The Journal of International Medical Research 052-048
2008; 36: 222–226 [first published online as 36 (2) 1]

MRI Screening of Dysbaric Osteonecrosis in Hyperbaric-chamber Inside Attendants

H Ozkan[1], G Uzun[2], S Yildiz[2], G Sonmez[3], H Mutlu[3] and S Aktas[4]

[1]Department of Orthopaedics and Traumatology, Gulhane Military Medical Academy, Etlik, Ankara, Turkey; [2]Department of Underwater and Hyperbaric Medicine, and [3]Department of Diagnostic Radiology, GMMA Haydarpasa Teaching Hospital, Uskudar, Istanbul, Turkey; [4]Department of Underwater and Hyperbaric Medicine, Istanbul Medical Faculty, Istanbul University, Istanbul, Turkey

Inside attendants are medical staff who accompany patients during hyperbaric oxygen treatments. Dysbaric osteonecrosis (DON) is a well-known consequence of hyperbaric exposure. The aim of this study was to evaluate DON in inside attendants using magnetic resonance imaging (MRI). The bilateral shoulder, hip and knee joints of 12 inside attendants (four men, eight women; mean age 29 years; age range 22 – 36 years) were investigated. The mean ± SD duration of employment as an inside attendant was 3.8 ± 3.0 years (range 1 – 9 years) and the mean ± SD number of hyperbaric exposures was 198 ± 267 (median 96; range 30 – 950). None of the inside attendants had a history of decompression sickness. The MRIs of the attendants did not reveal bone lesions consistent with DON. This study failed to find an increased risk for DON in inside attendants. Additional multicentre epidemiological studies are warranted to investigate the occupational safety of inside attendants.

KEY WORDS: Inside attendants; Occupational safety; Hyperbaric exposure; Dysbaric osteonecrosis; Hyperbaric oxygen therapy

Introduction

Hyperbaric oxygen (HBO) therapy is the administration of 100% oxygen in a special chamber at a pressure greater than that at sea level.[1] HBO is used worldwide in the treatment of several disorders, including decompression sickness, acute gas embolism, carbon monoxide poisoning, necrotizing infections and non-healing wounds.[1] The treatments are carried out either in monoplace or multiplace (walk-in) hyperbaric chambers. Whilst the former accommodates a single patient, the latter accommodates two or more patients at the same time and permits medical personnel to accompany patients during HBO treatments to care and supervise them. These medical personnel are referred to as inside attendants.

HBO therapy encompasses three stages: compression, isobaric phase and decompression. In the compression phase, the hyperbaric chamber is slowly pressurized to the treatment pressure, which is usually between 2 and 3 atmospheres absolute (atm). During the isobaric phase, patients breathe 100% oxygen at intervals whereas, in contrast, the inside attendants breathe

ambient air most of the time. Finally, the treatment is completed by depressurizing the chamber to sea level air pressure (decompression). On account of compression, decompression and breathing air under high pressure, inside attendants resemble divers. Acute adverse events related to hyperbaric exposure, including decompression sickness, have been reported in inside attendants.[2] There is a scarcity of information, however, about long-term negative effects of hyperbaric exposure on inside attendants.

Dysbaric osteonecrosis (DON) is a form of aseptic bone necrosis, which develops as a result of hyperbaric exposure in divers and caisson workers. DON lesions usually affect long bones with fatty marrow, such as the humerus, femur and tibia.[3,4] DON has been reported in 70% of Turkish sponge divers and 3.1% of German Navy divers.[3,5] Although the pathogenesis of DON is not clear, recent evidence suggests that asymptomatic gas bubbles formed after hyperbaric exposure play a key role in the pathogenesis of DON.[6] Venous gas bubbles have been detected in inside attendants after assisting HBO treatments,[2] therefore, we formed the hypothesis that inside attendants are also at risk of DON. As far as we can determine, however, inside attendants are not screened for DON. The aim of this study was, therefore, to evaluate asymptomatic inside attendants for DON using magnetic resonance imaging (MRI).

Subjects and methods

SUBJECTS ENROLLED

Medical personnel who had served as inside attendants for more than 6 months and were still working as inside attendants at the time of recruitment were asked to participate in the study. Inside attendants who had previously dived for recreational purposes were excluded. All participants were recruited from the Department of Underwater and Hyperbaric Medicine, GMMA Haydarpasa Teaching Hospital between January 2006 and May 2006.

The pressure of HBO therapy is determined by the disease of the patient to be treated and is carried out at 2.4 – 3 atm for non-healing wounds and at 6 atm for diving accidents.

Verbal informed consent was obtained from each subject before participation in the study. Ethical approval was obtained from the Gulhane Military Medical Academy local ethics committee.

MEDICAL ASSESSMENTS AND EVALUATIONS

In addition to medical examination, detailed laboratory tests including complete blood counts, erythrocyte sedimentation rate, serum cholesterol, triglyceride, high-density lipoprotein, aspartate transaminase, alanine transaminase, uric acid, glucose level and urine analyses, were performed prior to the study in order to rule out other potential causes of aseptic bone necrosis. A questionnaire was used to obtain details of medical history, hyperbaric exposure history, smoking habits and alcohol intake of the subjects.

MRI examinations of the shoulders, including the proximal upper arms, the pelvis including the proximal femoral bones, and knees with the adjacent femoral and tibial bones, were performed on a 1.5 Tesla magnetic resonance unit (Siemens Vision, Erlangen, Germany). MRI examination consisted of T1 weighted images in the axial and sagittal planes, and T2 weighted images in the axial and coronal planes.

Results

Twelve inside attendants (four men, eight

women) were included in the study and data analysis. Two other individuals were excluded due to prior recreational diving experience. The mean (± SD) age of the inside attendants was 28.9 ± 3.7 years (range 22 – 36 years). The mean (± SD) duration of working as an inside attendant was 3.8 ± 3.0 years (range 1 – 9 years) and the mean (± SD) number of treatment attendances was 198 ± 267 (median 96; range 30 – 950).

The 12 inside attendants were subjected to a pressure of 2.4 – 3 atm during routine HBO treatment, while only two underwent US Navy Treatment Table 6A (USN TT6A) treatment at 6 atm in addition to routine HBO treatment. None of the attendants had experienced decompression sickness after HBO treatments. Four inside attendants had experienced middle-ear barotrauma.

High blood cholesterol and lipids were determined in two individuals in laboratory tests and high liver enzymes in one. Other laboratory analyses were within normal limits. None of the subjects reported steroid use. Six of the 12 inside attendants were smokers (mean ± SD of 7.3 ± 10.0 cigarettes/day). Five inside attendants reported that they consumed alcohol occasionally but none had a habit of regular alcohol intake.

MRI examinations of the inside attendants did not reveal bone lesions consistent with osteonecrosis. Cystic lesions in the femoral head were only detected in two inside attendants; they had undergone only routine HBO treatments.

Discussion

Inside attendants are a unique group of medical workers with special safety issues. The European Committee for Hyperbaric Medicine recommends initial and periodical medical examination of attendants according to national regulations on working under pressure, to assess their fitness for hyperbaric exposure.[7] Inside attendants are often exposed to compressed air for long enough to need proper decompression.[2,8] Terminal oxygen breathing and personnel rotation are measures usually taken to prevent decompression sickness,[8] however venous gas bubbles have been demonstrated to be present in inside attendants after assisting HBO treatments at 2.4 atm for 115 min.[2] The incidence of decompression sickness in inside attendants varies widely from 0.01% to 0.6% (Baker PC, unpublished). The inside attendants recruited into the present study showed no incidence of decompression sickness over a total of 2386 HBO treatments.

There is growing concern about the long-term negative effects of hyperbaric exposure on the central nervous system, lung and bones of divers. However, there is limited information about the long-term effects of hyperbaric exposure on inside attendants. Thorsen *et al.*[9] investigated the effect of hyperbaric exposure on the lung functions of 14 inside attendants, evaluating them on a yearly basis for 4 – 6 years. They found that the lung functions of inside attendants are significantly changed after hyperbaric exposure, in a similar manner to professional divers. Ors *et al.*[10] evaluated 10 inside attendants and 10 control subjects for ischaemic brain lesions. They found three lesions in two inside attendants and none in controls, however, the difference between the groups was not statistically significant.

DON is a well-known occupational hazard for divers and caisson workers. DON lesions may lead to joint pain, deformity and arthritic changes.[11] The incidence of DON increases with greater dive depths, and numbers and periods of exposure to pressure.[12] Although some authors reported a correlation between the number of dives

and DON, just a single hyperbaric exposure may result in DON.[13] The incidence of DON is higher in those with a higher incidence of decompression sickness.[3] The correlation between decompression sickness and DON indicates that nitrogen gas bubbles are involved in the pathogenesis of DON. Evidence suggests that nitrogen gas bubbles, formed by inadequate decompression after a hyperbaric exposure, may harm adiposites in the bone marrow and initiate a coagulation cascade leading to intra-osseous thrombosis and local ischaemia.[6]

Direct radiography has been used widely in the surveillance of divers and compressed air workers for DON. However, DON lesions cannot be detected on direct radiographs until 8 weeks after harmful exposure.[4] In the present study, MRI was used because it has a higher sensitivity and specificity than direct radiography, however DON was not detected in the small group of inside attendants studied. When inside attendants are compared with commercial and military divers, there is a clear difference in the pressure experienced and the length of exposure. This may account for the absence of DON lesions in inside attendants.

The low number of participants evaluated influenced the statistical power of this study. To detect a disease with low prevalence such as DON requires the assessment of a large group of subjects. Despite the low number of subjects, it is hoped that this study will interest others who work in this field and encourage them to conduct a more extensive study in the future.

In conclusion, osteonecrosis was not detected in hyperbaric-chamber inside attendants. The results of this study do not exclude the possibility of the development of DON in inside attendants as the study was small. Additional multicentre epidemiological studies are warranted to monitor the occupational safety of inside attendants.

Conflicts of interest

The authors had no conflicts of interest to declare in relation to this article.

• Received for publication 24 September 2007 • Accepted subject to revision 26 September 2007
• Revised accepted 9 January 2008

References

1 Feldmeier JJ (ed). *The Hyperbaric Oxygen Committee Report*. Kensington, MD: Undersea and Hyperbaric Medical Society, 2003.
2 Risberg J, Englund M, Aanderud L, *et al*: Venous gas embolism in chamber attendants after hyperbaric exposure. *Undersea Hyperb Med* 2004; **31:** 417 – 429.
3 Toklu AS, Cimsit M: Dysbaric osteonecrosis in Turkish sponge divers. *Undersea Hyperb Med* 2001; **28:** 83 – 88.
4 Jiang CQ, Wang B, Yu CF, *et al*: Dysbaric osteonecrosis by X-ray and CT scan in Chinese divers. *Undersea Hyperb Med* 2005; **32:** 169 – 174.
5 Bolte H, Koch A, Tetzlaff K, *et al*: Detection of dysbaric osteonecrosis in military divers using magnetic resonance imaging. *Eur Radiol* 2005; **15:** 368 – 375.
6 Jones JP, Neuman TS: Dysbaric osteonecrosis. In: *Physiology and Medicine of Diving* (Brubakk A, Neuman T, eds), 5th edn. London: WB Saunders; 2003; pp 659 – 680.
7 *Recommendations for Safety in Multiplace Medical Hyperbaric Chambers*. European Committee for Hyperbaric Medicine, 1998. Available at: http://www.echm.org/ECHM-Documents.htm (last accessed 4 June 2007).
8 Sheffield PJ, Pirone CJ: Decompression sickness in inside attendants. In: *Hyperbaric Facility Safety: a Practical Guide* (Workman WT, ed). Flagstaff, AZ: Best Publishing Company; 1999; pp 643 – 663.
9 Thorsen E, Vaagbø G, Forland M, *et al*: Longitudinal follow up of lung function in personnel attending patients undergoing hyperbaric oxygen therapy. Presented at: UHMS Annual Scientific Meeting, 25 – 29 May 2004, Sydney, Australia. Available at http://www.uhms.org/AccAbsDBase/2004%20a

bs/N.htm (last accessed 8 October 2007)
10 Ors F, Sonmez G, Yildiz S, *et al*: Incidence of ischemic brain lesions in hyperbaric chamber inside attendants. *Adv Ther* 2006; **23:** 1009 – 1015.
11 Davidson JK: Dysbaric disorders: aseptic bone necrosis in tunnel workers and divers. *Baillieres Clin Rheumatol* 1989; **3:** 1 – 23.
12 Chryssanthou CP: Dysbaric osteonecrosis. Etiological and pathogenetic concepts. *Clin Orthop Relat Res* 1978; **130:** 94 – 106.
13 James CCM: Late bone lesions in caisson disease: three cases in submarine personnel. *Lancet* 1945; **ii:** 6 – 8.

Author's address for correspondence
Dr Gunalp Uzun
GATA Haydarpasa Egitim Hastanesi, Sualti Hastaliklari ve Hiperbarik Tip Servisi, 34668 Uskudar, Istanbul, Turkey.
E-mail: gunalpuzun@yahoo.com