A 20-year analysis of compressed gas diving-related deaths in Tasmania, Australia

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Key words
Diving deaths; Diving incidents; Incidents; Risk management; Root-cause analysis; Safety; Case reports

Abstract
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Introduction: This study reviews diving deaths that occurred in Tasmanian waters over a 20-year period.
Methods: Detailed analysis was undertaken of deaths that occurred from 01 January 1995 to 31 December 2014. The cases were collated from numerous sources. Utilising a chain of events analysis, factors were identified and assigned to predisposing factors, triggers, disabling agents, disabling injuries and cause of death. These were then scrutinised to ascertain regional variables, remediable factors and linkages which may benefit from targeted risk mitigation strategies.
Results: Seventeen deaths were identified across this 20-year period, which included one additional case not previously recorded. All were recreational divers and 15 were male. Five were hookah divers, 12 were scuba divers. Important predisposing factors identified included equipment (condition and maintenance), pre-existing health conditions, diver experience and training. These factors can now be used to promote public health messages for divers.
Conclusions: This 20-year study highlighted regional variations for Tasmanian deaths and presents opportunities for strategies to prevent diving deaths in the future. Of particular concern was the diving practice of ‘hookah’ diving, which has no governing regulations. The study highlighted the importance of applying a structured methodology such as chain of events analysis to scrutinise diving deaths.

Introduction

Diving-related fatalities in Australian waters have been collated and reported since the early 1970s, initially as *Project Stickybeak*,[1] and then continued by the Divers Alert Network Asia-Pacific (DAN AP) dive fatality reporting project, with the aim of identifying the causes of fatal dive incidents, and to reduce their incidence.[2,3] A series of reports identified the critical incidents and causative factors in the overall Australian experience but there have been no studies that accounted for regional variables.

It is likely that Tasmania has regional idiosyncrasies compared to the rest of Australia. For instance, a large percentage of Tasmania’s recreational divers use ‘hookah’ surface-supply breathing equipment. Exact numbers of hookah divers are unknown but they account for up to 30% of divers annually requiring treatment for decompression illness (DCI) at the Royal Hobart Hospital (RHH).[4] It was thought possible that hookah divers may be over-represented in Tasmanian diving accidents and fatalities. Water temperature in Tasmanian waters is cooler than the rest of Australia.[5] Diving in cooler water requires greater thermal protection, the associated need to carry more weights, and the potential of increased exertion. These can create an increased risk of a thermal- or buoyancy- or cardiac-related injury, or immersion pulmonary oedema (IPE).[6]

In December 2015, Tasmania’s population was 517,400 and, for its size, it has a relatively large recreational diving population.[7] In 2014–2015, there were 8,742 recreational rock lobster diving licences and 12,083 recreational abalone licences issued.[8] This implies a participation rate of 2.3% to 4.0% of the population undertaking underwater recreational fishing without including commercial divers or recreational divers who do not hold fishing licences.

Over the years 1995 to 2009 there were 154 deaths recorded by DAN AP in compressed gas divers in Australia (0.52 per million population per year).[9] Tasmania had 12 deaths in the same period, with a death rate of 1.68 per million population per year, indicating a potential regional anomaly.

Table 1
Key words/search phrases for electronic identification of Tasmanian diving death coronial reports

Period : 01 January 1995 to 31 December 2014
Diving
Tasmania
Scuba
Hookah
Fatality
Surface-supply breathing apparatus
Compressed gas
Cerebral arterial gas embolism (CAGE)
Decompression illness
Decompression sickness
Death
Mortality

There is merit in investigating diving deaths in a structured way, for instance, applying root cause analysis (RCA) to diving accidents to trace their aetiology.[10] This process has been refined further to include predisposing factors via a five-step analysis and structured template.[11] This could be applied to Tasmanian diving deaths to identify predisposing and causative factors that may assist future preventative strategies. Therefore, the aims of this study were:

- to identify all compressed gas diving deaths in Tasmania over a 20-year period and the events preceding each death;
- to identify and evaluate Tasmanian diving practices and risks, using the five-step, sequential chain of events analysis;
- to generate public health messages to inform divers and to assist future prevention strategies.

Methods

STUDY DESIGN

A retrospective consecutive case series analysed all diving-related deaths associated with the use of compressed gas in Tasmania between 01 January 1995 and 31 December 2014. The study was approved by The Tasmanian Health and Medical Human Research Ethics Committee (Ref No. H0014793).

IDENTIFICATION AND SELECTION OF SUBJECTS

For inclusion in the study, the deceased diver must have breathed compressed gas in the aquatic environment. There was no central database in Tasmania which had sufficient detail to identify all diving deaths, hence a multimodal approach was used to capture all Tasmanian diving deaths. Previous information from DAN AP suggested that the total study population would be no more than 20 subjects. Searches were undertaken from the following sources:

- coronial records;
- interviews with the RHH Hyperbaric staff and the Tasmanian State Director of Forensic Pathology;
- hyperbaric facility records from 1995;
- DAN AP records (including *Project Stickybeak*);
- newspaper reports from Tasmanian major newspapers;
- hand search of the *SPUMS Journal* and *Diving and Hyperbaric Medicine*.

Reports were searched by using key words/search phrases as detailed in Table 1.

STUDY VARIABLES AND MEASUREMENTS

The basic data sought for each of the deaths included age, sex, year of death, equipment used, type of diving (recreational or professional), level of training, experience, geographical location of incident dive, previous medical history including dive medical, incident dive trend and cause of death. All available records were examined. These included: Coroners' reports; autopsy and toxicology reports; police and witness statements, equipment reports and gas analyses and medical records.

Each diving death was evaluated using chain of events analysis (CEA).[11] The analysis sequentially identified predisposing factors, triggers, the disabling agents, disabling injury(ies) and cause of death.[11] Each death was independently analysed by each author. Working sequentially was intended to minimise bias and reduce variability when assessing the divers' likely actions prior to their death. The findings were then cross-referenced. Each step of the original diving root cause analysis categories were divided into a number of broad sub-categories, permitting a structured approach.[10,11] The additional fifth category, 'predisposing factors' was also divided into a number of subcategories Table 2.[11]

Trends in causation and, in particular, identifiable factors that may be preventable and remediable were looked for. These factors were used to guide recommendations for preventive strategies and public health campaigns. Using this study methodology, it was possible that a cause of death other than that stated by the Coroner might be identified. In this event, such cases were highlighted and discussed.

STATISTICS

Although the data were categorical in nature, the expected small numbers and potentially diverse causative factors were likely to allow only basic statistical analyses which included incidence, mean, standard deviation, medians and interquartile ranges, ratios and percentages. All data were

Table 2
Predisposing factors contributing to the diving accident[11]

Predisposing Factor	Description
Health-related factors	Contributing to the dive accident (e.g., cardiovascular disease, epilepsy, diabetes, mental or physical fatigue)
Organisational/Training/Experience/Skills-related	Diver's practical readiness to dive (e.g., suitability of training course design and conduct, the overall dive organisation by a dive operator, the level of skill and/or experience of the diver)
Planning-related	Decisions made prior to the dive
Poor communication or co-ordination	Between dive team members and/or operator
Absence of appropriate equipment; using obviously faulty equipment	Specifically contributed to the accident
Activity related risks	Higher risk in-water activity
Unsafe supervision	Lack of or inadequate supervision
Other	Other factors not in this list
Unknown or none	No cause identified; insufficient information

tabulated, and basic statistical calculations undertaken using Microsoft® Excel. Normality of data was assessed using the D'Agostino and Pearson omnibus normality test with GraphPad Prism 6 software (GraphPad Software inc. version 6.0e 2014, La Jolla CA). Death rate was expressed as a rate per million population. Populations were calculated as an average of the five yearly Australian Bureau of Statistics December census edition data (1996–2011).[7]

Results

Over the 20-year study period, 17 deaths were identified associated withcompressed gas diving in Tasmania were identified. Age data were statistically not inconsistent with a normal distribution but, because of small study numbers, medians and interquartile ranges are documented. Fifteen divers were male, and two female; median age (all divers) 40 years (range 29–66, interquartile range 34–50). Most deaths (11 of 17) occurred during summer (all in South-East Tasmania), three in Autumn, two in Winter and one in Spring. All victims were recreational divers. Of the 17 deaths, five of the victims used hookah and 12 scuba equipment.

The Tasmanian death rate was calculated as 1.77 deaths per million population per year.[7] One of the deaths identified had not previously been recorded by Project Stickybeak or DAN AP. For two of the diving deaths more comprehensive documentation (not previously held by DAN, or Project Stickybeak), was identified that allowed full CEA. The locations of where deaths occurred shows a high occurrence rate within 100 km radius of Hobart (Figure 1). All were in the marine environment.

PREDISPOSING FACTORS (PF)

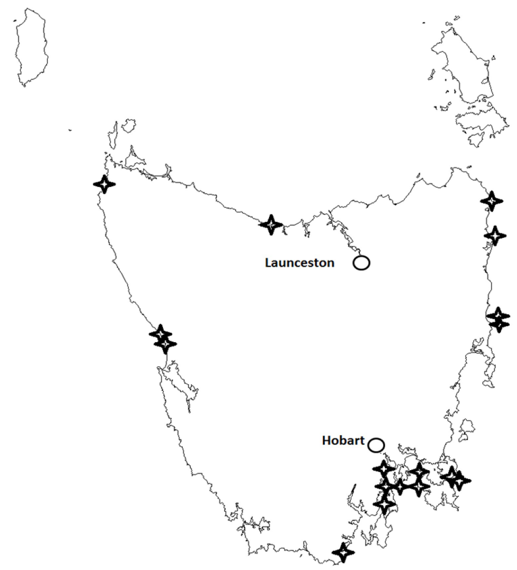
Tables 2 and 3 summarise 41 predisposing factors identified in the 17 divers. It was established that 15 of the 17 divers had two or more predisposing factors. In fact, one diver (CG-16) had five predisposing factors identified. Two divers had more than one equipment issue. Table 4 summarises the equipment factors which contributed to deaths.

Health conditions affected eight divers whose age ranged from 29 to 58 years, with a median of 46 years. Three of the divers had a recent significant health issue whilst two had a possible medical PF identified at autopsy. These included severe cramps for one diver, an aborted dive due to ear clearing problems and a previous likely severe episode of IPE. The other five cases all had significant cardiac disease and one also had concomitant respiratory disease. There was no evidence that any of the victims had undergone a recent dive medical.

Organisational/training/experience/skills-related factors predisposed to the deaths of eight victims while inexperience contributed to four. Two victims had returned to diving after a prolonged absence. The remaining two victims were inexperienced in the type of diving being undertaken (one being a night dive and the other in cold water).

Dive planning problems potentially contributed to seven fatalities. Four divers had planning problems affecting a safe buddy system. They either chose not to dive with a buddy or had formed a group of three divers. A further three dived in recognised poor conditions or were without adequate surface

Figure 1
Location of Tasmanian diving deaths between 1995 and 2015



rescue. The final three PF groups included the type of diving activity, i.e., poor visibility, kelp diving, strong currents (n = 4), poor communication (n = 3), and lack of supervision (n = 3). Poor communication led to poor diving plans that ultimately led to the divers' demise. Unsafe supervision led to delays in identifying problems, or difficulty with rescue, once in danger.

TRIGGER FACTORS (TF)

Table 3 summarises 26 TFs in 17 divers. One diver (Case 16) had three potential TFs, but it was unclear which was the most important. Five of the six equipment-related triggers involved the use of faulty hookah equipment. The sixth fatality was using incorrectly assembled scuba equipment. All hookah deaths involved equipment failure or inappropriate setup. The use of a Y-connector in the air hose distal to the hookah pump hose outlet resulted in air being diverted from one diver when the second one on the same system ascended. There was contamination of the air supply due to an incorrect inlet/ exhaust set up, whilst a T-piece dislodgement resulted in loss of the air supply. None of the hookah divers had an accessory air supply. Primary diver error involved either running out of air or losing a buddy. The buoyancy trigger involved inexperience with the use of a particular BCD. Two divers ran out of air whilst at depth, whilst in two cases it was not possible to clearly identify a trigger.

DISABLING AGENTS (DA)

Twenty-three DAs were identified (Table 3). Twelve divers had a single DA; four divers had two DAs and three DAs were identified in one case (Case 02). Problems with ascent were identified as the DA in five cases. The gas supply issues were either carbon monoxide contamination or loss of air. The buoyancy problems were attributable to difficulty with weights in three and problems with the BCD in one. Medical DAs were IPE in two and one with ear clearing difficulties. Environmental DAs were due to impact with rocks with subsequent head injuries.

DISABLING INJURIES (DI)

Twenty DIs were identified in 17 divers (Table 3). One victim (Case 02) had evidence of both asphyxia and cerebral arterial gas embolism (CAGE), creating a degree of uncertainty. Two cases of head trauma also had asphyxia – these divers (Case 09 and Case 14) were assigned two DIs.

CAUSE OF DEATH

The causes of death shown in Table 3 were those given by the Coroner. For 14 cases, the results of the CEA agreed with the Coroner's conclusions (10 drowning and 4 CAGE). However, after review in this study, the causes of death for three divers (Case 02, Case 06, Case 15) were considered to be different to the Coroner's determination.

Discussion

EPIDEMIOLOGY OF TASMANIA'S DIVING DEATHS

Tasmania had nearly four times the national average for diving deaths in the study period (1995–2009 Australian deaths = 0.46 per million population per annum). Although 'snapshot' surveys are available which estimate diving participation rates, there are no reliable national longitudinal participation data.[12] Hence, it is not possible to determine if Tasmania's higher death rate is due to higher participation or greater risk for the divers. The geographical and seasonal distribution of death mainly occurring in South-East Tasmania in summer is likely attributable to proximity to Hobart (highest population centre), warmer summer diving conditions, accessible sheltered waterways and coinciding with the open rock-lobster season.

The median age of divers (40 years), was similar to national data;[2,13–15] however, of the most recent six Tasmanian deaths, five were aged over 45 years (median 52 years, range 40–66). This may indicate participation risk from older divers who require greater medical input and surveillance. SPUMS recommends that regular medical checks for divers should commence at age 45, even in the absence of known health issues.[16] Of all Tasmanian deaths, only 12% were female, compared to 23% nationally.[2,13–15] Without knowing female participation rates, it is not possible to draw conclusions about prevalence by sex.

In previous studies, it was identified that lack of regional data was a limitation.[2] This series identified possible regional

Table 3
Predisposing factors identified in 17 diving deaths; trigger factors identified in 17 diving deaths (n = 26); disabling agents detected in 17 diving deaths (n = 23); disabling injuries identified in 17 diving deaths (n = 20); CAGE – cerebral arterial gas embolism; IPE – immersion pulmonary oedema

Case	Predisposing factor	Trigger factor	Disabling agent	Disabling injuries	Cause of death
01	Health/Planning	Environment/Exertion	Unknown	Asphyxia	Drowning
02	Health	Primary diver error/ Unknown	Ascent/Medical/ Buoyancy	Asphyxia/CAGE	Unclear–potential for drowning/CAGE
03	Poor communication or co-ordination/Absence of appropriate equipment/Obviously faulty equipment	Equipment	Ascent	CAGE	CAGE
04	Organisational/Training/Experience/Skills	Equipment	Gas supply	Other	Drowning
05	Organisational/Training/Experience/Skills	Equipment	Gas supply	Other	Drowning
06	Health	Environment/Exertion	Medical	Other Medical	Drowning/IPE
07	Health/Organisational/Training/Experience/Skills/Absence of appropriate equipment/Obviously faulty equipment	Environment/ Equipment	Unknown	Asphyxia	Drowning
08	Organisational/Training/Experience/Skills/Planning/Absence of appropriate equipment/Obviously faulty equipment	Primary diver error	Gas-supply/Ascent	CAGE	CAGE
09	Plannin/Poor communication or Co-ordination/Activity	Environment	Environment	Asphyxia/Trauma	Drowning
10	Organisational/Training/Experience/Skills/Unsafe supervision	Gas-supply/Primary diver error	Ascent	CAGE	CAGE
11	Organisational/Training/Experience/Skills/Planning/Absence of appropriate equipment or obviously faulty equipment/Activity	Environment/ Equipment	Buoyancy/Equipment	Asphyxia	Drowning
12	Planning/Absence of appropriate equipment; or obviously faulty equipment/Activity/Unsafe supervision	Environment	Gas supply/Equipment	Asphyxia	Drowning
13	Health/Absence of appropriate equipment or obviously faulty equipment/Activity	Equipment/Gas-supply	Ascent/Buoyancy	CAGE	CAGE
14	Health/Planning	Environment	Environment	Asphyxia/Trauma	Drowning
15	Organisational/Training/Experience/Skills	Environment	Medical	Cardiac	Drowning/IPE
16	Organisational/Training/Experience/Skills/Planning/Poor communication or co-ordination/Absence of appropriate equipment or obviously faulty equipment/Unsafe supervision	Buoyancy/Anxiety/ Stress/Primary diver error	Buoyancy	Asphyxia	Drowning
17	Health/Absence of appropriate equipment or obviously faulty equipment	Unknown	Unknown	Asphyxia	Drowning

Table 4
Equipment predisposing factors; hookah equipment trigger factors

Hookah	Other faults
Homemade hookah	No accessory safety air source
Previously compressor had other function	Incomplete assembly pre-dive – attributed to both hookah and scuba
Fuel leak, no inlet filter	Faulty or no buoyancy control device
Absent non-return valve in breathing line	Over-weighted
Made of non-stainless steel (significant corrosion)	Tight wetsuit
No suitable snorkel or intake extension	Not serviced

risk from diving in the colder waters around Tasmania. Two divers were from overseas and had not dived in cold water before. Feelings of claustrophobia and buoyancy control problems can result from wetsuit compression, exacerbated if a wetsuit is tight and/or thicker. This appeared relevant in one of the deaths. In addition, two victims were likely to have suffered from IPE, known to be exacerbated by cold water immersion.[6]

OCCUPATIONAL VERSUS RECREATIONAL DIVER DEATHS

Despite Tasmania's large population of active professional divers, there were no occupational diving deaths, which is surprising given that professional divers made up 41% of divers treated for decompression illness in Tasmania in 2010.[4] Australia-wide data between 2008 and 2011[2,13–15] revealed that commercial diving accounted for three deaths (out of 39 compressed gas diving deaths nationally) over this four-year period.[2,13–15] Occupational divers are subject to Federal Work Health and Safety (WHS) Legislation and Australian/New Zealand Standards. These govern diver operations and supervision, equipment maintenance and mandate yearly medical health risk assessment. Occupational divers are required by law to have training appropriate to the activity they are undertaking, to perform risk assessments, and work in teams that provide appropriate supervision. These are appropriate 'upstream' risk mitigation strategies to maintain diver safety. Tasmania appears to have a good safety record with professional diving, if absence of deaths is used as a measure of safety.

It must be acknowledged that better systems need to be implemented to improve Tasmania's recreational diving safety record. Hookah divers were over-represented in Tasmanian diving deaths (over a quarter of all deaths). Australia-wide data shows hookah divers constituted 10.3% of all compressed gas diving between 2008 and 2011.[2,13,14,15] Precise data on participation rates (hookah vs. scuba) are not available, but warrant further research.

CHAIN OF EVENTS ANALYSIS

Problems with equipment contributed to 10 out of 17 deaths. Faulty equipment was the major predisposing factor contributing to diving deaths. This had downstream effects whereby a PF identified with equipment became a trigger for equipment problems in six out of 17 deaths. For all hookah diving deaths, the compressors were in disrepair and/or had inappropriate or hazardous configurations which were apparent before divers entered the water. Key issues for hookah equipment were use of home-made apparatus, hazardous air intake and air-hose setups, disconnections, use of y-connectors in diver air hoses, absence of an accessory air supply and excessive weighting of divers. Hookah divers also dived without buoyancy compensators, preventing stabilisation at the surface in an emergency.

In Tasmania, recreational hookah equipment can be purchased and operated without any training and without regulation. The responsibility for maintenance rests solely with the owner, hence the capability of producing a home-made apparatus. The deaths in this report demonstrate a need for regulation around the use and maintenance of hookah apparatus, the training of divers who use hookah and the mandating of accessory air supplies. The authors have been unable to identify any training systems or courses for recreational hookah divers in Australia. This contrasts with widespread availability of scuba courses.

Recreational scuba training, equipment maintenance and scuba cylinder filling are usually undertaken by dive shops, who are governed by Australian Standards and Federal WHS legislation. Divers have relatively easy access to dive shops in Tasmania and, although some oversight of cylinders occurs when they are filled at commercial filling stations, the onus is still on the diver to have their regulators serviced regularly. The scuba equipment used by three of 12 divers for whom it was checked was found to have faults, had not been maintained or servicing was not documented. Where equipment was identified as a causative factor, incorrect assembly was contributory. With equipment problems featuring as a significant predisposing factor, the need for divers to ensure their scuba equipment is well maintained and properly assembled is an important safety message.

Health issues were the second most common PF contributing to diving deaths, present in almost half of the victims. Health issues were also identified as the DA for three victims, directly following the identified PF. Had these older divers received appropriate health risk assessment, their deaths may have been avoided. This study has highlighted the need for medical risk assessment to be undertaken, particularly in older divers. We found no evidence that any divers with medical issues had received any medical risk assessment regarding diving. In Australia, there are no enforceable regulations which mandate any form of medical assessment of recreational scuba divers of any age.

Lack of experience relative to the diving conditions was identified as a PF in almost half of these deaths. It became apparent through chain of events analysis that inadequate (or relative) experience led directly to fatal outcomes. On that basis, it is reasonable to advocate that all recreational divers should have training that is appropriate to the dives being undertaken, and that refresher courses or at least skills assessment are mandatory when divers have had a prolonged period out of the water. At present, a scuba diving qualification is issued as a lifetime certification, irrespective of how frequently a diver enters the water.

Failures of the buddy system contributed to 14 of the 17 fatalities in this study. These were classified as planning-related (PF) and primary diver error (TF). These victims either dived alone or intentionally/accidently parted from their buddy. In fact, only three divers were with a buddy, which is an identical proportion to that reported for victims Australia-wide from 1972–2005.[3] The high number of dive fatalities occurring when the buddy system broke down highlights the importance of this system in contributing to safety. With an alert buddy, a distressed or impaired diver may be identified prior to becoming incapacitated and rescued swiftly. Whilst the diver may not always be saved, as seen in some of the cases in this series, it does afford the victim a better chance of survival.

The activity-related factors identified mainly related to poor choices when diving in hazardous sea conditions, leading to a chain of events which was ultimately fatal. Environmental factors included cold water immersion, dangerous sea conditions, current and waves and dangerous features such as rocks, caves, kelp or ropes (risking entanglement). Extra time and effort to observe and assess the diving environment prior to a dive is a worthwhile safety investment; choosing not to dive is an important option that may be overlooked. Risk assessment and dive planning are usually not taught until more advanced recreational courses.

As demonstrated in CEA by other authors, there are often multiple factors contributing to negative outcomes.[10] Many fatalities had multiple PFs that contributed to a diver's death. Such PFs can be addressed through public health messages, and education. Some may require strengthening of regulations and training, particularly relating to recreational hookah equipment and health surveillance.

Including PF in investigating diving deaths, analysing a chain of events rather than looking for a single root cause, added value to this study. Without assessing PF, important pre-immersion issues that contributed to diving deaths would be missed and important opportunities for risk mitigation would be lost. Analysis of linkages between PFs and TFs highlighted some areas for further research and possible prevention strategies. For example, linkages of diver health to impact from the environment are very important for safe diving in Tasmania. Campaigns to improve equipment maintenance and eliminating home-made equipment may save lives. In addition, a focus on diver training, particularly in the area of pre-dive decision making may help to reduce the incidence of fatalities. Emphasis on the advantages of the buddy system should be part of this training.

Investigating diving deaths presents many challenges, even with a systematic approach. For two cases (CG-02 and CG-17) it was difficult to ascertain or assign a trigger, despite reasonable information from the scene. Three of the cases (CG-01, CG-07 and CG-17) had an unknown DA owing to missing information, difficulty appropriating information or the fact that these deaths occurred unwitnessed. One fatality (CG-02) had three DAs assigned; it was difficult designating which agent was the most important in precipitating death. On some occasions, multiple possibilities need to be accepted when analysing diving deaths.

The identification of DIs was relatively straight-forward, well-conducted autopsies making it possible to assign these with reasonable accuracy. They again flowed logically into the cause of death as described by the Coroner. However, for cases CG-02, CG-06 and CG-15, it was considered after CEA that there was a likely alternative causation of death other than that given by the Coroner. For CG-02, despite extensive analysis of available information, it could not be determined whether the diver experienced a rapid ascent causing CAGE (which was never witnessed) or whether the diver drowned at depth. The Coroner's report stated: "*Without knowing the deceased's dive profile, it is extremely difficult to postulate the exact pathological sequence of events*". This diver did have a CT which led to the conclusion of CAGE as there was gas throughout the body. However, there was also evidence of drowning. Without clear history of a rapid ascent and off-gassing prior to a delayed post-mortem CT scan, the diagnosis of CAGE is less convincing.

In CG-06 and CG-15, IPE was considered a more plausible cause of death than the coronial finding.[17] IPE is difficult to diagnose at autopsy; the pathological findings being similar to those of drowning.[17] During CEA both divers demonstrated risks for IPE, including previous similar episodes and pre-existing medical issues. Both were over 50 years of age, placing them at a higher risk. In 30% of cases of IPE in scuba divers, there is a likelihood that this had occurred on previous dives.[17] Autopsy in both cases confirmed cardiac disease which may have increased susceptibility to IPE. The CEA highlights the benefits of having an expert prospectively involved when diving deaths are analysed.

LIMITATIONS

This was a retrospective series and it is recognised that data may be incomplete for individual cases and that some cases may have been missed. The study methodology was structured to limit such problems by utilising a model template that has been verified to allow a more effective and systematic collection and analysis of these data.

Data quality was variable; in particular deaths occurring up to the year2000 had less comprehensive information. At times this was inevitable due to absence of witnesses, or the diver being separated from buddies.

Autopsy reports can sometimes have a degree of uncertainty, because of the difficulty in determining the presence of CAGE, delays in performing an autopsy or difficulties in identifying medical causes such as dysrhythmias or differentiating IPE from drowning.[14]

Even with five-step chain of events analysis, it remains possible that other important co-factors were overlooked.

The number of deaths (17 over a 20-year period) was low. Despite this, it proved possible to gather important information that has potential to improve safety for divers in Tasmania into the future.

Conclusions

Seventeen diving deaths were recorded in Tasmania over 20 years; all recreational divers (five on hookah and 12 on scuba). There were no diving deaths in the professional sector during this period. The key public health messages for divers include:

- Health – promotion of regular diver health reviews, especially for those with known medical conditions or > 45 years of age.
- Equipment condition and maintenance – recreational gear should be subject to similar standards to those for commercial divers.
- Hookah compressors – require a system of oversight for use in the recreational environment, including air testing certification. There is a need for a specific recreational hookah diver training course and mandating a functioning accessory air supply.
- Training – all divers should have regular training to ensure they maintain safe diving practices. Divers who have not dived for some time should undergo refresher training. The buddy system should be reinforced.
- Acclimatisation to the colder waters surrounding Tasmania has been identified as a key risk for visiting divers. These divers should receive initial higher-level supervision and support until their competence in colder water is confirmed.
- Choosing not to dive is an important option that may be overlooked by divers.

These data and key messages will be presented to the Tasmanian Government and to the Coroner's office, as well as presenting to local dive regulators and diving communities to ensure that this diving knowledge is dispersed to help reduce future fatalities.

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