Hyperbaric Oxygen Therapy (HBOT) Treatment in Malaysia

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ABSTRACT

Hyperbaric Oxygen Therapy (HBOT) is a new treatment modality in which the patient intermittently breathes 100% oxygen while the treatment chamber is pressurized to a pressure greater than sea level (hyperbaric environment). Application on modern HBOT was introduced as early as the 1950's and has rapidly been practiced all over the world mainly in developed countries as well as developing countries. In Malaysia, it was introduced as early as the 1960's by the Royal Malaysian Navy (RMN) to treat underwater mishaps. It gained popularity and recognition when the Institute of Underwater and Hyperbaric Medicine (IUHM) started treating specific clinical diseases in the late 1990's using HBOT. Since then, there have been demands of HBOT among civilian patients, with more hyperbaric facilities expected in the near future. The objective of this paper is to provide a brief report on HBOT as a new modality of treatment in Malaysia, as well as to discuss some of its issues and challenges.

Keywords: Hyperbaric Oxygen Therapy (HBOT), Royal Malaysian Navy (RMN), Institute of Underwater and Hyperbaric Medicine (IUHM), Hyperbaric Recompression Chamber Facilities

INTRODUCTION

The earliest hyperbaric therapy trial was documented as early as in 1662, when Henshaw built the first hyperbaric chamber, or 'domicilium'. There were a number of beneficial effects reported from increased pressure, and by the year of 1877, chambers were used widely for many conditions, though there was little scientific rationale or evidence at that time [1].

The first report on the use of modern Hyperbaric Oxygen Therapy (HBOT) was in 1956 by Professor I. Boerema of Amsterdam. He published an article on the practice of administering oxygen to patients under hyperbaric conditions as well as the rationale of using HBOT [2]. Research conducted by the US military after the Second World War throughout the late 1950' s and early 1960' s brought greater knowledge about survivable pressures [1]. Based on their findings, extensive research was conducted and HBOT was recommended and used in a wide variety of medical conditions.

Since then, many developed countries have set up their hyperbaric recompression chamber facilities for HBOT as well as for research and development [3].

Developing countries have also developed this treatment modality by installing hyperbaric recompression chambers facilities mainly in their military settings [4]. With this continuing growth all over the world, it has been found that HBOT has a distinct role in the modern era.

In South East Asia, HBOT is widely used in Thailand, Philippines, Brunei, Singapore and Indonesia as well as in Malaysia [4,5,6,7]. In Malaysia, it was introduced as early as the 1960's by the Royal Malaysian Navy (RMN) to treat their injured divers from underwater mishaps (mainly decompression illness and arterial gas embolism) [5,6]. HBOT gained popularity and recognition when the Institute of Underwater and Hyperbaric Medicine (IUHM) of Malaysian Armed Forces started treating specific clinical diseases based on the recommendation by the Undersea and Hyperbaric Medical Society (UHMS) in the late 1990's [5,6].

With increasing demands for patients and potential benefits of HBOT, a few private hospitals and medical centers in Malaysia have set up hyperbaric recompression chamber facilities in their premises. The first private hyperbaric recompression chamber facility was set up in Ipoh (Northern Peninsular Malaysia), which began treating patients in early 2001 [5,6]. This was followed by others in Penang and Kuala Lumpur [5,6,8]. A leading University Hospital also set up its own hyperbaric recompression chamber facility in early 2004 [5,6]. Recently, the Hospital Angkatan Tentera (HAT) Tuanku Mizan, a military hospital in Kuala Lumpur installed the latest hospital-based hyperbaric recompression chamber facility for similar purposes [9].

HYPERBARIC OXYGEN THERAPY (HBOT)

HBOT is a treatment modality in which a patient intermittently breathes 100% oxygen while the treatment chamber is pressurized to a pressure greater than sea level (1 atmosphere absolute, ATA) 10. It has been considered as a controversial treatment in the mainstream medical community. However, the implementation of HBOT in a variety of diseases has been increasing to the present day [11,12].

Indications and benefits of HBOT

The UHMS approves the use of HBOT for a few conditions for which there are reasonable scientific evidence and well-validated clinical experience. The UHMS currently approves the treatment of 13 conditions for HBOT (summarized in **Figure1**).

The benefits of HBOT can be classified into four categories: (1) mechanical effects, (2) bacteriostatic effects, (3) treatment of poisoning, and (4) treatment of hypoxia. Mechanical effects are used to reduce air bubble size in situations of air or gas embolism or decompression sickness. Bacteriostatic effects are used to treat necrotizing infections and osteomyelitis. Treatment of poisoning is generally for carbon monoxide or cyanide poisoning by enhancing the displacement of carbon monoxide from hemoglobin and enhancing tissue oxygenation. As HBOT enhances tissue oxygenation, hyperbaric treatment of hypoxia promotes healing in certain wounds such as those resulting from delayed radiation injuries or compromised skin grafts and flaps [12].

1. Air or gas embolism
2. Carbon monoxide poisoining
3. Clostridal myocitis and myonecrosis (Gas Gangrene)
4. Crush, compartment syndrome an other acute traumatic ischemias
5. Decompression sickness
6. Enhancement of healing in selected problem wounds
7. Exceptional blood loss (anemia)
8. Intracranial abscess
9. Necotizing sft tissue infection (necrotizing fasciatis)
10. Osteomylitis (refractory)
11. Delayed radiation injury (soft tissue and bony necrosis)
12. Skin grafs and flaps (compromised)
13. Thermal burns
14. Idiopathic Sensorineural Hearing Loss

Figure 1. Indication as approved HBOT by Undersea and Hyperbaric Medical Society (UHMS)

Method of administration of HBOT

HBOT method of administration can be applied in monoplace or multiplace chambers. In a monoplace chamber (**Figure 2**), a single patient is placed in the chamber which is pressured with 100% oxygen. Monoplace chambers are used to treat stable patients with chronic medical conditions, where multiplace chambers (**Figure 3**) are pressurized with air, and oxygen is given via a face-mask, a hood tent or with an endotracheal tube 1. Multiplace chambers are used to treat many patients at the same time and also for treating critically ill patients who require a medical attendant within the chamber. The treatment is given at 2 ATA or 3 ATA and the average duration of therapy is 60 to 90 minutes and is administrated intermittently, usually once a day 13.

Physiological basis of HBOT

The effects of HBOT are based on the physiological and biochemical effects of hyperoxia and can be explained by three gas laws (Boyle's, Dalton's and Henry's Law). Boyle's Law states that at a constant temperature, the pressure and volume of a gas are inversely proportional. Dalton's Law states that in a mixed gas, each element exerts a pressure proportional to its fraction of the total volume (partial pressure). Henry's Law states that the amount of gas dissolved in a liquid or tissue is proportional to the partial pressure of that gas in contact with the liquid or tissue [1].

Most oxygen carried in the blood is bound to hemoglobin, which is 97% saturated at atmospheric pressure. Some oxygen is however, carried in solution, and this portion is increased at pressure according to Henry's Law, maximizing tissue oxygenation. When breathing normobaric air, arterial oxygen tension is approximately 100 mmHg, and tissue oxygen tension is approximately 55 mmHg. When the concentration of oxygen is increased to 100% at 3 ATA, arterial oxygen tensions can be increased to 2000 mmHg, and tissue oxygen tensions to around 500 mmHg. This increase allows a delivery of 60 ml oxygen per liter of blood (compared to 3 ml/l at atmosphere pressure), which can reach physically obstructed areas where red blood cells cannot pass. This enables tissue oxygenation even with impaired hemoglobin oxygen carriage, such as in carbon monoxide poisoning and severe anemia [1].

IMPLEMENTATION OF HBOT IN MALAYSIA

Military Hyperbaric Recompression Chamber Facilities

Figure 2. Patient undergoing HBOT in monoplace chamber

Figure 3. Patients in multiplace chamber

Currently, there are a few hyperbaric recompression chamber facilities in Malaysia. The existing are mainly available in military settings (RMN and Special Forces (Commando)), and are managed by military personnel for treatment of diving accidents during diving training and exercises [5].

The IUHM which is part of the 96 Armed Forces Hospital in Lumut Naval Base, is the first kind of hospital-based hyperbaric recompression chamber in Malaysia, and is considered a pioneer in expanding HBOT as a new treatment modality in Malaysia. Its set-up was accelerated with the acquisition of a multi-place three-compartment recompression chamber in 1996 which is able to accommodate 14 patients at any one time [14]. It expanded its services to not only treating diving-related illnesses, but also clinical cases recommended by the UHMS such as non-healing ulcers mainly diabetic foot ulcers as well as osteomylitis, necrotizing soft tissue infections, carbon monoxide poisoning, radiation-induced necrosis, compartment syndromes and skin graft/flap [5].

The Tuanku Mizan Armed Forces Hospital, the newest military hospital has installed a multiplace hyperbaric recompression chamber in its premises in early 2009 and fully operational since then. The acquisition of the chamber is mainly to cater for armed forces personnel as well as civillians and will be a referral centre for HBOT in Malaysia [9].

Civilian Hyperbaric Recompression Chamber Facilities

Until now, there is no hyperbaric recompression facility available in any government clinic or government hospital. However, the Hospital Universiti Sains Malaysia (HUSM) in Kubang Kerian has become the first University Hospital in Malaysia practicing HBOT in 2004 [6].

Several private hospitals and medical centers have also set up hyperbaric recompression chamber facilities in their premises. The first private HBOT medical centre was set up in 2001 in Ipoh. This was followed by other centers in Kuala Lumpur [5,6]. A few established private hospitals in Penang have also implemented HBOT as part of their available services in the past few years.

ISSUES AND CHALLENGES

Cost Impact on Government and Stakeholders

The cost is tremendous as one hyperbaric recompression chamber facility can cost up to a few million of ringgit (RM). For example, the Malaysian Armed Forces (MAF) spent almost RM 4.6 million (1996) in total to install a hyperbaric recompression chamber facility (3 compartment 14 men chamber) in IUHM at the Armed Forces Hospital in Lumut Naval Base [16]. This hospital spends more than RM 100 thousand per year for maintenance of its hyperbaric chamber. The cost for a monoplace chamber ranges from RM 300 to RM 400 thousand each.

Other factors which need consideration are human resources, such as training, competency and accreditation of staff as well as where the hyperbaric recompression chamber facility should be located. Therefore, proper long term planning in terms of cost effectiveness and benefits are necessary for developing HBOT in the future.

Cost Impact on Patients

The charges for a session of HBOT differ from place to place. An average 90-minute HBOT in the United States costs between US$300 and US$400 [17]. The cost of 30 to 40 sessions for the treatment of a problem wound can therefore range from US $9000 to US$16000 [17]. Meanwhile, the hyperbaric recompression chamber facility in Canada charges only C$100 per 90-minute session [18].

Cost for one session of HBOT in a private health sector in Malaysia ranges from RM140 to RM360 depending on the type of disease, duration of treatment and the type of HBOT treatment which is used. Fifteen sessions are needed in the treatment of diabetic ulcers or non-healing ulcers, which range from RM5000 to RM6000 for a complete session. Cost plays a major role in getting HBOT treatment since it is rather expensive in private sectors and most of the expenses are not covered by any medical insurance. To cut the cost, patients can be treated as outpatients; for example patient with stable diabetic foot ulcers.

Occupational Safety and Health in a Hyperbaric Recompression Chamber Facility

Workers who operate hyperbaric recompression chamber facilities namely chamber operator, chamber nurses and HBOT physicians are at higher risk of being exposed to a variety of hazards. This also includes patients who receive HBOT. Physical hazards (pressure, heat, noise, and fire), chemical hazards (oxygen leakage and toxicity, carbon dioxide toxicity), ergonomic problems and occupational stressors are common and identified hazards in operating hyperbaric recompression chamber facilities. These hazards should be monitored and minimized to ensure the occupational safety and health of these groups of workers as well people in surrounding areas. Hazard assessments should be conducted regularly, preventive measures should be adhered to, and the workers need appropriate work schedules to avoid over-exposure to these hazards.

Pre, periodic and post medical employment screenings are recommended for workers involved in operating hyperbaric recompression chamber facilities. Those with past medical history of untreated pneumothorax, malignancies, pacemakers, chronic sinusitis, seizure disorders, emphysema, history of thoracic surgery, optic neuritis or otoslerosis, and congenital spherocytosis are not fit to work in this setting. If these personnel have illness, such as acute respiratory tract infections or acute sinusitis or are pregnant, they should not be working in the operating chambers until all signs and symptoms cleared, or after giving birth. To ensure the safety and health of the workers, strict medical guidelines should be implemented and reviewed regularly.

Only trained professional workers are recommended to perform HBOT procedures. HBOT physicians should be present during

critical phases of the treatment, namely pressurization and depressurization of the chambers.Chamber operators should be efficient in chamber operations, as well as be knowledgeable in the theory and application of gas laws, chamber safety, and patient assessment. Chamber nurses should be trained to recognize signs and symptoms of gas toxicity, and actions to be taken during HBOT [12]. The workers should be provided with medical insurance, as well as contribute to the Social Security Organization (SOCSO), for compensations and protection in case of accidents or death.

In monitoring the risk of fire in the recompression chambers, a safety guideline or protocol should be available. For example, in the United States, the National Fire Protection Association (NFPA) published a Manual on Fire Hazards in Oxygen-Enriched Atmospheres in 1969 and later in 1970, a Standard for Hyperbaric Facilities. These manuals are updated and reviewed regularly every three years [3,19]. The hyperbaric recompression chamber facilities have to set up their own safety guidelines and protocols based on international standard requirements, such as emergency fire procedures and handling liquid oxygen and oxygen toxicity.

Authorization from higher authorities is needed before a hyperbaric recompression chamber facility can be ready to operate. Authorized government and private sectors, such as the Department of Safety and Health (DOSH) should inspect these facilities and produce reports to ensure that the hyperbaric recompression chamber is safe for use. Surrounding signage is also very important when operating the hyperbaric recompression chambers. Signs such, as “No Smoking Area” and “Prohibited Area” should be available in operating areas. Safety procedures, occupational hazards monitoring and security for the workers should be emphasized and practiced.

CONCLUSION

With increased awareness among medical specialists and patients, HBOT is expected to become a popular alternative or adjunctive modality of treatment in Malaysia. All related agencies and institutions of higher learning need to network in order to develop this treatment modality into a well recognized subspecialty. At present, there are a few local publications on HBOT in Malaysia [20-24]. There is a need for hyperbaric recompression chamber centers to share their findings and reports on the uses of HBOT.

ACKNOWLEDGEMENT

The authors are grateful and wish to acknowledge and thank to those who were involved in the initial development and implementation of the HBOT in Malaysia.

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