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DOI:

10.4103/bc.bc_12_19

Novel application of near-infrared spectroscopy in detecting iatrogenic vasospasm during interventional neuroradiological procedures

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Abstract:

One of the complications of carotid artery stenting (CAS) is iatrogenic vasospasm caused by mechanical irritation of the blood vessel lumen by a guidewire, catheter, stent retriever, or distal protection devices. Although often self-limiting, the mechanical vasospasm can cause reduction in the cerebral blood flow and result in catastrophic ischemia, especially when undetected and persistent. Real-time cerebral oximetry with near-infrared spectroscopy (NIRS) could detect episodes of cerebral hypoxemia due to vasospasm and facilitate intervention for prevention of hypoxic brain injury during neuro-intervention procedures such as CAS. We present a case scenario where NIRS detected iatrogenic vasospasm even before the conventional tests could identify the event during CAS.

Keywords:

Carotid artery stenting, cerebral vasospasm, near-infrared spectroscopy

Introduction

Iatrogenic vasospasm is caused by mechanical irritation of the blood vessel lumen by a guidewire, catheter, stent retriever, or distal protection devices during interventional neuro-radiological procedures. Although often self-limiting, mechanical vasospasm can cause a reduction in the cerebral blood flow, resulting in catastrophic ischemia. We present a case report where near-infrared spectroscopy (NIRS) detected iatrogenic vasospasm even before the conventional tests could identify the event during carotid artery stenting (CAS). Informed consent had been obtained from the patient before publication.

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Case Report

A 49-year-old man, who was a chronic smoker and hypertensive, was diagnosed with symptomatic left carotid artery stenosis and was posted for revascularization with CAS under monitored anesthesia care. On the day of the procedure, he was premedicated with oral alprazolam 0.5 mg. In the interventional suite, standard ASA monitoring such as electrocardiogram, pulse oximetry (SpO_2), and noninvasive blood pressure was initiated, and his vitals were within normal limits. Under local anesthesia, peripheral venous access was obtained in the left hand, and the left radial artery was cannulated for invasive blood pressure recording. Bi-frontal electroencephalogram (EEG) and patient state index (PSI) electrode along with bilateral frontal NIRS sensor for monitoring cerebral oxygenation (rSO_2) were attached.

How to cite this article: Padhy SK, Ajayan N, Hrishi AP, Thakkar KD, Sethuraman M. Novel application of near-infrared spectroscopy in detecting iatrogenic vasospasm during interventional neuroradiological procedures. Brain Circ 2019;5:90-3.

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Submission: 01-06-2019
Revised: 03-06-2019
Accepted: 09-06-2019

A baseline PSI of 98, right-sided rSO_2 of 82, and left-sided rSO_2 of 78 were recorded.

Under local anesthesia, the right common femoral artery was punctured, and selective angiogram of the bilateral common carotid artery (CCA), internal carotid artery (ICA), and vertebral artery was also taken. Angiogram showed 80% stenosis of the left CCA middle segment of length 1.8 cm. As a radiologist was navigating the guidewire across the stenotic segment, we noticed a sudden decrease in rSO_2 from 78 to 48 on the ipsilateral side [Figure 1]. To identify the etiology of cerebral desaturation and for prompt intervention, we followed the devised algorithm commonly practiced.^[1] As it was a case of unilateral desaturation, The neuroradiologist was alerted who withdrew the guidewire backward and ruled out catheter malposition/kinking. At this juncture, as the low rSO_2 values persisted, we ruled out systemic causes such as hypoxia, hypotension, and hypocapnia. The patient was calm and afebrile and did not have clinical/electrographic seizures, thereby ruling out any increase in cerebral metabolic oxygen demand. The patient did not have any neurocognitive decline during this time but complained of minimal weakness of the right side toward the end of the cerebral desaturation episode, which lasted for around 3 min. Furthermore, to rule out complications of CAS which could lead to ischemia such as thromboembolism, vasospasm, and dissection, an intracranial angiography was done which revealed absent flow distal to the ICA bifurcation (middle cerebral artery and anterior cerebral artery could not be visualized). Iatrogenic vasospasm was suspected, and nimodipine 1 g was given intra-arterially after which rSO_2 of the left side improved to 76 and angiography did subsequently show increased flow across the vessels [Figure 2].

Discussion

Carotid artery stenosis is a disease condition commonly associated with stroke and is caused by

atherosclerosis. Its treatment mainly comprises carotid endarterectomy (CEA) and CAS. The International Carotid Stenting Study compared stenting with endarterectomy and found that procedure-related risk of stroke was higher in the CAS arm.^[2] Peri-procedural complications of CAS such as stent thrombosis, carotid artery dissection, cerebral embolism, hyperperfusion syndrome, intracranial hemorrhage, and contrast encephalopathy can result in catastrophic events, such as stroke and death.^[3] Thus, neurological monitoring for rapid recognition and evaluation of these events holds paramount importance in this procedure.

Various monitoring devices such as EEG, evoked potentials such as somatosensory-evoked potential (SSEP), cerebral oximetry, transcranial Doppler (TCD), and stump pressure have shown comparable results in the prevention and management of complications during CEA, but the utility of these devices in the interventional radiology suite is not feasible.^[4] Moritz *et al.* compared the accuracy of TCD, NIRS, and SSEP in detecting cerebral ischemia in patients undergoing CEA. They concluded that TCD and NIRS had better accuracy for detecting cerebral ischemia compared to SSEP, and continuous TCD monitoring during CEA is technically challenging, making NIRS an excellent monitor in this setting.^[4] No such clinical trials comparing the monitoring modalities have been conducted in the CAS group. Among the monitors, NIRS-based cerebral oximetry has the advantage of being noninvasive, continuous, and real-time and requires less technical expertise compared to TCD, and the pharmaceutical interventions have no impact on it, unlike on SSEP and EEG.^[5,6] A preliminary study which assessed the feasibility of real-time measurement of rSO_2 in patients undergoing CAS found that the rSO_2 changes were easy to evaluate and significantly correlated with the ischemic neurological symptoms.^[5] A major lacuna in using NIRS neurological monitoring was that an ischemic threshold value of rSO_2 had not been defined. Recent studies have shown that a change in the rSO_2

Figure 1: Near-infrared spectroscopy monitor showing regional cerebral oxygenation of right and left frontal lobes. Note that the left cerebral oxygenation is 43% and the right cerebral oxygenation is 88% during the event of unilateral cerebral desaturation

Figure 2: Near-infrared spectroscopy monitor showing regional cerebral oxygenation of right and left frontal lobes after intra-arterial nimodipine. Note that the left cerebral oxygenation has risen to 81% denoting cerebral reperfusion

value of 20% from baseline has a negative predictive value of 97% and a positive predictive value of 35% for cerebral ischemic complications.^[7] Matsumoto *et al.* in a study in patients presenting for CAS had concluded that increase in rSO₂ by >10% post-CAS is an excellent predictor of cerebral hyperperfusion syndrome in the postprocedure period.^[8] NIRS is beneficial in detecting cerebral reperfusion as a result of recanalization of the major artery by either mechanical thrombectomy or intravenous thrombolysis.^[9]

Detection of vasospasm in the interventional settings by NIRS has not been reported till date. One of the well-described complications of neuro-interventional procedures such as CAS is iatrogenic vasospasm caused by mechanical irritation of blood vessel lumen by a guidewire, catheter, stent retriever, or distal protection devices.^[10] In procedures like CAS, the incidence of vasospasm is exacerbated by risk factors such as atherosclerosis and hypertension, which these patients are more prone to. The incidence of vasospasm during CAS was found to be 40% in one study.^[5] The tortuosity of the vessels can also exacerbate the endoluminal surface irritation and damage by the guidewire and the distal protection devices.^[5] Vasospasm induced by iatrogenic causes are usually transient, as it resolves with the withdrawal of stimuli and in rare scenarios require the intraarterial injection of vasodilators such as nimodipine or milrinone. Local vasospasm can also cause the failure of stent placement and difficulty in the retrieval of guidewire or protection device. Although often self-limiting, mechanical vasospasm can cause cerebral ischemia, especially when undetected and persistent.^[11] A direct neurocognitive assessment has been shown as the most reliable method of cerebral ischemia; however, in our case, it did not identify the cerebral hypoxia in its initial period probably because of lag period of the brain sensitivity to hypoxia.^[11] NIRS monitoring in patients who are undergoing interventional procedures such as CAS under sedation or general anesthesia would be beneficial as it is not possible to evaluate the oxygenation and microcirculation status of the brain by clinical neurological evaluation. NIRS could be a valuable tool to monitor rSO₂ in the interventional neuro-radiological procedures where identification of cerebral hypoxia is pertinent although its application in neurosurgical settings has limitations.^[12]

Conclusion

To recapitulate, we would like to highlight the importance of using NIRS monitoring during CAS procedure wherein abnormal rSO₂, defined as a 20% bilateral or unilateral reduction from baseline values or an absolute decrease below 50%, can be significant. We were able to anticipate and treat a time-sensitive

complication like vasospasm with the help of NIRS, which we believe would have been missed due to absence of clinical manifestations in its initial phase.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Acknowledgment

We want to acknowledge Dr. Jayadevan ER MD, DM, Additional Professor, Imaging Sciences and Interventional Radiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum, for his valuable suggestions.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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