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SM Vascular Medicine

Research Article

Correlation of Near Infrared Spectroscopy Measurements of Tissue Oxygen Saturation with Transcutaneous pO2 in Patients with Chronic Wounds

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Abstract

Background: Assessment of tissue oxygenation and vascular function is an integral component in the management of chronic wounds. Current practice in wound centers is screening with Pulse Volume Recording (PVR) or Transcutaneous Oxygen Saturation (TCO_2) to evaluate safety of compression wraps, utility for vascular intervention and expected response to Hyperbaric Oxygen Therapy (HBOT).

A near infrared (NIR) spectroscopy device (Kent, Calgary) using 4 wavelengths of light to determine O_2 saturation of hemoglobin (Hgb) in cutaneous tissue has been developed. The low absorption of light by H_2O and melanin in the NIR range allows for measurement of absorption of deoxygenated and oxygenated hemoglobin and for the calculation of O_2 saturation. The purpose of this study is to determine the correlation between the gold standard TCO_2 and NIR spectroscopy in measuring cutaneous O_2.

Materials and methods: 20 patients with Fitzpatrick skin types I-III who had measurements of TCO_2 (Perimed, Stockholm) also had simultaneous measurements obtained by NIR spectroscopy. The investigation was reviewed and approved by Institutional Review Board for Human Subjects at WVU. The Hemoglobin/O_2 dissociation curve at 370 degrees C, pH=7.4 and pCO_2=40 was used to calculate O_2 saturations from measurement of TCO_2.

Results: Data pairs were analyzed using linear regression and the relationship y=0.93 x+5.35 with a correlation coefficient=0.92 and r^2=0.84 was calculated.

Conclusions: There was a significant correlation between measurements of tissue oxygenation using TCO_2 and NIR spectroscopy. NIR spectroscopy has the advantage of not requiring skin contact and measurements can be taken even in the wound bed. Other advantages include: 1). Time (2 minutes vs. 90 minutes) and 2). Disposable cost ($150 –$TCO_2$ vs. $0-NIR spectroscopy). 3). The ability to perform serial studies over time. Further studies are warranted to determine if this information is useful in determining response to HBOT or in predicting wound-healing trajectory.

Introduction

Screening for vascular insufficiency and tissue oxygenation is an important element in the evaluation of chronic wounds. A wound is considered chronic when it has failed to heal in 4 weeks (1). Common etiologies of such wounds include arterial ulcers, venous stasis ulcers, diabetic foot ulcers, pressure ulcers, and soft tissue radionecrosis secondary to therapeutic radiation. Current techniques of screening include Pulse Volume Recording (PVR) and transcutaneous measurement of pO_2. If data from such screening reveals abnormalities then more specific evaluation is indicated such as ultrasound or digital angiography (including MR and CT). PVR is useful to determine adequacy of global circulation but is less useful in evaluation of the microcirculation. TCO_2 measures pO_2 of tissue and does correlate with the status of local microcirculation (2-4). Both PVR and TCO_2 are labor intensive requiring approximately 1 hour of nurse/technician time to perform in our center. When using TCO_2, there is a disposable cost of approximately $150. NIR spectroscopy when performed with this device can be completed in a few minutes and without disposables.

Materials and Methods

The investigation was reviewed and approved by Institutional Review Board for Human Subjects at WVU.

20 subjects (11 male, 9 female, ages 54-72) with lower extremity wounds (venous, arterial, diabetic and radiation injury) and with Fitzpatrick skin types I-III (the "lighter" 3 of 6 skin types) were evaluated for local tissue oxygenation in immediate proximity to these wounds with orientation of 12 o'clock, 6 o'clock, and 9 o'clock using a TCO_2 monitor (Perimed, Stockholm) and a mean value was calculated. Simultaneously, an image of the periwound area was acquired

using NIR spectroscopy (Kent, Calgary). The hemoglobin/oxygen dissociation curve at 37 degrees, pH=7.4 and pCO_2=40 was used to calculate O_2 saturation from TCO_2 (measured in mmHg). Data pairs were analyzed using a program for calculating linear regression.

Results

The relationship between TCO_2 and NIR spect was defined as y=0.93 x+5.35 with a correlation coefficient=0.92 and r^2=0.84. TCO_2 calculated saturation% NIR saturation%.

1	79	71
2	49	55
3	60	58
4	70	74
5	90	84
6	88	79
7	55	60
8	42	29
9	60	70
10	65	59
11	51	48
12	41	38
13	71	65
14	80	82
15	75	70
16	30	28
17	49	55
18	59	65
19	57	65
20	65	59

Discussion

NIR technology has been available since the late 1970s (2) and has found applications in fields ranging from industrial to medical. The development of non-invasive and more portable systems has rendered this technology practical to use in clinical settings from exercise physiology (3,4) to critical care (5-7).

NIR technology is based on measuring the absorbance of light in the near infrared spectrum from 700-1000 nm (fig 1). Oxygenated and deoxygenated hemoglobin are the primary light absorbers (chromophores) at these wavelengths. Other endogenous chromophores such as melanin and water have low values for light absorption (coefficient of absorption) relative to hemoglobin's in this spectrum. Differences in absorption coefficients between oxygenated and deoxygenated hemoglobin allow for the calculation of oxygen saturation of the sampled tissue (fig 2). The instrument used in this investigation (Kent, Calgary) (fig 3) uses four IR wavelengths. The components include a light source, optical bundles (for emission and reception), a computer processor, and monitor (fig 4). The

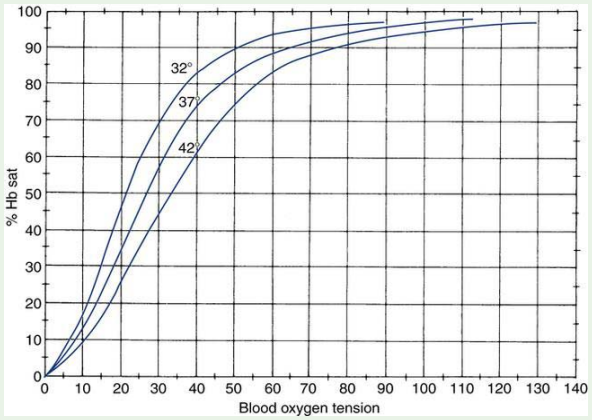

Figure 1: Hemoglobin/oxygen dissociation curve.

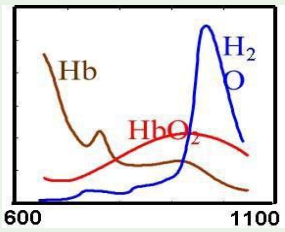

Figure 2: Absorption coefficients for chromophores in the electromagnetic spectrum from 600- 1200nm.

Figure 3: NIR device.

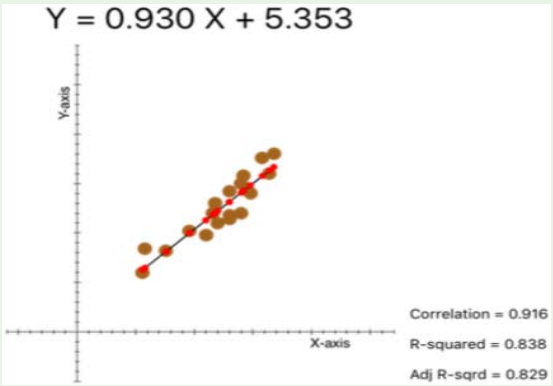

Figure 4: TCO_2 *vs* NIR Spectroscopy linear regression.

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Figure 5: Digital image of wound.

measurement of O_2 tissue saturation is a composite of oxygen quantities in capillaries, venules, and arterioles and is a correlate for mixed venous O_2 (8). Local O_2 saturation is dependent on the relationship between O_2 delivery (DO_2) and oxygen consumption in the sampled tissue. Low values for O_2 saturation could imply either decreased O_2 supply (decreased local perfusion, decreased cardiac output, anemia, or hypoxemia) or increased extraction of O_2 from Hgb due to a hyper metabolic state. High O_2 saturation could result either from increased O_2 delivery or decreased oxygen utilization (mismatched perfusion/failure of capillary auto regulation) or mitochondrial dysfunction with inability to use O_2 (9).

For example, a reasonable interpretation of the image in (figure 5) would be: because the O_2 saturations proximal and distal to the wound are normal, arterial insufficiency is not a major factor in the etiology of this wound (figure 6). The low O_2 saturation in the wound bed is likely the result of increased O_2 consumption secondary to hyper-metabolism. Potentially, serial measurements could reflect improvement or deterioration of the wound prior to any change in wound size or appearance and influence management.

A limitation of this technology as applied to the evaluation of limb ischemia or wound care is the variability of melanin in patients' skin. Although melanin's coefficient of absorption in the near infrared spectrum is low relative to hemoglobin, it does still influence values obtained in patients with darker skin. Software algorithms have been developed and continue to be refined to compensate for this. All subjects in this study were from Fitzpatrick skin type's I-III. This becomes less of a limitation when measurements are acquired serially, and trends rather than absolute values are analyzed.

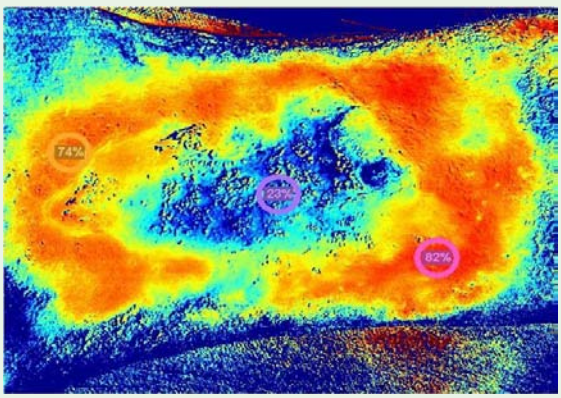

Figure 6: Color map of oxygen saturations in the region of the wound.

Conclusion

There was a significant correlation between measurements of tissue oxygenation using TCO_2 and NIR spectroscopy. NIR spectroscopy has the advantage of not requiring skin contact and consequently measurements can be taken even in the wound bed. Other advantages include: 1). Time (2 minutes vs. 90 minutes) and 2). Disposable cost ($150 –$TCO_2$ vs. $0-NIR spectroscopy). Further studies are warranted to determine if this information is useful in determining response to revascularization, HBOT, or in predicting wound-healing trajectory.

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