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Continuous non-invasive hemoglobin monitoring in pediatric trauma setting

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Trauma is the leading cause of death in pediatric patients, and hemorrhagic shock accounts for approximately 30% of deaths.[1 2] Hemodynamic instability as hypotension and tachycardia, tachypnea, and alterations in mental status represent the clinical signs of suspected hemorrhage.

However, the diagnosis in the pediatric population is a challenge because baseline blood pressure, heart rate, and respiratory rate values can vary significantly in different age groups. Indeed, in the pediatric population, the robust sympathetic response to hypovolemia is able to sustain normal blood pressure values until up to 25% of circulating blood volume has been depleted.[3]

Hemoglobin (Hb) monitoring is routinely performed with multiple blood samples for conventional laboratory Hb testing during hospitalisation. In the adult population, it was estimated that for every 1 mL of blood removed, Hb concentration and hematocrit dropped by 0.07 g/L and 0.019%, respectively.[4] Because in pediatric patients blood volume is less than in adults (estimated blood volume 80 mL/kg) and most analyzers are designed for standard adult tubes requiring a blood volume of 5–7 mL,[5] multiple blood samples can cause iatrogenic anemia. Moreover, in the case of intra-abdominal blood loss related to solid organ injury, the subtle decline in Hb caused by samples may contribute to additional imaging, testing, or blood transfusions.

Continuous non-invasive hemoglobin (SpHb) monitoring may represent a potential solution, facilitating the earlier detection of acute decompensation in pediatric trauma patients and allowing more rapid interventions.

SpHb is based on pulse CO-Oximetry and uses multiwavelength technology, providing continuous, non-invasive measurement of Hb. After passing through the measurement site, the light received by the photodetector generates electrical signals that, processed by advanced algorithms, provide an estimation of Hb based on its absorbance characteristics. To avoid external light interference, an opaque optical shield covers the probe. Figure 1 shows the device used to monitor SpHb.

SpHb monitor can represent a 'good' choice to detect the changes in Hb concentration in traumatized patients, especially pediatric, and provide evidence to support clinicians' early decision-making and transfusion planning.

SpHb showed acceptable accuracy and precision compared with standard central laboratory Hb measurements in the operating room. Furthermore, after the first Hb assessment by both methods, the clinician can follow the trend of variations in Hb using the non-invasive method.[6] However, literature data on the role of SpHb in pediatric trauma setting are lacking.

To the best of our knowledge, only two observational studies were performed on pediatric patients with trauma and assessed the clinical performance of SpHb compared with Hb values provided by laboratory tests.

Ryan *et al*[7] conducted the first prospective observational study to test the use of SpHb monitoring for the initial assessment of 114 pediatric patients with trauma. In this study, adequate values were obtained almost 90% of the time. In addition, the Hb values measured by the SpHb device demonstrated a strong correlation with laboratory testing results. The mean bias between SpHb and laboratory testing was −4.90 g/L, with the 95% confidence limits (95% CI) of the data falling between −29.00 and 19.00 g/L.

In 2018, Welker *et al*[8] performed a retrospective study to demonstrate whether SpHb represented an effective and safe method to monitor Hb concentration in pediatric patients with solid organ injury. The sample size consisted of 24 pediatric trauma patients, of whom 21 had evaluable data pairs. The bias between SpHb and laboratory Hb monitoring was 8.0 g/L, with 95% CI ranging between 39.40 and −23.30 g/L. Moreover, the authors

Figure 1 The figure shows the Masimo sensor (Masimo Rainbow Disposable Adhesive Sensor) and monitor (Masimo Radical-7, Masimo Corp, Irvine, California, USA). The sensor, placed on a finger hand, emits multiwavelength light. After passing through the measurement site, the light received by the photodetector generates electrical signals processed by advanced algorithms. The device provides an estimation of hemoglobin based on its absorbance characteristics. Furthermore, the device provides data about carboxyhemoglobin and methemoglobin concentration. SpHb, continuous non-invasive hemoglobin.

applied a criterion of ±10.00 g/L as an acceptable variation from the bias line. Based on this criterion, there were 24 outlier data pairs (51.1%).

Despite the encouraging results, these studies showed several limitations. First, the average Hb value was greater than 120.00 g/L.[7] As stated by the authors, no patients required operative or percutaneous vascular intervention for bleeding due to solid organ injury.[8] This suggested that patients did not show significant bleeding at the time of injury.

Second, pediatric age encompasses a wide range, from 0 to 18 years. In the presented studies, the average age was 9–11 years, suggesting that data are lacking for the younger population that may most benefit from this technology. Younger patients may not be eligible for SpHb use due to the limits of the machinery or the probe size. In detail, the SpHb probe is typically placed on a finger hand and covered to avoid external optical interference. On this aspect, Jung *et al*[9] analyzed SpHb in neonates with a wide range in weight (from 370 to 4270 g) admitted to the neonatal intensive care unit. The sensor was placed on the wrist of the neonate's right hand and covered with an opaque probe cover to eliminate interference from ambient light. They showed a similar bias to the mentioned studies (8.60±34.0 g/L).

Third, tachycardia, hypothermia, decreased oxygen saturation, and low Hb values suggest that the patient might have significant blood loss. All these factors are related to low-quality signal, causing a failure rate in reading SpHb of 11%.[7] In Phillips *et al*,[10] decreased oxygen saturation and body temperature were confirmed to be significant risk factors for an inability to obtain SpHb reading. Lastly, contrary to patients under general anesthesia, the spontaneous movements of the probe site can alter the SpHb reading.

In conclusion, literature data about the role of SpHb monitoring in pediatric trauma patients are scarce and inconclusive. Still, SpHb can represent a safe and valuable tool to traditional Hb monitoring, facilitating earlier detection of an acutely decompensating pediatric trauma patient and allowing for more rapid intervention. Furthermore, this technology can be applied within an established institutional clinical practice guideline to reduce the need for laboratory Hb monitoring and, consequently, the risk of iatrogenic anemia due to multiple blood samples.

Further well-designed studies are needed and should have the following purposes: (1) evaluate SpHb accuracy and precision in a large cohort of patients showing significant bleeding at the time of injury; (2) provide data in the younger pediatric population; (3) evaluate differences related to the probe site placement (ie, finger hand vs wrist vs toe); and (4) evaluate SpHb trend to guide proper blood product management in this population.

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