Diving with pre-existing medical conditions

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Abstract
(Lippmann J, Taylor D McD, Stevenson C, Williams J, Mitchell SJ. Diving with pre-existing medical conditions. *Diving and Hyperbaric Medicine*. 2017 September;47(3):180-190.)
Introduction: This is the second report based on a survey of Divers Alert Network Asia-Pacific (DAN AP) members who dive with cardiovascular and respiratory conditions and diabetes. It examines the medical management of the divers' conditions, any diving modifications used to mitigate the risk and outcomes.
Methodology: An online cross-sectional survey was sent to 833 divers who had declared a targeted medical condition when applying for DAN AP membership between July 2009 and August 2013.
Results: Two-hundred-and-sixty-eight respondents (32%) provided sufficient information on their conditions to be included in the analyses. These included ischaemic heart disease (31), arrhythmias (20), cardiac septal defects (31), other cardiac conditions (10), hypertension (127), diabetes (25), asthma (40) and pneumothorax (5). Forty-nine per cent had sought specialist diving medical advice about their condition and 23% reported modifying their diving practices to mitigate their risk. The cohort had completed 183,069 career dives, 57,822 of these since being diagnosed with their medical condition. There were 27 individuals who reported having decompression illness (25 of whom were subsequently diagnosed with a persistent foramen ovale), and two individuals who experienced an arrhythmia during diving.
Conclusions: Some DAN AP members are diving with medical conditions which could potentially impact the safety of their diving. A minority modified their diving practices to mitigate the risk of their condition and approximately half sought specialist diving medical advice. The incidence of diving-related problems precipitated by known and managed pre-existing health conditions seems low but further studies of larger cohorts and incorporating fatality data would be necessary to confirm this. These results are limited by the 32% response rate and potential for bias towards selection of those most careful with their health.

Introduction

Medical conditions such as asthma, diabetes and many cardiac conditions were long considered absolute contraindications to scuba diving.[1–3] Some sufferers have ignored such advice and, over time, diving medical organisations have progressively modified their advisories on diving with conditions such as asthma and diabetes to allow candidates meeting certain criteria to dive. As a result, it seems likely that an increasing number of divers with these and other co-morbidities, including a variety of cardiovascular conditions, are diving. This has created an increasing need to learn more about the medical conditions of active divers, how these are managed and the impact, if any, that these conditions may have on diving practices and experiences.

This is the second report from a study investigating Divers Alert Network Asia-Pacific (DAN AP) members with declared cardiovascular and respiratory conditions and diabetes (targeted conditions). The first report provided information about the demographics, diving history and activity of members with the targeted conditions and compared these to members without these conditions.[4] This article more closely examines the medical management of the divers' conditions, and how these divers modify their diving practices (if at all) in an attempt to mitigate the risk of a diving incident consequent upon their medical condition.

Methods

Ethics approvals were received from the Human Research Ethics Committees of Austin Health and Deakin University, both in Victoria, Australia. An anonymous, online, cross-sectional medical conditions survey (MCS) was conducted on a cohort of 833 DAN AP adult (> 18 years old) members. The divers had joined DAN AP between 01 July

2009 and 01 August 2013 and had, at the time of joining, declared that they suffered from hypertension, diabetes, respiratory or cardiac conditions. The cardiac conditions mainly comprised ischaemic heart disease (IHD) (previous myocardial infarction and angina), arrhythmias, and septal defects (i.e., persistent foramen ovale (PFO) and atrial and ventricular septal defects). These self-reported diagnoses were interpreted at face value.

An invitation to participate in the survey was sent to these members in August 2013, a reminder was sent in October 2013 and the survey was closed in December 2013. No inducements to participation were offered. Invitees were assured of their anonymity and that responding or otherwise would have no impact on their insurance status.

The MCS consisted of a two-part questionnaire. The first part sought details of the respondents' demographics and diving activity. The second part focused on their targeted medical condition and its management. There were also specific questions about any impact these conditions had on the respondents' diving practices and any adverse incidents that had occurred. The questionnaires are available at <http://www.danap.org/research/med_conditions/>.

All invitees were able to access the first part of the questionnaire, as well as the set of questions relating to their declared condition(s). Participants were invited to enter their responses directly into an online, dedicated, structured query language (MySQL) database (Oracle, Redwood CA).

STATISTICAL ANALYSIS

Responses were downloaded into MS Excel® (Microsoft Corporation, Redmond WA) for collation. Respondents reporting more than one relevant condition (e.g., hypertension and diabetes) were included in the analysis for each relevant condition. A descriptive analysis based on means and standard deviations or median and ranges as appropriate was conducted using SPSS Version 22 (IBM, Armonk, NY; 2013). A conservative minimum required sample size was calculated using the NSS online calculator,[5] assuming a proportion with any specific characteristic of 0.5 and a confidence interval of ± 0.05. The minimum sample size required was calculated to be 263.

Results

Three-hundred-and-forty-three of 833 divers (41.2%) who had reported a targeted medical condition in their DAN membership application responded to the questionnaire. Two hundred and sixty-eight (32.2% of invitees) of the respondents (78.1%) provided sufficient information for inclusion in the study. The mean (SD) age of the invitees was 50 (12) years and 73% were males. By comparison, the mean (SD) age of the respondent cohort was 52.4 (12) years and the proportion of males was 70%. Twenty-one respondents had multiple conditions. Males were in the majority for all diagnostic subgroups except septal defects (10 of 31 male). The mean (SD) age for males was 53.5 (11.8) years, and for females 48.7 (12.4) years (Table 1). The overall mean (SD) body mass index (BMI) was 27 (4) $kg.m^{-2}$. Males had a mean (SD) BMI of 28 (4) $kg.m^{-2}$ and females 26 (4) $kg.m^{-2}$.

The medical conditions of interest were cardiac conditions (92 cases), hypertension (127), diabetes (25) and respiratory conditions, predominantly asthma (45).

Overall, these divers reported a median (interquartile range, IQR) of 350 (150, 800) total dives over a median time of 12 (6, 22) years, with a median of 150 (60, 350) dives done post-diagnosis. Males had dived much more frequently than females (median total dives of 1,000 (388, 2,125) and 400 (225, 1,000) respectively). Details of their diving histories and activities are reported in Table 2. These 268 divers had completed 183,069 career dives including 57,822 since being diagnosed with their medical condition. Other than 27 individuals with decompression illness (DCI) (25 of whom were subsequently diagnosed with a PFO) and two cases of arrhythmias (see later), they reported no other relevant adverse events from diving.

Table 1

Demographic information of 268 individual divers with 289 targeted medical conditions (some with multiple conditions); BMI – body mass index; IHD – ischaemic heart disease; N/A –not applicable; * single case; mean (SD) shown for age and BMI

	Medical condition								
Group	**IHD**	**Arrhythmia**	**Septal defect**	**Cardiac**	**Hypertension**	**Diabetes**	**Asthma**	**Pneumothorax**	**Total**
	(*n* = 31)	(*n* = 20)	(*n* = 31)	(other, *n* = 10)	(*n* = 127)	(*n* = 25)	(*n* = 40)	(*n* = 5)	(*n* = 289)
Sex									
M/F	28/3	16/4	10/21	6/4	102/25	19/6	24/16	5/0	187/102
Age (yrs)									
All	59.1 (7.2)	60.1 (13.6)	45.5 (10.7)	47.3 (11.7)	56.8 (9.4)	54 (11)	40.3 (12.4)	48.4 (12.1)	52 (12)
Male	58.3 (6.7)	63.0 (8.8)	49.2 (8.9)	46.8 (14.1)	56.6 (9.7)	56.1 (10.1)	40.5 (13.9)	48.4 (12.1)	53.5 (11.8)
Female	71.0 (0)*	43.5 (18.2)	46.6 (11.0)	48.0 (8.7)	57.2 (8.5)	53.8 (9.2)	40.0 (10.1)	N/A	48.7 (12.4)
BMI ($kg \cdot m^{-2}$)									
All	29.1 (4.2)	25.8 (4.2)	25.6 (3.6)	24.7 (4.9)	28.1 (3.8)	29.4 (5.1)	25.8 (3.7)	27.0 (2.2)	27.3 (4.2)
Male	29.3 (4.1)	26.5 (4.2)	27.8 (3.0)	24.2 (3.8)	28.4 (3.8)	29.7 (4.8)	26.4 (4.3)	27.0 (2.2)	28.0 (4.2)
Female	23.8 (0)*	22.1 (1.1)	24.5 (3.4)	25.2 (6.9)	26.6 (3.5)	28.3 (6.5)	25.0 (3.0)	N/A	25.5 (3.8)

Table 2

Diving history and characteristics of survey respondents; *n* = number responding to the question; median and interquartile range (IQR) shown; IHD – ischaemic heart disease; nr – not recorded; >30 m – dives deeper than 30 m

Group	**IHD** (*n* = 31)	**Arrhythmia** (*n* = 20)	**Septal defect** (*n* = 31)	**Cardiac** (other) (*n* = 10)	**Hypertension** (*n* = 127)	**Diabetes** (*n* = 25)	**Asthma** (*n* = 40)	**Pneumothorax** (*n* = 5)	**Total** (*n* = 289)
Years diving									
All	19 (11, 30)	8.8 (5, 25)	10 (9.5, 24)	10 (10, 16)	15 (7, 24.5)	14 (7, 25)	8 (5, 11)	13 (6, 13)	12 (6, 22)
Males									13 (5, 25)
Females									10 (7, 17)
Total dives									
All	600 (200, 1,000)	550 (168, 2,300)	440 (300, 1,000)	250 (124, 400)	600 (370, 1,500)	500 (193, 1,200)	100 (80, 150)	1600 (900, 2,300)	350(150, 800)
Males									1000 (388, 2,125)
Females									400 (225, 1,000)
Dives since diagnosis									
All	165 (80, 337)	221 (100, 500)	58 (10, 145)	nr	151 (76, 400)	200 (89, 400)	220 (115, 344)	60 (20, 103)	150 (60,350)
Males									nr
Females									nr
Dives past year									
All	31 (20, 73)	30 (19, 87)	30 (20, 85)	25 (15, 30)	30 (20, 50)	40 (25, 50)	30 (15, 50)	40 (30, 40)	30 (20, 50)
Males									30 (28, 58)
Females									35 (20, 50)
>30 m depth(%)									
All	10 (5, 38)	5 (1, 40)	10 (3.5, 40)	3 (1, 18)	9 (5, 24)	5 (5, 15)	10 (2, 30)	18 (5, 30)	10 (3, 25)
Males									10 (5, 30)
Females									5 (2, 20)
Decompression									
All	2 (0, 5)	0 (0, 13)	2.5 (1, 20)	0 (0, 1)	1 (0, 5)	2 (0, 10)	1.5 (0, 5)	2 (1, 20)	1 (0, 5)
Males									1 (0, 5)
Females									0 (0, 3)
Technical									
All	0 (0, 3)	0 (0, 18)	2 (0, 30)	0 (0, 0)	0 (0, 5)	0 (0, 2)	0 (0, 0)	1 (1, 20)	0 (0, 5)
Males									0 (0, 5)
Females									0 (0, 4)
Repetitive									
All	70 (30, 90)	60 (50, 90)	40 (25, 90)	70 (9, 94)	70 (22, 90)	80 (24, 100)	90 (60, 100)	81 (70, 94)	75 (25, 95)
Males									75 (25, 90)
Females									80 (40, 95)

Table 3
Risk control interventions including medical and diving practices; number (*n*) and percentage shown; IHD – ischaemic heart disease; nr – not recorded; * of those questioned about this

Intervention	Medical condition									
	IHD ($n = 31$)	**Arrhythmia** ($n = 20$)	**Septal defect** ($n = 31$)	**Cardiac, other** ($n = 10$)	**Hypertension** ($n = 127$)	**Diabetes** ($n = 25$)	**Asthma** ($n = 40$)	**Pneumothorax** ($n = 5$)	**Total** ($n = 289$)
Medication	22 (71)	15 (75)	1 (3)	2 (20)	93 (73)	23 (92)	15 (38)	nr	151 (56)
Surgery	19 (61)	1 (5)	25 (81)	0 (0)	nr	nr	nr	nr	45 (49)*
Diving changes	10 (32)	7 (35)	20 (65)	nr	nr	16 (64)	7 (18)	2 (40)	62 (47)*
Consult dive doctor	8 (25)	13 (65)	23 (74)	nr	32 (25)	12 (48)	37 (93)	2 (40)	127 (49)*

INTERVENTIONS

Table 3 shows relevant interventions, where reported, categorized as medication, surgery, changes in diving practice, and diving medical consultation. Specific interventions and activities are discussed by condition in the commentary below.

ISCHAEMIC HEART DISEASE (IHD)

These were divers who reported a previous myocardial infarction (MI) (22 divers), angina (10), "*coronary stent*" (without reference to the indicating symptoms or event) (2), "*coronary artery bypass graf*t" (again, without reference to the indicating symptoms or event) (1), and "*partially occluded coronary artery*" (without explanation of the indication for an angiogram) (1). Fifteen of the 31 respondents with IHD reported co-morbidities of hypertension, diabetes and/or arrhythmia. Corrective interventions included stenting (13) and coronary artery bypass (6). The median (IQR) time since intervention was 5 (2.5, 8) years. These 19 respondents reported having done a total of 8,622 dives since intervention (including one male instructor and technical diver with 4,000 dives) with a median (IQR) of 100 (60, 250) dives. Relevant medications included statins (18), antihypertensives (14), antiplatelet agents (9), beta blockers (6) and anticoagulants (1). No respondents reported current chest pain or precipitation of cardiac-related symptoms during diving.

ARRHYTHMIA

Reported arrhythmias included atrial fibrillation (AF) (9 divers), ventricular tachycardia (3), supraventricular tachycardia (SVT) (3), first degree heart block (1), unspecified heart block (1) and unifocal ventricular ectopics (1). Two conditions were unspecified. One respondent (a male with Advanced and Enriched air certifications) had corrective surgery, an ablation for SVT, and had subsequently done more than 700 incident-free dives. Relevant medications included beta blockers (7), anticoagulants (2) and antiplatelet agents (2). One diver reported taking the antiarrhythmic flecainide.

Two respondents reported having experienced symptoms from their arrhythmia during diving. One of these, diagnosed with SVT, had two SVT-type events while exerting himself on the surface post-diving. The other, diagnosed with AF which was generally well-controlled, went into AF during a dive. On another occasion, this diver had an unrelated episode of "*very mild*" DCI (symptoms unspecified).

SEPTAL DEFECTS

Of the 31 respondents with a septal defect, 27 reported a PFO, three an atrial septal defect (ASD) and one a ventricular septal defect (VSD). The median (IQR) number of dives conducted prior to diagnosis of a septal defect was 438 (252, 763). The relative proportions of technical and decompression diving among respondents with known septal defects was higher than for the remainder of the cohort, albeit still generally low.

The total years' diving were similar for divers with a PFO or an ASD (10 (7.8, 18) versus 9 (7, 18.5) respectively) . However, divers with a PFO had done more dives than those with an ASD before diagnosis; 400

(224, 775) vs. 240 (140, 345) respectively. The diver with a VSD had been diagnosed prior to beginning to dive, had no intervention and had done 130 uneventful dives at the time of this survey. Twenty-five of the 31 respondents with septal defects had suffered DCI prior to discovery of their defect which is unsurprising because it is DCI events that typically provoke investigation for such lesions. These accounted for 25 of the 27 respondents with medical conditions who reported having DCI over the course of their diving careers.

Twenty-five of the 31 respondents underwent surgery to insert a closure device and, of these, 22 reported an effectively-closed shunt. These 25 respondents who underwent closure had undertaken 15,849 dives prior to the intervention with 23 individuals suffering DCI. After closure, they had completed 2,771 dives with only one individual (who was among the 22 who reported an effectively closed shunt) having a recurrence of DCI (several episodes of skin rash only). This individual exhibited no residual shunt in his post-procedure echocardiogram and has completed over 1,000 dives since.

One respondent reported taking long-term aspirin since his PFO closure. Medications taken by three others were unrelated to their septal condition.

OTHER CARDIAC CONDITIONS

Ten respondents reported having "*other cardiac conditions*" but only seven specified the condition (mitral valve prolapse (6) and heart murmur (1)). None of these seven reported taking medications, but one of the others was taking an anti-hypertensive agent.

HYPERTENSION

One-hundred-and-twenty-seven respondents reported having hypertension; the median (IQR) time since diagnosis of hypertension being 7 (4.5, 15) years. The main medication types reported included angiotensin II antagonists (43, 34%), ACE inhibitors (41, 32%), calcium channel blockers (29, 23%) and ß blockers (13, 10%). The respondents with declared hypertension were asked to report their last blood pressure measurement, although it was not specified if this was measured by a healthcare professional or themselves. The mean (SD) reported systolic BP was 128 (9) and diastolic 78 (7).

Only one diver reported a general on-going problem associated with hypertension (headache) and none reported problems with diving as a result of their condition. One diver with hypertension also reported having had DCI but did not specify his symptoms. Perceived risks of diving with hypertension reported by the divers included cardiac events, stroke and decompression illness.

DIABETES

Twenty-five respondents reported diabetes. The mean (SD) BMI was 29 (5) $kg.m^{-2}$ with four of normal weight, 13 overweight and eight obese. The median (IQR) time since diagnosis was 7.5 (6, 11.5) years and the total number (range) of dives conducted since diagnosis was 9,143 (30 to 3,500) dives. Four divers were insulin-dependent, 19 were controlled by oral medications plus diet and exercise, and two by diet and exercise alone. Medications reported were biguanides (19), sulfonylureas (6), insulin (4), dipeptidyl peptidase-4 inhibitors (4), alpha glucosidase inhibitor (1), meglitinide (1) and thiazolidinedione (1).

Only one respondent reported having ever been admitted to hospital as a result of their diabetes. Seven divers reported having self-managed a hypoglycaemic event ('hypo') in any context (none while diving), two of these having done so in the previous year. No respondent required the help of another person to manage their symptoms during the previous year. Of those who reported having a 'hypo', the median (IQR) time since the last 'hypo' was 2 (1.25, 2) years. Three respondents reported diabetes-related complications. These were cardiac, kidney disease and visual problems. Thirteen of the 25 had undergone an exercise ECG as part of their assessment.

Sixteen of the 25 diabetic respondents (including three of the four who were insulin-dependent) measured their blood glucose level (BGL) before diving, although none practiced strictly in accordance with the relevant guidelines of the South Pacific Underwater Medicine Society (SPUMS) or Undersea and Hyperbaric Medicine Society (UHMS).[6,7] The frequency of pre-dive measurement varied from one to three times, and the timing from 15 minutes to three hours before diving. The mean (SD) minimum BGL that these respondents reported to be acceptable before diving was 6.1 (1.6) $mmol \cdot L^{-1}$ with a range of 3.5 to 10 $mmol \cdot L^{-1}$. Five respondents changed their medication regimen prior to diving – three did not take their oral medications and two insulin-dependent divers reduced their insulin dose. Four respondents reported changing their mealtime to increase carbohydrate and sugar intake before diving. Only six respondents routinely checked their BGL post-diving (including two of the four insulin-dependent divers), only one of these doing so more than once. One insulin-dependent respondent reported checking his BGL hourly for three hours, while the other five respondents who routinely checked did so at periods of five minutes to several hours after diving.

Sixteen respondents reported being aware of the relevant guidelines and 10 of these indicated that these guidelines had influenced their diving practice. This included BGL monitoring, increased vigilance, greater medical oversight and careful buddy selection. Nine of the 12 respondents who consulted a diving doctor had periodic diving medical

reviews, at intervals of 6–12 months. Perceived risks reported by the diabetics included loss of consciousness in- or underwater, confusion and an increased risk of decompression illness.

ASTHMA

Forty respondents reported asthma. Twenty-eight of 30 who answered the relevant question reported having been diagnosed with asthma before taking up diving. The median (IQR) time since diagnosis of asthma was 19 (13, 30) years. Eleven respondents had been admitted to hospital between one and four times, with the median (IQR) number of admissions being 1 (1, 2). The median (IQR) time since last admission was 16 (15, 23) years. The time since last asthma symptoms ranged from one week to 20 years with a median (IQR) of 2 (0.3, 10) years. Fifteen respondents had symptoms during the previous year including wheeze (13), reduced exercise capacity (9), dyspnoea (5) and increased sputum production (3). Identified asthma triggers were allergy (13), infection (8), cold (5) and stress (1). Thirteen respondents used 'preventer' medications, most often daily and 22 used bronchodilators (in all cases salbutamol) either daily (5), monthly (5) or annually (12). There were no reported exacerbations of asthma while diving. The perceived risks from asthma reported by the divers included pulmonary barotrauma, dyspnoea and reduced exercise capacity.

PNEUMOTHORAX AND CHEST SURGERY

Five respondents reported having had a pneumothorax one to five years previously. All were divers at the time of their event. Few condition-specific data were provided by two of the divers so the following is based on the three others. All were left-sided; two were trauma-related and were managed with a chest drain. The other was spontaneous and required no treatment. The two with trauma-related injuries underwent subsequent CT scans (one specifically for informing future diving) while the respondent with the spontaneous event did not. Subsequently the spontaneous pneumothorax victim had conducted 20 dives, whilst the two traumatic pneumothorax victims had completed 30 and 200 dives with no reported problems. Another respondent had a pulmonary lobectomy to remove cancer 11 years prior. He underwent a subsequent CT scan and returned to diving after consultation with a diving doctor. He subsequently had done 750 incident-free dives.

MEDICATIONS

One-hundred-and-fifty-one respondents reported taking a total of 337 medications. The main classes of medications taken are shown in Table 4. The full list of individual drugs is available on request from the corresponding author at <johnl@danap.org>.

Table 4

Classes of medications from 151 respondents (some used multiple medications); * % based on 337 reported drugs used by 151 respondents; # includes two respondents on clopidogrel; table does not include medications taken by less than three respondents

Class	Frequency	(%)*
Statins	51	(15)
Angiotensin 2 receptor antagonists	43	(13)
ACE inhibitors	41	(12)
Calcium channel blockers	29	(9)
Bronchodilators	22	(7)
Biguanides	19	(6)
Diuretics	17	(5)
Antiplatelet agents#	16	(5)
ß blockers	15	(4)
Inhaled glucocorticoids	13	(4)
Proton pump inhibitors	12	(4)
Sulfonylureas	6	(2)
Insulin replacement	4	(1)
Dipeptidyl peptidase-4 inhibitor	4	(1)
serotonin reuptake inhibitors	3	(1)
Serotonin-norepinephrine reuptake inhibitors	3	(1)
Non-steroidal anti-inflammatories	3	(1)
Anticoagulants	3	(1)
Thyroxine replacement	3	(1)
Total	307	(91)

DIVING MODIFICATIONS

Sixty-two (23%) respondents reported having directly modified their diving practice. It is possible that this is an under-estimate as many failed to respond to this question. Reported modifications included:

- exertion avoidance (MI, angina, arrhythmia);
- stress avoidance (MI, angina, asthma);
- reduced depth (MI, angina, septal defect);
- use of nitrox, more conservative dive profiles, padding decompression time or safety stops to be longer than prescribed by tables or computers, longer surface intervals (septal defects);
- less repetitive diving, especially true of the respondents with septal defects who engaged in a much lower proportion of repetitive dives than most of the other groups;
- careful buddy selection and briefing (diabetes, arrhythmia);
- avoidance of cold water (arrhythmia, asthma);
- reduced ascent rate (septal defects, pneumothorax).

In addition to the above actual diving modifications, some respondents also reported:

- increasing vigilance for symptoms before, during and after diving (arrhythmia, diabetes, asthma);
- adjustment of their medication (diabetes, asthma).

Discussion

This study identified the characteristics, behaviours and outcomes of active divers with significant medical conditions. Despite our focus on some conditions that are perceived to significantly impact on diver safety, and setting aside the 25 cases of DCI occurring in divers with unrepaired septal defects, our respondents reported only five other significant adverse events in over 183,000 career dives, 57,000 of which occurred post-diagnosis and 13,000 over the year immediately preceding completion of the questionnaire. This is not surprising as, in many cases, the conditions had been or were being appropriately managed (e.g., closure of septal defects, coronary stenting, coronary bypass grafting, effective glucose control in diabetes) and that specific risk mitigation measures had sometimes been introduced to their diving practice. Although our numbers are small and these voluntarily reported data deserve cautious interpretation, our findings are generally supportive of an argument that these diagnoses per se are not necessarily contraindications to diving as they have frequently been considered in the past.

ASTHMA

Traditionally one of the greatest controversies in fitness to dive discussions involved asthma which, for a long time, was regarded as a complete contraindication to diving. Common triggers associated with the diving environment include exercise, cold, the breathing of cold, dry air, anxiety and salt water aspiration. An exacerbation while diving creates the potential for gas trapping and pulmonary barotrauma, as well as the potential for drowning as a result of dyspnoea.

Various surveys of diving cohorts in Australia, the United Kingdom (UK), the United States (USA) and of German-speaking divers have indicated a prevalence of active asthma in approximately 3–9% of respondents.[4,8–12] There have been reports of pulmonary barotrauma and arterial gas embolism in asthmatics,[8,13] but the extent to which asthma materially increases the risk of barotrauma remains unclear. A survey of DAN America members[13] appeared to indicate an increased risk of DCI in those with asthma, while a U.K. report[8] did not. Our respondents diagnosed with 'asthma' reported no related problems in 7,613 dives. Given the small numbers it is difficult to categorise this as anything other than 'reassuring', but like others, we see no signal of increased risk in our data.

Nevertheless, there are sufficient grounds for believing the risk is more than merely theoretical. A prospective study of 100 UK divers reported that 20 who would have been excluded, based on prevailing selection criteria,[14] had problems during diving including wheezing underwater.[15] Moreover, there are reports of diving fatalities that were directly attributed to asthma.[16,17] The absence of related problems in ours and other's data may indicate that the risks of diving, particularly in mild asthmatics, is small or that most divers manage their asthma and diving activities adequately.

In our cohort of 40 divers, 37 had consulted a diving physician about their asthma. This would have allowed both optimisation of their condition and discussion of how best to manage it in relation to diving. Various diving medical guidelines are available (including those of SPUMS[18]) to guide both the physician and the diver in this setting, and all divers with asthma are well-advised to have a diving medical assessment by a doctor with relevant training.

DIABETES

Historically, diabetes mellitus, especially in its insulin-dependent form, has been considered an absolute contraindication to diving. The main concern is the consequences of reduced mentation or unconsciousness because of hypoglycaemia during diving. Blood glucose levels (BGLs) do fall with diving and such falls could be substantial and potentially dangerous under demanding conditions. Other concerns include diabetes-related end-organ damage, especially co-existing cardiac disease.

However, in 1991, the UK Sports Diving Medical Committee softened its position and the British Sub-Aqua Club (BSAC) and some other UK-based certification agencies led the way in enabling selected diabetic divers to dive, albeit with some restrictions. Several studies have subsequently been conducted to monitor the habits and blood glucose levels of divers with diabetes before, during and after real or simulated diving exposures.[19–23] The accumulation of these data, with an associated low incidence of related problems, suggests that people with diabetes can dive safely provided risks are managed effectively by appropriately educated individuals.

As a result, the prohibition on diving with diabetes has eased and more individuals with diabetes are diving, preferably under the general oversight of their endocrinologist as well as a diving physician. In a 2000 survey of 346 experienced Australian divers, only one respondent (0.2%) reported having diabetes.[10] However, in 2014-15, 21/1,119 (1.9%) DAN AP members, 8/350 (2%) PADI members and 9/806 (1%) of PADI-certified divers (most of whom did Open Water Diver courses in the previous four years) who responded to a general diving activity survey reported having diabetes (unpublished DAN AP data). Although survey data are subject to a variety of limitations including response bias, this likely indicates an increase in the number of diabetic divers in Australia.

A 2005 workshop sponsored by the UHMS and DAN led to the development of guidelines for recreational diving with diabetes mellitus.[7] These guidelines describe protocols for diver selection and management of insulin during a day of diving. Although they have been largely endorsed by several diving medical organisations (including SPUMS), there are

few data describing their uptake and utility.[24] Only 16 of the 25 respondents with diabetes were aware of the UHMS/DAN or SPUMS guidelines and none reported strictly following them. Of concern is the substantially lower mean minimum pre-dive blood glucose level (BGL) of 6.1 mmol.L^{-1} in this study, versus 8.3 mmol.L^{-1} recommended by UHMS/DAN, or 9.0 mmol.L^{-1} recommended by SPUMS. However, this must be interpreted cautiously. Our BGL data are derived from all respondents (including diabetics who do not use insulin) whereas the quoted recommendations apply to insulin-dependent diabetics. In addition, less than half of the respondents had consulted a diving doctor and fewer had periodic diving medical reviews. These findings identify an educational opportunity for improving practice but it is not obvious how diabetic divers or prospective divers can be encouraged to engage with a diving doctor. At the very least, we recommend that those who do so should be provided with the SPUMS or DAN/UHMS guidelines and strongly urged to follow the practice recommendations contained therein.

SEPTAL DEFECTS

There are few available data on diving with most cardiac-related conditions. One exception to this is PFO which has received considerable attention and has been identified as a risk factor for cutaneous, inner ear, cerebral and spinal DCI.[25–28] Twenty-five of the 27 respondents who reported having DCI were diagnosed with an intra-cardiac right-to-left shunt, predominantly a PFO. This was the only group with a higher proportion of females, although there appears to be no evidence of a higher incidence of PFO in women.[29] Overall, this group was relatively young and did more decompression and technical diving. It is plausible that these diving activities result in higher venous gas emboli loads, therefore making the diving-related clinical complications of a septal defect more likely, which in turn makes it more likely that the defect will be detected.

Subsequent risk management through surgical intervention and/or changes to diving practice (e.g., our respondents reported less repetitive diving than other cohorts) appear to have been very successful. Similar results were reported in a study of UK divers.[30] Twenty-two of the 28 respondents with a PFO in that study had been diagnosed after an episode of DCI; 20 divers had a surgical closure and 16 returned to diving. Those who continued to dive without closure successfully adopted more conservative diving practices similar to those used by the Australian cohort.

CARDIAC CONDITIONS AND HYPERTENSION

Factors such as central fluid shifts caused by immersion, exercise, cold-induced vasoconstriction, changes in gas density, static lung loads and psychological stress can increase cardiac preload, afterload, heart rate and myocardial work. Based on first principles, this would make a myocardial event more likely in predisposed individuals. A study of 947 recreational scuba diving fatalities indicated that a myocardial event was the likely disabling injury in 26% of the deaths.[31] Not surprisingly, fatality reports suggest that risk increases in older divers and in males.[32,33] UK fatality data show an increasing incidence of cardiac-related incidents against a background of an ageing diving population.[34,35]

Recent data suggest that 22% of Australians over 18 years old had one or more cardiovascular diseases with the prevalence being greatest in older age groups.[36] It is inevitable that individuals with various degrees of cardiovascular disease are diving. A survey of Australian divers in 2000 suggested that this applied to 5.7% of respondents.[10] More recent DAN AP survey data indicate that this may have been an underestimation or has subsequently increased, suggesting a prevalence of 9% in recently certified divers and 12–17% in predominantly older, long-time and experienced divers (unpublished DAN data).

It is clear that cardiac disease is prevalent and represents a very real risk in diving and snorkelling,[31] especially if it is poorly-managed. On the basis of witness reports and evidence of cardiac disease or abnormality at autopsy, many diving deaths have been attributed to arrhythmias.[37–44] However, in the absence of a definitive post-mortem test this remains speculative. These Australian data also reveal that, although some victims were under treatment for cardiac disease at the time of their demise, in many their condition was undiagnosed. Any condition that increases the risk of arrhythmia and/or myocardial ischaemia may compromise safety and needs to be thoroughly investigated, preferably with involvement of a diving medical specialist. In this study, only 21 of 51 divers with ischaemic heart disease or arrhythmia reported having consulted a diving physician. A UK study also reported a low rate of diving medical consultation in those with cardiac disorders.[30]

Arrhythmias

A consensus discussion on cardiac disease during the 2010 DAN Fatality Workshop included a recommendation for automatic exclusion from diving for those with "*arrhythmias causing impairment of exercise tolerance or consciousness*".[45] Fitness-to-dive considerations for an individual with arrhythmias should include factors such as the nature of the arrhythmia, the frequency and effect of episodes, the presence and type of causative disease, the treatment used and its success. In addition to considering the likelihood of an episode while diving, it is important to consider the potential adverse effects of medications, including the potential for reduced exercise capacity associated with beta-blockers or the potential for increased bleeding associated with anticoagulants.

Two of this survey's respondents with arrhythmias (20) reported at least one episode while diving, fortunately

without injury. Most were well-controlled by medication and under diving medical oversight, but about two-thirds reported that they had not modified their diving practices (e.g., by avoiding exertion, cold water, mandatory decompression) in response to their condition.

Ischaemic heart disease

In this survey, 19 of the 31 respondents with IHD had undergone revascularisation although the degree of success is unknown. Complete revascularisation with restored exercise capacity without ischaemia may enable relatively safe diving in low-stress environments.[46] However, only 10 of the 31 divers reported changing their diving behaviour. The divers with IHD were experienced, long-time divers and this might explain a reluctance to change established patterns. Only two of the 10 divers who reported having had angina had sought specific diving medical advice or changed their diving practices.

Hypertension

Given that hypertension was the most frequently managed problem in Australian general practice during 2013–14,[47] it is not surprising that respondents with hypertension represented the largest subgroup in this study. The majority (93 of 127, 73%) of hypertensive respondents were on a blood pressure control regimen. This contrasts with a UK study in which fewer (50%) of the divers with the diagnosis of hypertension took medications, the most common being ACE inhibitors and angiotensin-II antagonists.[30] None of the hypertensive divers in this study reported problems with diving over a total of 32,840 dives. Similarly, despite potential adverse effects of some medications used to manage hypertension,[48] none were reported. The most common antihypertensives used were angiotensin II receptor antagonists, which have been suggested as the preferred agents for the treatment of hypertension in divers.[48]

Medical screening

Current diving medical screening guidelines recommend a cardiovascular review for all males at age 45 and females at age 55 years.[45] Active or prospective divers should follow this advice; in any case, consult a diving medical physician in the event that they suffer from any significant chronic or acute medical condition that could be impacted by diving. Overall, only about half of this group had consulted a diving physician about their medical condition. Presumably many of the remainder may have discussed their circumstances with their general practitioner or specialist. However, in the experience of these authors, in the absence of specific diving medical knowledge, it is likely that some of the potential triggers of the diving environment may not have been sufficiently considered.

LIMITATIONS

This study has several limitations:

- The response rate of 32% may have introduced a response bias.
- The results are based on a survivor group of divers and fail to account for diving fatality victims with similar conditions that might have contributed to their demise, as well as divers who may have survived an event and stopped diving as a consequence. Therefore, the study sample may be biased towards milder forms of these conditions.
- DAN AP members are probably not typical of the general diving population. They are likely to be older, have an increased likelihood of co-existing disease, have more available funds, may travel more and may better understand their potential vulnerability and the need for and benefits of having appropriate insurance.
- Some applicants for DAN membership may have been reluctant to declare medical conditions for fear of it affecting their ability to obtain or retain insurance coverage, although it is made clear that failure to declare a relevant condition may nullify coverage. As a result, there were likely to have been more than the 833 members invited to join the MCS who were suffering from the targeted health conditions. In addition, although the survey was anonymous, it is possible that there may have been divers reluctant to disclose diving incidents owing to concern that their insurance cover might be affected. If so, this is another potential source of bias.
- The nature of some of the more historical questions may have introduced a recall bias.
- Many responses were excluded from the analysis due to missing replies to certain questions.
- The number of dives performed by divers with particular conditions is relatively small for the purposes of an epidemiological evaluation. Our ability to interpret the associated risks is therefore limited.

Conclusions

These results are limited by the 32% response rate and potential for bias towards selection of those most careful with their health. However, a substantial minority of DAN AP members are diving with medical conditions such as cardiac conditions, hypertension, diabetes and asthma which could potentially impact the safety of their diving. Many of the conditions were controlled by medications, several of which could themselves have adverse effects while diving. Surgical intervention was common for divers diagnosed with a PFO or ischaemic heart disease. Only one quarter of the divers reported modifying their diving practices to accommodate their condition, and only half had sought specialist diving medical advice. Despite the obvious concerns, our respondents with known and largely managed medical problems have dived with very few

incidents associated with their conditions. Conclusions based on survivor populations must be cautious and our numbers remain relatively small, but it does seem that, if these medical conditions are identified and managed appropriately, the risks associated with diving may be acceptable. More research with larger cohorts is needed to better understand the risks in an ageing comorbid diving population.

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Conflicts of interest

John Lippmann is the Founder and Chairman of DAN AP. DAN is involved in the collection and reporting of dive accident data and provides evacuation cover and dive injury insurance to recreational divers.

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