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CASE REPORT

Decompression sickness of medical personnel of a hyperbaric centre: A report of cases during 25 years of activity

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ABSTRACT

Medical hyperbaric sessions for Hyperbaric Oxygen Therapy, conducted at 2.4–2.5 ATA for 80 to 120 minutes, expose staff to increased risk of DCS due to the inhalation of compressed air, which increases gas solubility in body fluids as per Henry's Law. This study evaluates the incidence and risk factors of decompression sickness (DCS) among medical personnel in a hyperbaric centre over a 25-year period. Decompression sickness, characterized by gas bubble formation in tissues during planned decompression, was documented in 6 cases among 41,507 sessions. Symptoms varied from mild cutaneous to severe neurological manifestations, dependent on bubble size and location. Risk factors identified include age, physical condition, dehydration, and BMI. Preventative measures included adherence to decompression protocols, hydration, oxygen pre-breathing, and physical fitness maintenance. Despite these precautions, the occurrence of DCS underscores the inherent occupational risk faced by hyperbaric medical staff. The study advocates for stringent safety protocols and continuous monitoring to mitigate this risk.

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Keywords: hyperbaric oxygen therapy, decompression sickness, occupational risk, hyperbaric centre

INTRODUCTION

Medical personnel (doctors, nurses) employed in a hyperbaric centre are at risk of decompression sickness (DCS). During a standard hyperbaric session, the pressure inside the chamber increases up to 2.4–2.5 ATA, and the session duration is from 80 to 120 minutes. In accordance with national regulations[1], during each hyperbaric session, medical personnel provide direct medical care to patients.

During the session, medical personnel breathes compressed air contained inside the hyperbaric chamber. According to Henry's law, under conditions of increased pressure in a hyperbaric chamber, the solubility of gas in liquids increases. During decompression, gas dissolved in the body is released and if the decompression process is too fast, the inert gas precipitates from the blood, and the gas bubbles formed are responsible for the occurrence of decompression sickness. Gas bubbles are formed mainly in organs where the volume of dissolved inert gas is the highest. If they remain in the organs, they cause local symptoms. However, if they enter the pulmonary circulation, a significant volume of bubbles will be eliminated by the "lung filter". If the volume of gas bubbles in the pulmonary filter exceeds critical value or the patent foramen ovale (PFO) opens, the bubbles will arterialize and create arterial gas emboli [1].

[1] Regulation of the Ministry of Health regarding guaranteed health benefits in the field of hospital care announced on 20th Oct 2014, Polish Journal of Laws, position 1441. Available online (lastly visited 4th March 2024): https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20140001441.

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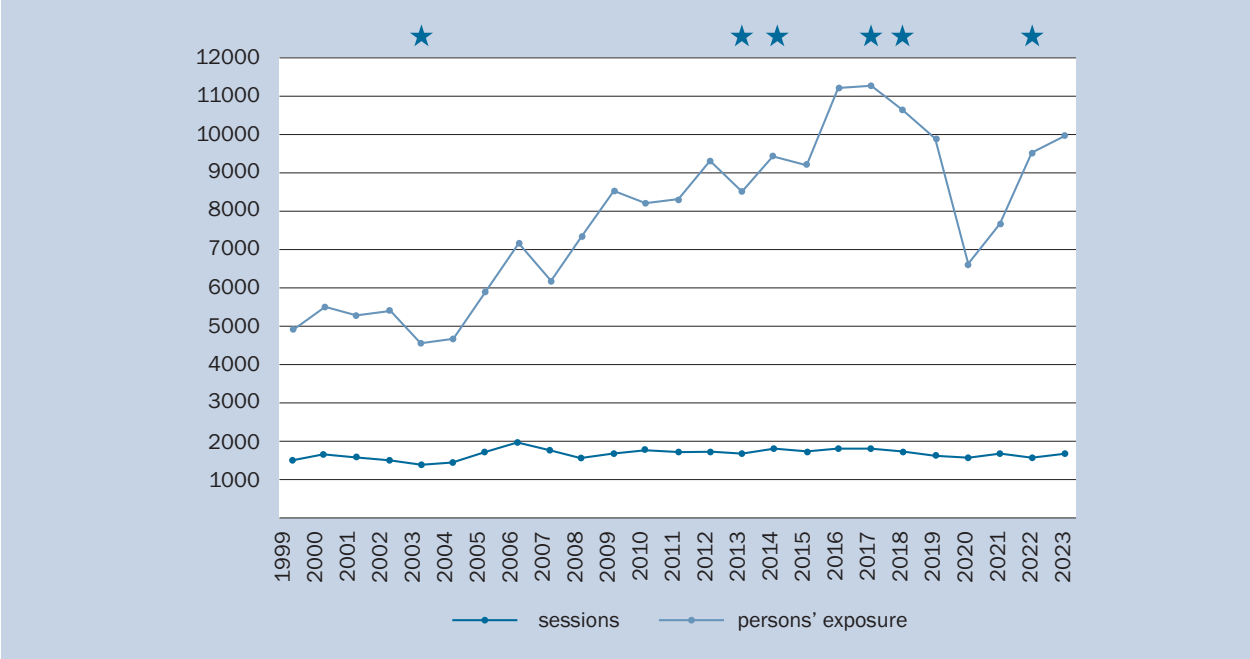

Figure 1. The number of chamber compressions (so-called sessions) determining the exposure of personnel (1 attendant/1 session) and the number of patients (persons/exposure) treated in the chamber in particular years. Cases of DCS in personnel are marked with asterisks. Sudden drop of patients treated in 2020–2021 is related with the COVID-19 pandemic

The risk of DCS depends on environmental and physiological factors. Physiological factors, including age, physical capacity and body hydration, influence the possible risk of DCS occurrence [1].

Symptoms of decompression sickness depend on the size and location of gas bubbles (intravascular and extravascular), as well as the body's response in the form of local or generalized inflammatory reactions and intravascular coagulation. Depending on the organ location, we distinguish: 1) musculoskeletal form (flu-like muscle pain, deep joint pain independent of movement, 2) cutaneous form (itching and marbling, 3) neurological form (cerebral, spinal or peripheral, 4) vestibular-cochlear form (hearing disorders, balance disorders), 5) lymphatic form (swelling of arms, breasts, skin folds on the abdomen), 6) circulatory-respiratory form (tachycardia, hypotension, decrease in arterial blood saturation, shock). Depending on the severity of symptoms, the following can be distinguished: a mild form of DCS, including skin symptoms (marbling, itching), lymphatic symptoms (local swelling), distal joint pain or severe fatigue inadequate to the physical exercise performed, and a severe form of DCS, including neurological or circulatory symptoms or pain in the lumbosacral region, shoulder girdle or pelvic girdle, or symptoms of a mild form of DCS that do not resolving after 30 minutes of breathing pure oxygen [2].

The basic risk for medical personnel participating in a hyperbaric session is the exposure pressure during the session and the total time spent under the pressure. Decompression sickness should be suspected whenever symptoms succession after a session that occurred within the last 24 hours.

Additional factors predisposing to the development of decompression sickness in medical personnel are: age (over 40–45 years), dehydration of the body, fatigue, lack of physical condition and overweight [3].

In the event of DCS, recompression treatment is applied according to recompression tables (US Navy T5, T6 or Comex Cx 30), during which pure oxygen or heliox breathing is applied at a pressure of 2.8 ATA to 4 ATA for 2 hours 15 minutes. up to 7 hours 30 minutes [4].

The aim of the study is to discuss cases of decompression sickness among the medical personnel of the hyperbaric centre during the 25 years of its operation.

Over the last 25 years (from 1999 to 2023), 41,507 medical compressions were performed in multi-place hyperbaric chambers at the local hyperbaric medicine centre. Between 1,363 and 1,966 sessions are conducted annually (an average of 1,660 sessions per year, see Fig. 1). The centre operates 24/7 and is equipped with several multi-place hyperbaric chambers allowing for simultaneous treatment of 3 to 12 patients. Depending on the size of the hyperbaric chamber, 1 to 12 patients (median 5) are treated during each session. The exception is the years 2020–2021, where during the Sars CoV-2 pandemic, the applicable epidemiological restrictions led to the need to reduce the number

of patients during sessions in multi-place chambers. However, the fact of the limited number of patients participating in a single session did not reduce the exposure of hyperbaric personnel, because the average number of hyperbaric sessions (regardless of the number of patients participating in a session) did not change.

In accordance with Polish regulations, each session is secured by qualified medical personnel (doctor, specialist in anaesthesiology and intensive care, emergency medicine specialist or anaesthesiologic nurse) all of them additionally trained in diving and hyperbaric medicine. The profile of most of the so-called standard sessions consisted of compression (from 5 to 15 minutes), breathing for 60 minutes of 100% oxygen at a pressure of 2.5 ATA with two 5-minute air breaks (70 minutes), and decompression (from 5 to 20 minutes depending on the required decompression). Only in 302 cases (0.73%) sessions were performed in accordance with the therapeutic recompression tables (US Navy table T5, T6 or Comex Cx30).

Decompression of medical personnel is planned using decompression tables used during professional diving[2]. In the case of standard sessions, until 2007, decompression tables from Draeger were used for this purpose, and since 2007, decompression tables for professional diving introduced by national regulations have been applied [5].

Taking into account the specific nature of the work of medical personnel and the scope of activities performed, since the establishment of the Centre in 1986, additional safety factors have been introduced, independent of the adopted decompression planning system: limiting the number of hyperbaric sessions to one within 24 hours, no more than 5 times a week, recommended breathing 100% oxygen 10 minutes before the start of decompression (for standard sessions up to 2.5 ATA) and during the entire decompression, prohibition of extensive physical exercise after the session, changes in ambient pressure, including flights and temperature changes, including hot baths and saunas.

During therapeutic recompression sessions according to US Navy tables T5, T6 or Comex Cx30), medical personnel breathe oxygen during decompression in accordance with the indications included in the instructions for use, extended — in accordance with internal instructions — by an additional 30 minutes of oxygen breathing [6].

During 25 years of work, during 41,507 hyperbaric sessions, decompression sickness occurred 6 times, in 5 medical personnel (one person twice).

[2] Regulation of the Ministry of Health regarding underwater workers qualification announced on 25th Aug 2022, Polish Journal of Laws, position 2174. Available online (lastly visited 4th March 2024): https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20220002174/0/D20222174.pdf

CASES

CASE REPORT NO. 1, CUTANEOUS FORM OF DCS

A 59-year-old woman working as a nurse in a hyperbaric centre for 18 years (2013), weight 95 kg, height 1.62 m (BMI 36), medical history of hypertension. At the beginning of her daily 12-hour shift work, she participated in a standard hyperbaric session. In accordance with internal recommendations, she breathed 100% oxygen for 10 minutes before the start of decompression and during the entire decompression. The session went as planned: 6 minutes of compression, 70 minutes of exposure to increased pressure, 6 minutes of decompression. About 2 hours after the end of the hyperbaric session, the woman began to feel pain, distension and lymphedema of the left breast. Then there was swelling and redness in the neck area (image of marbled skin) — Figure 2. Normobaric oxygen therapy (NBO) was urgently implemented, administering 100% oxygen through a face mask with one-way valves and a reservoir, which only resulted in a reduction in the redness of the neck skin. Due to the persistence of symptoms, the patient was qualified for recompression treatment according to USN table 6. After treatment in the chamber, the local condition further improved and the skin lesions disappeared. After the session, the patient was discharged home with a recommendation to take a break from working in the hyperbaric chamber for 7 days.

CASE REPORT NO. 2, CUTANEOUS FORM OF DCS

A 53-year-old woman working as a nurse in a hyperbaric centre for 8 years (2018), height 1.53 m, weight 80 kg (BMI 34), suffering from hypertension, participated in a standard hyperbaric session during 12-hour daily shift work (full exposure lasted 78 min with a maximum pressure of 2.5 ATA). In accordance with internal recommendations, she breathed 100% medical oxygen during decompression. About one hour after the end of the session, during which she performed physical exertion related to her work as a nurse in the Intensive Care Unit, she noticed a small-spotted, itchy rash on the left side of the upper chest (Fig. 3). The nurse was qualified for therapeutic recompression according to USN T5 table. As a result of the treatment, the skin symptoms resolved. After the session, the patient was discharged home with a recommendation to take a break from working in the hyperbaric chamber for 7 days.

CASE REPORT NO. 3, CUTANEOUS FORM OF DCS

A 40-year-old woman, working as a nurse in a hyperbaric centre for 17 years (2014), height 1.73 m, weight 75 kg (BMI 25), history of hypothyroidism, during a 12-hour daily shift, participated in a standard hyperbaric session, exercising direct care to patients. The session went smoothly. During decompression, she breathed 100% medical oxygen. After the session, she felt burning and itching of the skin around her abdomen — Figure 4. The patient was given 100%

Figure 2. Clinical case no. 1. Skin lesions on the skin of the neck

Figure 3. Clinical case no. 2. DCS skin lesions on the skin of the left breast

oxygen under normobaric conditions for approximately 1 hour. The symptoms resolved without the need for hyperbaric oxygen therapy. The nurse was advised to breathe 100% medical oxygen for 10 minutes before starting decompression during each hyperbaric session she attended.

CASE REPORT NO. 4, NEUROLOGICAL FORM OF DCS

A 28-year-old woman, working as a nurse in a hyperbaric centre for 8 years (2003), height 1.76 m, weight 55 kg (BMI 17.8), no history of comorbidities. At the beginning of her daily 12-hour shift work, she participated in a standard hyperbaric session. She provided direct care to a patient with carbon monoxide poisoning. During the session, the patient was agitated, anxious and aggressive, requiring constant attention, as a result of which she did not breathe 100% oxygen before or during decompression as recommended by internal protocols. About 15 minutes after the end of the hyperbaric session, she felt intense itching on her scalp and then over her entire body. She did not associate it with hyperbaric

Figure 4. Clinical case no. 3. DCS skin lesions on the right side of the abdomen

exposure. About 50 minutes after the end of the hyperbaric session, while returning home by car, she felt tingling in her lower limbs and weakened muscle strength, and nystagmus occurred, as a result of which she had problems with driving. She reported this fact to the doctor on duty at our hyperbaric centre. The next morning, approximately 14 hours after the first symptoms appeared, she reported to our hyperbaric centre. The symptoms from the previous day persisted. A neurological consultation and interview were conducted, and it was decided to place the patient in a hyperbaric chamber. The patient was qualified for USN T6 therapeutic recompression and 5 subsequent standard hyperbaric sessions. After the treatment, the symptoms resolved completely. A month's break from work under increased pressure condition was recommended.

CASE REPORT NO. 5, NEUROLOGICAL FORM OF DCS

A 51-year-old man, working as a doctor in a hyperbaric centre for 22 years (2017), experienced diver, height 1.76 m, weight 87 kg (BMI 28), history of hypertension, hypothyroidism and prolapse of the nucleus pulposus of the spine. He participated in a standard hyperbaric session in the morning and provided direct care to patients. He did not follow internal procedures and did not breathe 100% oxygen, neither before nor during decompression. 5 minutes after the end of the session, he felt pain in the back area extending from the spine to the left buttock and left thigh. Then, numbness occurred in the left thigh. Physical examination revealed loss of temperature and touch feeling and pain in the left thigh. Muscle strength was normal, Romberg's symptom was negative. Spinal form of DCS was diagnosed. The patient was qualified for therapeutic recompression according to the USN T6 table with the option of conversion to Comex Cx 30. After 10 minutes of breathing 100% oxygen at a pressure of 2.8 ATA, the neurological symptoms completely disappeared; the session was continued according to the USN T6 scheme. After the session a month's break from work under increased pressure condition was recommended. A follow-up TEE (transoesophageal echocardiography) with

Figure 5. Case no. 6. DCS skin lesions of the abdominal integuments accompanying the neurological form of DCS

contrast administration did not reveal the presence of PFO. This case was described separately [3].

CASE REPORT NO. 6 MIXED NEUROLOGICAL AND CUTANEOUS FORM OF DCS

A 56-year-old man, working as a doctor in a hyperbaric centre for 27 years (2022), experienced diver, height 1.76 m, weight 92 kg (BMI 29.8), history of hypertension, hypothyroidism and prolapse of the nucleus pulposus of the spine. Five years earlier, he had already had the spinal form of DCS described above (case no. 5), successfully treated with USN T6 table. During a standard hyperbaric session, he provided direct care to patients, and the session ran smoothly. According to internal recommendations, he breathed 100% oxygen for 10 minutes before decompression begins and throughout its duration. Thirty minutes after the end of the session, the patient felt pain in the back area radiating from the spine to the right buttock and right thigh, and he felt numbness in the right thigh. Physical examination revealed decreased sensation of temperature, pain and touch in the right thigh. Muscle strength was normal, Romberg's symptom was negative. A non-burning and non-itchy rash appeared on the abdomen — Figure 5. A combined neurocutaneous form was diagnosed and therapeutic recompression USN6 was performed with the option of conversion to Comex Cx30.

After completing a 20-minute cycle of breathing 100% oxygen at a pressure of 2.8 ATA, all ailments, both neurological and cutaneous, completely resolved; the session continued according to USN T6. A month's break from work under increased pressure conditions was recommended.

DISCUSSION

The local hyperbaric centre was established in 1986. Initially, it functioned as the Department of Hyperbaric Medicine and Maritime Rescue of the Institute of Maritime and Tropical Medicine in Gdynia. In 1998, it was transformed into the National Centre for Hyperbaric Medicine. Currently, it operates as the Clinic of Hyperbaric Medicine and Maritime Rescue within the structure of a clinical hospital — the University Centre for Maritime and Tropical Medicine of the Medical University of Gdańsk. Despite the longer history of operations, the object of this publication is the history of the last 25 years (from January 1, 1998 to December 31, 2023). During this time, 6 cases of DCS were observed in medical personnel as compared with 41,507 compression sessions. This constitutes 1 case in 6,918 compressions (0.014%).

In five of the DCS cases described above, personnel had one or two risk factors; except for one person who was 28 years old at the time of falling sick, the remaining people were aged 40 to 59, five people had a BMI equal to or above 25, the sickness concerned four women and one man (two cases of DCS). Personnel attended sessions no more frequently than every 24 hours and the majority (5/6) breathed 100% oxygen before and during decompression. DCS symptoms occurred from 10 minutes to 6 hours after the hyperbaric session.

Although the use of decompression tables in hyperbaric centres is considered safe for medical personnel, decompression sickness does occur among them. This local centre most often uses a standard hyperbaric session conducted at a pressure of 2.5 ATA what allows for a non-decompression

exposure of up to 80 minutes in accordance with the Minister of Health Regulation. According to standard procedures, personnel inside the chamber breathes compressed air to ensure proper care for patients throughout the session; however, according to ECHM recommendations [7], medical personnel should additionally breathe 100% medical oxygen. In our centre the medical staff breathe 100% medical oxygen 10 minutes before starting decompression from a pressure of 2.5 ATA and during decompression. Despite adherence to those preventive measures, DCS cases still occur with an increased number of persons/exposure (Fig. 1).

Some hyperbaric centres around the world also describe their experiences related to occupational risks of medical attendants [8, 9]. According to the data contained in the sixth edition of the ECHM recommendations [7], until 2003, only two cases of DCS in the neurological form were reported in patients (pressure up to 2.4 ATA in a centre in Bergen (Norway) and pressure up to 2.5 ATA in a centre in Ravenna (Italy).

In 2012, Johnson-Arbor Kelly described a case of type 2 DCS (neurological form) in a 50-year-old attendant who reported paraesthesia and muscle weakness in the lower limbs (10). After recompression treatment, the symptoms disappeared. However, after a dozen months or so, imaging tests revealed a patent foramen ovale (PFO) in the man.

In France, between 2005 and 2011, twelve hyperbaric centres analysed accidents among medical personnel related to occupational risks related to hyperbaric exposures [9, 11]. In the group of 73 analysed cases, the average age was 43 years and an average of approximately 198 exposures were calculated per attendant. Two persons reported the cutaneous form of DCS, and 3 persons reported type II, i.e. the neurological form.

It is also worth mentioning the fatal case of decompression sickness reported in 1992 in a nurse (52 years old) who, shortly before her death, worked as an attendant in a hyperbaric chamber during a session with a patient after a diving accident [12].

David Cooper's team [13] analysed cases of decompression sickness in a group of 155 attendants over a 14-year period. The collected material showed that among the group of medical personnel, only 0.41% of occupational risk cases were related to exposure to hyperbaric conditions that manifested itself as symptomatic decompression sickness. The same team [14] performed Doppler ultrasonography (USG) examinations on patients to screen for asymptomatic DCS, using oxygen decompression for a period of 20 minutes and performing the examination again 120 minutes after exposure. A higher risk of asymptomatic decompression sickness was observed, depending on body weight, age, frequency of exposure and gender (higher in females).

According to the European Code of Good Practice for Hyperbaric Oxygen Therapy — Review 2022 [15]: "Facilities must adopt a set of published decompression procedures in order to reduce to a minimum the risks associated with single and repeated exposures. They may include additional safety considerations to the standard procedures (for example, breathing nitrox during session or oxygen during decompression). Procedures should consider the limits of repeated exposures (pressure, duration and surface interval) per person within a 24 hour period and the number of daily exposures without a break. Obligation for decompression stops should be kept to the minimum, enabling decompression to atmospheric pressure within a reasonable time".

From our practice, in the prevention of decompression sickness in medical personnel, attention should also be paid to irreversible factors, such as age, and reversible factors, such as fatigue of medical personnel, dehydration, and BMI. Regardless of the adopted decompression planning system after hyperbaric sessions, considerable emphasis in preventing the occurrence of DCS in hyperbaric personnel is placed on:

- 24-hour breaks between hyperbaric sessions,
- hydration of the body before and after the session,
- breathing medical oxygen for at least 10 minutes before the start of decompression and during the entire required decompression calculated according to the adopted decompression system,
- taking care of one's physical condition, striving to maintain a normal BMI,
- avoiding heavy physical exercise for at least 12 hours after session,
- avoiding temperature changes, including hot baths, saunas, Jacuzzis and sunbathing,
- avoiding changes in pressure (including flying) for at least 24 hours after the session.

CONCLUSIONS

Attendance of medical personnel hyperbaric sessions causes the risk of DCS. Adoption of whatever decompression planning system for occupational exposures does not eliminate this risk. The risk is even greater because it is influenced by additional factors specific to medical personnel, such as age, fatigue, dehydration and non-optimal physical capacity.

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ARTICLE INFORMATION AND DECLARATIONS

Author contributions: JK — designed the study, co-wrote the manuscript; OS — designed the study co-wrote the manuscript, collected the data; BM — collected the data, contributed writing the manuscript; RS — contributed to the discussion, contributed writing the manuscript; EL, ZS — contributed writing the manuscript.

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