Review Article

Innovating in Pain Assessment of the Critically Ill: Exploring Cerebral Near-Infrared Spectroscopy as a Bedside Approach

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Abstract:

Nurses play a crucial role in the evaluation and treatment of pain in the critically ill patient. This responsibility is all the more critical with this particular population because many may not be able to self-report their pain level and the typical behavioral signs of pain may be subtle or absent. According to recent recommendations, vital signs should not be used as primary indicators of pain but rather considered as a cue to begin further assessment. Other than vital signs, human brain reactivity to pain has been extensively studied with the use mainly of magnetic resonance imaging and positron-emission tomography. However, the use of these sophisticated methods may be unrealistic in the critically ill. Of interest to assessing these patients in a clinical setting is the noninvasive measurement of regional cerebral tissue oxygenation with the near-infrared spectroscopy (NIRS) technique. There are indications that NIRS is capable of detecting the cerebral hemodynamic changes associated with sensory stimuli, including pain. The objective of this review paper is to provide nurses with a better understanding of NIRS technology, including a review of the literature on functional studies that have used NIRS in critically ill populations, and how it could be used in both research and practice. Current NIRS techniques have well recognized limitations which must be considered carefully during the measurement and interpretation of signals. Thus, its clinical use is yet to be fully established. Nonetheless, cerebral NIRS technique as an approach to assess brain activity in response to pain should not be abandoned.

Pain is one of the most prevalent reported symptoms by the critically ill (Rotondi et al., 2002; Puntillo, White, Morris, Perdue, Stanik-Hutt, Thompson, & Wild, 2001). Because it is a powerful warning signal of imminent or ongoing tissue

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injury, it warrants urgent attention. Generally, health care providers rely on the patient's self-report of pain to provide effective pain management strategies. However, because many critically ill adults receive sedating agents, present altered levels of consciousness, or are mechanically ventilated during their stay in the intensive care unit (ICU), self-report may not be possible to obtain and the typical behavioral signs of pain may be subtle or absent. Consequently, clinical researchers have explored the use of associated signals, such as vital signs, metabolic markers (e.g., cortisol), and brain activity to identify and detect pain more objectively. As the use of neurodiagnostic techniques (e.g., magnetic resonance imaging [MRI], positron-emission tomography [PET], near-infrared spectroscopy [NIRS], etc.) becomes more common in pain research, an understanding of these complex and specialized technologies is crucial.

When the patient's self-report cannot be obtained, the use of behavioral indicators of pain is strongly recommended by the American Society for Pain Management Nursing (Herr, Coyne, McCaffery, Manworren, & Merkel, 2011). Among the few behavioral pain scales that have been developed for the purpose of detecting pain in critically ill adults, the Critical-Care Pain Observation Tool (CPOT) (Gelinas, Fillion, Puntillo, Viens, & Fortier, 2006) and the Behavioral Pain Scale (BPS) (Payen, Bru, Bosson, Lagrasta, Novel, Deschaux, Lavagne, & Jacquot, 2001) are the ones suggested in recent systematic reviews (Li, Puntillo, & Miaskowski, 2008; Pudas-Tahka, Axelin, Aantaa, Lund, & Salantera, 2009; Sessler, Grap, & Ramsay, 2008) as well as in clinical recommendations for pain assessment in the intubated or unconscious patients (Herr et al., 2011).

Although physiologic indicators (i.e., vital signs), such as heart rate, blood pressure, respiratory rate, and arterial oxygen saturation are often relied on by health professionals to evaluate pain in critically ill patients (Manias, Botti, & Bucknall, 2002), they should be used with caution. Indeed, changes in vital signs can be attributed to other sources of distress, physiologic conditions, homeostatic changes, and medications (Herr et al., 2006). Moreover, relying on vital signs can lead to misinterpretation of pain, because they have been shown to decrease the internal consistency of many multidimensional pain assessment instruments, supporting the notion that they may not be specific to the pain response (Carnevale & Razack, 2002; Gelinas & Johnston, 2007; Herr et al., 2011; Ista, van Dijk, Tibboel, & de Hoog, 2005; Ramelet, Rees, McDonald, Bulsara, & Abu-Saad, 2007; van Dijk, de Boer, Koot, Tibboel, Passchier, & Duivenvoorden, 2000; van Dijk, de Boer, Koot, Duivervoorden, Passchier, & Bouwmeester, & Tibboel, 2001). Therefore, vital signs should not be used as primary indicators of pain but rather considered as a cue to begin further assessment of pain (Herr et al., 2011).

The time has now come to look at other potential physiologic measures of pain. Other than vital signs, human brain reactivity to pain has been extensively studied with the use mainly of cerebral hemodynamic methods such as PET and functional MRI in both normal subjects and subjects with clinical pain conditions (Apkarian, Bushnell, Treede, & Zubieta, 2005; Treede, Kenshalo, Gracely, & Jones, 1999). However, the use of these sophisticated cerebral hemodynamic methods may be unrealistic in the critically ill. Of interest to assessing critically ill patients in a clinical setting is the noninvasive measurement technique of regional cerebral hemodynamics with NIRS.

Near-infrared spectroscopy can be used to detect subtle changes in the brain concentration of oxygenated (HbO_2) and deoxygenated hemoglobin (HbH), from which we may obtain the level of regional cerebral oxygen saturation (rSO_2) (Calderon-Arnulphi, Alaraj, & Slavin, 2009; Highton, Elwell, & Smith, 2010; Suzuki, Takasaki, Ozaki, & Kobayashi, 1999). These measured indicators are inferred to reflect changes in cerebral metabolism and perfusion. Though NIRS is still new in the field of pain, it has been recently demonstrated with NIRS that changes in the oxygenation levels of specific regions of the brain occur in response to painful stimuli in term and preterm infants (Bartocci, Bergqvist, Lagercrantz, & Anand, 2006; Slater, Cantarella, Franck, Meek, & Fitzgerald, 2008; Slater, Cantarella, Gallella, Worley, Boyd, Meek, & Fitzgerald, 2006). Similar pilot findings have also been observed in cardiac surgery adults (Gelinas, Choiniere, Ranger, Denault, Deschanmps, & Johnston, 2011). Thus, it would appear that there are new and exciting avenues for the assessment of pain response that may be more sensitive and perhaps more specific for certain populations, such as the critically ill. An additional feature of this type of neurodiagnostic technology, as compared to MRI and PET devices, is its portability directly to the bedside of these unstable patients. Although NIRS has been used in functional (fNIRS) studies, which refers to a method that monitors hemodynamic response to brain evoked activation following stimulation (Leff, Orihuela-Espina, Elwell, Athanasiou, Delpy, Darzi, & Yang, 2011), its use in assessing pain evoked response is quite recent. Therefore, further studies are necessary to determine the validity and the feasibility of these novel assessment technologies in different painful conditions and populations.

Because the use of NIRS in research and critical care clinical settings is increasing, and considering the nurse's key role in pain assessment, it is important