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Review

Pre-operative methods to predict need for shunting during carotid endarterectomy

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HIGHLIGHTS

- Pre-operative imaging can reliably identify which patients undergoing CEA will not require intra-operative shunting.
- MRA and acetazolomide stress SPECT imaging have shown to be the most promising imaging modalities.
- However, the available evidence is limited and there is a need for more rigorous studies to be conducted.

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ABSTRACT

Objectives: To establish whether pre-operative investigations are able to predict cerebral tolerance to carotid cross clamping during carotid endarterectomy (CEA).
Methods: A search of the MEDLINE database from 1950 to 2015 was made in combination with manual cross-referencing using the search strategy: ("carotid" [all fields] AND "endarterectomy" [all fields]) AND "preoperative" [all fields]) AND "clamping" [all fields]) AND ("MRA" [all fields] OR "MRI" [all fields] OR "CT" [all fields] OR "CTA" [all fields] OR "EEG" [all fields] OR "Doppler" [all fields] OR "angiography" [all fields]). A total of 20 studies were identified as eligible for inclusion.
Results: 3D Time of Flight MRA and acetazolomide stress SPECT imaging have been reported to have a negative predictive value of 96% and 94% respectively for the need for intraoperative shunting during carotid endarterectomy.
Conclusions: There is some evidence to suggest that pre-operative imaging investigations can reliably identify which patients undergoing CEA will not require carotid shunting for neurological protection. However, this evidence is limited and there is a need for more rigorous studies to be conducted.

1. Introduction

Carotid artery endarterectomy (CEA) is an effective treatment modality in patients suffering from symptomatic and asymptomatic carotid artery stenosis [1]. These benefits have been seen despite a stroke and death rate within 30 days of the operation of between 5% and 10% [2].

Primary collateral vessels are those of the circle of Willis, which respond rapidly to hypoperfusion and form the principal collateral pathway. Secondary collateral pathways constitute the ophthalmic artery and leptomeningeal vessels, these require time to develop [3]. The circle of Willis allows for inter-hemispheric blood flow mainly via the anterior and posterior communicating arteries. Considerable variability exists in the anatomy of the circle of Willis and it is incomplete in approximately 70% of healthy individuals [4]. In the event of carotid artery cross-clamping the configuration, size and patency of its vessels may be risk factors in the development of cerebral ischaemia.

There are two prevalent schools of surgical practice regarding shunting when performing CEA. One school advocates the habitual use of shunting, often performing the procedure under general anaesthesia. The other school uses a selective shunting strategy based on continuous electroencephalogram (EEG) monitoring, carotid stump pressure measurements, somatosensory evoked potentials (SSEPs) or trans-cranial Doppler (TCD) or neurological signs in the awake patient to assess the need [5]. Interestingly, a recent

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meta-analysis has reported that there are insufficient data to support either the selective or routine strategy [6]. Shunting is not a benign manoeuvre and complications include air or plaque embolization, intimal tears, and carotid dissection.

Although the outcomes of local anaesthetic versus general anaesthetic CEA have not been shown to be significantly different [7], there has been a trend amongst UK surgeons who do not routinely perform shunting to perform CEA under LA. This confers the advantage of objective and functional assessment of cerebral perfusion by assessing consciousness level of the awake patient. Using this approach, the need for shunting has been reported to be as low as five per cent. This has led to reduced routine experience with insertion of carotid shunts and perhaps increased anxiety associated with their now infrequent use.

There may be a benefit to risk stratifying patients requiring CEA into those who are at low risk of requiring intra-operative shunting versus those who are at higher risk. Dedicated high risk operating lists could be set up, supervised by competent surgeons and anaesthetists experienced in the operation and in shunting. The aim of this paper is to review the evidence regarding pre-operative imaging with a view to establish whether pre-operative investigations before CEA can predict those who will not require shunting.

2. Methods

A search of the MEDLINE database from 1950 to 2015 using the PubMed interface was made in combination with manual cross-referencing. The search was performed using the search strategy:

("carotid" [all fields] AND "endarterectomy" [all fields]) AND "preoperative" [all fields]) AND "clamping" [all fields]) AND ("MRA" [all fields] OR "MRI" [all fields] OR "CT" [all fields] OR "CTA" [all fields] OR "EEG" [all fields] OR "Doppler" [all fields] OR "angiography" [all fields]). A total of 20 studies were identified as eligible for inclusion.

Abstracts were screened for relevance to the topic by author PN. Inclusion criteria were any study pertaining to the topic. These are reviewed below.

3. Results

A total of 20 studies were identified as eligible for inclusion (**PRISMA flow diagram**; Fig. 1).

3.1. Angiography

There are a number of historical papers in the literature correlating pre-operative angiography findings with assessment of intraoperative cerebral ischaemia after carotid artery clamping. Schwartz et al. compared the pre-operative angiograms of 30 patients (16 whom had required shunting) with intra-operative EEG findings suggestive of cerebral ischaemia [8]. Contrast injection was given into both carotid arteries and lack of adequate collateral flow was deemed to exist if either of the A1 segments or anterior communicating artery (Acom) could not be visualised with either injection and if the posterior communicating artery (Pcom) was absent or the posterior cerebral artery (PCA) was of fetal origin (arising from the carotid syphon). All of the patients studied who had no collateral flow demonstrated to the ipsilateral side being surgically treated (15 of 30) demonstrated EEG changes and underwent shunting. Of the remainder, only one had EEG changes and underwent shunting. Lopez-Breznehan et al. [9] also retrospectively analysed preoperative angiograms of 67 patients who underwent CEA under GA with intraoperative EEG monitoring to detect cerebral ischaemia. They report that angiographic cross-filling of the anterior and middle cerebral arteries from the contralateral carotid artery through the anterior communicating artery protected against intraoperative cerebral ischaemia with a sensitivity of 74%, specificity of 57% and positive predictive value of 79%.

Wain et al. correlated pre-operative demonstration of inter-cerebral 'cross-filling' on angiography with somatosensory evoked potential (SEP) guided carotid shunt placement in 87 patients undergoing CEA under GA [10]. They report that 41% of patients did not have cross-filling from the contralateral internal carotid artery. Of these, 25% required a shunt based on SEP measurements; none of the 51 patients with adequate cross-filling were shunted ($p < 0.001$). Furthermore, 94% of the patients without cross-filling but with a patent ipsilateral Pcom did not require a shunt. They report sensitivity and negative predictive value of 100% but specificity of 65% and a positive predictive value of 25%. In their cohort, some patients without collateral flow did not require shunt insertion suggesting that angiography might underestimate collateral pathways.

An observational study correlated pattern of collateralisation and corresponding middle cerebral artery (MCA) flow rates using TCD in 20 patients undergoing CEA [11]. The patients underwent CEA under either local or general anaesthesia and only one patient was shunted. Incidence of neurological events was found not to differ. Patients with only an ipsilateral Pcom had significantly lower flow in the ipsilateral middle cerebral artery during carotid clamping compared to patients who had only a functioning Acom and those who had both an Acom and Pcom. This was despite intra-operative blood pressure being higher in those patients without a patent Acom and Pcom. The authors suggest that patients with only an intact Pcom experience lower middle cerebral artery blood flow during carotid occlusion than those with Acom and refer to previous reports of higher stroke rates in these people [12,13].

A study from South Korea correlated pre-operative angiographic findings with consciousness level and motor function after carotid clamping in 67 patients undergoing awake CEA. Of the 55 patients with either an Acom or Pcom, only 7.3% required shunting. Of the 12 patients who had neither Acom or Pcom, 10 (83.3%) showed signs of cerebral ischaemia necessitating shunting [14].

Angiographic evaluation of collateral flow may be limited by the inability to predict the functional significance of an imaged vessel. Visualisation of collateral blood vessels does not always mean that it will be able to adequately perfuse the ipsilateral hemisphere. Furthermore, angiography is limited in assessing the relative contributions of the anterior and posterior collateral circulations. Although the Acom is the dominant source of collateral blood flow, the Pcom can compensate in the presence of anterior communicating artery hypoplasia [15].

3.2. Magnetic resonance angiography (MRA)

MRA is a non-invasive imaging modality; several techniques are available, such as time of flight (TOF), phase contrast (PC), and contrast enhanced angiography. For vessel visualisation, each technique has its advantages and disadvantages [16,17]. MRA is able to provide both accurate morphological and haemodynamic information concerning blood flow in individual blood vessels.

Rutgers and colleagues conducted a prospective study correlating preoperative quantitative volume flow measurements in the ICA, Basilar artery (BA) and Middle Cerebral artery (MCA) as assessed by phase contrast MRA with the development of intra-operative ischaemic EEG changes under general anaesthesia. Of the 86 patients recruited 62 had ICA stenosis only, while 24 had ICA