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RESEARCH ARTICLE

THE CONTRIBUTION OF HYPERBARIC OXYGEN THERAPY TO THE HEALING OF INFECTED BURN WOUNDS

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Abstract

Background: Hyperbaric oxygen therapy (HBOT) is defined as the inhalation of pure oxygen (100%), by a patient placed in a steel or polymer chamber, at supra-atmospheric pressures going from 1.5 to 3 ATA. Many studies have reported that hyperbaric oxygen therapy promotes wound healing in addition to its effectiveness on polymorphic microbial flora andextensive microvascular obstruction causing necrosis within the infection.

Methods: Our work is a retrospective studyover 14 years concerning 36 patients collected in the Burns Unit of the Mohamed V military hospital in Rabat. It included patients that were admitted in our burn unit and that presented infected burns or were infected during their hospitalization. We excluded all patients with contraindications to this treatment.

Results: The average age of the patients was 28 years, the sex ratio was 1.3. Burns were secondary to the flame in 50% of cases. More than 20% of the body surface was affected in 86,2% of the patients. The face was the most affected (52%), followed by the upper limb (20%). Our patients have received an average of 12 sessions of hyperbaric oxygen therapy after an assessment combining an electrocardiography, an oro-facial and pulmonary examination in order to avoid secondary complications.

Conclusion: This study highlights the efficiency of hyperbaric oxygen therapy in the treatment of acutely infected burns in order to achieve wound healing or to prepare the site for possible surgical coverage. However, its application is limited by certain factors.

Introduction:-

The burn is defined as a partial or total destruction of the skin coating or underlying tissues by a thermal, electrical, chemical agent or by ionizing radiation.

In Morocco, burns are a public health issue. Their risk is very high, seen the large use of small gas bottles (3kg). (1) Infectious complications at the acute phase are one of the leading causes of death. This high susceptibility to

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infections is mainly explained by the loss of the skin covering, the first line of immune defense, and the immune disorders induced by the initial aggression. Their prevention is an essential parameter of the management.

At a time when resistances are becoming a concern, research on adjuvant therapies such as Hyperbaric Oxygen Therapy (HBOT) which serves as "primary" or "adjunct" therapy in a wide range of pathologies. It is, however, an "old" technology used for the first time successfully to treat decompression illness. Since that time, HBOT has been used in the treatment of numerous medical conditions including carbon monoxide poisoning, infections, and trauma.(2) HBOT is nowadays expanding its range of indications. However, its application is limited by the availability of a suitable structure.

This study, which was conducted on 36 patients in the Burns Unit of the Mohamed V Military Hospital in Rabat, aims is to assess the effectiveness of HBOT in the treatment of infected burns in the acute phase.

Patients and Methods:-

The present work is a retrospective study of 36 cases of infected burns in the acute phase observed over a period of 14 years, spanning from 2007 to 2020 in the Burns Unit at the Mohammed V Military Hospital in Rabat.

Our work mainly focuses on the contribution of hyperbaric oxygen therapy in the treatment of infected burns in the acute phase seen the local availability of a hyperbaric chamber. The data was collected with the consent of the patients, respect for their anonymity and the confidentiality of their information. We retained 36 cases (9 Men and 12 Women).

We included in this study all patients hospitalized for burns infected at admission or during their hospitalization. These patients were treated with hyperbaric oxygen therapy. Thus, for each patient, a form that included a pulmonary examination with thoracic X-ray, a cardiovascular examination with ECG and an ENT examination was filled.

We excluded patients with contraindications to hyperbaric oxygen therapy such as: angina and unstable asthma, a burnt body surface area (BSA) greater than 60% with deep lesions, those who can't be moved and those with incomplete files.

We collected the files data concerning age, sex, medical history, clinical, biological and radiological assessment, treatments and evolution.

Clinical data included:

-Burnt Body Surface Area (BSA) was defined in adults and children by using "Wallace's rule of nine"
-Burn depth and Complications
-Associated lesions confirmed by medical examination including: smoke Inhalation, hypoxia (Carbon monoxide (CO) or cyanide (CN)), Traumatic injuries
-Evaluation of the initial prognosis using: Baux score and UBS score
-Biology data included: CRP/ WBC/ Bacteriology/ Procalcitonine

Our patients had from 10-20 sessions of HBOT (multiplace hyperbaric chamber at a rate of 2.5 ATA under pure oxygen for 90 minutes per session and per day) associated with an adapted but nonsystematic antibiotic therapy and daily wound care. The evolution was assessed by clinical examination of the lesions at the fifth, fifteenth and twentieth sessions of HBOT.

Management of the burn victim during hospital stay included:Pre-conditioning, Hydro-electrolytic resuscitation, Analgesia, Sedation/ Anesthesia, Hematological parameters and coagulation, Initial antibiotic therapy and tetanus prevention, Nutrition, Prevention of hypothermia, local treatment and rehabilitation and physiotherapy.

Results:-

Epidemiology

The maximum age of our patients has reached 85 years while the minimum age has reached 10 days with an average age of 28 years.

In our series, patients aged less than 15 years represented 15% of the studied population. Young adults between 15 and 45 years old made up over half with a percentage of 55%. 30% of cases were over 45 years old.

Among the 36 patients treated, 58% were male with a sex ratio of 1.3. 12 patients were diabetic representing 33%. The rest had no medical or surgical history or any toxic or smoking habits.

The study found a domination of domestic accidents (56.9%) followed by work accidents (20%), (10%) were due to Road Accidents, (9%) were caused by an assault and (4.1%) were due to suicide attempts.

18 patients (50%) suffered from thermal burns (by flames), 9 patients (25%) presented electrical burns and 6 chemical burns (16.67%). The burn mechanism was not specific in 3 patients (8.33%). The small gas bottle (3kg) was the main cause of burns (51.9%).

Clinical data

Most patient had 20 -50% of BSA affected by the burn. Limbs and face in association or not to the trunk were the most exposed. The face was affected in 19 patients (52%), upper limbs in 7 patients (19.44%), lower limbs in 5 patients (14.68%) and trunk in 5 patients (13.88%). Deep 2nd degree burns (50%) were the most common, followed by mosaic burns deep 2nd degree and 3rd degree.

The average length of hospital stay was 11 days which increased significantly with age. All patients had an initial biological workup as a reference (hemogram, hemostasis, blood ionogram, urea, and creatinemia) for the biological evaluation of the effectiveness of hydration, the detection of hydro-electrolytic disorders at the initial phase and the impact of the fluid leak on the renal function. Further examination was requested depending on the context, a chest X-ray when respiratory damage was suspected, an ECG and a dosage of troponin, CPK and LDH in the event of an electrical burn, CT scan in case of associated injuries (multiple trauma).

Table I:-Initial biological assessment.

Bilan	**Anomalie**	**Pourcentage**
Complete blood count	Anemia <9g/dl Anemia ≥ 9g/dl	5,3 % 10,6 %
	Thrombopenia	0%
	Hyperleukocytosis	42,4%
Ionogram Renalefunction LDH, CPK Troponin	Hypo-protidemia	17,7%
	Hypo-albuminemia	42,4%
	Hyponatremia	61,9%
	Hypokalemia	2,6 %
	Hyperglycemia	64,6 %
	functionalrenalfailure	4,4%
	CPK > 130 U/L	3,5%
	LDH > 195 U/L	0%
	Troponin> 0,1 ng/l	0%
PT-PTT	PT < 75% PTT > 38s	18,5% 3,5%
Thorax X-Ray	Normal in all patients	
ECG	Normal in all patients suffering electric burns	

Therapeutic data

Demling's rule (peripheral venous line in unburned area> peripheral venous line in burnt area> central venous line in unburned area> central venous line in burnt area) was respected in the vascular approach of our patients, Peripheral venous line was taken in 33 of our patients (92%), while 3 patients (8%) benefited from a central venous line, especially for patients with extensive BSA or hemodynamic instability in admission.

All our patients underwent volume expansion according to Evans' formula at the time of admission and then adapted to diuresis, the solution used for filling was 0.9% saline.

They also had enteral nutrition for an average of 2.3 days, with a high protein high calorie diet based on tolerance.

We introduced the combination of paracetamol and codeine an analgesic to all our patients. Antibiotics were adapted to the antibiogram results

The dressings were changed daily. After washing with antiseptics such as Polividone iodine, or chlorexidine, we used a silver salt based interface with topical silver sulfadiazine.

We deplore a single case of amputation of a lower limb in a patient suffering from arteritis who was late to admission, and in whom therapeutic combination (antibiotic therapy and hyperbaric oxygen therapy) could not improve the condition.

This therapeutic combination made the control of infection possible and improved the lesions in the remaining 35 cases. It helped accomplishing effective debridement and granulation of the wounds, allowing us to cover the loss of substance using either a simple skin graft for 23 patients or more complex flaps for 12 patients.

Clinical cases
Case n°1
A 26 year old patient suffered from chemical burn of right lower limb, infected on admission.

The patient underwent 10 sessions of HBOT with regression of signs of necrosis and infection. He was then prepared for a skin graft.

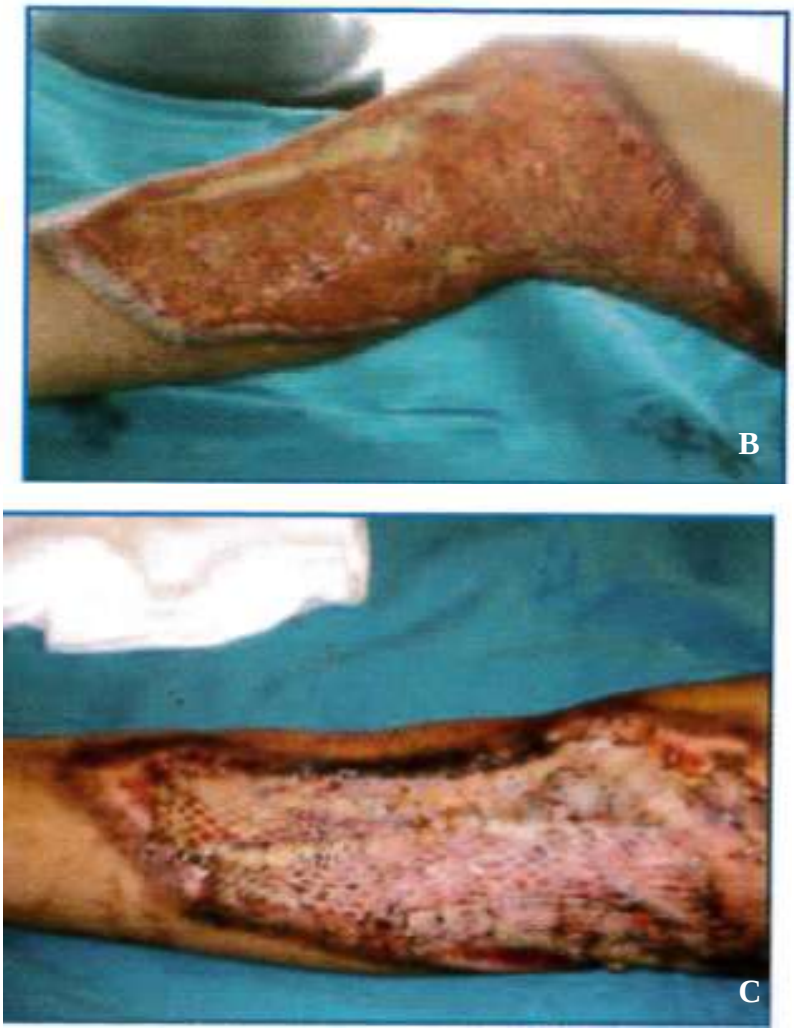

Figure 2:- Progress of a chemical burn of the lower limb.
A: Clinical aspect at admission, B: Clinical aspect after HBO sessions, C: Skin graft

Case n°2
A 15 year old child, suffered from flame burn on the hand treated traditionally by plant application.
The patient underwent 15 HBOT sessions; the outcome was favorable with a wound granulation followed by a cover flap.

Figure 3:- Progress of a flame burn of the hand.
A: Clinical aspect at admission, B :Aspect after HBOT, C:Flap coverage (Delto pectoral flap + inverted temporalis flap)

Case n°3
30 year-old patient presenting with a deep 3rd degree burn in the right side of the face, who was late to admission. Good progress was noted after 18 sessions of HBOT.Delto pectoral and inverted temporalis flap was used for coverage.

Figure 4:- Evolution of a flame burn of the face
A: Clinical aspect at admission , B: Clinical aspect after 18 sessions of HBOT, C: Coverage using Delto pectoral + inversed temporalis flap

Discussion:-

Burn wounds are complex. Their severity is determined by their depth into the skin layers, they are classified into superficial (epidermal), partial thickness, and full-thickness burns. They involve a dynamic pathophysiologic process made of an area of coagulation, surrounded by a region of stasis, bounded by an area of hyperemia. Tissue damage worsens by prolonged inflammation, vascular congestion, hypercoagulability with thrombosis that impairs blood flow. The main problem is the failure of oxygen and nutrient supply to injured cells. Several series have studied the utility of different agents in modulating the mechanisms of burn wound healing. (3,4)

Hyperbaric oxygen therapy is defined as the inhalation of pure oxygen (100%), by a patient placed in a steel or polymer chamber, at supra-atmospheric pressures going from 1.5 to 3 ATA. Therefore, increasing the O2 pressure gradient and promoting oxygen diffusion into tissues. Oxygen also dissolves in plasma and reaches deficient tissue through macro and microcirculation, thus insuring revitalization of tissues, grafts and organs on one hand and boosts certain medicinal effects on the other hand.(5,6)

The efficacy of hyperbaric oxygen in the treatment of thermal injury was proven in several works of literature. Series studying HBOT have reported: Reduction in fluids, lesser conversion to full thickness injury, preservation of marginally viable tissue, improved microcirculation, reduction in edema, faster epithelialization and less inflammatory response. A significant reduction in cost of treatment and hospital stay with adjunctive hyperbaric oxygen therapy has been reported.(7)

The clinical application of HBOT requires heavy equipment and specific staff training. Currently there are no standard protocols for specific pathologies. The treatment procedures vary according to the pathologies (acute or chronic) and centers (doctors in charge). The treatment is of variable duration and can consist of a unique session as is the case for carbon monoxide poisoning or can be allocated over several sessions once or twice a day. A session's duration is generally estimated from 30 to 90 minutes.

According to the equipment type, the patient's medical condition, and after following the instructions for use with regard to safety, the subject is placed comfortably (seated or lying down) then the oxygen inhalation system is applied to the patient's. The patient should be kept under close surveillance throughout the session.

The implementation of hyperbaric oxygen therapy requires a few conditions, the absence of which may limit its application:

- The local availability of aproper structure (Figure 5).
- A good general condition is essential. The patient must be transportable and must also tolerate being inside the chamber. Medical and psychological preparation for claustrophobic patients is necessary to prevent confinement anxiety. (Figure 5)
- An assessment combining anoro-facial, pulmonary and electrocardiography examination in order to avoid accidents of hyperbaric oxygen therapy (oxygen toxicity).

HBOT is known to be used either as a primary or alternative technique for the treatment of infections. Regardless the antibiotic resistance, the use of HBOT can treat effectively acute infections caused by antibiotic resistant pathogens.(8)

Partially, the antimicrobial effects of HBOT are considered to result from the formation of reactive oxygen species. HBOT was found to be beneficial for different infections, particularly in deep and chronic infections such as necrotizing fasciitis, osteomyelitis, chronic soft tissue infections, and infective endocarditis as it builds up the antimicrobial effects of the immune system and has a synergistic effect with certain antimicrobial agents.(9–11)

Like all health-related technologies, hyperbaric oxygen therapy has certain transient side effects that are sometimes severe and more or less predictable, that are usually due to inadequate use.(12)Barotrauma of the middle ear is at the top of the list of complications. Sinus, teeth and pulmonary barotrauma is also described. Alterations in visual acuity, such as myopia or hyperopia, secondary to hyperbaric oxygen therapy, have been reported most often in the case of prolonged treatments. These symptoms are usually transient, but there are few specific studies to these side effects.(13) Some experimental studies (carried out on animals and under special conditions) report the toxicity of oxygen on certain organs, in particular on the central nervous system. The origin and mechanisms of this toxicity are still poorly understood.(14) In the current medical practice of hyperbaric oxygen therapy, the chosen protocols rule out the risk of toxicity from hyperoxia.(15)

HBOT requires continuous and close monitoring and control before, during and after the therapeutic procedure. Regardless of the pathology targeted, the patient subjected to HBOT must meet strict physiological and psychological criteria (even if they are not yet standardized). Moreover, this procedure requires a high-performance technical and professional environment.

Figure 5:- hyperbaric chamber (Mohamed V Military Hospital-RABAT).

Conclusion:-

Burn management can be a major problem in developing countries. We were able to demonstrate, through this study, that hyperbaric oxygen therapy can be beneficial in the treatment of infected burns at the acute phase, making it possible to control the infection (in combination with an appropriate antibiotic therapy) and thus giving more chances to a surgical cover procedure.

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