BMH MEDICAL JOURNAL

BMH Med. J. 2022;9(4):77-79. **Editorial**

Near-Infrared Spectroscopy Tissue Oximetry

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Keywords: Near-Infrared Spectroscopy, tissue oximetry, cerebral oximetry, renal oximetry, hepatic oximetry, muscle oximetery, NIRS

Near-Infrared Spectroscopy (NIRS) tissue oximetry is a novel noninvasive method used to evaluate tissue oxygenation. Though NIRS was first described more than 40 years ago, use of NIRS has increased significantly worldwide in the past decade [1]. NIRS is based on the fact that near-infrared light is able to penetrate biologic tissue and can obtain real-time noninvasive information on tissue oxygenation. Oxygenation-dependent light absorbing characteristics of hemoglobin is utilised in NIRS.

Cerebral oximetry has been studied most widely in the field of cardiac surgery [1]. This is because these surgeries can lead to significant neurologic complications and associated morbidity and mortality. NIRS can also monitor oxygenation in muscles. NIRS monitoring in muscles has found application in the field of sports science [2].

In cerebral oximetry, fiber optic sensors are positioned on each side of the forehead and covered by an opaque plastic patch to prevent ambient light [3]. Near infrared light can penetrate 25-30 mm into the head from the surface of the scalp. So, in adults with thicker skull, near infrared light penetration into the cerebral cortex is only 3-5 mm, while in neonates with a thinner skull, it can penetrate 10-15 mm [4]. In cerebral vasculature, 75% is venous and 25% arterial. Hence cerebral oximetry reflects venous saturation to a larger extent. Skin pigmentation can attenuate near infrared light and affect NIRS measurement [5].

In one device for cerebral oximetry, four different wavelength laser lights are emitted for maximization of accuracy. Reflected lights are captured by fiber optic sensors and interference from tissues outside the brain is subtracted. NIRS is being used in thoracic surgeries, aortic arch surgeries, carotid endarterectomy as well as abdominal and neurosurgical procedures. NIRS values have been correlated with reference values of cerebral tissue oxygen saturation derived from simultaneous radial artery and jugular bulb venous blood samples [3].

Oxygenation of the brain and kidneys can be monitored during interventions in the cardiac catheterization laboratory. In a study, it was found that when a cardiac arrhythmia develops, NIRS values fall simultaneously. When desaturation develops, NIRS falls 10-15 seconds earlier than pulse oximetry. On improving saturation, NIRS returns to earlier values 10-15 seconds before pulse oximetry readings. Thus, it may provide an early warning [6]. A survey of the Congenital Cardiac Anesthesia Society in 2021 among its members showed the usage of NIRS by 34.7% in the cardiac catheterization laboratory and 97.1% in cardiac surgery under cardiopulmonary bypass. Use in cardiac surgeries without

cardiopulmonary bypass was 76.3% and that in major non-cardiac surgeries was 39.3% [7].

Low renal NIRS tissue oximetry has been correlated with acute kidney injury after infant cardiac surgery. Prolonged low renal NIRS oximetry correlated with renal dysfunction, decreased systemic oxygen delivery and overall postoperative course in infants with congenital heart disease undergoing biventricular repair [8]. It has been suggested that kidney injury after cardiac surgery may be undetectable with assessment of creatinine alone and continuous monitoring of renal regional tissue oximetry may be more sensitive to important subclinical acute kidney injury [9].

NIRS monitoring has also been used for monitoring kidney and liver allograft perfusion. A systematic review found three studies concerning renal transplantation and two studies dealing with liver transplantation. Authors concluded that preliminary studies related NIRS monitoring to kidney and liver allograft perfusion both in adults and children. They suggested further investigation to establish the normal range of NIRS values and factors influencing NIRS monitoring [10].

How is NIRS different from pulse oximetry?

Pulse oximetry calculates the percentage of oxygenated hemoglobin in arterial blood. NIRS calculates changes in oxyhemoglobin and deoxyhemoglobin in the tissue under investigation, which contains both arterial and venous blood.

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