Original articles

Formulating policies and procedures for managing diving related deaths: a whole of state engagement from frontline and hospital services in Tasmania

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Abstract
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Introduction: Tasmania is a small island state off the southern edge of Australia where a comparatively high proportion of the 558,000 population partake in recreational or occupational diving. While diving is a relatively safe sport and occupation, Tasmania has a significantly higher diving death rate per head of population than other States in Australia (four times the national diving mortality rate).

Methods: Three compressed gas diving deaths occurred in seven months between 2021–2022 prompting a review of the statewide approach for the immediate response of personnel to diving-related deaths. The review engaged first responders including the Police Marine and Rescue Service, hospital-based departments including the Department of Hyperbaric and Diving Medicine, and the mortuary and coroner's office.

Results: An aide-mémoire for all craft groups, digitalised checklists for first responders (irrespective of diving knowledge), and a single-paged algorithm to highlight inter-agency communication pathways in the event of a diving death were designed to enhance current practices and collaboration.

Conclusions: If used, these aids for managing diving related deaths should ensure that time-critical information is appropriately captured and stored to optimise information provided for the coronial investigation.

Introduction

Tasmania is an island state situated off the southern edge of Australia, the land size being similar to Ireland or Switzerland. The Tasmanian population was approximately 558,000 in 2021,[1] with potentially 18,500 recreational divers (approximately 3.7% of the population) based on recreational fishing licences[2,3] (with the consideration that some people may hold dual licences, some will hold none, and some licence holders will only be snorkellers rather than compressed gas divers), and an imprecise number of occupational divers.[4] Tasmania has a burgeoning aquaculture industry (farmed seafood) and wild harvest industry. Wild seafood harvest licenses allow for an estimate of commercial diver numbers extrapolated from issued licenses. The diver numbers from the aquaculture industry would necessitate direct contact with the numerous businesses to determine exact numbers. From a commercial perspective, what is known is from the commercial licences managed by the Water and Marine Resources, Fisheries Compliance and Licencing Branch, with 119 active abalone and 53 commercial (including periwinkles, sea urchins, and Undaria) dive licences (J.S. personal communication, August 29, 2023). Occupational diving in Tasmania also includes police, military, scientific, and offshore oil and gas industry divers. There is no centralised database to document either active recreational or occupational divers.

Commercial fishing, aquaculture, and associated processing industries contributed $1.15 billion total gross value to the Tasmanian economy in 2017/18.[5] Diving is a popular sport for Tasmanians, however, accuracy around population data for divers is difficult to achieve due to imprecise surveys, lack of a centralised occupational divers register, and an unregulated recreational divers' register.

According to published information from a combination of reports including the Australasian Diving Safety Foundation, Divers Alert Network Asia-Pacific, and 'Project Stickybeak', from 1995 to 2015 Australia had a total of 222 compressed

gas diving-related deaths, an average of 11 per annum.[6–8] Over these 20 years Tasmania recorded 17 compressed air diving deaths, more than three times the national mortality rate (1.67 versus 0.53 deaths per million population).[2,6–8] The majority of compressed gas diving-related deaths occurred in a 100 km radius of Hobart.[2] Between September 2021 and March 2022, four diving related deaths (three compressed air, one snorkeller) occurred in Tasmanian waters, stimulating a review of the statewide approach for the immediate response of personnel to diving-related deaths, from first responders through to the mortuary.

The Department of Diving and Hyperbaric Medicine (DDHM) at the Royal Hobart Hospital initiated a review of the current chains of communication, external services and internal departments involved, and looked to improve the collection and storage of information and equipment from the sites involved with the diving death. The DDHM's input was often requested by the Tasmania Police Marine and Rescue Service (MRS). Initial retrieval considerations are frequently discussed with the DDHM physicians and forensic analysis of the diving equipment is provided by the DDHM technicians. It was of concern to the DDHM physicians and technicians that critical information for the post-mortem analysis of the victim and their equipment could be lost due to the lack of a centralised, documented process. The DDHM therefore engaged with the office of the Statewide Forensic Medical Services to discuss the merit of implementing a documented process for internal (at the Royal Hobart Hospital) and external agencies. There was also an analysis of how processes across the other hospitals and health centres in Tasmania would be co-ordinated in the event of a deceased diver to support preservation of information for the coronial investigation. The MRS were instrumental in their engagement with the other frontline services, and the coroner's associate, with clarifying the aims of the project.

The main aims for constructing multidisciplinary policies and procedures in approaching a diving victim were to:

- Engage collaboratively with frontline agencies who are the first responders to diving fatalities, the coroner's office via the coroner's associate, and respective departments and personnel within the Tasmanian Health Services who may be involved in a diver's death, with the ultimate aim of providing concise and comprehensive facts for the coroner;
- Construct a reference document (e.g., an aide-mémoire [*Appendix 1]) to support frontline agencies, the coroner's office, and the respective hospitals and departments in approaching this relatively rare event;
- Provide reproducible methods for documentation of information (e.g., digitalised inventory of diving dress and equipment [*Appendix 2] in addition to body worn camera footage) from the scene of the diving incident to the securing and storage of diving equipment for post-mortem analysis;
- Capture time sensitive information, such as ensuring timely access to a post-mortem computed tomography scan, or erect chest X-ray;
- Troubleshoot potential issues with victims being retrieved from remote regions, particularly with respect to time for retrieval to the Royal Hobart Hospital, mode of transport, and weather logistics; and
- Formalise points of communication between external agencies and the hospitals in a single-paged algorithm [*Appendix 3].

We aimed to create statewide protocols for compressed gas diving only, excluding snorkelling and free diving, as the pathophysiology implicated in deaths for these activities may be different. These attendance protocols would also be designed to be instituted for serious diving incidents where death is a possibility to ensure valuable evidence is not lost. It is not the intention of this paper to present or analyse the cause of death of the victims or scrutinise the events surrounding the diving death, rather to focus on elements to enhance the response and communication across agencies and organisations involved in the initial retrieval of the victim, access to, and provision of, time-critical assessment of the victim, recording and retrieval of their equipment, and, ultimately, resolution of the coronial investigation.

Methods

The MRS and DDHM collaborate closely in the event of compressed gas diving deaths, with application of their combined knowledge to assist analysis of diving events and equipment and determine contributing factors to the death. As there were an exceptional number of dive victims over the 2021/22 Summer, an introspective assessment of current hospital-based systems was triggered, as well as procurement of frontline service engagement to develop replicable documents for implementation across the State. This project was conducted through in-person meetings, telephone contact, and email with invested craft groups and their representatives.

In the event of a serious diving-related event, the police statewide radio dispatch services is usually the first point of contact for collation of information on behalf of the Tasmanian Police and Ambulance Tasmania. They, in turn, notify the appropriate services such as the coroner's associate, local uniform members, MRS, and Tasmanian Police Forensic Services, and the Office of the State Forensic Pathologist (based in Hobart). Previously, a non-officiated line of communication ensued from the MRS to the DDHM at the Royal Hobart Hospital, which had been historically implemented through word of mouth. This process stemmed from a time when the MRS engaged with the DDHM to assist

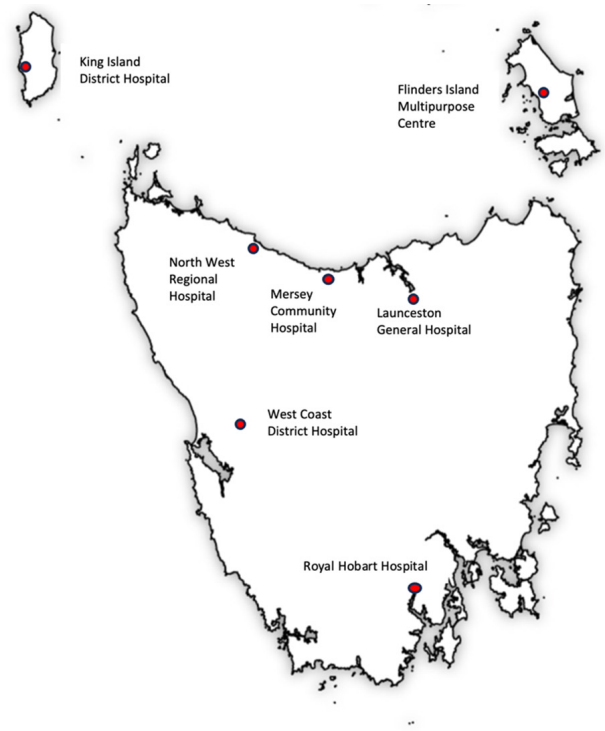
Footnote: * Appendix 1–3 are available on DHM Journal's website: https://www.dhmjournal.com/index.php/journals?id=335

with the post-mortem assessment of the diving gear. With changes in roles and responsibilities within the groups, there was a risk that corporate memory could be lost. In addition, due to the limited number of MRS personnel and the fact that they are based in Hobart, there was a risk for omission of critical information due to inexperienced attending police officers for incidents outside southern Tasmania. There was also a potential risk for delay in timely imaging of the victim to assess whether cerebral arterial gas embolism (CAGE) could be a contributing factor in the death. Therefore, radiology services were also included in the algorithm. From a conversation between the MRS and the DDHM in early 2022, it became evident that expanding the discussion to include the other agencies and departments was essential to ensure inclusive and comprehensive practice in facilitating the best possible outcome for these emotive, stressful, and uncommon incidents.

Tasmania has 12 public hospitals and community centres that service the population in the local region. There were six sectors in the state that were identified for inclusion in the project. The Royal Hobart Hospital in the south, Launceston General Hospital in the north, North West Regional Hospital and Mersey Community Hospital in the north west, West Coast District Hospital in the west of the state, King Island District Hospital and Health Centre, and Flinders Island Multipurpose Centre service the six sectors (Figure 1). In the event of a diving-related death where the victim cannot be retrieved to the Royal Hobart Hospital (preference) alternative plans for each sector were required.

Figure 1

Tasmanian state hospitals and medical facilities involved in the statewide diving related deaths algorithm. Image of the map of Tasmania with hospital locations provided as red spots



Results

Tasmania has a close-knit diving community due to its small population, size and niche recreational and commercial interests and investments in the marine environment. The technicians' in the DDHM work in close association with the MRS and Coroner's Office in assisting with post-mortem analysis and assessment of diving equipment. This combination provided a unique opportunity to engage with ancillary services in revising current practices while addressing the timely management of diving deaths. The impetus was due to the recognition of a lack of a formal process for intrahospital, interhospital and external-agency collaboration in response to a diving-related death. By formalising lines of communication across and within organisations (plus including the possibility of victims not being able to be brought to the Royal Hobart Hospital in a timely manner) this collaboration is projected to improve precision by identifying various contributors to the death, as well as enhancing on-site acquisition of diving equipment.

FRONTLINE AGENCIES

The Tasmanian MRS group engaged the external agency representatives to determine the roles and responsibilities of each craft group. The first responders (State Communications and Operations – representing the radio dispatch services, forensic police services, Ambulance Tasmania, retrieval services) and the coroner's associate were able to illustrate their roles and responsibilities and describe how these integrated with an event, such as a diving death. These discussions were documented and published as an 'aide-mémoire' (*Appendix 1), formulating a coherent line of communication between craft groups. The importance of accurately recording the 'in-situ' status of equipment was recognised. In order to facilitate accurate recording of the equipment a checklist of essential items for first responders attending the scene of a diving death, including basic instructions and explanations, was also created. Three checklists, namely: self-contained underwater breathing apparatus (scuba), surfaced supplied breathing apparatus (SSBA) (including hookah), and mixed gas rebreather (scuba mix) were constructed in such a way that the initial attending police officer, irrespective of their knowledge or experience with the different elements of compressed gas diving, would be able to complete (*Appendix 2). These checklists have been incorporated into Tasmanian police templates as a living document that can be accessed electronically by any personnel attending a diving death scene. Tasmania police procedures were also amended to request attendance at the scene by a police dive squad supervisor where possible, however, specialist verbal advice could be offered at minimum.

HOSPITALS

The Royal Hobart Hospital is the largest referral centre in Tasmania and is where State-wide Forensic Medical Services are based. For three of the six sectors (South, North, and North West) there are dedicated Executive Directors of Medical Services who provide coordination and administrative support to hospital-based medical services for their region. In the rare event that the victim could not be brought to the Royal Hobart Hospital, the Executive Directors of Medical Services for North and North West were engaged by the DDHM to assist with formulation of site-specific considerations for receipt of the diving victim. This was particularly relevant regarding obtaining time-critical post-mortem imaging should the body be housed in their mortuary until transfer to the Royal Hobart Hospital was possible. The radiology departments and external radiology providers were therefore also involved in the collaboration. The West Coast District Hospital based in Queenstown (West), King Island District Hospital and Health Centre (King Island), and Flinders Island Multipurpose Centre (Flinders Island) have a unique structure in that the hospital or centre is primarily serviced by the local general practitioner(s) with provision of medical services coordinated through Ochre Health Group. In this instance, the Tasmanian co-ordinator for Ochre was identified to be the point of contact, allowing for communication across the sites should initial, time-critical post-mortem imaging need to take place in these locations.

RADIOLOGY SERVICES

Radiological services for all six health services (North West Regional Hospital includes the Mersey Hospital campus) differ with the Royal Hobart Hospital and Launceston General Hospital both having all hour's access to in-house radiology, including computed tomography (CT) scans. The North West facilities can access urgent radiology support afterhours (2300 to 0700) through a private radiology group, which comes with a private fee for CT scans. The West, King Island, and Flinders Island facilities have access to X-rays only. Where private services are required, the coroner's associate, on behalf of the coroner's office, provides the authority to request access to these resources (see *Appendix 3).

In order to determine if decompression illness (DCI), particularly cerebral arterial gas embolism (CAGE), is implicated in the diving death, a timely post-mortem CT of the victim's head, chest and abdomen is required within eight hours to detect gas, particularly in the cerebral arteries and heart chambers.[9] The optimal timing of a post-mortem CT is within three hours. This is because of nitrogen off-gassing in the victim during the post-mortem period which can contribute to artefactual gas at autopsy.[9] Beyond eight hours, there is considerably less value in a post-mortem CT due to the presence of gas from putrefaction.[9] Where CT services are not accessible, as for the services supported by Ochre Health Group, erect chest X-ray (CXR) should suffice in assisting with visualising gas in the thorax within the time restriction.[9] Post-mortem CTs and CXRs are also difficult to interpret with a history of cardiopulmonary resuscitation (CPR), particularly with advanced CPR involving intubation and positive airway pressure support.[9]

Discussion

DIVING AS A DISCIPLINE

There are currently five disciplines of diving (snorkelling, free diving, scuba, surface supply breathing apparatus, mixed gas scuba diving), which are primarily divided according to what gas used for breathing (compressed air vs other gas mixtures), and how it is accessed (self-contained vs surface-supplied). Snorkellers swim on the surface with the aid of a mask, snorkel and fins and do not use compressed gas. Free diving is when divers breathe air at the surface and breath-hold dive. This cohort of divers were excluded from this current diving deaths assessment due to the absence of compressed gas causes of death. Scuba diving is when divers breathe air from cylinders mounted on their back. Surface supply breathing apparatus is when divers have an umbilicus attached to their air source, supplying air from the atmosphere via a compressor or from large gas cylinders on the surface. Surface supply is used interchangeably with the term 'hookah' breathing apparatus. Technical diving using scuba equipment and mixed gases (oxygen with a specific mix of nitrogen and/or helium) is becoming more popular. Mixed gases can also be utilised via surface supplied breathing apparatus. Technical diving can also include the use of rebreather circuits, which allow the breathing gas to be 'scrubbed' of carbon dioxide and re-breathed in order to extend diver submersion time and has the added bonus of producing very few exhaled gas bubbles.

There are many organisations and groups within Tasmania that support and train the diving industry, both commercially and recreationally. Tasmania is home to one of only two diver training schools globally that provides construction and saturation diving instruction that complies with Australian Diver Accreditation Scheme (ADAS) level 1 to 4 certification. There are some 12 recreational dive clubs in Tasmania, including a university-based organisation. The Institute for Marine and Antarctic Science is a centre of excellence with education and research with the University of Tasmania and supports many scientific divers. Tasmania and its associated islands provide 26% of the Australian production for the commercial wild fish and aquaculture industry with only 0.9% of the land mass.[3,10]

RISKS WITH DIVING

Diving is a safe pastime and occupation. However, there are known inherent risks with compressed gas diving. Regarding diving in Tasmanian waters, there are regional anomalies

that add risks, such as the colder water temperature, remote locations, and technical difficulty of diving. There is an increased risk of immersion pulmonary oedema, for example, due to the colder temperatures.[11,12] The colder water can induce hypothermia, impacting on a person's ability to self-rescue. Diving in colder temperatures (generally < 14°C) necessitates wearing thicker insulation with the need to increase weights and the resultant greater exertion required by the wearer. It can also increase the risk of DCI through augmented 'on-gassing'.[13] A recent study found that there is a negative effect on thicker wetsuits (> 7 mm) on smaller chest circumferences with respiratory function (change of FVC up to 15%).[14] The colder water (~11°C) in winter, however, still entices divers as it provides the best conditions with visual clarity underwater, with the better, well known Tasmanian dive sites down to 40 m depth.[15]

A recent study[2] conducted an assessment of factors contributing to Tasmanian diver deaths between 1995–2015 based on previously published methodology.[16] Of the 17 Tasmanian recreational compressed gas diving deaths, five were SSBA and 12 were scuba divers, with no occupational diver deaths in this period.[2] While drowning was the main cause of death, CAGE was the next most common (four or five of 17 deaths).[2]

CAGE AND POST-MORTEM CT SCAN

Cerebral arterial gas embolism secondary to pulmonary barotrauma is a known disabling condition and cause of death in compressed gas diving. It is implicated in approximately 15% of Australian diving deaths[6] and was overrepresented in up to 5/17 (29%) of Tasmanian diving deaths.[2]

Nitrogen accumulates in body tissues and intravascular space with depth of diving over time. The nitrogen can then precipitate out of solution due to decreased ambient pressure with ascent. The ascent can be to the water's surface, and may then be exacerbated by altitude (e.g., during retrieval). This contributes to post-mortem decompression of the tissues, which, combined with decomposition, can result in artefactual gas over time, hence the urgency for post-mortem CT or erect CXR and considerations for the method of retrieval of the victim.[9] An X-ray is the only imaging available in the remote Tasmanian locations of Queenstown, King Island, and Flinders Island.

TRANSPORT

Nitrogen off-gassing places theoretical restrictions on modes of transport over 300 m altitude, i.e., with road travel via mortuary ambulance, fixed-wing or rotary-wing retrieval.[17] The primary consideration, however, is time to imaging and not so much the effect of altitude on the tissues with respect to 'off gassing' and post-mortem decomposition. The retrieval services, DDHM physician and forensic pathologist should discuss considerations for retrieval of the body, and the coroner's associate confirms the decision for the method of transport, i.e., land versus air. The preference is for the victim to be brought to the Royal Hobart Hospital, where the Office of the State Forensic Pathologist is based. This is where the majority of post-mortems for diving deaths have taken place in the past. Rarely, does urgent initial processing of the deceased body need to take place outside of the Royal Hobart Hospital. The prioritisation of a deceased retrieval was agreed by all parties to be triaged lower than a live retrieval. This could influence where the victim would initially be assessed, dependent on location, weather conditions, and access to appropriate transport means. Therefore, all six medical services needed to be engaged in the process for assessing a diving death.

CARBOXYHAEMOGLOBIN

Other potential influences on a diver's death could include disabling doses of drugs, ethanol, and carbon monoxide (CO). The latter has been implicated in compressed gas diving deaths, particularly with SSBA as it is a colourless, odourless, tasteless, non-irritative gas that can enter the diver's breathing gas supply, and which competes with oxygen binding to haemoglobin, forming carboxyhaemoglobin (COHb). The depuration rates for COHb, drugs, and to some extent, ethanol are such that the concentrations remain stable in the victim after death and allows for delayed sampling which can be undertaken by the forensic pathologist at post-mortem.[18–20]

LIMITATIONS

This project was successful in that Tasmania is a small state regarding population size and land mass. The processes undertaken to enact the state-wide engagement may not be appropriate in larger states but could be applicable to individual regions in Australia.

Conclusions

Diving is a relatively safe sport, although diving deaths are over-represented in Tasmania. This could be due to the greater number of divers per head of population and the more challenging marine conditions. Between September 2021 and March 2022 there were three compressed gas diving deaths in Tasmania that stimulated a review of the statewide response from frontline to hospital-based personnel. Each craft group plays a pivotal role in providing timely post-mortem assessment and collection of information from:

- the diving site (i.e., photo documentation of the site, body-worn camera footage, equipment set-up, corroborating witness statements);
- the deceased body (i.e., depending on location post-mortem CT/erect CXR, autopsy); and
- collation of information (i.e., body-worn camera footage, witness statements, post-mortem diving equipment analysis, expert analysis of all information).

We would encourage other states to consider the benefits of establishing interagency collaboration. The statewide engagement in diving-related deaths fostered sharing of knowledge, camaraderie, and appreciation for each craft group's value in supporting the Tasmanian community.

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