

A Prospective Nonrandomized Study on Carotid Surgery Performed under General Anesthesia without Intraoperative Cerebral Monitoring

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Background: The purpose of this study was to assess our experience of carotid surgery habitually performed under general anesthesia without intraoperative intracerebral monitoring, and following a pre-established perioperative protocol, which includes extensive use of an intraoperative shunt (IOS). **Methods:** This study included 311 consecutive carotid operations performed over 32 months. This patient cohort represents 14% of our total experience in carotid surgery (2219 operations, major stroke/mortality rate: 1.4%). The IOS was inserted routinely in the presence of intraoperative *blood pressure instability* during cross-clamping and when the *predictable clamping time* might have exceeded 20 minutes. A moderate and stable hypertension was maintained throughout surgery without IOS. **Results:** Overall, 120 (38.6%) endarterectomies were performed with primary closure, 73 (23.5%) with eversion technique, 113 (36.3%) with patch angioplasty, and 5 (1.6%) with other techniques. Out of 113 patch angioplasties, 111 (98.2%) were performed with an IOS. This was utilized in only 3 cases of direct carotid reconstructions or other carotid endarterectomy techniques (1.5%). Overall, the IOS placement rate was 36.7%. Postoperatively, 2 major strokes (.64%), 2 minor strokes (.64%), 4 hyperperfusion syndromes (1.3%), and no mortality were recorded. No cases of cross-clamp ischemia/shunt-related perioperative strokes were observed. **Conclusions:** The low perioperative stroke rate reported in this prospective study proves the advantages of wide use of IOS during carotid surgery. This coupled with a large experience in carotid surgery and close monitoring and support of blood pressure, are the major determinants of these results that demonstrate the low risk of shunt-related complications for surgeons who regularly utilize an IOS. **Key Words:** Carotid surgery—*intraoperative shunt—perioperative stroke—*intraoperative cerebral monitoring—general anesthesia—clamping ischemia.**

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Introduction

Despite a 1980 prospective study demonstrating the feasibility of performing a carotid endarterectomy (CEA) without an intraoperative shunt (IOS),¹ nowadays almost all carotid surgeons use it either routinely or selectively.²

For those who prefer selective shunting, the decision is based on different methods of intraoperative cerebral perfusion monitoring (ICM). Over the last 20 years, different kinds of ICM methods have been used to assess the adequacy of cerebral blood flow during internal carotid artery (ICA) cross-clamping: techniques that monitor

cerebral hemodynamics (i.e., transcranial Doppler sonography,³ carotid artery stump pressure⁴), those that evaluate cerebral oxygen metabolism (i.e., jugular bulb monitoring,⁵ near-infrared spectroscopy⁶), and those that detect cerebral functional state during carotid cross-clamping (i.e., electroencephalography,⁷ evoked potentials,⁸ local anesthesia⁹). Awake testing is generally considered to have the highest sensitivity and specificity and, according to several authors, represents the gold standard among all methods of cerebral monitoring.⁹ In a relevant percentage of cases, however, local anesthesia is not practical and, furthermore, the true significance of brain dysfunction emerging at carotid cross-clamping during local or regional anesthesia has yet to be clearly defined. Additionally, controversy still exists over the optimal method for cerebral perfusion monitoring,¹⁰ and some surgeons doubt that the information provided by such monitoring reliably identifies patients at risk for stroke related to cross-clamp hypoperfusion.¹¹

ICM during carotid surgery could become superfluous with routine use of an IOS, but, as reported by several authors over the last 10 years, this could result in an increase in shunt-related perioperative strokes.¹⁰

The purpose of this prospective nonrandomized study was to assess our experience of carotid surgery performed under general anesthesia from 1998 to date, without using ICM techniques and following a pre-established perioperative protocol, which includes extensive use of the IOS.

Methods

Our prospective nonrandomized study included 311 consecutive carotid operations performed between January 2010 and September 2012 in 285 consecutive patients (in 26 patients—8.4% bilateral procedures). This patient cohort represents ca. 14% of our total experience in carotid surgery including 2219 operations performed between May 1998 and December 2013, with an overall major stroke/mortality rate of 1.4%. All the procedures included in this study were performed by 3 high-volume vascular surgeons, under general anesthesia without using ICM techniques. The most common surgical techniques were employed indifferently (primary closure, eversion, and patch angioplasty), considering the specific carotid anatomy and stenosis characteristics. Carotid stenting, carotid aneurysms, carotid restenosis, carotid traumas, dissections, and chemodectomas were not included. All data were prospectively collected using Excel software.

The IOS (Pruitt-Inhara; LeMaitre Vascular Inc., Burlington, MA) was inserted routinely in the presence of intraoperative *blood pressure instability* during ICA cross-clamping and when the *predictable clamping time* might have exceeded 20 minutes. The empiric evaluation of postclamping *backflow* from the ICA was considered in the decision to place an IOS only in the presence of un-

certain intraoperative situations. In all cases, a moderate intraoperative hypertension (*systolic blood pressure*: 10%-15% above baseline) was maintained (up to a maximum of systolic blood pressure value of 160 mmHg) during carotid cross-clamping time when the operation was performed without IOS placement.

Regarding *blood pressure stability*, hypotension was defined as systolic blood pressure under 100 mmHg and deemed prolonged if it lasted longer than 8 minutes.^{12,13} Hypertension was defined as systolic blood pressure over 160 mmHg.^{12,13} Systolic blood pressure variation was defined as the difference between the highest and lowest systolic blood pressure over 30 mmHg.^{12,13} The IOS placement was considered mandatory in all cases when blood pressure instability, hypotension, or hypertension occurred after ICA cross-clamping.

Predictable clamping time was defined as the presumable duration of internal carotid clamping time evaluated by the surgeon following the adopted surgical technique, carotid lesion characteristics, as well as ICA anatomy and diameter. We considered 20 minutes as tolerable ICA cross-clamping time without intraoperative shunting because in our experience the duration of clamping time did not exceed this value in nearly all CEAs performed via direct carotid reconstruction (habitually performed without an IOS and, in our experience, with no evidence of clamping ischemia).

A significant backflow was empirically defined as an excellent and pulsate backflow from the ICA after proximal carotid cross-clamping.

Other clinical and anatomical variables such as symptoms, contralateral lesions (stenosis or occlusion), and the preoperative cerebral-computed tomography (CT) imaging were not usually considered among the IOS indications. These variables were evaluated by the surgeon case by case only in specific circumstances (always in association with the other above reported IOS placement indications).

Anesthesia was basically performed via titration of propofol for anesthetic induction (usually 2-2.5 mg/kg) coupled with rocuronium bromide (usually .6 mg/kg) for neuromuscular blockade. A careful balance of the volatile anesthetic agents was used for blood pressure stability control and support during surgery (both in cases of CEAs performed with and without the IOS). We used intravenous low-dose dopamine (in cases of perioperative hypotension) and intravenous nitroglycerin drugs (in cases of hypertension) only in cases of difficulty in controlling blood pressure via volatile anesthetic agents. In cases of severe ICA stenosis (>90%), previous cerebral ischemic events, prolonged clamping time without IOS, or prolonged intra- or perioperative hypertension, a mannitol bolus (250 mg in half an hour) was usually administered at the end of carotid reconstruction.

For the quality control, an intraoperative angiography was performed selectively following the surgeons'

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