Transcutaneous Oxygen Testing of the Hyperbaric Problem Wound Referral

Radiometer Webinar Series

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Disclosure

I have occasionally served as a consultant for Radiometer, Inc., and have occasionally received compensation for speaking at conferences sponsored by Radiometer, Inc.
Lecture Outline

- Genesis & clinical evolution of transcutaneous oximetry
- Algorithmic implementation for hyperbaric referrals
- Normal, adequate, abnormal LE values
- Provocative maneuvers
- Site selection principals
- Interpretational fundamentals
Naming Conventions

Transcutaneous oximetry

Transcutaneous oxygen (tension) testing

$TcPO_2$ vs. $tcpO_2$

$PtcO_2$ vs. $ptcO_2$

TCOMS
Transcutaneous Oximetry

Non-invasive physiologic assessment of skin microcirculatory oxygen delivery

~ in contrast to standard hemodynamic & anatomic testing
Historical perspectives

Neonatology
Plastic Surgery
Orthopedic Surgery
Vascular Surgery
THE SYSTEMIC OXYGEN SUPPLY TO THE SURFACE OF HUMAN SKIN

N. T. S. EVANS AND P. F. D. NAYLOR

Abstract. The oxygen tension at the surface of inflamed and non-inflamed forearm skin was measured with a polarographic electrode system which excluded the direct oxygen supply from the atmosphere. The tension at equilibrium on the surface of non-inflamed skin was less than 3.5 mm Hg, during the breathing of either air or oxygen. Spontaneous fluctuations in tension occurred with an R.M.S. amplitude which was about 20% of the mean tension. On skin inflamed by treatment with thufilol, nicotine or ultra-violet light, or by stripping with Sellotape, the oxygen tension rose to about 30 mm Hg during the breathing of air, and to about 350 mm Hg during the breathing of oxygen. The effects of partial and total occlusion of the blood supply to the arm and of indirect heating of the subject were studied. The oxygen gradient from the sub-papillary capillaries to the skin surface was calculated from two sets of data, and mean values of 40 mm Hg ± 9 S.D. and 45 mm Hg ± 7 S.D. were obtained.

Oxygen gradient across the skin  Skin oxygen tension
Skin blood flow

It has long been known (Gehrlich, 1851) that oxygen passes into human skin from the atmosphere, and Shaw and Messer (1931) showed that when the skin is allowed to reach equilibrium with a limited volume of gas, the oxygen tension in the gas becomes low. The oxygen tension at the skin surface when the atmospheric oxygen supply is excluded may conveniently be measured using the polarographic method. The tension thus measured is dependent upon both the oxygen tension in the superficial blood vessels of the skin and the metabolic consumption of oxygen by the epidermis and dermis. A polarographic electrode system suitable for such measurements was designed, and its construction and use in the study of forearm skin are described below.

Methods

The polarographic electrode assembly is shown in fig. 1. The cathode consisted of a platinum wire, 25 μ in diameter, sealed by an electric heating coil into 1 mm bore soda glass tubing having an external diameter of about 5 mm. For one series of experiments electrodes were made having three or more such wires sealed separately.

Accepted for publication 10 April 1967.
Quantitative Continuous Measurement of Partial Oxygen Pressure on the Skin of Adults and New-Born Babies

R. Huch, D.W. Lübbers, and A. Huch
Max-Planck-Institut für Arbeitsphysiologie Dortmund
and Frauenklinik der Universität Marburg, Germany

Received August 21, 1972

Summary. It is possible to perform continuous quantitative \( P_{O_2} \) measurements on vasodilated skin by means of surface Pt electrodes according to Clark when the electrode is fixed to the skin with a synthetic plastic material and in situ calibration is performed. A new in situ calibration of the \( P_{O_2} \) electrode is described. At first the skin \( P_{O_2} \) increases with \( O_2 \) insufflation. After perfusion stop the skin \( P_{O_2} \) shows a linear decrease because of the skin respiration, down to a \( P_{O_2} \) at which hemoglobin liberates chemically bound \( O_2 \). At this \( P_{O_2} \), value of hemoglobin is known it is possible to use it for calibrating the electrode. The \( P_{O_2} \) of normal skin is about 0.7 Torr. After vasodilatation obtained by rubbing with a nicotinic acid derivat (Finisfig*, Ansero, Wiesbaden), \( P_{O_2} \) increases to a mean value of 38.1 (± 8.1) Torr (n = 77). Under these conditions, skin \( P_{O_2} \) reaches arterial values never in adults and rarely in new-born babies.

Keywords: Pt Electrode — Surface \( P_{O_2} \) of Skin — in situ Calibration of the \( P_{O_2} \) Electrode — Skin Hyperemia.

Oxygen pressure on the skin is determined by factors such as arterial oxygen pressure, skin blood circulation, skin respiration, and diffusion conditions for \( O_2 \).

Hitherto the difficulty in measuring skin \( P_{O_2} \) has consisted in the fact that there was no method for calibrating the \( P_{O_2} \) electrode in situ and that it was impossible to fix the electrode on the skin without loss of mobility of the body. For the measurement it is necessary to use electrodes of sufficient long-term stability. This was achieved by membrane-covered Pt-multiwire electrodes (Clark 1960) which were stabilized by an intermediate layer according to Gleichmann and Lübbers (1960). A new method was developed for in situ calibration which considers the change of oxygen solubility caused by the chemical binding of \( O_2 \) to

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Huch R, et al. 1972
Pflügers Archiv;337(3):185-198
Transcutaneous PO$_2$ in Flaps: A New Method of Survival Prediction

Bruce M. Achauer, M.D., Kirby S. Black, and David K. Litke
Irvine, Calif.

Transcutaneous oxygen monitoring equipment is now used routinely in neonatal intensive care units and is potentially available also to the plastic surgeon. The original intention of transcutaneous PO$_2$ was an attempt to determine the arterial PO$_2$ by noninvasive methods.$^3$ The correlation with arterial oxygen has been extensively studied.$^3$ Tissue oxygen levels have been monitored in flaps by various means and have been shown to reflect circulation.$^3$ It occurred to us that PO$_2$ might also reflect circulation in certain skin sites, assuming that a normal arterial PO$_2$ exists. Our initial investigation supported this theory,$^4$ as did Swezey’s studies.$^5$ Although circulation of a skin flap can be assessed with microspheres, x-ray scans, and fluorescein dye, these are not readily applicable to constant monitoring.

**Electrode configuration and theory**

A transcutaneous oxygen sensor in a Clark-type configuration was used. It consisted of a silver anode and a platinum cathode (Fig. 1) surrounded by KCl electrolyte and a Mylar membrane, employing polarography to sense oxygen. A voltage of -0.7 V was applied between the cathode and anode, and the current that flowed between them was directly proportional to the number of oxygen molecules reduced at the cathode.

In a normal person, the amount of oxygen coming through the skin is very small. To increase this amount, local hyperemia was produced by a heating coil inside the silver anode of the electrode. The heat capacity of the anode gave stability to temperature fluctuations, which was serendipitously controlled by an electronic comparator circuit, thus maintaining the temperature set at ±0.2°C.

This increase in blood flow increased the measurable amount of oxygen diffused through the skin.

Great variation is found in the actual readings. To compare one animal with another and one species with another, each flap measurement was expressed as a percent of the reading obtained in a nonoperative site on the same organism at the same time.

Percent of normal = Flap PO$_2$/normal PO$_2$

Thus differences in level of anesthesia, skin thickness, and so forth could be eliminated. This procedure also served as a constant check on the functioning of the equipment.

Before applying the electrode, the skin was cleansed with alcohol and then an attachment jig was placed on the skin with a double-sided adhesive (Fig. 2). A drop of water was applied to the skin under the sensor for gas and heat transfer and was then inserted into the attachment jig. Equilibration of the blood flow and gas transport took 10 to 20 minutes. The sensor we used for a major portion of the experiments was a Beckman prototype instrument, but we also employed a radiometer instrument and found it acceptable.

**Materials and methods**

**Rabbit Experiments**

Sixteen male, white New Zealand rabbits were anesthetized with intravenous sodium pentobarbital (0.5 gm/kg). Then 4 x 12 cm flaps were raised on their backs, and the flaps were made

From the Division of Plastic Surgery at the University of California, Irvine.

Achauer BM, et al. 1980
Plastic & Reconstructive Surg;65(6):738-745
Oxygen inhalation–induced transcutaneous PO₂ changes as a predictor of amputation level

Timothy R. S. Harward, M.D., Jaroslav Volny, R.S., Frank Golbrumnon, M.D., Eugene F. Bernstein, M.D., Ph.D., and Annette Fronck, M.D., Ph.D., San Diego and La Jolla, Calif.

Noninvasive transcutaneous PO₂ (TopO₂) determinations have been developed to study peripheral vascular occlusive disease. To evaluate this technique as a predictor of amputation outcomes, a blind, prospective study of 101 patients undergoing 119 amputations (33 above-knee [AK], 57 below-knee [BK], and 39 footlevel) was performed. TopO₂ measurements were obtained from the dorsum of the foot and 10 cm distal to the patella, both prior to and 10 minutes after inhalation of 100% oxygen. On the basis of preliminary results, initial TopO₂ values >10 mm Hg or an increase >10 mm Hg after oxygen inhalation were considered to predict a successful outcome, whereas failure was predicted when the initial TopO₂ value was <10 mm Hg and the increase after oxygen inhalation did not exceed the 10 mm Hg level. In the BK amputation group the test was 95% sensitive, 100% specific, and 95% accurate. Retrospective utilization of the above criteria in patients who had undergone both oxygen inhalation testing and AK amputation suggested that 9 of 17 (53%) might have undergone a more distal amputation successfully. These results document the effectiveness of an initial TopO₂ determination coupled with the response to 100% oxygen inhalation as an excellent predictor of the outcome of lower extremity amputations.

### Table 1. Classification of wound healing after amputation

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful</td>
<td>Wound healing completes in 4 weeks.</td>
</tr>
<tr>
<td>Successful with peripheral healing</td>
<td>Difficult healing of more than 4 weeks.</td>
</tr>
<tr>
<td>Failure</td>
<td>Extensive healing more than 4 weeks.</td>
</tr>
<tr>
<td>Failure with peripheral healing</td>
<td>No further intervention necessary.</td>
</tr>
</tbody>
</table>

Increased emphasis on rehabilitation has encouraged the surgeon to move amputation levels as distally as possible. In an effort to predict more accurately amputation success at each level, surgeons initially attempted to correlate clinical signs (i.e., operative bleeding, skin color, and level of dependent rubor) with amputation success rates. More objective methods were sought to accurately assess tissue perfusion status.

### Recent advances

Hart et al. introduced a method for measuring the transcutaneous partial pressure of oxygen (TopO₂) in normocapnia, which reflected the arterial PO₂ levels, provided that severe hemodynamic disturbances could be excluded (e.g., shock). A logical extension of this technique was to evaluate patients with peripheral vascular disease and, especially with rest pain, ischemic ulcers and gangrene when amputation was contemplated. Preliminary results in this laboratory demonstrated that TopO₂ provided good separation between those limbs in which amputation failed and the majority of limbs in which
TRANSCUTANEOUS OXYGEN TENSION MEASUREMENT IN PERIPHERAL VASCULAR DISEASE

Frederick A. Matsen III, M.D., Craig R. Wyss, Ph.D., Larry R. Pelegana, M.D., Richard B. Krugmire, Jr., Charles W. Simmons, Rachael V. King and Ernest M. Burgess, M.D., F.A.C.S., Seattle, Washington

The key to understanding and managing the patient with peripheral vascular disease is the ability to quantify the severity of the vascular insufficiency. If available, this quantification would be a powerful means of facilitating the diagnosis of vascular disease, evaluating the natural history of different disease processes, demonstrating the effectiveness of various treatment modalities and assisting in the selection of ideal amputation levels. Several methods are of proved clinical use, such as the determination of segmental blood pressure and the measurement of the rate of "Xe washout. We are investigating a different approach to the assessment of the adequacy of local cutaneous circulation, that is, the use of the transcutaneous pO2 sensor. Although monitoring of transcutaneous pO2 is of established value in following the arterial pO2 of neonates, we have also found it to be useful in quantitating oxygen delivery to the skin of adult extremities. In this article, the method, data from normal persons and our first results for patients with peripheral vascular insufficiency are presented.

METHOD

We used a standard, commercially available transcutaneous pO2 sensor which was held to the skin with an adhesive ring. This sensor polarographically quantitates oxygen diffusing from the skin through its thin polyethylene membrane. The probe contained a thermistor controlled heating element that allowed the skin beneath the membrane to be maintained at the desired temperature. Prior to application, the system was zeroed in a sodium sulfite solution at 43 degrees C. and calibrated in water at room air, also at 43 degrees C. The stratum corneum of the skin, at the desired measurement site, was removed by repeated stripping with cellophane tape. After the probe was in place, the local skin temperature was raised to 45 degrees C. for ten minutes and then lowered to 44 degrees C. for another ten minutes or until a stable pO2 reading was obtained. All measurements were taken with the patient in the supine position, unless otherwise specified. Standard sampling sites were 10 centimeters above the patella, 10 centimeters below the patella and on the dorsum of the foot, approximately over the medial cuneiform bone. In most persons, transcutaneous pO2 measurements were also made over the left fourth intercostal space on the chest.

Those included in the study were 13 normal volunteers of both sexes, ranging in age from 22 to 33 years. In some normal persons, the transcutaneous pO2 was measured with the limb in different positions in relation to the heart. Patients included four men with arteriosclerotic vascular disease and five men with diabetic vascular disease. Their ages ranged from 46 to 72 years.

In some instances, the results were available both before and after a treatment procedure, such as vascular reconstruction or amputation. In these instances, treatment was carried out by physicians not knowing the results of the pO2 determinations. Segmental systolic blood pressures were obtained at the arm, thigh, leg and ankle with a Doppler, and an appropriately sized blood pressure cuff. Ischemic radii were calculated by dividing the systolic blood pressure at a given leg level by the systolic brachial artery blood pressure of that patient, as described by Wagner (7).

RESULTS

In Figure 1, results are given for the 13 normal persons. The average transcutaneous pO2 values were slightly less at the periphery than centrally. In Figure 2 is demonstrated a typical relationship of transcutaneous pO2 measured at the foot to foot position relative to the heart in the normal

Matsen FA, et al. 1980
Surgery, Gynecology & Obstetrics;150:525-528
Superiority of Transcutaneous Oximetry in Noninvasive Vascular Diagnosis in Patients With Diabetes

Carl J. Hauser, MD; Stanley R. Klein, MD; C. Mark Mehlinger, MD; Paul Appol, MPA; William C. Sheemaker, MD

Transcutaneous oximetry (TcPO₂) was directly related to skin oxygen delivery. Regional transcutaneous oximetry (RTO) compared peripheral and truncal (PcPO₂), yielding a regional perfusion index indicative of local limb perfusion. The relative diagnostic values of RTO, Doppler ankle-brachial pressure ratio (ABR), pulse volume recording (PVR), and toe pulse reappearance time (PRT/T) were studied in 64 limbs of patients with diabetes. These limbs were clinically classifiable into classification, rest pain, and gangrene groups. Regional transcutaneous oximetry had a higher diagnostic accuracy than ABR (χ² = 27.47, P < .001), PVR (χ² = 8.60, P < .05), and PRT/T (χ² = 10.98, P < .05). Regional transcutaneous oximetry was universally applicable and the degree of hypoxia observed correlated with clinical symptoms. Significant hypoxia predicted large-vessel angiographic lesions, many of which were reconstructible. Regional transcutaneous oximetry should be the initial noninvasive test in diabetic peripheral vascular disease.

Nowhere is the need for accurate noninvasive vascular testing more obvious than in the patient with diabetes who has peripheral vascular disease. The diabetic limb may be compromised by accelerated atherosclerosis, arteriolar sclerosis, neuropathic injury, and decreased resistance to invasive infection. All or some of these may contribute to limb threat, but since the treatment of such pathologic entity differs, the appropriate management requires clarification. Which processes are of primary importance in each case? The ever-present diagnostic and therapeutic considerations is whether limb ischemia exists and, if it does, whether it can be treated by vascular reconstruction. The anatomic feasibility of reconstruction can only be determined by angiography, but the morbidity of angiography and relative infrequency of reconstructible disease in these patients mandates a selective approach.

Noninvasive vascular diagnostic techniques assess arterial hemodynamics in the leg and have proved very helpful in the selection of patients without diabetes for arteriography. Cuff occlusion tests, however, are often inaccurate in patients with diabetes because the calibration of the arterial tree results in hemodynamics that correlate poorly with perfusion of the limb.

Regional transcutaneous oximetry (TcPO₂) has been shown to assess limb ischemia in peripheral vascular disease directly by comparing the cutaneous oxygenation of involved limbs with that of uninvolved regions of the body. We therefore believed that it might be uniquely suited to noninvasive diagnosis in the patient with diabetes. In this study, we compared TcPO₂ with standard noninvasive tests in the diagnosis of limb ischemia and as an aid to clinical judgment in the assessment of the need for angiography in patients with diabetes.

SUBJECTS AND METHODS

Clinical Series

During the period from July 1983 to September 1984, 46 consecutive patients admitted to Harbor-UCLA Medical Center because of vascular disease were referred for evaluation of peripheral vascular disease by transcutaneous oximetry. Patients averaged 65 years of age (range, 46 to 77 years); 25 were men and 21 women. Twenty-seven patients were insulin dependent and 19 controlled their diabetes by diet or oral hypoglycemic therapy. A significant smoking history (greater than ten pack-years) was found in 31 patients (46%). Thirty-four vascular reconstructive procedures were subsequently undertaken in 28 patients, ten major amputations were performed, and there were four deaths in the group.
Superiority of tcpO₂ Assessment

~ non-invasive lower extremity studies

Superiority of tcpO₂ to Doppler studies highly significant
Hauser CJ, 1984

Regional tcpO₂ had higher diagnostic accuracy than ABI; PVR & TPRT in diabetic vascular disease
Hauser CJ, 1984

tcpO₂ provides most objective description of dermal metabolism & oxygen availability
Rhodes G, 1985

tcpO₂ high degree of accuracy (vs. ABI; xenon-133; Doppler pressures) in predicting amputation site healing
Malone JM, 1987
Low tcpO$_2$ Predicts Abnormal Arteriography

96% of 66 limbs with tcpO$_2$ < 30mmHg had abnormal arteriogram

Ballard JL, et al. 1995

tcpO$_2$ <30mmHg a reliable indicator of need for arteriography, with 98% limbs showing significant disease

Bunt TJ, et al. 1996
## Risk Factors For Diabetic Amputation

<table>
<thead>
<tr>
<th>Pathophysiologic Factor</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutaneous circulation</td>
<td>161</td>
</tr>
<tr>
<td>~ tcpO$_2$ &lt;20 vs. &gt;40mmHg</td>
<td></td>
</tr>
<tr>
<td>Peripheral arterial circulation</td>
<td>55.8</td>
</tr>
<tr>
<td>~ Doppler ABI &lt;0.45 vs. 0.70</td>
<td></td>
</tr>
<tr>
<td>Neuropathy</td>
<td>15.1</td>
</tr>
<tr>
<td>~ lacking distal vibratory sense</td>
<td></td>
</tr>
<tr>
<td>Ulcers become infected</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Reiber GE, et al. 1992
The tcpO$_2$ Hyperbaric Algorithm

Is wound healing complicated by hypoxia?
Is any such hypoxia reversible?
Is patient responding to HBO therapy?
Has a therapeutic endpoint been reached?

Not undertaking such determinations?
...Margolis et al. Diabetes Care 2013
What is a Normal Lower Extremity tcpO₂ Value?

Dermal oxygenation mapped in healthy volunteers

Eickhoff JH & Engell HC 1981
Franzeck UK, et al. 1982
Sheffield, PJ & Workman WT, 1985
Jonsson K, et al. 1987
Orenstein A, et al. 1988
Dowd GS, et al. 1993(a)
Dowd GS, et al. 1993(b)

a ‘normal’ tcpO₂ falls within a range of values (53-92 mmHg)

reasonable to conclude that normal values exceed 50 mmHg
What tcpO$_2$ Values Considered Suboptimal?

Values $> 40$ mmHg representative of adequately oxygenated tissue

$\sim$ normal oxidative function

Basic/clinical data suggests threshold range of $< 35-40$ mmHg as sub-optimal for O$_2$ dependent wound healing

One definition of ‘critical limb ischemia’ $< 30$mmHg

$\sim$ degree of adverse influence increases as values decrease
Probability of Healing

Padberg FT, et al. 1996
Surgical Research; 60(2)
What About Any Control Sites?

Left second intercostal space grossly reflects state of ‘central’ oxygenation....*normal range 65-90mmHg (1.0 ATA)*

*regional perfusion index (RPI)*

Contra-lateral reference sites may represent poor comparison of normal to diseased tissue
Evolution of Provocative Maneuvers

Treadmill exercise-induced change in **Regional Perfusion Index**

Temporary limb ischemia-induced change in tcpO2 recovery *‘TORT’*

Limb elevation-induced change in **RPI**...not limb elevation, *per se*

*Each directed at assessment of PVD; surgical planning*

*None related to the issue of wound healing*
tcpO2 Provocative Manoeuver: HBO Referrals

Oxygen inhalation only provocative option that answers the key question:

*Does physiologic capacity exist to respond locally to centrally delivered oxygenation?*

Employable across continuum of tcpO2 algorithm

Confirms adequacy of hyperbaric treatment pressure
Normobaric 100% Oxygen Challenge

Response ranges

> 300 mmHg...*regional large vessel disease unlikely*

200-300 mmHg...*minimal regional large vessel disease*

100-199 mmHg...*non-limb threatening ischemia*

51-99 mmHg...*significant ischemia: further arterial study*

< 50 mmHg...*high grade ischemia: further arterial study*
Systemic Factors Influencing tcpO₂

Pulmonary & cardiac function
Oxygen content
Central vascular perfusion
Peripheral vascular perfusion
Smoking, caffeine ingestion
Vaso-active pharmacologic/other such substances
Environment (temperature /altitude)
HR: 80 yowm
Dx: Diabetic left foot gangrene
Respiratory failure

Reference: 42 mmHg (FiO$_2$ 50%)
<table>
<thead>
<tr>
<th>Local Factors Influencing tcpO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obesity</td>
</tr>
<tr>
<td>Edema</td>
</tr>
<tr>
<td>Increased skin thickness</td>
</tr>
<tr>
<td>Cutaneous radiation tissue injury</td>
</tr>
<tr>
<td>Bony prominences</td>
</tr>
<tr>
<td>Poor skin preparation</td>
</tr>
<tr>
<td>Poor electrode attachment</td>
</tr>
</tbody>
</table>
Site Selection; Anatomic Factors

Sensor site selection straightforward enough if...

Clear understanding of question in need of address

Appreciate principal determinant that answers question

Principal testing site(s) consistent with that determinant

Any necessary secondary testing site(s) incorporated
Transcutaneous Oximetry: When To Delay Testing

Immediately post hemo-dialysis
Nutritive skin perfusion impaired during dialysis, sufficient in some cases to produce chest/cardiac & leg pain

~ significant tcpO2 decreases in pts. with & without PVD

Markedly edematous tissue

Edema represents a diffusion barrier between functioning capillaries & skin
Transcutaneous Oximetry: When To Delay Testing

**Caffeine ingestion**

*Restrict caffeine-containing substances prior to tissue oximetry*

~ *significant differences (S.D. 270 mmHg) in healthy subjects, sufficient to screen out otherwise suitable candidates*

Stephens M, *et al.* 1999
UHM;26(2): 93-97

**Nicotine**

*Avoid any use for at least two hours prior to tissue oximetry*

Arch Surg; 126:1131-1134

**Supplemental oxygen administration**

*Absence of conversion factors*
# Peri-operative tcpO₂ Values

~ following limb revascularization

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean (mmHg)</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>9.27**</td>
<td>12.14</td>
</tr>
<tr>
<td>POD #1</td>
<td>17.73*</td>
<td>15.86</td>
</tr>
<tr>
<td>POD #2</td>
<td>20.36*</td>
<td>5.61</td>
</tr>
<tr>
<td>POD #3</td>
<td>36.82**</td>
<td>18.80</td>
</tr>
</tbody>
</table>

* Not significant

* * Significant $p = 0.001$

Arroyo CI, et al. 2002
J. Foot Ankle Surg. 41(4)
Possible Etiologies

Post-operative edema

Vasospasm, due to high pressures

Ischemia-reperfusion injury

Endothelial cell trauma

Micro embolic events

Effects of dye
Transcutaneous Oximetry

This evidence-based approach to hyperbaric wound healing confers:

- More exacting patient selection
- Algorithmic case management
- Improved clinical outcomes
- Enhanced cost-effectiveness
Normobaric Transcutaneous Algorithm

Algorithm 1

Baseline transcutaneous oximetry

Wound hypoxia (<40mmHg): at one or more sites

Yes

Normobaric (100%) oxygen challenge periwound values

Exceed 100mmHg

Adequate reversal

Hyperbaric candidate

To Algorithm 2

Range from 50-100mmHg

Further arterial testing

Reconstructible disease

No

HBO not presently indicated

Work up for other etiologies

Refer to Wound Center

Fail to reach 50mmHg

Not a hyperbaric candidate under the present flow circumstances

Further arterial testing

Reconstructible disease

Yes

Consider quality of life, clinical and economic issues

In-chamber Ptc02 if favoring HBO therapy

Trial of HBO if value(s) exceed 200mmHg

To Algorithm 2

No

HBO presently difficult to justify

Repeat Ptc02 post procedure

Wound hypoxia

Yes

HBO not presently indicated

No
Algorithm 1

Baseline transcutaneous oximetry

Wound hypoxia (<40mmHg): at one or more sites

Yes

Normobaric (100%) oxygen challenge periwound values

Exceed 100mmHg

Adequate reversal

Hyperbaric candidate

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Fail to reach 50mmHg

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Yes

Further arterial testing

Reconstructible disease

No

HBO presently difficult to justify

Refer to Wound Center

Work up for other etiologies

To Algorithm 2
In-Chamber & Follow-Up Transcutaneous Algorithm

Algorithm 2

Commence HBO at 2.0 ATA: Hypoxic wounds

Obtain tcPO₂ value within 15 minutes at 2.0 ATA

tcPO₂ in excess of 200mmHg?

No

Titratre to 2.1 ATA

tcPO₂ > 200mmHg?

No

Continue to titrate upwards in 0.1 ATA increments

Do not exceed 2.5 ATA

tcPO₂ > 200mmHg?

No

Further arterial diagnostic testing

Yes

Maintain at 2.0 ATA

Repeat tcPO₂ at 1.0 ATA at 14 bxs

Values 40mmHg, or greater

Yes

Hold HBO

Weekly follow up

Standard care

Continued healing?

Yes

Continue HBO

Repeat tcPO₂ at 1.0 ATA as indicated

Hold HBO at 40mmHg

No

Deterioration

Hold HBO: Further diagnostic testing

No

Yes

No

5 – 10 bxs

Continue HBO

Hold HBO at 40mmHg

Yes

Do not exceed 40 bxs

No

Hold HBO

Schedule follow up

Continued healing?

Yes

No

Yes

No