Regular medication use by active scuba divers with a declared comorbid medical condition and victims of scuba and snorkelling-related fatalities

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DAN – Divers Alert Network; Diving deaths; Diving incidents; Health status; Pharmacology; Recreational diving

Abstract
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Introduction: The aim of this study was to describe the nature of regular medications taken by active comorbid scuba divers (having a declared medical comorbidity) and scuba divers and snorkellers who died following a diving incident.
Methods: We undertook a retrospective, observational study from July to October, 2020. Data on 268 active comorbid divers were obtained through a 2013 survey of Divers Alert Network Asia-Pacific members. Data on 126 deceased scuba divers and 175 deceased snorkellers were obtained predominantly from 2001–2013 reports to Australian State Coronial Services.
Results: The active comorbid divers were significantly older, less likely to be male, and more likely to be taking one or more medications than the two deceased subject groups ($P < 0.001$). Cardiovascular, endocrine and psychotropic medications accounted for 53.4%, 9.9% and 6.4% of all medications taken, respectively. Almost one tenth of the deceased divers took at least one psychotropic medication, a proportion significantly greater than the other groups ($P = 0.01$).
Conclusions: Medication use among active comorbid divers is common which likely reflects their declared medical condition. Nevertheless, they appear to be diving relatively safely, often with conditions once thought to be absolute contradictions to scuba diving. The deceased divers took significantly more psychotropic medications. It is possible that their underlying psychological/psychiatric conditions rendered them more at risk of a diving incident. Increased vigilance for psychological conditions may need to be considered during diving medical examinations.

Introduction

The scuba diving population is aging.[1,2] Concurrent with this is the increasing prevalence of medical comorbidities among divers, some of which may have significant implications for diving safety, specifically cardiovascular and respiratory diseases, and diabetes.[3–5] In fitness to dive evaluations, the simple presence or absence of a comorbidity is a blunt discriminator of its importance. For example, there is likely a considerable difference between diabetes being managed only by diet and exercise compared to being managed with a strict regimen of frequent insulin injections. Given this, scrutiny of a potential diver's medication regimen is of importance.

Traditionally, the main concerns about medications taken by scuba divers have involved medications to reduce the risk of ear barotrauma[6,7] and motion sickness.[8,9] More recently, increasing numbers of aging divers and snorkellers have reported taking a broad range of regular medications, mainly for cardiovascular conditions.[5,10–13] Concerns about the interactions of some medications with the hyperbaric environment have been described.[9,13–16] Some medications (e.g., angiotensin-converting-enzyme inhibitors [ACE-I]) affect fluid balance and vascular tone and may compound the cardiac effects of immersion. Others (e.g., beta-blockers) reduce exercise tolerance and may limit a diver's ability to deal with exertional requirements. Some may cause drowsiness (e.g., benzodiazepines), increase the likelihood of narcosis (e.g., antihistamines) or lower the seizure threshold (e.g., tramadol).[16]

Given these theoretical concerns, the use of regular medications among victims of scuba diving fatalities has raised questions about the contribution that their medications may have had. Sometimes it is difficult to determine if it is the medications themselves or the underlying comorbidities that may have contributed to the death. Although respondents to a recent survey[10] reported no significant problems associated with their medication use, this was a relatively small survivor

cohort and further research involving larger groups of divers is required to better understand this area of potential risk. In exploring this issue, a 2019 systematic review concluded that there is no evidence of significant risk due to changes in medication mechanisms in the hyperbaric environment and that most medications are not contraindications to diving.[14] However, it was acknowledged that the available evidence is limited and called for additional human studies.

This study aimed to comprehensively describe the nature of regular medications taken by three subject groups: active comorbid scuba divers, and victims of scuba diving or snorkelling-related fatalities. It is hypothesised that, if comorbidities were a significant contributor to diving and snorkelling fatalities, the pattern of medication use across the three groups would be similar.

Methods

We undertook a retrospective, observational study using existing data sources. Data on active comorbid scuba divers were obtained through a 2013 anonymous, online, cross-sectional survey of adult Divers Alert Network Asia-Pacific (DAN AP) members with a declared medical condition. The survey methodology is described in detail elsewhere.[10] Data on victims of scuba diving and snorkelling-related fatalities (deceased divers and deceased snorkellers, respectively) were obtained from reports to various Australian State and Territory Coronial Services on fatalities that occurred during 2001–2013, inclusive. This involved a comprehensive key word search of the National Coronial Information System (NCIS).[17] The methodology for identifying relevant NCIS cases is described in detail elsewhere.[11,18] For snorkelling-related fatality cases prior to 2004, data were obtained from coronial reports in conjunction with relevant Project Stickybeak reports.[19–21]

Ethics approval for the components of data collection were variously obtained from the Human Research Ethics Committees of Austin Health, Royal Prince Alfred Hospital, Deakin University, the Victorian Department of Justice, the Coroner's Court of Western Australia, and the Queensland Office of the State Coroner.

Data on demographics (age, gender) and regular medication use were extracted electronically from the data sources. Two hospital pharmacists (DP, KB) reviewed all medications reported and deleted those with indeterminate names, non-medications (e.g., amino acid supplements and herbal products) and non-regular over-the-counter medications (e.g., paracetamol, pseudoephedrine). Medication trade names were changed to generic names. Where a combination product was used, the component medications are reported individually. A senior hospital pharmacist (ST) then separated all medications into relevant major and minor medication classifications: cardiovascular, endocrine, neurological, psychotropic, respiratory or 'other' types of medication.

The primary outcome measure was the proportion of subjects in each group who regularly took at least one medication from a major medication classification. This allowed comparisons of the nature of the medications taken by the three subject groups (active comorbid divers, deceased divers and deceased snorkellers). Not all medications are detailed within this report; the focus being on those most relevant to diver safety (e.g., medications for ischaemic heart disease, epilepsy).

No *a priori* sample size calculation was undertaken as all cases who responded to the DAN AP survey and all scuba- and snorkelling-related deaths were included. The data are reported descriptively as absolute numbers (with percentages) and means (with standard deviations). Comparison of proportions and means employed the Chi-square and analysis of variance tests, respectively. SPSS for Windows statistical software (version 26.0, SPSS Inc., Chicago, Illinois, USA) was employed for all statistical analyses. The level of significance asumed was 0.05.

Results

Survey data on 268 active comorbid divers were available and there were 126 and 175 cases related to scuba diving and snorkelling fatalities, respectively. The mean age and gender mix of the three groups differed significantly ($P < 0.001$, Table 1). Overall, the deceased divers were

Table 1
Subject demographics and regular medication use

Parameter	Active comorbid divers *n* = 268	Deceased divers *n* = 126	Deceased snorkellers *n* = 175	*P*
Age, years mean (SD)	52.5 (12.1)	44.5 (12.0)	48.9 (18.1)	< 0.001
Males, *n* (%)	187 (70.0)	99 (78.6)	157 (89.7)	< 0.001
Takes one or more regular medications *n* (%)	155 (57.8)	36 (28.6)	39 (22.3)	< 0.001

Table 2

Absolute numbers of medications taken by the subject groups. COPD – chronic obstructive pulmonary disease; *Only if the medication was purely for epilepsy, i.e., phenytoin. Medications that had indications other than epilepsy were not included in this subclassification. #lithium (n = 3, one in each subject group), diazepam (two), nitrazepam (one), temazepam (one), clonazepam (one), alprazolam (one), dexamphetamine (one in the deceased diver group), bupropion (one), methylphenidate (one in the active group), melatonin (one)

Medication classification	Total number of medications taken by subject group (rate of use per subject)		
	Active comorbid divers n = 268	Deceased divers n = 126	Deceased snorkellers n = 175
Cardiovascular	209 (0.78)	25 (0.20)	56 (0.32)
Antihypertensives	143	14	24
Medications for dyslipidaemia	52	6	13
Medications for angina	1	1	8
Medications for heart failure	4	1	3
Other	9	3	8
Endocrine	46 (0.17)	3 (0.02)	5 (0.03)
Medications for diabetes	37	2	3
Other	9	1	2
Neurological	3 (0.01)	4 (0.03)	5 (0.03)
Antiepileptics*	0	1	0
Other	3	3	5
Psychotropic	11 (0.04)	14 (0.11)	10 (0.06)
Antidepressants	7	8	4
Antipsychotics	0	1	2
Other#	4	5	4
Respiratory	16 (0.06)	7 (0.06)	2 (0.01)
Medications for asthma or COPD	16	6	2
Other	0	1	0
Other	56 (0.21)	37 (0.29)	34 (0.19)
Total number of medications	341 (1.27)	90 (0.7)	112 (0.6)

younger than the active comorbid divers and deceased snorkellers were almost all male.

The use of regular medications differed significantly across the groups ($P < 0.001$, Table 1). More than one half of active comorbid divers took at least one regular medication, a proportion more than twice that documented for the deceased divers and snorkellers. A total of 161 different medication entities were taken by all groups combined, with active comorbid divers taking the greatest variety of these medications.

The 268 active comorbid divers took a total of 341 medications, whilst the 126 deceased divers took 90 medications and the 175 deceased snorkellers took 112 medications: rates of 1.27, 0.71 and 0.64 medications per subject, respectively ($P < 0.001$, Table 2). Approximately one half of medications taken by the groups combined (290, 53.4%) were for cardiovascular conditions with the active comorbid divers accounting for the large majority of these. Approximately one tenth of medications were for endocrine conditions and, again, most were taken by the active comorbid divers. The rate of psychotropic medication use was greatest amongst the deceased divers at 0.11 medications per subject. The numbers of respiratory medications were quite low although a considerable number of asthma medications were taken by the active comorbid divers.

The nature of the medications taken by the groups differed significantly ($P < 0.001$). Table 3 describes the number and percentage of all subjects in each group who took medications in major and minor medication classifications. For example, 16 (12.7%) of the 126 deceased divers took at least one cardiovascular medication. More than one quarter (28.3%) of all subjects took at least one cardiovascular medication, with the greatest proportion (44.4%) in the active comorbid

Table 3

Absolute numbers (%) of subjects who take one (or more) medication from each of the medication groups and subgroups. *Five snorkellers were known to be taking medications. However, the nature of these medications is not known. Hence, the number (%) of snorkellers taking medications is underestimated. #Only if the medication was purely for epilepsy i.e., phenytoin. Medications that had indications other than epilepsy were not included in this subclassification

Medication classification	Numbers (%) of subjects who take one or more medications		
	Active comorbid divers *n* = 268	Deceased divers *n* = 126	Deceased snorkellers *n* = 175*
Cardiovascular	119 (44.4)	16 (12.7)	26 (14.9)
Antihypertensives	96	14	17
Medications for dyslipidaemia	52	5	10
Medications for angina	1	1	7
Medications for heart failure	3	1	3
Other	3	1	1
Endocrine	32 (11.9)	2 (1.6)	4 (2.3)
Medications for diabetes	23	1	2
Other	10	1	2
Neurological	2 (0.7)	4 (3.2)	3 (1.7)
Antiepileptics#	0	1	0
Other	2	3	3
Psychotropic	8 (3.0)	12 (9.5)	6 (3.4)
Antidepressants	7	9	4
Antipsychotics	0	1	1
Other	4	4	4
Respiratory	13 (4.9)	5 (4.0)	2 (1.1)
Medications for asthma or COPD	13	5	2
Other	0	1	0
Other	37 (13.8)	19 (15.1)	26 (14.9)

diver group. This group also had a substantially greater proportion of subjects who took an endocrine medication, the majority of which were for diabetes.

The proportion of subjects who took an ACE-I was greatest in the active comorbid diver group compared to those who were deceased. These medications were taken by 15.7%, 3.2% and 4.0% of active comorbid divers, deceased divers and deceased snorkellers, respectively. The proportion of subjects who took beta-blockers was similar across all groups. These medications were taken by 4.5%, 1.6% and 2.3% of subjects, respectively.

There was an excess of psychotropic medication use within the deceased diver group. Almost one tenth of subjects in this group took one or more psychotropic medications, a proportion approximately three times greater than that of the active comorbid divers and the deceased snorkellers ($P = 0.01$).

Discussion

This study has found that many scuba divers and snorkellers take regular medications for a range of medical comorbidities. This is consistent with the findings of a 2000 survey of 709 active scuba divers in Australia and the United States (US).[12] However, substantially more active comorbid divers in our study took a medication (57.8%) than divers from Australia (15.6%) or the US (22.8%) in the 2000 survey. The reasons for this likely relate to the fact that our survey explicitly included divers with a declared medical condition. There is also the possibility of prevarication bias in the 2000 survey.[12] At that time, diving with some comorbidities was less acceptable (e.g., cardiac disease) and some medications may not have been disclosed.

Overall, a wide range of medications was taken by all subjects – 161 different medication entities in total. Of these, the active comorbid divers took a significantly greater range than the deceased subjects. This is likely related to the greater proportion of active divers who took any medications and consistent with their known major pre-existing condition profiles.[4,5,10,11]

Cardiovascular medications, especially those for hypertension and hypercholesterolaemia, were the most common medications taken in each of the subject groups. Cardiovascular medications were particularly common in the active comorbid diver group, taken by almost one half of subjects. Relatively few of the deceased subjects took ACE-I and beta-blocker medications compared to the active comorbid diver group. Hence, despite concerns about

the effects of these medications in the diving environment (particularly beta-blockers),[16] these concerns do not appear to be supported by the patterns of medication use in this study.

It is also notable that a sizable proportion of active divers took an endocrine medication, mainly for diabetes. This proportion is substantially higher than for the deceased subject groups. Once again, these findings likely reflect the pre-existing medical conditions and the older age of the active comorbid divers.

One important finding was that almost one tenth of deceased divers took a psychotropic medication. This proportion is less than that of the general Australian population (16.3%) during 2013–2014,[22] a similar period to the active comorbid diver survey.[10] However, it is almost three times that of the active comorbid divers and deceased snorkellers. The psychotropic medications were mostly antidepressants but also included anxiolytics/sedatives (mainly benzodiazepines) and antipsychotics. In 2013–2014, 11.5% and 1.9% of Australians took antidepressants and antipsychotics, respectively.[22] The use of diazepam, clonazepam and alprazolam hints that these subjects were treated for anxiety. However, medications classed as antidepressants may be used for a range of indications other than depression, including chronic pain syndromes. It is not possible from the data available to comment upon the specific indication for which the antidepressants were prescribed. The use of dexamphetamine and methylphenidate is likely to have been used for attention deficit hyperactivity disorder.

In Australia over the past few decades, there has been a large increase in the use of psychotropic drugs, most notably antidepressants.[23] However, the reasons for this apparent excess of psychotropic medication use in the deceased diver group are unclear. This does, however, raise the possibility that the use of these medications may have been associated with the diving deaths. However, given the available information, it is not possible to attribute the deaths to the divers' underlying co-morbidities, the medications themselves or any other factor.

There is evidence that the hyperbaric environment can affect the mental capacity of subjects taking dimenhydrinate (an antihistamine).[9] Also, there are suggestions that some antidepressants may increase the risk of nitrogen narcosis and induce seizures.[15] Presently, however, there is little robust evidence to indicate that this environment affects the actions of psychotropic medications to an extent that puts the diver at significantly greater risk.[14,15] A more likely possibility is that a psychiatric comorbidity may render the diver less fit to dive by affecting cognition, emotion and behaviour. However, it is not known if the deceased divers on psychotropic medications were more prone to poor decision-making, panic attacks or other aberrant behaviour that could have contributed to their diving incident. It has been reported that individuals with raised anxiety trait levels are more likely to experience anxiety and panic in stressful diving situations.[24] This is thought to relate to a dysregulation of the hypothalamic–pituitary–adrenal axis that may initiate a strong response to a relatively mild stress. Importantly, it has also been reported that divers with mental health issues do not consistently declare their condition or psychotropic medication use on diver certification forms.[25] Finally, as the majority of psychotropic medications were antidepressants, it is possible that some divers did not have their depression well-controlled, if this was the indication for which the antidepressants were prescribed. This raises the possibility, albeit unlikely, that one or more of the deaths was intentional though there is no clear evidence to suggest that this was the case. Although there are occasional reports of diver-related deaths through suicide, other suicide methods are much more common and usually do not place other individuals at risk, as a diving suicide may do for the diving buddy.[26]

Small but important proportions of subjects were taking medications for asthma, once thought to be an absolute contra-indication to scuba diving.[5] Over time, asthma has moved from an absolute to a relative contra-indication to scuba diving.[27,28] It is now recognised that, if this condition is well-controlled, the theoretical risk of diving with asthma is mitigated.[28] It is hoped that the divers on asthma medications are taking them to ensure their management is optimised.

The retrospective design and relatively small sample sizes of this study do not allow definitive conclusions. Some of the suggested reasons for the findings can, therefore, only be conjecture. We recommend that large, similar studies of medication use by active and deceased divers are undertaken. In particular, the apparent excess of psychotropic medications among deceased divers needs to be further investigated. If this association is supported by future research, this will have implications for fitness to dive and may support psychological testing as part of a diving medical examination. While this may be advisable, it has been reported that the diving medical physician may have neither the time nor the experience to conduct an adequate psychological assessment.[24] One potential solution may be thorough screening by means of an extensive questionnaire with attention to psychiatric disorders and psychotropic medication use. If this suggests doubt about the diver's fitness to dive then referral to a psychiatrist with an understanding of diving medicine may be indicated.

This study has other limitations. The 2013 survey[10] was only sent to divers with a declared medical condition which almost certainly explains the higher prevalence of overall medication use amongst this group. Non-response to the survey may have resulted in selection bias and the self-report of medication use may have been affected by recall or prevarication bias. Selection bias is unlikely among the deceased diver and snorkeller groups as all subjects were included. The medication data relating to the deceased subjects will be an underestimate. The use of some medications by the active comorbid divers may also

have been an underestimation if the use of medications was not disclosed during diving medicals or the divers survey. In a small number of cases, it was noted that medications were taken but the actual names were not available. Also, inaccuracies may be present in their medication lists as they were obtained by subject self-report and not verified by another source. Some medications taken have several, quite different, indications. For example, carbamazepine can be used for epilepsy, neuropathic pain, mania and bipolar affective disorders. Given the retrospective nature of this study, the exact indication for a medication was often not known. When this occurred, we assigned the indication to the less serious condition. For example, if there was no medical history of epilepsy, the use of carbamazepine was assumed to be used for neuropathic pain. Hence, the prevalence of some comorbidities will be an underestimation.

Conclusion

In this study, the use of medications among active comorbid divers, deceased divers and snorkellers was common. The active comorbid divers differed from the two deceased groups in that they used significantly more medications. This likely reflects their declared medical conditions and older age. Notwithstanding these characteristics, the active comorbid divers appear to be diving relatively safely with conditions once thought to be contraindications to scuba diving. This suggests that there are multiple influences on mortality in diving beyond medical comorbidities. The deceased divers took more psychotropic medications. It is not clear if these medications themselves contributed to their deaths. More likely is the possibility that their underlying psychological or psychiatric conditions rendered them more at risk in the diving environment. If these findings are replicated in future studies, there may be sufficient evidence to consider the incorporation of psychological testing into diving medical examinations.

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