High-Density Transcranial Direct Current Stimulation (HD-tDCS): Skin Safety and Comfort

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Transcranial Direct Current Stimulation (tDCS) is a non-invasive procedure where a weak electrical current (260 μA to 2 mA) is applied across the scalp to modulate brain function. tDCS has been applied for therapeutic purposes (e.g., addiction, depression, mood and sleep disorders) as well as cognitive performance enhancement (e.g., memory consolidation, motor learning and language recall). Despite safety and cost advantages, the developments of tDCS therapies have been restricted by spatial targeting concerns using existing two-channel systems. We have developed novel technology for High-Density tDCS (HD-tDCS) that improves spatial focality. Integral to the system are specialized HD-tDCS electrodes ($<$12 mm diameter) which allow safe and comfortable passage of current across the scalp. Here we evaluate a range of HD-tDCS electrode designs for comfort as well as test electrode over-potential, pH, and temperature. Passing 2 mA current for 22 minutes, both anodal and cathodal stimulations were evaluated independently. Subjective sensation during forearm stimulation was evaluated in 8 subjects. The benefits of skin electrical or chemical pre-conditioning were tested. Conductive Rubber, Ag, AgCl, pellet electrodes and AgCl ring electrodes were evaluated in combination with salty gels (Signa and CCNY4) and nominally electrolyte free gel (Lectron). The use of AgCl ring electrodes in combination with CCNY4 gel resulted in no significant pH, temperature, or over-potential changes under either polarity stimulation and was well tolerated by subjects. HD-tDCS may thus be applied with 2 mA per electrode for up to 22 minutes without skin irritation. Moreover, skin pre-conditioning can eliminate sensation such that HD-tDCS can be applied in a blinded fashion and under a broad range of therapeutic and performance enhancement applications. Our HD-tDCS system allows non-invasive, safe, and targeted modulation of selected cortical structures for electrotherapies that are individualized as well as optimized for a range of therapeutic applications.

Intra-Operative Pulse Oximetry

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Bowel resection surgery is a commonly performed operation used to treat a variety of gastro-intestinal tract disorders, including cancer. The surgery entails excising the diseased portion of intestine, and then creating a surgical anastomosis, or reattachment of the remaining ends. One of the major complications following bowel resection surgery is breakdown or leakage from the anastomosis, which affects 20% of patients, with an associated 10-15% mortality rate. The surgical creation of anastomosis frequently involves dividing blood vessels and can introduce unrecognized twists and tension on the intestine. As a result, the blood supply to the site of anastomosis is often hampered, limiting the oxygen supply that is essential for adequate anastomotic healing. We are proposing a device that enables surgeons to obtain real-time feedback on local tissue oxygen saturation (SpO2) during operative procedures. Such data will not only help surgeons realize any bowel oxygenation compromising maneuvers, but also help perform an anastomosis at the site of maximal tissue oxygenation, thus minimizing the occurrence of postoperative anastomotic leakage and improve patient outcomes. This report details the specifications, fabrication, operation and performance of a handheld wireless pulse oximeter suitable for the intraoperative measurement of tissue SpO2 during bowel surgery. The device adapts principles and technology developed for non-invasive pulse oximetry, and introduces tissue interface, physician tools, and signal processing algorithms for intra-operative application. The handheld device includes local display of SpO2 level ($<$1 s refresh) at the contacted tissue, and signals the operator on degraded signal quality/faults. An onboard micro-controller digitizes and processes signals transduced through a controlled LED array. Signal processing and display parameters were optimized for operating room conditions. A disposable functionally-transparent cover provides both device and tissue protection. Through serial or Bluetooth wireless transmission (250 Kbps), SpO2 and pulse signals can be processed on a PC or operating room VI. The incorporation of a pressure sensor to increase accuracy and robustness is explored. The device was validated intra-operatively on rodent and bovine surgical models.