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Adjunctive hyperbaric oxygen therapy in severe burns: Experience in Taiwan Formosa Water Park dust explosion disaster

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ABSTRACT

Background: Despite major advances in therapeutic strategies for the management of patients with severe burns, significant morbidity and mortality is observed. Hyperbaric oxygen therapy (HBOT) increases the supply of oxygen to burn areas. The aim of this study was to determine whether HBOT is effective in the treatment of major thermal burns.

Methods: On June 27, 2015 in New Taipei, Taiwan, a mass casualty disaster occurred as fire erupted over a large crowd, injuring 499 people. Fifty-three victims (20 women and 33 men) were admitted to Tri-Service General Hospital. Thirty-eight patients underwent adjunctive HBOT (HBOT group), and 15 patients received routine burn therapy (control group). Serum procalcitonin (PCT) level, a sepsis biomarker, was measured until it reached normal levels (<0.5 μg/L). The records of all patients from June 2015 to March 2016 were analyzed retrospectively. Outcome measures that were compared between the groups included the use of tracheostomy and hemodialysis, total body surface area (TBSA) and the number of skin graft operations, length of hospital stay, infection status, and mortality.

Results: The mean age of the patients was 22.4 years, and the mean TBSA was 43%. All the patients survived and were discharged without requiring limb amputation or being permanently disabled. Patient characteristics did not differ significantly between the groups. PCT levels returned to normal significantly faster ($p = 0.007$) in the HBOT group.

Conclusion: Multidisciplinary burn care combined with adjunctive HBOT improves sepsis control compared with standard treatment without HBOT. Prospective studies are required to define the role of HBOT in extensive burns.

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1. Introduction

Burn accidents in large-scale events can be a devastating public health crisis. Burn is often a devastating event for the patient because of the physical and psychosocial trauma, and severe burns can lead to significant morbidity and mortality [1]. The revised Baux score developed by Osler et al. [2] to predict mortality after burn is calculated as the sum of age and the total body surface area (TBSA) burned plus 17 points for inhalation injury. The treatment of acute burns includes fluid resuscitation and the maintenance of hemodynamic stability, escharotomy, nutritional support, topical and intravenous antimicrobials, wound dressing, surgical debridement, and skin graft [3].

The pathophysiology of acute burn proceeds in a time-dependent manner. Therefore, proper and timely intervention and control of the pathogenic mechanisms involved in thermal injury are critical to a successful clinical outcome. Oxygen can stimulate wound healing because the enzymes involved in bacterial killing, collagen synthesis, angiogenesis, and epithelialization require a plasma oxygen level of >25 mmHg in the wound tissue [4–6]. Hyperbaric oxygen therapy (HBOT) is a treatment designed to increase the supply of oxygen to the burn area and thus improve healing. However, the results of a systematic review and a randomized prospective trial did not find sufficient evidence to support or refute the effectiveness of HBOT in the management of thermal burns [7,8].

On June 27, 2015, flammable starch-based powder exploded at Formosa Fun Coast, a recreational water park in New Taipei City, Taiwan. This was one of Taiwan's worst mass burn casualty incidents in which 499 people were injured and 15 died [9]. Fifty-three patients were sent to Tri-Service General Hospital for burn management. The aim of this research was to study the effects of HBOT in these patients who suffered from starch-based powder explosive burns.

2. Materials and methods

On June 27, 2015, 53 patients with explosive burn were sent to Tri-Service General Hospital, Taipei, Taiwan. The patients were immediately assessed by plastic surgeons to determine the TBSA and burn depth. The patients were randomly and equally assigned to seven plastic surgeons. The members of the burn teams included respiratory therapists, pharmacists, psychiatrists, physical therapists, nephrologists, and infectious disease experts, who were all immediately involved in the treatment of these patients.

All the patients received the same treatment according to the burn treatment protocol of our hospital that included fluid resuscitation, nutritional support, topical and intravenous antimicrobials, wound dressing, and surgical treatment. Patients with inhalation injury proven by bronchoscopy were intubated and transported to the intensive care unit. All the burn patients were immediately given broad-spectrum antibiotic therapy, and this was later adjusted according to the culture reports. Serum procalcitonin (PCT) is a sepsis biomarker whose level is used to guide antibacterial therapy and its duration [10,11]. PCT levels were measured daily until they reached normal levels (<0.5 μg/L).

Because of the limited availability of hyperbaric chamber space, it was not possible for all patients to receive HBOT. Moreover, the effectiveness of HBOT in burn treatment is controversial. Therefore, 38 patients under the care of five plastic surgeons received adjunctive routine burn management and adjuvant HBOT (HBOT group), and 15 patients under the care of two plastic surgeons were treated with routine burn management as described above (control group). The decision to receive HBOT or not was according to the preference of the surgeons. All the patients were older than 18 years. The exclusion criteria for the HBOT group were pregnancy, pneumothorax, severe chronic obstructive pulmonary disease, recent chest surgery, upper- or lower-airway infection, psychiatric conditions (particularly claustrophobia), concussion or head injury, convulsions, epilepsy, or heart disease (ejection fraction < 35%). The patients in the HBOT group received HBOT as soon as their hemodynamic variables were stable. The number of HBOT sessions was decided by the plastic surgeons and doctors administering the HBOT according to the wound condition.

The clinical and demographic data (mean age, sex, degree of burn, presence or absence of inhalation injury, and admission lab data) of the two groups are summarized in Table 1. The patient outcomes, such as the need for tracheostomy and hemodialysis, TBSA and number of skin graft operations, TBSA of re-graft, length of hospital stay, days required for the normalization of PCT levels, and number of sessions and complications of HBOT from June 2015 to March 2016 were recorded and analyzed retrospectively (Table 2).

The study was approved by the Tri-Service Hospital Institutional Review Board Committee before the initiation of the data analysis.

2.1. *HBOT protocol*

Each patient in the HBOT group was positioned in the hyperbaric chamber and received 90 min of 100% oxygen at 2.5 atmosphere absolute (ATA) while inside the chamber. Patients used the chamber 5 days per week except on the day of an operation or if their hemodynamics were unstable.

2.2. *Statistical analysis*

Statistical analyses were performed using SPSS for Windows (version 16.0; SPSS, Inc., Chicago, IL, USA). The chi-square test was used to analyze the treatment efficacy. Fisher's exact test was used instead of the chi-square test when any expected frequency was <1 or when 20% of the expected frequencies were ≤5. Results are expressed as the mean ± standard deviation (SD). A p-value of <0.05 was considered to indicate significance.

3. Results

The mean age of the 53 admitted patients (20 women and 33 men) was 22.43 years, and their mean TBSA was 42.97%. All the patients were healthy with no medical problems except for the