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Case Report

Electroretinography during embolization of an ophthalmic arteriovenous fistula

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Received: 04 February 13 Accepted: 28 February 13 Published: 28 March 13

This article may be cited as:
Padalino DJ, Melnyk V, Allott G, Deshaies EM. Electroretinography during embolization of an ophthalmic arteriovenous fistula. Surg Neurol Int 2013;4:40.
Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2013/4/1/40/109653

Abstract

Background: Intraoperative neuromonitoring (IONM) is used for real-time evaluation of neuronal tracts and reflexes in the anesthetized patient, when a neurologic exam is not possible. Changes in IONM signals forewarn of possible neurological deficit. This real-time feedback allows for immediate alterations in therapeutic technique by the treating physician. Transcranial visual evoked potentials are not reliable for evaluating the integrity of the prechiasmatic visual system. Electroretinography (ERG) has been used in animal models for monitoring retinal ischemia and can be used in humans as well to monitor for prechiasmatic ischemia of the retinae and optic nerves.

Case Description: We present a case where ERG signal amplitude and latency changed during ophthalmic arteriovenous fistula embolization, resulting in an intraprocedural decision to refrain from embolization of additional arterial pedicles to preserve vision. After awakening from general anesthesia, the patient had no deficits in visual acuity or field testing, but did complain of transient pain with eye movement that resolved the next day and worsened with episodes of blood pressure elevation.

Conclusions: ERG may be helpful for detecting prechiasmatic ischemic changes during endovascular procedures and may provide early warning signs to the surgeon before the onset of permanent retinal damage. Further investigation is needed to assess the utility of ERG monitoring during the treatment of orbital and periorbital vascular lesions.

Key Words: Arteriovenous, electroretinography, embolization, fistula, malformation, neurophysiology

Access this article online
Website: www.surgicalneurologyint.com
DOI: 10.4103/2152-7806.109653
Quick Response Code:

INTRODUCTION

Arteriovenous malformations (AVMs) and arteriovenous fistulas (AVFs) are high pressure, high flow, arterio-venous shunts without an intervening capillary network. The abnormal hemodynamic forces within the vascular malformation can lead to hemorrhage from high intravascular pressures, ischemia from a vascular steal phenomenon, and neurological deterioration from venous congestion. A large AVM natural history study demonstrated that there is a 4% annual risk of hemorrhage from these lesions and treatment, when possible, is recommended.[10]

Treatment options for orbital AVFs include open surgical occlusion and endovascular embolization. When embolization is required, we prefer to use vinyl ethyl alcohol (Onyx, ev3/Covidien, Irvine, CA), a nonadhesive liquid embolic agent, for endovascular embolization of vascular malformations. Selected patients who are unable to tolerate endovascular therapy with conscious sedation are placed under general anesthesia with neuromonitoring. Immediately prior to vessel embolization, the specific artery is injected with methohexital sodium (Brevital) and neuromonitoring signals are watched closely for changes that would suggest it is not safe to embolize that pedicle.

The use of intraoperative neuromonitoring (IONM) has been shown to be useful for improving outcomes in neurosurgical procedures such as aneurysm clipping and spinal surgery, but transcranial visual evoked potentials (VEPs) as a means of predicting visual deficits has not been as successful.[5,11,12,16] This is largely due to the complex, bilaterally innervated, pathways of the visual fiber tracts traveling from the retina to the visual cortex. Electroretinography (ERG) detects early acute retinal ischemia in animal models and improvement in human ERG signals correlated with better visual function.[1,4,6,7]

CASE REPORT

A 17-year-old right handed male initially presented to his primary care physician with a 4-year history of a growing pulsatile midline scalp mass just behind the hairline. Initially suspected to be a cyst, it was biopsied resulting in significant bleeding. Subsequently, computed tomography angiography demonstrated a vascular scalp lesion and he was referred to the senior author. Digital subtraction angiography (DSA) showed a dural AVF supplied by bilateral superficial temporal, ophthalmic, and the right middle meningeal arteries. The AVF drained via the facial vein into the internal jugular vein. The pulsatile lesion was aesthetically displeasing to the patient and painful with palpation. After discussing the various treatment options including observation alone, it was decided that the AVF would be treated with transarterial embolization.

At the time of treatment, general anesthesia was standard care at our institution for AVF embolization. Using total intravenous anesthesia (TIVA, 150 mcg/ml/min propofol) with IONM, we monitored motor evoked potentials (MEPs), somatosenory evoked potentials (SSEPs), electroencephalography (EEG), auditory brainstem response (ABR), VEPs, and ERG signals. Monitoring was done to evaluate for all potential neurophysiologic changes both locally and distant from the site of the procedure due to blood flow changes during embolization. ERG electrodes were placed above the eye and responses were monitored after independent light emitting diode flash stimulation. Baseline ERG recording to flash stimulation yielded a polyphasic response with a 25.8 ms latency and an amplitude of 14 µV [Figure 1]. VEPs were also recorded concurrently with electrodes CZ, OZ, O1, and O2, for comparison. After baseline signals were acquired, the right femoral artery was accessed sterilely. A standard micropuncture access kit, 6F sheath, and 6F MPC Envoy were used to catheterize the left internal carotid artery. Cerebral DSA was performed [Figure 2a-c] and then a Marathon microcatheter (eV3/Covidien, Irvine, CA) and Mirage 0.008″ microwire (eV3/Covidien, Irvine, CA) were used to selectively catheterize the left ophthalmic artery and superselective DSA was performed to confirm the position of the microcatheter tip within the arterial pedicle of the AVF. DSA showed no retinal blush confirming positioning of the microcatheter distal to the branching point of the central retinal artery from the ophthalmic artery. A total of 3 mg of methohexital sodium (Brevital) was injected into the AVF pedicle without changes in IONM signals. Subsequently, Onyx 18 (ev3/Covidien, Irvine, CA) was used to embolize the arterial pedicle without changes in IONM. However, 10 min later, as the second left ophthalmic pedicle was about to be accessed for potential embolization, we noted a significant change in ERG (10 ms increase in latency and 30% decrease in amplitude) compared with baseline and signals on the right [Figure 1].

Postembolization DSA showed a more prominent retinal blush suggesting increased flow through the central retinal artery [Figure 2d-f]. With no additional manipulations, the change in ERG signal subsequently returned to baseline within several minutes when blood pressure was decreased from a baseline systolic of approximately 90. A decision was made to stop the procedure after single pedicle occlusion due to a concern for possible retinal hyperemia and damage that may result in retinal damage if we performed additional embolizations. After awakening from general anesthesia, the patient had no deficits in visual acuity or field testing, but did complain of transient pain with eye movement that resolved the

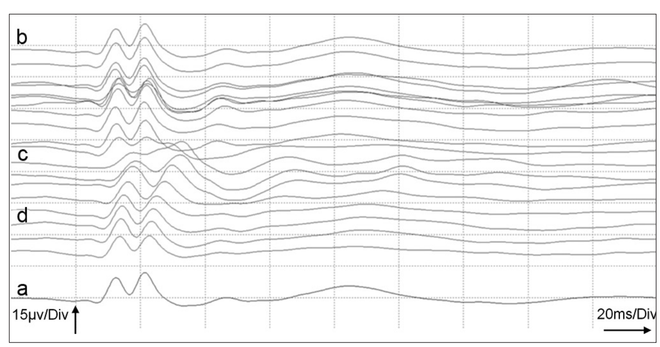

Figure 1: Electroretinogram (ERG) signals showing the baseline signal response (a) Early procedural preembolization ERG signals, (b) Flattening amplitude by about 30% and increased latency by about 10 ms at about 10 min postembolization, (c) Spontaneous return of the normal baseline ERG signal, (d) By the end of the case

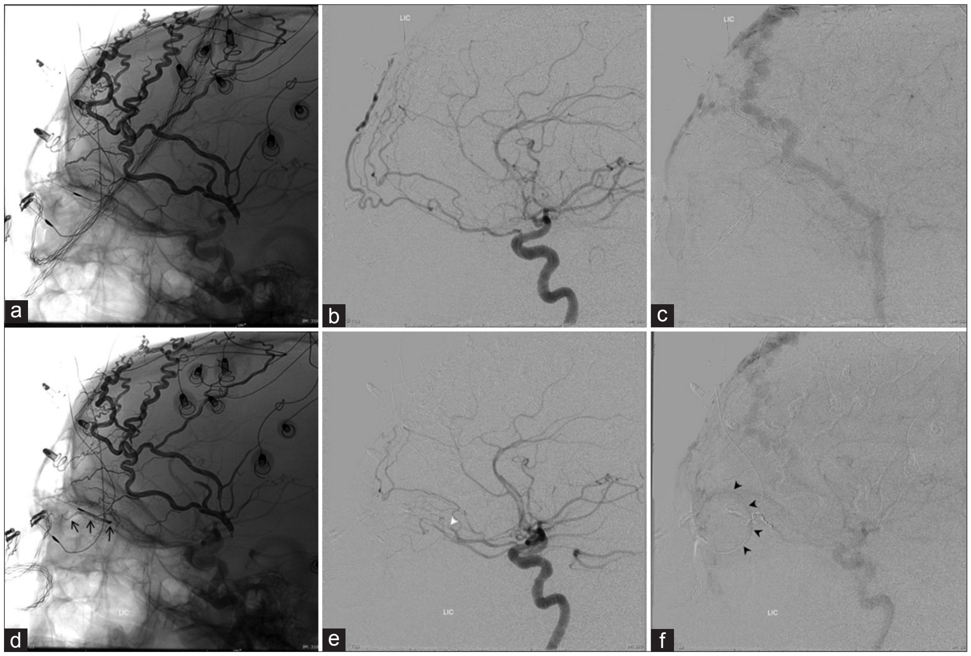

Figure 2: Lateral views preembolization (a, b, c) and postembolization (d, e, f) of a left ophthalmic artery branch to the AVF nidus. The native view postembolization, (d) shows the Onyx glue cast (black arrows). The arterial phase DSA postembolization, (e) shows the vessel cutoff at the proximal end of the Onyx glue cast in the AVF arterial feeding branch (white arrow-head), compared with the filling of this branch seen preembolization, (b) The capillary phase DSA postembolization, (f) shows the enhanced contrast seen filling the left retina (black arrow-heads) compared with preembolization (c)

next day and worsened with episodes of blood pressure elevation.

The treatment was staged to minimize large acute hemodynamic changes in the retina that potentially could cause retinal damage. Staged embolization resulted in angiographic cure of the lesion without complication.

DISCUSSION

Monitoring of the prechiasmatic visual pathways in anesthetized patients undergoing surgical and endovascular procedures, presents a particular challenge to the monitoring team. Transcranial VEP is unreliable for monitoring these visual pathways and is associated with poor reproducibility and clinical correlation.[2,3,13,15] The reason for this poor correlation is that the visual fibers from each retina travel to both occipital poles such that nonspecific illumination of the entire retina currently makes it impossible to reliably detect small changes in a specific anatomical region of the retina until there is irreversible retinal damage.

ERG is a powerful electrophysiological technique for assessing small changes in retinal function. Despite this, its use in neurosurgery has largely been unexplored. In a porcine model of retinal ischemia, ERG was shown to develop decreased amplitude and increased latency, during balloon occlusion of the retinal artery supply.[8] Additionally, total obliteration of retinal perfusion (including collateral circulation) resulted in complete loss of ERG signals. Others have used combined ERG and VEP monitoring during ophthalmic artery surgery and demonstrated the reproducibility of intraoperative ERG recording.[13,15] In that study, the investigators recorded changes in ERG and VEP signals during clip ligation and coil embolization of an aneursym in two different patients, which prompted them to cease further manipulation of the lesions with subsequent return of signals to baseline without residual visual deficits. In another report, the authors described treatment of a ruptured ophthalmic artery aneurysm that resulted in loss of VEP but preservation of ERG signal during temporary clipping of the ophthalmic artery, suggesting that ERG may be more sensitive and specific for retinal dysfunction.[14]

The ERG changes seen after AVF embolization correlated temporally with DSA evidence of retinal hyperemia from redirection of ophthalmic artery blood flow. This hypothesis is further supported by ERG signals returning to normal concurrently with reduction in blood pressure. The ERG changes made us reconsider single-staged embolization of the entire AVF during the procedure due to the possibility of permanent visual deficit. Embolizations were staged every 6-weeks as per our standard of care for AVFs and AVMs. Staged embolization resulted in angiographic and clinical evidence of cure without subsequent complications or changes in ERG.

ERG can easily be implemented at any institution where neuromonitoring is available and could be useful for monitoring retina ischemia and hyperemia when patients are in the prone position, such as spine surgery and posterior fossa cranial surgery, where anterior optic neuropathy puts the patient at risk for blindness.[9] Limitations of ERG include the inability to monitor the postchiasmatic visual pathways including the visual white matter pathways and occipital cortex.

CONCLUSIONS

Based on the existing literature, ERG appears to be a promising modality for electrophysiological monitoring of the prechiasmatic structures and provides early detection of impending retinal injury in existing and validated porcine animal models of retinal ischemia. Similar ERG signal changes may be seen in the anesthetized human patient indicating possible retinal injury due to ischemia. Further investigation is needed to assess the utility of ERG monitoring during the treatment of orbital and periorbital vascular lesions.

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