School of Biomedical Engineering, Science & Health Systems

Functional Near-Infrared Spectroscopy as a Monitor for Depth of Anesthesia

Executive Summary
1. Background

The proposed product is a medical device for evaluation of the depth of anesthesia awareness during surgery. The device is based on functional near-infrared (fNIR) technology and relies on optical techniques derived from the physical principles of light absorption and reflectance to detect changes in the hemodynamic response of the cortex to brain activation. A monitoring apparatus for objectively and continuously quantifying the depth of anesthesia of a patient during surgery would not only reduce the incidence of patient awareness (0.13%), but also would allow the anesthesiologist to administer the minimal dose of anesthetic required to achieve the desired depth of anesthesia. The proposed system is intended to be utilized in any settings where sedation is given. As many as 95 million patients annually in the United States undergo procedures for which anesthesia depth monitoring would prove useful, thus affording a potentially large market.

The fNIR Depth of Anesthesia Monitoring Technology is available for licensing from Drexel University now. See Paragraph 9 for contact information.

2. Product

What unmet medical need does the product address?

Awareness under general anesthesia is a rare condition that occurs when surgical patients become conscious, or awake, and can recall events or conversations that happen in the operation room. Less commonly noted is excruciating pain which may accompany unintended awareness during general anesthesia. When using other kinds of anesthesia, such as local or regional anesthesia with sedation, it is expected that patients may have some recollection of the procedure which is neither expected nor desired under general anesthesia. Studies report that approximately 0.13% of anesthesia awareness incidences at medical institutions, predicting 26,000 cases yearly in the United States occurred during general anesthesia. Despite this is rare event, even one incident is important to the clinician who recognizes that this can be a distressing or traumatic experience for the patient and can leave a lifetime of residual emotional and psychological problems ranging from sleep disorders, daytime anxiety and post-traumatic stress disorder.

Prevention of awareness during anesthesia in a non-paralyzed patient requires only an alert anesthesia provider. There has been interest in developing sophisticated and automatic depth of anesthesia monitors that can continuously and reliably monitor the anesthesia state during a surgical procedure. To date, such devices have largely been based on the measurement of electrophysiological signals such as electrocardiographic (ECG) signals, electroencephalographic (EEG) signals, auditory and somatosensory evoked potentials, and craniofacial electromographic (EMG) signals. All of the above biophysiological parameters involve measurable electric currents, whereas the functional near-infrared (fNIR) technology uses biological parameters (hemodynamic variables) which are not mediated by measurable electric currents. A monitoring apparatus for objectively and continuously quantifying the depth of anesthesia of a patient during surgery would not only reduce the incidence of awareness, but also would allow the anesthesiologist to administer the minimal dose of anesthetic required to achieve the desired depth of anesthesia. Furthermore, since most of the opioids have direct effect on hemodynamic response through neuro-vascular coupling, it would be highly advantageous to have a device and a method for monitoring a patient's depth of anesthesia based on hemodynamic changes rather than based on standard electrophysiological techniques.

What Technology is the Product based on?

The product is a medical device for evaluation of the depth of anesthesia awareness during surgery. The device is based on functional near-infrared (fNIR) technology and relies on optical techniques derived from the physical principles of light absorption and reflectance to detect changes in the hemodynamic response of the cortex to brain activation. fNIR uses near infrared spectroscopy to continuously track hemodynamic and thereby metabolic changes in the brain. Oxygenated and de-oxygenated hemoglobin levels of cerebral blood are measured independently and continuously. These metrics have been correlated with neural activity by numerous studies and provide a map of cognitive function (an optical topograph). Assessment for depth of anesthesia is based on our ongoing studies in measuring level of brain activation of patients under anesthesia in response to stimuli such as sensory effects in operating room, pain, pharmacological agents, etc.
Drexel's Optical Brain Imaging group has been at the forefront in the development of portable and wireless fNIR systems, clinical technology validation as well as in the development of signal processing of fNIR including noise and artifact removal. The team has already been working on design of various versions of the fNIR systems tailored to specific clinical and nonclinical applications, such as neurorehabilitation, brain computer interface for locked-in patients, cognitive function monitoring for unmanned aerial vehicle (UAV) ground control operators, brain hematoma detection, etc.

Who Owns the Intellectual Property Rights on the Technology?

The core fNIR IP is secured from Dr. Britton Chance through an agreement with Drexel University: US6397099 Non-invasive imaging of biological tissue, US6272367 Examination of a biological tissue using photon migration between a plurality of input and detection locations, US5853370 Optical system and method for non-invasive imaging of biological tissue, US5792051 Optical probe for non-invasive monitoring of neural activity. The depth of anesthesia monitoring IP is protected by U.S. provisional patent application 61/101,671, “Functional near infrared spectroscopy as a monitor for depth of anesthesia”. This patent application provides extensive coverage of the technology and owned by Drexel University.

3. Market Size and Potential

Who are the Customers and what is the Potential for this device?

A monitoring apparatus for objectively and continuously quantifying the depth of anesthesia of a patient during surgery would not only reduce the incidence of patient awareness (0.13%), but also would allow the anesthesiologist to administer the minimal dose of anesthetic required to achieve the desired depth of anesthesia. The proposed system is intended to be utilized in any settings where sedation is given. As many as 95 million patients annually in the United States undergo procedures for which anesthesia depth monitoring would prove useful, thus affording a potentially large market. During general anesthesia, clinicians use multiple ways to ensure that the patient receives sufficient amount of anesthetic and remain unconscious by relying on their clinical experience, training and judgment. The staggering legal costs (~$20 per surgery) combined with cost savings from reduced anesthetics usage have proven to be a very strong driver for hospitals to adapt such technologies.

4. Competitive Landscape and Advantage

Two devices directly purport to monitor the depth of anesthesia: the BIS monitor (Aspect Medical Systems) and the A-line Auditory Evoked Potential Index (AAI, Danmeter). The BIS utilizes a proprietary algorithm that combines measurements of patient movement with the information from Fourier-transformed EEG epochs to a number between 0 and 100. Use of adjunctive opioids during both general anesthesia and conscious sedation cause these devices to underestimate the depth of anesthesia. Since most of the opioids have direct effect on hemodynamic response through neuro-vascular coupling, it would be highly advantageous and reliable to have the fNIR system for monitoring depth of anesthesia based on hemodynamic changes rather than based on EEG techniques. Despite its deficiencies and lack of trust by anesthesiologists, Aspect has been able to create a $200M market for Anesthesia Awareness Monitoring. With predicted performance improvements, the size of the market can grow substantially.

What are the advantages of this technology?

The Joint Commission, which inspects hospitals in the US, has made awareness during general anesthesia a “sentinel event.” (If you’re a hospital, a practitioner, or a patient, you definitely want to avoid these). Although much desired and discussed, the commercially available Anesthesia Awareness Monitoring platforms have not
been accepted for widespread use because of the worries that they could give anesthesiologist a false sense of security. By improving the correlation between the monitor's score and awareness, this technology will offer the opportunity to capture a strong market share, increase the size of the market while improving the standard of care by reducing the unnecessary and costly use of anesthetics.

5. Regulatory

Marketing of any medical devices in the US is regulated by the US FDA, CDRH division. The technology will most likely go through the FDA’s Pre-market Notification 510(K) process. In this process, we will demonstrate that our device is safe and effective. The FDA guidelines state, “A 510(k) application demonstrates that a new device is substantially equivalent to another device that is legally on the market without a Pre-Market Approval (PMA).” There are other monitors for the depth of anesthesia and there are a lot of FDA approved NIR systems for various brain related applications (monitoring of cerebral oxygen, for example).

6. Reimbursement

Due to the pioneering work of Aspect Medical, monitoring awareness of patients is a reimbursable procedure. Furthermore Aspect’s studies showed that by monitoring awareness hospitals were able to reduce expenses on sedatives by 40-60%, depending on location (OR vs. ICU), or $150 saving per day in the ICU.

7. Development status

The basic research and validation of fNIR technology was published by us in the last several years [Neuroscience Letters, 416:55-60, 2007, IEEE Engineering in Medicine and Biology, 26(4):38 – 46, 2007, IEEE Engineering in Medicine and Biology, 25(4):54 – 62, 2006, IEEE Trans. on Neural Systems and Rehabilitation Engineering, 13(2):153-159, 2005]. The proof-of-concept study of the anesthesia monitoring application was completed on 26 patients. The aim was to investigate robust physiological marker(s) to distinguish two anesthesia stages, namely deep and light anesthesia based on the fNIR measures. The fNIR sensor was placed and a preliminary signal was obtained prior to administration of any medication. During deep anesthesia, deoxy-Hb averages displayed a very slow rate of change (3.4%). In contrast, as the patient emerges to wakefulness, this rate of change increases drastically (48%). [Kurtulus Izzetoglu, Neural Correlates of Cognitive Workload and Anesthetic Depth, PhD Thesis, 2008]. We have also been able to improve the sensors with design that are tailored for the patient and operation room settings. A set of noise removal procedures have been developed on the raw light intensity measurements before extracting the hemodynamic signals. Performance of these algorithms was tested on the data collected during the pilot study.

8. The Team

Kurtulus Izzetoglu, Ph.D. is a research assistant professor in the School of Biomedical Engineering at Drexel University. Subsequent to five years of industrial experience, he joined the functional optical imaging research team at Drexel University and has worked on development of the optical brain imaging systems (fNIR). His current research focuses on human performance assessment and intra-operative awareness during surgery using the fNIR technology.

Jay Horrow, M.D. MS, FAHA is a professor in Anesthesiology, Pharmacology & Physiology at Drexel University College of Medicine and a professor in Epidemiology and Biostatistics at Drexel University School of Public Health. Dr. Horrow supervises clinical research studies to evaluate fNIR’s clinical use in measuring the depth of anesthesia.

Kambiz Pourrezaei, Ph.D. is a professor in the School of Biomedical Engineering Science & Health Systems at Drexel University. A major focus of Dr. Pourrezaei’s research has been in developing portable and wireless
fNIR devices for brain monitoring. His research also involves the use of micro and nanotechnology for studying the attachment of protein and cells to surfaces of biomaterials.

Banu Onaral, Ph.D. is H. H. Sun Professor of Biomedical Engineering and Electrical Engineering at Drexel University. Dr. Onaral's academic focus, both in research and teaching, is centered on information engineering with special emphasis on complex systems and biomedical signal processing in optics and ultrasound. She has led major research and development projects, in particular fNIR technology development and its applications to various areas, such as human performance assessment, depth of anesthesia monitor, brain computer interface, etc.

9. Further information and licensing inquiries

For licensing information please contact:

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