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Systematic review of clinical applications of monitoring muscle tissue oxygenation with near-infrared spectroscopy in vascular disease

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A B S T R A C T

Background: The use of wavelengths of the near-infrared region by near-infrared spectroscopy (NIRS) has been studied for several applications in vascular disease. This systematic review aims to explore the clinical relevance of monitoring muscle tissue oxygenation in vascular disease with NIRS.
Methods: A systematic search in PubMed, EMBASE, CINAHL and Cochrane databases was performed to identify clinical NIRS studies, published until April 2015, involving muscle tissue oxygenation in vascular disease.
Results: After screening 183 manuscripts, 38 studies (n = 2010) were included. Studies concerned peripheral arterial disease (PAD) (twelve studies, n = 848), compartment syndrome of lower extremities (seven studies, n = 205), deep vein thrombosis (DVT) (six studies, n = 429), buttock and lower extremity ischaemia in abdominal aortic aneurysm repair (six studies, n = 139), free flap failure (five studies, n = 354), and spinal cord ischaemia in thoracoabdominal aortic aneurysm repair (two studies, n = 35). Nine studies compared NIRS with gold standards and provided cut-off values. Four studies regarding chronic compartment syndrome and DVT determined higher sensitivity (78%–97%) than specificity (56%–76%). Two studies regarding PAD and buttock claudication determined higher specificity (87%–95%) than sensitivity (33%–88%). Three studies regarding free flap failure determined sensitivity and specificity of 100%.
Conclusion: We found sufficient evidence to use NIRS in clinical setting for assessment of chronic compartment syndrome of lower extremities, and as surveillance tool for detection of free flap failure. So far, clinical relevance of routine use of NIRS in other vascular applications is less clear. Cut-off values to discriminate are not yet unanimous and better validation has to be awaited for.

Contents

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Background

In the last decades, the use of wavelengths of the near-infrared region of the electromagnetic spectrum by near-infrared spectroscopy (NIRS) has been studied for several applications in vascular disease (Vardi and Nini, 2008; Cohn, 2007; Scheeren et al., 2012; Nielsen, 2014; Zheng et al., 2013; Murkin and Arango, 2009; Pennekamp et al., 2009; Hamaoka et al., 2011; Ferrari et al., 2011).

NIRS is a technique that uses near-infrared light to noninvasively monitor oxygen saturation of cerebral and muscle tissues. The technique has been first described by Frans Jöbsis in 1977 (Jöbsis, 1977; Jöbsis-Vandervliet, 1999). NIRS is based on the fact that 1) specific wavelengths of red and near-infrared light have the ability to penetrate through biological tissue, including bone tissue, 2) absorption of these specific red and near-infrared wavelengths are dominated by haemoglobin and 3) absorption varies between oxygenated and deoxygenated haemoglobin. Most commercially available NIRS optodes consist of a light source and two receiving photodetectors. The light source emits red light and near-infrared light through sampled tissue to its photodetectors. From the amount of light that is detected at the photodetectors, NIRS calculates the absorption of red and near-infrared light by oxy- and deoxyhemoglobin. Subsequently, the proportion of oxyhemoglobin can be determined. The penetration depth is approximately equal to half the distance between the light source and the detectors, resulting in a maximum penetration depth of approximately two centimetres (Homma et al., 1996). NIRS is a portable machine, which allows bedside monitoring of patients. Most NIRS monitors display tissue oxygen saturation (StO_2), and changes in concentration of oxyhemoglobin, deoxyhemoglobin and total haemoglobin. NIRS is already incorporated in daily vascular practice for monitoring cerebral oxygenation to detect stroke during cardiothoracic aortic surgery, and carotid endarterectomies (Zheng et al., 2013; Murkin and Arango, 2009; Pennekamp et al., 2009). NIRS is approved by the U.S. Food and Drug Administration for noninvasive, continuous monitoring of cerebral and somatic tissue oxygenation (http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K960614).

Recently, the application of NIRS measurements in cerebral oxygenation monitoring has been extensively reviewed (Nielsen, 2014; Zheng et al., 2013). Therefore, this review focuses on NIRS measurements of muscle tissue oxygenation in vascular disease. In 2008, Vardi and Nini (Vardi and Nini, 2008) reviewed the use of NIRS specifically for the evaluation of peripheral vascular disease. The current review provides an update of references regarding the use of NIRS measurements in peripheral vascular disease. Moreover, this review also explores the clinical role of NIRS in other types of vascular conditions. Although NIRS measurement of muscle tissue oxygenation is increasingly investigated, it has not yet been adopted in daily vascular practice. In this systematic review, we aim to explore the clinical relevance of monitoring muscle tissue oxygenation in several applications in vascular disease with NIRS.

Methods

Literature search

Two authors (RB and CU) independently performed a literature search to identify studies investigating NIRS in patients with vascular disease. PubMed database was searched for papers published until April 2015, using the following keywords: "Spectroscopy, Near-Infrared" [MeSH] AND "Vascular Diseases" [MeSH] AND "Tissues" [MeSH]. Free text words were also used instead of Mesh terms to avoid missing recent manuscripts that had not yet been given a Mesh label. EMBASE database was searched with the following terms: "Spectroscopy, Near-Infrared" AND "Vascular Diseases" AND "Tissues". CINAHL database was also checked for relevant studies with the following keywords: "Spectroscopy, Near-Infrared" AND "Vascular Diseases" AND "Tissue". The Cochrane database of Systematic Reviews was searched with the following words: "Spectroscopy, Near-Infrared".

Validity assessment

After identifying relevant titles, all abstracts were read and eligible manuscripts were retrieved. A manual cross-reference search of references of relevant manuscripts was performed to identify other studies not selected in the search. The methodological quality of the manuscripts was assessed using the methodological index for non-randomized studies (MINORS) quality score (Slim et al., 2003). MINORS assesses the methodology of both non-comparative and comparative studies. Non-comparative studies are evaluated on eight quality items. Comparative studies are evaluated on twelve quality items. For each quality item, a score of 0 indicates that it was not reported in the manuscript, 1 indicates that is was reported but inadequately, and 2 indicates that is was reported adequately. This results in a maximum MINORS score of 16 for non-comparative studies and 24 for comparative studies. In this review, a score ≤8 was considered poor quality

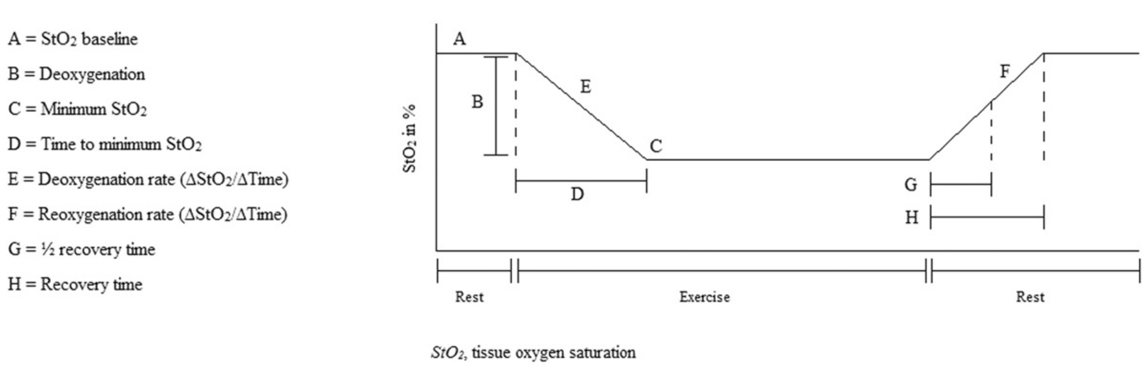

Fig. 1. Parameters of the NIRS curve during exercise.