Key Points
1. The author was able to predict wound healing trajectories based on initial tissue oxygen saturation readings.
2. Tissue oxygen saturation readings were taken directly from the wound bed.

Introduction
The most common etiologies for wounds encountered in the outpatient clinic are venous insufficiency, diabetic neuropathy, and arterial insufficiency. Populations within each of these etiologies have circulatory defects that place these patients at risk for delayed wound healing and other negative conditions. Although venous etiology patients have a reported incidence of arterial insufficiency from 15% to 30% (1), ischemic and neuroischemic diabetic wounds constitute 15% and 50% of that population respectively (2). The diabetic foot wound patient is of great concern, because of their high risk for amputation and subsequent mortality (3). Lacking accurate and timely assessment of the ischemic condition risks delaying adjunctive treatments (such as hyperbaric therapy or vascular intervention) that could correct a patient’s negative healing trajectory. Considering these needs the author initiated a single cohort retrospective study with Multispectral Oximetry Imaging* to understand how tissue oxygen saturation readings relate to perfusion and healing trajectories.

The review was completed with a multispectral oximetry imaging device which takes multiple images in the near-infrared (NIR) spectrum of light and calculates the tissue oxygen saturation, pixel by pixel, and displays the resultant image. The NIR light harmlessly passes through the skin and is reflected off the capillaries which supply blood to the tissue. The short wavelength region of NIR light has two key features that make it useful for measuring the viability of living tissue. First, NIR light is weakly absorbed by tissue and therefore can penetrate more deeply into the tissue than visible or ultraviolet light. Second, the main absorbers of near infrared light are hemoglobin and water. Most importantly, the wavelength dependent light absorption of hemoglobin differs if it is carrying oxygen from when it is not. Thus by measuring near infrared light reflected back from tissue, the presence or absence of hemoglobin and the amount of oxygen it contains can be detected.

Methods
Images of the patient’s lower extremity or foot wounds were taken using Multispectral Oximetry Imaging. The six patient cohort consisted of two diabetic and four venous etiology wounds. One of the venous wounds also had an arterial co-morbidity. The anatomical area and amount of the lowest tissue oxygen saturation were recorded. Wound measurements and the general condition of the periwound were also noted. Each of these patients completed standard of care based on the given etiologies from the initial study to week six (+/- 3 days). This is with the exception of Patient 3 whose final measurements were recorded 4 weeks from the initial study. Previous tissue oxygenation saturation readings were then compared to the trajectory of wound healing from week one to week six.

The Multispectral Oximetry Imaging device was calibrated and then positioned 16 inches from the desired observation area. Once aligned, the image was taken and the patient’s circulatory status was defined by selecting points of the image. Selected results and the corresponding images were saved.

Results
The author found that this non-contact imaging device was able to read tissue oxygenation directly at multiple sites of the wound bed. Results from these readings
provided important details in predicting wound healing trajectory.

**Patient 1**

Patient diagnosed with venous insufficiency and arterial insufficiency at the right anterior lower leg. Patient’s wound bed oxygen saturation of 21% had a 22% percent reduction in wound volume over a 6 week period of time. The ability of the device to show multiple readings of oxygen saturation at the wound bed is beneficial in understanding why one portion of the wound improved to some degree as another portion of the wound bed had a reading of 46%. Oxygen saturation to the periwound was elevated at 46% to 55%.

Measurements: 03/11/14 4.2 x 1.5 x 0.3
04/29/14 3.5 x 1.4 x 0.3 22% Smaller

**Patient 2**

Patient diagnosed with venous insufficiency located at the right medial lower leg. Patient’s wound bed oxygen saturation of 23% had an increase in wound volume by 43% over a 6 week period of time. This patient’s wound had existed for 3 years prior to entry into our clinic with a previous arterial study which was negative. Also of note is that this patient had higher readings of 63% to his periwound, which may provide a false negative reading for other non-invasive peripheral arterial disease studies.

Measurements: 03/11/14 10.2 x 6.1 x 0.3
Patient 3
Patient diagnosed with venous insufficiency at the right lateral lower extremity wound. Patient’s wound bed oxygen saturation of 43% had an increase in wound volume by 2% over a 4 week period of time. Oxygen saturation to the periwound was elevated at 65% to 76%.

Measurements: 03/01/14  6.5 x 3.5 x 0.2
    04/29/14  5.8 x 4.0 x 0.1  2% Larger

Patient 4
Patient diagnosed with venous insufficiency with a left lateral ankle wound. Patient’s wound bed oxygen saturation of 64% had a decrease in wound volume of 95% over a 6 week period of time. In this limited study the author has noted a significant improvement in the closure of the wound when tissue oxygenation readings are above 60%.

Measurements: 03/14/14  1.7 x 1.5 x 0.2
    05/02/14  95% Epithelized  95% Smaller
Patient 5
Patient diagnosed with a diabetic foot ulcer located at the right plantar foot. Patient with wound bed oxygen saturation of 40% had no improvement in wound volume over a 6 week period of time. Oxygen saturation to the periwound was elevated at 76% to 81%.

Measurements: 03/12/14  1.0 x 1.0 x 0.3
04/30/14  1.0 x 1.5 x 0.2  No Healing

Patient 6
Patient diagnosed with a diabetic foot ulcer with a left lateral foot wound. Patient’s wound bed oxygen saturation of 80% had a closed wound bed over a 6 week period of time.

Measurements: 03/13/14  1.9 x 1.0 x 1.2
05/01/14  Healed
Discussion

Multispectral oximetry imaging provides immediate Tissue Oxygen Saturation (StO2) images of the wound bed, and surrounding tissue, based on short wavelength multispectral imaging. Utilizing this mode of operation helps precisely extract oxygenated and de-oxygenated hemoglobin from deeper tissue. The author noted important benefits of the multispectral oximetry imaging device. First, the device works to provide an image taken 16 inches away from the wound bed and this allows the user to understand what is happening directly at the wound bed versus other devices that are typically used in the outpatient wound care setting. Currently available technology for assessing microcirculation (transcutaneous oxygen monitoring) is unable to assess oxygen levels directly at the wound bed. As discussed with Patient 1, circulation based oxygen readings can be significantly different in the short distance from periwound to wound bed. More so, oxygen readings can vary even in the context of a single wound bed (as seen in Patient 2). From a clinical standpoint this may explain in some cases why wounds tend to stall after initial improvement. Understanding this level of detail, moreover, is important for clinicians in insuring positive outcomes in the course of a patient’s care.

Citations

The author sees applications beyond assessing oxygen levels of wounds and extremities. Studies also look to the advantage of the device in forecasting outcomes in compromised laps (4) and real time (in surgery) observation of perfusion during CABG surgery (5).

Secondly, the device was able to take multiple oxygen saturation readings in the wound bed. Moreover, angiography is unable to detect microcirculatory deficits.

Summary

Integrating vascular intervention and assessment into a clinic’s care pathway has shown significant benefit in reducing negative outcomes for patients including a significant reduction in lower extremity amputations (6, 7). With this in mind, the objective of this study was to understand how integrating a multispectral imaging device into our wound clinic environment could provide an understanding of how tissue oxygen saturation readings apply to forecasting patient outcomes. Ultimately, the author believes that understanding tissue oxygen saturation provides important guidance for initiating adjunctive treatments which could reverse a negative or delayed wound trajectory.
