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Real-Time Perfusion Monitoring in Hemodynamically Compromised Pediatric Patients Using Near-Infrared Spectroscopy During Fluid Resuscitation: A Hospital-Based Observational Study

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Abstract

Background: Near-Infrared Spectroscopy (NIRS) is a non-invasive modality that offers real-time insights into regional oxygen saturation (rSO_2), helping clinicians assess tissue perfusion in critically ill patients. This study evaluates the utility of NIRS in pediatric patients with hemodynamic compromise undergoing fluid resuscitation.

Methods: A prospective observational study was conducted at a tertiary pediatric ICU in India from July 2023 to February 2025. Pediatric patients (<18 years), excluding neonates, presenting with dehydration, hypovolemia, or shock were included. Cerebral ($CrSO_2$) and somatic (RSo_2) oxygen saturation were monitored using NIRS before and after fluid resuscitation. Additional parameters included sensorium, pulse volume, core-peripheral temperature gradient, lactate, pH, and renal function.

Results: A total of 168 patients were analyzed. Post-resuscitation, there was a significant improvement in $CrSO_2$ ≥95% (from 40.48% to 73.21%, p<0.001) and RSo_2 ≥95% (from 11.9% to 38.1%, p<0.001). Lactate levels <2 mmol/L increased from 48.21% to 70.83% (p<0.001), and palpable pulse volume improved from 54.17% to 79.76% (p<0.001). Significant changes were also noted in SBP percentile, urea levels, sensorium, and temperature gradient.

Conclusion: NIRS is a reliable, non-invasive tool for real-time assessment of perfusion in pediatric patients with hemodynamic compromise. Its integration into resuscitation protocols can enhance clinical decision-making and improve patient outcomes.

Keywords: Near-infrared spectroscopy, pediatric shock, fluid resuscitation, real-time perfusion, tissue oxygenation, $CrSO_2$, RSo_2.

Introduction

Effective monitoring of tissue oxygenation and perfusion in pediatric critical care is vital to guide timely interventions. Traditional methods such as pulse oximetry and blood pressure have limitations in detecting early tissue hypoperfusion. Near-Infrared Spectroscopy (NIRS) offers non-invasive, continuous monitoring of regional oxygen saturation (rSO_2) in various organs and may serve as a sensitive adjunct in managing shock and dehydration.

This study aimed to assess the clinical utility of NIRS in monitoring real-time tissue perfusion in children undergoing fluid resuscitation for hemodynamic compromise.

Methods

Study Design and Setting

Prospective, hospital-based observational study at Chhatrapati Shivaji Subharti Hospital, Meerut.

Inclusion Criteria

- Pediatric patients (<18 years, excluding neonates)
- Clinical signs of shock (tachycardia/bradycardia, hypotension, altered sensorium, core-periphery temperature difference >4°C)
- Requirement for fluid resuscitation

Exclusion Criteria

- Neonates
- Major congenital anomalies
- Breach of skin at probe sites

Monitoring and Intervention

NIRS (INVOS device) sensors placed on cranium ($CrSO_2$) and flanks (RSo_2) Baseline and post-resuscitation monitoring at 24 hours Simultaneous monitoring of vitals, sensorium (AVPU scale), lactate, pH, urea, creatinine, SBP percentile

Statistical Analysis

Paired t-test and Fisher's exact test were used to compare pre- and post-resuscitation parameters. A p-value <0.05 was considered statistically significant.

Results

Demographics

- Total patients: 168
- Age <1 year: 31.55%
- Male: 56.55%
- Most common weight range: 1–20 kg (61.9%)

Hemodynamic and Perfusion Markers

Parameter	At Admission	24 hrs Post-Resuscitation	p-value
SBP <5th percentile	4.17%	1.19%	<0.001
$CrSO_2$ ≥95%	40.48%	73.21%	<0.001
RSo_2 ≥95%	11.90%	38.10%	<0.001
Lactate <2 mmol/L	48.21%	70.83%	<0.001
Urea >20 mg/dL	81.55%	64.29%	<0.001
Alert Sensorium	36.31%	58.93%	<0.001
Palpable Pulse	54.17%	79.76%	<0.001

pH and creatinine changes were not statistically significant (p=0.059 and p=0.1003, respectively).

Discussion

This study validates NIRS as a practical, non-invasive modality for assessing real-time tissue perfusion in pediatric patients with dehydration and shock. The significant post-resuscitation improvements in rSO_2, lactate clearance, SBP, and sensorium reflect NIRS's sensitivity in detecting and guiding perfusion correction. Our results are in line with existing literature emphasizing the role of NIRS in monitoring cerebral and somatic oxygenation in pediatric critical care.

NIRS has particular relevance in pediatric populations due to their thinner soft tissues and the need to avoid invasive monitoring. Despite limitations such as cost and standardization, its value in guiding fluid therapy is evident.

Conclusion

NIRS provides a real-time, non-invasive method for monitoring cerebral and somatic oxygenation in hemodynamically unstable pediatric patients. This technology complements traditional vital signs and enhances clinical decision-making during resuscitation, supporting its broader use in pediatric intensive care units.

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