Original Article

Monitoring of Limb Perfusion after Vascular Surgery in Critical Limb Ischemia Using Near-Infrared Spectroscopy: A Prospective Observational Study

Tanveer Singh Kundra, Ashwini Thimmarayappa[1], Sunder Singh Subash[2], Parminder Kaur[3]

Department of Anaesthesiology, Government Medical College, Patiala, [3]Department of Critical Care, Max Hospital, Mohali, Punjab, [1]Department of Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bangalore, Karnataka, [2]Department of Anaesthesiology, Kerala Institute of Medical Sciences, Trivandrum, Kerala, India

Abstract

Background: Intra and postoperative perfusion monitoring should be used in critical limb ischemia patients undergoing vascular surgery to improve outcomes and reduce costs. While a pulse oximeter can be applied on the affected limb to monitor the arterial saturation of the limb, thus reflecting flow in that limb, we need to focus on other important parameters like muscle oxygen consumption and regional blood flow for a good outcome. Near-infrared spectroscopy (NIRS) can be used in such patients to monitor regional and tissue oxygenation. **Methodology:** In this prospective observational study, 30 adult patients undergoing infra-inguinal bypass were recruited. All these patients were given combined spinal-epidural anesthesia. In addition to routine monitoring, a pulse oximeter and NIRS electrodes were applied on the affected limb. rsO2, limb spO2, and Doppler signals were noted before the induction of anesthesia (baseline) and postoperatively at 0, 6, and 12 h. Improvement in rsO2 and limb spO2 values after surgery was noted and fall in these values was evaluated. Pearson correlation between rsO2 and limb spO2 was assessed. The data was analyzed using repeated-measures ANOVA. **Results:** Pearson correlation between rsO2 and limb spO2 was $r > 0.8$. Two patients had a fall in rsO2 in postoperative period, which co-related with a fall in limb spO2 and decreased/absent Doppler signals. **Conclusion:** NIRS represents a noninvasive and reliable means to monitor limb perfusion in patients undergoing vascular surgery for rest pain.

Keywords: *Near-infrared spectroscopy, rest pain, tissue perfusion*

Introduction

Critical limb ischemia (CLI) is a severe obstruction of the arteries which markedly reduces blood flow to the extremities (hands, feet, and legs) and has progressed to the point of severe pain and even skin ulcers, sores, or gangrene. The pain caused by CLI can wake up an individual at night. This pain is also called "rest pain" and is often in the leg. CLI needs immediate comprehensive treatment by a vascular surgeon or vascular specialist. This condition will not improve on its own. With the rise in risk factors such as smoking, diabetes, lifestyle changes, etc., there has been an increase in the number of patients presenting with CLI to a vascular surgeon.

Intraoperative and postoperative flow monitoring should be used in these high-risk patients undergoing vascular surgery to improve outcomes and reduce costs. While a pulse oximeter can be applied on the affected limb to monitor the arterial saturation of the limb, thus reflecting flow in that limb, we need to focus on other important parameters like muscle oxygen consumption and regional blood flow for a good outcome.

Near-infrared spectroscopy (NIRS) was introduced as a technique to determine the degree of tissue oxygenation several decades ago.[1] NIRS is a noninvasive technique that allows determination of tissue oxygenation based on spectrophotometric quantitation of oxy- and deoxyhemoglobin within a tissue.[2]

NIRS principle is based on the use of near-infrared electromagnetic waves for qualitative and quantitative assessments of molecular factors related to tissue oxygenation. Although this technique can be applied in any tissue, it is primarily used for monitoring peripheral oxygenation in the muscle.[2]

How to cite this article: Kundra TS, Thimmarayappa A, Subash SS, Kaur P. Monitoring of limb perfusion after vascular surgery in critical limb ischemia using near-infrared spectroscopy: A prospective observational study. Ann Card Anaesth 2020;23:429-32.

Submitted: 18-Sep-2019
Revised: 10-Jan-2020
Accepted: 22-Mar-2020
Published: 19-Oct-2020

Address for correspondence:
Dr. Ashwini Thimmarayappa, Department of Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bangalore, Karnataka, India. E-mail: tanveerashwini@yahoo.com

Access this article online

Website: www.annals.in

DOI: 10.4103/aca.ACA_137_19

Quick Response Code:

NIRS has also been used for the determination of oxygen consumption in muscle during exercise.[3]

Hence, we hypothesize that by using NIRS in the intra and postoperative period, we can reliably monitor the regional and tissue saturation of the operative limb, and can serve as a good guide to oxygen consumption in the affected limb, besides reflecting changes in flow in that limb. All this could contribute to a better outcome in the patient.

The aim of this observational study was to observe the efficacy of NIRS in monitoring regional oxygen saturation and detecting complications in the affected limb and whether it can have a role in predicting a good outcome of the patient operated for critical leg ischemia.

Methodology

Ethical approval was taken from Hospital Ethics Committee dated 27-04-2018. Written informed consent was obtained from 30 adult patients undergoing infra-inguinal bypass surgery in this prospective observational study, over 6 months. Demographics of the recruited patients is depicted in Table 1. All these patients were given combined spinal-epidural anesthesia. Intraoperative monitoring was done with noninvasive blood pressure (NIBP), pulse oximeter, and ECG tracing. In addition, a pulse oximeter was applied on the affected limb. NIRS monitoring was also done on the operative limb. A rsO2 and limb spO2 value was obtained at baseline, before the induction of anesthesia. Intraoperatively, rsO2 and limb spO2 values were monitored throughout the procedure. Post-procedure continuous rsO2 and limb spO2 monitoring was done for 12 h and values were noted immediately after, at 6 h and at 12 h after shifting to recovery. A Doppler study was also done at all these time intervals, i.e., at baseline and at 0, 6, and 12 h after shifting to recovery. If Doppler signals were absent, it was mentioned as 0 in the proforma and if present, it was mentioned as 1.

Improvement in rsO2 and limb spO2 values after surgery was noted and fall in these values was evaluated. It was decided to perform a Doppler examination if a fall in rsO2 or limb spO2 was observed and to take corrective measures based on the Doppler examination.

The correlation between rsO2 and limb spO2 values was observed. Whether a decline in rsO2 values co-related with a serious complication like the formation of thrombus was evaluated.

Pearson correlation was assessed between rsO2 and spO2 at different time intervals. Correlation coefficient values range from being negatively correlated (−1) to uncorrelated (0) to positively correlated (+1). (0.0 is no association, +0.2 is weakly positive, +0.5 is moderately positive, +0.8 is strongly positive, +1.0 is perfectly positive).

The data was analyzed using repeated-measures ANOVA. A P value <0.05 was considered statistically significant.

Results

rsO2 and limb spO2 showed positive correlation (Pearson correlation r > 0.8) [Table 2].

There was an improvement in spo2 and rso2 values from their respective baseline values with improvement in blood flow after surgery, i.e., P values were significant for both rso2 and spo2 values when compared between their:

1) baseline and post procedure
2) baseline and at 6 h
3) baseline and at 12 h [Table 3].

The improvement in blood flow after surgery was confirmed by Doppler signals.

Two patients had a fall in rsO2 and limb spO2 in the recovery. Immediate Doppler examination was done to confirm absent/decreased limb blood flow in these patients. In one of the patients, the Doppler signals were absent and patient was taken up for reexploration. In the second patient, the Doppler signals were weak and it was decided to administer heparin infusion to that patient.

Discussion

From the results of the present study, it can be observed that rsO2 very reliably co-relates with improvement in limb flow. To monitor improvement in limb flow, we used limb spO2 and Doppler signals in our study.

Two patients had a fall in rsO2 in the present study. In one of these patients, the rsO2 value became unrecordable. In that patient, the spO2 value also became unrecordable. On Doppler examination, the patient had absent signals and was taken up for reexploration in which a thrombus was detected.

Table 1: Demographics and co-morbidities of the recruited patients

Demographic variables and co-morbid conditions	Observed values/ number of patients with the co-morbid condition
Age (in years)	55.24±10.54
Sex (Male:Female)	22: 8
Diabetes Mellitus	18
Hypertension	20
H/o any previous neurological event (TIA, stroke, motor weakness)	5
H/o any previous cardiac event (chest pain, MI)	2

Table 2: Pearson correlation values between rsO_2 and spO_2

	Correlation coefficient
Baseline	0.99
At 6 h	0.90
At 12 h	0.91

Table 3: Improvement observed in rsO_2 values and limb spO_2 values after establishment of flow

	Baseline			Post-procedure				At 6 h				At 12 h			
	Mean	Std. error	95%CI	Mean	Std. error	95%CI	*P*	Mean	Std. error	95%CI	*P*	Mean	Std. error	95% CI	*P*
rsO_2	27.27	3.92	19.25-35.28	41.97	1.25	39.42-44.51	0.00*	48.20	1.57	44.99-51.41	0.00*	53.57	2.41	48.64-58.49	<0.00*
Limb spO_2	38.13	5.25	27.40-48.87	58.13	1.64	54.78-61.48	0.00*	68.47	2.65	63.04-73.89	0.00*	74.67	3.57	67.36-81.97	<0.00*

**P* significant when compared with baseline value

In the second patient, the rsO2 decreased from 43 to 30 (significant decrease of 30%). But the spO2 mildly fell from 54% to 49% (i.e., 9%). The patient had weak Doppler signals and it was decided to start a heparin infusion for this patient. Gradually the rsO2, spO2, and Doppler signals improved in this patient. Thus, we see that NIRS can play a very important role in noninvasively diagnosing and monitoring perioperative complications in such patients.

The additional benefit of using NIRS over limb spO2 is that limb spO2 only provides information about the arterial saturation in the affected limb, while NIRS reflects regional oxygen saturation, tissue oxygenation, and oxygen consumption in the affected limb. Moreover, pulse oximetry is not a very sensitive test for peripheral vascular disease as concluded by Jawahar *et al*.[4] who found that only 54% of patients with severe PVD had an abnormal baseline limb spO2, with an additional 23% having an abnormal reading when the limb was elevated to 12 inches. Another issue with pulse oximetry is that pulse oximeters do not reliably predict change in saO2 at low arterial hemoglobin-oxygen saturation.[5]

Again, the additional advantage over Doppler is that NIRS can be monitored continuously as opposed to Doppler. In fact, if there is a fall in rsO2 value, a Doppler can be done at that point of time to confirm fall in flow in that limb and hence complications can be detected early in the affected limb. This can lead to a better outcome and can decrease the amputation rates in these patients.

Already this technique has found its role in monitoring peripheral tissue perfusion in critically ill patients.[2] Giannotti *et al*.[6] found that NIRS has utility in the diagnosis of lower extremity compartment syndrome in trauma patients. Similarly, cerebral NIRS represents an exciting prospect for the noninvasive monitoring of cerebral tissue oxygenation and perfusion in the context of traumatic brain injury (TBI).[7] NIRS has also been used to monitor perfusion during carotid endarterectomy.[8,9]

Ubbink and Koopman[10] tried to use NIRS in the routine diagnostic work-up of patients with leg ischemia. They concluded that NIRS is a very reproducible tool to assess tissue oxygen saturation but is not useful for the routine work-up of patients with leg ischemia. The probable reason for this conclusion was the type of subjects enrolled in their study. Forty-four patients were investigated for the presence of arterial occlusive disease. Out of the 44 patients included, 16 presented with complaints of leg pain, not likely to be caused by leg ischemia. Twenty patients had intermittent claudication. Nine patients suffered from pain at rest. Thus, the subjects were at different stages of the disease. Collateral blood flow is initially sufficient to supply the tissues with oxygen. However, when the patient reaches the stage of rest pain requiring intervention for the same, the collateral blood flow is not enough to supply adequate oxygen to the tissues. Hence, NIRS may not be a useful technique for routine diagnostic work-up of patients presenting with different stages of limb ischemia. However, NIRS has got value for patients presenting with rest pain scheduled for a procedure and can be effectively used to monitor regional oxygen saturation and limb perfusion during and after intervention, as can be seen in the present study.

One of the limitations of the study is that we did not use quantitative Doppler with pulsatility index. We only had access to a qualitative Doppler instrument in which we could only subjectively quantify the Doppler signals as weak, good, or very good signals.

The present study may be regarded as a pilot study which has shown a correlation of rsO2 values given by NIRS with the Doppler signals. One of the future investigations could be at what cut-off value of rsO2, there is a weakening or cut-off of the Doppler signals. But for that, we need a quantitative Doppler with a pulsatility index.

Hence, from the present study, the authors conclude that NIRS is a very useful noninvasive technique which can provide additional information regarding regional oxygen saturation and tissue oxygenation in patients undergoing vascular surgery for rest pain. It can be used perioperatively as a continuous monitor of limb perfusion and to detect and manage complications, ultimately leading to a good patient outcome.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Jöbsis FF. Noninvasive, infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters. Science 1977;198:1264-7.
2. Lima A, Bakker J. Near-infrared spectroscopy for monitoring peripheral

tissue perfusion in critically ill patients. Rev Bras TerIntensiva 2011;23:341-51.

3. Colier WN, Meeuwsen IB, Degens H, Oeseburg B. Determination of oxygen consumption in muscle during exercise using near infrared spectroscopy. Acta Anaesthesiol Scand 1995;107:151-5.
4. Jawahar D, Rachamalla HR, Rafalowski A, Ilkhani R, Bharathan T, Anandarao N. Pulse oximetry in the evaluation of peripheral vascular disease. Angiology 1997;48:721-4.
5. Carter BG, Carlin JB, Tibballs J, Mead H, Hochmann M, Osborne A. Accuracy of two pulse oximeters at low arterial hemoglobin oxygen saturation. Crit Care Med 1998;26:1128-33.
6. Giannotti G, Cohn SM, Brown M, Varela JE, McKenny MG, Wiseberg JA. Utility of near-infrared spectroscopy in the diagnosis of lower extremity compartment syndrome. J Trauma 2000;48:396-401.
7. Davies DJ, Su Z, Clancy MT, Dehghani H, Logan A, Belli A. Near-infrared spectroscopy in the monitoring of adult traumatic brain injury: A review. J Neurotrauma 2015;32:933-41.
8. Mille T, Tachimiri ME, Klersy C, Ticozzelli G, Bellinzona G, Blangetti I, *et al*. Near infrared spectroscopy monitoring during carotid endarterectomy: Which threshold value is critical? Eur J Vasc Endovasc Surg 2004;27:646-50.
9. Williams IM, Mortimer AJ, McCollum CN. Recent developments in cerebral monitoring—near-infrared light spectroscopy. An overview. Eur J Vasc Endovasc Surg 1996;12:263-71.
10. Ubbink DT, Koopman B. Near-infrared spectroscopy in the routine diagnostic qork-up of patients with leg ischaemia. Eur J Vasc Endovasc Surg 2006;31:394-400.