Wound Healing
Use of Transcutaenous Oximetry and Laser Doppler with Local Heat Provocation to Assess Patients with Problem Wounds

Summary of a clinical study conducted in collaboration with PJ Sheffield, D Dietz, KI Posey and A Ziemba, Nix Wound Care & Hyperbaric Medicine Center, San Antonio, Texas, U.S.A

Introduction

Predicting non-healing wounds is not always straightforward. Reliable diagnosis requires information about both the macro- and the microcirculation. Macrocirculation is often assessed using ultrasound, angiography and peripheral pressure indexes such as ankle-/toe-brachial index. Microcirculation can be diagnosed using laser Doppler technology and transcutaneous oxygen (tcpO_2).

Laser Doppler technology is a non-invasive method in which laser light is used to detect blood perfusion in the microcirculation. The measuring depth is around 0.5 - 1 mm, reaching the superficial vessels: arterioles, venules, shunts and capillaries. For diagnostic purposes, laser Doppler is often combined with a provocation, for example in the form of heating. The response to a provocation is a more repetitive measurement than just measuring blood perfusion at a basal level, since the microcirculation itself is extremely dynamic and may vary extensively under normal conditions.

TcpO_2 measurement is a well-established non-invasive method which quantifies the amount of oxygen that diffuses from the capillaries and through the skin. Contrary to laser Doppler, which measures all the vessels in the microcirculation, tcpO_2 only reflects the status of the capillaries, i.e. the nutritive flow.

Combination of both techniques provides excellent information about local tissue blood perfusion and local oxygenation. TcpO_2 is complemented by laser Doppler in cases where tcpO_2 values are falsely low due to inflammation or acute oedema. Laser Doppler on the other hand is complemented by tcpO_2 when the capillary bed is impaired but the subcapillary/macrocirculation is normal.

In this prospective outcome study, hyperbaric oxygen treatment (HBO) candidates were assessed using both tcpO_2 and laser Doppler combined with heating. ***The aim was to evaluate whether these methods could be valuable tools to predict the outcome of the HBO treatment.***

Material and Methods

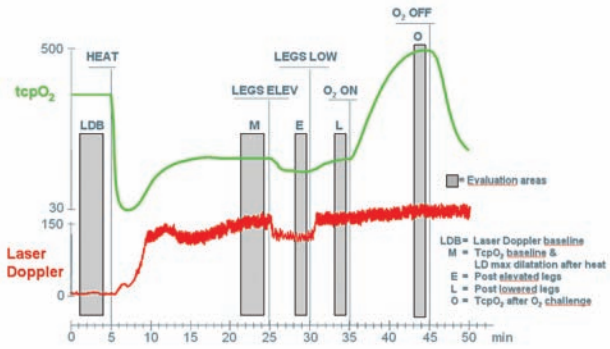
Patients

The predictive value of tcpO_2 and laser Doppler with heating was compared in 22 healthy volunteers and 46 randomly selected patients with problem wounds who presented for assessment as potential HBO candidates.

TcpO_2 electrodes and laser Doppler probes positioned in proximity to the wound

Predictive Protocol

Two laser Doppler probes and a number of tcpO_2 electrodes were placed on each subject on the lower extremities. In the case of an existing wound, probes and electrodes were positioned 1 cm from the edge of the wound. Both methods were run in parallel. For laser Doppler, an initial baseline was recorded followed by local heating. In addition, leg elevation and leg lowering were included as provocative tests. For tcpO_2, the protocol started with an initial equilibration time of approximately 20 minutes, followed by baseline recording, leg elevation and leg lowering. Finally, oxygen challenge was introduced for 10 minutes followed by an additional 5 minutes' recording.



Experimental protocol

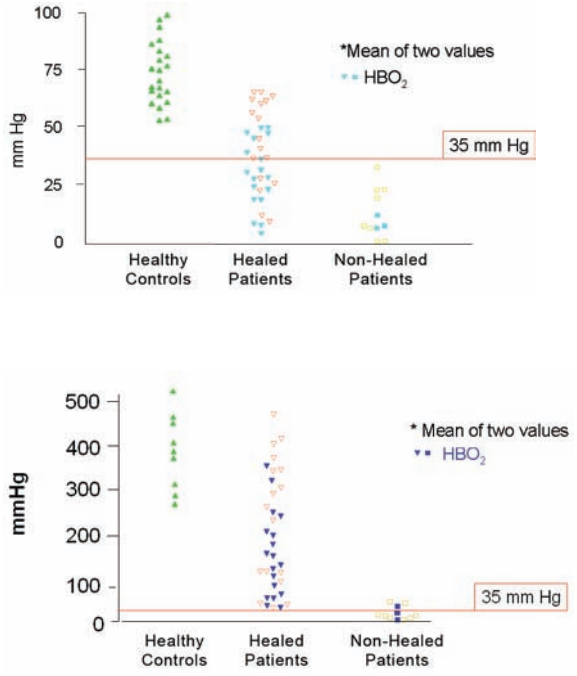
Results and Discussion

Of the wounds in 46 patients, 35 healed and 11 did not heal. In the group of healed patients, 17 underwent standard wound care and HBO treatment, and 18 only wound care. In the non-healers group, 3 were subjected to both wound care and HBO treatment and 8 to wound care only.

The mean laser Doppler and tcpO_2 values were used for data analysis. Statistically significant differences were found between healthy controls and patients for both laser Doppler ($p<0.0001$) and tcpO_2 ($p<0.0001$), and between healed and non-healed patients for both laser Doppler ($p<0.0001$) and tcpO_2 ($p<0.0002$). It was further observed that laser Doppler values increased and tcpO_2 values decreased when inflammation was present.

Many studies indicate that tcpO_2 values below 35 mmHg predict a non-healing wound. In this study, all non-healing wounds had a value below this threshold, but it is important to note that several of the healed wounds also fell into this range. This implies that some wounds with a potential to heal might be classified falsely. On the other hand, when including the response to oxygen challenge, a picture with better discrimination was obtained. In this case, all wounds that healed reached values above 35 mmHg.

In the case of laser Doppler, the percentage change in blood perfusion and the maximum value reached upon heating were evaluated. Values below 20 Perfusion Units and below 150% increase were indicative of non-healing wounds.



Mean tcpO_2 values in healthy controls, healed and non-healed patients, Top: baseline values. Bottom: maximum value during O_2 challenge. A more discriminative picture is obtained when looking at the values during O_2 challenge.

Combination of tcpO_2 and laser Doppler provides ***excellent information*** about local tissue ***blood perfusion*** and ***local oxygenation***. This is particularly important in cases where tcpO_2 values are falsely low due to inflammation or acute oedema.

Parameters for healing:

tcpO_2:

- value at O_2 challenge >35 mmHg
- increase from baseline during O_2 challenge >100%

laser Doppler with heating:

- value during heating >20 PU
- increase from baseline during heating >150%

Conclusion

TcpO_2 and laser Doppler are routinely used in wound healing centers to predict wound healing potential. TcpO_2 reflects the local tissue oxygen status identifying tissue that is hypoxic. Laser Doppler reveals the microcirculatory blood perfusion, identifying ischaemic tissue. TcpO_2 is in addition used to qualify patients for HBO treatment by assessing their ability to respond to oxygen challenge.

The microcirculation is extremely dynamic with extensive variations within the normal value range. To be able to use techniques such as laser Doppler for diagnostic purposes it is essential to use provocative tests. Heating locally at the measurement site will cause maximum dilation, enabling the use of laser Doppler to assess the tissue reserve capacity and severity of ischaemia.

In this study the aim was to see if laser Doppler with heat provocation in combination with tcpO_2 with oxygen challenge could be useful tools for predicting wound healing outcome. 46 patients and 22 healthy controls were included in the study.

The results indicated that both laser Doppler with heat and tcpO_2 with oxygen challenge were valuable tools for predicting wound healing outcome. The study also proved that by combining both techniques, additional information could be obtained, facilitating data interpretation. This was particularly important in cases where the tcpO_2 values were falsely low due to inflammation or acute oedema. Low values of tcpO_2 may sometimes be difficult to interpret, since the cause may be due to cardiopulmonary malfunction, impaired macrocirculation (arteriosclerosis), poor capillary function, high consumption of O_2 (e.g. inflammation) etc. Laser Doppler with heat provocation will help to distinguish between these. For instance, in this study, one patient with a tcpO_2 value ~ 1 mmHg, well below the threshold value of 35 mmHg, healed. This same patient, showed a high baseline laser Doppler value, indicating that the low tcpO_2 value was a consequence of an inflammatory process, emphasizing the importance of additional information for a complete picture of wound healing.

Collaboration with Dr Paul Sheffiield et al.

References: Wound care practice, edited by Paul Sheffield et al. Best Publishing Company 2004, p 117-156

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