5. DECOMPRESSION SICKNESS

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Rationale

Decompression sickness ("bends", DCS) arises from the generation of bubbles of inert gas in the tissues and/or blood in volumes sufficient to interfere with organ function (1-5), caused by rapid decompression during ascent from diving, flying, or a hyperbaric/hypobaric chamber. Bubble formation occurs when the speed of decompression exceeds the rate at which diffusion and perfusion reduce the tissue inert gas partial pressure. The resulting clinical manifestations include joint pains (limb bends), cutaneous eruptions or rashes (skin bends), neurological dysfunction (peripheral or central nervous system bends), cardiorespiratory symptoms and pulmonary edema (chokes), shock and death (6). Several mechanisms have been hypothesized by which bubbles may exert their deleterious effects. These include direct mechanical disruption of tissue, occlusion of blood flow, platelet deposition and activation of the coagulation cascade (7), endothelial dysfunction (8, 9) and capillary leakage (10-12), complement activation (13, 14) and leukocyte-endothelial interaction (15).

The diagnosis of DCS is made on the basis of signs and/or symptoms after a dive or altitude exposure (16). Manifestations most commonly include paresthesias, hypesthesia, joint pain, skin rash and malaise. More serious signs and symptoms include motor weakness, ataxia, dyspnea, urethral and anal sphincter dysfunction, shock and death (6, 16, 17).

Chest radiography prior to HBO_2 treatment in selected cases may be useful to exclude pneumothorax (which may require tube thoracostomy placement before recompression) and to exclude causes unrelated to diving for which treatment other than HBO_2 would be appropriate (e.g. herniated disc). However, imaging studies are generally not helpful (18, 19), and should not be relied upon to confirm the diagnosis of DCS or be used in deciding whether a patient with suspected DCS needs HBO_2.

In addition to general supportive measures, including fluid resuscitation, airway protection, and blood pressure maintenance, the definitive treatment of decompression sickness is compression to suitable pressures greater than sea level. Improvement of decompression sickness symptoms as a result of compression was first noted in the Nineteenth Century (20). Recompression was first reported as a specific treatment for that purpose in 1896 (21). Oxygen breathing was observed to improve the signs of decompression sickness in animals (22). The use of oxygen with pressure to accelerate gas diffusion and bubble resolution in humans was first suggested in 1897 (23) and eventually tested in human DCS and recommended for the treatment of divers (24). The rationale for treatment with hyperbaric oxygen (HBO_2) includes immediate reduction in bubble volume, increasing the diffusion gradient for inert gas from the bubble into the surrounding tissue, oxygenation of ischemic tissue and reduction of CNS edema. It is also likely that HBO_2 has other beneficial pharmacological effects, such as a reduction in neutrophil adhesion to the capillary endothelium (25, 26). The efficacy of administration of oxygen at increased ambient pressure (hyperbaric oxygen, HBO_2) is widely accepted, and HBO_2 is the mainstay of treatment for this disease (27-30).

A wide variety of initial hyperbaric regimens have been described, differing in treatment pressure and time, partial pressure of oxygen and diluent gas. Although there are no human outcome data obtained in prospective, randomized studies for the treatment of diving related decompression sickness, broad principles that are generally agreed upon (26) include: (a) complete resolution is most likely to result from early hyperbaric treatment (17): (b) the US

Navy oxygen treatment tables (31) (and the similar RN and Comex tables), with initial recompression to 60 fsw (18 msw, 2.82 atm abs) have been the most widely used recompression procedures for decompression illness (DCI) treatment beginning at the surface, and have achieved a high degree of success in resolving symptoms if the delay to treatment is not excessive (17, 28, 32, 33).

Monoplace chambers were originally designed for the continuous administration of 100% oxygen and were not equipped to administer air for "air breaks". For monoplace chambers of this type, tables are available for treatment of decompression sickness that are shorter than standard USN treatment tables (34-36). Retrospective evidence, using telephone follow up, suggests that such tables may be as effective as standard USN tables for the treatment of mildly or moderately affected patients (27, 37). However, many monoplace chambers are now fitted with the means to deliver air to the patient, and thus can be used to administer standard USN treatment tables.

For the vast majority of cases of DCS, superiority of treatments at pressure exceeding 2.82 atm abs or using helium as the diluent gas or using saturation treatments, has not been demonstrated. The use of treatment schedules that deviate from the US Navy oxygen treatment tables or published monoplace tables are best reserved for facilities and personnel with the experience, expertise and hardware necessary to deal with untoward responses.

While longer delays to treatment tend to be associated with incomplete resolution of symptoms, the data currently available have not established a maximum time (hours or days) after which recompression is ineffective (38-44).

The vast majority of cases respond satisfactorily to a single hyperbaric treatment. For patients with residual defects following the initial recompression, repetitive treatments are recommended until clinical stability has been achieved. HBO_2 should be administered repetitively as long as step-wise improvement occurs, based upon clearly documented symptoms and physical findings. Complete resolution of symptoms or lack of improvement on two consecutive treatments establishes the end-point of treatment. Although a small minority of divers with severe neurological injury may not reach a clinical plateau until 15-20 repetitive treatments have been administered, formal statistical analysis of approximately 3,000 DCI cases supports the efficacy of no more than 5-10 repetitive treatments for most individuals (45). In a group of 414 recreational diving accidents the median number of hyperbaric treatments was two, and only 6% of divers received more than 5 treatments (17).

Administration of 100% oxygen at ground level (1 atm abs) is recommended as first aid for all cases of DCS, and can be definitive treatment for altitude-induced DCS (46, 47). For definitive treatment of altitude-induced cases that do not respond to ground level O_2, and for DCS after diving, HBO_2 remains the standard of care (30, 31, 48).

Adjunctive treatment such as first-aid oxygen administration, fluid resuscitation and, for patients with leg immobility, venous thromboembolism prophylaxis are indicated. These are discussed in detail in a separate monograph (49). A summary of current recommendations for adjunctive therapy is available on the Undersea and Hyperbaric Society website (http://www.uhms.org).

Guidelines for Use of HBO_2 in Decompression Sickness

The use of HBO_2 for decompression sickness should be considered an AHA level I recommendation in spite of the absence of type 1 evidence (randomized controlled trials). Hyperbaric oxygen is the definitive treatment for this entity and has a history of many years of

effective and safe application. No other definitive treatments exist. All other treatments are adjunctive to hyperbaric oxygen.

Utilization Review

The choice of treatment table and the number of treatments required will depend upon: (1) the clinical severity of the illness; (2) the clinical response to treatment; and (3) residual symptoms after the initial recompression. Depending on the patient's initial response, there may be repetitive treatments. Patients should be treated until clinical examination reveals no further improvement in response to the HBO_2 treatments. The need for follow up ("tailing" treatments) should be supported by documentation of the clinical evaluation before and after each treatment. Utilization review should occur after 10 treatments.

Cost Impact

Only those people exposed to increased ambient pressure (divers or compressed air workers) or who suffer decompression sickness at altitude are affected. Therefore, the application of HBO_2 will be limited because there are relatively few individuals who develop this condition. HBO_2 is a treatment that usually provides resolution or significant improvement of this disorder that can otherwise result in permanent spinal cord, brain or peripheral nerve damage or death. It is therefore an exceptionally cost effective treatment.

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