Original Article

Indian Journal of Diabetes and Endocrinology
Volume 1 Number 1, January - June 2019

Evaluation of Hyperbaric Oxygen Therapy for Diabetic Wounds and Transcutaneous Oximetry as a Predictor of Wound Healing: A prospective Study at Prana HBOT Center Mumbai

Manoj Gupta

How to cite this article:

Manoj Gupta. Evaluation of Hyperbaric Oxygen Therapy for Diabetic Wounds and Transcutaneous Oximetry as a Predictor of Wound Healing: A prospective Study at Prana HBOT Center Mumbai. Indian Journal of Diabetes and Endocrinology. 2019;1(1):5-10.

Abstract

Background: It is general trend amongst patients with diabetes that usually they are at risk for developing foot ulcers irrespective of age, gender, symptoms, or adequacy of glycemic control. HBO therapy is currently approved for a variety of tissue healing and other applications. Transcutaneous Oximetry [TCOM] is a simple, reliable noninvasive technique for the objective assessment of wound perfusion and oxygenation. Its definitive role in predicting the wound healing has not yet been proven. *Objective:* We undertook a prospective study to evaluate the role of Hyper Baric Oxygen Therapy in healing of diabetic wounds and to determine whether Transcutaneous Oximetry can predicts healing. *Study Design:* A prospective study was performed to realize the aim and objectives of this study. *Place of Study:* The study was carried out at the Prana HBO Centre, which is owned by the Investigator and located in the Northern parts of Mumbai, in India. *Methods:* The center has one Sechrist Monoplace hyperbaric chamber and a TCOM machine with 3 electrodes. The oxygen gas supply is from oxygen cylinders of 7000 liters' capacity each. The data was collected from all the patient files, which are stored at the center. Transcutaneous Oximetry monitoring system was utilized for measuring tissue oxygenation ($TcPO_2$) in all the patients of both groups. *Observation and Discussion:* There was 68% reduction in wound area (mean baseline area of 22 cm 2 decreased to 7 cm 2 at 30 day of therapy, as per there mean value in group HT by using paired t test, there is highly significantly improvement in wound with p value 0.00001. Hyperbaric oxygen therapy increases the chances of healing of ulcers by decreasing exudates and very well promotes granulation tissue, as well the wound size decreases and wound tissue type and healing is improvised. *Conclusion:* Hyperbaric Oxygen Therapy definitely has an adjunctive play in management of non healing ulcers usually in diabetic patients.

Keywords: Transcutaneous Oximetry; Hyperbaric Oxygen Therapy; Ulcers.

Author's Affiliation: Director, Prana Hyperbaric Oxygen Therapy Center, Mumbai, Maharashtra 400092 , India.

Corresponding Author: Manoj Gupta, Sailee Hospital & Diagnostic Center, Prathamesh Horizon, New MHB Colony, New Link Road, Borivali West, Mumbai, Maharashtra 400091, India.

E-mail: drmanojgupta222@gmail.com

Received on 08.12.2018 **Accepted on** 15.01.2019

Introduction

Diabetics succumb to plenty of foot disorders, including, neuropathy, infection, Charcot arthropathy, and peripheral arterial disease, amongst them foot ulcers are relatively most common and characteristic diabetic foot wound, and they are significant source of morbidity and disability [1]. By definition Ulcers are defined as any break in the cutaneous barrier that usually extends through the full thickness of the dermis.

It is general trend amongst patients with diabetes that usually they are at risk for developing foot ulcers irrespective of age, gender, symptoms, or adequacy of glycemic control. Multiple Factors associated with an increased risk of foot ulcers in patients with diabetes shall include neuropathy, foot deformity, limit joint mobility, trauma, ischemia, male sex, and previous history of ulceration [2]. Screening tests in diabetics can help identify patients at increased risk of diabetic foot ulceration and include neuropathy symptoms

and disability scoring indexes, measurement of vibration perception threshold and peak plantar foot pressures [3].

Patients with diabetes at increased risk for foot ulceration may show some benefit from prophylactic interventions which also include education, prescription footwear, intensive podiatric care, and evaluation for surgical interventions [4].

Hyperbaric Oxygen therapy (HBOT) is a systemic treatment option; wherein a patient breathes pure oxygen at greater than one atmosphere pressure for a specified period of time. It is defined as breathing 100% oxygen at pressures higher than normal atmospheric pressure at sea level in a hyperbaric chamber. (one ATM is equal to around fourteen pounds per square inch (PSI), 1 kilogram per square centimeter). Therapeutic effects of hyperbaric oxygen therapy are due to increase in dissolved oxygen in plasma and tissue oxygen delivery. It is proved that Oxygen is a has an important role in the physiology of wound healing, HBO therapy is a useful adjunct in the treatment of diabetic foot ulcers by it heals to increase tissue oxygen tensions to the levels that shall promote wound healing and limit edema, and shall also destroy certain anaerobic bacteria, it augmenting neo-vascularization, stimulates fibroblast proliferation and differentiation, increases collagen formation as well stimulate leukocyte microbial killing [5,6]. HBO therapy is currently approved for a variety of tissue healing and other applications.

Transcutaneous Oximetry [TCOM] is a simple, reliable noninvasive technique for the objective assessment of wound perfusion and oxygenation. The definite role of transcutaneous Oximetry in analyzing a wound healing had not yet been proved clearly. We undertook a prospective study to evaluate the role of Hyper Baric Oxygen Therapy in healing of diabetic wounds and to determine whether Transcutaneous Oximetry can predicts healing [7].

Material and Methods

Study Design

A prospective study was performed to realize the aim and objectives of this study.

Study setting

The study was carried out at the Prana HBO Centre, which is owned by the Investigator and located in the Northern parts of Mumbai, in India. The center has one Sechrist Monoplace hyperbaric chamber and a TCOM machine with 3 electrodes. The oxygen gas supply is from oxygen cylinders of 7000 liters' capacity each. The center has all the requisite certifications and registrations as required by the local authority in Mumbai. The data was collected from all the patient files, which are stored at the center. Transcutaneous Oximetry monitoring system was utilized for measuring tissue oxygenation ($TcPO_2$) in all the patients of both groups. Measurements were recorded on non inflamed skin 1 cm proximal to the upper margin of ulcer. $TcPO_2$ findings were recorded on zero, tenth, twentieth, and thirtieth day. $TcPO_2$ was used and the findings were calculated by an electrochemical transducer, and it remain attached to skin and use of adhesive ring and contact liquid was used. The measuring site was cleaned carefully by a disinfectant (spirit). By analyzing and measuring the oxygen reduction current with the help of measuring cell it was concluded for skin oxygen partial pressure. TCOM data was also collected from the Centre register which is maintained separately. The Investigator is the medical practitioner working in this center and the physician who consulted the patients. The study is limited to the patients who were seen at the Centre during two years. Written informed consent was obtained from all the patients and record maintained.

Inclusion criterion

Patients referred from surgical specialties to the hyperbaric oxygen therapy center Prana Mumbai, with the complaint of non healing ulcer, were included in the study. Patients in the age group of 20–68 years of either sex with diabetic non healing ulcer, despite receiving conventional therapy, were included in the study.

Exclusion Criterion

The study excluded all those patients who were consulted by the Investigator but were not treated with HBO, nor they were evaluated for HBO (e.g. by means of TCOM studies) and Patients who were not willing for HBOT, those with active upper respiratory tract infection, with any active lung pathology or pregnancy were excluded from the study.

Statistical Analysis

All the data was collected from patient and the findings noted in register, which is manually maintained at the center. The primary outcome variable was the wound size. The collected data

was directly captured in an MS excel spread sheet for analysis. Factors associated with following the approved protocols, association was determined by calculating the descriptive statistics, correlation, with 95% confidence intervals. The paired and unpaired t test was used to determine statistical significance between the two groups and pre and post exposure. A significance level of 0.05 was used for all these tests.

Ethics review

This study was performed within the scope of international ethical guidelines and legislation. Ethics review and approval was provided by Stellenbosch University (number: U16/06/015) and the ethics committee of the Hyperbaric Society in India.

Observations

In the study total more than 67 cases were recruited and ended up with final 56 number of patient who fulfilled all the inclusion criteria for the study. Total 56 patients completed the study period and no patient was excluded during the study analysis. The demographic profile was comparable in the two groups of hyperbaric therapy and conventional treatment groups. Classification of diabetic foot ulceration was Adapted from Wagner [8]. In reference to the co morbidities of the patients, refer to table no 2, wherein 15 patients with diabetes mellitus and hypertension and were smokers. Common sites of wound were leg 13, forefoot 10, mid foot 14, great toe 10, other toe 4 and other sites were around 5 no of cases.

Table 1: The Wagner Classification of diabetic foot ulceration [Adapted from Wagner] [8].

Grade	Clinical Description
0	No open ulcer, high risk
1	Superficial ulcer with subcutaneous involvement
2	Deep ulcer with tendon or joint involvement
3	Deep ulcer with bone involvement
4	Wet or dry gangrene (forefoot), without cellulites
5	Generalized (whole foot) gangrene

Table 2: Patients Characteristics

Variables	Group HT	Group CT
Age	49±9.8	52±11.2
Sex (M/F)	24/04	22/06
Co morbidities		
Diabetes mellitus	11	11
Hypertension	15	14
Varicose vein	5	4
Vascular insufficiency	4	5
Smoking	14	15

There was 68% reduction in wound area (mean baseline area of 22 cm 2 decreased to 7 cm 2 at 30 day of therapy) as per there mean value in group HT by using paired t test, there is highly significantly improvement in wound with p value 0.00001. There was mild change in wound area which shows 8% decrease in wound area (mean baseline area of 20.5 cm 2 changed to 18.9 cm 2 at 30 day of therapy, by using paired t test, there was no significant improvement in wound with p value 0.1938 in group CT. (Table 2).

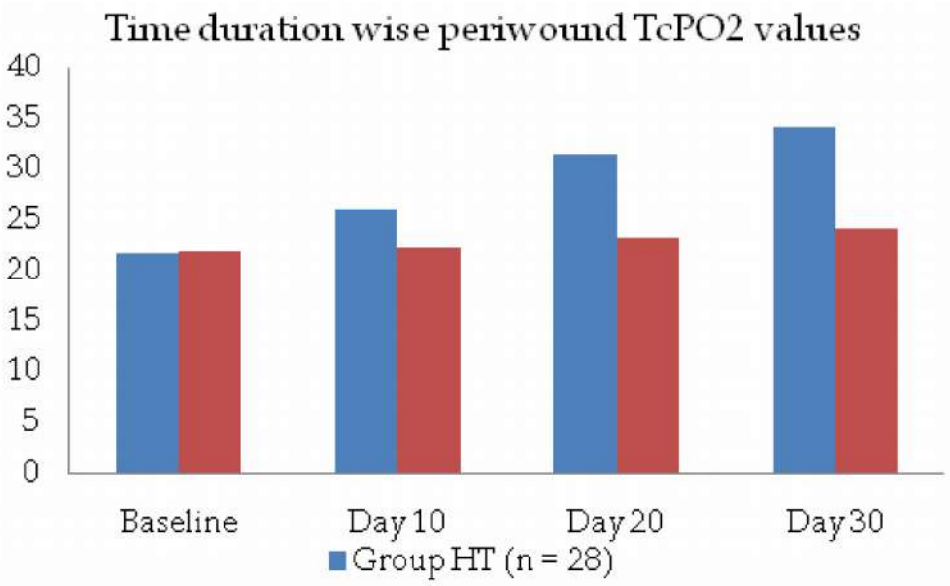

Fig. 1: Time duration wise peri wound $TcPO_2$ values

Table 3: Comparison of wound tissue score from baseline at different time intervals of therapy

Variables		Improvement in wound score (n)	No change in wound score (n)	Deterioration in wound score (n)
Group HT (n = 28)	After 10 days	17	11	0
	After 20 days	19	9	0
	After 30 days	20	6	2
Group CT (n = 28)	After 10 days	6	22	0
	After 20 days	7	19	2
	After 30 days	7	19	2

A significant improvement in wound score was observed in group HT as compared to group CT after 30 days of treatment. Refer table No 3. Significant improvement in wound score was observed after every 10 sittings of HBOT in group HT, after 30 days of treatment 20 patients showed improvement in group HT, whereas no change was observed in 6 patient of HT group and there had been deterioration in wound score in 2 cases of HT group. As compared to group HT, patient who received only CT therapy also showed improvement in 7 patients, whereas no change in 19 patient of CT group, 2 patient of group Ct there had been deterioration in wound score. (Table 3).

As per Table 4, a positive correlation was found between $TcPO_2$ value and various markers of wound healing, such as decrease in area of the wound, decrease in exudates amount, and improvement in wound score. In observation it was found to be negative correlation amongst amputation rate and the value of $TcPO_2$. Peri wound $TcPO_2$ values were monitored at regular intervals in both the groups and a positive correlation was found between $TcPO_2$ values and various markers of wound healing, such as decrease in area of the wound ($P = 0.000567$), decrease in exudates amount ($p = 0.000021$), and improvement in wound score ($p = 0.0047$). A negative correlation of (-0.56) was found between $TcPO_2$ values and amputation rate ($p = 0.000972$). Higher the peri wound $TcPO_2$ levels, lesser is the amputation rate ($p \leq 0.05$). Higher the peri wound $TcPO_2$ levels more are the chances of wound healing. It was observed that correlations individually were very significant in group of HT whereas it was not significant in group CT.

Fig. 2: A diabetic patient was accomplished by utilizing conventional modalities including a course of hyperbaric oxygen therapy.

Discussion

In our study it is very clear that hyperbaric oxygen therapy increases the chances of healing of ulcers by decreasing exudates and very well promote granulation tissue, as well the wound size decreases and wound tissue type and healing is improvised. It is also very clear from our observation that $TcPO_2$ values and various other parameters of wound healing taken into consideration in this study such as decrease in area of the wound, decrease in exudates amount and improvement in

Table 4: Correlation of peri wound $TcPO_2$ and various parameters of wound healing

Parameters	Group HT (n = 28)		Group CT (n = 28)		Combined Group (n = 56)	
	Corr. Coeff.	P Value	Corr. Coeff.	P Value	Corr. Coeff.	P Value
Improvement in tissue grading (decrease in wound score)	0.64	0.000123	0.3112	0.0535	0.482	0.0047
Improvement in exudates (decrease in exudates)	0.768	0.000001	0.2861	0.07	0.6943	0.000021
Change in wound size (decrease in wound area)	0.7948	0.000001	0.2951	0.0637	0.583	0.00057
Amputation rate	-0.5837	0.00056	-0.2349	0.1145	-0.56	0.000972

wound score. It was also seen in our findings that a negative correlation was seen between $TcPO_2$ values and amputation rate.

Findings of other authors like Oriani et al. [9] and Baroni et al. [10]., who reported that better healing changes and least amputation rate was appreciated after hyperbaric oxygen therapy as compared to conventional therapy in diabetic patient with chronic non healing ulcers, this findings are in concurrent agreement with our findings and study and shows a positive effects of adjunctive of hyperbaric oxygen therapy. In addition, as per Jain KK [11] et al. Hyper Baric Oxygen Therapy has bactericidal and bacteriostatic effects on both aerobic and anaerobic bacteria through the action of the super oxide enzyme, which acts more rapidly at high oxygen tensions (30 to 40 mm Hg).

As per Brakora MJ [12] et al. Hyperbaric Oxygen Therapy has also been shown to have synergistic effects with aminoglycosides, trimethoprim, nitrofurantoin, and sulfisoxazole. Furthermore, hyperoxic vasoconstriction that takes place during Hyper baric Oxygen Therapy reduces capillary pressure and increases vascular permeability. The resulting decrease in transcapillary fluid transfer increases extravascular fluid resorption, which reduces lower extremity edema [13]. Niinikoski JH et al. [14] In his animal studies, demonstrated that wound healing was an oxygen dependent process by measuring transcutaneous oxygen pressure TcP02. By employing the same technique, Sheffield [15] demonstrated that chronic tissue hypoxia could be corrected by HBOT. As per Wattel F [16] et al. hyperbaric oxygen therapy may be added as to conventional treatment of diabetic foot ulcers, if it is clearly that peri wound $TcPO_2$ in 2.5 ATA HBO is over 200 mm Hg.

Complication during treatment, none of the patients suffered a serious complication from HBO, such as a pnemothorax, or seizure etc. However, some minor side-effects were experienced like ear pain in the chamber most likely as a result of mild barotrauma of the ears. However, Barotrauma wasn't noted as a complication for any of these patients. One patient suffered hypoglycemia during a treatment, while eleven patients suffered visual changes related to the HBO.

Conclusion

To conclude Hyperbaric Oxygen Therapy definitely has an adjunctive play in management of non healing ulcers usually in diabetic patients. It is well settled by the study that the complicated wound require immediate attention with multidisciplinary approach, aggressively which include administration of hyperbaric oxygen therapy. However conventional treatment and approach is also equally required to decrease the amputation rate and to increase the well outcome of the patients. It is clear from the study that $TcPO_2$ values shall be useful in predicting the response of hyperbaric oxygen therapy and definitely have a positive correlation with regards to wound healing. The results of this study will definitely contribute to evidence-based decision making on the use of Hyperbaric Oxygen Therapy as an adjunctive therapy in patients with a diabetic foot ulcer.

Conflict of Interest: The author declares no conflict of interest for this study.

Acknowledgement

Author acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript.

Reference

1. Rathur HM, Boulton AJ. The diabetic foot. Clin Dermatol 2007;25:109-120.
2. Boyko EJ, Ahroni JH, Stensel V, et al. A prospective study of risk factors for diabetic foot ulcer. The Seattle Diabetic Foot Study. Diabetes Care. 1999;7: 1036-42.
3. Armstrong DG, Lavery LA, Vela SA, Quebedeaux TL, Fleischli JG. Choosing a practical screening instrument to identify patients at risk for diabetic foot ulceration. Arch Intern Med. 1998;158:289-92.
4. Singh N, Armstrong DG, Lipsky Ba. Preventing foot ulcers in patients with diabetes. JAMA 2005;293: 217-28.
5. Bakker DJ. Hyperbaric oxygen therapy and the diabetic foot. Diabetes Metab Res Rev. 2000;19 (Suppl 1):S55-58.
6. Strauss MB. Hyperbaric oxygen as an intervention for managing wound hypoxia: its role and usefulness in diabetic foot wounds. Foot Ankle Int 2005;26:15-18.
7. Niinikoski J. Clinical hyperbaric oxygen therapy, wound perfusion, and transcutaneous oximetry. World J Surg. 2004;28:307-11.
8. Wagner FW. The dysvascular foot: a system for diagnosis and treatment. Foot Ankle. 1981;2:64–122.
9. Oriani G, Meazza D, Favales F, Pizzi GL, Aldeghi A, Faglia E. Hyperbaric oxygen in diabetic gangrene. J Hyperb Med. 1990;5:171-5.

10. Baroni G, Porro T, Faglia E, Pizzi G, Mastropasqua A, Oriani G, et al. Hyperbaric oxygen in diabetic gangrene treatment. Diabetes Care. 1987;10:81-6.
11. Jain KK. Physical, physiological and biochemical aspects of hyperbaric oxygenation. In Textbook of Hyperbaric Medicine, pp 480–495, edited by Jain KK, Neubauer R, Correa JG, Hogrefe & Huber, Toronto, 1990.
12. Brakora MJ, Sheffield PJ. Hyperbaric oxygen therapy for diabetic wounds. Clin Podiatr Med Surg 1995;12:105–117.
13. Strauss MB. Crush injury and other acute traumatic peripheral ischemias. In Hyperbaric Medicine Practice, edited by EP Kindwall, Best Publishing Company, Flagstaff, 1995. pp.525–50.
14. Niinikoski JH. Clinical hyperbaric oxygen therapy, wound perfusion, and transcutaneous oximetry. World J Surg. 2004;28:307–11. Epub Feb 17, 2004.
15. Sheffield JP. Tissue oxygen measurements. In Problem Wounds: The Role of Oxygen, edited by JC Davis, TK Hunt, Elsevier, New York, 1988.pp.17-51.
16. Wattel F, Mathieu D, Fossati F, Nevie`re R, Coget JM. Hyperbaric oxygen in the treatment of diabetic foot. Undersea Biomed Res. 1990;17:160-1.

*****