USN Treatment Table 9: Tender or Diver - Which Do You Choose?

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Background

Although U.S Navy hyperbaric chambers are primarily used to support surface decompression procedures and treat cases of decompression illness arising from operational dives, Navy chambers are occasionally used to provide clinical hyperbaric treatments. In 1999, Revision 4 of the US Navy Diving Manual promulgated the first Navy treatment table specifically designed to address non-diving, medical disorders.[1] As it was the ninth treatment table in use by the Navy, it aptly became named Treatment Table 9 (TT9). This clinical table, based on the Undersea and Hyperbaric Medical Society's *Hyperbaric Oxygen (HBO2) Therapy Committee Report—1996: Approved Indications for Hyperbaric Oxygen Therapy*, has since been used by Undersea Medical Officers (UMO) to manage clinical diseases considered amenable to hyperbaric oxygen treatment.

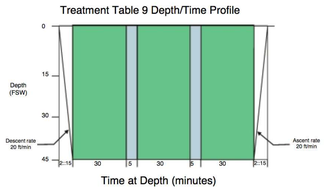

Figure 1 – USN Treatment Table 9

In all cases, one or more medical personnel directly attend to the patient during the HBO2 treatment. In contrast to the patients, who breathe oxygen throughout the majority of treatment, "Inside Tenders" are exposed to chamber air at pressures equivalent to 45 feet of seawater (fsw). Consequently, tenders incur decompression obligations commensurate with the total time of air breathing at that depth. Until recently, the US Navy Diving Manual did not contain a decompression schedule for dives to 45 fsw.[2] Thus, a TT9 "dive profile" had to be converted to an equivalent dive on the next deeper decompression schedule, which in this case invoked a 50-foot schedule. Since the "total bottom time" for a clinical TT9 usually exceeds 100 minutes, the tender's dive profile routinely violated the Navy's USN56 "no decompression" limits for that depth.

Depth (feet/meters)		No-Decompression Limits (min)
10	3.0	unlimited
15	4.6	unlimited
20	6.1	unlimited
25	7.6	595
30	9.1	405
35	10.7	310
40	12.2	200
50	15.2	100
60	18.2	60
70	21.3	50
80	24.4	40
90	27.4	30
100	30.5	25
110	33.5	20
120	36.6	15
130	39.6	10
140	42.7	10
150	45.7	5
160	48.8	5
170	51.8	5
180	54.8	5
190	59.9	5

Figure 2 - US Navy Diving Manual (Revision 5) No-Decompression Limits

In a diving environment, such a dive profile requires a decompression stop for three minutes at a depth of ten feet.

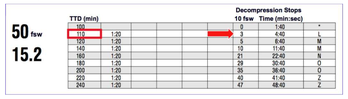

Figure 3 – 50 Foot Decompression Schedule

However, given that TT9 is a clinical treatment designed to provide patients with 90 minutes of oxygen therapy, the insertion of a decompression stop for the tender has been deemed impractical. Consequently, alternative methods to reduce the tender's risk of developing decompression sickness (DCS) were employed. To that end, the amplifying instructions appended to TT9 explicitly direct tenders to breathe 100% oxygen during the last 15 minutes of the third patient oxygen treatment period and during chamber decompression to ambient pressure.

Treatment Table 9

1. Descent rate - 20 ft/min.
2. Ascent rate - 20 ft/min. Rate may be slowed to 1 ft/min depending upon the patient's medical condition.
3. Time at 45 feet begins on arrival at 45 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, oxygen breathing may be restarted 15 minutes after all symptoms have subsided. Resume schedule at point of interruption (see paragraph 21-5.5.6.1.1).
5. Tender breathes 100 percent O_2 during last 15 minutes at 45 feet and during ascent to the surface regardless of ascent rate used.
6. If patient cannot tolerate oxygen at 45 feet, this table can be modified to allow a treatment depth of 30 feet. The oxygen breathing time can be extended to a maximum of 3 to 4 hours.

Figure 4 – TT9 Amplifying Instructions

Such a strategy has theoretically proven to be both safe and effective in mitigating the risk of tender DCS. Indeed, since 2001, Naval Safety Center data reports no cases of tender DCS in association with TT9 use.[3,4] This is also congruous with reported civilian experience. Witucki et al analyzed a series of 18,861 clinical treatments at 45 fsw and lasting 80 – 120 minutes, during which tenders breathed oxygen for the final 15 minutes of the treatment period.[5] Although these tenders did not breathe oxygen during the 5-10 minute chamber decompression to the surface, no cases of tender DCS were seen (95% CI, 0, 0.00021). While this is indeed a remarkable safety record, one might question whether, in the complete absence of reported TT9 DCS cases, tender breathing of supplemental oxygen provides meaningful prophylaxis against tender DCS or, more accurately, represents an excessive degree of caution.

Enhancing the argument for excess precaution was the April 2008 introduction of Revision 6 to the US Navy Diving Manual.[6] Unlike its predecessors, which used USN56 Standard Air Decompression Tables that have remained essentially unaltered since inception in 1956, Revision 6 promulgates a number of fundamental changes to the US Navy Diving Manual. For the purposes of this abstract, the most important change has been the inclusion of new decompression schedules based on the Thalmann VVal-18 and VVal-18M algorithms.[2] In contrast to the previously employed 50-foot schedule, Revision 6 added a new, 45-foot schedule, extending the applicable no-decompression limit for a TT9 from 100 to 125 minutes.

Figure 5 - US Navy Diving Manual (Revision 6) No-Decompression Limits

Depth (fsw)	No-Stop Limit (min)
30	371
31	334
32	304
33	281
34	256
35	232
36	212
37	197
38	184
39	173
40	163
41	155
42	147
43	140
44	134
45	125
46	116
47	109
48	102
49	97
50	92

In most cases, the total duration of a clinical TT9 fails to exceed the Revision 6 no-decompression limits. Consequently, divers participating in non-repetitive, open water dives equivalent to a TT9 time-depth profile would no longer incur a mandatory decompression obligation. Nevertheless, Revision 6 does not incorporate any changes to the amplifying instructions for TT9 and inside tenders retain their obligation to breathe supplemental oxygen during the last 15 minutes of patient oxygen treatment and chamber decompression to ambient pressure.

Given the historical lack of TT9-associated DCS cases and the extended, 125-minute no-decompression time afforded by Revision 6, the utility of supplemental oxygen breathing seems questionable for tenders participating in TT9 treatments ≤ 125 minutes in length. Indeed, one might hypothesize that it would be reasonable to consider inside chamber attendants as divers rather than tenders for the purposes of determining their decompression obligation. To that end, this retrospective record review examines whether a local, departmental-level policy change re-classifying TT9 inside chamber attendants as divers rather than tenders resulted in an increased incidence of attendant DCS.

Materials and Methods

Beginning 01 May 2008, subsequent to promulgation of Revision 6, the Senior Undersea Medical Officer at the Naval Operational Medicine Institute (NOMI), detachment Naval Aerospace Medical Institute (NAMI), implemented a Hyperbaric Department policy change whereby all inside tenders would be treated as Navy divers for the purposes of determining decompression obligations. Consequently, personnel participating as inside tenders during clinical HBO2 treatments were no longer obligated to breathe supplemental oxygen during the course of a TT9. No other changes to routine hyperbaric chamber operating procedures or post-treatment patient and tender monitoring procedures were made. After a period of one year, a retrospective analysis of the Department's existing dive logs was conducted.

Results

Between May '08 and May '09, a total of 180 clinical TT9 chamber treatments were recorded. These dives involved 17 tenders participating in a total of 200 tender dives. Tender age ranged 20 – 48 years (mean 30 years). Both male and female tenders were represented in this data set. The primary professional backgrounds of the tenders included Navy First Class Divers (6), Diving Medical Technicians (4), a Diving Officer (1), Undersea Medical Officers (2), non-diving clinical staff (2) and Resident physicians (2). Figure 14 illustrates the distribution of the TT9 total dive times.

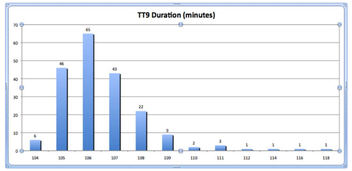

Figure 6 – TT9 Duration Graph

Analysis of the TT9 time profiles revealed a duration range of 104 – 118 minutes, with mean, mode and median values of 107, 106 and 110 minutes, respectively. Despite the variability in tender characteristics and TT9 duration, zero cases of tender DCS were found among the 200 tender exposures recorded. Assuming a 95% confidence interval, this represents a DCS incidence of ≤ 1.5% (95% CI, 0, 0.015). By way of baseline comparison, Departmental dive log data for the one-year period prior to the release of US Navy Diving Manual Revision 6 also revealed zero cases of tender DCS over 92 total TT9 exposures, yielding a DCS incidence of ≤ 4.9% (95% CI, 0, 0.0494).

Discussion

The institution of a local, departmental-level policy change re-classifying TT9 inside chamber attendants as divers rather than tenders did not result in an increased incidence of attendant DCS. Based on the probabilistic models used to construct the decompression schedules incorporated into Revision 6, one would anticipate the estimated DCS risk for a 45-foot dive lasting 125 minutes to range between 1.7 and 3.4%.[2] Interestingly, this is nearly identical to the 1.7 – 3.5% risk predicted for a 50-foot, 110-minute dive using the USN56 Standard Air Decompression Tables, the most commonly selected schedule following TT9 clinical treatments, and greater than the 0.6 – 2.1% risk predicted for the no-decompression limits of the 50-foot USN56 schedule.[2]

In practice, remaining within the no-decompression limits of the USN56 tables has been associated with a variable incidence of DCS. The earliest reports indicated an incidence of about 5%.[7] However, lower rates have been recorded, with operational records reporting an overall incidence of DCS for the US Navy Air Tables of 1.25%.[8] Finding the middle ground, one summed report covering 1673 wet and dry, single air dives, reported a DCS incidence of 3.8%.[9] Understandably, the recently released VVal-18 decompression schedules have not been similarly validated by real-world diving experience.

Regardless, using either the above predictive models or past diving experience as a guide, our reported incidence of tender DCS is less than what would be expected for 45-foot dives ≤ 125 minutes. This is consistent with reported civilian experience with 10,000 treatments using a clinical HBO2 table similar to TT9. Although their clinical profile frequently incorporated a 10-minute decompression stop at 10 fsw, Potani et. al. reported a DCS incidence of 0.15% for air breathing tenders during clinical treatments ranging 80 – 132 minutes in length.[10] Thus, in terms of DCS risk, foregoing tender supplemental oxygen breathing during uncomplicated TT9 chamber treatments affords a safety profile at least as safe as that considered acceptable for no-decompression dives in the operational environment.

Disadvantages of Tender Supplemental Oxygen Breathing

In the absence of documented cases of tender DCS during TT9 use, the theoretical protections offered by an oxygen breathing period remain just that… theoretical. Furthermore, such extra protection is not without associated cost. Counterbalancing the theoretical safety advantage offered by tender supplemental oxygen breathing are several potential detractors. These include:

- Discomfort from Mask Wear
- Impaired Communication with Topside Tenders and Patients
- Increased Chamber Oxygen Concentrations
- Increased Maintenance Demands
- Potential Tender / Patient Entanglement
- Decreased Attentiveness to the Patient

Although the mask, a Scott Pressur Vak II, can be worn for prolonged periods of time without significant adverse consequences, this does not imply that the mask's use is described as comfortable. Further, since the tender must hold, instead of strap, the mask in place during wear (a precaution against tender oxygen toxicity), the tender must endure arm fatigue, the functional loss of one hand and a potential for increased DCS risk in the extremity distal to circulatory impairment induced by the bent elbow. While the latter risk has not borne out in TT9 practice, this does not preclude its potential impact during more provocative dive profiles.

Figure 7 – Mask Fatigue

From a more practical standpoint, mask wear clearly affects tender communication with both the patient and "topside" chamber personnel. When worn, the ambient noise of a patient's oxygen hood all but precludes the ability of the patient to understand tender directions while a mask is in place. Similarly, masks lacking built-in communication technology significantly impair the ability of the tender to converse with topside Diving Supervisors, tenders and UMOs.

Figure 8 – Mask Induced Communication Impairment

Tender attempts to combat such communication difficulties are often associated with inadvertent increases in chamber oxygen levels. Although chamber masks generally incorporate an adjustable "second stage" pressure regulator (which limits oxygen free flow into the chamber when not in use), oxygen is still able to enter the chamber atmosphere through leaks around ill-applied masks and during periods when the tender's mask is removed to facilitate communication.

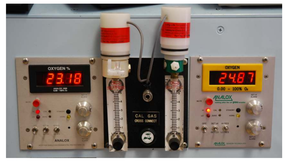

Figure 9 – Chamber Oxygen Alarms

Inherent to mask use is the requirement for maintenance. Recurrent tender use increases requirements for mask cleaning and sanitation. This process is time consuming and associated with both added operating costs and reduced mask shelf life.

Figure 10 – Mask Maintenance

The need for mask exhaust and supply hoses also raises potential ergonomic issues during tender movement about the chamber environment. While serious injury is unlikely, entanglement of the tender, patient and chamber equipment may occur.

Figure 11 – Hose Entanglement Risk

Finally, any time spent addressing issues related to the tender's use of the oxygen mask inherently distracts the tender from the primary task at hand; attending to the patient.

Figure 12 – Mask Associated Tender Distraction

Consequently, were it not for the theoretically reduced DCS risk afforded by tender breathing of supplemental oxygen during t a TT9's final phases, it is unlikely that any tender or dive locker would voluntarily choose to employ the practice

Conclusions

mplementing a policy whereby inside chamber attendants participating in TT9 clinical treatments are regarded as divers instead of tenders for the purposes of calculating decompression obligations did not increase the incidence of tender DCS over baseline. Although the total number of exposures included in this review was small relative to previous civilian studies evaluating similar clinical HBO_2 profiles, we were able to demonstrate that the incidence in tender DCS subsequent to implementation of this Departmental policy (i.e. ≤ 1.5%) remains less than the DCS risk expected using either the USN56 Standard Air Decompression Tables or those contained in Revision 6 to the US Navy Diving Manual (i.e. 1.7 – 3.5%). Consequently, we have shown that foregoing TT9 requirements for tender breathing of supplemental oxygen during the terminal phases of TT9 clinical treatments lasting ≤ 118 minutes is at least as safe, in terms of DCS risk, as that considered acceptable for dives in the operational environment. Given that supplemental oxygen breathing via facemask is associated with both tangible and intangible costs (i.e. potentially decreased tender comfort and safety, increased equipment maintenance requirements and degradation of tender attentiveness to the patient), it is recommended that the routine practice of tender supplemental oxygen breathing be reclassified as *optional* for those TT9 clinical HBO_2 treatments not exceeding the no-decompression limits of the US Navy Diving Manual Revision 6.

References

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