Case Report

NIRS: So Near Yet So Far (From the Brain)

Abstract

Cerebral oximetry is touted as a magic wand to detect cerebral hypoperfusion. Inability to completely exclude extracranial oxygen however is a limitation. Variation in scalp vascularity can magnify the limitations of relatively short emitter–detector distances. The combination of brain ischemia and cutaneous hyperemia, as is the situation during anaphylaxis and anaphylactoid reactions, can be associated with a paradoxical increase in cerebral oximetry values. This could compromise the quality and accuracy of care delivered. We report the association of red man syndrome with exaggerated cerebral oximetry values.

Keywords: *Anaphylaxis, brain injury, hemoglobins, Kounis syndrome, near infrared spectroscopy, oximetry, scalp/blood supply, vancomycin*

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Introduction

During potentially life-threatening allergic conditions associated with histamine release, such as anaphylaxis and anaphylactoid reactions, cutaneous blood flow is increased, while cerebral hypoperfusion can be severe.[1] Near infrared spectroscopy (NIRS) is supposed to be a real-time noninvasive indicator of regional perfusion.[2] However, for cerebral oximetry measurements to guide intervention, extracranial contamination is a confounding factor.[3,4]

Case Report

A 24-year-old female patient, weighing 74 kg, was posted for redosternotomy and relief of left ventricular outflow tract obstruction (peak gradient 110 mmHg) due to recurrent subaortic membrane. In the past, she had been operated during infancy for repair of coarctation of aorta via left thoracotomy. Subsequently, she underwent three surgeries 10, 8, and 4 years ago via sternotomy for mitral valve replacement of incremental size (17, 23, and 27 mm) to accommodate growth requirements. Subaortic membrane resection and aortic valve repair was concurrently performed 10 years ago along with mitral valve surgery.

The patient had been diagnosed with an allergy to ceftriaxone, 4 years ago. A course of vancomycin had been administered 4 years earlier to treat sepsis with blood cultures positive for methicillin resistant staphylococcus aureus.

Blood hemoglobin (Hb) concentration was 10 g/dL and saturation of Hb on room air was 97% by pulse oximetry. Baseline cerebral oximetry (5100C INVOS OXIMETER Cerebral/Somatic, SOMANETICS, MA, USA) readings were 64% and 62% over the right and left frontal regions. Prior to induction of anesthesia, she had received injection methylprednisolone 1.5 g over 10 min intravenously. Arterial and central venous accesses were secured aseptically under ultrasound guidance and local infiltration with preservative-free lignocaine for analgesia. Standard techniques were employed for induction of anesthesia and endotracheal intubation.

The hospital infection control department advised 1 g of vancomycin (to be administered over 60 min) for infective endocarditis prophylaxis during the current surgery. Within 10 min of commencement of infusion, the patient developed generalized redness, which was prominent over the face and torso. A diagnosis of "red man syndrome" was made. Vancomycin infusion was paused for about 10 min and completed over the next hour. Patient was hemodynamically stable, and about 300 mL of lactated Ringer's solution was administered. Blood gases were normal. The concentration of inspired oxygen was 50% in a mixture of air and oxygen.

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About 10–15 min after commencement of vancomycin infusion, cerebral oximetry values increased from 63%–65% bilaterally to 86%–89%. The readings peaked at 90%–94% over the next half an hour. The values were in the mid-80s for the next 3 h. About 4 h later, they returned to baseline values (61%–63%) [Figure 1]. The prolonged but uneventful fourth redosternotomy enabled us to observe the effects of "red man syndrome" on exaggerated cerebral oximetry values. Further course of the patient was uneventful.

Discussion

In the case discussed above, the patient had in range cerebral oximetry values at baseline, which rapidly increased within 10 min of commencement of vancomycin infusion. The infusion was completed in about one and a half hours. Cerebral oximetry values stayed elevated for about 4 h and then returned to baseline. The patient was hemodynamically stable throughout.

Krabbe and Olesen have previously demonstrated that intravenous or intracarotid histamine infusion had no effect on cerebral blood flow.[5] Cerebral perfusion is known to be decreased during anaphylaxis type of reactions. This could be disproportionately worse than that due to hypotension alone.[1,6] Anaphylaxis is mediated by IgE. Red man syndrome is an anaphylactoid reaction, in which histamine is released by degranulation of basophils and mast cells independent of preformed IgE or complement.[7] Clinically, the situation may vary from being self-limited to a rapidly downhill course.

As discussed by Tosh and Patteril, the amount of oxygen is determined mainly by the absorption spectra of oxy and reduced hemoglobin. Near infrared wavelengths in the range of 650–940 nm penetrate the skull to reach the cerebral tissue. Oxygenated and deoxygenated hemoglobin have an absorption spectra of 700–1,150 and 650–1,000 nm, respectively.[8]

The cerebral oximetry probe consists of an emitter–detector separated by fixed distances. Near infrared light traverses the scalp, skull, and brain tissue. It is reflected back to the skin from various levels in a curved path. The path from the deepest tissue (brain) is a wide curve. This can be detected by greater separation between the emitter and detector [Figure 2]. At shorter distances, reflections detected are largely from extracranial tissues.[3,4]

Cerebral oximetry uses two photo detectors with each emitter. Near-field photodetection is subtracted from far-field photo detection and displayed as a tissue oxygenation number.[9] Davie and Grocott compared changes in cerebral oximetry readings with alteration of extracranial blood flow by inflation–deflation of a pneumatic cuff applied to the scalp. Of the three cerebral oximeters compared, the INVOS 5100C device showed maximum changes with alteration of extracranial blood flow. They attributed this to the relatively short distance between emitter and detector in INVOS, thus leading to extracranial contamination.[4]

Scalp hyperemia during red man syndrome, likely caused the elevation in cerebral oximetry readings of the 5100C INVOS device. Histamine release can be prolonged in patients with atopy. The cerebral oximetry values returned to baseline after about 4 h from the time of commencement of vancomycin infusion. Anaphylaxis and anaphylactoid reactions can result in cerebral hypoperfusion and brain injury. Needless to say, the paradoxical elevation of cerebral oximetry values in the face of potential cerebral hypoperfusion could be clinically misleading and the outcome, catastrophic.

Conclusion

Cerebral oximetry by NIRS can induce a false sense of security in critical situations of potential cerebral hypoperfusion, the very problem it is supposed to detect in real time. The manufacturers must include suitable warnings and confounding technological factors, which could seriously impair the utility of the modality.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have

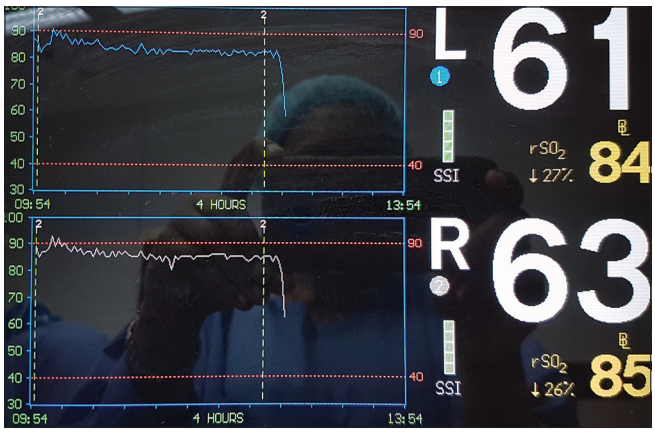

Figure 1: NIRS tracing depicting effect of vancomycin (baseline values are not seen as probe was changed upon sudden elevation in values)

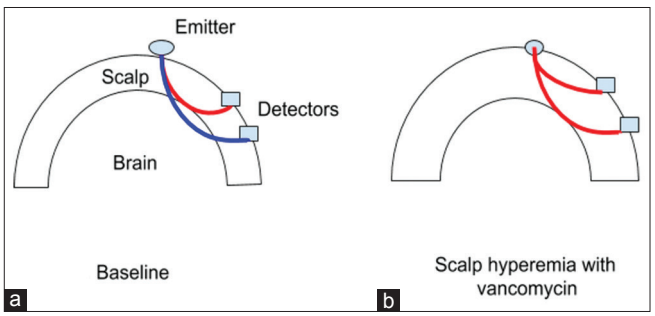

Figure 2: Effect of extracranial hyperemia on cerebral oximetry with relatively low separation between emitter and detector. In image (a), the detected signals are from both extracranial and intracranial tissue. In image (b), due to scalp hyperemia, the detected signals are from the scalp only. (Note: The red line indicates extracranial passage while the blue line indicates intracranial passage)

given his/her/their consent for his/her/their images and other clinical information to be reported to the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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