

# Accuracy of MR Angiography and Transcranial Doppler for cerebral collateral flow: a comparison with iaDSA in 97 patients with carotid occlusion.

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## Introduction

In many institutions transcranial Doppler (TCD) ultrasound, magnetic resonance angiography (MRA) and recently CT angiography have largely replaced intra-arterial digital subtraction angiography (iaDSA) for routine assessment of the internal carotid artery (ICA). Although the accuracy of non-invasive methods for the detection of ICA occlusion has been demonstrated, still three vessel iaDSA is needed to visualize the cerebral collateral flow from the contralateral ICA, the vertebrobasilar system and the external carotid artery. Information about cerebral collateral flow in patients with ICA occlusion is important since the presence of functional collaterals is associated with relatively low stroke risk. Because iaDSA is no longer routinely performed in patients with ICA occlusion it becomes increasingly important to clarify the diagnostic strengths and weaknesses of the most widely used non-invasive approaches to assess cerebral collateral flow, TCD ultrasound and MRA. In this study we compare TCD and MRA examinations of the collateral flow via the circle of Willis with the findings on iaDSA in a cohort of 97 consecutive patients with a symptomatic occlusion of the ICA.

## Methods

Ninetyseven patients (80 men, and 17 women; mean ( $\pm$ S.D.) age  $60.7 \pm 9.0$  years) with transient (n=19) or moderately disabling (n=57) cerebral ischaemic symptoms or retinal ischemic symptoms only (n=21) attributable to an angiographically proven extracranial occlusion of the ICA were recruited. On intra-arterial DSA collateral flow via the anterior communicating artery or posterior communicating artery was considered present if either collateral pathway showed at least filling of middle cerebral artery branches on the angiogram. MRA investigations were performed on a 1.5T whole body system (Gyroscon ACS-NT, Philips Medical Systems, Best, The Netherlands). To visualize the circle of Willis, 50 slices were obtained with a three-dimensional time-of-flight (3D TOF) technique. The direction of blood flow in the circle of Willis was assessed by two consecutive 2-dimensional phase contrast (2D PC) measurements of which one was phase-encoded in the anterior-posterior direction and one in the left-right direction. The imaging parameters of the 2D PC directional flow acquisition were: (TR/TE): 16 msec / 9.1 ms, flip angle: 7.5°; field of view: 250 x 250 mm; rectangular field of view: 100%; matrix size: 256 x 256; number of excitations: 8; slice thickness: 13 mm; slice orientation: transverse; single slice, and a velocity sensitivity of 40 cm/s. Collateral flow measurements with TCD were performed using a Multi-Dop X device (DWL, Sippligen, Germany) with two 2-MHz pulsed Doppler probes for insonation of cerebral vessels. Collateral flow via the ACoA was considered present if TCD showed reversed flow in the A1 segment of the anterior cerebral artery ipsilateral to the symptomatic ICA occlusion. Collateral flow via the PCoA was considered present if TCD showed a higher blood flow velocity in the P1 segment of the posterior cerebral artery compared with the middle cerebral artery on the side of the symptomatic ICA occlusion

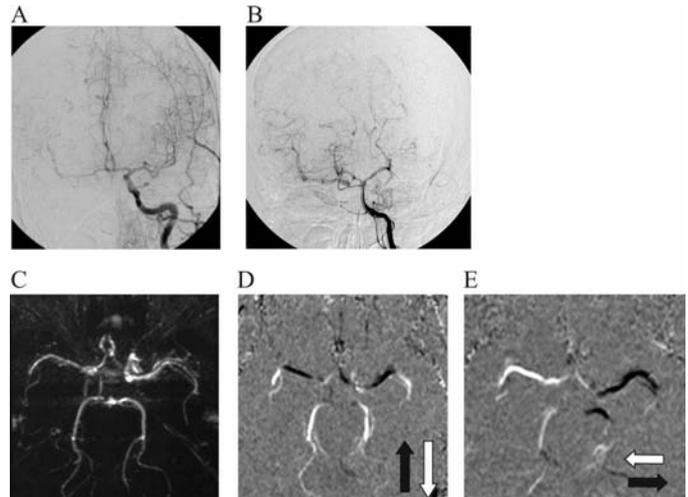
## Results

MRA and TCD collateral flow measurements via the anterior part of the circle of Willis yielded sensitivities of respectively 83% (95% CI, 72% to 94%), 82% (95% CI, 80% to 94%) and specificities of respectively 77% (95% CI, 65% to 99%), 79% (95% CI, 66% to 92%). No significant differences in sensitivity, specificity, positive and negative predictive value were found between MRA and TCD. For collateral flow via the posterior communicating artery the sensitivity of MRA of 33% (95% CI, 20% to 46%) was significantly lower compared to the sensitivity of TCD of 76% (95% CI, 64% to 88%; p=0.028). The specificity of MRA of 88% (95% CI, 73% to 100%) was significantly higher compared to the specificity of TCD of 47% (95% CI, 23% to 71%; p<0.001). No significant differences were found in positive and negative predictive value. With the combined non-invasive criteria the sensitivity were 92% (95% CI, 83% to 100%) and 88% (95% CI, 79% to 87%) and the specificity 65% (95% CI, 50% to 80%) and 41% (95% CI, 18% to 64%) for collateral flow via the anterior circle of Willis and the posterior communicating artery respectively.

## Discussion and conclusions

Although iaDSA is the gold standard for the assessment of collateral flow, the forced injection of contrast and local increases in arterial pressure may cause changes in resting flow conditions with potentially contrast filling of non-functional collaterals. Furthermore, the prognostic implications of the different sensitivities and detection rates of iaDSA, TCD and MRA for cerebral collateral flow patterns are uncertain. Moreover, iaDSA is thusfar the only available method for assessment of leptomeningeal collaterals at the brain surface. As an alternative to the phase contrast MRA method that we used MR saturation pulses can be applied for selective labeling of the vasculature proximal to the circle of Willis followed by dynamically imaging the (collateral) filling at the level of the circle of Willis. The advantage of phase contrast MRA is the straightforward planning of an imaging volume at the level of the circle of Willis, instead of the interactive planning of a saturation slab with different angulations for each patient scanned. Although collateral flow via the ophthalmic artery is incidentally detected on MRA images, the diameter of the ophthalmic artery is generally considered to be too small for accurate collateral flow detection.

In conclusion, we demonstrate that TCD and MRA collateral flow measurements should be interpreted with caution, for the presence of collateral flow via the anterior circle of Willis MRA and TCD are equally and highly accurate. With respect to the PCoA, TCD tends to overestimate and MRA tends to underestimate the presence of collateral flow compared to iaDSA. Combined assessment with TCD and MRA did not result in substantial diagnostic gain.



**FIGURE.** In a patient with right-sided ICA occlusion intra-arterial DSA demonstrated collateral flow via the anterior circle and posterior circle of Willis with filling of the middle cerebral artery (a, b). Second row shows time-of-flight (c) and 2D phase contrast MRA (d,e) of the circle of Willis in the same patient. The middle image shows 2D phase contrast MRA scan phase-encoded in the anterior-posterior direction (d). Blood flowing in the anterior direction is black and blood flowing in the posterior direction is white. Collateral flow via the posterior communicating artery (flow towards the occluded ICA, black) and the A1 segment (flow towards the posterior cerebral artery, white) is detected. The image on the right shows the 2D phase contrast MRA scan phase-encoded in the right-left direction (e). Blood flowing in the patient's right direction is white and blood flowing in the patient's left is black. Collateral flow via the A1 segment (retrograde flow, white) is detected. In this patient also TCD demonstrated presence of collateral flow via the anterior and posterior circle of Willis. In this patient the left posterior communicating artery is absent.