Optical Assessment of Blood Flow in Burned Tissues: Implications for Management

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11:30 – 11:45 am

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Objective:

Upon completion of the lecture, attendees should be better prepared to:

- Describe the capability of a noncontact optical diffuse correlation spectroscopy device to measure blood flow in burned tissues.

Abstract:

Introduction: The ability to assess burn wound perfusion, integral to the ability to heal, may guide treatment options and provide prognosis for healing. We performed a pilot study to evaluate the feasibility of a novel noncontact optical imaging device to assess 3-dimensional blood flow. The burn wound is in constant flux with three dimensional changes in blood flow intimately related to epithelialization and healing. The classic description of the tissue injury by Jackson (1952) was based on the effect of the burning agent on the blood flow described as “zones of injury.” We now know that the intermediate “zone of stasis” can change, both in surface area, and three dimensional volume, subject to changes in perfusion, inflammation, oxygenation and ischemia/reperfusion.

Clinical observation often depends on a day to day assessment of healing by color, capillary refill, temperature, turgor, and dermal bleeding, which are subjective and unreliable, which requires experience and can require some time before a decision is made for operative intervention. Currently available methods of imaging this region continue to have limitations. Techniques that have been studied for the prediction of tissue ischemia and subsequent necrosis, including fluorescence angiography (invasive) and Doppler flowmetry (superficial blood flow). Intraoperative fluorescence angiography requires intravenous injection of fluorescent dyes to assess blood perfusion on the skin surface (1 to 2 mm depth), which may not adequately reflect blood flow throughout the wound depth. Also, fluorescence angiography depends on a time window following dye injection as well as excitation light intensity, which may vary over subjects leading to measurement variability. Emerging optical techniques for acquiring quantitative blood flow measurements in wounds include conventional laser speckle contrast imaging (LSCI), hyperspectral imaging, laser doppler imaging and the more recent near-infrared (NIR) diffuse correlation spectroscopy/tomography (ncDCS/DCT). Each of these techniques have key issues that limit its clinical application. LSCI uses wide-field illumination and CCD detection of spatial speckle contrasts to achieve rapid high-resolution 2D mapping of blood flow distributions in superficial tissues with a depth less than 1 mm. Hyperspectral imaging involves large datasets, requiring complex computer based predictive models. Currently available methods to measure tissue oxygenation often require a probe in contact with the tissue.

Our biomedical engineering collaborators have developed a novel, noninvasive (dye-free), noncontact, fast, cost-efficient, high resolution, portable, CCD-based speckle contrast diffuse correlation tomography (scDCT) technique for 3-dimensional (3D) imaging of tissue blood flow. This technology has been successful in quantifying blood flow and predicting necrosis in reconstructive flaps and mastectomy skin flap. We performed a pilot study in patients whose burns wounds were felt clinically to need excision and grafting.

Methods: A novel, noninvasive (dye-free), fast, cost-efficient, high resolution, noncontact speckle contrast diffuse correlation tomography (scDCT) technique, has been developed to provide a perioperative 3-dimensional (3D) imaging of blood flow throughout the entire region/depth of a wound. A Galvo mirror is used to deliver near-infrared light (830 nm) from a long coherence laser diode to different source positions. The movement of red blood cells in the measured tissue produces a continuous fluctuation in a speckle pattern, which is captured by an EMCCD (electron-multiplying charge-coupled-device). A blood flow index (BFI) can be extracted from the spatial distribution of diffuse laser speckles detected by the EMCCD. The normalized boundary blood flow data are then inserted into a modified NIRFAST program (http://www.dartmouth.edu/~nir/nirfast/) for tomographic reconstructions. Validation of scDCT by our laboratory has been shown in the detection and characterization of flow relative to the background using tissue phantoms, in vivo validation of hyperemic response during forearm cuff occlusion, as well as intraoperative imaging of mastectomy skin flaps.

Measurement Protocol for Burn Wounds Using scDCT. Three patients with full thickness burn wounds and scheduled to undergo burn wound excision and grafting were chosen in this first phase study to validate the scDCT technology. A region of interest (ROI) was chosen for blood flow measurement prior to wound excision and grafting. The same ROI was studied on postoperative day 5 when the graft was clinically vascularized. Normalized blood flow values from preoperative and postoperative measurements were compared.

Results: Three burn patients were imaged using scDCT. Reconstructed 3-D blood flow distribution images show spatial variations in each individual before and after the treatment. The normalized blood flow values (relative to each individual normal blood flow) over the reconstructed tissue volume range from 0.84 to 1.38. Relatively lower baseline blood flow levels before the treatment were found around the wounded tissues, which was consistent with the visual observations of the tissue surfaces of ROI.

Conclusions: Pilot studies using scDCT demonstrate the feasibility and safety for noncontact 3D imaging of blood flow distributions in burn wounds. Using a noncontact optical probe allows measurements to be taken over the target tissue without interfering with sterility of the surgical field at the bedside or in the operating room. scDCT shows promise with the ability to provide objective data regarding burn wound perfusion, thus providing surgeons early identification of compromised and ischemic tissue volumes. We are currently expanding this study to include additional patients with a varying depths of burn injury.

References and Resources:

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Jayachandran M, Rodriguez S, Solis E, et al. Critical review of noninvasive optical technologies for wound imaging. Adv Wound Care 2016:5(8):349-359.
Huang C, Zhao M, Irwin D, Agochukwu N, Wong L, Yu G. Noncontact 3-dimensional Speckle Contrast Diffuse Correlation Tomography of Tissue Blood Flow Distribution. Submitted to IEEE Transactions on Medical Imaging.

Disclosure:

Robert W. Edmunds – No Relevant Financial Relationships to Disclose
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Lesley Wong – No Relevant Financial Relationships to Disclose