The Use of Near-Infrared Spectroscopy in Assessing Viability and Preserving Skin Flaps in Traumatic Skin Tears: A Prospective Case Series

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BACKGROUND

Tissue flaps are common. Historically, if tissue flaps look dusky or start to fail, the whole flap is generally removed creating a larger wound and a delay in healing. The anatomically displaced tissue created by a flap being removed does not allow the flap to act as a skin graft for the areas of tissue that are still viable. This is largely due to imprecision or inability to determine flap viability which has historically been tied to physician gestalt and visual inspection. A reliable method of assessing flap viability beyond visual inspection would be of immense benefit and likely would preserve more flaps and improve outcomes. One possible method of assessing flaps is non-contact near-infrared spectroscopy (NIRS) which has been used extensively in wound care, surgical applications and determination of skin flap viability.

METHODS

This was a single center prospective cohort study performed between June 2023 and July 2024. Patients that presented with a flap were clinically assessed for viability of tissue. After clinical assessment, patients were imaged with NIRS (SnapshotNIR, Kent Imaging Inc.) to determine viability of tissue. Tissue exhibiting deoxy-hemoglobin values equal to or exceeding 0.5 were deemed non-viable and sharply debrided to prevent infection risk. Any tissue exhibiting StO_2 values equal to or exceeding 50% were deemed viable and were approximated to normal anatomical position to continue monitoring at subsequent visits. To determine viability of flaps, tissue with a deoxyhemoglobin value greater than 0.5 or an StO_2 value of less than 50% were classified as non-viable. Non-viable areas of tissues were excised.

Results

Fourteen flaps were studied in eleven patients. Mean age was 71 years old with the youngest patient 26 years old and the eldest 94 years old. Eight out of eleven patients had significant comorbidities ranging from history of cancer to congestive heart failure and type 2 diabetes mellitus. Figure 1 demonstrates a case of a successful flap conservation and healing process. Flaps that failed to heal either had a component of contamination prior to initial presentation or a component of venous disease which led to excess tension and maceration of flap tissue (see Figure 2 as an example). However, history of significant disease did not seem to correlate strongly with outcome of flap healing. The oldest patient studied was a 94-year-old male with a history of abdominal aortic aneurism, anemia, coronary artery disease, stage 3 chronic kidney disease, and type 2 diabetes mellitus. He presented with a traumatic flap to his left radius. NIRS was performed and demonstrated values consistent with eschar and nonviable tissue along the distal margin of the flap. This was debrided, and the remaining viable flap was approximated to normal anatomical position and steri-stripped. On the next visit 6 days after initial presentation the flap had begun significant reepithelization to reattach to surrounding skin. The wound was reassessed, and no non-viable tissue was detected. 16 days after initial presentation the wound was deeply healed with 100% coverage and minimal residual inflammation detected by NIRS. The median wound cross-sectional area without the preserved flap (9.1 cm^2) was larger than with the preserved flap (1.6 cm^2; P = 0.0001). The relative reduction in wound size with preserved flaps was 78% and the absolute reduction in wound size with preserved flaps was 6.2 cm^2. The median time to heal with preserved flaps was 22 days compared to 28-42 days in the literature (P = 0.82).

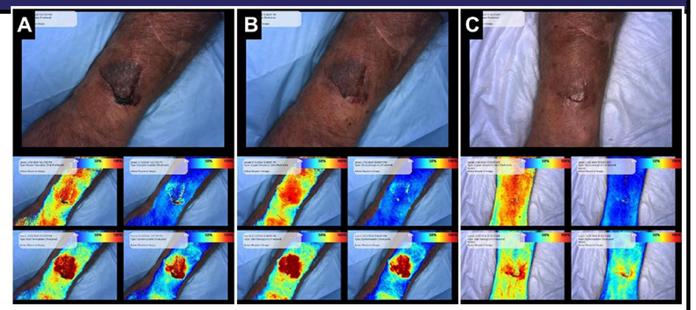

Figure 1: Panel A is from initial visit with traumatic flaps on the left upper extremity. Near-infrared spectroscopy identifies non-readable tissue at distal margin of flap (i.e., hematoma) but there is sufficient oxyhemoglobin that is conducive to healing throughout the entire flap. Panel B shows after the hematoma was debrided and the flap was reassessed clinically and with near-infrared spectroscopy. Images support near complete removal of non-viable tissue on distal margin of wound and oxygenated hemoglobin is still sufficient to promote healing. Following this image, the flap was anatomically approximated, tacked down with steri-strips, and covered with mepilex border dressing. Panel C demonstrates follow-up two weeks later after the flap was fully epithelialized. Re-assessment with near-infrared spectroscopy indicates that oxygenation values are similar to surrounding tissue, indicating that healing is deeply healed. Patient was then discharged from the wound care clinic.

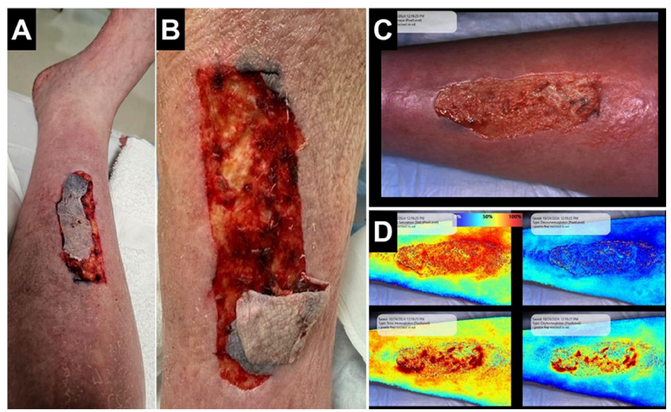

Figure 2: Example of a decision made to not attempt to salvage a tissue flap resulting in a larger wound. Panel A demonstrates who the patient presented with the tissue flap no longer covering the wound bed area. Panel B is a closeup of the wound bed partway through the removal of the tissue flap when the decision was made to not attempt to salve the tissue flap. Panel C is a subsequent follow up image where the tissue bed has increased without having proper coverage. Panel D demonstrates the hemoglobin view. The near-infrared spectroscopy readings indicate ample oxygenation and perfusion within the wound bed.

DISCUSSION

Preserved flaps significantly reduced the cross-sectional area of wounds. While underpowered and not statistically significant, there was a reduction in healing times with preserved flaps compared to the majority of reported healing times within the literature (i.e., 4.3 weeks). Patients often present to the emergency room with traumatic flaps which are promptly removed. This removal of any healthy tissue is a net loss as it provides a growth matrix for new tissue growth while also providing innate immune protection to infection by covering the wound. As such, preservation of flaps offers patients benefits beyond healing times. While we recognize that common practices and standards support the complete removal of traumatic flaps when presented, we contest that practice standards need to be updated to prevent unnecessary re epithelial formation that could be achieved with preservation of existing flaps.

CONCLUSION

Preservation of traumatic flaps significantly reduced cross-sectional wound areas while protecting against infection, providing tensile strength, and reducing the amount of re epithelialization required for wound closure. Times to heal were reduced by ~1 week when preserved flaps were used compared to average times to heal within the literature. Near-infrared spectroscopy was a significant aid in determining viability of flap tissue that allowed the preservation of tissue and reduced healing times. Clinical standards should be updated to utilize NIRS or other modalities to assess tissue viability and thereby preserve tissue and reduce times to heal in patients with wounds.