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Research Article /Araştırma

Hiperbarik oksijen tedavisi iç yardımcı personelinde disbarik osteonekroz taraması: klinik ve radyolojik değerlendirme

Screening for dysbaric osteonecrosis in hyperbaric chamber inside attendants: a clinical and radiological evaluation

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ABSTRACT

Aim: This study aimed to evaluate the clinical and radiological development of dysbaric osteonecrosis (DON) in hyperbaric chamber inside attendants who are exposed to prolonged and repetitive hyperbaric conditions during hyperbaric oxygen therapy (HBOT) sessions.
Materials and Methods: This retrospective study included 17 inside attendants who regularly participated in HBOT sessions between 2016 and 2022 at the Gülhane and Akyurt Hyperbaric Medicine Clinics. Demographic and clinical characteristics and the number of HBOT sessions were recorded. Plain radiographs of the hips, knees, and shoulders were reviewed for signs of DON.
Results: The mean age of participants was 41.3 ± 6.95 years, and the median body mass index was 26.1 kg/m². None of the 17 participants had a history of decompression sickness, steroid use, or regular alcohol consumption; hyperlipidemia was detected in only 4 individuals. The mean number of HBOT exposures was 272 ± 148 sessions. No joint pain or radiological signs of DON were observed in any participant.
Conclusions: The absence of clinical and radiological evidence of DON despite high cumulative exposure suggests that HBOT, when conducted under medically controlled protocols, appears safe for this occupational group. Further prospective studies with larger sample sizes and advanced imaging techniques are needed to validate these findings.

ÖZ

Amaç: Bu çalışma, hiperbarik oksijen tedavisi (HBOT) seanslarında uzun süreli ve tekrarlayıcı şekilde basınca maruz kalan iç yardımcı sağlık personelinde disbarik osteonekroz (DON) gelişimini klinik ve radyolojik olarak değerlendirmeyi amaçlamaktadır.
Gereç ve Yöntem: Retrospektif olarak planlanan çalışmaya, 2016–2022 yılları arasında Gülhane ve Akyurt Hiperbarik Tıp Kliniklerinde düzenli olarak HBOT seanslarına katılmış 17 iç yardımcı dâhil edilmiştir. Katılımcıların demografik özellikleri, klinik verileri ve toplam HBOT seans sayıları kaydedilmiş; kalça, diz ve omuz eklemlerine ait direkt grafiler incelenmiştir.
Bulgular: Katılımcıların yaş ortalaması 41.3 ± 6.95 yıl olup, vücut kitle indeksi medyanı 26.1 kg/m² idi. Katılımcıların hiçbirinde geçirilmiş dekompresyon hastalığı, steroid kullanımı veya düzenli alkol tüketimi öyküsü bulunmamış; yalnızca 4 katılımcıda hiperlipidemi saptanmıştır. Ortalama HBOT maruziyeti 272 ± 148 seans olarak hesaplanmıştır. Hiçbir katılımcıda eklem ağrısı veya radyolojik DON bulgusu saptanmamıştır.
Sonuç: İç yardımcıların, kontrollü protokollerle yürütülen HBOT maruziyetine rağmen klinik veya radyolojik DON gelişimi göstermemesi, bu meslek grubunda HBOT'nin güvenli bir uygulama olduğunu desteklemektedir. Daha geniş örneklemlerle ve ileri görüntüleme yöntemleriyle yapılacak prospektif çalışmalar, bu bulguların doğrulanması açısından önemlidir.

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INTRODUCTION

Hyperbaric oxygen therapy (HBOT) is a treatment modality used for various indications in which the patient intermittently breathes 100% oxygen in a hyperbaric environment at a pressure above sea level (1). In our country, this therapy is widely administered in clinics across various cities, typically at a pressure of 2.4 atmospheres absolute (ATA) and for sessions lasting approximately two hours. Both monoplace and multiplace hyperbaric chambers are utilized. Monoplace chambers are typically used for individual treatments and, due to their structural design, do not allow the presence of inside attendants during therapy. In contrast, multiplace chambers accommodate multiple patients simultaneously and enable an inside attendant—typically a trained healthcare professional—to accompany patients throughout the session. Inside attendants play a critical role in ensuring patient compliance, such as assisting with ear pressure equalization and proper mask use, as well as providing immediate support in the event of acute complications. This distinction between chamber types has important clinical implications, particularly regarding patient safety, real-time monitoring, and complication management during hyperbaric oxygen therapy.

Dysbaric osteonecrosis (DON) is a form of avascular bone necrosis that occurs in individuals exposed to elevated ambient pressures, such as professional divers and workers in hyperbaric or pressurized occupational settings (2,3). It is associated with long-term pressure exposure and is particularly prevalent among those who frequently operate in such environments. DON typically affects specific regions of long bones and is classified into two types based on anatomical location: juxta-articular (Type A) or medullary (Type B), depending on proximity to the joint surface. Reported prevalence rates in the literature vary widely, ranging from 0% to 70.6% (4). Risk factors for DON include dive profiles, decompression duration, and the magnitude of pressure exposure. However, the exact pathophysiological mechanisms underlying dysbaric osteonecrosis remain incompletely understood (5,6).

DON may pose a significant health risk for individuals exposed to elevated ambient pressures, particularly for divers who operate at greater depths and for prolonged durations (2). Numerous studies have investigated the prevalence of DON among divers (4); however, data regarding whether hyperbaric chamber inside attendants are similarly at risk remain extremely limited. The current scientific literature has not adequately addressed this issue, which holds critical importance from an occupational health and safety perspective.

Inside attendants encounter a different type of hyperbaric exposure compared to both divers and HBOT patients. Divers are exposed to varying gas mixtures at considerable depths, whereas HBOT patients undergo relatively short sessions following standardized treatment protocols. Inside attendants, however, are subjected to hyperbaric conditions repeatedly and over extended periods as part of their routine duties. Unlike patients, they inhale oxygen only during the final decompression phase of each session (7). Therefore, the pattern and characteristics of exposure in chamber attendants represent a unique profile, distinct from those of both divers and patients.

This study aims to perform a radiological and clinical evaluation of dysbaric osteonecrosis

in hyperbaric chamber inside attendants who are subject to prolonged and repetitive exposure to hyperbaric pressure during hyperbaric oxygen therapy sessions. The lack of prior research specifically targeting DON screening in this occupational group underscores the novelty of the study and its potential to contribute meaningfully to the existing body of knowledge. The results are expected to offer critical insights into the health implications of occupational hyperbaric exposure and support the development of evidence-based occupational health and safety strategies within HBOT practice.

MATERIAL AND METHODS

Design

This retrospective study was designed to evaluate the presence of DON among inside attendants working at Akyurt Hyperbaric Clinic and the Hyperbaric Medicine Department of Gülhane Training and Research Hospital. Within the scope of the study, medical records of all chamber attendants who participated in HBOT sessions between November 1, 2016, and October 25, 2022, were reviewed.

Demographic and clinical data were collected for each participant, including age, sex, body mass index (BMI), use of steroids, smoking and alcohol consumption, comorbidities, lipid profile, history of decompression sickness, and total number of HBOT sessions attended. For the assessment of dysbaric osteonecrosis, plain radiographs of the hips, knees, and shoulders were evaluated for each participant. Additionally, the presence of joint pain was queried.

Ethics

The study protocol was approved by the Gülhane Scientific Research Ethics Committee (Ethics Committee Decision No: 2024-111). All procedures were conducted in accordance with the latest revision of the Declaration of Helsinki.

Inside attendants with complete medical records and more than one year of documented HBOT exposure were included in the study; those with missing data were excluded.

Hyperbaric Oxygen Therapy Protocol

Due to Ankara's inland geographical location, cases of decompression sickness requiring treatment at pressures greater than 2.4 ATA are not typically encountered, except for occasional altitude diving activities, which are not commonly performed in the region. Therefore, virtually all hyperbaric oxygen therapy exposures involving inside attendants are conducted using a standardized 120-minute protocol at 2.4 ATA (243 kPa). The chamber is pressurized over 15 minutes, followed by a 90-minute treatment period at this pressure and a 15-minute decompression phase. Patients begin breathing 100% oxygen via mask or hood at the 10th minute of treatment. Intubated patients in multiplace chambers receive oxygen through an endotracheal tube. Oxygen is delivered in three 30-minute intervals, separated by two 5-minute air breaks. Inside attendants inhale 100% oxygen only during the final 10 minutes of the last oxygen period.

Radiological Evaluation

All radiographs were obtained using standard anteroposterior (AP) projections. Lateral or oblique views were not routinely performed unless clinically indicated. Bilateral pelvic radiographs were included to assess symmetry and to detect any unilateral findings that might otherwise be missed.

The anatomical regions selected for screening included the shoulders, knees, and pelvis. These sites were chosen based on literature indicating that DON most frequently affects the large long bones of the upper and lower limbs. Lesions are typically observed in the juxta-articular regions as well as in the head, neck, and shaft of long bones. The femoral head, humeral head, and femoral or tibial shafts are among the most commonly reported locations for DON involvement

Anteroposterior plain radiographs of the hip, knee, and shoulder joints of the participants were evaluated by a single radiologist with over ten years of experience in musculoskeletal imaging. Classic radiological findings suggestive of DON, such as subchondral radiolucency, crescent sign, joint surface irregularity or collapse, sclerotic areas, and cystic lesions, were investigated. Lesions were classified as Type A (juxta-articular) or Type B (medullary) based on their anatomical location. Type A lesions were characterized by subchondral lucency near the joint surface and joint space narrowing, while Type B lesions appeared as well-defined, round radiolucent foci located in the diaphyseal regions. (8).All evaluations were conducted in a blinded manner, without access to the participants' clinical data, and followed a standardized protocol .

Radiological screening was performed while the participants were still actively working and regularly exposed to HBOT. All participants had undergone HBOT within a few days to one week prior to imaging; however, the exact interval between the last exposure and imaging could not be documented individually.

Clinical Evaluation

Clinical evaluation was performed to assess the presence of symptoms potentially related to dysbaric osteonecrosis. Participants were verbally questioned about joint pain, stiffness, functional limitation, or restricted range of motion in the hips, shoulders, or knees, either during activity or at rest. The assessment was structured to record any symptomatic complaints for further review; however, no participants reported such symptoms. This evaluation was based on a structured symptom inquiry protocol designed to detect possible joint-related clinical signs.

Statistics

Data were analyzed using the Jamovi software (version 2.4.7). Descriptive statistical methods were applied in the study. Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum), while categorical variables were presented as frequencies and percentages. The distribution characteristics of continuous variables were assessed using the Shapiro–Wilk test. As the study was descriptive in nature, no advanced comparative statistical analyses were performed.

RESULTS

A total of 102 radiographs—comprising 34 knee, 34 femoral, and 34 shoulder images—from 17 participants were analyzed in this study. None of the inside attendants reported any symptomatic complaints.

The mean age of the participants was 41.3 ± 6.95 years, and the majority were female (n = 11, 64.7%). The median body mass index (BMI) was 26.1 kg/m² (range: 22.4–35.7). Six participants (35.3%) were active smokers, and none reported being ex-smokers. Three individuals (17.6%) reported alcohol consumption, all of whom described themselves as occasional or social drinkers.

Two participants (11.8%) had known comorbidities: one with hypertension and the other with Guillain–Barré syndrome. The mean number of HBOT sessions attended by the inside attendants was 272 ± 148 (Table 1).

There was no history of decompression sickness among the inside attendants. None of the participants reported any history of steroid use. Hyperlipidemia was identified in four individuals (23.5%). (Table 2).

DISCUSSION

This study provides a focused evaluation of hyperbaric chamber inside attendants with long-term and repetitive exposure to hyperbaric conditions. Despite cumulative occupational exposure, no clinical or radiological evidence of DON was detected. These findings offer an important basis for discussing the potential health implications of non-diving hyperbaric exposures and contribute to the limited literature on occupational safety in HBOT environments. The findings obtained are valuable; however, certain limitations should also be taken into consideration.DON lesions most commonly develop in long bones with fatty marrow, such as the humerus, femur, and tibia (9) . Based on this knowledge, our study assessed plain radiographs of the shoulder, hip, and knee joints in hyperbaric chamber inside attendants. Although magnetic resonance imaging (MRI) is recognized as the most sensitive method for detecting early-stage DON, its routine use is often limited by factors such as cost, accessibility, and institutional policy (3). In our setting, radiological evaluation was restricted to plain radiography due to these considerations. While plain radiographs can detect structural bone changes such as subchondral collapse, sclerosis, or joint space narrowing in advanced lesions, early medullary ischemic changes often remain radiographically silent (10).Therefore, the imaging method used

Table 1. Demographic characteristics of inside attendants

Variable	N (%), mean ± SD, Median (min–max)
Age (years)	41.3 ± 6.95
Gender	
• Male	6 (%35.3)
• Female	11 (%64.7)
BMI (kg/m^2)	26.1 (22.4 – 35.7)
Alcohol Consumption	
• Yes	3 (%17.6)
• No	14 (%82.4)
Smoking Status	
• Active Smoking	6 (%35.3)
• Non-smoker	11 (%64.7)
BMI: Body Mass Index, SD: Standart Deviation	

Table 2. Clinical and radiological findings, HBOT exposure, and selected risk factors

Variable	N (%), mean ± SD
Clinical Signs of DON	
Present	0 (0)
Absent	17 (100)
Radiological Evidence of DON	
Shoulder (bilateral) – Present	0 (0)
Shoulder (bilateral) – Absent	17 (100)
Hip (bilateral) – Present	0 (0)
Hip (bilateral) – Absent	17 (100)
Knee (bilateral) – Present	0 (0)
Knee (bilateral) – Absent	17 (100)
Number of HBOT Sessions	272 ± 148
Steroid Use	
Yes	0 (0)
No	17 (100)
Lipid Abnormalities	
Present	4 (23.5)
Absent	13 (76.5)

(DON: Dysbaric Osteonecrosis)

may have failed to identify very early or asymptomatic lesions. Despite the absence of clinically or radiologically apparent DON in our cohort, the possibility of underdetection cannot be entirely ruled out. Furthermore, the relatively small sample size and cross-sectional design of the study preclude long-term risk assessment.

The pathogenesis of DON has not been definitively established; however, it is generally accepted that DON may represent a late complication of decompression sickness (DCS), which often remains clinically silent. During the decompression phase, rapid liberation of inert gases dissolved in arterial blood can lead to arterial gas embolism. These gas bubbles may initiate coagulation within the intraosseous microvasculature, resulting in endothelial damage In anatomically predisposed regions such as the proximal femur, these pathophysiological changes may culminate in avascular necrosis of the femoral head, followed by subchondral microfractures and eventual collapse of the joint surface (11).

The prevalence of DON shows considerable variation depending on factors such as dive type, duration, depth, and geographical setting. It tends to be particularly high among groups involved in frequent and unregulated diving, such as artisanal fishermen. Reported rates include 76.9% in some fishing

communities (12), 65% in Hawaiian coral divers (13), 69% in Honduran lobster divers, 67% in Korean shellfish gatherers, and up to 70–85% in Turkish sponge divers (14,15). In contrast, DON is much less common among recreational SCUBA divers (11,16), although a prevalence of 25% has been noted among Turkish commercial diving instructors (17). Historical estimates from the 1970s also revealed prevalence rates of 2–5% in navy divers, 25–35% in tunnel workers, 16–55% in UK commercial divers, and 50–65% in fisher-diver populations (18,19). A controlled study involving 32 experienced military divers and 28 age-matched non-divers revealed similar rates of radiographic bone lesions in both groups, suggesting that DON risk in some well-monitored diving populations may not exceed that of the general population (20).

One proposed mechanism is that rapid decompression negatively affects intraosseous circulation, contributing to the onset of DON (21,22). Most cases of DON in divers are thought to be associated with at least one prior episode of DCS. In a study involving French recreational divers who presented to hyperbaric centers with musculoskeletal symptoms of DCS, magnetic resonance imaging (MRI) revealed DON in 19% of the individuals (11). In our study, none of the hyperbaric chamber inside attendants had a history of symptomatic DCS, nor was any radiological evidence of DON identified. Although no clinical or radiological findings of DON were observed in our study, it should be noted that DON may develop years after exposure. Therefore, the absence of findings in this cross-sectional evaluation does not entirely exclude the possibility of future DON development. Long-term follow-up studies are needed to assess this risk more accurately.

Obesity has been identified in the literature as a potential risk factor for DCS and, indirectly, for DON (23). In our study, participants' body mass index values generally fell within the normal to overweight range. Regular use of alcohol or corticosteroids has also been reported as a significant risk factor for osteonecrosis (24); however, these exposures were either absent or minimal among our participants. Additionally, Jones et al. have suggested that, beyond dysbaric effects, factors such as fat embolism and hyperlipidemia may contribute to the development of aseptic osteonecrosis (21), yet these metabolic risk factors were also uncommon in our sample. Although a small number of participants exhibited individual risk factors, the absence of any clinical or radiological findings of DON in all cases is a noteworthy observation.

In the development of DON, not only individual risk factors but also the nature of exposure and the specifics of pressure protocols play a role. Variables such as dive profile, decompression procedures, and compression rates have been shown to significantly influence DON risk, which may be mitigated through adherence to appropriate protocols (11). As discussed, adherence to standardized HBOT protocols may have played a role in the lack of DON findings observed in our cohort. Additionally, because chamber logbooks did not systematically record unplanned rapid decompressions or emergency exits, we could not assess the potential impact of such events on DON risk; although none were recalled by the clinical team, their occurrence cannot be definitively excluded.

Despite being extensively investigated by many authorities, dysbaric osteonecrosis still remains a serious occupational hazard with significant medicolegal implications. (22). It can progress asymptomatically and result in long-term musculoskeletal disability. For this reason, the British Tunneling Society recommends retaining compression and

decompression records for up to 40 years (25). Compressed air workers, such as those in diving and tunnel construction, are similarly exposed to increased ambient pressure but differ in terms of training and medical oversight. While commercial divers undergo specialized medical evaluations and receive diving medicine training, tunnel workers are typically educated and screened according to the specific demands of their roles. In both settings, safety is ensured through adherence to established protocols, involvement of trained personnel, and collaboration with medical teams. Physicians may be required to intervene in hyperbaric environments during emergencies. Overall, maintaining compliance with occupational safety standards remains essential to protect workers in all compressed air professions (26).

To the best of our knowledge, our findings are consistent with the only previously published study specifically targeting inside attendants, which used MRI in 12 workers and likewise reported no DON lesions (27).

CONCLUSION

This study is among the first to systematically evaluate DON in hyperbaric chamber inside attendants exposed to prolonged and repetitive HBOT. No radiological signs of DON were found in the hip, knee, or shoulder joints of 17 participants, and none reported joint-related symptoms. Most lacked major DON risk factors, and despite high cumulative exposure—averaging 272 HBOT sessions—no dysbaric complications were observed. These findings may indicate that HBOT, when administered under appropriate medical supervision, does not pose apparent safety concerns for this occupational group.

MRI—the most sensitive method for early DON—was not used; we relied on plain radiography, which can miss subclinical lesions that may later cause joint damage and affect fitness for duty. Therefore, highly exposed staff may benefit from periodic MRI follow-up. Inside attendants should receive education on DCS and DON, strictly follow compression/decompression protocols, and be selected and monitored with attention to modifiable risk factors (healthy BMI, no regular alcohol use, strong procedural compliance).

Future prospective studies with larger cohorts and advanced imaging are essential to validate these findings and to develop evidence-based occupational safety guidelines for healthcare workers in hyperbaric environments.

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