CASE REPORT

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The monoplace hyperbaric chamber and management of decompression illness

單位高壓供氧室和減壓病的處理

Three cases of decompression illness are reported. Two patients presented with joint pain and skin signs, while one patient presented with joint pain and neurological signs and symptoms. The patients received emergency recompression therapy in a Hong Kong clinic, using a monoplace hyperbaric chamber. All three patients were treated successfully and no residual signs or symptoms were evident on review at 90 days' post-treatment. Issues concerning the use of monoplace and multiplace hyperbaric chambers are also discussed, along with additional clinical applications of the monoplace hyperbaric chamber.

本文報告了三宗減壓病的病例。其中兩名患者出現關節痛和皮疹，另一名患者出現關節痛和與神經有關的徵狀。三名患者於香港一所診所接受了單位高壓供氧室的緊急加壓治療，結果都很成功，治療後90天復查時並未發現明顯後遺病徵。本文還討論了使用單位高壓和多位高壓供氧室的有關事務，以及單位高壓供氧室的其他臨床應用。

Key words:
Decompression sickness;
Diving;
Emergency treatment;
Hyperbaric oxygenation

關鍵詞：
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Introduction

Decompression illness is not a common occupational disease. However, it can occur in recreational scuba divers, commercial divers, and other workers using compressed air. The pathogenesis of decompression illness relates to residual nitrogen and bubble formation. The formation of a bubble, however, is only the first of a sequence of events that, depending on their location, may have no symptoms or may result in conditions that range in severity from skin rash and pruritus, to convulsions and death.

The monoplace hyperbaric chamber is designed to treat a single patient in one session, while the operators observe and maintain communication via a transparent acrylic tube and intercom. Due to the shortage of knowledge[1] and the limited availability of clinical hyperbaric chambers, the development of hyperbaric oxygen therapy is still in its infancy in Hong Kong.[2] All three cases in this report were managed in a private clinical hyperbaric centre, which has been in operation since April 2000.

Case report

Three local Chinese men, in-shore commercial divers aged between 35 and 38 years, presented with symptoms including joint pain, skin rash, and neurological complaints, after diving work on a local construction project. The diving characteristics, history, and presenting features of each patient are summarised in the Table.

Table. Characteristics of decompression illness (n=3)

Diving characteristics	Working depth and decompression table	Time at maximum depth (mins)	Possible predisposing factors
All dives using Surface Supplied Air Diving Equipments Limited training and experience in in-shore and civil diving	165 fsw/USN 170 fsw Air decompression table	18	Repetitive dive
	172 fsw/USN 180 fsw Air decompression table	22	Repetitive dive
	192 fsw/USN 200 fsw Air decompression table	15	Repetitive dive

Treatment method

Before admittance to the hyperbaric chamber, all cases underwent a brief physical examination, including assessment of mentation, coordination, cranial nerves, deep tendon reflexes, muscle strength, breathing, pulse, and blood pressure. Two of the patients presented with joint pain and skin rash only. They received therapy at 2.2 ATA with pure oxygen, according to the JP Le Péchon Table.[3] One patient presented with persistent headache, nausea, and right shoulder pain. He received therapy at 3.0 ATA with pure oxygen, based on the Hart monoplace treatment table.[4]

The desired treatment pressure was achieved within 9 minutes in two patients, while 15 minutes was required to achieve the desired treatment pressure in one patient, due to left ear equalisation difficulties. The two patients with joint pain and skin rash only, responded well within the first 25/5 minute oxygen/air treatment cycle. Thus, the treatment was completed within the specified timeframe, without the need for extension. An extension of 25 minutes oxygen and 5 minutes air cycle at 2.5 ATA was required for the patient with nausea and persistent headache, however, before complete resolution of symptoms. Slow decompression over 30 minutes followed treatment, with the divers monitored for any residual clinical signs and symptoms. Patient review the following day and at subsequent 3-monthly intervals found no evidence of residual signs and symptoms over a 90-day period.

Discussion

Choice of chamber

It is clear that a 'walk-in', multiplace chamber offers several advantages over a monoplace chamber. There are more options regarding choice of pressure and treatment gas, for example, and it is also possible to conduct a neurological examination throughout the treatment process. The use of a monoplace hyperbaric chamber for the treatment of decompression illness and air embolism has been controversial in the past. The original design of the monoplace chamber utilised 100% oxygen. Almost universally, these chambers were limited to a three-atmosphere (19.8 m) pressure capability. Standard US Navy recompression tables[5] stipulate breathing air at several intervals to reduce oxygen toxicity. Nowadays, some monoplace chambers are pressurised with air but also equipped with a built-in breathing system, using a tight-fitting demand mask to deliver oxygen and other modifications (Fig). This allows US Navy recompression tables used with multiplace chambers to be followed when therapy is provided using a monoplace chamber.

The majority of non-critically ill patients treated in a monoplace chamber can be monitored safely by direct observation alone. Respiratory rate is evident, as well as manifestations of anxiety, which can be a warning sign of central nervous system oxygen toxicity. Critically ill patients, however, require additional monitoring. This includes equipment for maintenance of an artificial airway, ventilators, haemodynamic monitors, a defibrillator, suction apparatus, oximeters, intravenous catheters, and in some cases chest drainage tubes. With the development of electrical, intravenous and gas portals, modern clinical monoplace chambers can allow electrocardiography,

Fig. Monoplace hyperbaric chamber with built-in breathing system

Time of onset of signs and symptoms	Presenting signs and symptoms	Treatment procedures and response
Within 1 hour of surfacing	Right shoulder static pain Localised skin rash and itching	Symptoms resolved with 30 minutes treatment at 2.2 ATA
Approximately 30 minutes after surfacing	Static left elbow and progressive right hip pain Localised skin rash and itching	Symptoms resolved with 30 minutes treatment at 2.2 ATA
Within 15 minutes of surfacing	Right shoulder static pain Persistent frontal headache Nausea and vomiting	Shoulder pain resolved with 30 minutes treatment at 3.0 ATA Headache and nausea resolved after a 25/5 oxygen/air extension at 2.5 ATA

blood pressure monitoring, intravenous infusion, and assisted ventilation if necessary. Critically ill patients can thus be managed, providing the facility is staffed with nurses, therapists, and physicians skilled in the management of the critically ill patient, as well as possessing a thorough understanding of hyperbaric physiology and the medical techniques unique to hyperbaric oxygen therapy.

A common query with regard to decompression therapy is whether one should transport a patient to a distant multiplace chamber for treatment, or provide recompression therapy immediately in a local monoplace chamber.[6] A recent review completed by the Divers Alert Network compiled the 90-day outcomes for patients treated in monoplace chambers compared with those treated in multiplace chambers. For patients with pain only or categorised as 'Type I',[7] residual symptoms were seen in 5.9% of patients treated in multiplace units, and in 7.7% of patients receiving treatment in monoplace hyperbaric chambers. These figures were 16.2% and 16.1% for multiplace and monoplace chambers, respectively in patients categorised as mild Type II cases, and 21.2% and 24.3%, respectively for patients with 'severe Type II' symptoms.[7] These good comparative results may reflect early referral to monoplace chambers, or the lack of more aggressive treatment in multiplace hyperbaric units, however. In Hong Kong, currently there is only one multiplace recompression chamber, which is located on a remote island. Emergency recompression treatment using this multiplace chamber therefore requires:

(1) Accident and Emergency Department consultation;
(2) a confirmed diagnosis of decompression illness;
(3) contact with the Fire Service Department by phone;
(4) transportation of the patient by ambulance to the island; and
(5) mobilisation of the doctor 'on-call' at the Labour Department for a treatment decision.

Hence, several hours of delay before treatment is common in Hong Kong when the multiplace hyperbaric chamber is selected for use. A well-equipped treatment centre using a monoplace hyperbaric chamber in contrast can deliver hyperbaric oxygen therapy within 1 hour of referral.

Choice of treatment table

Assuming one has a two-compartment multiplace hyperbaric chamber, with full pressure capability and mixed gas as well as oxygen available on the manifold, one can select the US Navy Standard treatment protocol based on the clinical condition. In patients presenting with joint pain only, as seen in two of the current patients, rapid resolution of signs and symptoms can be expected with use of oxygen as recommended in the JP Le Péchon table. Total intervention recommended is 2.5 hours at 2.2 ATA, with four 25/5 oxygen/air cycles to achieve the best result and reduce oxygen toxicity.

A practical limitation of the monoplace chamber is a maximum working pressure of 3 ATA. Thus, obtaining a treatment pressure of 2.8 ATA (26.5 pounds per square inch gauge pressure) as recommended in table 6 of the Standard US Navy recompression tables is a challenge.[5] Use of the Hart monoplace chamber treatment protocol at 3 ATA is therefore preferable in decompression illness associated with neurological symptoms. Current data indicate the Hart monoplace treatment protocol is well within safety margins for potential oxygen toxicity.[8]

Need for prompt treatment

Clinical experience of decompression illness and therapy suggests that delays in treatment render therapy less effective, regardless of type. It is also probable that longer treatment tables yield better results in cases of severe decompression illness. Current data indicate that it is preferable to use a monoplace chamber, even with a short treatment table, if it is close at hand, rather than to delay treatment while a multiplace chamber facility is reached, however.[9-10]

Other treatment indications for hyperbaric chamber use

The uses of hyperbaric oxygen therapy in the management of clinical problems other than decompression illness are also well documented.[11] These clinical conditions include air or gas embolism,[12] carbon monoxide poisoning,[13] clostridial infection, radiation injury,[14] problem wounds and compromised skin flaps and grafts,[15] anaemia due to exceptional blood loss, osteomyelitis,[16] and burn injury.[17] There are also a number of emerging applications for this technology—brown spider bite injury,[18] acute myocardial infarction,[19] and ileus associated with abdominal surgery.[20] Under the current well-established safety codes and standards of practice, with a team of a well-trained physician and technicians, the monoplace hyperbaric chamber is well-equipped to deliver appropriate treatment for these clinical problems.[21]

Conclusion

Hyperbaric oxygen therapy is a very useful adjunctive treatment modality for a number of clinical conditions. With further education of medical professionals and the public, hyperbaric oxygen therapy could potentially become a departmental service offered at many Hong Kong hospitals.

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