Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/burns

Evaluation of TCOM/HBOT practice guideline for the treatment of foot burns occurring in diabetic patients

Larry M. Jones [*], *Christopher Rubadue*, *Nicole V. Brown*, *Sorabh Khandelwal*, *Rebecca A. Coffey*

The Ohio State University Wexner Medical Center, 10th Avenue, N748 Doan Hall, Columbus, OH 43210, United States

ARTICLE INFO

Article history:
Accepted 5 August 2014

Keywords:
Diabetes
Foot burns
Practice guideline

ABSTRACT

Objectives: A multidisciplinary team developed an evidence-based guideline for the management of foot burns occurring in diabetic patients that included transcutaneous oxygen measurements (TCOM) and application of hyperbaric oxygen therapy (HBOT) to selected patients. This report represents an evaluation of preliminary TCOM/HBOT data.

Methods: This is a retrospective review of patients with diabetes mellitus (DM) who were admitted to a single American Burn Association (ABA) verified burn center for the treatment of foot burns. Patients were treated via the guideline if they were over the age of 16, admitted for the initial care of burns involving the feet between 4/01/2012 and 7/22/2013, and had a known or new diagnosis of DM.

Results: Eighteen patients were treated according to the guideline, 14 men and 4 women. Average age was 54 years + 14.78. Average BMI was 30.63 + 6.34. Median burn size was 0.88% TBSA (median partial thickness of 1% and median full thickness of 0.5%). The average HbA1c was 9.08 + 2.42. Seven patients received pre-operative HBOT, two received post-operative HBOT and three patients healed their wounds with HBOT alone. Average hospital length of stay was 13.39 days + 9.94 and was significantly longer for the group receiving HBOT. Admission HbA1c was not a predictor of the need for HBOT.

Conclusions: While TCOM/HBOT therapy has not been widely applied to the management of diabetic foot burns, the use of an evidence-based guideline incorporating TCOM/HBOT can provide a systematic way to evaluate the patients' microcirculation and ability to heal burns of the foot. The incorporation of TCOM determination and application of HBOT in selected patients with DM and burns of the feet warrant continued study.

1. Introduction.

At our American Burn Association (ABA) verified burn center 18% of patients admitted for the treatment of burns are diabetic with hemoglobin A1c (HbA1c) levels above the diabetes mellitus (DM) threshold of >6.5% [1]. Of that group, 27% have suffered burns to their feet. To provide efficient and effective care to this group of patients, a multidisciplinary team consisting of physician specialists in burn, plastic and podiatric surgery, endocrinology, and hyperbaric medicine along with nurses, pharmacists and physical therapists

* Corresponding author. Tel.: +1 614 293 5710; fax: +1 614 293 3425.
E-mail address: Larry.jones@osumc.edu (L.M. Jones).

http://dx.doi.org/10.1016/j.burns.2014.08.001
0305-4179/

developed an evidence-based guideline for the management of foot burns occurring in patients with DM [2].

Diabetes mellitus is notorious for the negative effect it has on normal wound healing. That effect is exerted through multiple mechanisms, many of which have local tissue ischemia and subsequent decreased local tissue oxygen tension as a common pathway [3,4]. Several investigators have shown that the critical oxygen tension required for wound healing is between 30 to 40 mmHg [5–8]. Yet it is not uncommon for oxygen tensions in wounded tissues to be lower than this threshold, as reported by Gordillo et al. [9]. Transcutaneous oxygen monitoring (TCOM) is one way to measure local oxygen delivery [10].

The concentration of oxygen in arterial blood is determined by the equation:

$$\mathrm{Ca}_{\mathrm{O_2}} = (1.34 \times \mathrm{Hgb} \times \mathrm{Sa}_{\mathrm{O_2}}) + (0.003 \times \mathrm{Pa}_{\mathrm{O_2}})$$

where Hgb represents hemoglobin, $\mathrm{Sa}_{\mathrm{O_2}}$ is the arterial oxygen saturation and $\mathrm{Pa}_{\mathrm{O_2}}$ is the partial pressure of oxygen in the blood [11]. The amount of free oxygen dissolved in the plasma $(0.003 \times \mathrm{Pa}_{\mathrm{O_2}})$ is negligible under normal barometric situations. However, the delivery of oxygen through hyperbaric oxygen therapy (HBOT) can increase this contribution to total arterial oxygen concentration by significantly increasing the $\mathrm{Pa}_{\mathrm{O_2}}$. According to Godman et al., this exposure to hyperbaric oxygen leads to a cytoprotective and angiogenic response in human microvascular endothelial cells that in turn are important steps in wound healing [12].

These positive effects have led to the application of HBOT in the management of chronic wounds, particularly diabetic foot ulcers. However, that application has been surrounded with controversy [13,14]. A Cochran Review in 2004 concluded that HBOT reduced the risk of major amputation in cases of diabetic foot ulcer [15]. An updated review in 2012 did not show that same reduction in amputation rates but did report an increased rate of ulcer healing when HBOT was employed [16]. Despite conflicting reports, criticisms of bias and small sample sizes, Steed et al. published an evidence-based guideline that cited Level I evidence for the inclusion of HBOT in the clinical management of diabetic foot ulcers [17].

While the medical literature contains many published reports on the use of HBOT in the management of diabetic foot ulcers, there are few regarding the use of HBOT in the management of diabetic foot burns. Indeed, some might argue that diabetic foot ulcers (chronic) and a burn wound (acute) in a patient with DM are two different diseases. Yet important similarities in wound healing, and impediments to wound healing, can be found in both models. The burn wound exhibits changes in the microvasculature that includes red cell aggregation, white cell adhesion and platelet microemboli [18,19]. Inflammatory mediators contribute to hyperpermeability of the microcirculation [20]. The ongoing tissue damage is, in part, due to the failure of the surrounding tissue to supply borderline cells with oxygen. Both types of wounds in the diabetic patient display increased extra-vascular osmotic activity, edema formation, and a site of entry for infection [3–5,10,19]. It is because of these wound similarities that data obtained through the treatment of diabetic foot ulcers can be applied to the treatment of diabetic foot burns.

By extrapolating data from the treatment of diabetic foot ulcers to the treatment of diabetic foot burns, the multidisciplinary group from our institution included the use of TCOM and HBOT in its guideline. This report is an evaluation of preliminary TCOM/HBOT data collected as a result of implementing that guideline.

2. Methods

A retrospective review of patients with DM admitted to a single ABA verified burn center for the treatment of foot burns following implementation of a previously published evidence-based guideline was conducted. Patients were treated via the guideline if they were over the age of 16, admitted for the initial care of burns involving the feet between 4/01/2012 and 7/22/2013, and had a known or new diagnosis of DM. A new diagnosis of DM was by HbA1c level performed on admission. Approval for the study was obtained from The Ohio State University Institutional Review Board.

2.1. *Data collection*

Patients were identified electronically by admission to the Burn Service from the institutional burn database. Data, which was collected retrospectively, included gender, age, admitting serum glucose, admitting HbA1c, burn mechanism, TBSA (total, partial and full thickness), TCOM's, number of hyperbaric treatments, length of stay, need for skin grafting, healing without skin grafting, complications (including unplanned readmission) and need for amputation.

2.2. *Guideline*

Hyperbaric Medicine consults are obtained on all patients with diabetes and burns of the feet. According to the guideline, if the patient has been previously diagnosed with DM or if the HbA1c level is >6.5%, that patient has peri-wound transcutaneous partial pressure of tissue oxygen measurements ($TcPO_2$) with placement of the sensors adjacent to the wound to assess the patient's ability to heal the wound (Fig. 1) [21,22]. Transcutaneous oxygen levels >50 mmHg are considered normal and unimpaired wound healing can be expected [23,24]. Levels between 40 and 50 mmHg are adequate for wound healing but if therapy is unsuccessful, HBOT and vascular studies are in order [25]. If the $TcPO_2$ is less than 40 mmHg, a normobaric oxygen challenge is obtained by having the patient breathe 100% O_2 and measuring the $TcPO_2$ [26]. A measurement of >300 mmHg indicates uncompromised arterial flow and unimpaired wound healing should follow. A result of <300 mmHg but >100 mmHg identifies those patients who will potentially benefit from HBOT. If the result is <100 mmHg, the patient undergoes an in-chamber HBO trial performed at 2 atmospheres of pressure. If the resulting $TcPO_2$ is >200 mmHg, the patient will benefit from HBOT [27].

Patients who are determined to benefit from HBOT undergo 14 treatments. If at that time there is improvement in the $TcPO_2$, the HBO treatments are continued to a total of 20 [28]. If the patient is a candidate for skin grafting, these HBO treatments are administered both pre and post-operatively for a total of 20 to 30 treatments [29].

Fig. 1 – Demonstration of peri-wound placement of TCOM sensors.

2.3. Definitions

Diabetes mellitus is defined as either (1) a history of being diagnosed with DM or (2) an admitting HbA1c of ≥6.5% based on criteria established by the American Diabetes Association [1].

Length of stay (LOS) is defined as the number of in-patient days from admission to discharge.

Unplanned readmission is defined according to the Agency for Healthcare Research and Quality (AHRQ) criteria that includes (1) unexpected admission for further treatment of the same primary condition, (2) further treatment of a condition related to the primary admission, or (3) unexpected admission for a complication of the primary condition for which the patient was previously hospitalized [30].

2.4. Statistical methods

Descriptive statistics were generated for all variables of interest. Continuous variables were expressed using the mean and standard deviation or median and range, depending on normality. Categorical variables were expressed using frequencies and percentages. Demographic and clinical characteristics were compared between those that did and did not receive HBOT treatments using two-sample *t*-tests (normally distributed variables), Mann–Whitney *U* tests (non-normally distributed variables), or Chi-Square tests (categorical variables) as appropriate. Logistic regression was used to assess HgA1c as predictor of HBOT. A p value < 0.05 was determined to represent statistical significance. Analyses were performed using SAS software, version 9.2, SAS Institute, Cary, North Carolina.

3. Results

During the study period, there were 24 patients with DM who were admitted for the treatment of burns on the feet. Four patients were not placed on the guideline at the discretion of the attending surgeon. One patient met criteria but refused TCOMs. One patient met criteria but was deemed not appropriate because of concurrently receiving *cis*-platin for the treatment of bladder cancer. Eighteen patients were treated according to the guideline. There were 14 men and 4 women. The average age was 54 years + 14.78 (range 29 to 86). The average height was 1.77 m + 0.12 (range 1.52 to 1.98), the average weight was 95.28 kg + 17.37 (range 71.4 to 122.4) and the average BMI was 30.63 + 6.34 (range18.6 to 43.4). The median burn size was 0.88% TBSA (range 0.25–7.0) with median partial thickness of 1% TBSA (range 0.25 to 2) and median full thickness of 0.5% TBSA (range 0.2 to 6). Burning mechanism was contact with a hot object for 10, hot liquids (scalding) for 6, chemical burn for 1 and sunburn for 1. No patient suffered an associated inhalation injury. The average hospital length of stay (LOS) was 13.39 days + 9.94 (range 2–39). There were no deaths.

Based on the patients' history, physical exam, medication list and/or laboratory determinations 11 had neuropathy, 2 had retinopathy, 10 had hypertension and 6 had hyperlipidemia. Additional co-morbidities are listed in Table 1. Nine patients were on oral glycemic agents, 11 were using insulin, 8 were taking statin drugs and 3 were taking gabapentin or pregabalin. The average HbA1c was 9.08 + 2.42 (range 5.6 to 13.8). Median admitting serum glucose was 138.5 (range 62–496). Results of baseline TCOMS, oxygen challenges, HBO challenges and HBOT are listed in Table 2.

Seven patients received pre-operative HBOT treatments and 2 patients received post-operative HBOT treatments. The median number of pre-operative HBOT treatments was 15 (range 9 to 20). Of the seven patients who received pre-operative HBOT, 3 healed their burn wound with HBOT alone and skin grafting was avoided. One patient who did not receive HBOT based on initial TCOM levels but who did undergo skin grafting displayed full graft take at discharge only to be re-admitted 9 days later for graft failure and gas-forming soft tissue infection. That patient eventually had a below-knee amputation. This represents the only case of graft loss and amputation that occurred in the study group. This patient was also the only re-admission.

Comparing the two groups (those who received HBOT and those who did not) there was no statistically significant difference in age, gender, TBSA, BMI or HbA1c levels. However,

Table 1 – Associated co-morbidities.

Co-morbidity	No. of patients (n = 18)
Neuropathy	11
Hypertension	10
Hyperlipidemia	6
Mental health issues	5
Alcohol use	4
Coronary artery disease	3
Smoker	3
Congestive heart failure	2
COPD	2
Retinopathy	2
Osteoarthritis	1
CVA	1
Renal disease	1
Chronic atrial fibrillation	1
Rheumatoid arthritis	1
Other chronic pain	1

Table 2 – Results of transcutaneous oxygen measurements (TCOM). Patients 12, 17, and 20 (*) healed burn wounds with HBOT and no grafting.

Patient	Baseline TCOM (mmHg)		O_2 challenge TCOM (mmHg)		HBO challenge TCOM (mmHg)		HBOT		STSG
	Right	Left	Right	Left	Right	Left	Pre-op Tx no.	Post-op Tx no.	
1		13		40			9	1	Yes
4	32	32	98	98			15	0	Yes
5							0	0	No
6			58	58	331	282	0	0	No
7			42		70		0	0	Yes
10		68		155			0	0	Yes
11		18		68		650	15	5	Yes
12*				88		298	16	0	No
13	48	100					0	0	No
14		62		104			0	0	Yes
15	48		126				0	0	Yes
16		54		96			0	0	No
17*		14		34		200	20	0	No
18	36		106				0	0	No
19		94		176			10	0	Yes
20*	28		40		580		14	0	No
21	84		110				0	0	No
22		54		98			0	0	Yes

the LOS was different in the two groups with those receiving HBOT having a significantly longer LOS. (Table 3). Admission HbA1c was not a predictor of the need for HBOT ($p = 0.1307$, odds ratio 1.429 with 95% confidence interval of 0.899 to 2.272, power = 35%).

4. Discussion

The American Diabetes Association estimates that 8.3% of Americans have DM [1]. Burns involving the feet of patients with diabetes are a common clinical presentation, which pose a significant management challenge for the burn team. Due to the associated peripheral neuropathy and insufficient oxygenation to the distal lower extremity, these patients are notorious for non-healing wounds, increased wound infection rates and ultimate need for limb amputation [5,31,32].

Evidence-based guidelines decrease variations in practice, decrease treatment costs and improve overall patient care [33–35]. Using an evidence-based guideline for the management of patients with DM who have suffered burns of the feet might also improve outcomes for those patients. A search of the English literature dealing with the subject published over the past 10 years failed to uncover such a guideline. Consequently, a multi-disciplinary group of faculty was convened at our institution and charged with writing a guideline for the management of patients with DM who had suffered burns of their feet.

The application of HBOT to burn wounds has previously been reported. Brannen et al. found no difference in mortality, length of stay, or number of surgical procedures in burn patients treated with HBOT when compared to a group of burn patients treated without HBOT [36]. A shorter healing time was reported by Hart et al. in burn patients who were treated with HBOT compared to a sham-HBOT treated group [37]. In a report of split thickness skin grafts, Perrins and Cantab showed a significantly higher percentage of graft survival in patients who were treated with HBOT [38]. However, none of those studies were directed primarily at patients with DM.

While little has been published specific to the management of foot burns in patients with DM, there is a wealth of information regarding the management of diabetic foot ulcers. Considering the similarities in the pathophysiology of the two wounds, our guideline group felt justified in applying the published literature pertaining to diabetic foot ulcers to burns of the feet suffered by patients with DM. We found that many of the management suggestions for foot ulcers, i.e. glucose control, off-loading, intense local wound care, were already in use by our burn team. One modality that is accepted in the treatment of diabetic foot ulcers but remains controversial in

Table 3 – Comparison of patient groups.

Variable	HBOT	No HBOT	*p*-Value
Age (years/mean)	50.00 ± 11.58	56.55 ± 16.51	0.3756
Gender	6M/1F	8M/3F	1.0000
TBSA % (median/range)	0.75 (0.5 to 7.0)	1.00 (0.25 to 4.00)	0.6767
BMI (mean)	29.10 ± 8.65	31.61 ± 4.56	0.4296
HbA1c (mean)	10.20 ± 2.92	8.37 ± 1.84	0.1208
LOS (mean)	21.43 ± 10.6	8.27 ± 5.16	0.0159

Table 4 – Comparison of demographics and outcomes.

	Barsun [26] (traditional treatment)	Ohio state (following guideline with TCOM & HBOT)
No. of patients	68 (collected over 10 years)	18 (collected over 16 months)
Age (years)	54 ± 13.1 (range 24 to 85)	54 ± 14.78 (range 29 to 86)
Gender	87% male (59 of 68)	78% male (14 of 18)
TBSA (%)	Ave. 4.2 ± 3.8% (range 0.5 to 15%)	Median 0.88% (range 0.25 to 7.0%)
Using insulin	59.6%	64.7%
Using oral agents	34.6%	52.9%
Admission glucose	Ave. 215.8 ± 109 (range 50 to 546)	Median 138.5 (range 62 to 496)
Admission HbA1c	9.08 ± 2.4 (range 5.0 to 14.7)	9.08 ± 2.42 (range 5.6 to 13.8)
LOS (days)	15.2 ± 14.2 (range 1 to 95)	13.39 ± 9.94 (range 2 to 39)
LOS/%TBSA	5.7 ± 5.8	Median 14.0 (range 1 to 54)
No. patients readmitted	19	1
Amputations	31 amputations in 11 patients	1 amputation in 1 patient

the management of burns is the use of TCOM's to evaluate the microcirculation and the application of HBOT to selected patients. The HBOT/diabetic foot ulcer literature was investigated by our group and recommendations based on that literature were included in our guideline.

A 2013 report by Barsun et al. described 68 patients with DM who had suffered burns of their feet [39]. This is the largest reported series of foot burns occurring in patients with DM and the only published series with which to compare our results. Table 4 compares the Barsun patients' demographics and outcomes using treatment methods that did not include TCOM determinations and application of HBOT with our group following the guideline and employing TCOM/HBOT. There are numerous similarities in baseline characteristics and diabetes specific measures between the two groups. However, Barsun reports 19 patients required readmission because of inability to heal their wounds and 11 patients ultimately experiencing numerous amputations. In our group, only one patient was readmitted for complications and inability to heal. That same patient represents the only amputation performed on our patients. Even allowing for our smaller sample size, the comparison suggests that TCOM's and HBOT should continue to be investigated as a treatment option in this clinical setting.

Good glycemic control results in improved outcomes for patients suffering DM [17,40]. At our institution, every patient admitted for the treatment of burns is screened for an elevated HbA1c. Our data does not suggest that HbA1c levels can be used to predict either the need for HBOT nor the patients' response. This may be due to the small sample size and the resulting low statistical power. Despite our preliminary results, we believe this HbA1c to HBOT relationship deserves special attention since HbA1c levels have been shown to be a predictor of wound healing [40].

The current CMS directive lists Wagner Grade 3 foot ulcers as the only indication for HBOT in patients with diabetes [41]. That same directive goes on to say that HBOT should be applied in those cases only when ''Failure to respond to standard wound care occurs when there are no measureable signs of healing for at least 30 consecutive days.'' If improved outcomes using HBOT for patients with DM and burns of the feet can ultimately be shown with a larger sample, then that CMS directive should be re-evaluated.

The presence of pedal pulses did not predict the patients' TCOM levels, their response to an O_2 challenge, nor their ultimate need for HBOT. Two patients had palpable pulses but were determined to be HBOT candidates based on TCOMs and O_2 challenge. Only one patient in the study had a formal noninvasive physiologic study of lower extremity arteries (ankle/brachial index, result = 0.3). This patient (no. 14) responded appropriately to the O_2 challenge and HBOT was not indicated. The patient went on to have skin grafting and healed with routine post-operative, non-HBOT, care.

There are several limitations of this study. It is retrospective and the sample size is small. While our data does not have the statistical power to show a definite benefit from TCOM/HBOT therapy, clinical observations made by the burn surgeons at our institution, representing over 100 years of combined experience, suggest with a larger sample size a statistical benefit may be shown. Particular cases in point are the three patients in our study group who were scheduled for skin grafting but healed their burn wounds with HBOT alone.

5. Conclusions

Any guideline must be a living document in that clinical data must be collected from following the guideline and applied to either justify continued use of the guideline or aid in its modification. This report of preliminary data obtained from following our guideline is meant to stimulate discussion, generate hypotheses and encourage collaboration for ongoing study. We believe that the incorporation of TCOM determination and application of HBOT in selected patients with DM and burns of the feet warrant continued study. While TCOM/HBOT therapy has not been widely applied in the management of foot burns occurring in patients with DM, the use of an evidence-based guideline incorporating TCOM/HBOT may provide a systematic way to evaluate those patients' microcirculation and their ability to heal their burn wounds.

Funding source

None.

Conflict of interest statement

None declared by any author.

REFERENCES

[1] American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care 2010;33:S62–9.

[2] Jones LM, Coffey R, Khandelwal S, Atway S, Gordillo G, Murphy C, et al. A clinician's guide to the treatment of foot burns occurring in diabetic patients. Burns 2014. http://dx.doi.org/10.1016/j.burns.2014.01.026.

[3] Brem H, Tomic-Canic M. Cellular and molecular basis of wound healing in diabetes. J Clin Invest 2007;117(5):1219–22.

[4] Goldstein LJ. Hyperbaric oxygen for chronic wounds. Dermat Ther 2013;26:207–14.

[5] Hunt TK. The physiology of wound healing. Ann Emerg Med 1988;17:1265–73.

[6] Schreml S, Szeimies RM, Prantl L, et al. Oxygen in acute and chronic wound healing. Br J Dermatol 2010;163:257–68.

[7] Tandara AA, Mustoe TA. Oxygen in wound healing—more than a nutrient. World J Surg 2004;28(3):294–300.

[8] Wattel F, Mathieu D, Coget JM, et al. Hyperbaric oxygen therapy in chronic vascular wound management. Angiology 1990;41(1):59–65.

[9] Gordillo GM, Sen CK. Revisiting the essential role of oxygen in wound healing. Am J Surg 2003;186:259–63.

[10] Greenhalgh DG. Wound healing and diabetes mellitus. Clin Plast Surg 2003;30:37–45.

[11] Alarcon LH. Physiologic monitoring of the surgical patient. In: Brunicardi FC, Brunicardi FC, Andersen DK, Billiar TR, Dunn DL, Hunter JG, Matthews JB, Pollock RE, editors. Schwartz's principles of surgery. 9th ed, New York, NY: McGraw Hill; 2010. p. 354.

[12] Godman CA, Chheda KP, Hightower LE, et al. Hyperbaric oxygen induces a cytoprotective and angiogenic response in human microvascular endothelial cells. Cell Stress Chaperones 2010;15(4):431–42.

[13] Bakker DJ. Hyperbaric oxygen therapy and the diabetic foot. Diabetes Metab Res Rev 2000;16(Suppl):S55–8.

[14] Wunderlich RP, Lavery PEJ. Systemic hyperbaric oxygen therapy: lower-extremity wound healing and the diabetic foot. Diabetes Care 2000;23:1551–5.

[15] Kranke P, Bennett M, Roeckl-Wiedmann I, et al. Hyperbaric oxygen therapy for chronic wounds. Cochrane Database Syst Rev 2004;(1):CD004123. http://dx.doi.org/10.1002/14651858.CD004123.pub2.

[16] Kranke P, Bennett MH, Martyn-St James M, et al. Hyperbaric oxygen therapy for chronic wounds. Cochrane Database Syst Rev 2012;(4):CD004123. http://dx.doi.org/10.1002/14651858.CD004123.pub3.

[17] Steed DL, Attinger C, Colaizzi T, et al. Guidelines for the treatment of diabetic ulcers. Wound Rep Reg 2006;14:680–92.

[18] Boykin JV, Eriksson E, Pittman RN. In vivo microcirculation of a scald burn and the progression of postburn dermal ischemia. Plast Reconstr Surg 1980;66:191–8.

[19] Arturson G. Pathophysiology of the burn wound. Ann Chir Gynaecol 1980;69:178–90.

[20] Heggers JP, Robson MC, Zachary LS. Thromboxane inhibitor for the prevention of progressive dermal ischemia due to the thermal injury. J Burn Care Rehabil 1985;6:466–8.

[21] Ballard JL, Eke CC, Burt TJ, Killeen JD. A prospective evaluation of transcutaneous oxygen measurements in the management of diabetic foot problems. J Vasc Surg 1995;22:485–90.

[22] Smart DR, Bennett MH, Mitchell SJ. Transcutaneous oximetry, problem wounds, and hyperbaric oxygen therapy. Diving Hyperb Med 2006;36:72–86.

[23] Niinikoski JH. Clinical hyperbaric oxygen therapy, wound perfusion, and transcutaneous oximetry. World J Surg 2004;28:307–11.

[24] Londahl M, Katzman P, Hammarlund C, Nilsson A, Landin-Olson M. Relationship between ulcer healing after hyperbaric oxygen therapy and transcutaneous oximetry, toe blood pressure and ankle-brachial index in patients with diabetes and chronic foot ulcers. Diabetologia 2011;54:65–8.

[25] Warriner R, Hopf H. Enhancement of healing in related problem wounds. In: Gesell L, editor. Hyperbaric oxygen therapy indications. Durham, NC: Undersea and Hyperbaric Medical Society; 2008. p. 67–83.

[26] Harward TR, Volny J, Golbranson F, Bernstein EF, Fronek A. Oxygen inhalation induced transcutaneous PO_2 changes as a predictor of amputation level. J Vasc Surg 1985;2:220–7.

[27] Fife CE, Buyukcakin C, Otto GH, Cheffield PJ, Warriner RA, Love TL, et al. The predictive value of transcutaneous oxygen tension measurement in diabetic lower extremity ulcers treated with hyperbaric oxygen therapy: a retrospective analysis of 1144 patients. Wound Repair Regen 2002;10:198–207.

[28] Zgonis T, Garbalosa JC, Burns P, Vidt L, Lowery C. A retrospective study of patients with diabetes mellitus after partial foot amputation and hyperbaric oxygen treatment. J Foot Ankle Surg 2005;44:276–80.

[29] Cianci P, Slade B. Acute thermal burn injury. In: Gesell L, editor. Hyperbaric oxygen therapy indications. Durham, NC: Hyperbaric Medical Society; 2008. p. 181–95.

[30] Hospital readmissions: percentage of unplanned and unexpected readmissions within 28 days of separation related to the primary admission, during the 6 month time period. U.S. Dept of HHS, Agency for Heathcare Research and Quality. ⟨http://www.qualitymeasures.ahrq.gov/content.aspx?id=32902#Section563⟩.

[31] Armstrong DG, Lipsky BA. Diabetic foot infections: stepwise medical and surgical management. Int Wound J 2004;1:123–32.

[32] Reiber GE, Boyko EJ, Smith DG. Lower extremity foot ulcers and amputations in diabetics. In: Diabetes in America, 2nd ed, National Diabetes Data Group, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 1995 (NIH Publication No. 95-1468).

[33] Sackett DL, Rosenberg WMC. The need for evidence-based medicine. J R Soc Med 1995;88:620–4.

[34] Sackett DL, Rosenberg WMC, Muir Gray JA, et al. Evidence based medicine: what it is and what it isn't. BMJ 1996;312:71–2.

[35] Zwar NA, Hermiz O, Comino EJ, et al. Do multidisciplinary care plans result in better care for patients with type 2 diabetes? Aust Fam Physician 2007;36(1–2):85–9.

[36] Brannen AL, Still J, Haynes M, Orlett H, Rosenblum F, Law E, et al. A randomized prospective trial of hyperbaric oxygen in a referral burn center population. Am Surg 1997;63:205–8.

[37] Hart GB, O'Reilly RR, Broussard ND, Cave RH, Goodman DB, Yanda RL. Treatment of burns with hyperbaric oxygen. Surg Gynecol Obstet 1974;139:693–6.

[38] Perrins DJD, Cantab MB. Influence of hyperbaric oxygen on the survival of split skin grafts. Lancet 1967;868–71.

[39] Barsun A, Sen S, Palmieri TL, et al. A ten-year review of lower extremity burns in diabetics: small burns that lead to major problems. J Burn Care Res 2013;34(2):255–60.

[40] Christman AL, Selvin E, Margolis DJ, et al. Hemoglobin A1c predicts healing rate in diabetic wounds. J Invest Dermatol 2011;131(10):2121–7.

[41] Centers for Medicare & Medicaid Services. National Coverage Determination (NCD) for hyperbaric oxygen therapy (20.29). Centers for Medicare & Medicaid Services; 2006: 100–3, http://www.cms.gov.