerebral arteries (PCAs) fed from the vertebrobasilar arteries (VBAs) (a). The second row shows posterior communicating arteries (PCoMs) smaller in size compared to the P1 segments with a combined contribution of the internal carotid artery (ICA) and VBAs to the perfusion territory of the right PCA, represented by the pink colour (b). The left PCA is fed from the VBAs (b). The third row shows a left PCoM with a similar size as the left P1 segment. The left PCA is fed from both the left ICA and VBAs as represented by the cyan colour (c). The right PCA is purely fed from the PCoM with an absent right P1 segment. The fourth row shows another patient with an absent P1 segment with pure feeding of the right PCA from the right ICA (d).