Original Article

Hyperbaric oxygen therapy for wound care

Oxigenoterapia hiperbárica para tratamento de feridas

La oxigenoterapia hiperbárica para cuidado de heridas

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ABSTRACT

Objective: To describe the most common types of wounds indicated for hyperbaric oxygen therapy and the results.

Method: Cross-sectional study at a Hyperbaric Centre in the city of Salvador, Bahia, Brazil. The medical records of 200 patients treated with hyperbaric oxygen were reviewed from January to November 2013. The variables of the persons, clinical, indications, number of sessions and wound care were analysed by means of descriptive statistics and the chi-square test of association incorporating Yates's correction with a level of 5%.

Results: The wounds that were most frequently indicated for hyperbaric oxygen therapy were venous ulcers, traumatic injury and diabetic foot. Patients with chronic wounds had fewer sessions (61.1%) and their wounds healed or were reduced (62.0%) compared to those with acute wounds.

Conclusion: Hyperbaric oxygen therapy is an effective treatment for patients with chronic wounds.

Keywords: Wound healing. Hyperbaric oxygenation. Nursing care.

RESUMO

Objetivo: Descrever os tipos mais frequentes de feridas com indicação para terapia por oxigênio hiperbárico e os resultados obtidos.

Método: Estudo transversal, realizado em um Centro Hiperbárico localizado na cidade de Salvador, Bahia. Os prontuários de 200 pacientes tratados com oxigênio hiperbárico foram revisados, no período de janeiro a novembro de 2013, analisando-se as variáveis da pessoa, clínicas, indicação, número de sessões e cicatrização da ferida, através de estatística descritiva e teste de associação Qui-quadrado de Pearson com correção de Yates, adotando-se um nível de 5%.

Resultados: As feridas mais frequentemente encontradas como indicação para terapia por oxigênio hiperbárico foram: úlcera venosa, lesão traumática e pé diabético. Os pacientes com feridas crônicas realizaram um menor número de sessões (61,1%) e tiveram suas feridas cicatrizadas ou reduzidas (62,0%) quando comparados com aqueles com feridas agudas.

Conclusão: A terapia por oxigênio hiperbárico é um tratamento efetivo para pacientes com feridas crônicas.

Palavras-chave: Cicatrização. Oxigenação hiperbárica. Cuidados de enfermagem.

RESUMEN

Objetivo: Describir los tipos más comunes de heridas con indicación de oxigenoterapia hiperbárica y resultados.

Método: Estudio transversal realizado en un centro hiperbárico situado en la ciudad de Salvador, Bahia. Las historias clínicas de 200 pacientes tratados con oxígeno hiperbárico fueron revisados en el período de enero a noviembre de 2013, analizando las variables de la persona, clínicas, la indicación, número de sesiones y la cicatrización de heridas a través de la estadística descriptiva y prueba de chi-cuadrado de asociación con la corrección de Yates, adoptando un nivel de 5%.

Resultados: Las heridas que más a menudo se encuentran como una indicación de oxigenoterapia hiperbárica fueron: úlceras venosas, lesiones traumáticas y pie diabético. Los pacientes con heridas crónicas realizaron un menor número de sesiones (61,1%) y tenían sus heridas curándose o reducidas (62,0%) en comparación con aquellos con heridas agudas.

Conclusión: La terapia de oxígeno hiperbárico es un tratamiento eficaz para los pacientes con heridas crónicas.

Palabras clave: Cicatrización de heridas. Oxigenación hiperbárica. Atención de enfermería.

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INTRODUCTION

Hyperbaric oxygen therapy (HBOT) was introduced in 1622, for medicinal purposes, by the British physician named Henshaw. Its use was expanded in the 19th century by Junod (1834) and Pravaz (1837) to treat diseases such as tuberculosis, cholera, deafness, anaemia and haemorrhage. The first applications of HBOT on skin lesions were documented in 1965[1].

In 1995, the Medical Council created Resolution 1457/95 to regulate HBOT as a therapeutic modality. In 2003, the Brazilian Society of Hyperbaric Medicine ("SBMH"), in accordance with safety and quality guidelines, established that nursing technicians should operate the hyperbaric chambers, when provided, and in 2008, nurses became members of the professional staff as required by the SBMH and the Undersea and Hyperbaric Medical Society (UHMS). There are currently 90 registered HBOT centres in Brazil and 2500 centres around the world[2].

HBOT is the application of 100% oxygen at two or three times the atmospheric pressure at sea level. This pressure increases arterial and tissue oxygen tension (2000 mmHg and 400 mmHg, respectively), which causes most of the physiological and therapeutic effects of this treatment. This therapeutic procedure has a range of positive effects for the healing process, and is consequently prescribed with other treatment in various clinical situations[3].

The Undersea and Hyperbaric Medical Society recognises 14 valid medical indications for HBOT, namely diabetic foot ulcer, radiation tissue injury, cystitis, chronic refractory osteomyelitis, conditions of acute ischaemia (including crush injuries, arterial thrombosis and reperfusion and compromised myocutaneous flaps), acute poisoning by carbon monoxide, serious soft tissue infections (including gas gangrene and necrotizing fasciitis), air embolism, idiopathic sudden sensorineural hearing loss, acute occlusion of central retinal artery, diving accidents (acute pulmonary barotrauma and decompression sickness), severe anaemia, refractory zygomycosis, and burns[4].

The treatment of wounds is often a challenge, especially for nurses. Even if treated correctly, some wounds such as venous and arterial ulcers, diabetic foot, burns, and radiation injuries do not always heal. Therefore, hyperbaric oxygen therapy (HBOT) can serve as an additional treatment for "complex wounds"[5].

Some studies found that the experimentally demonstrated effects of HBOT are improved tissue hypoxia, increased perfusion, reduced oedema, reduced regulation of inflammatory cytokines, proliferation of fibroblasts, collagen production, and angiogenesis. HBOT is also indicated to eradicate soft tissue and bone infections that are otherwise difficult to treat by mechanisms that include the destruction of microorganisms, thus improving the function of leukocytes and macrophages[3, 6].

However, there is a shortage of recent (in the last three to five years) clinical-epidemiological or nurse-related research on this subject, especially in Brazil. Moreover, since the insertion of nurses in the field of HBOT only occurred in 2008 and given the proven importance of this professional in wound care, either directly or as a member of an interdisciplinary team responsible for this form of patient care, a study of the indications and results of this therapy can provide greater knowledge and indication possibilities for patients with wounds, and improve planning for better quality care.

In view of the indications for HBOT, the results demonstrated in experimental research and the lingering shortage of field research regarding these indications and results, the guiding question of this study was: what kinds of wound are the most indicated for HBOT and what are the results?

The epidemiological magnitude of occurrence of wounds among the population, the shortage of few scientific studies published in Portuguese, and the scarce knowledge of health professionals on the subject justify the relevance of this study. Consequently, the aim of this paper is to describe the most common wounds indicated for hyperbaric oxygen therapy and the obtained results.

METHODS

This is a cross-sectional study conducted to measure the prevalence of health outcomes or health determinants, or both, in a population at one point in time or for a certain period, with a generally descriptive purpose. The resulting information can be used to explore etiology and improve healthcare planning[7].

It was conducted at the benchmark North Northeast Hyperbaric Centre located in the city of Salvador, Bahia, Brazil. The service has a cutting-edge multiplace hyperbaric chamber (accommodates several patients at the same time) with capacity of up to 10 patients per session.

The sample of the study consisted of all the patients with wounds that were submitted to hyperbaric therapy from January to December 2012, totalling 200 patients. The data were collected by consulting the patient records of the institution from January to November 2013. These data were used to complete a form containing the variable: age, sex, origin, profession, smoker/non-smoker, associated diseases, type of wound, indication of HBOT, number of ses-

sions, and result). The variable "profession" was categorised according to Brazilian Classification of Occupations[8].

The data were recorded and encoded in the referred form and entered into the database. They were analysed using descriptive statistics (absolute and relative frequencies) with measures of central tendency and dispersion for the continuous variables. The nominal variable "type of wound" was presented initially by frequency and then went on to form the recategorised dichotomic variable "indication" to enable the chi-square test of association with Yates's correction. The statistical programme SPSS 13.0 for Windows was used to create the database and analytical calculations.

The study observes the ethical requirements of Resolution No. 466/12-MS and was approved by the research ethics committee of the hospital complex HUOC/PROCAPE under opinion No. 138.118.

RESULTS

Two hundred records of patients with wounds who underwent HBOT treatment were analysed during the study period. The results are shown in the frequency distribution tables below, according to the variables of person, clinical, and type of wound, and the association between the HBOT indication, number of sessions, and wound healing/reduction at the end of treatment.

Table 1 presents the frequency distribution results of the people and clinical variations.

The highest frequencies were observed for the age group 50 to 92 years (average of 54, median of 57, and standard deviation of 18), male, from the capital, and non-smokers. In terms of profession, the highest frequency was for the unspecified occupations, which include "inactive" and "unemployed". The most frequent diseases were diabetes mellitus and cardiovascular disease.

Table 2 shows the results concerning the distribution of patients who underwent HBOT according to the type of wound.

Most of the patients with a HBOT indication were suffering from venous ulcer (21%) and traumatic injury (21%), followed by diabetic foot (17%).

Table 3 presents the association results concerning the number of sessions and wound healing or reduction at the end of the treatment, according to the HBOT indication.

The number of sessions ranged from 04 to 90 (29.7 average, median of 30 and standard deviation 14.6). A higher frequency of patients with chronic wounds (88) underwent a lower number of sessions and presented healed or reduced wounds (119) when compared with those who

Table 1 – Distribution of patients who underwent HBOT according to the people and clinical variables. Salvador, BA, Brazil, 2013

People and clinical variables	N (%)
Age group	
≤ 50 years	72 (36.0)
50 – 92 years	128 (64.0)
Sex	
Female	97 (48.5)
Male	103 (51.5)
Origin	
Capital	155 (77.5)
Interior	45 (22.5)
Occupation	
Armed forces, military police officer and fire fighters	05 (2.5)
Science and arts professionals	41 (20.5)
Medium-level technicians	03 (1.5)
Administrative services workers	04 (2.0)
Service workers, salespersons of retail shops and markets	17 (8.5)
Workers of goods manufacturing and industrial services	06 (3.0)
Maintenance and repair workers	02 (1.0)
Unspecified occupations	122 (61.0)
Smoking	
Yes	11 (5.5)
No	189 (94.5)
Associated diseases	
Diabetes mellitus	70 (35.0)
Cardiovascular disease	58 (29.0)
Neoplasias	15 (7.5)
Kidney disease	01 (0.5)
Haematologic disease	07 (3.5)
Neurological disease	02 (1.0)
Autoimmune disease	04 (2.0)
Inflammatory bowel disease	01 (0.5)
Disease of the lymphatic vessels	01 (0.5)
Bone disease	01 (0.5)

Source: research data, 2013.

had acute wounds. A significant statistical difference ($p< 0.05$) was observed for wound healing or reduction at the end of treatment.

DISCUSSION

The characterisation of the sample treated with HBOT showed a higher frequency of patients aged over 50. Similarly, other studies emphasise that a greater life expectancy occurs with a higher frequency of diseases that accompany aging, such as cancer, heart disease, hypertension, diabetes, and others[9-10].

Wounds or sores in elderly patients can heal more slowly in comparison with younger patients mainly due to inadequate nutritional intake, altered hormonal responses, poor hydration and immune, circulatory and respiratory impairment. These conditions increase the prevalence and complexity of wounds and delay their resolution[4, 6], thus constituting a challenge for nurses. The efforts of nurses must therefore target both the topic care of wounds and ways to maintain the good nutrition and hydration of patients.

There was also a greater frequency of male patients from the capital and with occupations classified as "unspecified" (which include "inactive" and "unemployed")[8]. This finding is consistent with the epidemiological panorama of the occurrence of complex wounds mentioned in another study conducted in north-eastern Brazil[10].

In relation to smoking, most of the patients were non-smokers. Although this finding is irrelevant to this study, the fact that most patient had a chronic disease with a complex wound as an aggravating circumstance could have influenced this finding.

Regarding the association with systemic diseases, the results found here showed that the most frequent diseases were diabetes mellitus, cardiovascular diseases, and neoplasias.

Diabetes is a significant factor that can affect the healing process by changing the cell membrane structure, by modifying inflammatory response due to changes of the chemotactic and phagocytic function of white cells, by reducing the supply of blood to the wound area due to occlusive arterial disease or changes to the distribution

Table 2 – Distribution of patients who underwent HBOT according to the type of wound. Salvador, BA, Brazil, 2013

Type of wound	N (%)
Venous ulcer	42 (21.0)
Traumatic injury	42 (21.0)
Diabetic foot	34 (17.0)
Arterial ulcer	19 (9.5)
Osteomyelitis	18 (9.0)
Radiation injuries	13 (6.5)
Surgical wound dehiscence	10 (5.0)
Pressure ulcer	8 (4.0)
Erysipelas bullosum	4 (2.0)
Burn	3 (1.5)
Necrotising fasciitis	2 (1.0)
Pilomidal cyst	2 (1.0)
Oral and maxillofacial facial injuries	2 (1.0)
Pyoderma gangrenosum	1 (0.5)

Source: research data, 2013.

Table 3 – Association between the HBOT indication according to the number of sessions and wound healing. Salvador, BA, Brazil, 2013

Variables	Indication		p-value
	Chronic wound	Acute wound	
	N (%)	N (%)	
Number of sessions			
Up to 30	88 (61.1)	56 (38.9)	0.064
More than 30	36 (64.3)	20 (35.7)	
Wound healing/reduction at end of treatment			
Yes	119 (62.0)	73 (38.0)	0.001
No	05 (62.5)	03 (37.5)	

Source: research data, 2013.

of blood flow (shunt) and reduction due to angiogenesis leading to a ischaemic microenvironment, and neuropathy leading to continuous trauma in the wound area[9, 11].

Coronary artery disease and peripheral artery disease may also compromise the healing of wounds since the blood supply reduced by atherosclerosis leads to tissue ischaemia. These effects alter the microcirculation and the occurrence of oedema that, in turn, compresses the capillaries even more and aggravates the ischaemic injury. In addition, if the wound is infected, poor perfusion can prevent the correct supply of systemic antibiotics resulting in polymicrobial infections and the advancement of osteomyelitis[6].

Some studies indicate that peripheral artery disease is usually overlooked as the cause of poor wound healing, especially in elderly individuals. It affects 12% to 14% of the general population and increases with age[4, 6, 12].

Among patients with neoplasia, 5% to 10% develop sores due to a primary tumour by skin metastasis or as a result of radiotherapy. The prevalence of radiation injuries is increasing partly due to the use of more aggressive treatment protocols involving chemotherapy combined with irradiation among elderly patients[4, 12].

The effects of radiotherapy are permanent and progressive. The pathological lesion obliterating endarteritis makes tissue fibrotic and hypovascular, and unable to repair even a minor injury. Clinically, patients suffer from osteoradionecrosis of the mandible, cystitis or radiation proctitis[4].

In relation to the type of wound treated with HBOT, the results revealed both chronic and acute wounds. The most frequent lesions found in the sample were venous ulcers, diabetic foot and traumatic injuries, as also found in several studies[12-13].

A complex, complicated or difficult wound to heal is defined as a wound that does not heal in an orderly and timely manner with conventional therapy. This definition applies to chronic and acute wounds regardless of etiology[1, 9].

A complex wound is often associated with one or more of the following: extensive skin loss, compromised tissue viability (concurrent with ischaemia and/or local necrosis), aggressive infections, and association with systemic diseases that hinder a normal healing process[4].

Venous ulcers are the most common lower limb wounds treated at outpatient clinics, and they are frequently recurrent or have unsatisfactory results[14], which can be associated with the higher frequency of HBOT indications in comparison with the other types of lesions.

Diabetic foot ulcers, in turn, have been the focus of most research on hyperbaric medicine since the etiology of these wounds is multifactorial and HBOT can solve many of these factors. In addition to HBOT, these wounds are often treated with care techniques such as debridement, bandages, pressure relief strategies, adequate glucose control, nutrition and antibiotics[1, 15].

As described in other studies, healing depends on cell replication, the formation of a new support matrix, and the removal of necrotic material of foreign or infective bodies. All these processes are energy-dependent and are only effective with adequate blood flow and the supply of nutrients and oxygen to the wound area[9].

Therefore, the approach to complex wounds is based on three principles: treat the primary etiology, locate and remove the delay factors (infection, necrosis, among others), and provide an ideal environment for healing. Conventional care includes cleaning, debridement, appropriate covers and other treatments[5, 12].

Hyperbaric oxygen is an adjunct therapy that is accepted for hypoxic wounds and is recommended by various medical societies, health organisations and health agencies around the world because, despite the presence of comorbidities, it improves angiogenesis and probably stimulates growth factors and other mediators of the healing process[1, 12].

Acute wounds, such as the traumatic wounds found in this study, are characterised as a rupture of the integrity of the surrounding soft tissue envelope of any portion of the body, and are mostly the consequence of surgery or trauma. Most acute wounds heal without difficulty, however, some are subject to factors that delay the healing process, such as local blood flow and oxygen supply, infection or damage to the vascular system.

A systematic review showed that HBOT appears to be effective for the treatment of complex acute wounds[15]. Hyperbaric oxygen improves the effects of acute traumatic ischaemia by means of four mechanisms, namely hyperoxygenation, vasoconstriction, influence on reperfusion, and factors associated with the patient[1].

Patients with complex wounds are usually referred to HBOT because all other therapies have failed after four to five weeks. Patients that will undergo this therapy must be selected with care and according to accepted guidelines. Nurses should consider HBOT in cases of hypoxic injuries (due to ischaemia) that are reversibility in the conditions offered by therapy conditions[4].

The results found here regarding the indication of HBOT, according to number of sessions by type of injury, demonstrated that the higher frequency of patients with chronic and acute wounds underwent up to 30 treatment sessions, and no significant statistical difference was observed for both groups of patients. This number of sessions is recommended in literature, which specifies 30 to

40 90-minute treatment sessions for chronic wounds in 2.4 oxygen atmospheres, and a maximum of 60 sessions for wounds that respond slowly[4].

As for the end of treatment, as observed in the medical records, the highest frequency of patients with chronic wounds undergoing HBOT managed to heal their wounds, although there was a statistically significant difference compared to the group that presented acute wounds.

According to some studies, the patients diagnosed with grade 3 or higher ulcers according to the Wagner Classification Scale may benefit from HBOT together with conventional treatment. These ulcer occur in the advanced stages of disease, and can manifest with deep abscess, osteomyelitis or sepsis. Grade 4 and 5 ulcers are mostly gangrenous lesions that compromise the member, thus requiring emergency HBOT together with full assistance for these conditions[4, 16].

Meta-analysis studies have been used regularly as a final judgement on the effectiveness of an intervention. According to the latest assessment, the use of HBOT as adjunct treatment to manage a refractory diabetic wound reduces the risk of major amputation (with an odds ratio of 0.236 and a confidence interval (CI) of 95%: 0.133 – 0.418) and improves healing (with an odds ratio of 11.64 and IC 95%: 3.457 – 39.196), with a level of evidence "A" (randomised controlled trials) and a grade of recommendation "I" (recommended)[15-17].

However, a study recommends that patients with occlusive arterial disease should have revascularization options before considering or starting HBOT[4]. Concerning the use of HBOT for treating venous ulcers, a review of randomised clinical trials found a single study (16 participants) and the data recorded after six weeks of wound size reduction and number of ulcers healed suggested the significant benefit of this therapy[13].

HBOT has also proved very successful as adjunct treatment for late complications of radiotherapy. It is particularly beneficial in the treatment of osteoradionecrosis and complications of radiation in the pelvic region (cystitis and proctitis). In addition to the healing benefits, HBOT also relieves local intractable visceral pain, and recurrent bleeding. Given the current level of evidence, the use of HBOT is recommended[1, 12, 16].

In the case of acute wounds, results of studies show that, when combined with the principles that recommend conventional wound care, HBOT can help the healing process, however, the few controlled studies for this type of wound have at most introduced one level of evidence and "A-II" recommendation, or "reasonable", for the use of HBOT in crush injuries, acute traumatic ischaemia, and compartment syndrome[3, 16].

As previously mentioned, nurses only joined the professional team for HBOT therapy in 2008, and to date only one national study discusses the need to standardise nursing care related to this therapy[2]. According to the authors, hyperbaric nursing care can generally be classified according to the pre, trans and post HBOT stages and respectively aim to prepare the therapeutic environment and the patient, ensure patient safety and comfort, monitor the session, ensure compliance, prevent complications, and ensure overall stability after therapy[2].

The authors did not find a Brazilian study that addresses the performance of nurses in HBOT, specifically in relation to wound healing, which stresses the importance of this study to extend the level of knowledge of nurses on HBOT as a possible and viable alternative for the arsenal of care that they already use, and to identify a field that must be further explored through new research.

Nurses must ensure that individuals with wounds meet the criteria for HBOT, which includes considering lack of significant results with the prior use of scientifically proven and consensually accepted therapies, and verifying the existence of adequate vascularity[2, 18]. Moreover, they should consider, together with the doctor and patient, the availability and accessibility of a HBO service since proximity can affect the convenience and cost of this treatment. Consequently, nurses should take into account the functional capacity of the individual and the existence of relatives and/or caregivers[18].

Nursing care for patients undergoing HBOT must primarily focus on patient education, patient monitoring, and the continuous evaluation of the healing process. Therefore, nurses should work with the interdisciplinary team, with the patient, and with the family to determine the educational needs and perform the relevant interventions[2].

CONCLUSIONS

The study described the wounds that are often indicated for HBOT. These wounds are chronic wounds, venous ulcers, and diabetic foot ulcer, followed by acute trauma-related wounds. It also identified the diseases that are often associated with these wounds, namely diabetes mellitus, cardiovascular disease, and neoplasia. These findings are consistent with current literature.

It was demonstrated that the patients who underwent up to 30 sessions of HBOT managed to heal or reduce their chronic wounds during admission in comparison with patients with acute wounds, for which there are no parameters for comparison.

Although there are no clinical profiles or biomarkers that can differentiate non-responders from responders, the results found on the number of sessions and the consequent healing can support the practices of specialist nurses (enterostomal therapy or dermatology nurses), and of nurses who are part of the interdisciplinary team in hospitals.

These results provide relevant information about the main types of wounds with HBOT indications, and show that this adjunct therapy can be important to treat patients with chronic wounds in care and help nurses provide better quality care.

It was also possible to identify a gap regarding nursing practices in hyperbaric oxygen therapy to treat wounds, and the consequent need for further research on this subject that targets health education.

The limitation of this study is the temporal ambiguity of the possible cause-and-effect association as a result of cross-sectional study design. Thus, new research of a longitudinal nature should be conducted to establish the association between healing and type of wound treated with HBOT.

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