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Nitrogen Narcosis in Hyperbaric Chamber Nurses

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Abstract: Hyperbaric nursing has become a specialty requiring high skill and knowledge. Nitrogen narcosis is a perceived risk for all inside hyperbaric chamber nurses. The actual degree of impairment at pressure has not been quantified. Twenty eight subjects participated in the study. Sixteen hyperbaric nurse candidates and five experienced hyperbaric nurses completed Trail Making Test A (TMTA) pre and post compression and at 180 kPa and 300 kPa. Seven experienced hyperbaric staff acted as an unpressurized reference. Time to completion of the test was recorded in seconds; pre-test anxiety and perceived symptoms of narcosis at 300 kPa were also recorded. There were no statistically significant differences in the corrected TMT A times at the four different time periods. There was a trend to poorer performance by the nurse candidates at 180 kPa however this was not statistically significant. Most subjects felt some degree of narcosis at 300 kPa. Most hyperbaric chamber nurses can overcome the effects of nitrogen narcosis at 180 and 300 kPa to maintain or improve performance in the TMT A. Poor performance by hyperbaric nurse candidates maybe due to individual susceptibility or lack of ability to compensate. Due to the risk of nitrogen narcosis outside chamber staff should continue to make clinical decisions about patient care.

Keywords: Nitrogen Narcosis, Hyperbaric Research, Psychology, Nursing

Introduction

Hyperbaric nursing is a specialty involved in the care of patients receiving hyperbaric oxygen treatment. Nurses, from a wide background of experience including emergency and critical care, complete training in hyperbaric and diving medicine. Hyperbaric nursing courses include both theoretical knowledge and practical skills to equip nurses for working in the hyperbaric environment. The nurses must be medically fit to "dive" and perform training dives during their courses including a compression to 300 kilopascals (kPa).

SCUBA divers with decompression illness are treated in hyperbaric chambers using standardized treatment tables. Two initial treatment tables are commonly used at The Townsville Hospital Hyperbaric Medicine Unit. The Royal Navy 62 (RN 62) treatment table prescribes compression to 180 kPa and the diver breathes oxygen. The Comex 30 treatment table prescribes compression to 300 kPa and the diver breathes heliox (50% helium and 50% oxygen) until 180 kPa where they are changed over to oxygen. The inside nurse attendant breathes air during either treatment other than during the final stages of decompression when they breathe oxygen. It follows that there is a widely perceived risk of nitrogen narcosis for the inside nurse. Consequently the outside staff make all the patient care decisions and the inside nurse performs the skills at the request of the outside staff. However, the actual degree of impairment in inside nurses has not been quantified. While much research has been done on SCUBA divers, mostly in deep diving (Biersner *et al*., 1978; Whitaker and Findley, 1977) in water and in dry chambers, (Petri, 2003; Gallway *et al*., 1991) no studies have investigated the effect of nitrogen narcosis on hyperbaric chamber nurses.

Nitrogen narcosis was made famous in the Self Contained Underwater Breathing Apparatus (SCUBA) diving community by Jacques Cousteau who called it "l'ivresse des grandes profondeurs" or rapture of the great depths. Cousteau and Dumas (1958) It was correctly associated with the narcotic effects of nitrogen breathed under pressure by Behnke *et al*. (1935), but its

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precise mechanism of action still remains controversial. Experimental evidence supports the importance of hypercapnia in divers but variations in alveolar CO_2 tensions seems to have little effect on the magnitude of the nitrogen component in compressed air narcosis. Bennett and Rostain (2003). The traditional view was that nitrogen was an inert gas, highly soluble in lipids and not involved in biochemical processes. However, more recent work has found that nitrogen acts on nerve cell membranes interfering with impulse conduction (production, release and uptake of several neurotransmitters) most likely at the synapses (Rostain *et al.*, 2011).

The signs and symptoms of nitrogen narcosis have been described as similar to those of alcohol intoxication: Stimulation, excitement, euphoria and slowing of mental activity with delayed response to stimuli. Early investigations demonstrated that at a depth of 30 metres of sea water (msw) (300 kPa) there is impairment of memory, concentration, calculations, powers of association and fine motor functions and also a tendency to fixate on ideas. Behnke *et al*. (1935) Intellectual functions are generally more severely affected than manual dexterity. Increased concentration can ameliorate these effects. The effects of nitrogen narcosis are variable, with some divers being more susceptible than others. It may be potentiated by emotional instability, alcohol use, fatigue, hard work, apprehension and anxiety. Frequent exposure to compressed air may afford some adaptation (Bennett and Rostain, 2003).

Various subjective feeling scales, physiological measurements and cognitive function tests have been used to assess for nitrogen narcosis. Subjective feeling scales have attempted to equate the feelings of nitrogen narcosis with that of alcohol intoxication (Monteiro *et al*., 1996; Hobbs, 2008) or delineate the effects of anxiety or other emotional factors on the onset of nitrogen narcosis. Biersner *et al*. (1978); Gallway *et al*., 1991; Davis *et al*., 1972; Rogers and Moeller, 1989; Hamilton *et al*., 1995) Studies using physiological measurements have included heart rate and blood pressure (Biersner, 1987), balance (Rogers and Moeller, 1989), EEG changes (Pastena *et al*., 2005) and critical flicker fusion frequency. Balestra *et al*. (2012) Many different cognitive tests have been used in the research of nitrogen narcosis and no clear ideal test for quantifying nitrogen narcosis has yet been identified. The cognitive function tests that have been used to measure nitrogen narcosis can be categorized into four behavioural endpoints: Reaction time, mental arithmetic, memory and manual dexterity. The specific test chosen in each study appears dependent on the facility, accessibility to equipment and the type of subjects.

This study was designed to determine whether nitrogen narcosis occurs in hyperbaric chamber nurses during compression to 180 and 300 kPa using Trail Making Test A (TMT A). It was expected that mild impairment would be seen at 300 kPa with increased time to complete TMT A and an increased number of errors. As no formal assessment of susceptibility to nitrogen narcosis is performed during hyperbaric nursing courses, the aim of this study was to quantify the effects of nitrogen narcosis on both experienced and novice hyperbaric chamber nurses during a compression to 180 and 300 kPa.

Methods

Participants

Ethical approval was obtained from the Townsville Health Service District Human Research Ethics Committee. (HREC/09/QTHS/2) Twenty eight subjects participated in the study. Relevant demographic data including alcohol consumption, body mass index, scuba diving experience and age were gathered from the subjects' diving medical examination record. The intervention group consisted of sixteen hyperbaric nursing candidates and five experienced hyperbaric nurses. This group was pressurized to 300 kPa as a routine part of the hyperbaric nursing course. The non-pressurized reference group consisted of seven experienced hyperbaric staff currently working in the hyperbaric medicine unit. All participants who were pressurized had a current Australian Standard 4774.2 2002 dive medical. Written informed consent was obtained.

Materials

The hyperbaric chamber used was the triple lock rectangular unit located at The Townsville Hospital, Townsville, Queensland. The pressurizations were undertaken in the inner lock, which has a working pressure of 500 kPa and is used when completing an RN 62 or Comex 30 treatment table. A certified hyperbaric technician operated the chamber for all pressurizations.

The TMT A was used as an objective measurement of mental impairment during the pressurization. TMT A is easy to perform, requires no objects that cannot be compressed and does not require an extensive amount of time to complete. Thus using TMT A does not influence the bottom time of the practice dive and does not require adjustment to the decompression schedule. TMT A was initially developed as a test in the (AITB, 1944) and was incorporated into the Halstead-Reitan battery group of tests in 1958. This test has been used to assess the general intellectual ability of USA Army recruits (AITB, 1944) and to detect cognitive ability in aging drivers (Stutts *et al*., 1998), dementia in the elderly (Reitan, 1958), portal systemic encephalopathy (Conn, 1977) and inert gas narcosis. Jakovljevic *et al*. (2012) It assesses visual scanning, number sequencing and visuomotor speed. NBN (1997) The test is designed so that healthy individuals should be able to complete the test in less than 30 sec. However age and education level have been found to influence results and normative data stratified

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by these variables have been developed and suggested as providing better reference values for impaired performance (Tombaugh, 2004) and improving the reliability. NBN (1997) TMT A consists of 25 sequentially numbered circles distributed on a sheet of paper, which the candidate must link with a pen in correct order whilst their performance is timed. The time taken in seconds constitutes the ‘score’ for the test. There are four variations of the TMT A available and they have been found to have the same degree of difficulty (Conn, 1977).

Hyperbaric staff outside the chamber acted as time keepers for each test (one time keeper per subject).Participants were asked to rate their level of anxiety about the 300 kPa chamber dive during their first (baseline) TMT A assessment; after their last assessment participants were asked whether they felt like they experienced nitrogen narcosis at 300kPa and if yes to describe the feeling as nitrogen narcosis is also known to be expressed in a subjective component (Hamilton *et al*., 1995).

Typically, the TMT is performed under direct observation with errors in the number tracing sequence identified and corrected immediately. This was not possible in this study as the timers were outside of the hyperbaric chamber. To adjust for this, the TMT forms were reviewed following completion; where participants missed a number in their sequence tracing, a time penalty of 2 sec was added to their score for each error. The two sec is an estimate of the time required for redirection of the subject by the timer if an error had been noted during the testing.

Design

Prior to entering the chamber a ten number practice test was completed to ensure that the subjects understood the instructions and could perform the test. The hyperbaric nurse candidates were then divided into approximately equal sized groups (three or four) to perform the pressurizations. Each group had an experienced hyperbaric nurse as the inside attendant. The subjects then entered the chamber and were comfortably seated. Prior to compression the subjects graded their subjective experience of anxiety about the 300 kPa exposure (none, mild, moderate or severe). Test instructions were then read (and were re-read prior to each of the four tests). A different ‘parallel form’ of the test (in which the numbers are arranged differently) was utilized for each of the four test repetitions performed by each subject. TMT A version 1 (T1) was completed at 0 kPa and the pressurization subsequently commenced at a rate of 30 kPa per min. TMT A version 2 (T2) was completed on arriving at 180 kPa. TMT A version3 (T3) was completed on arriving at 300 kPa and decompression was commenced after completion of several training skills unrelated to the study. Subjects breathed 100% oxygen throughout the decompression from 140 kPa to 0 kPa as required during a normal decompression from a Comex 30 or RN 62 treatment table. TMT A version 4 (T4) was completed on arrival back at 0 kPa prior to exiting the chamber. The hyperbaric technician responsible for compressing the chamber ensured the dive was within the table limits. A hyperbaric physician was in attendance during the compressions.

The reference group performed an identical sequence of tests at similar inter-test time intervals whilst seated inside the chamber, but without pressurization. There was always a minimum of two staff in the reference group testing sessions to approximate the testing environment.

Data Analysis

All data were entered into a Microsoft Excel 2003 (Microsoft Corporation, Redmond, Washington, USA) spread sheet and then exported into SPS Version 19 (IBM Company, Armonk, New York, USA) for analysis. Fisher’s exact Test (FET), Analysis of Variance (ANOVA) and Kruskal-Wallis (K-W) test were used as appropriate to compare baseline demographic variables of the study groups.

For the primary analysis, each subject served as their own control. We determined change in TMT A time from baseline to each pressurization, as well as change in TMT A time between each pressurization. We also determined the number of subjects who “failed” (corrected TMT A time >30 sec) at each protocol stage.

Although TMT A times were normally distributed across all study groups and all time points, changes in TMT A times were not universally normally distributed. Thus, we used Wilcoxon Sign Rank test to evaluate changes in TMT A time between each protocol stage. We also used FET to evaluate associations between subjective feelings of narcosis and “failing” TMT A. A p-value less than 0.05 was used to establish statistical significance.

Results

Hyperbaric nurse candidates were significantly younger than staff, but otherwise there were no significant differences in demographics between the pressurized group and the reference group. (Table 1) There were fewer males than females in the pressurized group which is representative of the gender distribution in the nursing profession.

Most (71%) of the experimental group subjects stated that they felt some level of narcosis at 300 kPa. One subject, nurse candidate 2, had the feeling of being “very drunk” at 300 kPa, but had reported no anxiety prior to the pressurization and performed the worst at 180 kPa. (Table 2) Another nurse candidate, who had no anxiety before the pressurization, stated they felt “happy and embarrassed” at 300 kPa.

Table 1: Baseline Demographics

	Nursing Candidates	Nursing Staff	Reference Group	Significance
N	16	5	7	
Male [n, (%)]	4(25)	2(40)	4(57)	FET, p = 0.368
Age (mean ± SD)	34(7)	44(4)	39(9)	ANOVA, p = 0.038
SCUBA experience [n, (%)]	6(37.5)	1(20)	4(57)	FET, p = 0.444
BMI (mean ± SD)	26.8(4.2)	26.8(4.2)	25.9(4.4)	ANOVA, p = 0.875
Drinks/Week (median [IQR])	2 [1-4]	10 [3-11]	4 [2-6]	K-W, p = 0.143
Anxiety [n, (%)]	10(62.5)	1(20)	N/A	FET, p = 0.355
Symptoms of Narcosis [n, (%)]	12(75)	3(75)	N/A	FET, p = 0.648

Table 2. Raw results Trail Making Test a completion time in seconds; number of errors; corrected time

Type	T1	T1 Errors	Time 1 Corrected	T2	T2 Errors	Time 2 Corrected	T3	T3 Errors	Time 3 Corrected	T4	T4 Errors	Time 4 Corrected
Candidate* 1	24	0	24	19	0	19	17	0	17	13	0	13
Candidate 2	21	0	21	45	0	45	22	0	22	14	0	14
Candidate 3	22	0	22	34	1	36	24	0	24	22	0	22
Candidate 4	17	0	17	21	0	21	22	0	22	27	0	27
Candidate 5	33	0	33	26	0	26	21	0	21	23	0	23
Candidate 6	16	0	16	26	0	26	24	0	24	14	0	14
Candidate 7	37	0	37	33	0	33	22	0	22	28	0	28
Candidate 8	24	0	24	15	0	15	14	0	14	16	0	16
Candidate 9	16	0	16	18	0	18	14	0	14	15	0	15
Candidate 10	25	0	25	25	1	27	15	0	15	30	0	30
Candidate 11	21	0	21	26	0	26	18	0	18	28	0	28
Candidate 12	19	0	19	14	0	14	14	2	18	13	1	15
Candidate 13	25	2	29	23	2	27	18	1	20	21	0	21
Candidate 14	19	0	19	23	0	23	19	0	19	23	0	23
Candidate 15	14	0	14	19	0	19	21	0	21	27	1	29
Candidate 16	17	0	17	21	0	21	27	0	27	16	0	16
Experienced† 1	24	0	24	26	0	26	29	0	29	28	0	28
Experienced 2	22	0	22	21	0	21	22	0	22	27	0	27
Experienced 3	17	0	17	11	0	11	12	0	12	11	0	11
Experienced 4	20	0	20	21	0	21	18	0	18	22	0	22
Experienced 5	21	0	21	16	0	16	16	0	16	17	0	17
Reference¥ 1	17	0	17	31	0	31	20	0	20	24	0	24
Reference 2	16	0	16	18	0	18	14	0	14	13	0	13
Reference 3	28	0	28	21	0	21	25	0	25	31	0	31
Reference 4	14	0	14	12	0	12	16	0	16	15	0	15
Reference 5	16	0	16	14	0	14	15	0	15	15	0	15
Reference 6	24	0	24	17	0	17	15	0	15	23	0	23
Reference 7	17	0	17	14	0	14	16	0	16	16	0	16

*Hyperbaric Nursing Candidate, †Experienced Hyperbaric Nurse, ¥ Non-compressed Hyperbaric Staff

Table 2 shows the raw results. Two nurse candidates exceeded 30 sec at T1; a third nurse candidate made two errors at T1, but applying the 2-sec per error penalty still did not put this subject over the 30-sec threshold. Four subjects exceeded 30 sec at T2 (180 kPa), including three nurse candidates (one of whom exceeded 30 sec at T1) and one reference subject; three nurse candidates committed errors at T2; again applying the penalty for errors did not put any subject over the 30-sec threshold. All of the subjects completed the TMT A in less than 30 sec at T3 (300 kPa), even after applying the penalty for two subjects who committed errors. At T4 one of the reference subjects exceeded 30 sec. One nurse candidate accidentally swapped test one and four but got the same time of 22 sec on both tests so they were included in the analysis. Table 3 shows the mean corrected TMT A times for the two experimental subgroups and the reference group; Fig. 1 graphically compares the corrected TMT A times for the two subgroups of the experimental cohort and the reference group, including the 95% confidence intervals for the corrected TMT A completion times.

Table 4 shows the median and inter quartile range change in TMT A times at each protocol stage. From baseline to T2 (180 kPa) there was not a statistically significant change in completion time. There was a decrease in TMT A from T1 (180 kPa) to T3 (300 kpa). While this difference between T1 and T3 TMT A times was not statistically significant, the decrease between T2 and T3 was significant. Finally, there was no difference between the TMT A times recorded after return to sea level and those recorded at any of the other protocol stages.

Table 4 also shows the results of subgroup analyses for nursing candidates and experienced staff, as well as those subjects who reported subjective feelings of narcosis. These results mirror those of the overall analysis.

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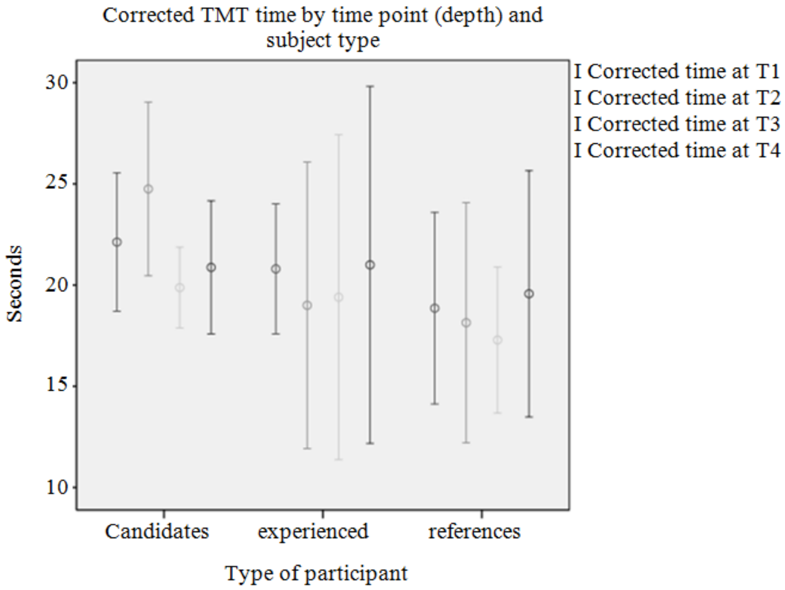

Fig. 1. Mean and 95% confidence intervals of Trail Making Test A times for each group at each time point

Table 3. Mean (±SD) Corrected TMT A completion times, seconds

	Test 1	Test 2	Test 3	Test 4
Candidates*	22.1±6.4	24.8±8.1	19.9±3.7	20.9±6.2
Experienced†	20.8±2.6	19.0±5.7	19.4±6.5	21.0±7.1
Reference¥	18.9±5.1	18.1±6.4	17.3±3.9	19.6±6.6

*Hyperbaric Nursing Candidate, †Experienced Hyperbaric Nurse, ¥Non-compressed Hyperbaric Staff

Table 4. Median (interquartile range) change in TMT A between pressures, (seconds)

	Change in Pressure				
Experimental Group	T2-T1	T3-T1	T3-T2	T4-T3	T4-T1
Reference¥ (n=7)	-2 (-7 to +2) p = 0.394	-1 (-3 to +2) p = 0.395	+1 (-4 to +4) p = 0.932	0 (-1 to +6) p = 0.223	-1 (-1 to +3) p = 0.863
All Compressed (n=21)	+2 (-5 to +4.5) p = 0.701	-2 (-8 to +3.5) p = 0.197	-2 (-7.5 to +1) p = 0.030	+1 (-2.5 to +5) p = 0.338	-1 (-1 to +4.5) p = 0.466
w/ Subjective Narcosis (n=15)	+2 (-5 to +4) p = 0.569	-2 (-10 to +2) p = 0.207	-3 (-11 to +1) p = 0.018	+2 (-4 to +5) p = 0.629	-1 (-8 to +4) p = 0.245
Candidates* Only (n=16)	+3 (-4.8 to +5) p = 0.392	-1.5 (-9.8 to +4.3) p = 0.244	-4 (-10.3 to +0.5) p = 0.018	+1.5 (-3.8 to +5.8) p = 0.587	-1.5 (-8 to +4.8) p = 0.410
Experienced† Only (n=5)	-1 (-5.5 to +1.5) p = 0.416	-2 (-5 to +2.5) p = 0.450	+1 (-1.5 to +2) p = 0.577	+1 (-1 to +4.5) p = 0.336	+2 (-5 to +4.5) p =1.00

*Hyperbaric Nursing Candidates, †Experienced Hyperbaric Nurses, ¥Non-compressed Hyperbaric Staff

There was no association between subjective feelings of narcosis and the results of the TMT A at T2, FET p = 1.0 (Table 5) and no subjects exceeded the expected completion time of TMT A at T3.

Table 5. Association between subjective narcosis and exceeding expected TMT A completion time

	Subjective Narcosis?	
TMT A Result	Yes	No
Failed	3	0
Not Failed	12	4

FET p = 1.00; sensitivity = 0.20; negative predictive value = 0.25

Discussion

Nitrogen narcosis is a condition caused by breathing compressed air characterized by euphoria or anxiety and impairment of performance and reasoning. The conventional view taught on diving courses is that nitrogen narcosis can become apparent to divers breathing air at depths of 30 msw (300 kPa). However, some researchers have suggested that impairment from nitrogen narcosis can be seen at shallower depths. Petri (2003); Davis *et al*., 1972; Synodinos, 1976; Fowler, 1972) Mild signs and symptoms of nitrogen narcosis can be seen from 100 to 300 kPa with more severe manifestations of hallucinations, unconsciousness and death at depths greater than 900 kPa. Lippmann and Mitchell, (2006) The Comex 30 treatment table is used in Australia, but more commonly in the UK. (Sharpe, 2008) This requires the inside chamber nurse to breathe air at 300 kPa, raising the possibility that they might be impaired by nitrogen narcosis.

This study found that while most hyperbaric nurses have subjective feelings of nitrogen narcosis they can overcome these effects at 180 kPa and 300 kPa to maintain (or in some cases improve) their timed performance in the TMT A. While we did not find any statistically significant degradation in TMT performance, three hyperbaric nurse candidates did exhibit obvious decrements in performance at 180 kPa, possibly indicating an effect of nitrogen narcosis (Table 2). These apparent cognitive decrements in inexperienced subjects could be interpreted as validating concerns about the potential for errors by attendant staff breathing air at common treatment pressures. However, it is notable that two of these subjects subsequently performed better at 300 kPa, when nitrogen narcosis would be expected to worsen. This result is difficult to interpret, but it raises the possibility that the initial decrement at 180 kPa may be related to factors other than narcosis. The distraction of 'becoming accustomed to' the initial deep compression may have impaired performance. There was also great competition between the participants, represented by friendly banter, as they heard the pens drawing lines on other participant's pages perhaps leading to performance pressure on the candidates. The candidates may not have thought that they should be "narked" at 180 kPa and therefore may not have concentrated as hard on the test at that time point.

The focus of most research on nitrogen narcosis has been in the scuba diver (Hobbs, 2008; Davis *et al*., 1972; Balestra *et al*., 2012; Synodinos, 1976) and not hyperbaric nursing staff. Attempts have been made to not only measure the effects of nitrogen narcosis but also to develop methods of adaptation especially for the professional diver. This has met with little success (Petri, 2003; Rogers and Moeller, 1989; Biersner, 1987), however some studies suggest that subjects may be able to compensate for the effects of nitrogen narcosis. Petri (2003) Our results support this finding as we did not find any statistical difference between hyperbaric nurse candidates and experienced hyperbaric nurse performance. However, the three hyperbaric nurse candidates who did exhibit decrements were not scuba divers and therefore inexperienced with narcosis perhaps suggesting naivety to the ability to compensate.

There is an assumption that nitrogen narcosis is comparable to intoxication with alcohol, leading to the term "Martini's Law", where the effects of nitrogen narcosis are likened to drinking one martini for each 10 msw. Studies looking at this relationship between alcohol intoxication and nitrogen narcosis have found that those subjects who felt less intoxicated after drinking also felt less nitrogen narcosis during a simulated dive to 500 kPa (Monteiro *et al*., 1996) and those more affected by alcohol were affected to a greater degree by narcosis. Hobbs (2008) However, a link between drinking history and nitrogen narcosis susceptibility has not been established and this phenomenon is probably related to individual susceptibility. Hobbs (2008) The three hyperbaric nurse candidates who did exhibit obvious decrements in performance at 180 kPa declared minimal weekly alcohol ingestion. This individual variation in susceptibility to nitrogen narcosis may place some staff and patients, at risk and perhaps assessment of hyperbaric inside nurse candidates using the TMT A at 180 and 300kPa could identify those more susceptible to nitrogen narcosis.

Limitations

The lack of a convincing demonstration of nitrogen narcosis with a clear dose-response at the incrementally greater ambient pressures was somewhat surprising although consistent with a recent study. Jakovljevic *et al*. (2012) However, our study has several weaknesses that may have distorted the result. First, TMT A is a blunt instrument and may not have been sensitive enough to find a difference. Strauss *et al*. (2006) Two previous studies have used the Trail Making Tests to assess nitrogen narcosis. Gallway *et al*. (1991) used a battery of tests including TMT A and B. Gallway *et al*. (1991) They found no evidence of nitrogen narcosis and planned on repeating the testing with a longer period at pressure prior to implementing the tests. A recent study attempting to assess impairment during mild nitrogen narcosis with sub anaesthetic levels of nitrous oxide used a computerized visual simple reaction time as well as TMT A and B. Jakovljevic *et al*. (2012) They did not find a significant impairment in performance stating that there is individual variation to the dose required to induce nitrogen narcosis.

A test interrogating a wider range of cognitive domains may have been more sensitive such as TMT B where the subject has to draw a line from the number 1 to letter A up to number 12 and letter L in an alternating fashion. However, one study using TMTs to assess hepatic encephalopathy found that TMT A was sufficiently sensitive to detect changes and easier and faster to perform than TMT B. Conn (1977) Practice effect may also become an issue using TMT B since as of yet there does not appear to be access to four different variations of the test. Practice effect could account for the improvement at 300 kPa but there was no significant difference between test 1 and 4 for all groups so practice did not seem to be a major factor.

The subjects were unblinded and motivated to perform well. The pressurization to 300 kPa was part of the hyperbaric nursing course and therefore all subjects were aware of the possibility of narcosis. There was a reduction in TMT A times from T2 to T3 lending evidence to the hypothesis that perhaps the nurses compensated for any effects of nitrogen narcosis by concentrating harder on the task at 300 kPa. It has long been long been thought that nitrogen narcosis occurs on arrival to depth (Pastena *et al*., 2005; Synodinos, 1976; Fowler *et al*., 1983) so our testing was performed within five minutes of arriving at 300 kPa. A recent study found that, using critical flicker fusion frequency, impairment was worse after 15 min at 323 kPa than upon initial arrival at pressure. Balestra *et al.* (2012) Perhaps our results would be different if the nurse candidates performed their training skills first and then completed the TMT A prior to depressurization.

Even though TMT A has been used to study nitrogen narcosis in the past it has not been validated for his purpose and the clinically significant change in TMT A completion time has not been previously determined. Our study was adequately powered to detect a five second change in TMT A times. We found a mean increase of approximately 2.7 sec in TMT A time from baseline to 180 kPa among our primary study group. For a three second difference in TMT A to achieve statistical significance would have required a sample size of 27 subjects. Whether a three second or five second change in TMT A time is clinically significant, remains to be determined.

Future plans would be to increase the numbers of participants in the study by performing the TMT A with each successive nursing course and/or changing to TMT B which may be a more sensitive test to detect subtle impairment by nitrogen narcosis. NBN (1997) Nurses could also be assessed during routine 18:60:30 treatments or during RN 62 and Comex 30 treatments. A performance test designed to replicate a nursing task, such as medication calculation or ventilator changes, would better assess and identify any clinically significant susceptibility to nitrogen narcosis at pressure. Also replicating the study and blinding the nurses to the pressure level and performing the test prior to depressurization may show different results.

Conclusion

There was no statistically significant difference in the time taken to complete TMT A at 180 and 300 kPa. Since most of the subjects stated that they felt some degree of narcosis, this suggests that TMT A may not be sensitive enough to detect mild levels of narcosis, (Strauss *et al*., 2006) and the current practice of not allowing the inside nurse attendant to make any major decisions while at 180 and 300kPa should not change. The inside chamber nurse attendant should also be made aware that narcosis maybe present at 180 kPa, an issue not previously emphasized. The hyperbaric physician should remain outside the chamber with the outside nurse attendant and all decisions about patient care should be made by surface support staff not under the influence of increased partial pressures of nitrogen. Further research is needed to identify and validate the best cognitive and motor tests for assessing nitrogen narcosis in hyperbaric chamber nurse attendants.

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Author's Contributions

All authors equally contributed in this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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