The Role of Cerebral Oxygen Saturation Measured by Near-Infrared Spectroscopy (NIRS) in Evaluating Pediatric Shock Resuscitation Outcome

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Introduction

Shock in children remains public health importance and becomes a significant cause of morbidity and mortality worldwide. Under-five children in developing countries are observed to have the highest mortality due to shock.[1] Approximately 6.2 million children die in the world each year because of diarrhea, pneumonia, malaria, measles, birth asphyxia, with proximate cause of death in almost all of these conditions is shock due to hypovolemia, hypoxia, ischemia, infection and anemia.[2-4]

Shock is a condition of circulatory dysfunction that results in acute energy failure and unmet metabolic demands of the body.[5] Hypoperfusion, decreased oxygen delivery to the tissues due to circulatory dysfunction, causes a shift from more efficient aerobic pathways to anaerobic metabolism, which results in lactate as the end product. Since several studies found shock patients with no lactate increase (alactatemia), the use of lactate as a biomarker of the resuscitation success still need further investigation.[6-9]

As an independent predictor of mortality, shock is characterized by a continuum of physiologic stages beginning with a systemic disturbance in tissue perfusion that may progress if not successfully treated, culminating in end-organ damage, irreversible shock, and death.[10] Additionally, shock survivors are at a higher risk of neurologic impairment.[11] To support a generic approach to resuscitation in sick children, the benefits should substantially outweigh risks. Meticulous patient monitoring is essential for early diagnosis and appropriate treatment in chidren with shock, and would assist in decreasing the risk of neurologic sequalae after the shock incidence.

The balance between oxygen delivery (DO_2) and oxygen consumption (VO_2) is considered as the mainstay concept of tissue perfusion in shock resuscitation.[12] Systemic venous oxygen saturation (SvO_2) reflects tissue perfusion better than any other parameter in monitoring resuscitation success.[13,14] However, its use is limited because it requires an indwelling catheter, is invasive, and can be associated with complications. Thus, a simple, accurate, and non-invasive means to measure regional oxygenation in the pediatric shock population could be beneficial to monitor resuscitation outcome.[12, 15]

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Near-Infrared Spectroscopy (NIRS)

Near-infrared spectroscopy (NIRS) is a non-invasive technology that continuously monitors regional tissue oxygenation. Originally used for assessment of oxygen saturation of the brain, its use has now been expanded to evaluation of oxygenation of tissues other than the brain. There is also growing evidence for the larger applicability of NIRS as an estimate of systemic venous saturation in correspondence with the adequacy of the circulatory status. New and promising advances may further this technology to become part of our standard armamentarium, in order to optimize patient care in daily anesthesia practice. The NIRS devices are usually portable, permitting bedside monitoring.

Near-infrared spectroscopy (NIRS) monitoring system is safe and easy to use in measuring tissue oxygenation.[16] It can provide continuous, real-time assessment of regional oxygen saturation (rSO_2) in a variety of tissues, including peripheral muscle, kidney, connective tissue, and brain.[17]

NIRS uses infrared light (700–900 nm) to monitor the tissue bed beneath the sensor containing small gas-exchanging vessels (arterioles, capillaries, and venules). In contrast to pulse oximetry which measures just the pulsatile arterial saturation, NIRS measures the mixed vascular oxygen saturation and is thought to roughly reflect 16% arterial and 84% venous saturation. In the optical window of 700–900 nm, light can pass easily through skin and bone, and most photon absorption is from haemoglobin. NIRS uses the Beer–Lambert law of tissue absorption. As light passes through the tissue, a certain amount of light is absorbed and scattered. Oxyhaemoglobin and deoxyhaemoglobin mainly absorb the light, while the other components (such as adipose tissue and fat) absorb to a lesser extent.[18]

NIRS gives an estimation of regional oxygen saturation (rSO_2) which is related to systemic oxygen saturation (SvO_2).[16,19] Li et al[20] investigated the correlations between rSO_2 or tissue blood oxygen saturation (StO_2) and $ScvO_2$, SaO_2, and PO_2, and explored the use of StO_2 as an indicator for shock. They found good correlations between StO_2 and $ScvO_2$ as a gold standart of tissue oxigenation (Figure 1). Also, even though cerebral NIRS monitoring during the perioperative management for children with congenital heart disease has been suggested to be standard of care, further study is needed to investigate the role of NIRS in pediatric patients with shock.[21-23]

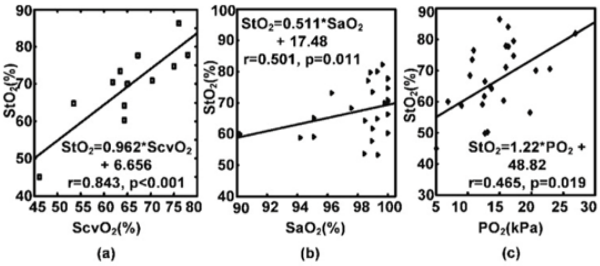

Figure 1. The Correlations Between StO_2 and Conventional Blood Oxygen Indices[20]

Measurement of skeletal muscle oxyhemoglobin levels by near-infrared spectroscopy (NIRS) offers a non-invasive method for monitoring adequacy of resuscitation in terms of normalizing tissue oxygenation. In an experimental study which included pigs undergoing hemorrhagic shock, it was showed that gastric tissue O_2 saturation, measured continuously with a prototype side-illuminating NIRS nasogastric probe, decreased rapidly, correlating with superior mesenteric artery blood flow.[14,24] In other human experiment it was found that cerebral cortex and calf muscle O_2 saturation measured by NIRS decreased in proportion to blood loss.[25]

Several studies have looked at the correlation between cerebral oximetry and SvO_2, jugular venous saturation, or mixed venous saturation in neonates and infants after cardiac surgery.[18] These studies found that cerebral SvO_2 correlated with SVC saturation (SvO_2) in paediatric cardiac surgical patients and NIRS was found to be a reliable trend detector and changes in cerebral SvO_2 correlated with changes to SvO_2.[26,27]

Conclusion

NIRS device can be used at the bedside for continuous monitoring of shock, and thus has the potential to become a clinical tool for shock management. The NIRS-measured rSO_2 has been verified by comparing to the conventional blood oxygen indices, especially $ScvO_2$. NIRS also has a role to play in the identification of low cardiac output together with serial lactate and mixed venous samples, prediction of long-term neurological outcome related to low cerebral oximetry intraoperatively and after operation in the intensive care unit. Finally, NIRS is likely to play an increasingly important role in the coming years in pediatric intensive care.

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