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Changes of wound dimensions and pain assessment in response to hyperbaric oxygenation therapy

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ABSTRACT

Introduction. Novel approaches to wound healing can provide decreased risk of complications, wider possibilities of further treatment, rehabilitation and care, and improved patient's quality of life. Most recent studies support the concept that HBOT accelerates the wound healing process.

Aim. This paper aims at presentation and discussion the outcomes of a research on chronic wounds healing using the HBOT. Particular attention was paid to changes of wound dimensions and pain assessment in response to HBOT.

Material and Methods. Inclusion criteria meet the medical records of eighty-nine adult patients with chronic wounds aged 18–85 years treated with HBOT. Wound length, wound width and pain were measured twice: before and after treatment.

Results. There have been observed favourable and statistically significant changes in all measured areas: pain assessment, wound length, and wound width. Improvement of pain assessment occured in 94.38% of patients, improvement of maximal wound length occurred in 94.38% of patients, improvement of maximal wound width occurred in 86.52% of patients.

Conclusions. Application HBOT in adult patients with chronic wound is an effective method of treatment. Age above 62 years, sex (men), lack of obesity, and number of HBOT sessions higher than 29 can be regarded as useful prognostic signs, however there is need for further research.

Keywords: rehabilitation, wounds healing, chronic wounds, hyperbaric oxygenation, hyperbaric oxygen therapy, HBOT.

Introduction

Hyperbaric oxygen therapy (HBOT) becomes more and more popular basic or supplementary method of the severe wound healing. It involves exposing patients to increased gas pressure while inhaling pure oxygen. Hyperbaric oxygenation is the use of 100% oxygen at pressures greater than atmospheric pressure (≥ *1.4 atmospheres absolute pressure* [1–5]). Such method increases the delivery of oxygen to damaged local tissues (wound), stimulates angiogenesis, immune response, collagen synthesis, and stem cell migration, in this way accelerating wound healing [4, 5]. Although pathophysiology underlying improved wound healing as a result of HBOT application is still under research [1, 6–8] there is common belief that HBOT has two primary mechanisms of action due to:

– hyperoxygenation (increase in dissolved oxygen in plasma due to increased partial pressure of arterial oxygen),
– decrease in bubble size (angiogenesis, vasoconstriction, fibroblast proliferation, leukocyte oxidative killing, toxin inhibition, antibiotic synergy) [5].

This way HBOT helps to maintain optimal wound oxygenation, macrocirculation, microcirculation, and nutrition [1, 6–8].

Main areas of the clinical HBOT application in wound healing were investigated by Bhutani & Vishwanath. They cover i.a. non-healing wounds (diabetic, vascular insufficiency ulcers), infected wounds (clostridial myonecrosis, necrotising soft tissue infections, Fournier's gangrene), traumatic wounds (crush injury, compartment syndrome), skin grafts and flaps, radiation-induced wounds, and thermal burns [5]. Such variety makes difficulties in precise assessment of the real recovery for decision-making process deriving form evidence-based medicine paradigm, usefulness of the prognostic signs, and compartmental studies.

Even if the clinical effectivity of HBOT seems be doubtless there is need for more detailed research on bigger samples researching possible indications, contraindications, and prognostic signs. This paper aims at presentation and discussion of the outcomes of a research on chronic wounds healing using the HBOT. Particular attention was paid to changes of wound dimensions and pain assessment in response to HBOT.

Material and Methods

The research design was a retrospective study. We reviewed the medical records of adult patients with chronic wounds treated with HBOT.

Inclusion criteria covered 18 years of age or older, chronic wounds confirmed by medical records, and lack of contraindications. As absolute contraindications to HBOT were regarded: chemotherapy with certain agents, untreated pneumothorax, history of spontaneous pneumothorax). As relative contraindications to HBOT were regarded: fever, systemic viral infections seizure disorder, retinal surgery, middle ear surgery, cataract exacerbation, spherocytosis, optic neuritis. Eighty-nine patients (63.12%) met the aforementioned inclusion criteria. Their clinical summary is presented in **Table 1**.

Adult patients with chronic wounds were treated using HBOT receiving ≥ 5 sessions. Patients were treated in Center of Hyperbaric Oxygenation and Wound Healing of the Military Clinical Hospital No. 10 with Polyclinic in Bygoszcz, Poland in 2014. The same twelve-person HBOT chamber HiperTech Zyron 12 (GTC, Sweden) was used in each patient.

Table 1. Clinical summary of the patients

	Patients n = 89 (100%)
Age [years]:	
– Min	18
– Max	85
– Mean	57.87
– SD	14.14
– Median	62
Sex:	
– Females	36 (40,45%)
– Males	53 (59,55%)
Value of Body Mass Index (BMI):	
– Min	20.28
– Max	55.1
– Mean	29.58
– SD	6.65
– Median	28.37
Number of HBOT sessions:	
– Min	5
– Max	70
– Mean	25.8
– SD	9.5
– Median	29

Maximal wound length and maximal wound width were measured twice: before and after treatment. Pain assessment (using the numerical rating scale) was done twice: before and after treatment. These values were often impaired in patients with chronic wounds. Selection of aforementioned parameters allow other scientists to replicate the study.

All the data in this study were collected and stored using the MS Access 2013 software. Aforementioned data were analyzed with the software Statistica version 12. Where available, mean, median, minimum value (Min), maximum value (Max) and standard deviation (SD) were calculated to show the results of this study. The Shapiro-Wilk test was used as a powerful normality test. Parametric t-Student's test and non-parametric Wilcoxon's test were used to compare scores. We used $p \leq 0.05$ as the significance level. Correlations (statistical relationships) were assessed between changes of pain assessment, wound length, and wound width observed as the result of the HBOT intervention. Change of results before therapy and after therapy was determined as a result of the substraction. To assess correlations Spearman's rank correlation coeficient (Spearman's rhos) was used.

This study was conducted in accordance with the Declaration of Helsinki and the guidelines for Good Clinical Practice (GCP). Freely given written informed consent was obtained from every patient prior to the study.

Results

Statistically significant and important changes reflecting recovery in numerical rating scale for pain assessment, maximal wound length, and maximal wound width were observed. The results for whole group of patients are shown in **Table 2** (all changes were statisticaly significant).

Improvement of pain assessment occured in 94.38% of patients, improvement of maximal wound length occurred in 94.38% of patients, improvement of maximal wound width occured in 86.52% of patients. The results of complete recovery are shown in **Table 3**.

Best results of the HBOT administration were achieved in particular groups of patients: men, 62 y.o and older (median of age), with BMI < 30 (i.e. non obese patients), with number of HBOT sessions ≥ 29 (median). Aforementioned outcomes may serve as ground for a clinical prognosis.

Statistically relevant corellations observed in the whole group of patients were as follows: poor (positive) correlations between changes in wound width and wound length, between pain assessment and wound length, and between pain assessment and wound width.

Statistically relevant corellations observed in the group of women were as follows: moderate (positive) correlations between changes in wound width and wound length, and between pain assessment and wound width. Corellations of the study results for men (Spearman's rhos) were not statistically significant.

Statistically relevant corellations observed in the group of patients in the age of 62 (median) and older were as follows: poor (positive) correlations between changes in wound width and wound length, and between pain assessment and wound width.

Corellations of the study results for patients younger than median (Spearman's rhos) were not statistically significant.

Statistically relevant corellations observed in the group of obese patients were as follows: moderate (positive) correlation between changes of wound width and wound length, and moderate (positive) correlation between changes of pain assessment and wound width.

Statistically relevant corellations observed in the group of patients with BMI < 30 (**Table 8**) were as follows: poor (positive) correlation between changes in wound width and wound length, and between pain assessment and wound width.

Table 2. Statistical analysis of the study results for the whole group of patients

	n	Mean	Median	Min	Max	SD
Before therapy						
Numerical rating scale for pain assessment	89	3.7	1	1	10	1,74
Max. wound length	89	6.13	2.1	1	26	2.2
Max. wound width	89	6.69	1.1	1	52	1.78
After therapy						
Numerical rating scale for pain assessment	89	2.95	0	0	10	1.23
Max. wound length	89	5.87	1,3	0	37	1.95
Max. wound width	89	5.94	0.5	0	44	1.59

Table 3. Number and percentage of complete recovery depends on measured parameters

	n	%
Numerical rating scale for pain assessment	66	74.16
Max. wound length	37	41.57
Max. wound width	39	43.82

Table 4. Corellations of the study results for the whole group of patients (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	0.251	0.233
Change of max. wound length		–	0.306
Change of max. wound width			–

n.s. = non significant (p > 0.05)

Table 5. Corellations of the study results for women (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	n.s.	0.501
Change of max. wound length		–	0.465
Change of max. wound width			–

n.s. = non significant (p > 0.05)

Table 6. Corellations of the study results for patients in the age of 62 years (median) and older (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	n.s.	0.322
Change of max. wound length		–	0.352
Change of max. wound width			–

n.s. = non significant (p > 0.05)

Table 7. Corellations of the study results for obese patients i.e. with BMI≥30 (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	n.s.	0.538
Change of max. wound length		–	0.294
Change of max. wound width			–

n.s. = non significant (p > 0.05)

Table 8. Corellations of the study results for patients with BMI < 30 (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	0.279	n.s.
Change of max. wound length		–	0.251
Change of max. wound width			–

n.s. = non significant (p > 0.05)

Statistically relevant corellations observed in the group of patients with number of HBOT sessions ≥ 29 (**Table 9**) were as follows: moderate (positive) correlation between pain assessment and wound length.

Statistically relevant corellations observed in the group of patients with number of HBOT sessions < 29 (**Table 10**) were as follows: poor (positive) correlation between wound width and wound length.

Table 9. Corellations of the study results for patients with number of HBOT sessions ≥ 29 (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	0.408	0.192
Change of max. wound length		–	0.198
Change of max. wound width			–

Table 10. Corellations of the study results for patients with number of HBOT sessions < 29 (Spearman's rhos)

	Change of numerical rating scale for pain assessment	Change of max. wound length	Change of max. wound width
Change of numerical rating scale for pain assessment	–	0.158	0.199
Change of max. wound length		–	0.39
Change of max. wound width			–

Discussion

Novel approaches to wound healing can provide a decreased risk of complications, wider possibilities of further treatment, rehabilitation and care, and improved patient's quality of life [1–3]. Most recent studies support the concept that HBOT accelerates the wound healing process [1–5], even after limb amputation [9]. The clinical effectivity of hyperbaric oxygenation is doubtless: it increases the percentage of completely healed patients (up to 74–100%), patients with recovery (up to 76–94.7%) and decreases the number of amputations relative to traditional approaches [1, 10, 11]. There is discrepancy among scientists concerning long-term effects of HBOT: improvements may disappear at the two week follow-up [12], even if Boykin and Baylis showed short- and long-term effectivity of HBOT [13]. Clinical trials on HBOT application are difficult to compare due to their heterogeneity in terms of the study design, kind of wounds involved and tools used to assess the outcome [4].

Our results support the hypothesis that HBOT is effective in wounds healing in adult patients. Favorable changes were observed in patients as a result of the therapy. Percentage of recovery and completely healed patients were similar to values observed by other researchers. Correlations may indicate important predictive relationships useful for further studies and in everyday clinical practice (as a part of decision-making process). Values of proposed prognostic signs should not be underestimated – it seems that many factors influencing HBOT efficiency are not identified so far [7, 14–16]. Efficiency of HBOT may depend on many factors (e.g. etiology of wound) – Ueno et al. showed HBOT less effective in wounds caused by diabetes mellitus and in patients who undergone hemodialysis [17], even if Boykin and Baylis showed short- and long-term effectivity of HBOT independently from wound etiology [13]. These findings highlight the increasing value of HBOT in wound healing.

No complications of HBOT (confinement anxiety, ear pain, hypoglycemic event, hyperglycemic event, shortness of breath, etc.) were observed. Despite aforementioned outcomes we should be aware that complications occurrence may vary, depending on e.g. patient clinical conditions, e.g. recent study by Kaur et al. reported incidence of complications and adverse results of HBOT such as ear discomfort/pain (20%), claustrophobia (13%), and generalized seizures (0.5%) [18].

There is need to admit that number of participants was higher than in previous studies concerning HBOT application in wound healing. Tools selection supports replication of the study and usefullnes of our results in clinical practice – they are easy to perform, time-efficient, accurate and inexpensive. Thus such selection of measuriement tools should not be regarded as limitation of our study.

The main limitation of the study is study design (retrospective before-after study) and lack of the reference group. We hope to remove this limitation during further studies. We intent to continue this study on bigger sample of patients based on randomized controlled trail (RCT) design. Current outcomes will be helpful to design better methodology, especially concerning more detailed searching for prognostic signs and correlations. Wound cause, patient history (including secondary changes), age, sex, obesity, number of HBOT sessions, exudation, etc. should be carefully taken into consideration. True may be an assumption that number of factors influencing wound healing may be huge causing neccessity of patient-tailored therapy rather than general method of wound healing.

HBOT is regarded to be useful basic or complementary method in wound healing. Thus directions for further research cover short- and long-term results of the use of HBOT alone and in combination with other therapies (traditional or emerging).

We hope that further studies ensure more independent sources of knowledge and experience necessary to confirm more detailed prognostic signs and correlations needed for clinical guidelines. The ultimate aim is to optimize the wound therapy in clinical setting.

To sum up: application of HBOT in adult patients with chronic wound is an effective method of treatment. Age above 62 years, sex (men), lack of obesity, and number of HBOT session higher than 29 can be regarded useful prognostic signs, however there is need for further research.

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Conflict of interest statement
The authors declare no conflict of interest.

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