Referral patterns and outcomes of dive medical examinations in a tertiary hyperbaric facility

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Key words
Fitness to dive, medicals – diving, medical conditions and problems, cardiovascular, respiratory, asthma

Abstract
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Introduction: Scuba diving involves risks, and candidates in Australia usually have a medical evaluation prior to undertaking a diving course. Hyperbaric physicians act as secondary referral practitioners for these assessments. This study aimed to identify reasons for these secondary referrals, and document the assessment process and outcome for potential dive candidates.
Methods: This was a retrospective case-note analysis of candidates for dive medicals presenting to the Department of Diving and Hyperbaric Medicine (DDHM) at the Prince of Wales Hospital, Sydney, over 10 years.
Results: We identified a total of 191 candidates aged 12 to 67 years. Most were candidates for recreational diving (n = 148, 77.5%) and 119 (62.3%) were male. Commercial dive candidates had higher median total number of dives (P = 0.005), median maximum depth ($P < 0.001$) and median years, diving (P = 0.018) than recreational dive candidates. Respiratory problems were the most common referral reason for presentation (35%), followed by CNS (14%), ENT (13%) and cardiovascular conditions (9%). Most candidates were assessed as 'fit to dive' (136 or 71%), 49 (26%) were 'unfit', while six (3%) were subject to restrictions. Forty-three candidates (22%) presented with a diagnosis of asthma, of whom 25 (13%) were considered 'fit to dive'.
Conclusion: The most common presentation for evaluation was for respiratory conditions, particularly asthma, but a wide range of medical conditions were assessed, and subjects were evaluated on an individual basis. Although current standards in Australia discourage asthmatic subjects from diving, over half of the candidates presenting with a possible diagnosis of asthma were assessed as 'fit to dive'.

Introduction

In Australia, it is near-universal practice for a formal medical assessment to be made prior to dive training. The aim is to screen dive candidates for conditions that could potentially compromise their safety underwater and to counsel candidates on the medical risks of this activity.[1] The South Pacific Underwater Medicine Society (SPUMS) advocates that all assessments are made by a physician with training in this area. Specialist diving physicians, many of whom work in clinical hyperbaric facilities, act as a secondary referral resource for more difficult problems. There are specific Australian Standards (AS4005.1 and AS2299) relating to examination of the candidate for recreational and commercial diving activity respectively.[2,3]

In this retrospective review, we intended to examine the pattern of referral to the Prince of Wales Hospital Department of Diving and Hyperbaric Medicine (DDHM), to characterise the findings at examination and document the recommendations for this group.

The nature of compressed-gas diving involves both exposure to alterations in ambient pressure and physiological changes that may lead to undesirable incidents. The medical risks of compressed-gas diving relate both to the rapid changes in ambient pressure (P_{amb}) and to the consequences of breathing gas at high P_{amb}. It is the purpose of the 'fitness to dive assessment' to identify and counsel those at increased risk of such adverse incidents.

The most common medical problems encountered while diving are barotraumas and decompression illness (DCI). Barotrauma occurs when any non-compliant gas-filled space within the body does not equalise with environmental pressure during descent or ascent.[4] The most common such space affected is the middle ear, while less common sites for barotrauma of compression include the respiratory sinuses and dental caries. The lungs are potentially vulnerable to barotrauma of ascent. Expanding gas may be trapped in the lungs as P_{amb} falls, either because of airway obstruction (e.g., bronchoconstriction) or pathological conditions (e.g., bullous disease). The extent to which asthma predisposes to pulmonary barotrauma (PBT) is debated but the presence of active bronchoconstriction is assumed to increase risk. Asthmatics who regularly require bronchodilator medications are usually discouraged from diving for this reason. While possible consequences of pulmonary barotrauma include pneumothorax and mediastinal emphysema, the most feared is the introduction of gas into the pulmonary veins leading to cerebral arterial gas embolism (CAGE).[5,6]

Methods

This was a retrospective analysis of case notes performed in a structured manner. Ethics approval for the study was granted

by the UNSW Human Research Ethics Advisory (HREA) Panels. All candidates for diving clearance presented to the DDHM at the Prince of Wales Hospital (POWH) between October 1998 and October 2008. Candidates were identified from a patient database utilised at the DDHM. Candidate information was categorised into demographics, reasons for referral, medical conditions, investigations and outcomes. Some data were retrieved from the full medical records. Individuals inappropriately labelled 'diver medical' and those with insufficient data were excluded.

Diving experience was recorded as the approximate number of dives, years, diving, maximum depth achieved, longest dive, previous adverse dive events, type of diver (recreational or commercial) and certification level. Lastly, the outcome of assessment was recorded with candidates labelled as 'fit to dive (FTD)', 'permanently unfit to dive', 'temporarily unfit to dive', 'for instruction under special circumstances' and 'undetermined'. The final category included candidates who did not return for follow-up appointments. All data were entered on a spreadsheet for analysis (Microsoft Office Excel, Seattle, Washington, USA).

INVESTIGATIONS

Some individuals were deemed fit or unfit to dive based on their medical history and examination alone. Others required further testing, including spirometry, bronchial challenge testing, chest X-rays (CXRs) and a wide range of other specialist investigations or were referred to other specialists as indicated for risk assessment. Since neither medical examinations nor pulmonary function tests are mandatory for a return to recreational diving, this information is not available for all subjects.

STATISTICAL ANALYSIS

No power calculations were performed for this opportunistic sample. Statistical analysis was performed in Graphpad Prism v5.0 for Macintosh (Graphpad Software, San Diego California, USA). Differences in proportions were analysed by Chi-square tests and between means using unpaired t-tests.

Results

A total of 198 individuals were referred for dive medical assessments over 10 years at the HBU. Seven were excluded due to insufficient documentation, leaving 191 subjects for analysis. The candidates were aged between 12 and 67 years (mean 32.8 years). 58% were aged between 21 and 35 years and 119 (62%) were male. One-hundred-and-forty-eight (77%) presented in relation to recreational diving (recreational candidates – RC), 42 (22%) for commercial diving (commercial candidates – CC) and in two cases this was unclear.

CANDIDATE DIVE INFORMATION

CCs were more likely to have previous diving experience and had made a significantly greater number of dives (CC median number of dives 275 (range 0–3500), RC 22.5 (range 0–4000), $P = 0.005$). Similarly, the CC group had made deeper maximum-depth dives (CC median 47 metres'sea water (msw), range 0–252, versus RC 22 msw, range 3–60, $P < 0.001$) and had significantly longer diving experience (CC median 12 years, range 0–32, versus RC median 3 years, range 0–32, $P = 0.018$). There was no significant difference in the proportion of previous diving incidents between the groups ($P > 0.4$).

REASONS FOR REFERRAL TO THE DDHM

Dive candidates often presented with a history of more than one problem or checked multiple boxes indicating several diseases in their dive medical questionnaires. We thus identified a total of 507 complaints from the 191 individual candidates. These complaints were broadly categorised by system affected, and these categories are presented in Table 1. Respiratory problems were the most common (32%), followed by ENT (17%), musculoskeletal (13%), CNS (13%) and cardiovascular (6%). On analysis of the primary complaint only, respiratory problems remained the most common (35%), followed by ENT (13%) and cardiovascular conditions (9%). A detailed breakdown of all respiratory complaints is given in Table 2 and a similar analysis of all presenting complaints is available from the corresponding author. We also examined the nature of the presenting complaints according to age (Table 3), which suggested that cardiovascular problems were more common in those over 40 years compared to younger groups, but the analysis was otherwise unremarkable (Chi-square 20.2, $P = 0.03$).

FITNESS TO DIVE

Candidates were analysed for their 'fitness to dive' status at discharge from the DDHM. One-hundred-and-thirty-one (71%) were passed as fit, 49 (26%) were assessed as permanently unfit and six (3%) were temporarily unfit to dive. The remaining six candidates (3%) were unfit according to the AS4005.1 due to paraplegia but passed for instruction under special circumstances. CCs were more likely to be passed fit than RCs (88% versus 66%, $P = 0.0002$).

Asthma

Forty-five (23%) candidates presented with a possible history of asthma (28% of the RC group versus 2% of the CC group, $P < 0.0001$). Current asthma was defined using the standard of either a significant bronchodilator response or evidence of bronchial hyper-responsivenes. Twenty candidates labelled as 'asthmatic' were symptom free and had not used a bronchodilator within the past five years. Five of the remaining 23 candidates used medication daily while the others required medication intermittently.

Table 1
Presenting problems in each category (total n = 507) for 191 subjects including those with a previous history of illness, active disease and those where the diagnosis was uncertain on presentation. Only the more common conditions in each category are listed.

Categories	Common problems	Number of problems
Respiratory (*n* =162)	Hayfever	49
	Asthma	44
	Bronchitis	19
	Coughing phlegm or blood	19
Ear, nose or throat (*n* = 85)	Sinusitis	23
	Nasal problems	17
	Deafness, tinnitus	11
	TM perforation	9
	MEBT	7
Central nervous system (*n* = 72)	Concussion, head injury	14
	Migraines	13
	Headaches unrelated to diving	10
	CNS DCI	10
	Fainting, blackouts	8
Musculoskeletal (*n* = 68)	Fractures	41
	Joint problems	19
Cardiovascular (*n* = 32)	Hypertension	11
	Palpitations, awareness of heartbeat	4
Gastrointestinal (*n* = 25)	Indigestion, peptic ulcer, acid reflux	12
	Non-infective liver disease	4
Other (*n* = 16)	Need for seasickness medication	13
	Severe motion sickness	2
Endocrine (*n* = 10)	Hypercholesterolaemia	5
	Hypothyroidism	4
	Diabetes	4
Mental status (*n* = 10)	Depression	4
	Attention deficit hyperactivity disorder	4
	Anxiety attacks	2
Eye or vision (*n* = 10)	Myopia	9
	Colour blindness	1
Skin (*n* = 9)	Eczema	3
	Psoriasis	3
	Keratosis pilaris	1
	rash	1
Infectious disease (*n* = 7)	Infectious mononucleosis	2
	Hepatitis	3
	Human immunodeficiency virus	1
	Leptospirosis	1
Haematological (*n* = 5)	Von Willebrand's disease	2
	Haemophilia	2
	Venous thrombosis	1
Kidney, urinary tract (*n* = 4)	Cystitis	2
	Renal failure	1
	Renal transplant surgery	1

Pulmonary function tests

Pulmonary function tests performed included spirometry (126 candidates), bronchodilator response and hypertonic saline challenge. Five of the seven candidates having a bronchodilator response test were positive and declared unfit to dive, while eight of 35 candidates having a hypertonic saline challenge were similarly positive and declared unfit. Five candidates had chest radiographs performed, all of which were normal. Overall, 25 of those with possible asthma (58%) were passed 'fit to dive' as no evidence of current asthma was found.

Table 2
Distribution of all respiratory problems; several individuals had more than one such complaint

Respiratory problem	Number of subjects	(%)
Hay fever	49	(26)
Asthma	43	(23)
Sinusitis	23	(12)
Coughing phlegm or blood	19	(10)
Bronchitis	19	(10)
Shortness of breath on exertion	12	(6)
Wheezing	10	(5)
Pneumothorax	8	(4)
Bullous disease	1	(0.5)
Subcutaneous emphysema	1	(0.5)
Haemothorax	1	(0.5)

COMMON NON-RESPIRATORY PROBLEMS

Many candidates ($n = 57$) presented with a history of ear, nose or throat complaints, including nine with aural barotrauma and nine with tympanic membrane perforation. Some (14) were referred for ENT consultation and investigations concerning middle ear auto-inflation, possible hearing loss and tympanic membrane compliance. A minority (12 of the 57 candidates) with ENT problems were assessed as 'unfit to dive' due to ear abnormalities. Other common complaints noted at referral were fractures (41), joint problems (16), migraines (13), other headaches (14), head injuries (14), hypertension (11) and previous DCI (10). A full listing of conditions is available from the authors.

Discussion

The majority of candidates had relative or absolute contraindications to scuba diving, suggesting that referrals were in general appropriate. Many requests concerned respiratory fitness to dive and, in particular, asthma. This remains a very active area of interest for SPUMS. The connection between respiratory diseases and the pathophysiological mechanisms of PBT remains contentious.[5–8] Risk factors for PBT include both physiological and behavioral aspects, such as rapid ascents or inappropriate breath holding, but PBT, may occur in the absence of these factors.[8,9] Current Australian standards for dive medicals place an emphasis on finding conditions that may cause air trapping.[2,3] However, in one of the few studies of airway function prior to the occurrence of PBT, PBT was more strongly associated with a decreased vital capacity (restrictive lung function) than airway obstruction in a group of escape trainee submariners.[10] In another study, also of escape trainee submariners, reduced lung compliance was associated with PBT, suggesting that small, stiff lungs are the problem, rather than mild airway obstruction.[11]

There is no good-quality evidence on which to base risk evaluation for asthmatic divers, but some observational surveys suggest that the relative risk for DCI in this group is twice that of non-asthmatics.[12] A case-control study of 196 divers found a 1.98-fold increase in the incidence of AGE in those with current asthma, but this increase was not statistically significant.[13] Asthma was identified as a contributing factor in 8% of 124 diving deaths in Australian and New Zealand divers, the majority of whom had clinically mild asthma.[14] On the other hand, although there is a reported 5% prevalence of asthma in recreational divers in the USA, many asthmatics have been shown to dive without incident and asthmatics are not statistically over-represented in diving fatalities or accidents in other reports.[1,6] For example, only one asthmatic was identified among 2,132 diving deaths in one report from the USA.[15]

Bronchodilator responsiveness and bronchial provocation tests may assist in the evaluation of potentially asthmatic candidates.[1] At POWH, a hypertonic saline challenge was performed in candidates who were not taking medication, but where current asthma was a potential relative contraindication to diving. Individuals with no abnormalities on other tests and who demonstrated normal bronchial reactivity (<15% decrease in FEV_1 after 8 minutes of inhaling nebulised 4.5% hypertonic saline) were usually passed as fit for diving. Regular use of inhaled glucocorticosteroids reduces BHR in asthmatics; therefore a view becoming more widely accepted is that candidates with well-controlled asthma may be fit to dive.[1,15]

Table 3
Presenting problems by age; includes those indicated by the candidate as the reason for referral, but excludes incidental findings on questionnaire or examination; cardiovascular complaints were more common in the older age group ($P = 0.03$); * includes spine, head injuries and headache

Categories	0–20 years	21–40 years	>40 years
Respiratory ($n = 52$)	2	40	10
Ear, nose or throat ($n = 59$)	2	45	12
Central nervous system* ($n = 61$)	5	45	11
Cardiovascular ($n = 26$)	1	11	14
Musculoskeletal ($n = 58$)	5	37	16
Other ($n = 107$)	11	66	30

Of interest in relation to CAGE, three resort divers in our cohort were referred to us for assessment having developed pneumothoracies while diving. Two had lung bullae detectable by CXR and were made permanently unfit for diving. The third individual, who had no evidence of pulmonary blebs or scars on CT scan, but had suffered a spontaneous pneumothorax three months prior to his visit, was advised to wait another six months before diving. Six candidates had a history of traumatic pneumothorax. Four were recreational divers and only one of these elected to have a high resolution CT scan to look for pulmonary parenchymal or pleural scarring. The CT was normal and that candidate was assessed as fit to dive. The remaining three, and both commercial divers, were assessed unfit.

Dive candidates with the inability to equalise pressure via the Eustachian tube are usually advised not to dive because of the high risk of MEBT and IEBT.[1–3] One candidate suspected of IEBT had three previous episodes of left MEBT, two left tympanic membrane perforations, three diving-related external ear infections and symptoms of vertigo and disequilibrium. Both the diving physician and an ENT specialist advised her not to dive.

Migraines with aura have been associated with the presence of a right to left intracardiac shunt, usually a patent foramen ovale, which, in turn, has been associated with an increased risk of DCI.[16] In addition, headaches that occur during diving can also compromise safety.[17] Individuals with migraines without aura do not typically experience exacerbations related to diving and are not more susceptible to developing DCI.[18]

Epilepsy is a contraindication to diving.[1–3] In this cohort, two recreational dive candidates presented with a diagnosis of epilepsy, but were cleared to dive. A 61-year-old man had a seizure in association with cerebral infarction following an aortic dissection. A further stroke was deemed unlikely by his neurologist, and the risk of DCI estimated to be one to two times the baseline risk given the presence of a cerebral scar. After counselling and risk assessment, he elected to return to recreational diving. Another candidate had been free of petit mal epilepsy for 10 years without medication. Although not consistent with AS4005.1, she was considered 'fit to dive' on condition her dive buddy was informed of her medical history. She was advised not to dive below 30 metres' depth.

Paraplegia is both a disability and an impairment that prevents qualification for a 'standard' open water certification. We assessed six paraplegic candidates who were passed fit to undertake instruction in a specifically developed diving programme.

Hypertension was a common presenting cardiovascular problem. Beta-blockers may both limit exercise and predispose to pulmonary oedema and other cardiac events upon immersion.[19] Of the 11 candidates with treated hypertension, two had a history of atrial fibrillation. One was controlled with amiodarone and elected to continue diving after risk assessment, counselling and a recommendation against further diving. The other had suffered a single episode related to caffeine ingestion. A test dive performed to 10 metres' depth did not result in any problems and he was cleared to dive. Dive candidates with cardiovascular risk factors probably require stress tests to detect ischaemic changes during moderate exercise.[19] These were not performed in a systematic way and we are developing a general policy for future cases.

In this study, we have identified the main triggers for referral to a specialist unit performing fitness to dive assessments, and have quantified the outcomes of those assessments. While we now have a greater understanding of the specific population of dive candidates we serve in this way, this study has a number of limitations. As this was a retrospective study, the data analysed were limited to written records of dive medical assessments, and there was no independent method of verifying the accuracy of the recorded information. This also meant it was not possible to assess whether candidates omitted certain health conditions from their dive medical questionnaire. It is our intention to commence a prospective collection of information in this area in order to provide a more complete and accurate characterisation of these individuals.

In this cohort, dive candidates presented with a variety of medical conditions, many of which were associated with respiratory concerns for FTD, in particular asthma. Despite the current SPUMS advice and the AS4005.1, more than half of those with a possible history of asthma were assessed as fit to dive. This suggests that a substantial proportion of those labelled as asthmatic require further investigations, rather than a blanket response of being unfit to dive. Further, we have documented the development of a more permissive approach that may allow both those with quiescent or well-controlled asthma to dive. A similar approach has been adopted in the latest update to the SPUMS advice to doctors performing dive medicals. This approach is broadly in line with those recommended elsewhere.[6] It is possible that similar approaches may be taken with other medical complaints that have traditionally been accepted as absolute contraindications to diving.

References

1 Mitchell SJ, Bennett MH. Clearance to dive and fitness to work. In: *Physiology and medicine of hyperbaric oxygen therapy*. Neuman T, Thom S, eds. Philadelphia: Saunders; 2008. p. 65-94.

2 AS 4005.1. *Training and certification of recreational divers.* Standards Australia. Strathfield, NSW: Standards Australia International; 2000.

3 AS/NZS 2299.1 Supplement 1:2007. *Occupational diving operations supplement 1: 2299: diving medical examination forms*. Standards Australia. Strathfield, NSW: Standards Australia International; 2007.

4 Edmonds G, Lowry C, Pennefather J, Walker R. Barotrauma. In: *Diving and subaquatic medicine*, 4th ed. London: Hodder Arnold; 2002. p. 55-110.
5 Tetzlaff K, Friege L, Reuter M, Haber J, Mutzbauer T, Neubauer B. Expiratory flow limitation in compressed air divers. *Eur Respir J*. 1998;12:895-9.
6 Godden D, Currie G, Denison D, Farrell P, Ross J, Stephenson R. British Thoracic Society guidelines on respiratory aspects of fitness for diving. *Thorax*. 2003;58:3-13.
7 Blatteau JE, Boussuges A, Gempp E, Pontier JM, Castagna O, Robinet C, et al. Haemodynamic changes induced by submaximal exercise before a dive and its consequences on bubble formation. *Br J Sport Med*. 2007;41(6):375-9.
8 Tetzlaff K, Reuter M, Leplow B, Heller M, Bettinghausen E. Risk factors for pulmonary barotrauma in divers. *Chest*. 1997;112:654-9.
9 Francis J. Pulmonary fitness to dive. *SPUMS Journal*. 2001;30(4):221-6.
10 Benton PJ, Woodfine JD, Francis TJR. A review of spirometry and UK submarine escape training tank incidents (1987–93) using objective diagnostic criteria. In: Elliot DH, ed. *Are asthmatics fit to dive?* Kensington, Maryland: Undersea and Hyperbaric Medical Society; 1996. p. 17-30.
11 Colebatch HJH, Ng CKY. Decreased pulmonary distensibility and pulmonary barotrauma in divers. *Respir Physiol*. 1991;86:293-303.
12 Gorman D, Veale A. SPUMS policy on asthma and fitness for diving. *SPUMS Journal*. 1995;25:213-5.
13 Corson KS, Dovenbarger JA, Moon RE, Bennett PB. Risk assessment of asthma for decompression illness. *Undersea Biomed Res*. 1991;18:16-7.
14 Edmonds C. Asthma and diving. Some observations and thoughts. *SPUMS Journal*. 1991;21(2):70-4.
15 Neuman TS, Bove AA, O'Connor RD, Kelsen SG. Asthma and diving. *Ann Allergy*. 1994;73:344-50.
16 Wilmshurst P, Nightingale S. Relationship between migraine and cardiac and pulmonary right-to-left shunts. *Clin Sci (Lond)*. 2001;100:215-20.
17 Cheshire WP, Ott MC. Headache in divers. *Headache*. 2001;41:235-47.
18 Neuman TS. Near drowning. In: Bove AA, editor. *Diving medicine*. 3rd ed. Philadelphia, PA: Saunders; 1997. p. 218.
19 Bove AA. Cardiovascular problems and diving. *SPUMS Journal*. 1996;26:178-86.

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Cartoon by Peter Harrigan originally published in the *SPUMS Journal*. 1985;15(1).