Decoding the Onset of Intraoperative Normal Pressure Perfusion Breakthrough with Near-Infrared Spectroscopy and Jugular Venous Oxygen Saturation Catheter in a Case of Arteriovenous Malformation Surgery

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Abstract

Multimodal monitoring can be a useful tool to design an appropriate anesthesia technique in the intraoperative period during the surgical excision of an intracerebral arteriovenous malformation (AVM). Intraoperatively, hyperperfusion syndrome can be attributed to causes like insufficient blood pressure control, occlusion of venous drainage before complete resection of arterial feeders, or inadequate hemostatic control of distended capillaries receiving arterial flow. We would like to highlight the potential role of near-infrared spectroscopy and jugular venous oxygen saturation catheter in detection of intraoperative normal perfusion pressure breakthrough and take necessary measures to prevent further insult with the help of this case report.

Keywords

- multimodal monitoring
- near infrared spectroscopy
- hyperperfusion syndrome
- arteriovenous malformation

Introduction

Arteriovenous malformations (AVMs) are characterized by direct connection between feeding arteries and draining veins without an intervening capillary network, resulting in a low-resistant, high-pressure shunt.[1] Important factors associated with high incidence of normal pressure perfusion breakthrough (NPPB) include angiographic evidence of steal, large-sized AVM, high-shunt flow > 120 cm/s, low pulsatility index of < 0.5 on transcranial Doppler, impaired autoregulation, and low-cortical artery pressure before excision with sudden and excessive increase after excision.[2] Traditionally, a thermal blood flow monitor and a laser flowmeter has been used to detect this highly enigmatic complication.[3] Near infrared spectroscopy (NIRS) being a continuous, real-time, noninvasive monitor with a good temporal resolution is an attractive option for monitoring the trends of cerebral oxygenation status both intra- and postoperatively.[4,5] Jugular venous oxygen saturation ($SjVO_2$) catheter provides information about the cerebral oxygen supply and demand and hence aid in physiologically guided management. Literature on the role of NIRS and $SjvO_2$ in diagnosis of NPPB following AVM resection is sparse and the role of such multimodal monitoring for detection of NPPB intraoperatively in AVM surgeries is not reported. Intraoperative detection of hyperperfusion syndrome in AVM surgeries can help in instituting interventions like selective flow modulation techniques by the neurosurgeon and induction of systemic hypotension by the neuroanesthesiologists. In our case, the sudden increase in bleeding from the AVM bed

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along with increase in regional cerebral oxygen saturation (rSO_2) pointed toward onset of NPPB, despite no systemic hemodynamic change. We could institute methods to control the blood pressure (BP) and the bleeding could be controlled, with NIRS showing decrease following institution of therapy.

Case Report

A 17-year-old previously healthy gentleman presented to our hospital with a history of insidious onset of moderate-to-severe holocranial headache. His Glasgow coma scale (GCS) score was 15/15. MRI scan revealed a compact nidus AVM measuring 3.8 × 3 × 3.3 cm in the right postcentral gyrus and posterior part of the paracentral lobule, which is supplied by predominantly anterior parietal branches of the right middle cerebral artery and draining into the superior sagittal sinus through right frontal and parietal cortical veins (Spetzler–Martin grade III). Preoperative functional MRI (fMRI) showed the lesion was overlying the sensory blood oxygen level-dependent (BOLD) activation area of the left hand and a close relation (1 cm posterior) to the motor BOLD activation area of the left hand and legs. He was scheduled for excision of the AVM under general anesthesia in supine position.

After the application of ASA standard monitors, general anesthesia was induced with injection fentanyl, injection propofol titrated to loss of verbal response, and injection vecuronium to facilitate endotracheal intubation. Maintenance of anesthesia was done using sevoflurane with oxygen: air (50:50) in volume-controlled ventilation with ventilation adjusted to maintain $EtCO_2$ of around 35 mm Hg. For neurological monitoring, NIRS sensors (Root O3 Monitor; Masimo Corporation, Irvine, CA) were applied bilaterally in the frontal region for monitoring rSO_2, and $SjvO_2$ catheter was inserted for repeated intermittent sampling and calculation of arteriovenous oxygen difference ($AVDO_2$) before and after the excision. Baseline NIRS values (rSO_2) were 64 on the right side and 68 on the left side, and the $SjVO_2$ value was 92% and $AVDO_2$ value was 0.8 mL/dl. Throughout the dissection phase, the NIRS was maintained ± 10% baseline. When the final arterial feeder and the sac were excised, there was a sudden increase in rSO_2 value of 98% on the right and 72% on the left (►**Fig. 1**). Simultaneously, the surgeons also noted sudden diffuse ooze from the bed of resected AVM which was difficult to control. There had been no change in the hemodynamics, anesthetic agents, ventilation status, and systemic factors that could explain the sudden change. Immediate diagnosis pointed toward occurrence of intraoperative cerebral hyperperfusion syndrome. The neurosurgeon was alerted for the same, and measures were taken to reduce the systolic BP from 120 mm Hg around 100 mm Hg with injection labetalol 5 to 10 mg boluses, requiring maximum dose of up to 25mg. After aggressive BP reduction, the rSO_2 value then came down to 77% on the right and 64% on the left, and $AVDO_2$ improved to 1.4 mL/dl with a $SjVO_2$ value of 80% (►**Fig. 1**). The oozing from the field decreased and the surgeons could achieve adequate hemostasis. Postoperatively, the patient was shifted to the ICU for strict BP control with

Fig. 1 Near-infrared spectroscopy (NIRS) showing acute rise in rSO2 values to 93 on right side (operated side) intraoperatively compared with left side. After reducing the blood pressure (BP), the NIRS value corresponded to left side.

continuous NIRS monitoring. After a neurological assessment, the patient was extubated and was found to have no clinical neurological deficits.

Discussion

The surrounding regions of intracerebral AVM undergo profound hemodynamic alterations due to its chronically hypoperfused state and a disturbed autoregulation response.[1] Hence, a return to normal flow after AVM resection can have adverse consequences. After the feeding arteries have been occluded, the blood which was previously going to the low-resistance shunt will be diverted to the neighboring previously hypoperfused areas, resulting in hyperemic complications like NPPB and hemorrhagic events.[2] Intraoperative NPPB can lead to failure to achieve hemostasis, brain bulge, and neurological damage. However, perioperative diagnosis of NPPB is made, based on clinical suspicion of features like increased blood loss from AVM bed, hemodynamic fluctuations, brain bulge, operative site hematomas, etc. It is important to diagnose the condition intraoperatively to differentiate it from mimics like cerebral ischemia, bleeding from residual AVM, etc.

NIRS has emerged as a promising tool in obtaining continuous real-time information of the cerebral oxygenation and hemodynamics during neurovascular surgeries in the intraoperative period.[6] NIRS measures the regional oxygenation from the frontal area, and so we used it as a continuous cerebral monitoring method for our patient who underwent frontoparietal AVM resection surgery.[7] Cerebral AVMs can be associated with hemodynamic dysfunction or diaschisis, which can result in low cerebral blood flow (CBF) not only around AVM but also in distant areas which can be missed with a regional oxygenation monitor like NIRS.

We used $SjVO_2$ for monitoring the global cerebral oxygenation, for measuring the shunt flow ratio after resection of the AVM, and for monitoring the management of subsequent complication in the postoperative period. The usefulness of $SjVO_2$ catheter has been described in both surgical resection as well as embolization. An alarmingly high baseline $SjVO_2$ value of > 90% has been associated with large volume AVM and with cerebral steal, which was observed in our patient.[8] Following the surgical resection, the $SjVO_2$ progressively declines which has been reported to be 24%. One prospective study described a mean decrease of 10% during partial embolization of 15 large supratentorial AVMs.[9] In our patient, there was a high baseline $SjvO_2$ value of 92%, which remained as 90% even after a significant excision of the lesion. A combined use of NIRS and $SjVO_2$ for AVM resection procedure facilitated detection of operative site hematoma needing re exploration, where an abrupt increase in $SjVO_2$ value with an ipsilateral decrease in rSO_2 value, causing regional hypoxia in postoperative period, has been reported.[10] In contrast, intraoperatively, we have noted abrupt increase in ipsilateral rSO_2 value, and no significant decrease in $SjvO_2$ value, immediately after AVM resection, which was associated with intraoperative bleeding, pointing toward a probable intraoperative NPPB. The $AVDO_2$ value was found to remain 0.8 mL/dl in this patient and increased to 1.4 ml/dl only after complete excision and BP control. In such cases of clinical ambiguity, when a baseline high value of $SjvO_2$ can hinder with clinical judgement, NIRS, being a continuous, regional monitor with excellent temporal resolution of approximately 1 millisecond, can be useful to make a probable diagnosis of hyperperfusion syndrome.[4] An acute and asymmetrical rise of rSO_2 to 98% on the operative site can point toward an elevated regional CBF due to hyperemic complications like NPPB and hemorrhagic events. Intraoperative rSO_2 value have been reliably used to identify patients at risk for hyperperfusion after carotid endarterectomy, which has a different pathophysiology,[11] but role of NIRS and $SjVO_2$ catheter in detection on intraoperative NPPB has not been reported. Our report shows that multimodal monitoring during AVM surgeries has high value in diagnosing and management of intraoperative occurrence of NPPB. The observed changes in NIRS and the perioperative events reported is an isolated observation and needs to be evaluated using a larger set of AVM patients undergoing neurosurgery.

Conflict of Interest

None declared.

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