

Provisional report on diving-related fatalities in Australian waters 2008

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Abstract

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Introduction: An individual case review of diving-related deaths, reported as occurring in Australia in 2008, was conducted as part of the DAN Asia-Pacific dive fatality reporting project.

Method: The case studies were compiled using reports from witnesses, the police and coroners. In each case, the particular circumstances of the accident and details from the post-mortem examination, where available, are provided.

Results: In total, there were 19 reported fatalities (the same as for 2007), 17 involving males. Twelve deaths occurred while snorkelling and/or breath-hold diving, and six while scuba diving. One diver died while using surface-supply breathing apparatus. Two breath-hold divers appear to have died as a result of apnoeic hypoxia, at least one case likely associated with hyperventilation. Two deaths resulted from trauma: one from impact with a boat and the other from an encounter with a great white shark. Cardiac-related issues were thought to have contributed to the deaths of five snorkellers and at least two, possibly three, scuba divers.

Conclusions: Trauma from a marine creature, snorkelling or diving alone, apnoeic hypoxia and pre-existing medical conditions were once again features in several deaths in this series.

Key words

Diving deaths, scuba, breath-hold diving, surface-supply breathing apparatus (SSBA), diving accidents, case reports

Introduction

Each year in Australia there are a number of deaths associated with snorkelling and diving using compressed gas (i.e., scuba or surface-supply breathing apparatus, SSBA). Although some incidents are unavoidable, many might have been avoided through more extensive education and training, greater experience, better planning and decision-making, appropriate medical screening, improved supervision, and/or better equipment choice and maintenance. The aim of the Diver Alert Network (DAN) Dive Fatality Reporting Project is to educate divers and the diving industry and to inform physicians on the causes of fatal dive incidents in the hope of reducing their incidence in the future and of detecting, in advance, those who may be at risk. This report discusses the diving-related fatalities between 01 January and 31 December 2008 that are recorded on the DAN Asia-Pacific (AP) database. When an incident is unwitnessed, it is difficult to determine exactly what has occurred. We have sometimes included considered speculation within the comments to provoke thought about the possible sequence of events leading to death.

Methods

As part of its ongoing research into and reporting of diving fatalities in Australia and elsewhere in the Asia-Pacific region, DAN AP has obtained ethics approval from the Victorian Department of Justice Human Research Ethics Committee, to access and report on data included in the Australian National Coronial Information System (NCIS); the Royal Prince Alfred Hospital Human Research Ethics

Committee; the Coronial Ethics Committee of the Coroner's Court of Western Australia and the Queensland Office of the State Coroner. The methodology used for this report was identical to that described previously for the 2004 Australian diving-related fatalities.¹

Breath-hold and snorkelling fatalities

BH 08/01

This 21-year-old, fit, healthy male was an experienced and frequent spear fisherman. On this day, he went spearfishing from a boat while a friend remained on board. There was a light wind and the sea was dead calm. He wore mask, snorkel, fins, a full wetsuit with hood, a knife and a weight belt with 4 kg of weight and was carrying a speargun. He did multiple breath-hold dives at between 15 and 20 metres of seawater (msw) at a variety of locations and caught many fish. On two occasions, he encountered large sharks which harassed him and tried to take his speared fish.

He was often observed to take several deep breaths prior to diving. On one dive, his friend noticed him rising towards the boat before "conking out" just below the surface beside the boat. The friend reached over and managed to grab the diver and lift him to the surface. The diver began to cough and, when asked if he had become unconscious, he denied this and said that he had just taken in some water. The friend was concerned that the victim was slightly disoriented but could not dissuade him from retrieving his spear, which had become embedded in a rock at a depth of about 20 metres' sea water (msw) after he had fired at a fish. The victim

re-entered the water and, after some hesitation, took some deep breaths and descended. When he failed to surface after an extended period, the friend became concerned. Several minutes later he saw a dark shape below the surface which he thought might possibly have been the victim but could not identify this or reach it before it seemed to drift away in the current. Some of the victim's equipment was found at the dive site three days later. The weight belt and wetsuit remnants indicated shark bites. His body was never found.

Comments: This diver practised hyperventilation prior to breath-holding, a well-known precipitant to apnoeic hypoxia of ascent. It is likely that he became unconscious, or very nearly so, briefly on the previous dive and he took a great risk diving again in his apparently disoriented condition. It is possible, given his friend's statement of events, that he suffered an underwater hypoxic blackout, subsequently drowned and that the sharks later attacked his body. It is also possible that shark attack was the primary event.

Summary: Fit and healthy; experienced spear fisherman; known to practise hyperventilation; apnoeic hypoxia on previous dive; appeared disoriented but dived again to retrieve spear; failed to surface; equipment found showed evidence of shark contact; body never found; probable drowning following post-hyperventilation apnoeic hypoxia; evidence of shark attack

BH 08/02

This 82-year-old male, an overseas tourist, was a passenger on a cruise ship visiting the Great Barrier Reef (GBR). He had a history of several heart attacks and was currently taking aspirin, a statin (type unknown) and nitrazepam but reportedly looked fit for his age. He had snorkelled about five times before, most recently one month earlier. Although he failed to disclose to the dive instructor any health conditions or that he was taking medications, the instructor was concerned about him because of his age and apparent anxiety. He alerted his supervisor and they agreed to observe him closely, along with some other elderly participants. There were nine snorkellers in the victim's group.

The victim entered the water wearing mask, snorkel, fins and a Lycra suit, and with a 'noodle' to provide additional floatation. Some current was running along the reef, and there was a moderate chop. The conditions were later described by the instructor as "*not perfect*", and that it would have been "*tough*" for some participants, including the victim. After a short time, the victim approached the instructor and was out of breath but said he was "*OK*", and, after catching his breath, returned to snorkelling. The instructor was then asked to assist another snorkeller to the boat and when he returned, an estimated two minutes later, he noticed that the victim was away from the group but appeared to be snorkelling normally. However, when he approached the victim, he found him to be unconscious, cyanotic and apparently apnoeic so he began in-water rescue

breathing and signalled for help. The tender arrived and the victim was dragged on board. There was insufficient space to perform cardiopulmonary resuscitation (CPR) so the instructor continued providing rescue breaths on the way to the main boat. Once on board, CPR was begun with the rescue breaths enhanced with supplemental oxygen. The delay from determining unconsciousness to commencing CPR was thought to have been about 10 minutes. After several cycles of CPR, gurgling sounds were heard while ventilating and the victim was briefly rolled onto his side to drain water from his mouth. His dentures also became displaced and were removed to facilitate a better mask seal. CPR was continued throughout the 35-minute boat trip back to the island base, but was unsuccessful.

Autopsy: The heart was heavy (481 g; normal range 331–469 g) but the ventricles were of normal thickness. The coronary arteries showed severe atherosclerosis with severe narrowing of the right coronary artery (~1 mm diameter) by atheromatous plaque 40 mm from its origin. The left coronary artery had significant narrowing 45 mm from its origin. There was subendocardial fibrosis of the myocardium on microscopic examination. The left and right lungs weighed 673 g and 579 g, respectively and there was evidence of moderate congestion and oedema. However, there did not appear to be excessive pulmonary oedema fluid. Toxicology screening showed traces of nitrazepam and aminonitrazepam. The cause of death was given as ischaemic heart disease due to severe double-vessel atherosclerosis.

Comments: This elderly victim withheld important information about his cardiac history. Had he been honest, he may not have been permitted to snorkel and this incident could have been averted. The dive instructor appeared to have been reasonably vigilant but was responsible for a group and was required to divert his attention from a person who required his attention to assist someone else.

Summary: Elderly; history of myocardial infarctions; limited experience; current and surface chop; became breathless (although claimed to have recovered); silent unconsciousness; cardiac-related death

BH 08/03

This victim was a 66-year-old, obese (BMI = 33.5 kg m⁻²) woman with a history of breast cancer and was under treatment for hypertension. She was taking doxazosin, spironolactone and celecoxib. She was reported to have been a good swimmer but had little snorkelling experience. She was an overseas tourist on a day trip to the GBR, accompanied by her daughter.

The weather was sunny with a light wind and the sea was calm. The victim was wearing bathers and t-shirt, mask, snorkel and fins. She and her daughter entered the water and, when the victim had trouble clearing water from her snorkel, her daughter got her a 'noodle' for additional

Table 1
Summary of snorkelling and breath-hold diving-related
BNS – buddy not separated; BSB – buddy separated before problem;

ID	Age	Sex	Height (cm)	Weight (kg)	BMI (kg m ⁻²)	Training	Experience	Dive group
BH08/01	21	M	183	n/s	–	n/s	yes	solo
BH08/02	82	M	175	80	26.1	n/s	some	GSB
BH08/03	66	F	164	90	33.5	n/s	some	BNS
BH08/04	52	M	176	77	24.9	n/s	n/s	GSB
BH08/05	53	M	178	85.5	27.0	nil	some	solo
BH08/06	47	M	n/s	n/s	–	nil	nil	BSB
BH08/07	21	M	181	74	22.6	n/s	yes	BSB
BH08/08	25	F	155	52	21.6	n/s	some	GNS
BH08/09	42	M	179	95	29.6	n/s	yes	solo
BH08/10	46	M	181	98	29.9	trained	yes	GSB
BH08/11	51	M	n/s	n/s	–	n/s	yes	BNS
BH08/12	25	M	170	78	27.0	n/s	yes	BSB

buoyancy. About a minute after they resumed snorkelling the daughter found her mother lying motionless, face-down and unresponsive. The daughter called for help and some of the charter boat staff retrieved the victim and towed her back to the boat, providing rescue breaths on the way. She was brought aboard and four doctors, who were passengers on the vessel, came to assist. The victim was cyanotic, apnoeic and pulseless and CPR was begun by the doctors, assisted by some crew members. An oropharyngeal airway was inserted and she was ventilated via a bag-valve-mask with supplemental oxygen. The victim regurgitated a large amount of stomach contents. An automated external defibrillator (AED) was attached after 10–15 minutes of CPR and one shock was advised and delivered but the victim failed to respond. No further shocks were indicated and the doctors pronounced the victim to be deceased after a total of 44 minutes of CPR.

Autopsy: There was over 400 ml of blood in the pericardial sac. The source of the haemorrhage was a rupture of the anterior wall of the left ventricle in an area of myocardial discolouration due to recent myocardial infarction. The heart weight (283 g) was within normal limits for body weight (213–457 g). The coronary arteries showed severe focal calcific atheroma with near-complete occlusion of the left main coronary artery and adjacent proximal left anterior descending (LAD) artery and a small left circumflex artery. The right coronary artery showed less than 60% luminal

narrowing. Histology of the heart showed necrosis and haemorrhage consistent with days-old recent infarction. The lungs (Lt 456 g; Rt 489 g) showed congestion and mild pulmonary oedema. Toxicology screening was not done. The cause of death was given as cardiac tamponade due to cardiac rupture resulting from recent myocardial infarction.

Comments: The dive operator reportedly mentioned the potential risks associated with certain medical, including cardiac, conditions, but the daughter stated that she and her mother did not take much notice, believing that it did not apply to them. The autopsy indicated that the victim had suffered a myocardial infarction in the previous few days but there was no mention in the witness reports that the victim had complained of any symptoms, or appeared to have been unwell. Typically rupture occurs three to five days post infarct owing to to weakening of the wall by tissue necrosis. Among forensic cases with rupture, the symptoms of the acute infarct are not infrequently mistaken for indigestion. The victim may well have died undertaking a variety of other activities, although water is an unforgiving medium in which to become unconscious.

Summary: Hypertension; 3–5 days post myocardial infarction (not disclosed, and may have been undiagnosed antemortum); good swimmer; little snorkelling experience; calm conditions; silent death; cardiac related

Table 1 (cont.)

fatalities in Australian waters in 2008

GNS – group not separated; GSB – group separated before problem; n/s – not stated

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Weights (kg)	BCD	Disabling injury
spearfishing	20	n/s	yes	4	n/s	asphyxia
recreation	n/s	surface	n/s	n/s	n/s	cardiac
recreation	n/s	surface	n/s	n/s	n/s	cardiac
recreation	n/s	surface	n/s	n/s	n/s	cardiac?
spearfishing	n/s	surface	n/s	n/s	n/s	asphyxia
recreation	3	surface	n/s	n/s	n/s	asphyxia
spearfishing	20	n/s	yes	n/s	n/s	unknown
recreation	n/s	surface	n/s	n/s	n/s	cardiac?
abalone	3–4	n/s	yes	12.25	n/s	asphyxia
crayfish	n/s	surface	n/s	n/s	n/s	cardiac
crabs	n/s	surface	yes	1.5	n/s	trauma
spearfishing	2.5	surface	n/s	n/s	n/s	trauma

BH 08/04

This 52-year-old male had a history of heart valve replacements in 1990 and 2006. A pacemaker was fitted in 2003 and he was currently taking warfarin and perindopril for hypertension. His wife later reported that his pacemaker was overdue for new batteries and that, two weeks earlier, he had seen a doctor as “*the top of his heart was not beating properly*”. She also stated that he had not taken his medications for one or two days prior to this incident. His previous snorkelling experience is unknown.

The victim, his wife and two friends had chartered a yacht and were on a sailing holiday on the GBR. He, his wife and one friend decided to snorkel from the boat while the other friend was on a nearby beach. There was no information about the sea conditions or what equipment he was using other than a mask, snorkel and wetsuit. After a short time, the victim swam ahead of the others and out of sight. After being in the water for about 15 minutes, his companions returned to the yacht some 50 metres distant. They could not see the victim but were soon alerted by the friend on the beach who pointed to the victim about 70 metres from the yacht. They eventually started the tender, picked up the friend on the beach and went to the victim who was found to be floating face-down, unconscious, apnoeic and cyanotic. He was dragged aboard the tender where CPR was commenced. It was maintained despite continual

regurgitation while they made their way to a nearby vessel where it was continued by two medical students. The emergency services were activated and a medical rescue crew, who were coincidentally on a nearby island, were brought to the vessel and implemented advanced life support (ALS). Although initially there was no shockable rhythm, after administering adrenaline and sodium bicarbonate the doctor delivered several defibrillation shocks unfortunately without success.

Autopsy: The pharynx and larynx contained a moderate amount and the trachea and bronchi a large amount of watery fluid. The lungs were heavy (Lt 597 g; Rt 604 g), with evidence of severe congestion and oedema. The CT scan revealed fluid in the maxillary sinuses. All these findings suggest drowning. The heart weighed 721 g with severe hypertrophy of the wall of the left ventricle and the septum. These both measured at least 25 mm in diameter (normal < 14 mm). In the anterior wall of the left ventricle there was an area of almost full-thickness scarring. The wall of the right ventricle was thicker than normal (5–6 mm, normal < 4 mm) and the ventricle was dilated. The left atrium was extremely dilated and thick-walled. A dual-chamber pacemaker had been inserted into the right side of the heart, with one electrode attached to the wall of the right atrium and the other to the wall of the right ventricle, near its tip. There was a prosthetic aortic valve, which appeared to have been functioning normally. The ostia of the coronary arteries

were easily identified and were widely patent. Dissection of coronary arteries showed only mild atherosclerosis. Toxicology showed warfarin 0.6 mg kg⁻¹. The cause of death was reported as drowning following cardiac arrhythmia due to valvular heart disease and cardiomegaly.

Comments: This death was likely a result of a cardiac arrhythmia in a man with significant pre-existing aortic valvular heart disease and significant enlargement of the heart. He had recent symptoms of arrhythmia, and was due to have his pacemaker battery replaced, so it is unsurprising that this would be exacerbated by the known cardiac triggers associated with snorkelling.

Summary: Cardiac valve replacement and pacemaker; recent arrhythmia; unknown general fitness and snorkelling experience; unknown conditions; silent death; cardiac related

BH 08/05

This victim was a 53-year-old, apparently healthy male who was not known to be taking any medications. He went to the beach with a group of friends who planned to go spearfishing. He had said that he had done so before when he was young but was not known to have had any recent experience. Two of the friends entered the water and began snorkelling. A short time later, the victim decided to go spearfishing alone as his other friend didn't want to go in. He entered the water wearing a t-shirt, long pants, sandals and mask and carrying the hand spear. He had no snorkel or fins. The sea was choppy and there was a two-metre swell crashing onto the nearby rocks. After about 10 minutes, he was seen to remove his mask and drop his spear, and appeared to be struggling to stay afloat. He was drifting in the current towards the rocks and was 'dog paddling'. At one point he raised his hands and called "Hey", but then collapsed face-down and drifted in the water. A bystander helped to drag the victim onto the rocks, assessed him to be unconscious and apnoeic and began CPR. He continued this with the help of one of the victim's friends until an ambulance arrived about 25 minutes later. The paramedics continued resuscitation attempts but soon pronounced the victim to be deceased.

Autopsy: The lungs were heavy (Lt 668 g; Rt 812 g) and overexpanded, with the anterior margins of the lungs overlapping on the anterior surface of the heart, and they appeared to pit on pressure, with a dough-like consistency. The trachea and main bronchi contained small amounts of light-brown-stained fluid. The heart weighted 458 g and the left ventricle showed marginal hypertrophy (15 mm). The coronary arteries showed minimal atherosclerotic narrowing. There were superficial abrasions on the face and fractures of the right anterior third to seventh ribs. However, based on the description of the incident, these injuries probably occurred during recovery and resuscitation. Toxicology was negative. The cause of death was given as drowning.

Comments: An inexperienced spear fisherman wearing street clothing and swimming alone without snorkel or fins in choppy seas with a large swell was 'a tragedy waiting to happen'. He was likely to have become exhausted, struggling in water-logged clothing; an ounce of common sense could have prevented this (alcohol-free) calamity.

Summary: Apparently healthy; inexperienced; spearfishing alone with others nearby; wearing street clothes and no fins or snorkel; rough seas and current; drowning

BH 08/06

This 47-year-old man was an overseas tourist. His medical history is unknown and he and his wife had never snorkelled before. During the boat trip to an island, a snorkelling brief was provided by means of a video in the victim's language but it was later reported that he and his wife paid little attention to this. They were also provided with a snorkelling safety brochure in their own language and advised (in their own language) where to swim in a patrolled area.

After hiring mask, snorkel and fins from the local dive store (and refraining from also taking a Lycra suit and snorkelling vest), they entered the water off a patrolled beach. The conditions were described as "average", with a wind of 20–25 knots and a choppy sea. There was a slight current and the visibility was poor, being less than one metre. After about 15 minutes and in water with a depth of around 3 msw, they decided it was too choppy and that they would return to shore with the wife swimming in front of the victim. At one point she heard him call out but, failing to realise that he was likely to have been in distress, she continued to shore, struggling against the current. She became concerned when he failed to arrive after 5–10 minutes and began to look for him in the general vicinity, without success. After a further 30 minutes she notified the lifeguard who initiated a missing person alert. The beach was closed and swimmers were recalled from the water. After a search of more than an hour, the victim's body was found approximately 200 metres from shore on the sandy seabed at a depth of 2–3 msw. He was recovered but CPR was not attempted because of the submersion time of more than an hour. A rescue helicopter and medical crew arrived at the island but, after discussion with the ground staff, did not land.

Autopsy: Details are unavailable at the time of publication as the case has not yet been closed.

Comments: Much is unknown about this case as the coronial documents are currently unavailable. However, it does appear to highlight the difficulty often faced by lifeguards in identifying a snorkeller in distress among other swimmers and in relatively poor conditions. It also serves to highlight the problems that can more easily occur after buddy separation. Given the reported conditions and the victim's reported lack of previous snorkelling experience, it may

have been wise for him to have refrained from snorkelling in such conditions, or at least worn a snorkelling vest. It is important that operators involved in such activities provide considered advice to those of unknown or limited experience.

Summary: Unknown medical history; no previous snorkelling experience; poor conditions; separation; body submerged more than an hour; case not yet closed; disabling agent/cause of death unknown

BH 08/07

This 21-year-old, male student was fit and healthy and an experienced spear fisherman who would often breath-hold dive to 20–25 msw. He went spearfishing with two friends from a small private boat wearing mask, snorkel, fins, full wetsuit with hood, weight belt and knife and carrying a speargun, all of which were his own. The victim and one friend, who had dived together many times before, were diving while the other friend remained on the boat. They had multiple, uneventful dives at a first location before moving to a second site, which was a beacon where the depth of water was 20 msw with a predominantly sandy bottom. This was one of their regular spearfishing sites. The sea was calm and visibility initially 6–8 metres although this later deteriorated. There was a slight current.

After several dives at this site, the victim's buddy suggested that they return to the boat as there were few fish. After agreeing to this and while the buddy was returning to the boat, the victim dived again and surfaced briefly before disappearing again underwater and failing to surface. The concerned buddy made several unsuccessful dives to try to find the victim in the poor visibility, but only retrieved the victim's float and spear, to which a large fish was attached. He gave up after about five minutes as he was exhausted and believed that it was by now too late to help his friend. The boat driver sent up a flare and called for assistance on his mobile phone and they were joined by several recreational vessels and a helicopter, which performed an unsuccessful surface search. The victim's body was found by police divers several hours later very close to where he had been diving.

Autopsy: The mouth contained frothy fluid and upper airways a small quantity of frothy mucus. The lungs were heavy (Rt 820 g; Lt 720 g) and slightly over-inflated. The cut surface of the lungs showed intense basal congestion and oedema, suggestive of drowning. The heart weighed 290 g and was of normal size for the body weight with no coronary artery disease and no obvious abnormality. Toxicology was negative. The cause of death was given as drowning.

Comments: The precise mechanism by which this young, healthy and experienced breath-hold diver died is unknown. It is likely that he became unconscious from apnoeic hypoxia after an extended breath-hold dive. There was no evidence provided that he practiced hyperventilation. There was no

report of the amount of weight he was wearing, but it is likely that he was negatively buoyant as his body failed to rise to the surface.

Summary: Healthy; experienced spear fisherman; others nearby; speared fish; failed to surface; likely apnoeic hypoxia; drowning

BH 08/08

This 25-year-old woman was an overseas tourist on a working holiday. She and a friend went on a day trip to snorkel on the GBR. There were 14 passengers and two crew on board the charter vessel. The skipper later reported that the victim said that she had snorkelled before in Thailand and Cairns but this was not confirmed. There is no other information about her swimming or snorkelling experience. When completing the pre-snorkel medical questionnaire, she told her friend (who was translating for her) that her "*heart sometimes beats quickly*". She also mentioned that after she had had a tooth extracted it would not stop bleeding. After initially marking "*Yes*" to the heart condition question, this was changed to "*No*" after the receptionist said that the question only applied to "*serious heart conditions*". She also changed her answer to a question relating to nose bleeds after advice from the receptionist.

The group went snorkelling at a site about 30 metres from where the vessel was anchored close to a beach. The victim was wearing a stinger suit. The sea conditions were not reported. The skipper remained on the boat as a secondary lookout while the supervisor was watching the group from a tender. After going to the vessel to replace a snorkel for one of the group, the supervisor returned to the snorkelling area and found the victim face-down and motionless, with the end of her snorkel submerged. She had been in the water for about 20 minutes. When she was pulled into the tender she was unconscious and apnoeic and froth was coming from her mouth and nose. The supervisor drove the tender to the main vessel and the skipper came aboard and began CPR. He was later assisted by other passengers. Efforts were complicated by regurgitation of stomach contents and water. After about 30 minutes medical staff from a nearby resort arrived by boat and continued resuscitation efforts. A defibrillator was attached indicating pulseless electrical activity, adrenaline was administered and spontaneous cardiac output eventually returned. When the medical team from the rescue helicopter arrived and intubated the victim, they noted that her vocal cords were oedematous and that there was "*pink frothy sputum in the endotracheal tube, consistent with pulmonary oedema*". She was then placed on a ventilator and transferred to hospital where she died later that night.

Autopsy: The upper airways contained a large amount of frothy fluid. The lungs were heavy (Lt 755 g; Rt 808 g) and showed severe pulmonary oedema. The heart weighed 265 g and appeared normal with normal coronary arteries.

The brain was mildly oedematous and showed hypoxic ischaemic encephalopathy on CT scan, consistent with drowning. There was a thyroidectomy scar on the neck and no thyroid gland was detected at autopsy. Toxicology showed only lignocaine. The cause of death was given as drowning.

Comments: It is unknown whether this victim showed any signs of distress before becoming unconscious, as the primary lookout was temporarily elsewhere. Likely diagnoses include drowning and a cardiac dysrhythmia with immersion pulmonary oedema a remote possibility. Whilst there was a history of palpitations, ECG and cardiac echocardiogram performed in hospital after resuscitation were reported as normal and there was no other evidence to suggest a cardiac cause for a loss of consciousness. Although the rescue efforts of the dive crew and various medical crews were gallant, the delay in the initial recognition of a problem made ultimate success unlikely.

Summary: Possible history of tachycardia; some snorkelling; amongst group; silent unconsciousness; CPR successful; likely drowning/cardiac event

BH 08/09

This victim was an apparently fit 42-year-old male, an experienced snorkeller who often dived for abalone. He had told a friend that he had once gone to the doctor for an asthma attack but there was no report of the frequency or severity of attacks or if he had been taking medication for asthma. He went with a friend to a familiar beach to look for abalone. The sea conditions were calm and clear with no swell and only a small wind chop. The victim wore a mask, snorkel and fins, and a two-piece wetsuit and weight belt with 12.25 kg of weights. He had a knife strapped to his leg and carried a catch bag.

The victim entered the water alone. His friend remained on shore and tried to keep a lookout from their car parked on a cliff above. The victim snorkelled for about an hour before the friend lost sight of him. He became worried and mentioned this to an acquaintance who arrived and who then offered to conduct a search. The acquaintance entered the water approximately 25 minutes after the diver was last seen and, after searching for about 20 minutes, found the victim sitting on the seabed at a depth of 3–4 msw and about 30 metres from shore. He was unconscious and apnoeic, and still wearing his mask and weight belt, but the snorkel was out of his mouth, which was closed. He was not entangled. The rescuer dragged the victim to the surface and managed to support him there, despite being unable to remove the weight belt. He towed the victim to shore, where he found no palpable pulse. His hands were “*curled up and stiff*” and the rescuer decided that the victim was dead and did not attempt CPR. When ambulance officers arrived they pronounced the victim to be deceased. The victim’s weight belt had been threaded through under part of the wetsuit and was therefore difficult to remove. His knife was missing.

Autopsy: The autopsy was performed six days after death and the body showed decompositional changes. There was no fluid in the upper airways. The lungs together weighed 1095 g (normal range: 600–1000 g) and were congested. There was 50 ml of red putrefactive effusion in both pleural cavities. Decomposition can obscure some of the changes of salt water drowning. The heart weighed 363 g (normal range: 150–400 grams) and was structurally normal with no scarring or abnormalities identified on sectioning. The coronary arteries were unremarkable except for the distal portion of the LAD coronary artery, which demonstrated 30% narrowing from atherosclerosis. Coronary artery ostia were normal. Toxicology showed alcohol 0.025 g 100 ml⁻¹. The cause of death was given as drowning.

Comments: The victim was an experienced snorkeller so it is reasonable to assume that the threading of the weight belt under part of his suit was likely to have been intentional rather than accidental. Although it is unknown what triggered this accident, if the victim did attempt to access or remain on the surface in a distressed state, it would have been extremely difficult for him to release his weight belt to attain positive buoyancy. Any diver wearing weights must ensure that they can be readily and easily discarded if necessary. It is obvious that the distant lookout on land was ineffective.

Summary: Experienced; snorkelling alone with distant lookout on land; disappeared from sight; found unconscious underwater; weight belt threaded under suit; drowning

BH 08/10

This 46-year-old male had a medical history that included osteoarthritis (knees), sinusitis, gout, gastro-oesophageal reflux, hyperlipidaemia, cervical spinal disease requiring surgical fusion and disc arthroplasty. He also had anxiety neurosis for which he was receiving counselling and was taking mirtazapine. His family reported that he was a strong swimmer and a competent snorkeller who became a certified open-water diver 11 years earlier, although he had not snorkelled or scuba dived for the previous three years.

On this day, he went snorkelling in temperate waters with three other family members off a popular island with the intent to put out a crayfish pot. The weather was described as hot and very windy, with choppy seas, a slight current and poor underwater visibility. He was wearing mask, snorkel, fins and a short wetsuit. The group took it in turns supporting the pot while they swam out against the current. The victim duck-dived several times looking for a place to drop the pot, which was eventually dropped 80 metres from shore. However, while on the way, the victim indicated to one of the others that he would return to shore. Another family member on the beach saw the victim leaving the others and snorkelling towards shore; however, several minutes later she noticed that he was motionless about 30 metres from shore. She waded out and found him to be unconscious and apnoeic and began giving him some rescue breaths. With help, she

dragged him to shore and commenced CPR. Sometime later, a doctor and two nurses from the island arrived and took over resuscitation efforts but resuscitation was abandoned after the arrival of the local Flying Doctor medical staff.

Autopsy: The right and left lungs weighed 627 g and 598 g respectively and both lungs appeared hyper-expanded, protruding from the chest cavity on removal of the breast plate. The cut surfaces showed diffuse, patchy purple-coloured congestion, with free-flowing watery fluid. There was frothy mucus in the trachea. The heart weighed 394 g and appeared normal. There was a narrowing of at least 75% in the LAD coronary artery. There was no obvious scarring of the myocardium. Toxicology showed mirtazapine 0.2 mg L⁻¹. The cause of death was given as drowning with coronary atherosclerosis as a contributing factor.

Comments: It is likely that the exertion involved in dragging the cray pot triggered a cardiac event causing the victim to become unconscious and subsequently drown.

Summary: History of osteoarthritis, cervical spinal surgery, gout, GORD, hyperlipidaemia and anxiety; experienced snorkeller; choppy seas and dragging cray pot with others against slight current; abandoned group to return to shore prematurely; found unconscious close to shore; CPR unsuccessful; drowning (likely cardiac-related)

BH 08/11

This victim was a 51-year-old male who had over 30 years of snorkelling experience. His medical history was unreported. He went snorkelling with his son to look for crabs, wearing mask, snorkel, fins, sleeveless short wetsuit and weight belt with 1.5 kg. The conditions were calm with a slight swell. They swam out to about 50 metres from shore and then swam along the weed line. The visibility was about eight metres. After swimming about 300–500 metres and seeing very few crabs, they decided to turn back. The victim was swimming close behind his son when the son heard his father call out. When he turned around, he noticed a very large dark shape swimming rapidly underwater towards his father. He then saw his father pulled underwater. Witnesses on shore noticed a large dorsal fin, estimated to be one metre, and thrashing in the water and heard the victim's son's calls for help. Sometime later the crew of a rescue helicopter saw a diver's float and wetsuit top floating on the surface, which were identified to have belonged to the victim. The wetsuit was torn, consistent with bite marks from a large shark. Another helicopter filmed a large shark in the vicinity and another piece of the wetsuit was later found. A shark expert concluded from the bite marks and footage of the shark filmed that the attacking shark was a 4 to 4.5 metre great white shark (*Carcharodon carcharias*).

Autopsy: Body not recovered.

Comments: This diver was the unfortunate victim of a shark

attack. It was not reported whether or not the victim was carrying any crabs. If so, this could have been a precipitant to the attack. There was some fishing activity in the vicinity, another potential precipitant.

Summary: Experienced; looking for crabs; attacked by large shark; parts of wetsuit recovered but not body; presumed death by trauma

BH 08/12

This 25-year-old male was an experienced spear fisherman who went spearfishing with a friend from the shore in a marine park well known for its abundant marine life. The weather was sunny, there was little wind and the sea was calm and clear. The victim wore a black mask, snorkel and fins; army camouflage-coloured wetsuit with a black hood; and black and white gloves. He carried a speargun and Shark Shield. He and his buddy snorkelled for a while approximately 30–50 metres from shore in water about 3 msw deep. They were not using a float with a 'Diver Below' flag. The site is covered with reef and coral bommies interspersed on a sandy bottom.

After about 60–75 minutes, the buddy tired and returned to the beach, while the victim continued to spearfish. Shortly afterwards, a high-powered 8.5 metre tourist boat drove past at high speed and collided with the victim. Some of the passengers saw the victim surface briefly just in front of the boat and then heard thuds from an impact. The boat driver had not noticed the diver as he was driving from a rear console, the 12 passengers were seated in front of him and there was no designated lookout to warn him. After impact, passengers started yelling at the driver but he could not hear them as he was wearing ear-muffs to protect his ears from the engine noise and wind. However, he eventually stopped when he saw passengers waving to him to do so and they directed him back to where there was blood in the water and a mask, fins and speargun floating on the surface. They could see a dark shape below but abandoned attempts to retrieve the victim owing to concern about sharks. The depth of water was approximately 2.5 msw. The friend on shore heard the boat rush past and then saw it turn back and circle. He swam to the boat and was taken to the site where he could see the victim's body on the bottom, motionless and bleeding. However, he was unable to recover his friend, which was later done by crew from another vessel.

The coronial investigation concluded that the vessel was likely travelling in excess of 30 knots approximately 45 metres from shore in water which was a little deeper than three metres. Although this was believed to be unsafe, there was no regulation prohibiting this. The coroner made several recommendations which included imposing an 8 knot speed limit within 150 m of the low tide mark in that area.

Autopsy: There was head injury with large deep incised wounds in the left forehead and right face with skull

Table 2

Summary of scuba and surface-supply diving-related
BSB – buddy separated before problem; BSD – buddy separated during problem; GSB – group separated before problem;

ID	Age (yr)	Sex	Height (m)	Weight (kg)	BMI (kg m ⁻²)	Training	Experience	Dive group
SC08/01	70	M	177	76.5	24.4	trained	experienced	BSD
SC08/02	41	M	179	98	30.6	trained	some	BSB
SC08/03	48	M	184	119	35.1	trained	some	GSB
SC08/04	52	M	188	107	30.3	trained	n/s	GNS
SC08/05	66	M	170	76.6	26.5	trained	experienced	solo
SC08/06	35	M	170	91	31.5	trained	inexperienced	BSD
SSBA 08/01	30	M	178	78	24.6	trained	experienced	solo

fractures and laceration of the right frontal, temporal and parietal lobes of the brain. There was traumatic amputation of the right upper arm at the mid-humerus, and deep incised wounds on the right shoulder and on the right knee. The heart weighed 266 g and was normal apart from a 30–40% narrowing of the LAD coronary artery. The upper airways contained a small amount of blood-stained frothy fluid. The right and left lungs weighed 442 g and 388 g respectively and were mildly congested. Toxicology revealed traces of mirtazepine, cannabis and alcohol. The cause of death was given as head injury.

Comments: The injuries are typical for a diver struck by a boat propeller. Previously in this State, the use of a dive flag when snorkelling was mandatory but this regulation was repealed several years earlier and the use of the flag became optional but generally encouraged. Had the victim been towing a float and dive flag it would have increased the likelihood of his being seen. However, this would have been no guarantee under these particular circumstances where the boat was driven so fast, from the rear and without a proper lookout. The boat operator was lucky to have avoided prosecution. Despite a regulation that a vessel should not travel at a speed greater than 8 knots in water less than 3 m deep, he was afforded the benefit of doubt of water depth at that time, and whether he had exceeded the speed for which his vessel was licensed. The ‘culpability’ of the boat driver was owing to a combination of speed and not having a lookout, especially given the location of the driving controls.

Summary: Experienced; not displaying dive flag; hit by high-speed, stern-driven boat with inadequate lookout; trauma

Scuba diving fatalities (Table 2)

SC 08/01

This 70-year-old male had a history of ischaemic heart disease, stroke, mitral valve surgery (10 years prior), hypertension and hyperlipidaemia. He was a non-smoker and walked and cycled regularly to keep fit. He was on a variety of medications, including candesartan, cilexetil, atorvastatin calcium, clopidogrel, celecoxib and finasteride. He was an experienced diver who owned his own equipment and dived regularly, reportedly having done over 100 dives. His buddy reported that, two months earlier, the victim became very breathless when walking back from a dive wearing his equipment, this apparently being the first time this had occurred in the six years they had dived together.

They dived from shore near the entrance to a bay in relatively poor conditions, although nothing unusual for them. The weather was overcast and raining with a 15–20 knot wind, a surface chop, a one-metre swell and strong current. They dived to a maximum depth of around 24 msw, swimming with the current with visibility of 10–15 m. When they surfaced after 67 minutes to get their bearings, they were in the open ocean about 50–60 metres from the bay’s entrance and being pushed further away by the swell and current. The buddy encouraged the victim to swim towards shore but the victim said to his buddy something to the effect of ‘we have had it here’. Look, the swell has got us and we can’t swim back to the bay’. He then started to unzip his wetsuit top as he was breathing heavily. He did not respond to the buddy and did not swim. The buddy exited the water some 600 m from where they surfaced, ditched his equipment and re-entered the water to assist the victim who was now about

Table 2 (cont.)

fatalities in Australian water in 2008

+ sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ >50% full; nad – nothing abnormal discovered;

n/i – not inflated; n/s – not stated; CAGE – cerebral arterial gas embolism

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	BCD	Gas supply	Equip test	Disabling injury
recreation	24	surface	off	n/s	inflated	n/s	n/s	cardiac
hunting crayfish	11	surface	on	10.9	n/i	+	nad	cardiac?
recreation	34	n/s	n/s	17	inflated	nil	nad	CAGE
recreation	2	surface	n/s	n/s	inflated	n/s	n/s	cardiac
commercial	3	1	on	9.7	nil	++	faults	asphyxia
crayfish	10.7	surface	off	12	n/i	++	nad	asphyxia? CAGE?
collecting for aquarium	8.1	8.1	on	n/s	nil	+++	nad	cardiac? asphyxia? epilepsy?

30 m from the rocks. On arrival he found the victim floating on his back supported by his BCD, unconscious, apnoeic with foam coming from his mouth. Despite difficulty in the sea conditions, he began rescue breathing, without a response. Unable to drag the victim to shore, the buddy again exited the water and went for help, believing his friend to be dead. A rescue helicopter arrived around 90 minutes later, found the victim to be unconscious and cyanotic and floating on his back without mask and weight belt. The victim was retrieved and brought to shore where attending paramedics did not attempt resuscitation.

Autopsy: Erect and supine x-rays showed no obvious gas/fluid levels. The heart was heavy (548 g; 100 g heavier than one would expect) with left ventricular hypertrophy (16 mm, normal < 14 mm). There was evidence of previous surgery on the mitral valve, which was thickened, and there was calcification of the mitral valve ring and aortic valve. There was near-complete occlusion of the LAD coronary arteries, up to 75% occlusion of the right and left circumflex coronary artery, and scarring of the left ventricular wall on histology. Both lungs appeared hyperinflated and heavy (Lt 662 g; Rt 856 g) and showed prominent oedema fluid on the cut surfaces. The trachea and larger airways showed copious amounts of frothy fluid. Toxicology showed 3% carboxyhaemoglobin and traces of hydrochlorothiazide. The cause of death was given as drowning due to valvular and ischaemic heart disease.

Comments: Although his buddy reported that the victim became breathless on exertion, this was not reported to the victim's cardiologist at his last review. If breathlessness on exertion had been reported, investigated and confirmed, it is likely he would have been advised not to dive, and this

fatality averted. Loss of consciousness in the water often results in drowning. Distress leading to unconsciousness is a clear risk, especially in such physically strenuous and adverse circumstances as those encountered on the day of the dive.

Summary: Experienced; history of mitral valve repair, stroke, hypertension, hyperlipidaemia; history of breathlessness with exertion; surfaced in rough seas and strong current; breathless and unable to swim to shore; buddy attempted rescue breathing; drowning (cardiac-related)

SC 08/02

This 41-year-old male was described as energetic and fit with no known adverse health conditions, despite being obese (BMI 30.6 kg m⁻²). He was a non-smoker and only a light drinker who had passed a diving medical examination eight months earlier and had been certified as an open-water diver for seven months. He had completed over 20 dives, always with the same buddy, and was described as a careful diver who owned his own equipment, reported to be in good working order.

On this occasion, the victim and his buddy dived for crayfish from a 5.2 m boat anchored in a channel off a small island. Conditions were described as good, with a 10-knot wind, minimal chop and a 1 m swell. The depth at the site was around 11 msw, water temperature was 19°C, underwater visibility was about 4 m and there was a slight surface current. The victim was wearing a wetsuit and BCD with 8.1 kg of integrated weights, as well as an additional 2.8 kg in the pockets. He and his usual buddy dived while another friend remained on the boat fishing.

At the start of the dive the buddy's contents gauge read 240 bar, but it is unknown how much air was in the victim's cylinder. The plan was to surface when their air reached 120 bar, as was their usual practice. After swimming towards the reef, the pair reportedly turned back when their gauges read 120 bar, and swam along to the edge of the reef towards the boat before surfacing 20–50 m from the boat. At this point, the victim said that he would swim to the boat on the surface as he was low on air. The buddy descended to look at some rocks and return to the boat underwater. The friend on the boat then saw the victim swimming strongly towards him and he called out that he was out of air. By the time the friend had organised enough rope to throw to the victim, he was now on his back and finning but not making headway and then did not respond to his calls. The friend jumped into the water to assist but, before he reached him, the victim sank and despite several duck-dives the friend could not see him.

The buddy surfaced some time later and learned of the problem. He was almost out of air but had a quick and unsuccessful look underwater before re-surfacing and changing his tank. He dived again but failed to locate his buddy, finding only his 'cray loop'. In response to an emergency call made from another vessel, a police diver arrived about 30 minutes later and located the victim's body 20 m from where he was last seen. His mask was full of blood and water, his regulator was out of his mouth, his face was cyanotic, his BCD was not inflated and no weights had been ditched. His contents gauge read 10 bar and both second stage regulators purged effectively. His computer displayed a maximum depth of 11.3 msw and a dive time of 98 minutes. When tested by the police, his equipment was found to be in good working order.

Autopsy: Watery pink-coloured fluid readily extruded from the nostrils and there was frothy fluid in the trachea. The right and left lungs were over-expanded and heavy (Rt 934 g; Lt 916 g). The heart weighed 518 g (slightly heavy) and there was up to 20% narrowing of the coronary arteries by atheroma. Microscopic examination of one of the coronary arteries showed focal atherosclerotic narrowing (degree not specified). Toxicology was negative. The cause of death was given as drowning.

Comments: This diver failed to make himself positively buoyant on the surface, which he could have done by inflating his BCD or ditching some weights. Even if he had become unconscious, his friend on the boat could have retrieved him quickly and given him a better chance of survival. He was also not wearing a snorkel, with which he could have managed better on the surface if he was tired. Additionally, had the diver and his buddy returned to the boat close together, the buddy may well have been able to assist him and increase the likelihood of survival. Normally a 20% narrowing of the coronary arteries would not be regarded as significant. The listing of focal coronary atherosclerosis as a contributing factor in the cause of death in the final autopsy report suggests that the narrowing seen by later histology

may have been greater than 20%.

Summary: Experienced; intentionally separated from buddy; low on air; no snorkel; became unconscious whilst swimming on surface to boat; drowning (cardiac related?)

SC 08/03

This diver was a 48-year-old, severely obese (BMI 35.1 kg m⁻²) male. He had passed a diving medical examination a year earlier (six months after his initial certification) and had stopped smoking a year before that. He had recently lost 8 kg and was not known to be under medical treatment. Said to be a strong swimmer, he had gained his open-water scuba certification 19 months earlier and had subsequently done additional training courses including night, navigation, nitrox, deep and wreck diver certificates. He had also participated in a drysuit diving course a week or two earlier and had recently bought a new drysuit. He was not certified for this course as he failed to provide the required dive medical. His logbook indicated that he had done a total of 34 dives, with a lifetime maximum depth of 30 msw. Most of these dives were done in local temperate waters. On several of these dives he indicated that he had "*blown the ascent*" for various reasons generally related to poor buoyancy control. On one occasion he had surfaced without any remaining air and was not impressed when the boat operator pointed this out to him. He was described as a very enthusiastic diver who used to work on and configure his own equipment.

He was participating on a boat dive with six other divers on a wreck lying at a depth of 34 msw. Weather conditions were reported good, a slight swell, not too choppy, with underwater visibility of 5–10 m and a slight surface current, but none on the bottom. The victim was wearing a drysuit and a home-made horse-collar-type vest with twin 9l cu ft cylinders joined by a manifold which allowed a diver to switch between cylinders as the air in one became low, but did not enable decanting between the cylinders. The equipment was described by others as poorly configured, overly complicated, and very heavy, weighing 56 kg, including 8 kg of removable weights.

On the boat before the dive, the victim was noticed to be unusually quiet, looked pale and appeared unusually clumsy. He was buddied with two other divers. When he entered the water, other divers noted that he appeared to be heavy, floating very low, despite his BCD and drysuit being inflated. He initially had trouble dumping air to descend and managed to do so when one of his buddies helped him to find an inflator hose. After seeing him descending with his right side down in what was described as "*a bizarre manoeuvre*", the other two divers lost sight of the victim. A short time after reaching the wreck they noticed he was missing and backtracked to see if they could find him, without success. They then assumed he had joined another group and so continued diving.

After “about 10 minutes” others on the boat saw the victim break surface feet first, preceded by a burst of bubbles, and roll face-down in the water, seemingly unconscious. His BCD and drysuit were both inflated and the BCD was floating next to him, attached only by the inflator hose. An off-duty dive instructor who was on the boat jumped into the water, grabbed the victim and, with the help of others, brought him aboard. His mask was full of froth, which was also coming from his mouth. He was apnoeic, cyanotic and had no palpable pulse. The instructor and a friend began two-person CPR and continued while the boat sped towards shore, a 20-minute trip. Oxygen was available and ready but was not used as they believed they could not manage it in the circumstances. Within a few minutes of arrival at the jetty, paramedics commenced ALS. The victim was found to be asystolic and was intubated; IV access was gained and adrenaline was administered. ALS was discontinued after 30 minutes.

When tested, most of the equipment appeared to be functional, except that one of the three demand valves had been incorrectly assembled (with the diaphragm poorly seated) so that it would have delivered water, rather than air, if used. The equipment configuration was described as inappropriate and overly complicated. No air remained in either cylinder. The dive computer indicated that the victim had descended to a maximum depth of 32 msw over 1.5 minutes, and remained at that depth for a further 11 minutes before ascending rapidly to the surface over one minute.

Autopsy: An examination of the pre-autopsy CT scan imaging showed extensive dissemination of gas within the vascular system predominantly on the arterial side. There was marked gas formation within the cerebral arteries and within both cardiac chambers. At autopsy, gas bubbles were noted in the vertebral and basilar arteries and circle of Willis. Subcutaneous emphysema was not described. The heart appeared moderately enlarged (476 g) and the left ventricular myocardium uniformly measured 20 mm in thickness. The LAD coronary artery was focally 80–90% occluded by atherosclerosis. There was right renal artery stenosis with a hypoplastic right kidney (Rt kidney 46 g; Lt kidney 257 g). The trachea contained a small amount of blood-stained fluid. The lungs were well inflated and the right and left lungs weighed 698 g and 920 g respectively. Toxicology was negative. The cause of death was given as cerebral artery gas embolism (CAGE) in a man with significant single-vessel ischaemic heart disease.

Comments: This is a well-documented case of CAGE. It appears that the victim tried to ditch his equipment as it was found unclipped and was attached only by an inflator hose. This is likely in response to an out-of-air emergency, given that his cylinders were empty on retrieval. Some witnesses reported that the victim had appeared unwell prior to the dive and, given the autopsy finding of severe coronary atherosclerotic disease, it is possible that he suffered a cardiac event prior to or during the dive. The combination

of his obesity, inexperience and inappropriate equipment configuration was a recipe for disaster.

Despite reports from friends and the police that he was a capable and experienced diver, this victim had logged only 34 previous dives to a maximum depth of 30 msw. It is unusual for a diver of this level of experience to adopt a twin-cylinder configuration with all the associated complications of multiple regulators, hoses and clips. Such configurations are usually part of specialist training for advanced diving techniques. He seems to have been considerably over-weighted with equipment and this would have caused buoyancy and swimming problems during the dive, and would be expected to substantially increase gas consumption. Given his inexperience, especially at depth, the victim would have likely been suffering from nitrogen narcosis, which could have created or compounded problems that arose. The feet-first ascent likely occurred as a result of the equipment weighing him down, and the air in his drysuit rising to his feet, causing him to invert prior to or during the ascent.

Summary: Morbidly obese but no other known medical history; 90% occlusion of LAD coronary artery; trained; some experience; complicated and very heavy gear configuration; separated from buddies on descent; uncontrolled buoyant and out-of-air ascent to surface; CAGE

SC 08/04

The victim was a 52-year-old, obese (BMI 30.3 kg m⁻²) male with a long-standing history of hypertension, which was reportedly difficult to control and for which he was prescribed amlodipine. He had also had an abnormal glucose tolerance test 10 months earlier. He was certified as an open water diver 15 years earlier but his diving experience is unknown.

He was in a party of nine recreational divers, including an instructor, on a club shore dive. The group walked across rocks to enter the water, which was described as a little choppy. Shortly after entering the water, the victim was floating in water about 2 msw deep and about 20–30 m from the shore. His BCD was inflated but his fins were not on and the water was just too deep for him to stand. He appeared to be panicking although he told the instructor he was ‘OK’. The instructor descended to put on the victim’s fins, but when she surfaced after about 30 seconds, she found him slumped back, unconscious, grey and apnoeic. After giving two rescue breaths, she towed the victim to shore and commenced CPR, which she continued until relieved by paramedics about 45 minutes later. The victim was transferred to hospital, where he was found to be in asystolic cardiac arrest and failed to respond to further ALS.

Autopsy: The heart weighed 512 g (normal range: 142–451 g) and appeared dilated and “floppy”, but of normal configuration. The internal diameter of the right and left

ventricles measured 65 mm and 50 mm respectively. The right ventricular wall measured approximately 7–8 mm in thickness and the left ventricular wall was approximately 15 mm thick. The mid-portion of the LAD coronary artery showed up to 50% stenosis. The lungs were heavy (Rt 976 g; Lt 712 g). There was diffuse congestion and pulmonary oedema and the mouth contained some blood-stained fluid. Toxicology showed amlodipine 0.09 mg L⁻¹ and traces of atropine. The cause of death was given as atherosclerotic and hypertensive heart disease.

Comments: This death likely resulted from a cardiac dysrhythmia secondary to dilatational cardiomyopathy. Although 50% stenosis is not usually regarded as sufficient to cause sudden death, one author (CL) has seen cases where stenosis of less than 75% appeared to have been responsible for sudden death. It is likely that this cardiac event could have occurred in a variety of non-diving-related scenarios, although the physical demands of diving, combined with anxiety can readily trigger an event in a diver so predisposed. The efforts of the instructor were commendable.

Summary: History of poorly control hypertension and abnormal glucose tolerance test; qualified but with unknown experience; became unconscious on surface on entry and had not descended; CPR commenced rapidly and maintained until ambulance arrived; cardiac death

SC 08/05

The victim in this incident was a 66-year-old man who was a highly experienced diver who had dived regularly over the previous 40 years. He was in good health, other than for some arthritis, a non-smoker and social drinker. He was not taking any medications. He agreed to do a dive to free a rope tangled around the propeller of a yacht in a mooring area in a tidal river with a fast-flowing current. He was familiar with the dive site and was experienced in fixing moorings in the area. The weather was fine with a light to medium breeze; however, there was a 5–6 knot current. He was wearing mask, snorkel, fins, wetsuit, a weight belt with 9.7 kg and scuba gear. He was not wearing a BCD and did not appear to have a dive knife, although he was carrying a hacksaw.

The yacht owner towed the diver near to the bow of the yacht from where he let go of the rope and drifted underwater towards the stern, where the yacht was tangled in mooring lines. The water depth was 1–3 msw. By the time the owner had tethered the dinghy and walked to the stern, he saw the victim about a metre below the surface, motionless, with his regulator out of his mouth and being held under by mooring ropes. After jumping into the water to try unsuccessfully to free the victim, the owner climbed back aboard his yacht and called for assistance. A policeman arrived, entered the water and was eventually able to duck-dive down and cut the victim free from the two or three ropes in which he was entangled. He dragged the diver to shore where an ambulance officer attempted resuscitation, without success.

When the equipment was tested it was noted that the mouthpiece had been torn from the second stage and could not be purged. There was 80 bar of air remaining in the cylinder. When tested, the air contained high levels of water vapour and the carbon dioxide concentration was 120% of the allowable limit.

Autopsy: Careful subcutaneous dissection with the chest in the highest position revealed no obvious gas in the heart. The lungs appeared over-expanded, consistent with the diagnosis of drowning. The right and left lungs weighed 808 g and 624 g respectively and showed severe pulmonary oedema. The upper airways contained blood-stained fluid. The heart weighed 456 g (normal range 262–560 g) and there was a 50% stenosis of the LAD coronary artery. Toxicology showed alcohol 0.024 g 100 ml⁻¹. The cause of death was given as drowning due to entrapment by mooring rope and tidal flow and loss of facemask and regulator mouthpiece while scuba diving.

Comments: Diving in an area with a strong current and entanglement hazards is a recipe for potential problems. It is likely that the diver was pushed into the ropes by the strong current and wedged under them. His regulator appears to have been torn from his mouth and, if he was able to replace it, he would have been unable to use the purge button to clear it. Without a nearby buddy or surface watch with an alternative air supply, drowning was inevitable. His old-style weight belt would have been difficult to release quickly, although this is unlikely to have been a factor here as he was firmly trapped by the ropes. Although his air supply did not meet purity standards, it is unlikely that this was a factor in his demise. Given that he was carrying a hacksaw, it is reasonable to conclude that even had he been carrying a dive knife, he would not have been able to cut himself free in time.

Summary: Healthy; experienced; diving alone; strong current; entangled in mooring ropes; demand valve displaced and purge faulty; drowning

SC 08/06

This diver, a 35-year-old male, was obese (BMI 31.5 kg m⁻²) but otherwise reportedly fit and healthy. He had been certified as an open-water diver about six weeks earlier and had done a total of six dives, including his four shallow training dives. On this day, he and his buddy, another novice with whom he had done all of his diving, planned to dive for crayfish from the shore of a small island. They had been warned previously by their instructor that this site was subject to swell and strong surge. They were taken to the island by another friend with a boat, who was going to fish elsewhere and then return to pick up the divers later in the day. They brought three cylinders each as they were planning to do three dives. The weather was described as mild to warm with a light breeze, a small swell and slight surface chop. Visibility was 5–6 m and there was a strong current. The victim had recently bought new dive equipment.

In addition to mask, snorkel and open-heel fins (which he had borrowed), he was wearing a full wetsuit with hood but no boots, a BCD with tank and regulator (with 'octopus'), and a weight belt (possibly with 12 kg of weights, which is what he used during training).

He and his buddy entered the water and swam underwater away from shore. After a while, they checked each other's air and decided to return towards shore. While the buddy began to swim away from the island and work his way towards the surface slowly, he saw the victim ascend directly and rapidly. They were separated for 2 to 3 minutes and when the buddy surfaced, he could see the victim about 25 metres away being pushed toward rocks by the current and surge. He wasn't wearing his mask or snorkel and did not have his regulator in his mouth. The victim tried to climb onto some rocks but kept slipping and getting thrown around by the surge and smashed against the rocks. After calling out his buddy's name, the victim became quiet and floated face-down. The buddy swam to him, turned him over and tried to drag him out of the water but had trouble as the victim kept sinking. After inflating the victim's BCD, the buddy managed to drag him away from the rocks. He was unconscious and apnoeic, with froth coming from his mouth. The buddy then saw a nearby boat and called for help. The divers were brought aboard and the buddy commenced CPR, assisted by one of the men on the boat. This was continued en route to the jetty where an ambulance was awaiting their arrival. The paramedics found the victim to be cyanotic and asystolic and he failed to respond to ALS.

When later checked, his equipment was found to be in good working order and there was 50 bar of air remaining in his tank. His dive computer indicated that he had been to a maximum depth of 10.7 msw (average depth 7.6 msw) for a dive time of 25 minutes. His mask, snorkel, fins, weight belt, knife and cray noose were missing.

Autopsy: At the scene, the facemask had been lost and there was pulmonary oedema fluid coming from the mouth, features suggestive of drowning. A radiograph, taken approximately six hours post mortem, showed gas in the thoracic aorta extending into the carotid arteries. Gas collections were observed in the vascular system (predominantly arterial) and tissues. No other evidence of barotrauma was detected. The heart weighed 362 g and was normal with only mild coronary atherosclerosis. The right and left lungs weighed 656 g and 694 g respectively. The lungs were well inflated; there was no pulmonary oedema fluid in the upper airway (the pathologist noted that resuscitation had been attempted). The gas detected on X-ray was attributed to decompression, possibly post-mortem decompression. Toxicology showed traces of cannabis and 2% carboxyhaemoglobin. The cause of death was given as drowning, based particularly on the scene findings.

Comments: This inexperienced diver appeared to ascend too closely to rocks where there was a strong surge and current.

The interpretation of the gas seen at autopsy is difficult. It could represent:

- CAGE/pulmonary barotrauma due to a rapid ascent in an inexperienced diver low on air, or caught in an upward surge;
- post-mortem off-gassing;
- gas due to vigorous cardiopulmonary resuscitation.

The pathologist amongst the authors (CL) favours drowning due to strong surge and loss of facemask as a cause of death, mainly because of the plume of pulmonary oedema and the loss of the mask. He believes the gas seen on X-ray was likely due to CAGE or resuscitation.

Summary: Obese but otherwise healthy; recently trained and inexperienced; rapid ascent; smashed against rocks by strong current and surge; drowning

Surface-supply fatality

SS 08/01

This 30-year-old male was described as fit and strong. He had a history of epilepsy which began in his teens, however, although he had apparently been seizure- and medication-free for the previous five years. He had been certified as an occupational diver and had several years' experience collecting aquarium fish for sale. He was certified fit to dive by an experienced diving medical examiner 10 months earlier, but he had failed to disclose his history of epilepsy.

Together with his brother and another companion, the victim dived from his 12.5 m boat. His equipment included mask, fins, two wetsuits, a weight belt ("*with three or four weights*"), gloves and a dive computer. He did not wear a BCD or carry his bail-out cylinder (the regulator was missing). They dived using the victim's surface-supply breathing apparatus (SSBA). The victim did not wear a harness to which to attach the air hose. Instead, he secured the hose by passing it under his weight belt and through his legs. His first dive was to a maximum depth of 24.1 msw for 192 minutes, with all decompression indicated by the dive computer being completed. Although they had all dived separately, the victim and his brother completed their decompression/safety stop together. After a surface interval of 70 minutes, the three dived again. The victim's computer indicated a maximum depth of 17.3 msw for a total dive time of 120 minutes. The computer log showed that he had ascended faster than 9 m min⁻¹ at some stage, but there was no decompression requirement.

After that dive, the group moved the boat to another site and set anchor for the night. They drank a can of beer and the victim decided to dive again, which he did after a surface interval of 76 minutes. His brother watched him enter the water alone. The others then showered and logged their catch for the day. However, after about an hour, they realised that they had not noticed the air compressor activate for a while

and, on checking, confirmed that no-one was breathing from it. After tugging on the hose without a response from the victim, the companions began to haul in his hose, which was extended out to almost its full length of 100 m. Initially the hose appeared to be snagged, but after tugging hard it came free and the victim was hauled to the surface, backwards and upwards at an angle from depth, over about a minute. They dragged him aboard and found he was unresponsive, apnoeic and cyanotic and there was water, mucus and blood in his mask and froth and water coming from his mouth. Other than one missing fin, his equipment was in place, although they did not notice whether or not the regulator was in his mouth. They cut off the victim's wetsuit and began CPR, which they continued for over 2.5 hours. Although there was oxygen delivery equipment on board it was not used (the cylinder was missing anyway). They were relieved by a doctor from another vessel who, after peer consultation, declared the victim to be dead.

When tested, the compressor and regulator were functional and the air supply was free from contamination. The regulator mouthpiece was torn. The victim's dive computer indicated that the fatal dive was to a maximum depth of 8.1 msw for a total of three minutes.

Autopsy: The heart weighed 390 g and appeared normal. There was a focal 60% atheromatous stenosis at the junction of the left main and LAD coronary arteries with some inflammation in the plaque. Foam was noted in the mouth and the larynx, trachea and bronchi contained pulmonary oedema fluid. The right and left lungs weighed 910 g and 750 g, respectively. The lungs on section showed oedema and peripheral displacement of air. Overall, these lungs showed the features of wet drowning. Toxicology showed 5% carboxyhaemoglobin and a urinary alcohol of 0.014 mg 100 ml⁻¹. The cause of death was given as ischaemic heart disease.

Comments: There are a number of possible scenarios which could explain these events, although, given that it was unwitnessed, all are speculative. Such scenarios would include:

- A primary cardiac event related to the observed coronary lesions. While the critical stenosis for cardiac sudden death is usually taken to be 75% during exertion, CL has seen deaths believed to have been a result of 60% stenosis, particularly if the stenosis was recent and collateral circulation had not developed.
- An underwater epileptic event. Epileptic events have been reported to have occurred despite prolonged seizure-free periods post cessation of anti-epileptic medication.^{2,3}
- A primary drowning event resulting from possible hose entanglement and loss of regulator; it is important for such a regulator to be anchored to a harness so that it is not pulled from the mouth unexpectedly.

The dive computer record of a three-minute dive time was interesting, given that the witnesses were adamant that he had been underwater for at least an hour. This, together with the companions' statements that the victim was dragged in at an angle from depth, led the investigating coroner to conclude that there was most likely an error in the computer's record, a conclusion that seems reasonable, albeit apparently uncommon. The damage to the mouthpiece of the regulator could have occurred during recovery of the body, or could have indeed been the primary event. It is possible that the diver became entangled and the regulator was forced from his mouth.

Summary: Previous epilepsy not declared on dive medical; severe atherosclerosis; trained and experienced commercial diver; dived alone without proper surface watch; drowning

Discussion

APNOEIC HYPOXIA

This series includes the tragic deaths of two fit and healthy young breath-hold divers (BH 08/01 and BH 08/07) who likely died as a result of apnoeic hypoxia. It appears likely that at least one of these divers had practised hyperventilation, a well-reported precipitant for loss of consciousness during or after ascent.^{4,5} It is important for the diving medical and training community, dive clubs and spearfishing groups to better inform breath-hold divers of the risks of extended apnoea, with or without hyperventilation, and the potential benefits of a vigilant and efficient buddy system to facilitate a rapid rescue in the event of unconsciousness. Although this problem has been recognised for a long time, deaths related to apnoeic hypoxia are still common. For example, 19 of 130 snorkelling-related deaths in Australia between 1994–2006 appear to have resulted from prolonged breath-hold diving, largely in experienced divers.⁶

It is also important for such divers to adjust their buoyancy in order to be positively buoyant in the last few metres to the surface. In that way they will be more likely to rise to the surface if unconscious and so be easier to locate and rescue. Unfortunately this is less likely to occur if unconsciousness occurs at depth. Also of note, there is a relatively new product available for those keen apnoea divers who are willing to go to the effort and expense. The auto-inflatable *Freediver Recovery Vest* can be pre-programmed to a trigger depth or time and will auto-inflate and bring the wearer to the surface when either of these parameters is reached.⁷

CARDIAC-RELATED DEATHS

Coronary artery disease is a common cause for sudden, unexpected death, especially during exertion.⁸ Of the 130 snorkelling-related deaths reported in Australia between 1994 and 2006, 60 (46%) appeared to have been attributed to cardiac causes.⁶ Twenty-six of these victims (43%)

had no cardiac or other significant medical history. Once again, cardiac factors appear to be the disabling injury in many of the deaths in the present series, in both snorkellers (BH 08/02, BH 08/03, BH 08/04, BH 08/10 and possibly BH 08/08) and compressed gas divers (SC 08/01 and SC 08/04, and possibly SC 08/02, SC 08/03 and SS 08/01). This on-going and increasingly recognised issue highlights the importance of potential or active snorkellers and divers, as well as dive operators and doctors, appreciating the various cardiac stressors associated with these activities and carefully considering the suitability of the participant (and, sometimes, his/her equipment). This is often easier to ascertain in an individual with a relevant medical history if this person is forthcoming with the pertinent information, which is not always the case. Increasing age is a general indicator of an increased risk.⁹ In this series, the ages of victims of suspected cardiac-related deaths ranged from 41 to 82 years.

Of note, three of the nine likely cardiac-related deaths were in victims who were obese, with BMIs ranging from 30.3 to 35.1 kg m⁻². Even if a cardiac event did not underlie the death in some obese divers, obesity per se can be a contributory factor.^{10,11} The adverse effect of obesity on respiratory mechanics when immersed, the often excessively tight suit or equipment in obese divers, and the need for excessive weights are common in such divers and act to compromise safety. Undiagnosed obstructive sleep apnoea, diabetes, as well as hypertension and high cholesterol are more common in obese individuals, and are all risk factors for coronary artery disease.

The relevance of cardiac stress testing in asymptomatic individuals remains controversial. Current recommendations from the American College of Cardiology/American Heart Association are not to conduct tests in such individuals due to the high rate of false positives. However, it may be worth screening individuals who have multiple risk factors.^{12,13}

MEDICAL QUESTIONNAIRE

In Australia, as in many other countries, snorkellers and divers are often required to complete a short medical questionnaire prior to diving with a commercial operator – an important safety measure. Not uncommonly, participants seek clarification of some of the questions from staff of the dive operation, who usually have only a basic, if any, understanding of various medical conditions and their implications for diving. This problem may be exacerbated by a language barrier. Case BH 08/08 highlights this problem. It appears that, on the advice of the receptionist for the tour operator, the victim altered her declaration of a possible pre-existing medical condition(s), possibly contributing to her demise. Relevant training of everyone who is involved with taking bookings as well as those on board the vessels is imperative. Ideally, prospective divers and snorkellers should be vetted onshore, and at the time of enquiry about,

or making a booking for, a proposed diving or snorkelling outing. The questions should cover their medical history and condition and relevant experience prior to them committing to the proposed activity. In reality, this is not always practicable. However, this may assist in identifying, at a time when there is less pressure to proceed, those who should not snorkel or dive. Some of the case histories also show that the two-way communication of information between dive operator and client remains a challenge, especially when there are language barriers.

SUPERVISION OF IN-WATER ACTIVITY

The right balance between the number of snorkel/dive guide and that of participants is another ongoing challenge. Cases BH 08/02 and BH 08/08 again illustrates the difficulty in focusing on the entire group when one or more of the participants require attention. This problem is exacerbated when the group includes inexperienced and/or potentially medically challenged participants.

USE OF DEFIBRILLATORS ON DIVE BOATS

Although details are often not included or well-described in the reports provided to the coroners, it appears that in at least in one case (BH 08/03) an AED from the dive vessel (as opposed to defibrillators brought by medical attendants) was used, albeit unsuccessfully. In this case, the AED was attached after 10–15 minutes of CPR and a single shock advised and delivered. To provide the greatest potential benefit, these devices need to be available and utilised immediately. BLS plus defibrillation within 3–5 minutes of cardiac arrest can produce survival rates as high as 49–75%.¹⁴

BUDDY SYSTEM

The buddy system is generally taught and reinforced as an important part of diving and snorkelling safety, although diving with a buddy certainly does not guarantee safety. In fact, some commentators have argued that a buddy can sometimes endanger a diver, either directly through lack of competence or by causing an unsafe reliance to the detriment of increasing self-sufficiency. There is little doubt that training in self-sufficiency including equipment redundancy can be beneficial. Historically, a large proportion of dive accident victims die alone. A 34-year review of 351 compressed-gas diving accidents in Australia revealed that only 18% of victims were with their buddy when the fatal event occurred. Sixteen per cent had been diving solo, 49% had separated prior to the event and 17% separated during the event.¹⁵

Lack of a buddy or separation of a diver or snorkeller from their buddy is once again a feature in this series. Although the victims of BH 08/01, BH 08/05, BH 08/09 and SC 08/05 had supposed above-water look-outs (one being in a car high above!), it was unsurprising that these were

Table 3
Root cause analysis of diving-related fatalities in Australian waters in 2008

Case	Trigger	Disabling agent	Disabling injury	Cause of death
BH08/01	Apnoeic hypoxia (hyperventilation)? Presence of speared fish?	Sudden loss of consciousness? Shark attack?	Asphyxia? Trauma?	Unknown
BH08/02	Immersion; exertion?	Cardiovascular disease	Cardiac incident	Cardiac-related
BH08/03	Immersion; exertion?	Acute myocardial infarct	Cardiac incident (rupture)	Cardiac-related (cardiac tamponade)
BH08/04	Immersion; exertion?	Aortic valve replacement; enlarged heart	Cardiac incident (arrhythmia)	Drowning
BH08/05	Lack of buoyancy in poor sea conditions	Buoyancy-related	Asphyxia	Drowning
BH08/06	Poor sea conditions; inexperience?	Unknown	Unknown	Unknown
BH08/07	Prolonged breath-holding	Apnoeic hypoxia	Asphyxia	Drowning
BH08/08	Immersion; exertion; aspiration?	Unknown	Cardiac incident, arrhythmia? Asphyxia	Cardiac-related?
BH08/09	Unknown	Buoyancy-related?	Asphyxia	Drowning
BH08/10	Exertion	Cardiovascular disease	Cardiac incident	Drowning
BH08/11	Unknown	Shark attack	Trauma	Trauma?
BH08/12	Diving in presence of speeding boat	Contact with boat	Trauma	Head injury
SC08/01	Exertion	Ischaemic and valvular heart disease	Cardiac incident	Drowning
SC08/02	Exertion	Buoyancy-related	Asphyxia? Cardiac?	Drowning
SC08/03	Exertion.	Gas supply-related? Cardiovascular disease?	CAGE	CAGE
SC08/04	Exertion; immersion; anxiety?	Cardiomyopathy	Cardiac incident	Cardiac-related
SC08/05	Strong current; presence of mooring ropes	Entanglement; gas supply-related	Asphyxia	Drowning
SC08/06	Strong current and surge; rapid ascent?	Smashed against rocks. Ascent-related?	Asphyxia	Drowning
SS08/01	Unknown	Cardiovascular disease? Epilepsy? Gas supply-related?	Cardiac incident? Asphyxia?	Drowning

ineffective when needed. The buddies of the victims of BH 08/06, SC 08/02 and SC 08/03 lost contact with them, and the victim in SSBA 08/01 was diving solo and without a surface watch. A well-trained and vigilant buddy can be an important asset in an emergency. The time saved in searching for and recovering a missing diver may well prove an important factor in increasing their likelihood of survival, depending on the mechanism of their problem. The buddy in SC 08/01 was faced with a difficult decision; whether or not

to temporarily abandon his friend. His efforts were valiant, although sadly in vain.

SEA CONDITIONS

Even mild to moderate sea conditions can provide challenges for inexperienced snorkellers and divers. However, a choppy surface, or large swell, surge, strong current and/or poor visibility, or a combination of these factors, can

prove dangerous even for experienced veterans, who can sometimes become complacent. Poor conditions appeared to have been a factor in the deaths of at least seven of the victims (BH08/02, BH08/05, BH08/06, BH08/10, SC08/01, SC08/05, SC08/06). Dive sites need to be carefully assessed for suitability under the prevailing conditions, the likely problems that a diver might encounter and ways to avoid these. The diver needs to rationally consider his/her suitability to deal with the conditions. Divers sometimes adopt overly optimistic views about their ability to handle the adverse environment in which they dive. This is especially true for inexperienced divers, who can easily underestimate the challenges of diving in poor conditions, which include current, surge, surface chop and reduced underwater visibility. This should be reinforced in basic training, as well as in advanced courses.

DIVE FLAGS

Divers and snorkellers should continue to be strongly encouraged to clearly display a 'Diver Below' flag when on or under the water. Some of the authors believe that this should be supported by appropriate regulation. It cannot guarantee protection from careless boat drivers, as evidenced in BH 08/12, but it can certainly increase the likelihood of being seen and avoiding injury.

LIMITATIONS

As with any uncontrolled case series, there are inevitable limitations and uncertainties associated with our investigations.

Incomplete case data

Fatalities were sometimes unwitnessed, and reports provided by any witnesses and by police varied in their likely reliability, as did the expertise of the investigators. Autopsy reports can sometimes be unreliable owing to the difficulty of determining the presence of CAGE in the absence of relatively prompt post-mortem CT scans, and the inability to detect evidence of cardiac dysrhythmias, among other factors. Care must be taken to critically examine the available evidence and minimise speculation when determining the likely disabling injuries (Table 3).

Classification of cases

Classification of cases into a sequence of four events (trigger, disabling agent, disabling injury, cause of death) requires a single choice for each event, which may omit important factors in some cases.

Limited annual case data

Nineteen deaths are too few to determine reliable trends.

Conclusions

There were 19 reported diving-related fatalities during 2008 including twelve deaths while snorkelling and/or breath-hold diving, six while scuba diving and one while using a surface-supply breathing apparatus.

Causal factors associated with these deaths included inexperience, extended breath-hold dives, non-existent or poor buddy system, diving in poor conditions, poor equipment configuration, pre-existing medical conditions, shark attack and boat impact.

The likely disabling injuries in snorkellers were trauma, asphyxia and cardiac causes. In scuba divers, the disabling injuries appear to have been asphyxia, CAGE and cardiac causes.

Factors that may reduce mortality in the future include better supervision of inexperienced and older snorkellers; improved medical screening of older divers; better education of prospective and active divers about health risks; careful buddy monitoring; appropriate equipment configuration and use; the use of dive flags and care on the part of divers and boat operators in areas where both co-exist.

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Conflict of interest

John Lippmann is the Executive Director of Divers Alert Network (DAN) Asia-Pacific. 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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