Advances in Therapy® | Volume 23 No. 6
November/December 2006

Incidence of Ischemic Brain Lesions in Hyperbaric Chamber Inside Attendants

Fatih Ors, MD
Department of Radiology
Gulhane Military Medical Academy
Etlik, Ankara, Turkey

Guner Sonmez, MD
Department of Radiology

Senol Yildiz, MD
Gunalp Uzun, MD
Department of Underwater and Hyperbaric Medicine

Mehmet Guney Senol, MD
Department of Neurology

Hakan Mutlu, MD
Department of Radiology

Mehmet Saracoglu, MD
Department of Neurology
Gulhane Military Medical Academy
Haydarpasa Training Hospital
Kadikoy, Istanbul, Turkey

ABSTRACT

Concern is growing about the negative long-term effects of hyperbaric exposure on the central nervous system of divers. This study was conducted with magnetic resonance imaging (MRI) to evaluate attendants that work inside hyperbaric chambers (known as inside attendants) for hyperintense brain lesions. Ten inside attendants and 10 healthy nondiving subjects were included in the study. A questionnaire was used to obtain information about subjects' medical history, hyperbaric exposure history, alcohol intake, and smoking habits. T1-weighted, T2-weighted, and fluid-attenuated inversion recovery images were acquired with a 1.5-T MRI device. A lesion was included in the count if it was hyperintense on both T2-weighted and fluid-attenuated inversion recovery images. Although MRI revealed 3 hyperintense brain lesions in 2 of 10 inside attendants and in none of the controls, the differences between groups were not statistically significant (P=.147). The number of brain lesions counted did not correlate with the age of the inside attendants (r=0.007; P=.978), the number of hyperbaric exposures (r=–0.203; P=.574), or the duration of work as an inside

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Address reprint requests to
Dr. Senol Yildiz
Gulhane Military Medical Academy
Haydarpasa Training Hospital
Department of Underwater and Hyperbaric Medicine
34668 Kadikoy, Istanbul, Turkey

attendant (r=0.051; P=.890). Investigators found a correlation, however, between the number of cigarettes smoked in a day and the number of brain lesions identified (r=0.779; P<.01). An increased incidence of hyperintense brain lesions was not observed in inside attendants who had never experienced decompression sickness compared with nondiving controls. Additional multicenter epidemiologic studies are needed if the occupational safety of inside attendants is to be enhanced.

Keywords: | hyperbaric exposure; brain; neuroimaging; occupational safety

INTRODUCTION

Hyperbaric oxygen (HBO) treatments are administered by increasing the atmospheric pressure in a special chamber while the patient breathes 100% oxygen. During HBO treatment, 1 or more members of the medical staff accompany patients into the chamber to provide technical and medical support and to intervene in the event of an emergency. These medical staff members are referred to as inside attendants.

Clinical HBO treatments are frequently performed at pressures between 2.4 absolute atmospheres (45 ft or 14 m) and 3 absolute atmospheres (66 ft or 20 m); duration of treatment ranges from 90 to 120 min. In contrast to patients, inside attendants breathe compressed air during most of the time that HBO treatment is being administered. Inside attendants experience compression, decompression, and breathing of air under high pressure during HBO treatments, so they are subject to the acute and chronic adverse effects of hyperbaric exposure, just like divers.[1,2]

There is growing concern about the negative long-term effects of hyperbaric exposure on the central nervous system of divers.[3] An increased prevalence of brain lesions has been noted on magnetic resonance imaging (MRI) of sport divers and compressed air workers compared with nondiving controls.[4-7] It is hypothesized that asymptomatic intravascular gas bubbles formed after diving activity may lead to long-term ischemic changes in the brain.[5,8] Gas bubbles are formed even after decompression with exposure of only 3.5 m (12 ft).[9] Risberg et al[10] showed gas bubble formation in the circulation of inside attendants after clinical HBO treatments. The current investigators know of no study undertaken to assess long-term neurologic damage caused by repeated hyperbaric exposure in inside attendants. Therefore, this controlled study was begun to evaluate the brains of healthy inside attendants through the use of MRI.

METHODS

Inside attendants who worked at the Department of Underwater and Hyperbaric Medicine were asked to participate in this study. Inside attendants who had worked for less than 6 mo (2 subjects) and those who had dived for recreational or military purposes (2 subjects) were excluded from the study. Thus, the study group consisted of 10 inside attendants. A control group consisted of 10 age-matched healthy subjects who had not previously been exposed to a hyperbaric environment. None of the subjects had a history of cerebrovascular or cardiovascular disease, multiple sclerosis, or diabetes. The institutional ethics committee approved the study protocol, and written informed consent was obtained from each subject before the study began.

In addition to physical examination findings, a questionnaire was used to obtain information about subjects' medical history, hyperbaric exposure history (maximum depth, average depth, total number of dives, history of decompression sickness), alcohol intake (never, rarely, daily), and smoking habits (cigarettes/d).

MRI was performed with a 1.5-Tesla magnetic resonance scanner equipped with a head coil. T1-weighted and T2-weighted images were acquired. In addition, fluid-attenuated inversion recovery (FLAIR) images were obtained to improve differentiation between widened perivascular (Virchow-Robin) spaces and true brain lesions.[8] Images were reviewed by 2 radiologists who were blinded to the study groups. A lesion was counted if it was hyperintense on both T2-weighted and FLAIR images.

The 2 study groups were compared with the Mann-Whitney *U* test for continuous variables, and the Fisher exact test was used for categorical variables. Correlations between the number of dives, age of the subject, smoking behavior, and the number of brain hyperintense lesions identified were investigated with Spearman correlation test. Data were presented as means±standard deviation (SD). A *P* value <.05 was considered statistically significant.

RESULTS

Results from 10 inside attendants and 10 control subjects were gathered for analysis. Baseline characteristics of subjects did not differ significantly (Table).

In the study group, the mean duration of work as an inside attendant was 4.3±3.0 y (range, 1–9 y), and the mean number of treatments attended was 214±292 (median, 78; range, 30–950). Eight inside attendants were subjected to a depth of 45 to 60 feet during routine HBO treatments, and only 2 accompanied USN Treatment Table 6A at 165 feet, in addition to receiving routine HBO treatments (1 of them twice, the other, once). No inside attendant had a history of decompression sickness.

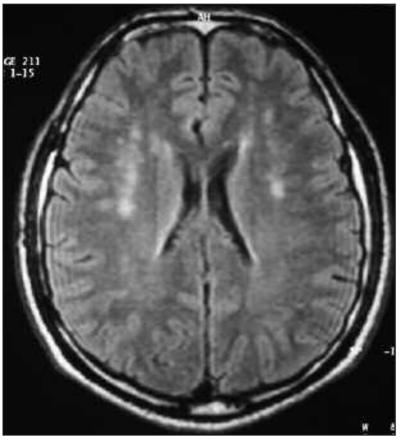
Baseline Characteristics and Hyperintense Brain Lesions in Inside Attendants and Control Subjects*

	Inside Attendants (n=10)	Control Group (n=10)	*P* Value
Age, y	30±3.0	29.2±3.6	.761
Sex, M/F	4/6	5/5	.500
Body mass index, kg/m²	23.6±1.8	24.3±2.6	.631
Smoking, cigarettes/d	7.8±11.0	5.3±6.7	.745
Alcohol intake, n			.500
Never	6	7	
Rarely	4	3	
Daily	0	0	
Hyperintense brain lesions, n	3	0	.147

*Data are presented as means±SD.

MRI revealed 3 hyperintense brain lesions in 2 of 10 inside attendants. In the 10 control subjects, MRI findings were normal. However, the differences between groups were not statistically significant (P=.147). In 1 case, a hyperintense lesion was observed in the left frontal white matter, and in the other case, 2 hyperintense lesions were observed in the centrum semiovale in bilateral deep white matter (Figure). No disease was detected in either case on the basis of detailed neurologic examination findings.

No correlation was noted between the age of the subject (r=0.007; P=.978), the number of treatments attended (r=–0.203; P=.574), the duration of work as an inside attendant (r=0.051; P=.890), and the number of brain lesions detected. However, a correlation was observed between the number of cigarettes smoked in a day and the number of brain lesions detected (r=0.779; P<.01).



MRI of an inside attendant with hyperintense lesions in bilateral deep white matter.

DISCUSSION

There is growing concern about the occupational safety of inside attendants. Although only 1 death of an inside attendant has been reported in the literature, the incidence of decompression sickness (DCS) in inside attendants is striking.[11] The reported incidence of DCS in inside attendants ranges between 0.01% and 0.6%.[1] Recently, Risberg et al[10] reported the development of serious neurologic DCS in an inside attendant at Haukeland University Hospital, Norway. No procedural error or personal risk was identified during the investigation. After this accident occurred, investigators conducted an experimental study to investigate the prevalence of venous gas embolism in inside attendants after routine (240 kPa for ~115 min with 12 min terminal oxygen breathing) and revised HBO treatment profiles (24 min terminal 100% oxygen breathing and 40.5% oxygen in nitrogen breathing during 90 min of the isobaric phase). It was found that inside attendants are subject to significant decompression stress, and it was decided that HBO treatments should not be performed in multiplace chambers for elective patients, so that the possible risk to inside attendants may be eliminated. Thorsen et al[2] investigated the effects of hyperbaric exposure on the lung function of inside attendants. Fourteen inside attendants were evaluated on a yearly basis for 4 to 6 y. The median number of exposures for inside attendants was 240 (range, 37 to 456). Investigators concluded that the lung function of inside attendants was significantly changed after hyperbaric exposure, similar to the experience of professional divers.

Acute disease conditions related to diving, such as decompression sickness and arterial gas embolism, may seriously damage the central nervous system of divers.[3] Furthermore, debate is ongoing about whether even uneventful hyperbaric exposure may cause long-term brain damage in divers.[3] Several neuroimaging studies have been performed to evaluate possible ischemic changes in the brains of different groups of divers.[4-8,12-15] However, the results of these studies are controversial.

Fueredi et al[4] obtained MRI images of 19 compressed air workers and 11 control subjects. The mean age of the compressed air workers was 55 y, and of the control subjects, 52 y. MRI revealed 152 hyperintense brain lesions on T2 images in 10 of 19 compressed air workers (53%) and 22 lesions in 2 of 11 controls (18%). However, no difference was observed between groups in terms of psychometric testing. Neither exposure time to a hyperbaric environment nor psychometric testing was correlated with number of brain lesions. Reul et al[5] found 86 hyperintense brain lesions on T2 images in 27 of 52 sport divers (52%) and 14 lesions in 10 of 50 controls (20%).[5] The mean age of the sport divers was 38.1 y, and of the control subjects, 36.5 y. No significant correlation was observed between the occurrence of lesions on MRI and years of diving experience or number of dives. However, investigators did not explore whether any previous injury or CNS lesion had occurred before divers were selected for the study.

Studies by Fueredi et al[4] and Reul et al[5] were criticized because of the absence of evaluation of FLAIR images together with T2 images to reduce the possibility of artifact on MRI.[8] Yanagawa et al[15] investigated 25 naval divers and 25 nondiving controls. They detected MRI abnormalities in 9 of 25 divers (36%) and in only 2 of 25 controls (8%). Cerebral abnormalities were correlated with age and smoking behavior in divers. Knauth et al[8] detected 41 brain lesions in 11 of 87 sport divers (12%). The lower proportion of MRI abnormalities detected in this study compared with previous studies is explained by the fact that a lesion was counted if it was hyperintense on both T2 and FLAIR images.

Tetzlaff et al[7] investigated 20 elderly experienced compressed air divers and 20 nondiving controls by means of cranial MRI and psychometric testing.[7] MRI revealed 40 hyperintense brain lesions in 12 of 20 divers (60%) and 48 lesions in 9 of 20 control subjects (45%). A correlation was found between the number and size of abnormalities and hours of diving on compressed air to 40 to 60 m (130–195 ft). No significant correlation was observed between psychometric test scores and MRI lesions in both divers and controls. Schwerzmann et al[6] identified ischemic brain lesions in 19 of 43 asymptomatic sport divers (44%); 7 lesions were detected in 6 of 52 controls (11%).[6]

However, other studies failed to find a significant difference between divers and nondiving subjects in terms of hyperintense brain lesions. Rinck et al[13] found a prevalence of 34% in professional divers and 43% in healthy nondiving controls for abnormalities on MRI. Sipinen et al[14] investigated 25 divers who had been treated for DCS, 29 divers with no prior history of diving accidents, and 24 healthy nondiving control subjects. They found hyperintense white matter brain lesions in only 4 of 25 divers (16%) who had been treated for DCS.[14] No correlation was seen between lesions seen on MRI and clinical neurologic findings. Hutzelmann et al[12] investigated 32 commercial and 27 navy divers and 48 nondiving controls for cerebral lesions detectable on MRI. In contrast to previous studies, investigators found an increased prevalence of hyperintense white matter lesions in nondivers (48%) over divers (37%).

In the present trial, investigators studied inside attendants for hyperintense brain lesions seen on MRI. Three hyperintense brain lesions were detected in 2 of 10 inside attendants; no lesions were found in 10 control subjects. However, differences between groups were not significant. The number of total exposures and average diving depth were markedly lower in inside attendants than in other groups of divers.[5-8] However, whether a correlation can be seen between the number of hyperbaric exposures and presence of brain lesions is not clear.[4,5,7] Personal risk factors may be important. Knauth et al[8] found an increased prevalence of brain lesions in divers with patent foramen ovale. Similar to the findings of Yanagawa et al,[15] investigators in the present study found a correlation between number of brain lesions and smoking habits among inside attendants.

The clinical relevance of brain lesions detected on MRI is also questionable. Wilmshurst[3] stressed that "evidence of pathological change is not proof of functional deficit." MRI lesions in divers are not associated with neurologic findings and impaired neurophysiologic testing.[4,7,14] In the present study, findings on neurologic examination of inside attendants with MRI lesions were normal. In addition, during the pathologic examination of brain tissue, damage was not observed in the hyperintense focuses seen on MRI.[16]

It may be stated that the low number of inside attendants evaluated was a limitation of this study. However, this number is acceptable when the number of attendants who work in an average HBO center is taken into account. In addition, subjects who had dived previously were excluded from the study so that the effects of HBO treatment alone could be clearly seen.

In conclusion, investigators did not find an increased prevalence of hyperintense brain lesions in inside attendants who had never experienced DCS. However, the results reported here do not exclude the possibility of long-term negative effects of hyperbaric exposure on inside attendants. Additional multicenter epidemiologic studies are needed if the occupational safety of this unique group of medical workers is to be enhanced.

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