Decompression tables for inside chamber attendants working at altitude

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ABSTRACT

Introduction: Hyperbaric oxygen (HBO_2) multiplace chamber inside attendants (IAs) are at risk for decompression sickness (DCS). Standard decompression tables are formulated for sea-level use, not for use at altitude.

Methods: At Presbyterian/St. Luke's Medical Center (Denver, Colorado, 5,924 feet above sea level) and Intermountain Medical Center (Murray, Utah, 4,500 feet), the decompression obligation for IAs is managed with U.S. Navy Standard Air Tables corrected for altitude, Bühlmann Tables, and the Nobendem© calculator. IAs also breathe supplemental oxygen while compressed. Presbyterian/St. Luke's (0.83 atmospheres absolute/atm abs) uses gauge pressure, uncorrected for altitude, at 45 feet of sea water (fsw) (2.2 atm abs) for routine wound care HBO_2 and 66 fsw (2.8 atm abs) for carbon monoxide/cyanide poisoning. Presbyterian/St. Luke's provides oxygen breathing for the IAs at 2.2 atm abs. At Intermountain (0.86 atm abs), HBO_2 is provided at 2.0 atm abs for routine treatments and 3.0 atm abs for carbon monoxide poisoning. Intermountain IAs breathe intermittent 50% nitrogen/50% oxygen at 3.0 atm abs and 100% oxygen at 2.0 atm abs. The chamber profiles include a safety stop.

Results: From 1990-2013, Presbyterian/St. Luke's had 26,900 total IA exposures: 25,991 at 45 fsw (2.2 atm abs) and 646 at 66 fsw (2.8 atm abs); there have been four cases of IA DCS. From 2008-2013, Intermountain had 1,847 IA exposures: 1,832 at 2 atm abs and 15 at 3 atm abs, with one case of IA DCS. At both facilities, DCS incidents occurred soon after the chambers were placed into service.

Conclusions: Based on these results, chamber inside attendant risk for DCS at increased altitude is low when the inside attendants breathe supplemental oxygen.

INTRODUCTION

Decompression sickness (DCS) is a clinical syndrome caused by the physical development of intravascular and tissue bubbles from inert gas coming out of solution during decompression [1]. Decompression sickness is described in divers breathing compressed air, or other inert gases [2] as well as from a rapid reduction in ambient pressure in aviators or high-altitude chamber workers [3].

KEYWORDS: hyperbaric oxygen, multiplace hyperbaric chamber, altitude, United States Navy, decompression tables, inside attendant, Nobendem, Bühlmann

Hyperbaric oxygen (HBO_2) is 100% oxygen administered to patients while compressed inside hyperbaric chambers [4,5]. Multiplace hyperbaric chambers can treat more than one patient at a time and are staffed by a chamber operator located outside the chamber and an attendant who stays inside for the duration of the pressure excursion. The chamber inside attendant (IA) breathes air during this hyperbaric exposure, and is therefore subjected to risk for DCS, similar to divers. The incidence of IA DCS is low [6,7], but the presentation can be dramatic [8-10]. Evidence supports that the inhalation of 100% oxygen near the end of the compression reduces the risk of DCS for IAs [11,12]. The patients treated with hyperbaric oxygen have no risk for DCS because they are breathing 100% oxygen during the chamber session, rather than breathing air.

Traditional dive tables were developed for diving at sea level. Nitrogen saturation is affected by the partial pressure of the inspired gas, and the U.S. Navy dive tables become invalid as the altitude increases and the partial pressure of nitrogen decreases. Specifically, the *U.S. Navy Diving Manual* states "dives conducted at altitude require more decompression than identical dives conducted at sea level" [13]. Safe diving at altitude requires advanced planning and the use of corrections or adaptations of these dive tables (13-17). Such corrections or diving tables built for altitude may be appropriate for IA work at altitude as well.

This paper will describe the methods undertaken by two hyperbaric medicine services operating at increased altitude to reduce the risk of DCS for their IA staff: Presbyterian/St. Luke's Medical Center, Denver, Colorado, and Intermountain Medical Center, Murray, Utah. We will also report the circumstances of observed IA DCS incidents at the two facilities. Because the two facilities use different treatment schedules and have different approaches to reducing decompression sickness risk, the facilities will be presented separately.

METHODS

Facility 1: Presbyterian/St. Luke's Medical Center, Denver, Colorado

Historical context

Operational planning for IA decompression started in July, 1984 [18]. Chamber staff considered the following interdependent and altitude-related questions:

1. How will IA decompression be accomplished safely in light of an average atmospheric pressure of 12.2 psia (0.83 atmospheres absolute/atm abs)?
2. How will chamber pressure be verified?
3. What operational measures could be taken to decrease errors?

We elected to use gauge pressure in feet of sea water (fsw), rather than absolute pressure, because U.S. Navy treatment tables would use the specified pressures at gauge rather than absolute pressure [13]. The HBO_2 treatment protocols selected were 2.4 atmospheres gauge (2.2 atm abs) (45 fsw) for wound healing and 3.0 atmospheres gauge (2.8 atm abs) (66 fsw) for treatment of carbon monoxide (CO) and clostridial myonecrosis. Despite the reduction in nitrogen exposure achieved by utilizing gauge pressure, air decompression tables based on the U.S. Navy Sea Level Equivalent Depth (SLED) correction [13] were still untenable IA exposures during patient treatment activities.

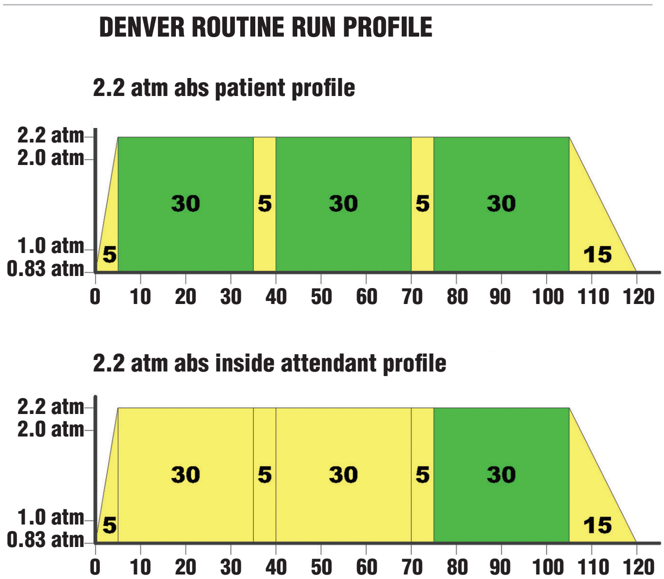
To use the U.S. Navy tables at altitudes greater than 1,000 feet, a SLED must be calculated using either Table 9-4 [13] or the Cross Correction technique [19,20]. The SLED from Table 9-4 for a pressure of 66 fsw at 6000 feet is 90 fsw. The Cross Correction technique is the barometric pressure at sea level divided by the local barometric pressure (14.7/12.2=1.20); therefore, 66 fsw *x* 1.20 = 79 SLED. Using the U.S. Navy tables for 80 fsw or 90 fsw is not practical in the clinical setting due to very long decompression times [13], and the U.S. Navy tables do not credit for use of oxygen or for time spent at a reduced pressure. At the time we set up our hyperbaric facility, computers with decompression algorithm programs had yet to be invented, and because patient care can require variable and unpredictable compression times, proprietary decompression algorithms were unsuitable.

We reviewed the literature available at the time [19-33] to determine the optimal supplemental oxygen breathing for inside attendants, attempting to balance the risk of oxygen toxicity and reduced communication and mobility against the risk for IA DCS. Early protocols (December 1990 to January 1992) using a shorter oxygen breathing time did result in reports of mild neurologic DCS symptoms: minor paresthesias, slight focal joint pain, and fatigue.

Selected treatment protocols and decompression risk reduction strategy

The altitude of the multiplace chamber at Presbyterian/St. Luke's Medical Center is 5,294 feet above sea level, with an average barometric pressure of 12.2 pounds per square inch absolute (psia) (0.83 atm abs). Gauge pressure is used for the treatment profiles, and the chamber pressure is verified by a semiannual cross accuracy check of all three analog pressure gauges (Pneumo, 1/4% accuracy, 1 foot divisions, sea water, 0-250, Perma-Cal Industries, Inc., Minden, Nevada) to a gauge pressure of 0 fsw and 66 fsw.

For routine patients, the wound healing profile is a five-minute compression to a chamber gauge pressure of 45 fsw (20.0 psig/2.2 atm abs), 100 minutes at pressure (comprising three 30-minute oxygen breathing periods and two five-minute air breathing periods), followed by a 15-minute decompression (Figure 1).



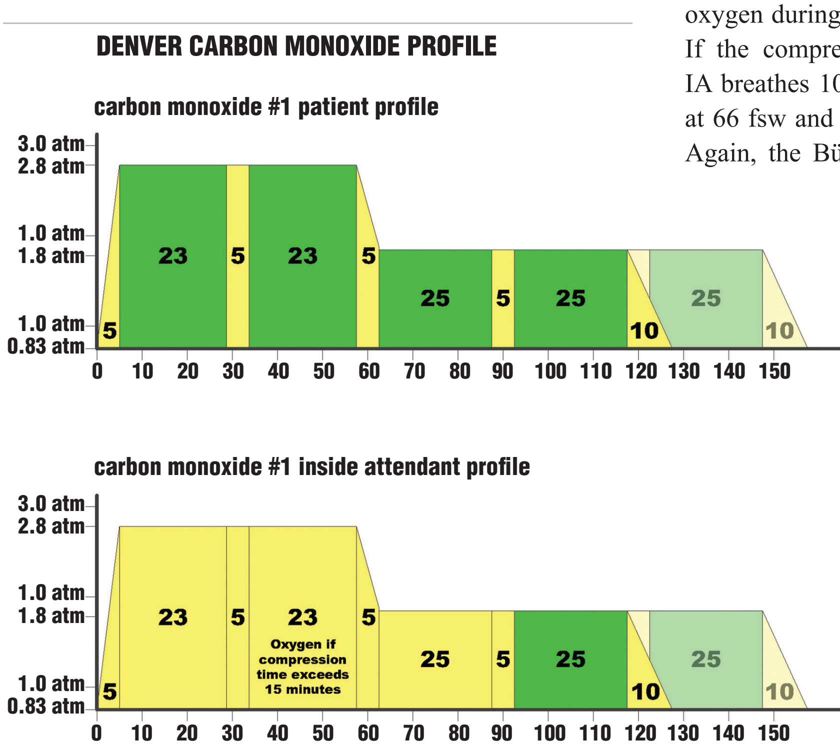


Figure 1 - top. Routine hyperbaric oxygen exposure at Presbyterian/St. Luke's Medical Center, Denver, Colorado. Yellow represents air breathing, green oxygen breathing. If the compression interval exceeds 15 minutes, the IA breathes 100% oxygen for a longer duration than the 30 minutes specified in the text that follows.

Figure 2 - bottom. Hyperbaric oxygen exposure for carbon monoxide poisoning at Presbyterian/St. Luke's Medical Center, Denver, Colorado. Yellow represents air breathing, green oxygen breathing. If the compression interval exceeds 15 minutes, the IA breathes 100% oxygen at the second 23-minute patient oxygen interval at 2.8 atm. The profile can be extended by an additional 30 minutes, in which case, the IA would have two 25-minute oxygen breathing periods at 1.8 atm.

For this profile, the IA breathes 30 minutes of 100% oxygen during the last patient oxygen breathing period (Figure 1). If the compression interval exceeds 15 minutes, the IA requires more time on oxygen. If the IA needs to lock in or out early, the Bühlmann 1986 (701-2.500 m altitude) dive tables are used [34]; the IA breathes 100% oxygen at any decompression stops.

For patients with carbon monoxide (CO) poisoning, the treatment profile is a five-minute compression to 66 fsw (29.4 psig/2.8 atm abs), two 23-minute oxygen periods with two five-minute air breaks, a five-minute decompression on air to 33 fsw (14.7 psig/1.8 atm abs), two 25-minute oxygen periods with a five-minute air break, and a 10-minute decompression on air (Figure 2). This treatment profile can be extended by another five-minute air break and 25-minute oxygen period at 33 fsw.

For the CO profile, the IA breathes 25 minutes of oxygen during the last patient oxygen period at 33 fsw. If the compression interval exceeds 15 minutes, the IA breathes 100% oxygen for both the last 23 minutes at 66 fsw and the last 25 minutes at 33 fsw (Figure 2). Again, the Bühlmann 1986 (701-2500 m) tables [34] are used if the IA needs to lock in or out early, and the IA breathes 100% oxygen at any decompression stops. If the extension is provided, the IA breathes 100% oxygen for the subsequent 25-minute patient oxygen period at 33 fsw.

We also developed policies specific to our routine and emergent treatment profiles for IA flying and mountain travel. Any IA exposure outside these set parameters is addressed by one of our board-certified hyperbaric physicians. Examples of these policies include:

- Repetitive pressure exposures are not allowed. A surface interval (SI) of 16 hours is required for routine 45-fsw (2.2 atm abs) treatments, 24 hours for all other treatment profiles.
- Flying and mountain travel to <8,000 feet can occur after a five-hour SI for 45-fsw (2.atm abs), 24-hour SI for all other treatment profiles.
- Mountain travel > 8,000 feet can occur after a 12-hour SI for routine 45-fsw (2.atm abs) treatments, 24-hour SI for all other treatment profiles.

- Inside attendant decompression and altitude excursions for the following are to be directed to the hyperbaric physician:

(1) all routine and emergent treatments that go longer than scheduled;

(2) all lock-in/lock-out pressure exposures; and

(3) all non-standard treatment profiles.

- Inside attendants suffer no penalty or stigma for reporting symptoms of possible DCS.

Facility 2: Intermountain Medical Center (IMC), Murray, Utah

Historical context

Operational planning for IA decompression started in January 2007. We used the *U.S. Navy Diving Manual* [13] as the "gold standard," calculating equivalent air depth (EAD) and SLED values for the gauge pressure in the chamber. We also used the Nobendem© decompression profile calculator [35], developed by Benton Zwart, M.D., for use by the U.S. Air Force for in-chamber planning of IA decompression obligations [36].

The SLED conversion for a 2.01 atm abs profile in Murray, Utah, is completed by using Table 9-4 [13] or the Cross Correction technique [19,20]: sea level barometric pressure (14.7 psia) / local barometric pressure (12.7 psia) = conversion factor (1.162).

To achieve 3.0 atm abs (44.1 psia), we pressurize the chamber to 31.4 psig (44.1 psia, 70.65 fsw (31.4 *x* 2.25 = 70.65)). The SLED for an altitude of 4,300 feet rounded up to 5,000 feet for Table 9-4 is 100 feet. Using the Cross Correction technique [19,20] (70.65 *x* 1.15), we can use a SLED of 82.09 fsw, or the 90-fsw table. Either correction requires a significant decompression obligation for our selected CO profile [37]: Either 100 fsw or 90 fsw for 140 minutes requires hours of decompression obligations, which is impractical at a clinical hyperbaric facility. However, the U.S. Navy standard air tables do not account for time on oxygen or time at a lower pressure and may not reflect true decompression risk when accounting for these variables.

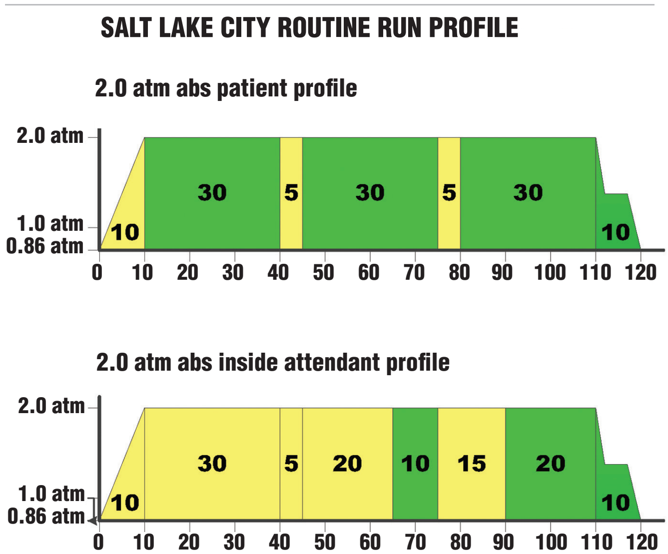
We have adopted the Nobendem© decompression profile calculator [35] to plan for decompression obligations [38], which requires input of local barometric pressure, safety factors, oxygen percent in the breathing mixture, times and pressures in fsw. There is no need to compute a SLED. Though the calculations in the Nobendem© calculator do not directly correspond to the current U.S. Navy tables, they do allow us to validate the oxygen breathing and multilevel pressures for reducing the risk of DCS for our IAs. We follow the U.S. Navy tables for short excursions, missed IA decompression obligations, or emergency procedures where a profile has not been worked out. We operate the multiplace chamber at 2.0 atm abs (29.4 psia, 16.7 psig) for the majority of our treatment protocols, which converts to 37.5 fsw (16.7 *x* 2.25 = 37.5). Using Table 9-4 [13], the SLED is 50 fsw, though by the Cross Correction technique (37.5 fsw *x* 1.162 = 43.57 fsw), the 45-fsw U.S. Navy air tables are indicated. According to Table 9-7 [13], 45 fsw for 110 minutes (45/114) requires no decompression and ends in a group letter M. Per Table 9-9 [13] for 5,000 feet altitude, 37.5 fsw would use the 50-fsw and 110-minute schedule, which requires a decompression stop with either air or oxygen and would end in a repetitive group of O. In either case, an IA must wait a lengthy interval to go to altitude using Table 9-6 [13].

Because we have IAs who may need to drive over a mountain pass at 7,000 feet to get home, it is our policy that the IA will exit the chamber with a U.S. Navy repetitive group designation of D or better using the Nobendem© calculator, which would require no wait time before travel to 7,000 feet [13,17].

For short excursions, maintenance and equipment testing we use either the U.S. Navy dive tables [13] corrected for altitude or the nitrox operations in Chapter 10 [13].

These tables are backed up by a real-time Nobendem© calculation [35]. We use the standard air tables for short excursions of 10-15 minutes to 2.0 atm abs or five to 10 minutes at 3.0 atm abs, where there is no real opportunity for nitrogen load to develop.

Chapter 9 of the *U.S. Navy Diving Manual* provides guidance for applying Cross Corrections to the standard sea level tables to determine the decompression requirement for air dives conducted at altitude [13], while Chapter 10 provides guidance for diving nitrox mixtures at sea level, but does not discuss diving nitrox at altitude [13]. The U.S. Navy describes nitrox as a gas blend of 20%-40% oxygen, with the balance being nitrogen [13]. When we requested guidance in this matter, the Navy advised that the proper decompression table to be used for a nitrox dive at altitude could be determined in a three-step process (personal communication with Dr. E. T. Flynn, Naval Sea Systems Command, October 2013):



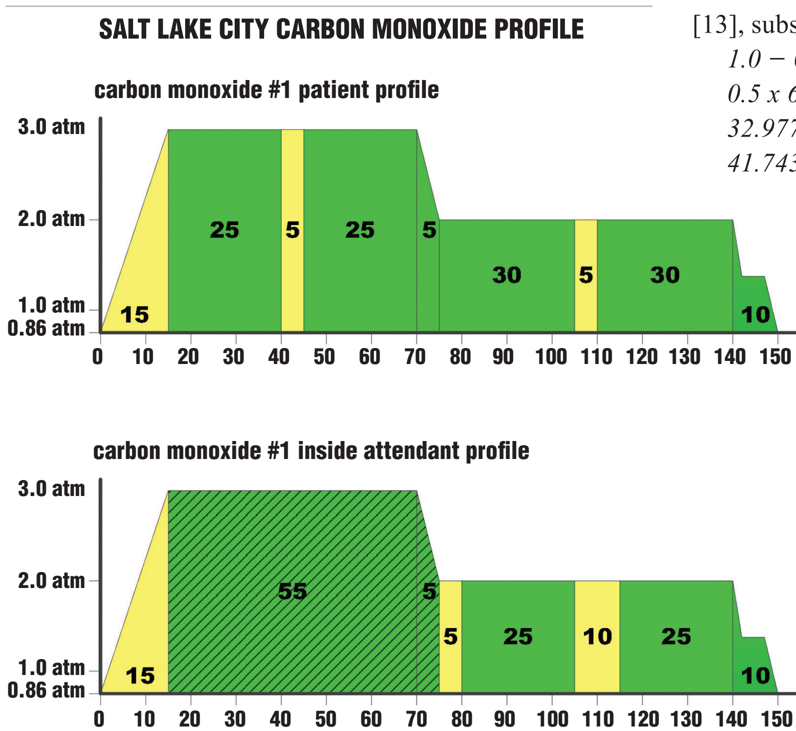


Figure 3 - **top. Routine hyperbaric oxygen exposure at Intermountain Medical Center, Murray, Utah.** Yellow represents air breathing, green oxygen breathing. The IA breathes 100% oxygen for 10 minutes during the patients' second oxygen breathing period and for 20 minutes during the patients' third oxygen breathing period, as well as during decompression.

Figure 4 - **bottom. Hyperbaric oxygen exposure for carbon monoxide poisoning Intermountain Medical Center, Murray, Utah.** Yellow represents air breathing, green oxygen breathing and green/black 50% oxygen/50% nitrogen. The IA breathes 50% oxygen/50% nitrogen for as much of the 3.0-atm excursion as possible, including the 5-minute decompression to 2.0 atm. At 2.0 atm, the IA breathes 100% oxygen for 50 minutes, plus during the decompression.

1. Compute the EAD at altitude using the equation in Paragraph 10-2.1 but with 33*P_{alt} substituted for 33 in both locations. P_{alt} is the barometric pressure at altitude in atm abs.
2. Compute the SLED by multiplying the EAD at altitude computed in Step 1 by the ratio of the barometric pressure at sea level to the barometric pressure at altitude (Cross Correction).
3. Decompress on the sea level air table whose depth is exactly equal to or next greater than the computed SLED.

As an example, consider a 2.0-atm abs exposure utilizing 50% oxygen/50% nitrogen for equipment testing or maintenance (*i.e.*, fire suppression system testing) using the standard air table corrected for our altitude: From 0.86 atm abs, we pressurize the chamber to 2.0 atm abs (29.4 psia, 16.7 psig) and convert this pressurization fsw (16.7 *x* 2.25 = 37.575 fsw). We calculate the EAD at altitude using the EAD formula in Chapter 10 [13], substituting the barometric pressure at altitude:

1.0 − 0.537.575 + 28.380.79 − 28.38 =
0.5 x 65.955 0.79 − 28.38 =
32.97750.79 − 28.38 =
41.7436 − 28.38 =
13.3636 fsw

Using the Cross Correction technique, the SLED is 15.52 fsw (13.36 *x* 1.162).

Selected treatment protocols and decompression risk reduction strategy

The altitude of the multiplace chamber at IMC is 4,500 feet above sea level, with an average barometric pressure of 12.7 psia (0.86 atm abs). Absolute pressure is used for the treatment profiles. The chamber pressure is verified using three sources; psig transmitter, psia transmitter and analog psig gauges (Fink Engineering, Melbourne, Australia). These devices are checked quarterly with a certified test gauge (Ashcroft Digital Test Gauge Type 302089SDL2100, Dresser Instruments, Stratford, Connecticut).

For routine patients, the wound healing profile is a 10-minute compression to 2.0 atm abs (16.7 psig/37.5 fsw/29.4 psia), 100 minutes at pressure (comprising three 30-minute oxygen breathing periods and two five-minute air breaks), and a 10-minute decompression (Figure 3).

For this profile, the IA breathes 10 minutes of oxygen during the second patient oxygen period and 20 minutes of oxygen during the last oxygen period and during decompression, including a five-minute safety stop at 1.8 atm abs (Figure 3). Using the Nobendem© tables [35], the IA exits the chamber with a Group C U.S. Navy repetitive group designation. We follow a standardized protocol for carbon monoxide poisoning [37], originally developed for the monoplace chamber.

To complete the first CO treatment, we pressurize to 3 atm abs (31.4 psig/70.65 fsw/44.1 psia) over 15 minutes. The patient receives a 25-minute oxygen breathing period at 3.0 atm abs, one five-minute air break, and a second 25-minute oxygen period. The patient continues to breathe oxygen while the chamber is decompressed over a five-minute interval to 2 atm abs. The patient then receives two 30-minute oxygen periods, split by a five-minute air break, and the chamber is decompressed over a 10-minute interval (Figure 4). The second and third CO treatments are the same profile as the 2.0-atm abs wound healing schedule.

During the first CO treatment, the IA breathes air on compression to 3.0 atm abs and then United States Pharmacopeia Drug Mix of 50% oxygen/50% nitrogen for as much as possible for the 60 minutes until the chamber reaches 2.0 atm abs. At 2.0 atm abs, the IA breathes oxygen for 25 minutes of the patients' 30-minute oxygen-breathing periods and during the 10-minute decompression, which includes a safety stop at 1.4 atm abs (Figure 4). We build a real-time Nobendem© spreadsheet to manage the oxygen breathing time of the IA, and using the Nobendem© tables [35], the IA exits the chamber with a Group B U.S. Navy repetitive group designation. Our policy is to utilize 50% oxygen/50% nitrogen as much as possible at 3.0 atm abs and to have the IA receive at least 40 minutes of 100% oxygen at 2.0 atm abs on the CO profile. The inside attendant may strap on the mask and move about the chamber when breathing 50/50 at 3.0 atm abs, but we require him/her to be seated, at rest and holding the mask to his/her face when breathing 100% oxygen at 2.0 atm abs unless there is a second IA in the chamber.

At Intermountain, we provide U.S. Navy Treatment Table 6 exposures in a monoplace environment [39], obviating IA decompression risk. To date, we have not used the multiplace chamber for this profile. The U.S. Navy recommends using gauge pressure for this table, without correction for altitude.

Staff members returning from a trip to sea level must equilibrate at our altitude for at least 12 hours before working as an IA. Repetitive pressurization is allowed with medical approval when the IA is classified with a USN Group A residual nitrogen designation. The IAs are primarily part-time paramedic firefighters and normally do not have more than two two-hour exposures to 2.0 atm abs per week. Flying after excursions is limited to 24 hours after a chamber run, and altitude excursions to greater than 8,000 feet are not allowed for 16 hours. Strenuous/jarring exercise is not recommended for four hours after any hyperbaric excursion. We maintain a conservative approach to diagnosing decompression illness and maintain an open culture, where IAs can report symptoms without penalty.

Most patients treated with HBO_2 at pressures greater than 2.0 atm abs are treated in our monoplace chambers, with the exception of groups of more than three patients with CO poisoning presenting at one time. Critically ill intubated patients, who are often treated at chamber pressures greater than 2.0 atm abs [40], are treated in monoplace chambers only at our facility [41], so there are no IA risk issues.

RESULTS

Facility 1: Presbyterian/St. Luke's Medical Center, Denver, Colorado

From December 7, 1990, to July 31, 2013, a total of 26,900 IA hyperbaric exposures were performed. Of those, 25,991 were exposed to 45 fsw (2.2 atm abs) for routine treatments, 646 at 66 fsw (2.8 atm abs) for treatment of CO poisoning, 48 at 66 fsw (2.8 atm abs) for treatment of clostridial myonecrosis, 211 for U.S. Navy treatment tables 5 and 6, and 4 for U.S. Navy Treatment Table 6A (13). These exposures included treatments by staff members who lived at 8,500 feet. Four cases of IA decompression sickness (DCS) have been treated, all in the first years of chamber operation. All DCS symptoms were self-reported paresthesias with fatigue or malaise. All symptoms promptly resolved when the IA was treated with U.S. Navy Treatment Table 6 [13].

Facility 2: Intermountain Medical Center, Murray, Utah

From Sept 30, 2008, to July 31, 2013, we performed 1,847 multiplace compressions, of which 15 hyperbaric exposures were for CO-poisoned patients at 3.0 atm abs. (All other CO patients were treated in monoplace chambers). These compressions were completed by staff members living between 4,000 and 7,000 feet of altitude. We have treated two of our staff members for suspected DCS with self-reported paresthesias. Both were treated with U.S. Navy Treatment Table 6 [13] in a monoplace chamber [39]. One case was later determined to be an ulnar nerve compression neuropathy and not DCS.

These DCS incidents occurred in 2011, using a less aggressive oxygen dosing schedule. Based on these occurrences, we added oxygen breathing time and the use of 50% oxygen/50% nitrogen. We have had no further incidents since these changes.

DISCUSSION

Based on the reported experience of these two facilities, IA risk for DCS at altitude is low when the risk for DCS is mitigated with supplemental oxygen and proper planning and preparation. Maintaining safe staff decompression and altitude excursion practices is the responsibility of the entire hyperbaric team. Each facility must use its best judgment and choose what procedures will safely work for the staff.

It may not be possible to compare these two experiences directly because of the large difference in years of experience, differing altitudes, and distinct treatment protocols. The use of oxygen is more aggressive at IMC than at Presbyterian/St. Luke's Medical Center. Both facilities experienced DCS prior to increasing oxygen breathing times and refining the schedule for oxygen breathing. Intermountain Medical Center has also used 50% oxygen/50% nitrogen to mitigate decompression risk for IAs.

Other techniques such as a concept of "zero time" or "repet up" can be used. "Zero time" is is when the IA's oxygen breathing time is not counted toward his/her bottom time. "Repet up" is for a multilevel exposure such as for CO poisoning [37] when there is at least 1 atm abs of pressure change. The IA decompression obligation is planned using the repetitive group from the first pressure to plan the time at the second pressure. The *U.S. Navy Diving Manual* does not support either of these concepts [13], nor do we endorse these practices.

On the other hand, the use of supplemental oxygen to reduce IA risk for DCS is well-established [2,6, 11,42-44]. Oxygen breathing carries risk for the IA, primarily central nervous system toxicity. The U.S. Navy allows the IA to strap on the mask at pressures of 1.8 or lower [13]. Based on the experience in the patient population, we expect that the risk of an oxygen seizure at 2.0 atm abs is very low [45-48]. To minimize the consequences of an IA seizure, at IMC we require that the IA be seated and hold the mask in place when breathing 100% oxygen unless there is another IA in the chamber with him/her. Short interruptions of less than five minutes for patient care are acceptable. Beyond central nervous system toxicity, the long-term effects of supplemental oxygen in these workers are unknown.

The recreational and scientific diving communities, public safety divers, and the U.S. Navy have adopted nitrogen/oxygen blends to increase their safety and to reduce nitrogen load during pressure excursions [13,17]. Other chambers have used gas blends that decrease the partial pressure of nitrogen for IAs and then permit direct decompression and chamber exit [49].

Facilities adopting alternative gas mixes or decompression tables do so at their own risk. Some models outside the standard U.S. Navy tables are empirical and based on theoretical application of observed data rather than direct human testing. The calculation of dive tables and excursion profiles can be imprecise. For example, many assumptions are incorporated into Nobendum© [35], which is based on a previous version of the U.S. Navy standard air tables and has not been experimentally validated. Very little information is available about implementing Nobendum© [50], and the responsibility for balancing pressure, time, breathing gas mix and decompression time always rests with the user.

CONCLUSION

We have presented experiences and protocols for chamber inside attendants at two multiplace chamber centers operating at approximately 5,000 feet above sea level. Both facilities provide supplemental oxygen to IAs to reduce the risk of DCS during hyperbaric exposure. Intermountain Medical Center has also incorporated mixed-gas breathing. At these facilities, the observed incidence of DCS in IAs working at increased altitude, while adhering to strict protocols for pressure, time exposures and oxygen inhalation, is very low.

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Conflict of interest
The authors have declared that no conflict of interest exists with this submission.

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