ORIGINAL ARTICLE

Monitoring distal limb perfusion using near-infrared spectroscopy in patients on intra-aortic balloon pump

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ABSTRACT

Background: The application of near-infrared spectroscopy (NIRS) in patients undergoing cardiopulmonary bypass for the purpose of monitoring cerebral perfusion is well known. There have been only a few reports of its use in adult patients undergoing peripheral veno-arterial extracorporeal membrane oxygenation to monitor lower limb perfusion. Aim and Objective: Our study aimed to understand the usefulness of NIRS monitoring for the early detection of reduced distal limb perfusion in patients who were placed on intra-aortic balloon pump (IABP) through femoral artery. Materials and Methods: We prospectively studied the use of NIRS monitoring for the early detection of reduced distal limb perfusion in 36 adult patients, who were supported with IABP between 2018 and 2019 (NIRS group). The decision to reinsert the IABP in the contralateral lower limb was made based on the NIRS system’s regional oxygen saturation (rSO2) values. To compare outcomes, the medical records of 45 adult patients who had previously received IABP without NIRS monitoring (control group) between 2017 and 2018 were reviewed retrospectively. Institutional Ethical Committee Approval was taken ref. no. IEC/39/18 dated January 22, 2018. Results: There was no significant difference between the frequency of reinsertion of IABP in the contralateral lower limb in both groups ($P = 0.414$). The mean time to reinsertion of IABP in the contralateral lower limb is shorter in the NIRS group (20.6 ± 21.4 vs. 40.0 ± 61.0 h). In the NIRS group, no patients underwent fasciotomy, whereas 13.5% did in the control group ($P = 0.030$). Conclusion: We believe that NIRS monitoring is an effective and accurate approach for detecting limb ischemia in IABP patients. Its use could lead to the early correction of perfusion deficits, as well as the avoidance of compartment syndrome and limb problems.

KEY WORDS: Intra-aortic Balloon Pump; Limb Ischemia; Near-infrared Spectroscopy

INTRODUCTION

Patients with severe cardiopulmonary dysfunction are frequently treated with an intra-aortic balloon pump (IABP). The femoral artery is typically utilized for IABP insertion in adults. However, limb ischemia occurs in about 8% of people with IABP, resulting in significant morbidity or fatality. Clinically and through Doppler pulse analysis, the lower limb perfusion is monitored traditionally. These monitoring approaches, on the other hand, may be incorrect, allowing limb hypoperfusion to go undiagnosed for several hours. As a result, for rapid identification of limb ischemia, an accurate real-time monitoring system is necessary. For example, near-infrared spectroscopy (NIRS) has been used to monitor cerebral perfusion in patients undergoing cardiopulmonary bypass and is well-documented in the literature. There have been only a few reports of its use in adult patients undergoing peripheral veno-arterial
extracorporeal membrane oxygenation (VA-ECMO) to monitor lower limb perfusion. As far as we know, NIRS has not been used to monitor lower limb perfusion in patients on IABP. We present our experience with continuous NIRS monitoring for the early diagnosis of diminished lower limb perfusion following IABP implantation in the femoral artery in this study.

MATERIALS AND METHODS

Between 2018 and 2019, we prospectively used NIRS monitoring for the early detection of reduced limb perfusion in adult patients with IABP insertion in femoral artery. The NIRS monitoring system available at our institute was used. Each lower limb’s calf was fitted with a pair of sensor pads. The value of regional oxygen saturation (rSO2), which denoted the adequacy of tissue oxygenation, was continuously monitored. Monitoring began shortly after the IABP was inserted and ended only after a successful wean to recovery or death. ICU nurses kept track of the rSO2 levels on the device every hour and alerted doctors if they dropped dramatically. A significant decline in rSO2 values that necessitates intervention was determined as a drop below 40 using the previously reported VA-ECMO methodology. Although Wong et al. defined significant events as a decline in rSO2 values of < 40 or more than 25% from baseline, we simply used the first condition to keep our approach simple. To rule out mechanical explanations, all patients with significant reductions in rSO2 levels were evaluated initially (improper placement or malfunctioning of sensor pads). If the sensor pads were not the problem, we attempted to enhance oxygen delivery to the tissues by increasing mean arterial pressure and hemoglobin levels. We reinserted the IABP in the contralateral lower limb bedside if rSO2 values remained below 40 despite the aforementioned managements. The clinical assessment of lower limb perfusion was done on a regular basis through physical examination. Doppler ultrasound was also used to evaluate the dorsalis pedis and posterior tibial artery for pulses.

Between 2017 and 2018, we analyzed the medical records of adult patients who had previously received IABP support without NIRS monitoring to compare the results (control group). Perfusion of the lower leg was evaluated clinically and with serial Doppler pulse monitoring of the dorsalis pedis and posterior tibial arteries during this time. We suspected the development of limb ischemia and reinserted the IABP in the contralateral lower limb bedside, if clinical symptoms of limb ischemia were observed – skin color change or calf muscle edema in the cannulated leg, for example, – or Doppler pulse signals were decreased. We directly evaluated intramuscular pressure in individuals with worsening calf muscle tension and conducted fasciotomy, if compartment syndrome was identified. Institutional Ethical Committee Approval was taken ref. no. IEC/39/18 dated January 22, 2018.

RESULTS

We included 36 adult patients between 2018 and 2019 who were monitored with NIRS while receiving IABP for more than 24 h (NIRS group). Adult patients on IABP for < 24 h were likewise ruled out. Between 2017 and 2018, 45 patients were included who received IABP for more than 24 h (Control group). In both groups of patients, there was no significant variation in age distribution (P = 0.468). The proportion of female patients in the NIRS group was substantially higher (58.33% vs. 24.33% and P = 0.007). The length of IABP support did not differ significantly between the two groups (P = 0.603) [Table 1]. The NIRS group experienced a significant decline in rSO2 values in 15 patients (41.6%); however, it was regained in three of these individuals due to therapy to enhance oxygen supply to the tissues. The other 12 patients, on the other hand, had to have IABP reinserted when their rSO2 levels did not improve despite the earlier management efforts. The NIRS group had a shorter mean time to reinsertion of IABP (20.6 ± 21.4 vs. 40.0 ± 61.0 h); however, the difference was not statistically significant (P = 0.342). The rate of Doppler pulse loss was not significantly different between the two groups (P = 0.540). Although there was no significant difference between the two groups in the frequency of skin color change in the cannulated leg (P = 0.155), patients in the NIRS group had a considerably reduced rate of calf muscle edema (8.33% vs. 28.8% and P = 0.032). The NIRS group had no patients undergo fasciotomy due to the development of compartment syndrome, whereas the control group had 13.5%, and the difference was statistically significant (P = 0.030) [Table 1]. In both groups, there were no cases that required amputation.

Patients in the NIRS group were divided into two groups based on whether or not they had clinical indications of limb ischemia after starting IABP [Table 2]. Between the two groups, there was no significant difference in age, sex, BSA, or mean duration of IABP support. In the ischemia

<table>
<thead>
<tr>
<th>Variables</th>
<th>NIRS</th>
<th>Control</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>36</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.5±17.9</td>
<td>58.3±19.7</td>
<td>0.468</td>
</tr>
<tr>
<td>Female</td>
<td>21 (58.33)</td>
<td>11 (24.44)</td>
<td>0.007</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>1.69±0.23</td>
<td>1.73±0.20</td>
<td>0.432</td>
</tr>
<tr>
<td>IABP duration (hours)</td>
<td>115.7±70.6</td>
<td>122.6±90.7</td>
<td>0.603</td>
</tr>
<tr>
<td>Reinsertion</td>
<td>12 (33.33%)</td>
<td>18 (40%)</td>
<td>0.414</td>
</tr>
<tr>
<td>Time to reinsertion (Hours)</td>
<td>20.6±21.4</td>
<td>40.0±61.0</td>
<td>0.342</td>
</tr>
<tr>
<td>Loss of Doppler pulse</td>
<td>14 (39%)</td>
<td>22 (49%)</td>
<td>0.540</td>
</tr>
<tr>
<td>Skin color change</td>
<td>9 (25%)</td>
<td>19 (42%)</td>
<td>0.155</td>
</tr>
<tr>
<td>Calf muscle swelling</td>
<td>3 (8.33%)</td>
<td>13 (28.8%)</td>
<td>0.032</td>
</tr>
<tr>
<td>Fasciotomy</td>
<td>0 (0%)</td>
<td>6 (13.5%)</td>
<td>0.030</td>
</tr>
</tbody>
</table>

NIRS: Near-infrared spectroscopy, IABP: Intra-aortic balloon pump
The initial rSO2 value in the ischemia group was slightly lower (47.7 ± 19.1 vs. 50.5 ± 15.0), but there was no statistically significant difference between the two groups (P = 0.504). At the start of monitoring, patients in the ischemia group exhibited a higher difference in rSO2 between two legs (16.0 ± 11.7 vs. 9.9 ± 9.0), but this did not achieve statistical significance (P = 0.207). Patients in the ischemia group, on the other hand, exhibited a substantially bigger peak difference in rSO2 between the legs (33.9 ± 14.7 vs. 22.5 ± 9.0, P = 0.022), and the minimum rSO2 value was much lower (23.0 ± 9.2 vs. 44.1 ± 10.2, P < 0.001). The rate of IABP weaning (P = 0.153) and survival to hospital release (P = 0.105) was not significantly different between the two groups.

**DISCUSSION**

Patients with severe cardiopulmonary dysfunction are frequently treated with an IABP. The femoral artery is typically utilized for IABP insertion in adults. However, limb ischemia occurs in around 8% of individuals with IABP, resulting in significant morbidity or mortality. Acute compartment syndrome, a surgical emergency, can develop if limb ischemia progresses. A poor prognosis is frequently related with a delay in diagnosis. Furthermore, many centers may fail to disclose limb ischemia when the patient has no other chance of survival. Patients who did not survive 24 h were also removed because the majority of them died from multiorgan failure or uncontrolled bleeding, not IABP-related problems. This implies that the rate of limb ischemia is likely to be significantly higher than 8%. As a result, all IABP patients undergoing femoral artery cannulation should have their lower limb perfusion monitored to detect limb ischemia and prevent compartment syndrome.

Clinical assessment and Doppler pulse evaluation are commonly used to monitor lower limb perfusion. Critically, sick patients using IABP, on the other hand, frequently have a number of problems that render conventional monitoring measures ineffective. Severe pain and sensory loss are common clinical symptoms of limb ischemia. The use of sedatives and muscle relaxants in patients with IABP makes it difficult to notice these symptoms. For monitoring lower limb perfusion, regular assessments for clinical symptoms of limb ischemia — loss of palpable pulses, skin color change, calf muscle edema, and so on — are helpful. However, these symptoms could be the result of limb ischemia that has already developed. Although Doppler pulse evaluation is a common approach for detecting limb ischemia, it can be incorrect in patients with peripheral vasoconstriction or no pulse waveform at all. As a result, not all IABP patients who do not have a Doppler pulse are at risk of limb ischemia. In our study, only seven of 14 patients (50.0%) who lost Doppler pulse in the NIRS group had clinical indications of limb ischemia, whereas 15 of 22 patients (66.7%) in the control group did. Furthermore, limb hypo-perfusion can be undiagnosed for several hours using these intermittent monitoring approaches. Many investigations have found that irreversible nerve and muscle damage begin after 6 h of ischemia in the lower extremity. Muscle necrosis occurs during the first 3 h, according to more recent research. As a result, for a rapid detection of limb ischemia in patients on IABP, an accurate real-time monitoring system is necessary. The idea for employing NIRS to assess distal limb perfusion in IABP patients arose from a number of comparable studies for VA-ECMO patients.

The non-invasive technique of NIRS is used to detect tissue oxygen saturation in real time. The use of NIRS technology to assess brain oxygenation was approved for the 1st time. It is routinely used to keep an eye on the brain after heart surgery. It is currently also used to evaluate tissue oxygenation in other organs, especially for the diagnosis of the lower extremity compartment syndrome. In their study for patients on peripheral VA-ECMO. There was no significant difference in the frequency of distal perfusion in both groups (P = 0.435) in

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**Table 2: Outcome of NIRS group**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Ischemia</th>
<th>No Ischemia</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>9</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>49.7±22.3</td>
<td>62.8±14.2</td>
<td>0.172</td>
</tr>
<tr>
<td>Female</td>
<td>5 (57%)</td>
<td>15 (57%)</td>
<td>0.672</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>1.75±0.36</td>
<td>1.67±0.17</td>
<td>0.917</td>
</tr>
<tr>
<td>IABP duration (hours)</td>
<td>7 (77.7%)</td>
<td>7 (25.93%)</td>
<td>0.027</td>
</tr>
<tr>
<td>Significant drop of rSO2</td>
<td>9 (100%)</td>
<td>4 (14.81%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Reinsertion</td>
<td>9 (100%)</td>
<td>3 (11.11%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Initial rSO2</td>
<td>47.7±19.1</td>
<td>50.5±15.0</td>
<td>0.504</td>
</tr>
<tr>
<td>Initial rSO2 difference</td>
<td>15.0±11.7</td>
<td>9.9±9.0</td>
<td>0.207</td>
</tr>
<tr>
<td>Peak rSO2 difference</td>
<td>33.9±14.7</td>
<td>22.5±9.0</td>
<td>0.022</td>
</tr>
<tr>
<td>Minimum rSO2</td>
<td>23.0±9.2</td>
<td>44.1±10.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>IABP weaning</td>
<td>6 (66.6%)</td>
<td>24 (88.8%)</td>
<td>0.153</td>
</tr>
<tr>
<td>Survival to discharge</td>
<td>5 (57%)</td>
<td>21 (77.7%)</td>
<td>0.105</td>
</tr>
</tbody>
</table>

NIRS: Near-infrared spectroscopy, IABP: Intra-aortic balloon pump
their investigation. The NIRS group has a shorter mean
time to distal perfusion (19.6 ± 21.4 vs. 42.0 ± 69.0 h).
Fasciotomy was not performed in the NIRS group, but it was
performed in 13.9% of the control group (P = 0.040), which
is similar to our findings. In nine adult trauma patients with
compartment syndrome, Gentilello et al.14 compared NIRS
data with direct assessment of compartment pressures.
When NIRS was compared to compartment pressure at
the same specificity, they discovered that NIRS had a higher
sensitivity. Some researchers started using NIRS monitoring
in ECMO patients. The monitoring of brain and tissue
oxygenation in four infants on ECMO was described by
Papademetriou et al.7 In a cohort of adult ECMO patients,
Wong et al.8 used NIRS to assess cerebral and lower limb
perfusion. They developed care regimens for VA-ECMO
patients who had clinically substantial reductions in the
lower limb rSO2 levels. Significant occurrences were
defined as a decline in rSO2 values below 40 or by more
than 25% from baseline. If large reductions in rSO2 levels
continued, their approach included preventive fasciotomy.
Six of the 17 patients who had VA-ECMO had a clinically
significant decline (35.3%), and four of these six patients
required prophylactic fasciotomy to prevent compartment
syndrome (66.7%). Although we used a similar procedure,
we just used the first condition to keep things simple. The
NIRS group experienced a significant decline in rSO2
values in 15 patients (41.6%); however, it was regained in
three of these individuals due to therapy to enhance oxygen
supply to the tissues. The other 12 patients, on the other
hand, had to have IABP reinserted when their rSO2 levels
did not improve despite the earlier management efforts.
In the NIRS group, no patient developed compartment
syndrome that necessitated fasciotomy. The difference in
rSO2 readings between the legs is not included in the Wong
et al.9 methodology. However, we believe that it would be
additional factors for making an intervention decision, as
confirmed by our study, more research is needed.

As previously stated, limb ischemia affects roughly 8% of
people. To put it another way, a large number of patients on
IABP may not require any treatment to avoid limb ischemia.
Only 12 patients (33.3%) in the NIRS group required
reinsertion, while 23 patients (63.88%) in the NIRS group
had no ischemia-related effects, such as a decline in rSO2
values, even without any treatment. Reinsertion alone in
patients with a large decline in rSO2 values, we believe, may
be sufficient to prevent compartment syndrome. Although
some centers do not employ NIRS to evaluate lower limb
perfusion, we believe it should be considered standard of care
in IABP patients.

Limitation

Because our study was not randomized, the results could be
skewed by a variety of reasons. To further analyze our
findings, a randomized trial would be required.

CONCLUSION

We believe that NIRS monitoring is an effective and
accurate approach for detecting lower limb ischemia in
IABP patients. Its use could lead to the early correction of
perfusion deficits, as well as the avoidance of compartment
syndrome and limb problems. On IABP, the quality of
care and outcomes for critically ill patients could also be
improved.

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