Monitoring Balloon Test Occlusion of the Internal Carotid Artery with Transcranial Doppler

A Case Report and Literature Review

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SUMMARY – *Angiographic balloon test occlusion (BTO) allows preoperative risk evaluation of patients undergoing permanent therapeutic occlusion of the internal carotid artery (ICA). The sensitivity of the BTO can be increased using different complementary techniques. Transcranial Doppler (TCD) stands out as a non-invasive, bedside method providing real-time monitoring of cerebral haemodynamics, therefore accurately identifying patients at risk of stroke. A case of a 30-year-old woman with a giant intracavernous aneurysm of the left ICA presenting with subacute left VI nerve palsy is described. A pre-operative TCD- and EEG-monitored BTO of the left ICA was performed. The 16.7% drop found in the middle cerebral artery's peak systolic velocity (PSV_{MCA}) predicts clinical and haemodynamic tolerance to the permanent loss of that vessel. This case illustrates the potential of TCD monitoring during temporary BTO of the ICA. It highlights its ability to provide a complete preclinical evaluation of collateralization and autoregulatory adaptation to unilateral ICA occlusion. TCD may also decrease the time of occlusion required for the BTO.*

Introduction

Balloon test occlusion (BTO) is a pre-operative angiographic test used to estimate the risk of stroke after permanent therapeutic occlusion of an internal carotid artery (ICA) involved by neck or skull base tumours and inoperable fistulae or aneurysms [1-3]. BTO decreases the risk of post-operative ischaemic stroke from up to 30% in unselected patients [1] to less than 13% in patients passing this test [4,5]. Stroke after ICA occlusion can occur by two mechanisms: haemodynamic compromise (predictable by BTO), or thromboembolization after vessel ligation [6].

BTO was first described in the early 1970s [7], and initially only symptomatic patients or those developing neurological deficits during the test were considered at risk of haemodynamic infarction, and therefore candidates for extracranial-intracranial bypass revascularization [6,8,9].

Since clinical monitoring alone has a low sensitivity, different complementary techniques have been used to increase prediction accuracy [1,10-16]. Among these, transcranial Doppler (TCD) stands out as a non-invasive bedside method providing real-time monitoring of cerebral haemodynamics that can accurately identify patients at risk of delayed ischaemic sequelae [2,17-19].

Despite the advantages of TCD and the absence of a universally accepted method to monitor the BTO, its potential is not yet widely recognized.

Case Report

A 30-year-old Caucasian woman presenting with subacute left VI nerve palsy is described. The patient had no relevant medical history and no previous episode of diplopia. The CT scan (Figure 1A) showed a large enhancing mass le-

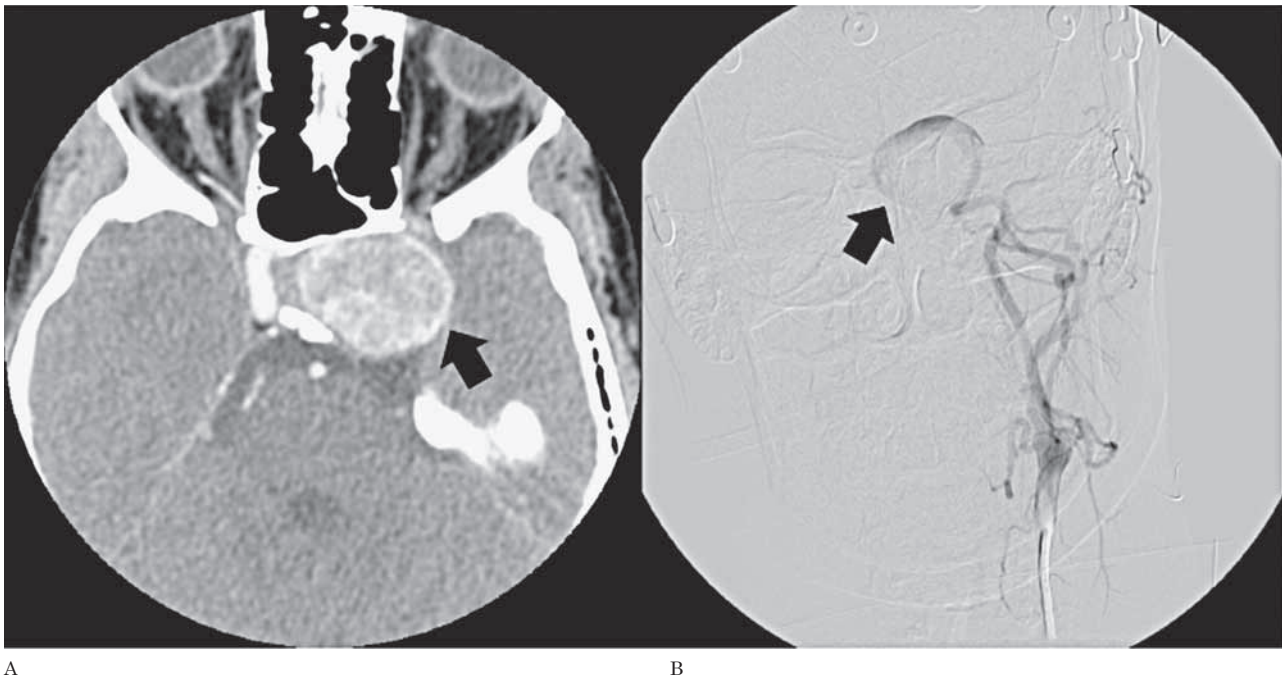A   B

Figure 1 Giant aneurysm of the left internal carotid artery, involving its intracavernous segment (arrows). A) Contrast-enhanced CT. B) Digital subtraction angiography.
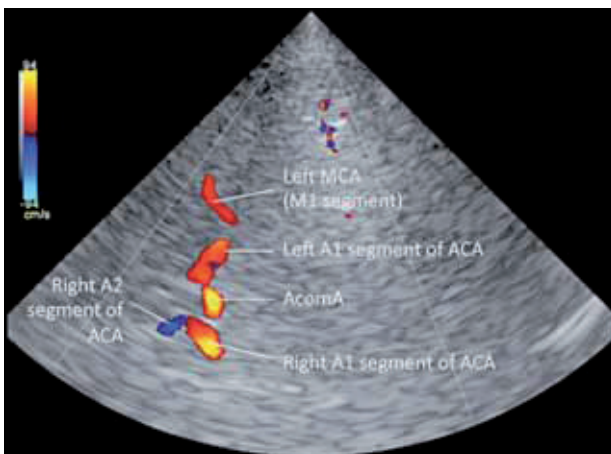

Figure 2 TCD evaluation during ICA occlusion shows collateralization through the anterior communicating artery (AcomA). Note the absence of a posterior communicating artery contribution. ACA - anterior cerebral artery; MCA - middle cerebral artery.

sion inside the left cavernous sinus, in close relation to the ICA. Diagnostic digital subtraction angiography (DSA) (Figure 1B) established the definite diagnosis of a giant intra-cavernous aneurysm of the left ICA. As a potential candidate for surgical therapeutic occlusion of the diseased vessel, the patient was referred to the interventional neuroradiology department for risk assessment. A pre-operative TCD- and EEG-monitored BTO of the left ICA was performed.

Baseline transcranial color-coded Doppler (TCCD) evaluation revealed blood flow inside the aneurysm (confirming it was not excluded

from the circulation), an anterograde left ophthalmic artery and an otherwise normal intracranial arterial and venous circulation. A 6F ENVOY® Guiding Catheter (DePuy Orthopaedics Inc., Raynham, MA, USA) was used to position a 4×20 mm HyperGlide™ Occlusion Balloon System (ev3 Endovascular Inc., Plymouth, MN, USA) just below the aneurysmal segment of the left ICA. Upon balloon inflation, adequate vessel occlusion was angiographically and sonographically documented. During the occlusive period (a total of 30 min), TCCD revealed collateralization through the anterior
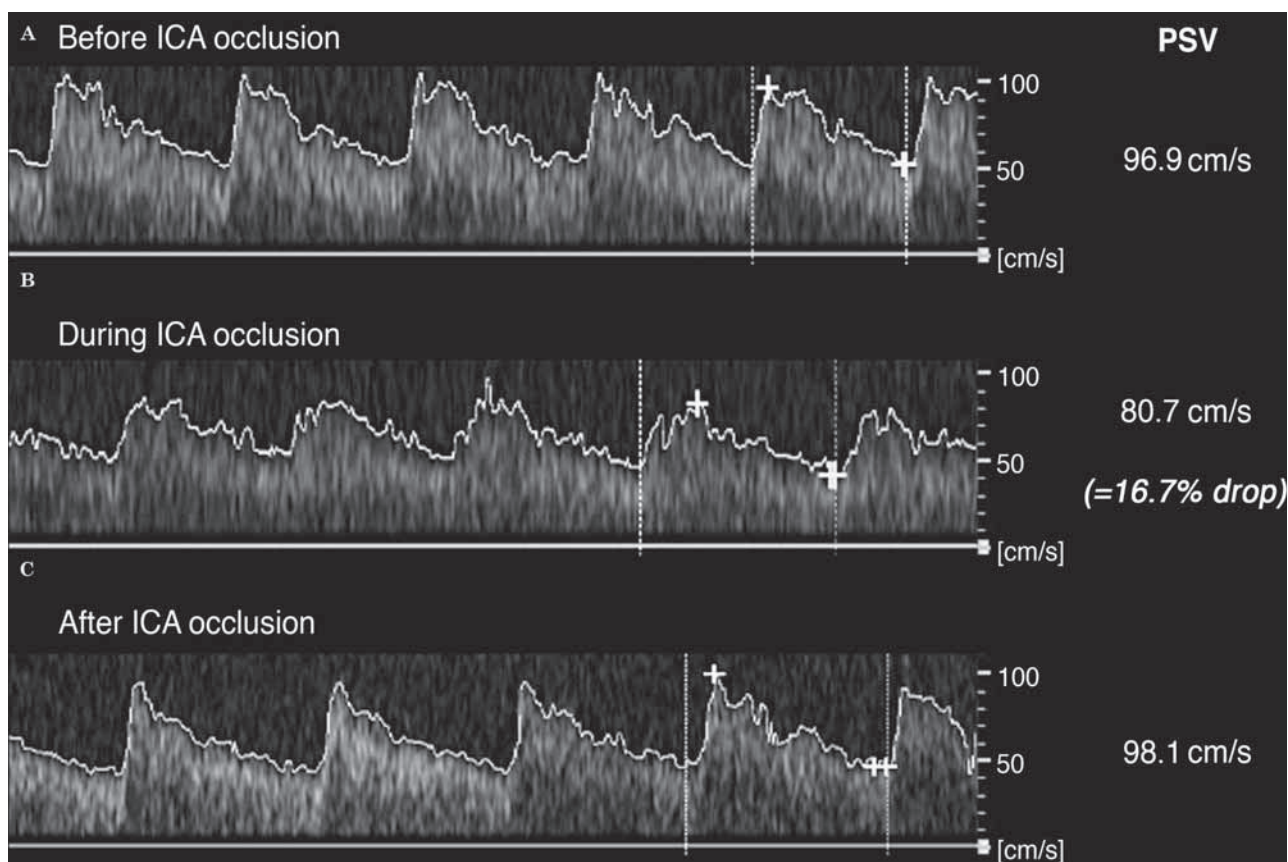
Figure 3 Angle corrected left middle cerebral artery flow variation registered by transcranial Doppler during the procedure. A) Before left ICA occlusion. B) During ICA occlusion. C) After balloon deflation. Note the documented 16.7% decrease of the peak systolic velocity of the middle cerebral artery (PSV), inferior to the 30% threshold.

Figure 4 Events following occlusion of a major cerebral artery, according to the decrease in brain tissue perfusion. Note how haemodynamic disturbances are immediate and can be detected with transcranial Doppler.
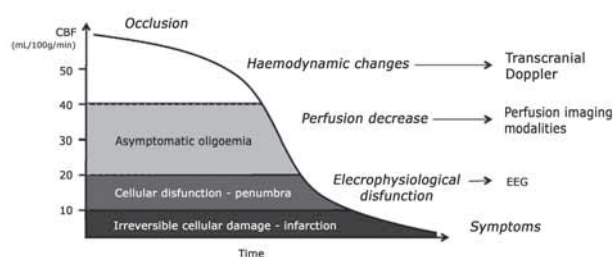
communicating artery (but not through the ophthalmic artery or the posterior communicating artery), maintaining adequate blood flow to the left middle cerebral artery (MCA) (Figure 2).

The baseline left MCA's peak systolic velocity (PSV_{MCA}) measured by TCD was 96.9 cm/s, dropping to a minimum of 80.7 cm/s during the occlusion of the ICA, and quickly returning to 91.8 cm/s after balloon deflation (Figure 3). The patient remained asymptomatic throughout the BTO, and no electroencephalographic changes were recorded. The 16.7% drop in the PSV_{MCA} documented predicts clinical and haemodynamic tolerance to the permanent loss of that vessel. To date, the patient is waiting for neurosurgical intervention.

Discussion

Transcranial Doppler ultrasound (TCD) is an accurate and widely used complementary examination for neurovascular study [20,21]. It has been validated for monitoring endovascular carotid balloon occlusion tests for almost 20 years

[22] with good results [2,17,19]. TCD is characterized by favourable logistics [19], is able to show early events in the ischaemic cascade (Figure 4), allowing the diagnosis of haemodynamic intolerance prior to symptomatic manifestations, and to provide real-time evaluation of the entire intracranial circulation [23]. It is also an excellent technique for follow-up [2]. Its main limitation is the inadequate temporal bone acoustic window in some patients, which renders TCD impossible to perform [24].

The published series report a decrease in $PSV_{MCA} < 30\%$ relative to baseline during the occlusive period as a consistent predictive value of clinical tolerance [2,17-19], with no false negatives. The PSV_{MCA} is considered an estimate of regional blood flow [25], specifically during the first seconds after balloon inflation, while MCA diameter and territory are constant and before cerebral autoregulation takes place [2,25,26]. A PSV_{MCA} reduction > 40% is thought to correspond to a tissue perfusion of approximately 30 ml/100 g/min, a threshold to symptom occurrence in quantitative CBF studies [4,16,19]. To date, no patients with predicted tolerance to ICA occlusion by TCD-monitored BTO (PSV_{MCA} drop < 30%) have suffered haemodynamic infarction after definite occlusion [2,17-19,27]. However, the risk of thromboembolism after arterial occlusion warrants antithrombotic prophylaxis [6]. Some authors also advocate the use of minimal occlusion times by implementing TCD monitoring [2,18] with the BTO. Since the haemodynamic response to ICA occlusion is immediate and can be evaluated by TCD, the classic extended occlusion times required for clinical symptoms to develop may no longer be necessary. In fact, Sorteberg et al. [18] reported 86% sensitivity and 93% specificity (positive predictive value of 86%) of TCD analysis of the first seconds after carotid occlusion. With shorter occlusion times, procedure safety and patient comfort could be improved [2].

The present case illustrates how TCD is able to document the major mechanisms of adaptation and clinical tolerance to ICA occlusion: collateralization and cerebral vascular autoregulation [17]. In our case, TCD also demonstrated the anterograde blood flow in the ophthalmic artery that no other complementary method was able to verify, as well as confirming the intra-aneurysmal blood flow shown by DSA. Together with the baseline evaluation of the intracranial circulation, and the direct visualization of collateralization during the procedure, these data improved risk stratification.

TCD is a convenient reliable method to monitor angiographic BTO of the ICA. Its use increases the procedure's sensitivity, allowing a preclinical diagnosis of haemodynamic intolerance and therefore shorter occlusion times.

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