



Can the External Carotid Artery Be Securely Ligated using the BRIG Technique in the Treatment of Carotid Disease?

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Abstract

Introduction: Ligating the external carotid artery during carotid artery surgery remains a debatable act for many surgeons due to the potential impact of facial arterial blood supply. However, in our previous report on the BRIG technique to treat carotid disease, only one patient developed jaw claudicating and no other symptoms of facial hypo-perfusion. The goal of this study is to scientifically substantiate these clinical findings by determining the impact of interruption and restoration of the carotid blood flow on the External Carotid Artery Stump Pressure (ECASP).

Methods: A prospective proof-of-concept study was performed, including nine consecutive patients who underwent BRIG surgery for symptomatic ICA stenosis or asymptomatic high grade ICA stenosis. A Javid shunt was used to measure the ECASP and the CASP during the procedure. An arterial line was used to measure systemic blood pressure. To compare the ECASP during clamping and after the restoration of ICA blood flow, multiple Students' T-testing was performed, correcting for multiple testing using the Holm-Sidak method.

Results: ECASP and ECASP /BP index did not significantly change during clamping of the carotid bifurcation and after restoration of cerebral blood. Both CASP and ECASP did not change significantly during clamping of the common carotid artery.

Conclusion: The internal carotid artery does not influence the ECASP and no high blood pressure needs to be present in the ECA for it to be functional. Based on these findings, we can conclude that the ECA can be safely ligated during the BRIG procedure.

Keywords: Carotid artery; Carotid disease; ECASP

Introduction

Currently, the gold standard surgical treatment of carotid artery stenosis is the classical carotid endarterectomy. Upon restenosis, the resection of the carotid bifurcation and interposition of a graft is often considered [1].

However, previously we proposed the use of the BRIG surgical technique for carotid artery disease, in which a PTFE graft is interposed and the external carotid artery is ligated. This technique in the primary treatment setting of carotid artery disease has shown excellent outcomes with limited comorbidity and a potential reduction in healthcare costs [2,3]. Nevertheless, the ligation of the external carotid artery, which is inherent to this procedure, remains a debatable act for many surgeons due to the potential impact of facial arterial blood supply. However, in our previous series of 153 patients that underwent BRIG treatment, only one patient had jaw claudication. Not a single patient had any other signs of facial hypo-perfusion 5 years after treatment. Importantly, none of the patients undergoing BRIG surgery underwent bilateral ligation of the ECA. If surgery was necessary bilaterally, on the least affected side a bifurcated graft was interposed, which was performed in 9.4% of previously described cases [3] (Figure 1A, 1B).

The goal of this study is to scientifically substantiate these clinical findings by determining the impact of interruption and restoration of the carotid blood flow on the External Carotid Artery Stump Pressure (ECASP). The measurement of the internal Carotid Artery Stump Pressure (CASP) is a simple, widely used method to assess cerebral hemispheric collateral blood flow during carotid surgery and is used to decide whether temporary shunting of the clamped carotid might be required to prevent hemodynamic stroke. We are the first to investigate the External Carotid Artery Stump

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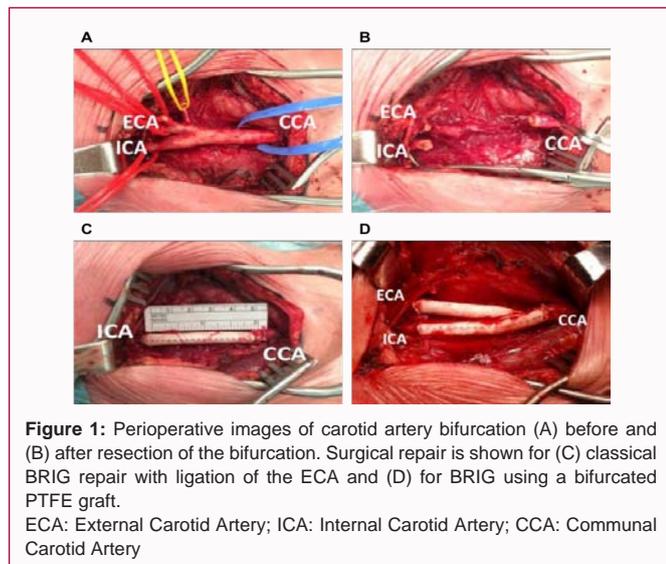


Figure 1: Perioperative images of carotid artery bifurcation (A) before and (B) after resection of the bifurcation. Surgical repair is shown for (C) classical BRIG repair with ligation of the ECA and (D) for BRIG using a bifurcated PTFE graft. ECA: External Carotid Artery; ICA: Internal Carotid Artery; CCA: Communal Carotid Artery

Pressure (ECASP) as a surrogate for facial perfusion.

Methods

Cohort design and carotid artery stump pressure measurements

A prospective proof-of-concept study was performed, including nine consecutive patients who underwent BRIG surgery for symptomatic ICA stenosis or asymptomatic high grade ICA stenosis. All patients signed informed consent for the conduction of the surgical procedure to be performed under general anesthesia.

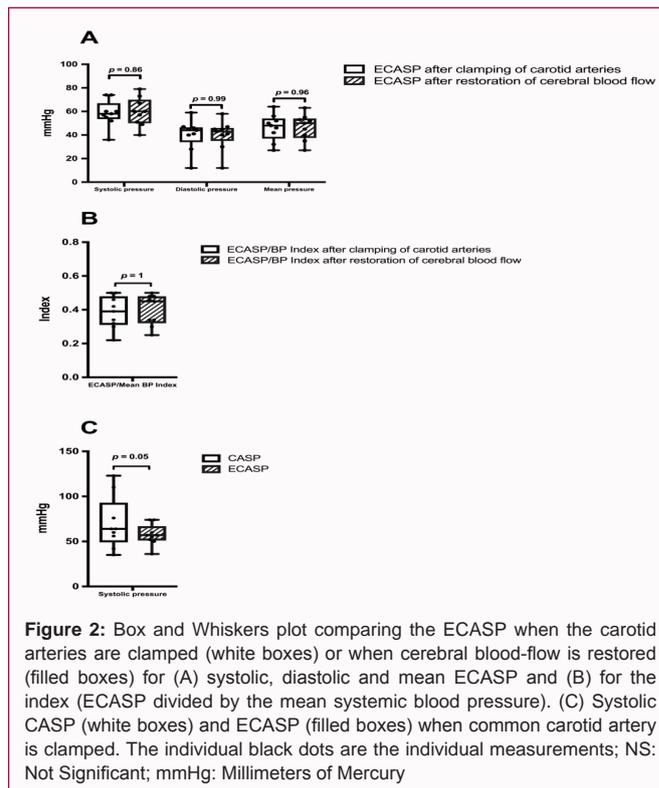
All the patients had a radial arterial line for monitoring of the systemic blood pressure. Systemic heparin was given before clamping the carotid bifurcation. The carotid bifurcation was clamped and the external carotid artery was ligated at his origin. A Javid shunt was used to measure the ECASP and the CASP during the procedure. Simultaneously, the systemic Blood Pressure (BP) and mean systemic BP were registered. After respecting the carotid bifurcation, revascularization of the internal carotid artery was obtained by the interposition of a 6 mm PTFE graft as previously described [3]. A shunt was never used; even if the CASP was <50 mmHg. At the time of clamping, the systemic blood pressure was augmented to be approximately 10% above the patient's baseline blood pressure. After restoration of the cerebral circulation, the ECASP, systolic/diastolic/mean systemic BP was measured again. At the end of the procedure, heparin was neutralized by administration of protamine and the patient was transferred to the ICU for a maximum of 24 hr.

Statistical analysis

To compare the ECASP during clamping and after the restoration of ICA blood flow, the mean values were compared for systolic, diastolic and mean pressure. To account for inter patient differences in systemic blood pressure which can influence the (E)CASP, the ECASP was normalized to systemic pressure (ECASP Index). ECASP was also compared to the CASP. These multiple comparisons between two groups were performed using multiple Student's T-testing, correcting for multiple testing using the Holm-Sidak method. Statistical analyses and graph design were performed in Prism v7.0 considering a statistical significance at $p < 0.05$.

Results

In this prospective study 9 patients were included (8 men and



1 woman) with a mean age of 70 years (range 89-62 yrs). Four patients underwent surgery for a symptomatic stenosis and 5 for an asymptomatic high gradestenosis. The preoperative morbidity and mortality was 0%. ECASP measurement during clamping of the carotid bifurcation and after restoration of cerebral blood flow did not show any significant changes in ECASP levels as did the ECASP Index (Figure 2A,2B). Next, the CASP and ECASP were compared during clamping of the common carotid artery, which did not show a significant difference, although two patients did have a lower ECASP compared to their CASP (Figure 2C). Finally, in two patients a Javid shunt was placed between the common and external carotid artery after resection of the carotid bulb. The CASP was measured during clamping of the common carotid artery and after the placement of the Javid shunt, which did not result in an increase of the CASP.

Discussion

This small prospective study investigated the impact of the ligation of the external carotid artery on the ECASP as a surrogate for facial perfusion. Our previously reported outcome results after BRIG treatment compared to classical carotid endarterectomy are encouraging, with lower rates of hospital mortality and morbidity rates as well as the lower rates of restenosis at long-term follow-up [3]. However, the ligation of the ECA, which is inherent to this procedure, remains a point of discussion for many surgeons due to the potential impact that it could influence induce facial hypo-perfusion with functional impact such as jaw claudication. However, in our previous study only one of the 153 included patients developed jaw claudication while eating after more than 5 years of follow-up. Furthermore, the potential advantages of the BRIG cannot be denied: a) removal of the sick part of the carotid artery, b) absence of a bifurcation and consequently turbulences, which can be responsible for restenosis, c) shorter clamping time of the ICA, d) simplified technique in case of coiling/kinking of the ICA, e) less surface thrombogenicity of the

PTFE graft compared to the CEA, f) no meticulous endarterectomy and fixation of the distal intima.

Based on the presented data, it can be hypothesized that when the external carotid artery is ligated, its effect on facial perfusion is limited which would explain why only one of our patients undergoing BRIG surgery develop jaw claudication. Experimental ligation of the external carotid artery in Chacma baboons did show a decrease in maxillary blood flow of 40% and 73% when ligated below and above the origin of the lingulofacial trunk respectively [4]. Furthermore, some case-reports exist on jaw claudication in the presence of an occluded or ligated external carotid artery, but data remains limited and it seems that this only occurs when both sides are affected or without a functional Circle of Willis [5,6]. This is supported by a case report of a patient with jaw claudication based on bilateral external several external carotid artery stenoses, which was resolved by unilateral endarterectomy [7].

This phenomenon can be explained by multiple hypotheses. First, it is known that multiple small arteries connect the ICA and ECA, which mainly goes through the ophthalmic artery [8]. Furthermore, frequently anastomoses exist between the occipital artery (branch of the ECA) and the muscular branches of the vertebral artery, of which its functional role remains limited [9]. However, based on our data the ECASP does not change when the ICA is clamped or circulation is restoring again (Figure 1B,2A). This suggests that the role of the ipsilateral ICA in maintaining ECASP through collaterals remains limited. In other words, the ECASP seems to be mainly determined by the contralateral ECA and not by the ipsilateral internal carotid artery and vertebral artery. This is also confirmed by the fact that the CASP does not increase after shunt placement between the common and ECA (see very small observation in our results section). Second, index data show that ECASP is low compared to systemic BP (Figure 2B), suggesting that a lower perfusion rate of the facial arteries does not necessarily result in functional changes. A possible explanation may be that chewing/eating is not comparable with walking, since the masticatory muscles are not used continuously during eating. Furthermore, it cannot be excluded that ECASP stump pressure (ECASP and index) will increase in the postoperative phase on the one hand by increasing blood pressure and on the other hand increase of reasonable collateral circulation.

Although our presented data are unambiguous, sample size remains small and future studies on a larger scale could validate our

findings and might define a ECASP threshold below which BRIG should be avoided. However, these data again are encouraging and support the feasibility of the BRIG technique and ligation of the ECA as upfront treatment in carotid artery disease.

Conclusion

The internal carotid artery doesn't have any effect on the external carotid artery stump pressure (ECASP). This study confirms that no high pressure needs to be present in the external carotid artery and that is why the external carotid artery can be safely ligated. We are therefore convinced that the BRIG technique should have a place in the treatment of carotid disease.

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