Case Report

A Transcranial Doppler Ultrasonography Finding During Carotid Endarterectomy Produced by Postoperative Carotid Plaque Acting as a One Way Ball Valve in the Internal Carotid Artery

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Abstract

The patient was a 71 year old male with asymptomatic left internal carotid artery stenosis > 95% who underwent carotid endarterectomy with transcranial Doppler ultrasonography and electroencephalography for neuro monitoring. The surgical course was complicated by postoperative carotid occlusion caused by a carotid plaque located distal to the operative site that acted as a one way ball valve. This allowed for retrograde flow through the internal carotid artery as demonstrated in the surgical field with back bleeding. The plaque did not allow for anterograde flow from the internal carotid artery to Circle of Willis, but this could not be evaluated prior to surgical closure. Upon initially unclamping the internal carotid artery, transcranial Doppler ultrasonography velocities remained low and did not return to baseline values. The patient emerged with postoperative right-sided hemiplegia and aphasia requiring immediate repeat carotid surgery. The plaque located distal to the operative site was removed and transcranial Doppler ultrasonography velocities exceeded baseline values, demonstrating restoration of anterograde blood flow in the internal carotid artery. The patient emerged this time neurologically intact at his baseline. This case demonstrates the role of Transcranial Doppler Ultrasonography in carotid endarterectomy for monitoring and eventual diagnostic and treatment decision.

ABBREVIATIONS

TCD: Transcranial Doppler Ultrasonography; CBF: Cerebral Blood Flow; ICA: Internal Carotid Artery; MCA: Middle Cerebral Artery; EEG: Electroencephalography; SV: Systolic CBF Velocity; MV: Mean CBF Velocity

INTRODUCTION

Carotid endarterectomy (CEA) is beneficial for selected patients with asymptomatic internal carotid artery stenosis of 60% or greater [1,2]. Electroencephalography (EEG), and/or transcranial Doppler ultrasonography (TCD) are used to monitor changes in cerebral blood flow (CBF) in the middle cerebral artery (MCA) during CEA. This case report presents a patient undergoing CEA monitored by TCD which immediately revealed a significant problem with CBF that required immediate reoperation due to occlusion of the internal carotid artery (ICA) by a plaque distal to the operative site that acted like a one-way ball valve permitting back flow but not forward flow. The authors aim to demonstrate the role of TCD in carotid surgery in the patient with postoperative carotid lesion.

CASE PRESENTATION

We herein present the 71 year-old man who presented to
our Department with an incidentally discovered high grade left ICA stenosis. His medical history included arterial hypertension, peripheral vascular disease, lupus erythematosus and asbestosis with a fifty pack-year smoking history. He denied a history of transient ischemic attack and was found to be intact on neurologic examination.

A preoperative CTA of the head and neck demonstrated severe left carotid artery stenosis > 95% with an ICA plaque 15-25mm distal to the carotid bifurcation (Figure 1). The right carotid artery was normal and the Circle of Willis was noted to be intact (Figure 1). Given severe asymptomatic carotid artery stenosis, the patient was brought to the operating room for a left carotid endarterectomy performed under general anesthesia.

**MONITORING**

**Electroencephalography (EEG)**

The patient was monitored intra operatively with a 16 channel XL-Tek EEG (Natus Medical Inc., San Carlos, CA, USA) with electrodes placed in a bipolar “double-banana” montage using the nomenclature of the International 10-20 electrode placement system with an Electro-Cap (Electro-Cap International Inc., Eaton, OH, USA). The skin beneath each electrode was gently abraded with the blunt end of wooden cotton tipped applicator and Electro-Gel (Electro-Cap International Inc., Eaton, OH, USA), a viscous solution of high concentration electrolytes, was injected through a hole in each electrode to make contact between the skin and tin electrodes.

**Transcranial Doppler**

A ST-3 TCD machine (Spencer Technologies, Seattle, WA, USA) was used to monitor CBF velocity. A2 MHz probe was applied over the temporal bone on the left side of his head. The MCA was insonated at an approximate depth of 50 mm from the scalp. A Marc 600 Head frame (Spencer Technologies) was used to hold the probe in place for the duration of the surgery. The TCD parameters evaluated in this study were systolic CBF velocity (SV) and mean CBF velocity (MV) measured in units of cm/sec. The velocities were calculated automatically by the ST-3 TCD monitor. Recordings of the Power-M-mode and Doppler signals (http://www.spencertechnologies.com/) were obtained continuously throughout surgery. SV and MV were recorded at baseline, prior to and during clamping of the left carotid artery, and after releasing the carotid artery clamp for the initial surgery (Figure 2A, 2B and 2C). Only SV and MV are recorded after returning to the operating room for exploration.

**Operation**

The procedure was performed with general anesthesia. Besides routine monitoring, a radial arterial catheter was placed for blood pressure monitoring. The patient was sedated with fentanyl (50 mcg) and midazolam (2 mg), induced with etomidate (20 mg), paralyzed with rocuronium (50 mg), and intubated with a 7.5 ETT. He was maintained with nitrous oxide in oxygen (70%) and sevoflurane ~1%. A phenylephrine drip was used to maintain blood pressure at the pre-operative baseline.

The left MCA was insonated at the appropriate depth of 50mm from the scalp and the Doppler ultrasound identified flow medial to lateral towards the probe (colored red, Figure 2A). The ipsilateral A1 division of the anterior cerebral artery was noted at 70mm with flow away from the probe (colored blue, Figure 2A), and the contra lateral A1 was noted at 80mm with flow towards the probe (colored red, Figure 2A), as expected under normal physiologic conditions.

A longitudinal incision was made in the common carotid artery (CCA) extending into the ICA at the level of carotid bifurcation. Prior to clamping the CCA, 7000 units of heparin (80 units/kg) was given intravenously. The activated clotting time (ACT) three minutes after heparin administration was 304 sec. The left CCA was occluded, followed by occlusion of the internal and external carotid arteries. No changes were seen on EEG. The directionality of the A1 blood flow shifted towards the probe (the color changed from blue to red, Figure 2B), demonstrating that contra lateral flow through the anterior communicating artery was at least partly supplying the left hemisphere. The systolic and mean velocities in M1 decreased from 66 cm/sec to 50 cm/sec and 43 cm/sec to 38 cm/sec respectively (Table 1, Figure 2A and 2B). These changes were consistent with an 11.6%
Figure 2. TCD was applied to the left temporal area and insonated on the middle and anterior cerebral arteries. Each screen is divided into two parts. The upper half is the Power-M-mode and the units on the left are in mm from the scalp. The values are from 30 to 80 mm. “Red” and “white” signals indicate CBF toward the 2 Hz probe, and “blue” away from the probe. MCA and ACA refer to middle cerebral and anterior cerebral arteries on the right (R) and left (L) sides. The vertical black bracket designates the depth of the MCA. Figures 2A, 2B and 2C are before, during and after carotid artery occlusion of the left carotid artery during the initial surgery. Of note, the region of the left anterior cerebral artery (L-ACA) in Figure 2A is “blue” and turns “red” in 2B and 2C indicating that flow in the A1 segment of the ipsilateral has reversed direction. The “yellow” line in all three figures is the depth at which the Doppler trace in the lower half of the three figures is recorded. The lower half is the Doppler trace. The units along the left of each trace are cm/sec. The range is from 100 to -20 cm/sec. Time is along the bottom. Each screen is 3 seconds.

<table>
<thead>
<tr>
<th>Table 1: Transcranial Doppler Recorded Systolic and Mean Velocities.</th>
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<tr>
<td>Peak CBF Velocity (cm/sec)</td>
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Abbreviations: CBF: Cerebral Blood Flow

A highly stenotic atherosclerotic plaque with soft thrombus in the arterial wall was identified in the ICA distal to the common carotid bifurcation by 15 to 25mm, as noted on preoperative imaging. After the plaque was removed, the arteriotomy was sutured closed without a patch. The internal, external and common carotid arteries were “back bled” by the surgeons demonstrating patency of the formerly stenotic carotid artery. Specifically, it was noted that there was excellent back flow from the left ICA. At this point the TCD velocity and directionality remained stable, approximately 10% below baseline (Table 1). A hand-held ultrasound Doppler in the field confirmed distal flow in the ICA. Total occlusion time was 34 minutes. After the carotid artery was unclamped, it was noted that neither SV (48 cm/s) nor MV (37 cm/s) returned to preclamp values (SV 66 cm/s, MV 43 cm/s) (Figure 1C).

Postoperative course

The patient was given reversal for muscle relaxants. Upon extubation, he was hemiplegic on the right and not following commands. He was reintubated for airway protection and emergent postoperative CTA demonstrated a left ICA occlusion distal to the operative site (Figure 1C). He was brought back for emergency operative exploration and plaque removal. At this second operation, TCDs demonstrated MCA velocity and cerebrovascular dynamics consistent with the SV and MV values after the CCA was first cross-clamped. Upon re-exploration, there was again robust back bleeding but a small, calcified piece of plaque was identified in the distal ICA that acted like a ball-valve to permit retrograde flow but occlude anterograde flow. Upon removal of the plaque and removal of clamps, the TCD velocity and directionality improved to 16.3% over the pre-cross-clamp value. The SV and MV velocities increased from 49 cm/sec and 31 cm/sec to 76 cm/sec and 50 cm/sec, respectively. This indicated restored flow and normal cerebrovascular dynamics, as well as increased cerebral blood flow. The patient awoke from surgical exploration neurologically intact.

DISCUSSION

With an incidence as high as 5%, perioperative carotid stroke is a major complication of carotid endarterectomy. Most often, they occur as a result of thrombus embolization after flow has been restored and are detected clinically postop
when neurologic changes occur. CT imaging then confirms the diagnosis. While this is current practice at most institutions, a more ideal approach would identify potential lesions prior to clinical presentation. A study by Gallati et al. aimed to identify pathological versus expected postoperative changes seen on CT angiography (CTA) performed 24 hours of CEA and found that intraluminal thrombi were more often seen in patients undergoing CTA for new postoperative stroke or TIA after CEA [3]. The most common reason for thrombus formation is bleeding from the vasa vasorum at the endarterectomy site. In such situations, angioscopy has proven a useful tool to identify such thrombi prior to surgical closure so that removal of the thrombus can be done [4]. While angioscopy is a useful adjunct to identify thrombus and CT imaging aids in diagnosing strokes, TCD can aid in identifying such lesions particularly at institutions that already use TCD routinely during CEA. At the Author’s institution, CEA is routinely performed with TCD and EEG. Since the events in this case report, low flows on TCD has identified another patient with intraoperative intraluminal thrombus. The surgeons were able to perform immediate surgical site exploration at the time of CEA and the patient was spared a wake up test with CT imaging and delay of appropriate care was avoided.

This case demonstrates another role for TCD, namely to determine that CBF to the brain returns to normal after surgery. In retrospect, the failure to return to previous values after the carotid artery was unclamped should have immediately indicated a problem despite excellent back bleeding.

TCD is used intra operatively during CEA to assess for cerebral hypo perfusion during carotid clamping, monitor for micro emboli, and to predict the likelihood of cerebral hyper perfusion syndrome [5]. Most frequently, TCD is used to identify cerebral hypo perfusion after carotid clamping and to guide intraoperative decision-making for shunt placement. However, the major limitation of intraoperative TCD is that a temporal window is not possible in 15-20% of patients [6]. In this particular case, cerebral blood flow dynamics measured by TCD clarified an unusual complication of residual plaque permitting back bleeding but occluding forward flow.

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REFERENCES