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Hyperbaric Oxygen Therapy in Chronic Vascular Wound Management

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Abstract

Many nonhealing tissues are hypoxic, with oxygen tensions frequently ranging from 5 to 15 mmHg. In such an environment, the normal wound healing sequence is disrupted or halted and phagocytic killing activity depressed. So the adjunctive use of hyperbaric oxygen (HBO), based on physiologic data and clinical observations, can provide the substrate necessary to initiate and sustain the healing process.

During a twelve-month period, 20 patients with a nonhealing wound were referred to the hyperbaric center: chronic arterial insufficiency ulcers in 9 cases, diabetic wounds (foot lesions) in 11 cases.

Adjunctive HBO therapy, initiated twice a day, consisted of pure oxygen, 2.5 ATA, 90 min. The average length of sessions was 46 (15-108). Complete healing was observed in 15 of 20 cases.

The wound management can be helped with the transcutaneous oxygen measurements under hyperbaric oxygen. The distal $TCPO_2$ at 2.5 ATA pure oxygen is a reliable test to predict final outcome (healing or no change), when these values were not different in normal air and in normobaric oxygen:

Distal $TCPO_2$	Healing		No Change
air	32 ± 31	NS	12 ± 4
1 ATA O_2	75 ± 70	NS	18 ± 10
2 ATA O_2	635 ± 388	p = 0.003	45 ± 20

In hyperbaric oxygen therapy, when the distal $TCPO_2$ value was inferior to 100 mmHg, all patients showed either no improvement or aggravation, and when the value was higher than 100mmHg, wound healing was achieved with all patients.

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Introduction

Tissue oxygen pressure plays an important part in the wound-healing process. On the one hand, tissue oxygen tensions of 30 to 40 mmHg are necessary for fibroblastic proliferation, fibroblastic synthesis of collagen,[1-4] and for capillary proliferation.[5-7] On the other hand, increased oxygen tensions enhance the bactericidal activity of white blood cells.[8-9]

Many nonhealing tissues are hypoxic, with oxygen tensions frequently ranging from 5 to 15 mmHg.[10] In such an environment, the normal wound-healing sequence is disrupted or halted and phagocytic killing activity depressed, thus leading to infection, which aggravates the problem.

Consequently, "the adjunctive use of HBO, based on physiologic data and clinical observations, can provide the substrate necessary to initiate and sustain the healing process."[11]

The present paper aims at providing: a clinical report on chronic vascular wounds, an approach to wound management with hyperbaric oxygen (HBO) treatment, and an assessment of transcutaneous oxygen measurements under hyperbaric oxygen in such cases.

Clinical Report on Chronic Vascular Wounds

The following report focuses on arterial insufficiency ulcers, venous stasis ulcers, and diabetic wounds.

The effects of HBO treatment on arterial insufficiency ulcers are reported in Table I. All the ulcers were refractory to conventional treatments before use of HBO. There is no difference between obstructive arteriosclerotic ulcers and ulcers of thromboangiitis obliterans in relation to the HBO response. Prolonged courses of HBO are necessary for healing (on average: thirty to fifty sessions), but the results are dependent on the characteristics of the wound (age, extent, depth, etc.). They are also dose dependent. In 60-70% of cases, ulcers healed completely. The period required for healing is often considerably reduced with split skin grafting once the ulcer base has been prepared with a course of HBO.

TABLE I
HBO in Arteriosclerotic Ulcers

Author(s)	Procedures	Cases	Healing	Improved
Kidokoro et al[29]	2.25 ATA O_2 20-70 sessions	22	12	
Hart and Strauss[15]	2 ATA O_2 90 min	16	12	
Kizer et al[13]	2 ATA O_2 90 min 11-117 sessions	22	5	4
Sakakibara et al[30]	2 ATA O_2 75 min 35-50 sessions	43		35
Barr and Perrins[16]	1.5 to 3 ATA O_2 all geriatric patients—amputation avoided in 65%	50	26	10
Yephuni et al[31]		370	192	113
Yagi[14]	2 ATA O_2 90 min (25 sessions or more)	95	62	

In general, HBO is not recommended for venous stasis ulcers, for which success is achieved through venous surgery, lower extremity elevation, counterpressure, local support, wound care, and skin grafting. But occasionally, when failure in these procedures occurs, HBO is warranted. Bass,[12] using HBO at 2 atmospheres absolute (ATA), obtained complete healing in 17 of 19 cases, and Kizer and al,[13] in 5 of 6 cases. Yagi[14] reported 10 cases of stasis ulcers that received HBO before and after Linton's surgical procedure; no recurrence of the ulcer was observed in any of the cases over a period of about ten years.

Foot lesions (gangrene and perforating ulcer) are common problems in diabetic patients. Despite assiduous conventional treatment, they cause serious disability or amputation. The effectiveness of HBO in the treatment of the diabetic wounds has been reported by Hart and Strauss,[15] Barr and Perrins,[16] Emhoff and Myers,[17] Pedesini et al,[18] and Faglia et al.[19]

The HBO treatment has a cleansing effect that halts wound infection. The surrounding tissues are revivified, allowing a plastic surgical intervention. In such cases, coordination with the surgeon is very important; HBO treatment will be prescribed before or immediately after the surgical operation.

Hart and Strauss[15] treated 11 patients with diabetic ulcers, using HBO at 2 ATA; all of them showed a fair response. Barr and Perrins[16] treated 24 patients with diabetic ulcer by using HBO; 67% of the ulcers healed, and in 18% of cases, amputation was avoided. In 26 cases affected by diabetic vasculopathies with soft-tissue ulcer (65%), finger or foot gangrene (25%), and lower limb gangrene (10%), Pedesini et al[18] observed good results in 88.6% of cases. The average number of HBO sessions was 34.3 per patient. The healing period was significantly shortened in all cases. Faglia et al[19] treated 26 hospitalized adult diabetic subjects, all with microangiopathies and affected by foot lesions, with a combination of strict metabolic control, daily curettage, and HBO. A control group of 20 insulin-treated microangiopathic diabetic subjects presenting foot gangrene (comparable age and duration of disease) was treated with metabolic control and daily curettage. In HBO-treated patients, healing of lesions was obtained in 24/26 cases; 2/26 worsened and later had amputations. In the control group, 2/20 patients improved, 10/20 patients were unchanged, and 8/20 worsened and had amputations. Comparison between the two groups (Chi-square test) revealed a highly significant difference.

Clinical Management with HBO treatment

"HBO therapy for difficult wounds should be undertaken with the clear understanding that it must be part of the vigorous, coordinated surgical team approach to total patient management."[11]

At first, a careful physical examination with particular reference to peripheral circulation is necessary. Noninvasive methods such as determination of lower extremity perfusion pressure,[20,21] oscillometry before and after effort with determination of the Pourcelot index, Doppler and Doppler laser evaluation, and phlethysmographic measurements may help to determine which patients are eligible for HBO treatment.

In some cases, arteriography should be applied to determine whether reconstruction vascular surgery should be performed prior to HBO treatment.

Transcutaneous evaluation of tissue oxygen tension in response to HBO breathing may also indicate whether oxygen should be delivered to the wound in a dose adequate to promote healing.

Regular and aggressive daily debridement of the wound is absolutely required as HBO therapy progresses; if necessary, debridement is effected under anesthesia.

Daily wound care and dressing changes are necessary to ensure a proper environment for capillary budding and epithelialization. The use of toxic agents, such as nonspecific antiseptics, is to be avoided.

Once a capillary base has been established, epithelialization will usually occur, but split skin grafting may be indicated to close the wound; hence, the period required for healing can be reduced considerably if the ulcer base has been prepared with a course of HBO. Nutritional status and metabolic control are important for a successful outcome.

$TcPO_2$ measurements under HBO are warranted for effective follow-ups. Wound healing may take a long time, and besides, patients should be considered for therapy on a case-by-case basis.

Assessment of Transcutaneous Measurements Under Hyperbaric Oxygen Prediction of Final Outcome of Nonhealing Wounds

Transcutaneous oxygen monitoring has been used in patients with peripheral vascular disease.[23-25] In these cases, transcutaneous oxygen monitoring has been shown to reflect tissue perfusion. Transcutaneous oxygen pressure of more than 50 torr has been defined to be predictive of a favorable outcome, when values inferior to 40 torr are associated with amputation.[26]

Sheffield[10,27,28] has demonstrated that problem wounds are often hypoxic and that oxygen is delivered to problem wounds during a course of hyperbaric oxygen treatment with elevation of wound oxygen tension. Unfortunately, however, specific oxygen dose requirements for individual patients have not yet been defined. In a series of 11 diabetic patients, below-knee lesions with $TcPO_2$ values inferior to 20 mmHg were shown to heal during a course of HBO treatment, if a $TcPO_2$ value of 900-1000 mmHg could be achieved upon initial exposure to 100% oxygen breathing at 2.4 ATA.[17]

Because it was not possible to find predictive values in chronic vascular wound treatment, we undertook a study to evaluate the usefulness of transcutaneous oxygen measurements at different oxygen pressures.

Patients and Methods

During a twelve-month period, 20 patients with a nonhealing wound were referred to our hyperbaric center: chronic arterial insufficiency ulcers in 9 cases, diabetic wounds (foot lesions) in 11 cases.

Adjunctive HBO therapy, initiated twice a day, consisted of pure oxygen at 2.5 ATA for 90 minutes. The average number of sessions was 46 (15-108). Complete healing was observed in 15 of 20 cases.

Transcutaneous oxygen measurements were taken by using a miniature electrode. The instrument is calibrated before each use. Final readings are taken after equilibration. Simultaneous readings are recorded from two sensors placed bilaterally on the extremities, near the wound, in a mirror fashion. The reference electrode is put in the upper front part of the thorax. These measurements are taken in three successive conditions: patient breathing at first normal air, then normobaric pure oxygen by facial mask, and finally, 2.5 ATA hyperbaric pure oxygen.

Results

Four different data are of interest.

1. If we consider the $TcPO_2$ reference as the absolute value (mmHg), there was no significant difference between transcutaneous oxygen pressures of patients who were healed and those who were not, whether patients breathed normal air, pure oxygen, or hyperbaric oxygen (air: 55 ± 28 vs 43 ± 19; 1 ATA O_2: 151 ± 57 vs 104 ± 51; 2.5 ATA O_2: 829 ± 197 vs 926 ± 109). (Figure 1) Such results show that a similar take of oxygen was consumed in the two groups.

By contrast, the distal $TcPO_2$ absolute value was measured in normal air, pure oxygen, or hyperbaric oxygen. The transcutaneous oxygen pressures in hyperbaric oxygen were significantly different according to outcome (healing or no change) when these values were not different in normal air and in normobaric oxygen: (air: 32 ± 31 vs 12 ± 4; NS; 1 ATA O_2: 75 ± 70 vs 18 ± 10, NS; 2.5 ATA O_2: 653 ± 388 vs 45 ± 20, $p = 0.003$). (Figure 2)

2. If we consider the difference between transcutaneous oxygen pressure in 2.5 ATA pure oxygen and in normal air, there was a significant difference between successful and unsuccessful outcomes: 621 ± 390 vs 33 ± 18, $p = 0.004$. But there was no difference at 1 ATA pure oxygen: 42 ± 50 vs 6.6 ± 11.2, NS. (Figure 3)

3. If we consider the ratio between distal $TcPO_2$ and $TCPO_2$ reference, in normal air, pure oxygen, and hyperbaric oxygen, only the ratio obtained with hyperbaric oxygen measurements results in a predictive outcome with a significant value: (ratio air: 0.597 ± 0.48 vs 0.30 ± 0.12, NS; ratio 1 ATA O_2: 0.52 ± 0.47 vs 0.25 ± 0.33, NS; ratio 2.5 ATA O_2: 0.80 ± 0.43 vs 0.0043 ± 0.016, $p = 0.001$). (Figure 4)

4. If we consider the meaning of these different criteria, distal $TcPO_2$ and the ratio distal $TcPO_2/TcPO_2$ reference, in normal air and in pure oxygen, are not good predictors. But in

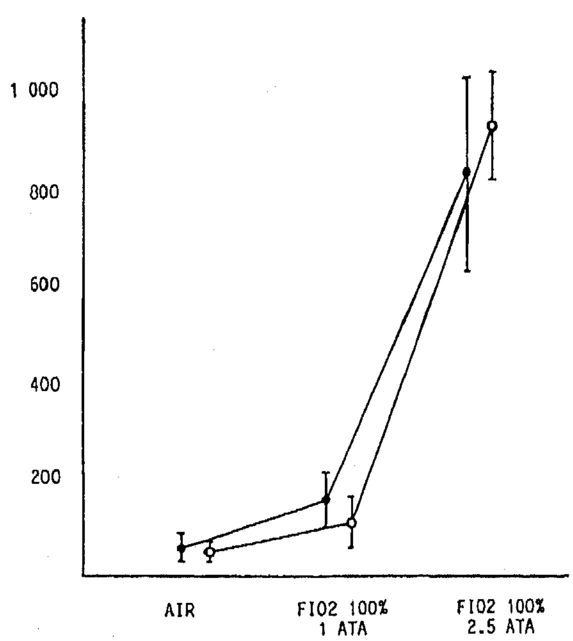

FIG. 1. $TcPO_2$ Reference (mmHg)

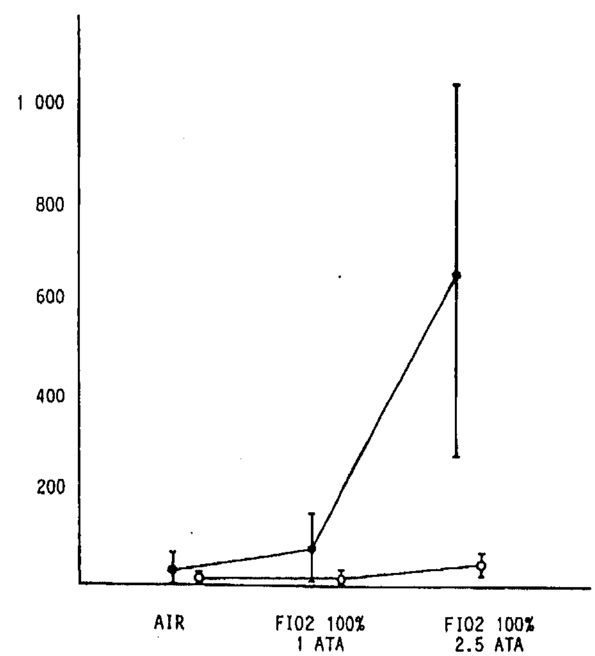

FIG. 2. Distal $TcPO_2$ (mmHg)

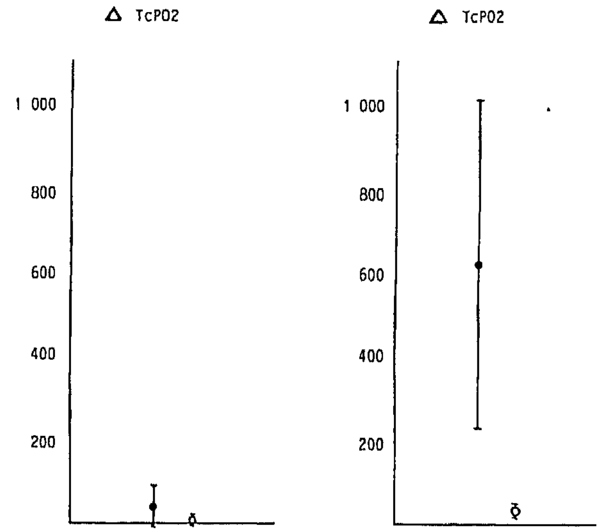

FIG. 3. (left) 1 ATA; F102 100%—Air; (right) 2.5 ATA; F102 100%—Air

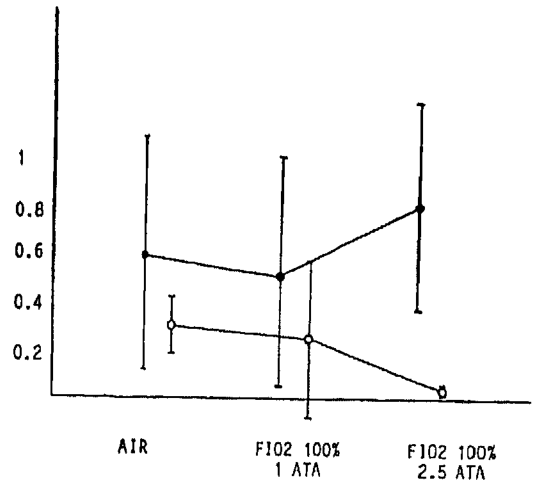

FIG. 4. Distal $TcPO_2$/$TcPO_2$ Reference

hyperbaric oxygen, when the distal $TcPO_2$ value was lower than 100 mmHg, all patients showed either improvement or aggravation, and when the value was higher than 100 mmHg, wound healing was achieved with all patients. In hyperbaric oxygen, when the distal $TcPO_2$ value was lower than 50 mmHg, the condition of all patients worsened. The interval between 50 and 100 mmHg of distal $TcPO_2$ value is, for us, the specific range in which hyperbaric oxygen therapy is the most strongly indicated, because only repeated measurements of distal $TcPO_2$ can predict a good evolution of the chronic vascular wound.

Conclusion

Chronic vascular wound management with hyperbaric oxygen therapy can thus be helped with the transcutaneous oxygen measurements under hyperbaric oxygen. The distal $TcPO_2$ at 2.5 ATA pure oxygen is a reliable test to predict final outcome with wound healing. Further studies will be necessary to confirm this assessment.

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