

Status of the Circle of Willis and Intolerance to Carotid Cross-clamping During Carotid Endarterectomy

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WHAT THIS PAPER ADDS?

Identification of a non-invasive system that may reasonably predict the intolerance to cross-clamping during carotid endarterectomy is important in order to plan the correct therapeutical approach. Results of our analysis demonstrate that MRA may identify patients at risk for intolerance and that two, or more, interruptions of the Circle of Willis are associated with high risk of intolerance to cross-clamping.

Purpose: During carotid endarterectomy (CEA), an intolerance to the cross-clamping (CC) can occur. The purpose of this study was to evaluate whether preoperative magnetic resonance angiography (MRA) can predict CC intolerance.

Material and methods: Seventy-one patients (57 males, 14 females, mean age 71.8 years, age range 46–86 years) underwent 71 CEA procedures under local anaesthesia. Before CEA, patients underwent an MRA of the Circle of Willis (CoW) and were then classified into three groups: group A consisted of patients with a complete CoW, group B included patients with one agenesis/obstruction in the CoW and group C comprised patients with two or more agenesiae/obstructions in the CoW. The association between the number of anatomical variants in the CoW, corrected for the status of the contralateral carotid artery, and the onset of CC intolerance was evaluated.

Results: The prevalence of intolerance to CC was 15.5% (11/71). The Fisher test and logistic regression analysis showed a statistically significant association between the intolerance to CC and two or more agenesiae/obstructions in the CoW (p value < 0.00001 and p < 0.001, respectively). No neurological complications were observed.

Conclusion: The results of our study showed that two or more agenesiae/obstructions of the CoW identified by MRA were associated with a high risk of intolerance to CC during CEA.

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Carotid endarterectomy (CEA) is considered a safe and effective method to prevent stroke in the short- and long-term period in patients with severe internal carotid stenosis.^{1–3} During CEA, carotid cross-clamping (CC) is performed to allow for artery incision and the removal of plaque. However, the role of the CEA is mainly related to its 'safety' (low incidence of post/peri-procedural complications). Carotid CC causes blood flow reduction to the Circle of Willis (CoW), and some patients show intolerance to CC; in these cases, it is necessary to use a temporary shunt. The incidence of intolerance to carotid CC varies between 7% and 30% according to different studies.^{4–6} Differences in the incidence mainly depend on the use of different methods for

detecting neurological deficits or for cerebral perfusion analysis, such as the trans-cranial Doppler (TCD).

Because of the risk of cerebral ischaemia during carotid CC, it is mandatory to adopt methods of cerebral monitoring that can rapidly and effectively reveal any sign of intolerance and indicate the need for the intra-operative use of a shunt. Monitoring of cerebral functions can be achieved through both clinical and instrumental means. In the clinical case, local anaesthesia allows for continuous and direct monitoring of cerebral functions when the patient is invited to answer the surgeon or to perform some movements with the contralateral upper limb (i.e., squeeze a rattle). Monitoring of neurological status can also be performed in cases of general anaesthesia by using short-action drugs (i.e., remifentanyl); immediately before carotid clamping, infusion of the drug is suspended, the patient regains consciousness and is asked to squeeze a toy in his or her contralateral hand.^{7,8} Many centres opt for instrumental monitoring with electroencephalography (EEG), or somatosensory evoked

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potentials (SSEPs) or TCD, which can detect a sudden alteration of the cerebral function or a deficit in the intracranial flow. However, these surveys are complex, expensive and require expert operators. Some authors eschew the use of any cerebral monitoring devices and propose the routine use of the shunt; however, this practice carries a significant risk of complications (mainly distal dissection of the internal carotid artery) due to shunt placement. Therefore, the selective use of the shunt for cases of CC intolerance is the first choice of most operative groups.^{9–11}

Local anaesthesia is largely used for CEA.¹² The onset of intolerance to the CC during CEA under local anaesthesia can produce difficulties in the management of the patient because of a loss of consciousness, convulsions, respiratory problems and haemodynamic instability.

The purpose of this study was to evaluate whether preoperative magnetic resonance angiography (MRA) evaluation of the CoW can predict CC intolerance.

MATERIAL AND METHODS

Patient population

Between October 2010 and December 2011, 71 patients (57 males and 14 females) in the age range of 46–86 years (mean age 71.8 years) underwent 71 carotid endarterectomies under local anaesthesia. Each patient signed an informed consent and was informed about the potential risks related to the general co-morbidities, occlusion or severe stenosis of the contra-lateral carotid or reduction of the intracranial collateral circulation.

The degree of carotid stenosis was assessed according to the European Carotid Surgery Trial criteria² by using preoperative Duplex scans and computed tomography (CT) angiography of the epiaortic vessels. The decision for surgical treatment was based on SPREAD guidelines.¹³ Nineteen patients had significant bilateral carotid artery stenosis (>70%), and the contralateral carotid artery was obstructed in six additional patients. All patients underwent an MRA study of the CoW. The patients were classified into three groups: group A included patients with a complete CoW, group B consisted of patients with one agenesis/obstruction in the CoW and group C included patients with two or more agenesiae/obstructions in the CoW.

All CEAs were performed under local anaesthesia. During the procedure, the patient was invited, before, during and after the CC, to answer some questions and to squeeze a toy (rattle) in the contralateral hand to check for intolerance to the carotid CC. In cases of CC intolerance, a silicone T-Tube (Pruitt-Inahara shunt[®], Le Maitre Vascular, Burlington, MA, USA) was inserted through the same arteriotomy used for the CEA.

MR technique

All examinations were performed with a Gyroscan 1.5-T superconducting magnet (Philips, Best, The Netherlands). In all patients, a three-dimensional (3D) time of flight (TOF) MRA of the CoW was performed. 3D multislab TOF MR

angiograms were obtained from the petrous portion of the internal carotid artery to the level of the genu portion of the corpus callosum by using the following imaging parameters: 25-35/3-7/1 (TR/TE/excitation), a flip angle of 20°, five slabs, an effective section thickness of 0.8 mm, a field of view of 200 mm and a matrix of 256 × 256 pixels. The angiographic images were reconstructed with a maximum intensity projection (MIP) and volume-rendering (VR) algorithms.

Identification of variants in the CoW

The presence of anomalies in the CoW on preoperative 3D TOF MR angiograms (Fig. 1) was evaluated. The following arteries were evaluated: the anterior communicating artery (AcoA), the A1 segments, the P1 segments, and the left and right posterior communicating arteries (PcoAs). As previously described by Hoksbergen et al.¹⁴ we used a forced-choice method (absent or present) in the decision analysis and those arteries that could not be visualised were defined as absent, while those that could be visualised were defined as present. We dedicated special care to differentiating the PcoAs from the anterior choroidal arteries by scrolling through the sections and sequentially determining the course of the arteries. The communication of the PcoA with the posterior cerebral artery had to be visualised for defining the PcoA.

Because the purpose of this work was to explore the association between agenesiae/obstructions in the CoW and intolerance to carotid CC, in the case of fusion of the anterior cerebral arteries (absence of AcoA) the anterior collateral pathway was defined as functional and therefore not absent.

After review of 3D TOF MR angiograms, CoW morphology was classified as an optimal communicator when no anatomical variations were detected, sufficient communicator when one variation was detected and poor communicator when two or more variations were identified.

Two experienced vascular radiologists with 6 and 4 years of experience in MRA imaging evaluated the CoW independently, and the inter-observer concordance was tested. In the case of disagreement between the observers, a consensus was reached by consulting a third senior radiologist with 9 years of experience in MRA imaging.

Statistical analysis

The prevalence of CC intolerance was expressed as cases per 100, and 95% confidence intervals (CIs) were calculated according to the Poisson distribution.

The association between agenesis/obstruction in the CoW and age was analysed with the Kruskal–Wallis test. The association between agenesis/obstruction in the CoW and gender, smoking habit, hypertension, diabetes, hypercholesterolaemia, CC intolerance and contralateral ICA stenosis was analysed with the Fisher chi square test.

The potential confounding effect of contralateral ICA stenosis on the association between CC intolerance and the agenesis/obstruction in the CoW was explored through a multivariate logistic regression. CC intolerance was the

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