

# Interaction of cerebrovascular disease and contralateral carotid occlusion in prediction of shunt insertion during carotid endarterectomy

María J. Estruch-Pérez<sup>1</sup>, Angel Plaza-Martínez<sup>2</sup>, María J. Hernández-Cádiz<sup>1</sup>, Juan Soliveres-Ripoll<sup>1</sup>, Cristina Solaz-Roldán<sup>1</sup>, María M. Morales-Suarez-Varela<sup>3</sup>

<sup>1</sup>Anaesthesiology and Critical Care Department, Dr. Peset University Hospital, Valencia, Spain

<sup>2</sup>Vascular Surgery Department, Dr. Peset University Hospital, Valencia, Spain

<sup>3</sup>Unit of Public Health and Environmental Care, Department of Preventive Medicine, University of Valencia, Spain; Unit of Clinical Epidemiology, Dr. Peset University Hospital, Valencia, Spain; and CIBER of Epidemiology and Public Health (CIBERESP), Spain

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## Corresponding author:

María J. Estruch Pérez MD  
Anaesthesiology and  
Critical Care Department  
Dr. Peset University Hospital  
Avda. Gaspar Aguilar n° 90  
46017 Valencia (Spain)  
Phone: +34654800851  
Fax: +3496.386.25.01  
E-mail: estruch\_mar@gva.es

## Abstract

**Introduction:** To assess the possible role and the interaction of cerebrovascular disease and vascular stenosis on the necessity of shunt insertion during carotid endarterectomy (CEA).

**Material and methods:** Eighty consecutive patients undergoing CEA under regional anaesthesia were prospectively enrolled. Patients were divided into two groups depending on whether they were shunted or not. The measured end-points were co-morbidities degree of contralateral and carotid stenosis and other intra- and postoperative outstanding parameters. ANOVA, Student's *t* and  $\chi^2$  tests were used ( $p < 0.05$ ). Variables differing significantly between groups and potential confounders were used in backward stepwise logistic regression to estimate the relative risk (RR, 95% CI) of shunt. In addition Wald's test ( $p < 0.05$ ) with and without adjustments for potential confounders was used with various different multivariate analysis models.

**Results:** Contralateral stenosis and cerebral vascular accidents (CVA) were more frequently observed in shunted patients. The RR for patients with contralateral stenosis  $\geq 50\%$  was 1.3 (95% CI 1.0-1.5) and for patients with previous CVA was 1.2 (95% CI 1.0-1.4). For contralateral stenosis and CVA together the RR increased to 7.7 (95% CI 1.0-14.4). A model based on contralateral stenosis and CVA was found to be statistically significant ( $p = 0.003$ ) for shunt (RR = 1.1, 95% CI 1.0-2.1). Relative excess risk due to interaction of both factors was 6.2.

**Conclusions:** The findings suggest that patients with contralateral stenosis  $\geq 50\%$  and previous CVA have a higher risk of requiring shunt use during CEA than patients with these risk factors separately.

**Key words:** carotid endarterectomy, shunted patients, cerebral ischaemia.

## Introduction

Carotid endarterectomy (CEA) has become a well-established technique to prevent the risk of stroke in symptomatic and asymptomatic patients, as reviewed in recent trials [1, 2]. However, the long-term benefit must outweigh the perioperative risk (stroke and death). Most perioperative strokes

are ischaemic and some are caused by low blood flow during the carotid clamping period. The insertion of an intraluminal shunt to minimize the risk of low flow and intraoperative stroke has been used. A recent Cochrane Review [3] of routine versus selective carotid artery shunting showed that the currently available data were too limited to support or refute the use of routine or selective carotid shunting in patients undergoing CEA under general anaesthesia. However, the use of a shunt makes the operation technically more demanding and carries potential complications such as embolism or damage to arterial walls. Shunt insertion has also been related to postoperative internal carotid artery (ICA) re-stenosis after CEA [4] and to subclinical neurocognitive dysfunction [5], although the literature also shows controversy. In this context, it would be an advantage to preoperatively predict which patient will need a shunt. Neuromonitoring methods easy to apply, such as bispectral index, have been investigated for monitoring of cerebral ischaemia to allow selective shunt insertion [6].

Factors such as moderate ipsilateral carotid stenosis, degree of contralateral stenosis or preoperative symptoms of cerebrovascular disease [7-15] have been associated with shunt placement due to cerebral ischaemia during CEA. These reports suggest shunting patients with the factors mentioned with poor strength of association that could improve with the combination of factors. With awake patients under regional anaesthesia it was possible for us to use a selective shunt while monitoring neurological status during surgery. With this approach, we undertook an observational prospective study to identify preoperative or intraoperative characteristics of the patients associated with neurological changes consistent with cerebral ischaemia which needed shunting. In particular, we assess the possible role and the interaction of cerebrovascular disease and vascular stenosis on the necessity of shunt insertion during CEA.

## Material and methods

This prospective observational single-centre study was conducted in the vascular surgery department at Dr Peset Hospital, Valencia, Spain, from November 2005 to December 2007. The protocol was approved by the local ethics committee, which waived the requirement for informed consent as data were collected while care of patients conformed to standard procedures currently used in our institution. During a three-year period, all patients undergoing CEA [1, 2] were operated on under a regional anaesthesia protocol and they were invited to participate in the study. Patients allergic to regional anaesthetics, who refused regional anaesthesia, with cognitive limitation, anxiety, orthopnoea, a known language barrier or ASA

V were excluded from the protocol. Based on these criteria, 80 patients were included and, of these, only one was converted to general anaesthesia.

Perioperative management was standardized. For the preoperative selection of study patients the main tool used for extracranial screening, diagnosis and follow-up was Echo-Doppler testing in accordance with the consensus conference of the Society of Radiologists in ultrasound [16]. Other studies such as arteriography or magnetic resonance angiography were only used if doubts were found with echo-Doppler testing about the stenosis percentage [1].

Standard instrumentation was used in the operating room: all patients were monitored using five-lead ECG, pulse oximetry, and invasive measurement of mean arterial pressure (MAP). An 18G intravenous cannula was placed in the forearm and intravenous premedication, either 1-2 mg of midazolam (MDZ) or 1 mg MDZ and 50 µg of fentanyl, was given 10 minutes before placing a cervical plexus block to provide anxiolysis, as deemed necessary by the anaesthetist. During the procedure, each patient received oxygen at 3 l/min via nasal prongs. For regional anaesthesia, 20 ml of bupivacaine 0.375% was administered for the deep cervical plexus block following a modified version of the single-injection technique proposed by Winnie *et al.* [17] or using a three-injection technique at C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub> as described by Moore [18]. Mepivacaine 2% (20 ml) was administered for the superficial cervical plexus block at the midpoint of the posterior border of the sternocleidomastoid muscle. If the patient noted pain during surgery, the surgeon administered supplementary 1% lidocaine directly around the carotid sheath. Also, 0.10 mg of fentanyl was used in cases when additional sedation or pain relief was required in the course of the surgery. The MAP was maintained using vasodilators or volume expanders and catecholamines to maintain systolic blood pressure within the normal limits ( $\pm 20\%$  of basal blood pressure values).

Carotid stenosis consists of removal of plaque through the open common carotid by means of a pre-jugular approach. Clamping of the internal and external carotid is necessary. Heparin (5000 U *i.v.*) was given before carotid cross-clamping. A clamping test was performed for 3 min to determine tolerance to low cerebral flow through the carotid artery. Cerebral ischaemia during clamping was assumed when neurological changes were detected and a Javid shunt was placed from the common carotid artery to the intact internal carotid artery. The carotid was closed directly or by means of a path. Heparin was reversed with protamine after surgery in some patients at the discretion of the surgeon. The patient was kept in the ICU for the first 24 h to allow close monitoring of blood pressure, neurological condition and drainage. Pre- and

postoperative routine antiplatelet drug therapies (acetylsalicylic acid, clopidogrel) were not withheld and were given according to pre-existing prescriptions. In all patients the CEA was performed using the same method and by the same surgical team. Patients continued to take their routine medication until the morning of surgery.

### Data collection

For each patient, the following data were collected: preoperative risk factors for morbidity and mortality (patient characteristics, smoking habit, main identified comorbidities); previous symptoms (cerebral vascular accident – CVA, transient ischaemic accident – TIA); American Society of Anesthesiology (ASA) classification, and preoperative medication; intra-postoperative data (degree of ipsilateral stenosis and contralateral carotid stenosis, duration of surgery and clamping, ICU and hospital stay, postoperative blood pressure, intra-postoperative antihypertensive therapy); and 30-day postoperative complications (death, neurological signs and symptoms (CVA, TIA), acute myocardial infarction (AMI), and other complications such as cranial nerve deficits and surgical haematoma). These data were prospectively entered into a database for later analysis.

Relevant previous symptoms were considered to be CVA or TIA, including amaurosis fugax as a symptom of carotid stenosis. Patients were considered to be asymptomatic if the aforementioned pathologies and the carotid stenosis had been detected following a full vascular assessment in the context of another vascular disease or as an incidental observation made during an examination for another non-vascular disease.

Cerebral ischaemia during clamping was assumed when neurological changes were detected. Specifically, the neurological changes considered to indicate cerebral ischaemia were as follows: focal neurological deficits (tested by requesting the patient to move each of their limbs and squeeze a toy); decreased consciousness [19], tested by assessing speech using the verbal component of the Glasgow Coma Scale; and dysarthria [19]. The period of carotid clamping used to record neurological changes during neurological monitoring was a 3-min clamping test. The need for Javid shunt placement was based on the occurrence of neurological changes during this 3-min clamping test and whether neurological deficits required conversion from regional to general anaesthesia prior to shunt insertion.

### Statistical analysis

For data analysis, we divided a *posteriori* the 80 individuals into two groups according to shunt insertion during surgery: shunted patients ( $n = 12$ ) and non-shunted patients ( $n = 68$ ).

Quantitative results are presented as means and standard deviations (SD), minimum and maximum, while qualitative results are reported as absolute and relative (percentages) frequencies.

Statistical analysis was performed in two steps. The first step was a descriptive analysis with two-way repeated measures ANOVA for continuous variables and the  $\chi^2$  test for proportions to compare differences between shunted and non-shunted groups;  $p$ -values less than 0.05 were considered statistically significant. In the second step, the associations of patient characteristics with shunt insertion were analysed using relative risk (RR, 95% CI), after which we ran various models adjusted by RR (95% CI) including variables found to be significant in the first step. Statistical analysis was also performed using forward stepwise logistic regression (cut-off value of  $p = 0.05$ ; Wald test) with the use of a shunt as the dependent variable, and the following as independent variables: high blood pressure (HBP); percentages of occlusion in ipsilateral disease and, separately, in contralateral disease; CVA; TIA; and asymptomatic status. Potential associations between preoperative and intraoperative variables and shunt were first tested by univariate analysis. We also calculated the relative excess risk due to interaction of the risk factors identified in the study [20].

Statistical calculations were performed using SPSS statistical software, v.15 (SPSS, Chicago, IL, USA).

### Results

The cohort investigated ( $n = 80$ ) comprised 71 men (88.75%) and 9 women (11.25%), who ranged from 45 to 82 years old (mean age:  $66.06 \pm 9.07$  years; mean weight:  $72.24 \pm 9.32$  kg). The mean degree of stenosis was  $85.2 \pm 8.7\%$ , with a minimum and maximum stenosis of 70% and 99%.

Previous symptoms were TIA including amaurosis fugax ( $n = 21$ ) and CVA that included reversible ischaemic neurological deficits (RINDs) ( $n = 41$ ) or both ( $n = 2$ ). In 62 symptomatic patients (77.5%) the degree of carotid stenosis was  $86.7 \pm 8.6\%$  and in the 18 asymptomatic patients (22.5%) it was  $80.5 \pm 7.6\%$ , with a  $p$  value = 0.019.

The demographic data and medical history of shunted and non-shunted patients are given in Table I. Shunted patients had significantly higher levels of contralateral stenosis and they had a higher frequency of previous symptoms (described before) although this was not significant.

In 15 patients (18.5%) clinical cerebral ischaemia was diagnosed by mental confusion, agitation, restlessness and/or contralateral upper limb motor deficit. In 11 of these patients (11/15, 73.3%) the deficit occurred at the time of the 3-min clamping test and it was reversed after shunt insertion. Overall, a shunt was needed in 12 patients (15.0%), 11 around the time of clamping when the deficit

**Table I.** Baseline preoperative characteristics of patients included in the study (n = 80)

Parameter	Shunt		Value of <i>p</i> *	
	Shunted patients (n = 12)	Non-shunted patients (n = 68)		
Age [years]	Mean $\pm$ SD	64.4 $\pm$ 7.9	66.4 $\pm$ 9.1	0.49
	Min-max	50-76	45-82	
	$\leq$ 65	8 (66.7%)	28 (41.2%)	0.11
	65-74	3 (25.0%)	25 (36.8%)	0.65
	$\geq$ 75	1 (8.3%)	15 (22.1%)	0.48
Gender	Male	11 (91.7%)	60 (88.2%)	0.88
	Female	1 (8.3%)	8 (11.8%)	
ASA	II	0 (0.0%)	8 (11.9%)	
	III	9 (75.0%)	49 (73.1%)	0.80
	IV	3 (25.0%)	10 (14.9%)	0.64
Surgical carotid	Left	8 (66.7%)	37 (56.1%)	0.49
	Right	4 (33.3%)	29 (43.9%)	
Degree of stenosis [%]	Mean	84.0 $\pm$ 10.1	85.4 $\pm$ 8.5	0.60
	70-90%	5 (41.7%)	33 (50.0%)	0.51
	> 90%	7 (58.3%)	33 (50.0%)	0.59
Contralateral stenosis [%]	Mean	66.7 $\pm$ 33.7	31.3 $\pm$ 33.1	0.04*
	$\leq$ 50%	2 (16.7%)	38 (55.9%)	0.01*
	50-70%	5 (41.7%)	19 (27.9%)	0.54
	$\geq$ 70%	5 (41.7%)	11 (16.2%)	0.10
With previous symptoms: 62/80 (77.5%)				
	TIA	1 (8.3%)	22 (32.4%)	0.18
	CVA	9 (75.0%)	32 (47.1%)	0.07
Asymptomatics: 18/80 (22.5%)				
HBP	56 (70.0%)	10 (83.3%)	46 (68.9%)	0.51
Controlled HBP	9 (75.0%)	39 (84.8%)		0.64
BP at admission	Mean $\pm$ SD			
	Min-max			
	Systolic BP	142.2 $\pm$ 18.4	141.2 $\pm$ 15.9	0.85
		130-180	100-170	
	Diastolic BP	74.5 $\pm$ 7.8	75.3 $\pm$ 11.2	0.82
	80-55	90-50		
IHD	4 (33.3%)	13 (21.0%)		0.55
AMI treatment	3 (75.0%)	9 (69.2%)		0.95
IHD progression in years	Mean $\pm$ SD	6.9 $\pm$ 3.1	4.6 $\pm$ 5.0	0.15
	Min-max	4-13	1-18	
Non-ischaeamic heart disease	0	6 (9.0%)		
Peripheral artery disease	6/12 (50.0%)	30/68 (44.1%)		0.71

Table I. cont.

Parameter	Shunt		Value of $p^*$
	Shunted patients ( $n = 12$ )	Non-shunted patients ( $n = 68$ )	
Antiplatelet drugs 62/80 (77.5%)	11 (91.7%)	51 (75.0%)	0.81
Aspirin	3 (25.0%)	17 (25.4%)	0.72
Clopidogrel	4 (33.0%)	24 (35.8%)	1
Aspirin + clopidogrel	4 (33.0%)	8 (11.9%)	0.14
Acenocoumarol	0	2 (3.0%)	
Renal disease	0	9 (13.4%)	
Dyslipidaemia 56 (70.0%)	11 (91.7%)	45 (67.2%)	0.18
Statin therapy 43/56 (76.8%)	9 (81.8%)	34 (75.6%)	0.72
Smoking habit	11 (91.6%)	53 (80.3%)	0.62
NIDDM/IDDM 15(18.8%)/10 (12.5%)	1 (8.3%)/1 (8.3%)	14 (20.9%)/9 (13.4%)	0.55/1

Data are mean  $\pm$  standard deviation (SD) or number (%) and minimum and maximum (min-max). TIA – transient ischaemic accident, CVA – cerebral vascular accident, HBP – high blood pressure, BP – blood pressure, IHD – ischaemic heart disease, AMI – acute myocardial infarction, NIDDM – non-insulin-dependent diabetes mellitus, IDDM – insulin-dependent diabetes mellitus  
\* $p$  value < 0.05,  $\chi^2$  and analysis of variance (ANOVA) tests

appeared. In just 1 patient (1/15, 6.6%) the deficit occurred before clamping with restlessness and agitation [19] and anaesthesia was switched over to general prior to insertion of the shunt. The other three patients (3/15, 20%) presented neurological deficits after the clamping period. None of these shunted patients reported permanent neurological deficits on discharge from hospital.

Table II shows perioperative data and postoperative complications stratified according to whether or not patients had a shunt placed. There were no statistical differences between patients. Regarding neurological complications, two (2.5%) of the non-shunted patients had CVAs after surgery while 1 patient suffered permanent deficit due to surgical carotid occlusion. Two non-shunted patients died 30 days after surgery: one from an intracranial haemorrhage, in the context of a hyperaemic response, and one from a ruptured aneurysm, while another non-shunted patient suffered from angina pectoris in the postoperative period. Eighteen patients (22.5%) suffered from other complications including cervical haematoma and cranial nerve paralysis, with no significant differences. In none of these patients was discharge delayed.

In Table III, the RRs of shunted patients are shown, with respect to non-shunted patients. We observed that contralateral stenosis  $\geq 50\%$  (RR: 1.3; 95% CI: 1.0-1.5) and previous symptoms of CVA (RR: 1.2; 95% CI: 1.0-1.4) were associated with shunt insertion. With contralateral stenosis  $\geq 50\%$  and previous symptoms of CVA combined, the RR increased to 7.7 (95% CI: 1.0-14.4). The calculated relative

excess risk due to interaction of contralateral stenosis  $\geq 50\%$  and previous symptoms of CVA was 6.2.

## Discussion

The main finding of this study was the interaction existing in patients with contralateral stenosis  $\geq 50\%$  associated with previous CVA, which has not been previously reported. These patients have a seven-fold greater tendency to require shunt insertion in patients under regional anaesthesia. Impaired ischaemic tolerance after previous strokes has already been observed [7, 12-14]. In the present study there was also a higher shunt frequency in patients who had suffered a prior stroke (83.3% vs. 76.6%), but this difference did not reach statistical significance, probably due to the small sample size. The shunt incidence in the group with a contralateral ICA  $\geq 50\%$  was 83.4% vs. 43%. Shunted patients had a poorer health status than non-shunted patients in terms of pre-, intra- and postoperative parameters. It is likely that shunted patients did not have sufficient collateral cerebral circulation or that they had more cerebral areas at risk of ischaemia from changes in functional metabolism [12, 21], so were more sensitive to any kind of cerebral hypoperfusion. The reported results could support the view that the presence of unilateral, asymptomatic carotid stenosis is not associated with an increased risk of stroke following cardiac surgery if prophylactic CEA is not performed [22].

If we had followed the recommendation that carotid surgery can be performed safely without a shunt in patients with contralateral stenosis  $\leq 50\%$  and without previous ACV, we would have

**Table II.** Perioperative data and postoperative complications

Parameter	Shunt		Value of <i>p</i> *	
	Shunted patients ( <i>n</i> = 12)	Non-shunted patients ( <i>n</i> = 68)		
Duration of surgery [min]	Mean ±SD	126.4 ±39.8	108.3 ±21.9	0.24
	Min-max	75-210	65-185	
Duration of clamping [min]	Mean ±SD	50.8 ±15.6	43.9 ±16.5	0.18
	Min-max	30-70	17-110	
ICU [days]	Mean ±SD	1.2 ±0.7	1.3 ±0.7	0.86
	Min-max	1-3	1-4	
Hospital stay	Mean ±SD	3.7 ±2.1	3.6 ±1.1	0.95
	Min-max	2-9	3-8	
Complications				
No complications		9 (75.0%)	48 (70.6%)	0.98
With complications		3 (25.0%)	20 (29.4%)	0.88
	Neurological	0	2 (2.9%)	
	Postoperative AMI	0	1 (1.5%)	
	30 day death	0	2 (2.9%)	
Other complications		3 (25.0%)	15 (22.1%)	0.88
Postoperative BP Mean ±SD				
Systolic BP	1 h	144.7 ±29.8	133.94 ±27.2	0.21
	6 h	136.2 ±28.8	133.2 ±27.1	0.73
	12 h	140.3 ±22.0	127.4 ±21.9	0.06
	18 h	148.1 ±19.3	135.7 ±21.9	0.07
	24 h	151.1 ±19.3	138.1 ±24.3	0.08
Diastolic BP	1 h	66.1 ±14.5	62.9 ±14.1	0.47
	6 h	62.2 ±14.9	60.3 ±14.2	0.67
	12 h	62.5 ±11.3	57.7 ±12.4	0.22
	18 h	65.6 ±10.3	60.6 ±12.6	0.20
	24 h	70.6 ±7.6	68.0 ±14.7	0.35
Intraoperative antihypertensive drugs		9/12 (75.0%)	38/68 (55.9%)	0.46
Postoperative antihypertensive drugs		6/11 (54.5%)	21/68 (30.9%)	0.13

Data are mean ± standard deviation (SD); BP – blood pressure, ICU – intensive care unit

put three patients at risk of developing major neurological deficits. Overall contralateral stenosis ≥ 50% and previous ACV wrongly predicted the requirement for a shunt in 36.8% (25/68), roughly a third of the patients. We found this a poor predictor relation with the awake neurological test.

Contrary to other reports where previous neurological symptomatology and/or intraoperative shunting were identified risk factors for increased complications [23], in our study there was not an increase of complications for patients with signifi-

cant preoperative variables (contralateral stenosis ≥ 50% and previous symptoms of CVA) or intraoperative shunt insertion and postoperative high blood pressures were not significant. Recent reviews have highlighted the importance of optimal medical therapy with antiplatelet drugs and statins [24, 25]. Statins are effective in reducing both first-ever and recurrent stroke [26] and antiplatelet drugs are also very effective to avoid the platelet hyperaggregation state in CEA [27]. Statin effects may improve collateral blood flow, enhance cerebral

**Table III.** Different models of relative risk for shunt use adjusted for previously identified patient characteristics

Patient characteristics	Shunt Relative risk (95% CI)
Contralateral stenosis $\geq$ 50.0%	1.3 (1.0-1.5)*
Previous symptoms CVA _ TIA	0.9 (0.8-1.2)
Previous symptoms CVA	1.2 (1.0-1.4)*
Contralateral stenosis $\geq$ 50.0% and previous symptoms CVA _ TIA	5.9 (0.8-43.5)
Contralateral stenosis $\geq$ 50.0% and previous symptoms CVA	7.7 (1.0-14.4)*

CI – confidence interval, TIA – transient ischaemic accident, CVA – cerebral vascular accident; \*significant interval, Wald test,  $p < 0.05$

vasodilation during periods of compromised flow, and prevent carotid thrombosis and embolism in the perioperative period. Both antiplatelet drugs and statins were used in 91.75% of shunted patients and 75-67.2% respectively of the non-shunted patients. The use of shunt and optimal medical preventative therapies should be complementary: shunt insertion would be usefully supported by antiplatelet therapy, to avoid associated thromboembolic complications, while the shunt would help to prevent stroke by hypoperfusion.

Selective shunting has been related to postoperative cognitive dysfunction [4]. Better cognitive outcomes have been observed following CEA under regional anaesthesia [28] and, in addition, cardiac and pulmonary morbidity associated with general anaesthesia can be avoided. While this approach involves more stress for the medical professionals involved, it seems to offer significant benefits to patients. The GALA study [29] compared general versus regional anaesthesia in 3526 patients. In relation to major complications of stroke, AMI or death, there was no evidence for deciding whether to use general or regional anaesthesia. However, regional anaesthesia did decrease shunt insertion (14% vs. 43%,  $p < 0.001$ ). The need to increase blood pressure was more common under general anaesthesia, while it was more often necessary to decrease blood pressure when regional anaesthesia was used. In other research, higher levels of postoperative hypertension have been attributed to pharmacological or surgical carotid sinus denervation [30]. Our patients also mainly needed anti-hypertensive drugs and this was most common in shunted patients in the intraoperative and in the postoperative period, especially 12 h post surgery (Table II). Hypertension is the most important risk factor for stroke [31] and reperfusion syndrome; for this reason it is advisable to monitor these shunted patients in the ICU during the immediate postoperative period. In the GALA study, rates of reversible cranial nerve lesions, haematoma and reintervention did not differ between the types of anaesthesia, in spite of the lower rates of shunt use in regional anaesthesia. In our study, there were

more of these complications in shunted patients, which we attributed to the arterial surgical manipulation, but the difference was not significant.

The limitations of this study are that a relatively low percentage of patients were shunted and had serious complications, and that the sample size is not sufficiently large to draw strong conclusions. However, this study has a high level of internal validity and homogeneity because it was carried out under a strict protocol and by the same team, preventing treatment protocol bias, which is not the case in other studies involving hundreds of patients from different hospitals and under different protocols.

Our findings suggest that patients with contralateral occlusion  $\geq$  50% and with previous CVA present greater risks of shunt use during CEA than patients with these risk factors separately. The combination of both contralateral occlusion  $\geq$  50% and previous CVA become synergic and strengthen the risk of shunt insertion.

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