

Original articles

Provisional report on diving-related fatalities in Australian waters 2009

John Lippmann, Christopher Lawrence, Andrew Fock, Thomas Wodak and Scott Jamieson

Abstract

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Introduction: An individual case review of diving-related deaths reported as occurring in Australia in 2009 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 21 reported fatalities (two more than in 2008), including 18 males and three females. Twelve deaths occurred while snorkelling and/or breath-hold diving, eight while scuba diving and one while using surface-supply breathing apparatus. Apneic hypoxia continues to be a problem with breath-hold divers and appears to have caused the death of three victims in this series. Cardiac-related issues were thought to have been the disabling injury in the deaths of at least three snorkel divers and at least three scuba divers. One of the victims was a student who became separated from her instructor on an introductory scuba dive in poor visibility.

Conclusions: Apneic hypoxia, pre-existing medical conditions, snorkelling or diving alone, separation and inadequate supervision 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 deaths associated with snorkelling and diving using compressed gas (i.e., scuba or surface-supply breathing apparatus, SSBA). Although some accidents are unavoidable, many might have been avoided through better education about the proposed activity and/or associated risks; appropriate medical screening; greater experience; common sense; improved supervision; or better equipment maintenance and design. The aim of the Divers Alert Network (DAN) Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and the diving industry and to inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future and of detecting, in advance, those who may be at risk. This report includes the diving-related fatalities between 01 January and 31 December 2009 that are recorded on the DAN Asia-Pacific (DAN AP) database. When an accident is unwitnessed, it is often very 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.

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 Human Research Ethics Committee, Department of Justice, Government of Victoria, Australia to access and

report on data included in the Australian National Coronial Information System (NCIS). In addition, ethics approvals have been sought and obtained from various coronial offices in certain Australian States and Territories. The methodology used for this report was identical to that described previously for the 2004 Australian diving-related fatalities.¹ When considering the possible sequence of events in each case, root cause analysis has been utilised.²

Breath-hold and snorkelling fatalities (Table 1)

BH 09/01

This 63-year-old male was described as a fit and healthy non-smoker and light drinker who attended the gymnasium three times a week. He was a strong swimmer and very experienced snorkeller and spear fisherman. He and his (much younger) buddy went spearfishing at a site that the victim had dived frequently. The conditions were choppy with a slight (0.7 metre) swell and visibility of 5 to 8 metres. The victim was wearing a mask, snorkel, fins, t-shirt and board shorts and carried a speargun.

The pair entered the water into a channel through the rocks. Once clear of this channel, they went in opposite directions and were then out of visual contact for the rest of the dive. After about an hour, when the buddy returned to the entry point, he was unable to see his friend. A short time later, a bystander approached to inform him that his buddy was on the rocks, approximately 100 metres away, apparently dead. That bystander had seen the victim floating face-down and

apparently lifeless near to the rocks. He entered the water, swam to him and, on rolling him over, found the victim to be unconscious with his mask down around his mouth and without a snorkel. He towed him to shore where other bystanders helped to drag the victim onto the rocks. He was found to be unconscious, apneic and without a palpable pulse so bystander Basic Life Support (BLS) was commenced and continued until paramedics arrived and attempted Advanced Life Support (ALS), albeit unsuccessfully.

Autopsy: No measurements were given by the medical examiner (a GP) who described the victim as “*large*”. The examination was limited to the chest. The heart was large, 500 g (normal range (NR)* 365 +/- 71 g), and showed severe coronary atherosclerosis in the proximal left anterior descending (LAD) coronary artery and patchy lesser coronary atherosclerosis generally. The right and left lungs weighed 1,000 g and 800 g respectively (nr 663 +/- 239 g, 583 +/- 216 g) and showed severe pulmonary oedema and free fluid in the major airway, suggesting terminal drowning. The cause of death was given as drowning. Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: Unrecognised ischaemic heart disease even in the apparently fit remains a significant risk factor, especially in the older diver. Had these divers stayed in visual contact and close together during the dive, it is possible that the buddy could have witnessed the incident and might have been able to assist. This may or may not have altered the outcome. Proponents of this ‘same-ocean’ buddy system must understand clearly that they really are on their own if something goes wrong.

Summary: Apparently fit and healthy; strong swimmer and experienced spear fisherman; choppy seas with mild swell; intentional separation from buddy; found unconscious by bystander; BLS unsuccessful; significant coronary vascular disease (CVD) at autopsy; drowning (likely cardiac-related)

BH 09/02

This victim was a 56-year-old male overseas tourist who was visiting the Great Barrier Reef (GBR). He and his wife were partaking in a day trip on a tourist vessel with 17 passengers and two crew. His wife described him as “*a well-rounded athlete*” who “*could swim OK*”, although he rarely entered the water. He had a history of sleep apnea, hypertension (on irbesartan) and an appendectomy three years previously. He was an inexperienced snorkeller but that morning he had snorkelled for about 30 minutes, played beach cricket and hiked up a hill, all prior to lunch. At no stage had he appeared, or complained to his wife of feeling unwell.

* **Footnote 1:** Normal ranges for heart and lung weights expressed by different pathology departments may differ slightly, and so the local ranges, based on age, sex, height and weight, are quoted for each victim.

At least one hour after lunch he went snorkelling with some family members and others from the vessel. He was wearing a mask, snorkel and fins and a full stinger suit. The weather was warm (26°C), there was a moderate wind (10–15 knots), a slight sea, current of about 0.5 knots and the visibility was reported to be good. The group snorkelled at the edge of a drop-off.

About 15 minutes after entering the water, the lookout noticed the victim and some family members snorkelling towards the boat. The victim initially appeared to be swimming well and was not using a ‘noodle’ to provide support. Although his daughter reached the boat and exited the water, the victim appeared to drift past, staring at those on board. The lookout became concerned and shouted “*are you OK?*”, after which the victim raised his arm weakly and appeared to wave goodbye to his wife. The lookout reached the victim just as he began to sink, rolled the victim over and found him to be unconscious. He gave two rescue breaths and towed the victim to the vessel where the skipper helped to drag him aboard and then commenced BLS. Supplemental oxygen was not available. BLS was continued for about 10 minutes as the boat motored to a nearby resort. On arrival, a guest, who identified herself as a nurse, found the victim to be pulseless, with a grey appearance and his eyes rolled back. She reported that she heard the movement of fluid in his stomach. The nurse and skipper continued BLS for several minutes after which resuscitation efforts were abandoned.

Autopsy: The heart weighed 386 g (NR 370 +/- 75 g). There was severe atherosclerotic stenosis of the LAD coronary artery and moderate atheroma of the right coronary artery. There was no scarring of the myocardium. The right and left lungs weighed 832 g and 704 g respectively (NR 651 +/- 241 g, 579 +/- 201 g) and were congested and oedematous. The cause of death was given as myocardial ischaemia. Toxicology: alcohol undetected; irbesartan 0.4 mg kg⁻¹.

Comments: It is possible that this death resulted from a cardiac arrhythmia due to ischaemic heart disease and the triggers present in snorkelling, e.g., immersion and exertion.

Summary: Hypertension and sleep apnea, but apparently healthy; not a strong swimmer; limited snorkelling experience; calm sea with slight current; collapsed while under observation; rapid rescue; BLS unsuccessful; significant CVD at autopsy; likely cardiac death

BH 09/03

The victim, a 26-year-old, male foreign national, was temporarily working in Australia. There is no information on his medical history although, to his friends, he appeared to be fit and healthy. He was reported to be a relatively poor swimmer. Late one afternoon, he and four friends (of the same nationality) went to a beach on the banks of a very large river. Here, the victim and one friend swam before having a snack with others on the riverbank. It was reported that the

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

ID	Age (yr)	Gender	Height (m)	Weight (kg)	BMI (kg m ⁻²)	Training	Experience
BH09/01	63	M	n/s	n/s	–	n/s	yes
BH09/02	56	M	182	85	25.7	n/s	some
BH09/03	26	M	n/s	n/s	–	nil	nil
BH09/04	71	M	176	89	28.7	nil	yes
BH09/05	61	F	165	88	32.3	nil	some
BH09/06	76	M	163	61	23.0	nil	nil
BH09/07	31	M	172	66	22.3	trained	yes
BH09/08	28	M	182	74	22.3	nil	nil
BH09/09	31	M	169	88	30.8	trained	yes
BH09/10	20	M	185	95	27.8	n/s	yes
BH09/11	68	M	174	78	25.8	n/s	n/s
BH09/12	64	F	163	113	42.5	n/s	n/s

victim did not drink any alcohol on the day of the incident. Possibly 15 to 30 minutes later, the victim and the same friend re-entered the water. His friend wore his own fins, while the victim borrowed the friend's mask and snorkel as he was keen to try these. He was also wearing shorts. The water was murky and there was a fast current that increased further away from the shore.

After about 15 minutes, the victim began to struggle to stay afloat. His friend grabbed him from behind and tried to support him but was forced to let go because of cramp. The victim submerged temporarily before he re-surfaced, waved his arms, and called "Help". At this point, the river was 70–100 m wide, the current was very strong and the swimmers were being swept downstream. Some bystanders responded to his call and entered the water to assist, some with the aid of an air mattress. However, by the time they reached the victim he had submerged and they were unable to find him. The friend was brought to shore with the aid of the air mattress.

The victim's body was found four days later, well down river. His mask was still present, although displaced, and his body was in a relatively advanced state of decomposition.

Autopsy: The body was decomposed. The heart weighed

160 g and showed decompositional change but was otherwise normal. Severe decomposition and the absence of a record of height and weight means that a valid normal weight for the heart cannot be given. The lungs were not weighed and showed decompositional changes. The upper airways contained gastric contents. The cause of death was given as drowning. Toxicology: blood alcohol 0.123 g 100 ml⁻¹, some or all of which may be owing to decomposition.

Comments: It is easy even for experienced swimmers to underestimate the strength of a current in a river or similar waterway, and deaths commonly occur in such places. For example, in Australia in 2011–12, there were 284 reported drowning deaths. Seventy-five (26%) occurred in rivers, creeks and streams (often involving currents), compared to 55 (19%) at beaches, and 43 (15%) in oceans and harbours.³ It is important to obtain local knowledge about potential hazards although, in this case, the victim and his friends spoke little English, which could have made this more difficult. It is difficult to tell whether the alcohol had been ingested or was generated by post-mortem decomposition.

Summary: Unknown medical history; appeared to be fit and healthy; weak swimmer; inexperienced snorkeller; large river with strong current; struggled to stay afloat; friend

Table 1 (cont.)

diving-related fatalities 2009

GSB – group separated before; n/a – not applicable; n/s – not stated

Dive group	Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	Disabling injury
BSB	spearfishing	n/s	surface	n/s	n/s	Cardiac incident
GSB	recreation	n/s	surface	n/s	n/s	Cardiac incident
BNS	recreation	n/s	surface	n/s	n/s	Asphyxia
BNS	recreation	n/s	surface	n/s	n/s	Asphyxia? Cardiac incident?
BNS	recreation	n/s	surface	n/s	n/s	Cardiac incident
n/s	recreation	1	surface	n/s	n/s	Cardiac incident?
solo	training	1.5	1.5	n/s	1	Asphyxia? Cardiac incident?
solo	recreation	2	n/s	n/s	n/s	Asphyxia
BSB	spearfishing	12	n/s	yes	n/s	Asphyxia
solo	spearfishing	15	2.4	yes	3	Asphyxia
GSB	recreation	20	surface	n/s	n/s	Asphyxia
GSB	recreation	n/s	surface	no	n/a	Asphyxia? Cardiac incident?

present but cramped and unable to assist; attempted rescue by bystanders; drowning

BH 09/04

This victim, a 71-year-old male, was described by his general practitioner as “*fit and healthy*”. He had suffered from back stiffness resulting from ankylosing spondylitis for the past 30 years but was no longer taking medication for this and was on no other medications. He and his wife swam daily during the summer months at their local ocean beach. He was described as “*not a bad swimmer*” who wore goggles (it is unclear whether these were swim goggles or a mask; both were mentioned in various reports) and a snorkel, as his back condition made it difficult for him to lift his head while swimming.

On this occasion, the victim and his wife were having their regular swim in calm, shallow water. There was no mention of any current. After a short time, as the wife was leaving the water, she heard a strange sound and turned to see her husband removing his goggles and gasping for breath. She went back into the water and, with the assistance of another swimmer, helped the victim onto the beach. A nearby tourist, who happened to be a doctor, began BLS. When paramedics arrived, they found the victim to be

asystolic and they continued resuscitation en route to a nearby hospital. Although he initially appeared to respond to ALS, the victim’s condition deteriorated and he was soon pronounced dead.

Autopsy: The trachea contained a small amount of frothy fluid. The right and left lungs weighed 682 g and 596 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). There was diffuse pulmonary oedema and congestion. The heart weighed 426 g (NR 400 +/- 69 g). There was mild atherosclerosis of the coronary arteries without significant stenosis, mild sclerosis of the mitral valve and minor thickening of the blood vessels in the AV node. The cause of death was given as drowning.

Toxicology: alcohol undetected (limit not stated).

Comments: It is not clear what caused the drowning. Ankylosing spondylitis can have cardiovascular manifestations, which include atrio-ventricular block and bundle branch block and valvular disease.⁴ It is also possible that the victim developed immersion pulmonary oedema, most likely secondary to a dysrhythmia.

Summary: Ankylosing spondylitis; otherwise appeared to be fit and healthy; regular swimmer; swam with goggles and snorkel because of back stiffness; calm and shallow;

became breathless and collapsed; prompt BLS and ALS unsuccessful; drowning

BH 09/05

This 61-year-old woman was an overseas tourist visiting the GBR with her husband. Her husband described her as “*in good health and not taking any medication for a heart complaint*”. However, she was obese (BMI 32.3 kg m⁻²) and was taking an unknown medication for hypertension. Her husband reported that she was a competent snorkeller although she had apparently got into some difficulty while snorkelling in Italy on another occasion. She did not declare any medical conditions to the snorkel operator.

She was with a group of 20 tourists of the same nationality (including an interpreter) on a day tour on a vessel with 88 passengers. The passengers were split into two groups, the victim being part of the first group offered the opportunity to snorkel from an island beach fringed by a coral reef that began about 20 metres from the shore. There was a buoyed line at the extremity of the snorkelling area, beyond which the strength of the current was considered unsafe. A tender was tied to the inside of this line and a lookout was aboard this tender to help snorkellers if required. There was another lookout on the beach. The weather was described as sunny but the surface conditions were unreported. The operator’s staff reported that there was little current initially, but it appears that this quickly changed to become less than 1 knot near the beach increasing to 5 knots further out.

The victim and her husband entered the water from the beach, wearing a mask, snorkel, fins and a full-length stinger suit. After a short time, she returned to shore to get better-fitting fins while her husband swam towards the buoyed rope where fish were being fed from the tender. After changing fins, the victim re-entered the water and, accompanied by another passenger (a weak swimmer who was using a ‘noodle’ buoyancy aid), snorkelled towards the tender. However, when she encountered a strong current she became anxious and began to panic. Her buddy shared his ‘noodle’ with her and soon her husband arrived on board another tender and together they were towed to chest-deep water. The tender then departed to assist other snorkellers caught in the current. In fact, 16 out of the 20 snorkellers needed assistance from the tender owing to the current.

The victim became unconscious soon after walking to shore with the help of her husband and another passenger. The husband assessed her as apneic and pulseless and commenced BLS. He was quickly relieved by three doctors (two of whom were part of the tour group and one who was a guest on the island). A bag-valve-mask was used to provide oxygen-supplemented ventilation; an automated external defibrillator (AED) brought from a nearby boat reported “*No shock advised*” (i.e., the victim was not in ventricular fibrillation or ventricular tachycardia). BLS was continued

for 50 minutes, without success. A rescue helicopter with paramedics arrived but the topography of the island made it too difficult to move the victim to the helipad for evacuation. The doctors pronounced the victim to be deceased.

Despite one of the investigating policemen suggesting that the operator may have been negligent in allowing the snorkelling while such a strong current was present, the Workplace Health and Safety investigation did not support a prosecution, nor did the investigating coroner recommend one. Although the area was known to be prone to strong currents, these were reported to be somewhat unpredictable.

Autopsy: The heart weighed 402 g (NR 362 +/- 77 g). There was severe atherosclerotic narrowing of the ostium of the right coronary artery and mild atherosclerosis of the other coronary arteries. Histology revealed subendocardial fibrosis but no acute ischaemic changes. The right and left lungs weighed 537 g and 469 g respectively (NR 561 +/- 256 g, 491 +/- 204 g). The lungs showed mild to moderate congestion and oedema. The trachea and bronchi contained a small to moderate amount of mucoid exudate. The liver showed fatty change. The cause of death was given as myocardial ischaemia due to right coronary artery stenosis due to atherosclerosis.

Toxicology: (performed on cranial blood, usually femoral venous blood is used) alcohol undetected (< 10 mg 100 mL⁻¹); diethyltoluamide (DEET) present – the significance of this finding is unclear.

Comments: This victim’s cardiac event was likely precipitated by exertion against a strong current and associated anxiety, and could have occurred in a variety of other physical and/or anxiety-provoking situations. It is obvious that the tour operator erred in allowing its passengers to snorkel at that time given the strength of the current that developed and the number of snorkellers requiring assistance. It appears that the current is unpredictable at that site. An operator is well advised to discourage inexperienced and/or obviously unfit clients from snorkelling in such areas. The operator’s staff appears to have been well prepared and responded quickly and appropriately to the circumstances.

Summary: Obesity; hypertension; previous snorkelling experience (including an unknown adverse experience); strong current; collapsed on reaching shore; cardiac death

BH 09/06

This 76-year-old male was an overseas tourist on a tour of the GBR with a group from his country. He had a history of hypertension for which he was prescribed medication (unknown). His wife later reported that he had previously suffered from diabetes mellitus but apparently no longer required medication for this. He did not declare any medical conditions to his travel insurer or to the tour operator on its pre-snorkel medical questionnaire. It appears that the victim

was only a weak swimmer with no previous snorkelling experience. The group had been given a snorkel briefing, translated into the victim's language by an interpreter. In addition, each member was also given a written translation of the snorkel briefing on the day prior to the incident. After this briefing, some of the group went snorkelling. The victim was seen walking in the water and looking down into it through a mask, although he was not seen to be snorkelling as such.

On the following day he elected to go snorkelling with up to five others from his group, under the watch of a lookout. The group entered the water from the sandy beach of an island bay. The weather was described as clear and the sea calm. He was wearing a mask and snorkel, shorts and a t-shirt. Floatation aids had been offered but he had not taken any. He also had not buddied-up with another snorkeller.

The lookout reported that he saw the victim wade into waist-deep water to about 30 metres from shore from where he began snorkelling. About a minute later, the lookout became concerned when he noticed that the victim had not moved and, when the victim did not respond to his calls, the lookout ran into the water and went to him. After shaking the victim without eliciting a response, the lookout rolled him over and found him to be unconscious, pale and apparently apneic, but with his mask and snorkel in place. He quickly towed the victim to shore and placed him into the recovery position, causing a large amount of water and froth to be exuded from the victim's mouth. After checking for, and not finding, a palpable pulse, the lookout and another staff member immediately began BLS. It was estimated that BLS was commenced within four minutes of noticing the victim motionless in the water. Supplemental oxygen was provided and an AED was attached about a minute later but advised that no shock be given. A nurse from the nearby resort arrived and assisted with resuscitation efforts, which were ceased after 25 minutes in accordance with medical advice over the phone.

Autopsy: The heart weighed 427 g (NR 370 +/- 75 g) and showed concentric left ventricular hypertrophy (17 mm). There was greater than 75% narrowing of the LAD and circumflex coronary arteries with scarring of the left ventricle consistent with previous infarction, but no acute ischaemic changes. The right and left lungs weighed 559 g and 500 g respectively (NR 651 +/- 241 g, 579 +/- 201 g). The lungs showed anthracosis, congestion and moderate pulmonary oedema. The trachea and bronchi contained fluid debris. The cause of death was recorded as drowning. Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹); flunitrazepam 0.01 mg kg⁻¹ (this is unusual as this is a fast-acting benzodiazepine used as a sedative).

Comments: It appears likely that this victim drowned as a result of a cardiac arrhythmia due to severe pre-existing ischaemic heart disease. It is interesting to note that, although he was elderly, a poor swimmer and had no snorkelling

experience, he was not paired with a buddy or using a buoyancy aid. Of note also, the police investigator reported that the interpreter spoke very poor English, making it likely that the pre-snorkelling briefing was poorly translated and important advice may not have been relayed. It is unknown if the presence of a buddy and/or the use of a buoyancy aid would have prevented this death. However, both are desirable, especially with an elderly, weak swimmer and inexperienced snorkeller.

Summary: History of diabetes mellitus; hypertension; weak swimmer; no previous snorkelling experience; good conditions; waist-deep water; no buddy; no buoyancy aid; silent unconsciousness; drowning (likely cardiac-related)

BH 09/07

This 31-year-old male was apparently very healthy with no known significant medical history. He was an experienced spear fisherman and underwater photographer and held an Advanced Open Water Scuba qualification. He had been learning some apnea diving techniques to extend his breath-hold capability and had practised these on multiple occasions doing underwater laps in a local swimming pool, each session lasting for approximately an hour. On this occasion, he again came to the pool to practice. The pool, which was 20 metres long with depths varying from 1.0 to 1.6 metres, was located in a gymnasium complex. Although no lifeguard was present, there was a surveillance video camera (non-recording), which was monitored from the reception desk. The victim was wearing mask and long free-diving fins and was carrying a 1 kg weight (described as "looking like a dumbbell") in his hands. He was alone in the pool.

About 3–5 minutes after he was last seen swimming underwater, a witness noticed him motionless, face-down on the bottom against one end of the pool (and out of view of the camera) with a plume of bloody fluid coming from his mouth and nose. After asking someone to call for an ambulance, the witness pulled the victim onto the pool deck and checked his vital signs. He was unconscious and apneic with no palpable pulse. The witness then rolled him onto his side to drain his airway before beginning BLS. This was an estimated five minutes from the time the victim was last seen swimming. When paramedics arrived approximately five minutes later, they found the victim in asystole and implemented ALS, which continued for approximately 30 minutes. Spontaneous circulation returned for a short period although the victim remained apneic. He was transported to hospital but died shortly afterwards.

Autopsy: The heart weighed 417 g (NR 370 +/- 75 g) and appeared normal. There was no coronary artery disease. Sections from the artery to the AV node showed fibromuscular dysplasia. The lungs were heavy and showed widespread oedema, suggestive of drowning. The right and left lungs weighed 1,014 g and 868 g respectively

(NR 651 +/- 241 g, 579 +/- 201 g). There was a small amount of fluid in the trachea and bronchi. Histology of the lung showed focal pneumonitis. The cause of death was given as drowning.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: This appears to be another case of a healthy, experienced breath-hold diver failing to appreciate the potential dangers of extended apnea, even when practised in the confines of a shallow pool. Doing so alone without the guarantee of immediate rescue proved fatal. However, the significance of fibro-muscular dysplasia of the artery to the AV node is controversial, so a cardiac arrhythmia related to this cannot be excluded. Autopsy alone does not exclude conditions such as long QT, Brugada syndrome or catecholaminergic polymorphic ventricular tachycardia.

Summary: Apparently very fit and healthy; fibro-muscular dysplasia of artery to AV node seen at autopsy; experienced breath-hold diver; alone in pool pushing breath-hold limits while swimming repetitive underwater laps; drowning (likely due to apneic hypoxia although cardiac arrhythmia possible)

BH 09/08

This overseas tourist, a 28-year-old male, was a social drinker and moderate smoker who, apart from suffering haemorrhoids and myopia, was reported by his family to be a healthy young man. He was a non-swimmer and had used a mask and snorkel for the first time two days earlier while standing in shallow water watching fish.

On this day, he and two friends went to a popular snorkelling area off a sandy beach. The weather was described as warm and sunny and the visibility was up to eight metres. Although the area is prone to strong, long-shore currents, the current was described as weak at the time. The friends snorkelled for a while and the victim, wearing his newly-purchased mask and snorkel, stood in waist-deep water with his face on the surface and watched fish through his mask. He was wearing only board shorts and had no floatation aid. After about 45 minutes the three returned to the beach. The others wanted to go for a walk and the victim decided to re-enter the water alone. Approximately 10 minutes later, the friends heard calls for assistance and when they walked back along the beach saw rescuers performing BLS on their companion.

Another snorkeller had noticed the victim motionless on the seabed at a depth of 1.8 msw about 15–20 metres from shore. His mask was about two metres away but his snorkel was not visible. The snorkeller prodded the victim with her foot and, after there was no response, called for help and was soon joined by her brother. Together they dragged the victim onto the shore. When they placed him in the recovery position, water and froth exuded from his mouth. He was apneic and apparently pulseless (the radial pulse was checked although this is a poor indicator of absence of circulation in such a circumstance) so BLS was commenced

by the rescuers and bystanders. Ventilations were continued despite the outflow of copious amounts of froth and water. One witness described what appeared to be a “purple jellyfish” coming from the victim’s mouth. Resuscitation was continued for 60 to 90 minutes. At one point, rangers arrived with oxygen equipment. When paramedics arrived more than an hour later, the victim was found to be asystolic and was pronounced dead.

Autopsy: The brain was large and heavy 2,002 g (NR 1,449 +/- 161 g) with prominent cerebellar tonsils consistent with an Arnold-Chiari type 1 malformation and megaloccephaly. The heart weighed 392 g (NR 370 +/- 75 g) and was normal with no coronary atherosclerosis. The lungs were very heavy and oedematous. The right and left lungs weighed 1,508 g and 1,392 g respectively (NR 651 +/- 241 g, 570 +/- 201 g). The upper airways contained fluid. The cause of death was given as drowning.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: Individuals with abnormalities such as the Arnold-Chiari malformation (in which there is downward displacement of portions of the medulla and cerebellum into the cervical spinal canal) have reported increased incidents of sleep apnea and are at risk of sudden death from brainstem compression. Indeed, sudden death may be the first indication of an underlying Arnold-Chiari malformation. There have been a number of reported cases in childhood (ages from 17 months to 17 years) of sudden death in the absence of pre-existing neurological deficits.⁵ It is not possible to tell if the brain pathology caused the drowning, but the forensic pathologist who performed the autopsy believed that it was likely. Alternatively, this victim was a non-swimmer who was alone at the time of the accident. The seabed in the area can become steep and there was a current and it is possible that he stepped into deeper water and panicked, possibly removing his mask and snorkel, and silently drowned.

Summary: Asymptomatic Arnold-Chiari malformation; non-swimmer; non-snorkeller; no buoyancy aids; standing alone in waist-deep water wearing mask and snorkel looking at fish; alone; possible sudden death from brain malformation or stepped into deeper water; drowning

BH 09/09

This victim was a healthy 31-year-old non-smoker with no significant medical history. He was a good swimmer and was certified as an Assistant Scuba Instructor. He was also a highly-experienced spear fisherman who did so regularly, reportedly diving every weekend. He had been diving for seven years and was president of a local dive club.

He set off spearfishing with three friends with whom he had dived with often, although it was the first time he had been to this site. The weather was fine and sunny, a light wind and calm sea, a one-metre swell and some surge. The water

temperature was around 15°C and visibility varied from 3–10 metres. The victim was wearing a mask and snorkel, long fins, a lycra suit underneath a full-length wetsuit with hood, an inner vest with some weights, and outer wetsuit vest, bootees and gloves. He had a weight belt with three weights and carried a speargun with 30 m of line and a float with flag. All of the others also had floats with flags. They dived as two buddy pairs, with each diver generally about 50 m from another, although sometimes as far as 100 metres.

After a little over 2 hours the other pair of divers left the water. The victim's buddy exited 15 minutes later, noticing his friend's buoy bobbing in the water at that time and presuming that he was fine. He had last spoken to the victim about 30 minutes earlier, comparing their catches. However, a while later, the group became concerned when they noticed that the float (which was 700–800 m from shore) had not moved for some time and they could not see any sign of their friend. They alerted a jet skier who went to the float. He reported back that he could see the speargun on the seabed but saw no sign of the victim. The police were called and a search was begun, initially by people at hand and shortly afterwards by the police. The victim's spear was soon retrieved, embedded in what was described as a 2.5 m wobbegong shark. The victim's body was found the next day lying face-up on the seabed at a depth of 12 metres' sea water (msw), adjacent to a wall rising to a rocky ledge 3–4 m from the bottom. His mask, fins and weight belt were in place but his snorkel was out of his mouth.

Autopsy: The autopsy was performed two days after death. The heart weighed 320 g (NR 400 +/- 69 g) and was normal with up to 10% narrowing of the coronary arteries by atherosclerosis. There was blood-tinged frothy fluid in the lower airways. The lungs were moderately expanded and heavy. The right and left lungs weighed 760 g and 660 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). The cause of death was reported to be drowning (possibly subsequent to "shallow water blackout").

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: It is impossible to know what caused this victim's demise as it was unwitnessed – yet another failure of the 'buddy system'. It is possible that he became unconscious as a result of apneic hypoxia. There were no reports indicating whether or not he practised hyperventilation. It is also possible that he got dragged underwater by the shark and subsequently drowned.

Summary: Healthy; assistant scuba instructor; regular and experienced spear fisherman; poor buddy system; 2.5 m shark on spear; drowning (apneic hypoxia?)

BH 09/10

This 20-year-old male, a highly accomplished surf lifesaver and ironman who was extremely fit and healthy, had been spearfishing infrequently for about two years. He joined

a group from a local spearfishing club on a five-day spearfishing trip on a large live-aboard vessel on the GBR. At an initial safety briefing, they all signed a disclaimer which, among other things, warned of the dangers of 'shallow water blackout' and the potential for hyperventilation to increase the likelihood of it occurring.

The 13 passengers dived in groups of three or four, each having access to a tender with outboard motor and hand-held radio. They also had access to a crew member to drive it if they so wished. The victim buddied up with two others for the trip. He wore mask, snorkel and fins; a full-length, two-piece 4 mm wetsuit with hood; a weight belt with two 1.5 kg weights, gloves, bootees and a dive knife. He carried a float with 25 m of line which was attached to his spear gun.

The second day, one of his companions noticed that he would lie on the seabed at 22 msw for up to about two minutes waiting for fish to swim by. The victim later mentioned that he was able to dive to 22 msw for two minutes and 10 seconds. The companion expressed concern that this technique was risky owing to "not being aware of your depleting oxygen stock" and the victim agreed that he would avoid doing this and would not dive beyond 25 msw without support from another diver. The companion also noted that the victim spent very little time on the surface between dives. The other companion also noticed the short surface intervals but was impressed with the victim's breath-holding capabilities and ability to reload his speargun underwater without surfacing.

On the third day, the victim and his companions set off again in their tender, without a crew member on board. He was apparently well, but mentioned that he had sore ears from equalisation problems the day before. The weather was described as clear with a light wind, waves of less than one metre, good visibility and a water temperature of 22°C. The trio drifted in the current in water of depths from around 10 to 14 msw with the unmanned tender drifting behind. At times they were up to 100 m apart. After approximately three hours, the other divers boarded the dinghy and saw the victim's float 50 to 70 metres away. They watched the float for about a minute, becoming concerned when it appeared to be dragging and their companion had not yet surfaced.

One of the companions re-entered the water and, when she swam down the line, saw the victim lying on his back on the bottom, apparently unconscious. He was lying about 10 m from his spear, which was embedded in the reef. She surfaced and called for help before diving down to the victim, who was at a depth of 14.6 msw, releasing his weight belt and bringing him to the surface. A plume of blood came from his mouth. The two companions dragged the victim into the tender and removed his mask which was half-filled with blood. There was "a lot of bright arterial blood and bloody foam coming from his mouth and nose". One companion gave several rescue breaths, despite the continued outflow of blood-stained, frothy sputum with each breath. They

radioed the main vessel to report the problem. After checking for and finding no palpable pulse, one of the companions began BLS while the other drove the tender to the main vessel. The victim was brought aboard the main boat and BLS was continued and supplemental oxygen provided with ventilations via a bag-valve-mask. The skipper had alerted the Royal Flying Doctor Service (RFDS) and BLS was continued for at least an hour with telephone consultation with the RFDS doctor, who then advised that efforts be abandoned given a submersion of at least eight minutes and the lack of response to BLS.

The victim's dive watch/computer indicated that he had performed 68 breath-hold dives that day. The final dive was to a maximum depth of 14.9 msw for a total time of more than eight minutes. The record indicates that he began to ascend to the surface after one minute and 44 seconds but, after reaching a depth of 2.1 msw, appears to have sunk to the bottom (14.6 msw) over a minute and remained there for almost six minutes before being rescued.

Autopsy: There were numerous petechiae on the conjunctiva of both eyes (possibly the result of mask squeeze). The heart weighed 545 g (NR 400 +/- 69 g) with symmetrical left ventricular hypertrophy. There was no histological evidence of hypertrophic cardiomyopathy, and the coronary arteries showed no atherosclerosis. The trachea and main bronchi contained bubbly haemorrhagic fluid. The lungs were very heavy and waterlogged. The right and left lungs weighed 1,400 g and 1,420 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). The cause of death was given as drowning (possibly subsequent to "shallow water blackout").

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: The heart was heavy but this is consistent with the so-called 'athlete's heart', i.e., work hypertrophy associated with high-level athletic training such as 'ironman' training. This condition can be associated with high vagal tone and bradycardia. The finding of petechiae on the conjunctivae is unusual in this reviewing pathologist's (CL) experience. It could be the result of mask squeeze but is described in up to 5% of natural deaths.⁶

It is likely that this victim died while trying to free his embedded spear from the reef. With a documented breath-hold dive of almost two minutes, coupled with exertion from trying to retrieve the spear, it is likely that he succumbed to apneic hypoxia shortly before reaching the surface. As a result of a 'loose' buddy system, he was unconscious and apneic underwater for around six minutes in relatively warm waters, resulting in a poor prognosis for survival. It is unknown whether or not he practised hyperventilation prior to breath-holding.

Summary: Very fit and healthy; accomplished surf lifesaver and ironman; experienced spear fisherman; poor buddy system; spear embedded in reef; drowning (apneic hypoxia)

BH 09/11

This 68-year-old male was reported to have been healthy other than suffering from reflux, for which he took pantoprazole. He was on a day trip on a large sightseeing vessel which visited several islands of the GBR. He did not declare any medical conditions on the pre-snorkel questionnaire. He was reported to be a competent swimmer but there is no indication whether he had previous snorkelling experience. His wife described him as looking pale and unwell that morning.

After a briefing, the group was provided with snorkelling equipment, including an offer of vests or 'noodles' as buoyancy aids. The victim did not take a buoyancy aid. Some of the group then entered the water to snorkel. There were 37 passengers but there is no indication of how many of these snorkelled. The victim was wearing board shorts, a t-shirt and a mask and snorkel but there is no mention whether or not he was wearing fins. There were two lookouts on the main boat. The conditions were described as calm with a light wind. There was a current, which one crew member later reported as 2 knots, but it must have been beyond where most of the group were snorkelling as most had no problem with the current. They were briefed on the designated snorkelling area, which was up to 20 msw deep.

The victim was seen by one of the lookouts shortly after entering the water. He was dog-paddling towards the boat but then put his face down and snorkelled with his arms beside him. He was not noticed again. However, when the group returned to the vessel some 45 minutes later, a head-count revealed that one person was missing and a search was commenced. The victim was found about 10 minutes later floating face down on the surface 50–80 m from the vessel. He was unconscious and apneic. A person on the tender quickly gave him several rescue breaths, dragged him aboard and began BLS during transfer to the main vessel. BLS was continued with ventilations now being provided using a bag-valve-mask and supplemental oxygen. The victim regurgitated water and other stomach contents. When the boat arrived at an island about 45 minutes later, it was met by the island nurse who reported the victim to be cyanotic with mottled skin and fixed, dilated pupils. She inserted an oropharyngeal airway and attached a defibrillator but no shock was given. After several more minutes of BLS, efforts were abandoned and the nurse declared the victim to be dead.

Autopsy: The brain was heavy (1,629 g; NR 1449 +/- 161 g). The trachea and main bronchi contained a large amount of frothy, pink, watery fluid. The right and left lungs weighed 583 g and 571 g respectively (NR 663 +/- 217 g, 569 +/- 221 g) and showed moderate oedema and large amounts of frothy fluid on the cut surface. The heart weighed 334 g (NR 400 +/- 69 g) and was normal with mild atherosclerosis of the coronary arteries. The cause of death was given as drowning.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: The victim's prior snorkelling experience is unknown but the lookout's report of him "dog-paddling" towards the boat does not inspire confidence that he was competent. It is unknown whether he got into difficulties within the designated snorkelling area or if he swam or was carried outside it by the current. In any case, it is evident that the lookouts were ineffective, this being unsurprising if a large number of the passengers were in the water at once. He might have been feeling unwell and this could have been exacerbated by the snorkelling, or he might have simply drowned as a result of inexperience.

Summary: Apparently healthy; looked unwell in morning; reflux on pantoprazole; competent swimmer; unknown snorkelling experience; likely many snorkellers in water; lookout failure; drowning (silent?)

BH 09/12

This 64-year-old woman was an overseas tourist who was visiting the GBR with her husband. She was morbidly obese (BMI 42.5 kg m⁻²) and had an extensive medical history including asthma and allergies, hypertension, depression, hysterectomy, cataract removal, bladder repair and InterStim[®] therapy. She was taking a variety of regular medications including diltiazem, venlafaxine, pregabalin, clonazepam, ezetimibe, colesvalam, oestradiol, esomeprazole and an undisclosed, injectable asthma/allergy medication.

The victim was a poor swimmer who had only very recently taken lessons. Her snorkelling experience is unknown. The operator gave a brief to the approximately 20 prospective snorkellers. This included information on the use of snorkelling equipment, hand signals, the buddy system and also the requirement to report any health conditions to staff. The victim did not declare any conditions or medications on the written medical declaration and waiver form or report her health problems.

At the site, the conditions were described as clear with a moderate wind (10–15 knots), calm and with little current. Before he went off scuba diving, the victim's husband checked his wife who said she was fine. The victim was wearing mask and snorkel and a stinger suit and carried a 'noodle' floatation device. She entered the water and was soon seen by the lookout snorkelling alone about 6–8 metres from the boat. However, about five minutes later crew members became concerned to see her motionless and apparently unconscious, about four metres from the stern. No-one had heard any splashing or call for help. One crew member entered the water and towed the victim to the boat. Once on board, she was found to be unconscious, apneic, and with no palpable pulse. BLS was commenced by the crew and supplemental oxygen was provided. An AED was attached but it appears that no shock was given. BLS was continued for about 50 minutes until the arrival of paramedics, who soon after declared the victim to be dead.

Autopsy: The trachea and major bronchi were clear of fluid. The right and left lungs weighed 519 g and 584 g respectively (NR 561 +/- 256 g, 491 +/- 204 g) and were not oedematous. The heart weighed 434 g (NR 362 +/- 77 g) There was mild left ventricular hypertrophy (16 mm; NR < 14 mm). There was less than 10% narrowing of the coronary arteries by atherosclerosis and some focal myocardial scarring, contraction bands and some luminal narrowing of the intramyocardial arteries. Serum tryptase was mildly elevated at 43 µg L⁻¹, but mild elevations of post-mortem tryptase are common and of questionable significance. Death was attributed to drowning (with obesity-associated heart disease and asthma). *Toxicology:* ephedrine/pseudoephedrine chlorpheniramine, clonazepam and diltiazem in their therapeutic ranges; venlafaxine 1.5 mg L⁻¹ (which is in the potentially toxic range, although this drug is subject to post-mortem redistribution); alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: Had this victim declared her various medical conditions to the operator, it is likely she would have been strongly advised against, or possibly prevented from snorkelling, especially without being accompanied. However, prospective snorkellers and divers are often reluctant to declare potentially adverse health conditions for fear of being prevented from undertaking their chosen activity. After an investigation by Workplace, Health and Safety (WHS), the operator was advised to strengthen its warnings during the briefing about the impact of certain medical conditions on snorkelling safety.

This silent drowning could have been precipitated by a cardiac dysrhythmia, asthma or simply by aspiration causing laryngospasm and sudden unconsciousness. Cardiac fibrosis has been associated with heart failure and arrhythmias. The combination of drugs, particularly anti-arrhythmics, anti-convulsants and anti-depressants, especially in conjunction with pseudoephedrine and underlying myocardial changes, may well have been lethal. Finally, the victim was a poor swimmer. If this had been known to the operator, she should have been closely supervised. Routine questioning about swimming and snorkelling experience and ability is always advisable, accepting that answers must be taken on faith.

Summary: Morbid obesity; asthma, hypertension, depression, InterStim[®] therapy, multiple medications; poor swimmer with unknown snorkelling experience; reported to be well that morning; lookout but no buddy; silent drowning (?cardiac-related)

Scuba diving fatalities (Table 2)

SC 09/01

This fit-looking, 47-year-old male dived for crayfish or abalone regularly, usually alone. He was certified as an Advanced Open Water Diver 20 years earlier. When undergoing a pre-employment medical, he reported to the

Table 2

Summary of scuba and surface-supply diving-related

BNS – buddy not separated; BSB – buddy separated before; GSB – group separated before; SC – scuba; SS – surface-supply breathing apparatus

ID	Age (yr)	Gender	Height (m)	Weight (kg)	BMI (kg m ⁻²)	Training	Experience	Dive group
SC09/01	47	M	180	91	28.1	trained	experienced	solo
SC09/02	17	M	180	71	21.9	trained	some	BSB
SC09/03	20	F	n/s	n/s	n/s	in training	nil	GSB
SC09/04	59	M	183	81	24.2	trained	some	GSB
SC09/05	50	M	170	76	26.3	trained	experienced	GNS
SC09/06	52	M	186	107	30.9	trained	experienced	GSB
SC09/07	53	M	178	73	23.0	trained	experienced	BNS
SC09/08	33	M	170	57	19.7	trained	some	GNS
SS09/01	36	M	181	85	25.9	trained	some (not commercial)	solo

doctor that he had a history of epilepsy but had been fit-free for many years. The doctor subsequently gave him several repeat prescriptions for phenytoin 100 mg, 4 nocte. The doctor who performed the pre-employment medical, and subsequently prescribed phenytoin, had no training in diving medicine. He was unaware that the victim was a diver so had not discussed this with him.

On this day, the victim set out to dive alone at a well-known shore dive site, predominated by rocky reef and kelp and which was subject to a large swell and surge. Prior to going, he called a friend to enquire about the conditions and was told “*it’s not ideal but you’ve certainly dived in worse conditions so it should be OK*”. He was wearing a full-length wetsuit with hood, mask, snorkel, fins, knife, BCD, 12.2 l tank (WP 232 bar) and a pocket-style weight belt with seven weights (17 kg), booties and gloves. He had a catch-bag attached to his BCD by a clip.

Searchers saw his body the next morning about 10 metres from shore. He was floating in shallow water with waves washing over him. His yellow fins and his arms were visible on the surface. They waded out to him and found that one of his hoses (HP hose) was wedged between rocks and so they removed his BCD and tank and towed him to shore, leaving the equipment in the water. When later recovering this, they cut the snagged hose in order to free it. Air immediately began to escape but the searcher quickly turned off the valve.

When later inspected, the demand valve’s mouthpiece was reported to have been in good condition (despite what was described as a “*5 mm cut on its underside*”). When tested, the regulator was found to be “*acceptably functional*”. The inflate/deflate hose was missing from the BCD which consequently could not be inflated. Although out of test, the cylinder was in good condition and, when checked, held a pressure of 160 bar and the air met relevant purity standards.

Autopsy: Radiology revealed no arterial gas embolism. There was focal bruising on the left chest and right thigh. The heart weighed 425 g (NR 400 +/- 69 g) and the left ventricle measures 15 mm in thickness. There was no gas in the heart. There was mild atherosclerosis in the coronary arteries. The lungs were well inflated with moderate to severe oedema. The right and left lungs weighed 1,010 g and 876 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). There was froth in the trachea and bronchi. The brain weighed 1,525 g (NR 1,449 +/- 161 g) and appeared normal. Neuropathological examination revealed only cerebral congestion. Analysis of the vitreous revealed sodium of 150 mmol L⁻¹ and an osmolality of 350 mosmol L⁻¹ and such levels have been reported to be associated with drowning.⁷ The cause of death was reported to be drowning. (The forensic pathologist suggested that epilepsy could have contributed to the drowning.) Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹); cannabis 5 µg L⁻¹; 2% carboxyhaemoglobin (probably from smoking); phenytoin 7 mg L⁻¹.

Table 2 (cont.)

fatalities in Australian waters in 2009

GNS – group never separated; GSD – group separated during; + sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ >50% full; nad – no apparent defects; n/i – not inflated; n/s – not stated

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	BCD	Remaining air	Equipment test	Disabling injury
n/s	n/s	n/s	on	17	n/i	+++	some issues	Asphyxia
recreation	8	surface	on	7–8	n/s	++	nad	Asphyxia? CAGE?
training	3	surface	n/s	9.5	n/s	n/s	some issues	Unknown
recreation	14	surface	on	n/s	n/s	+	nad	Cardiac incident
training	2	surface	on	n/s	inflated	+++	nad	Cardiac incident
recreation	5	n/s	off	20	n/s	+++	CO ₂ 500 ppm	Cardiac incident
recreation	25	surface	on	6	inflated	+	CO ₂ 559 ppm	Cardiac incident? CAGE?
crayfish	17	surface	on	3	n/s	+	CO ₂ 500 ppm	Asphyxia
commercial	8	surface	off	n/s	n/s	+++	CO ₂ 500 ppm	Cardiac incident? CAGE? Seizure?

Comments: Although this victim had a history of epilepsy, it is not known whether or not this contributed to his demise. Although he had reportedly been seizure-free for many years, seizures can recur.^{8,9} A possible clue lies in the ‘cut’ in his mouthpiece, which could have been caused by his biting hard on this during a seizure. Diving alone, especially with a history of epilepsy, is ill-advised. Alternatively, it appears that the sea conditions might have been challenging and, although he was an experienced diver, it is possible that he was thrown against rocks and drowned as a result of impact and/or loss of the regulator. Given the amount of remaining air, especially in light of the loss of air when the hose was cut, the incident likely occurred early in the dive.

Summary: History of epilepsy on phenytoin; experienced solo diver; diving alone for crayfish/abalone; likely poor sea conditions; body found next day; plenty of air in tank; drowning (secondary to seizure?)

SC 09/02

This victim was a 17-year-old male who was apparently fit and healthy, on no medication except griseofulvin for a fungal foot infection. He was a good swimmer who had qualified as an Open Water Diver two years earlier but had logged little more than four hours’ diving since.

He and a friend went diving for abalone from the beach in a small rock-fringed bay. The victim had snorkelled at this site on the day before and was reportedly “*in good spirits*”.

He was wearing a mask, snorkel, fins and a knife, a full 5 mm wetsuit and gloves as well as hired scuba equipment including BCD, dive computer and weight belt with about 7–8 kg of weights. The conditions were described as “*not ideal for diving*”. There was a one-metre swell and also some surge in shallower water with visibility reported to be 10 metres and the water temperature 24°C.

Initially they snorkelled for about 20 minutes before changing to scuba and descending to about 8 msw where the bottom was rocky with some weed. After about four minutes, the victim noticed that he had lost his knife and signalled to his buddy to surface. After a short conversation on the surface they agreed to dive again, and re-descended. The victim, towing a flagged float and carrying the catch bag, swam closely behind his buddy who reported that he was unable to see the victim a short time later. After waiting a minute, the buddy surfaced to try to locate the float, which he was initially unable to see because of the swell. However, he then located it about 50 m away and swam over to it, expecting to find the victim when he pulled on the attached line. Unfortunately, the victim was not there so his buddy swam over to some rocks 50 m distant. He sent a companion, who was snorkelling nearby, for help before removing his gear to climb to higher ground to look for his friend. Unsuccessful, he donned his equipment and began an underwater search. After about 15 minutes, he located his friend under a rocky ledge at a depth of about 6 msw, lying face-down on the seabed. He was unconscious, his mask was full of bloody water and his regulator was out of his mouth.

The buddy inflated the victim's BCD and brought him to the surface. There he removed the victim's mask (and probably his weight belt). The victim was cyanotic and there was a lot of blood in his mouth. The buddy could not detect a palpable pulse and towed his friend to the rocks. Two bystanders began BLS, repeatedly rolling the victim onto his side to drain the blood and water coming from his mouth and nose. BLS was continued by a police officer and a search and rescue officer for about 30–40 minutes during which time an AED was attached, but no shock was advised. An ambulance paramedic then arrived and pronounced him dead.

The victim's dive computer record indicated that, four minutes into the dive, he ascended to the surface from a depth of 4.5 msw. The 'fast ascent' warning was activated, indicating that he had exceeded the recommended 10 msw minute⁻¹ (it appears that the ascent rate was likely 15–20 msw minute⁻¹). He then descended slowly over about 9 minutes to a maximum depth of 8 msw before ascending directly (possibly at a rate of 15–20 msw minute⁻¹) to the surface. He remained on the surface for about a minute before descending rapidly to a depth of 6 msw where he remained motionless for 75 minutes before he was brought quickly to the surface by his buddy.

When checked, his pressure gauge indicated 135 bar of air in his 12.2 L cylinder. Prior to the dive it had read 190 bar, indicating that his air consumption was not excessive. When later tested (both in the workshop and on a dive), no significant faults that could have contributed to his death were found with the equipment used by the victim. The air met relevant purity standards, although the cylinder later failed 'test' owing to internal corrosion.

Autopsy: A CT scan two days after death showed features indicative of gas embolization. There was subcutaneous emphysema in the anterior mediastinum and 20 ml of gas and frothy blood in the aorta and left ventricle. The heart weighed 344 g (NR 342 +/- 58 g) and was normal apart from the gas. There was no coronary atherosclerosis. There was widespread frothy fluid within the airways. The lungs were oedematous and the right and left lungs weighed 928 g and 940 g respectively (NR 670 +/- 249 g, 593 +/- 224 g). The report stated: "*Upon the free margin of the left upper and lower lobe, between the lung lobes, very superficial disruption of the pleural surface in the order of 6–8 mm in maximum depth ... was present in association with small bullae formation.*" There was frothy fluid tinged with blood in the trachea. The cause of death was given as drowning secondary to pulmonary barotrauma/cerebral arterial gas embolism (PBT/CAGE). Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: What caused this inexperienced diver to ascend is unknown. His equipment was functional and he had plenty of air. It is evident that he surfaced for a short time before becoming unconscious, probably as a result of PBT/CAGE, and then sinking. Although the investigating police officer

reported that the victim ascended very rapidly to the surface prior to sinking quickly back down, the computer record indicates that this ascent was probably at a rate approaching 20 m minute⁻¹ which, although faster than recommended, does not necessarily indicate a panicked ascent. Presuming that the diver then became unconscious, the subsequent rate of descent indicates that he was likely over-weighted. It is unfortunate that he did not inflate his BCD or ditch his weights to enable him to remain on the surface where he would have been found far sooner. Given the submersion time it is not surprising that resuscitation was futile.

Summary: Healthy; good swimmer; inexperienced diver; buddy separation; became unconscious after ascending to surface and sank to bottom; drowning (subsequent to CAGE?)

SC 09/03

This victim was a 20-year-old female, apparently healthy foreign national who was studying in Australia. She was described as an "*inexperienced swimmer*". She and some friends booked on an introductory scuba dive. At the dive shop, she completed the required paperwork and did not declare any medical conditions. She was fitted with a wetsuit. A dive briefing (in English) was given during the 20-minute boat trip to the dive site. Once at the site, the victim was in a group of four with her friends, under the supervision of one of two instructors.

The 'students' entered the water and floated on the surface supported by their BCDs, holding on to a rope at the boat's stern. The victim was wearing a mask, snorkel, fins, 5 mm wetsuit and reportedly a weight belt with 9.5 kg of weights. The group swam on the surface to shallow water near the shore of a small island where they were taught basic skills while standing or swimming in water of a depth of around 1.5 msw. The sea was reportedly choppy and waves disrupted the training from time to time. The visibility was reported to have ranged from 1 to 1.5 metres, described as "*cloudy from recent rains*", and there was a current. When satisfied with their skills, the instructor led the group into deeper water to a depth of around 2.5 msw. The students "*crawled along the bottom*" in a line, with the instructor just ahead, reportedly checking them regularly. The instructor could see the faces of the students but not their entire bodies. After one check, the instructor noticed that the victim was missing and ascended to the surface with the rest of the group. The instructor then called to the boat driver that a diver was missing, told the students to swim to the shore and then began a search.

Prior to the group surfacing, witnesses saw the victim surface alone, call for help and then apparently sink. The lookout jumped into the water to find her but was unable to see her in the cloudy water. The other instructor located the victim on the seabed about 40 minutes later. She was unconscious and apneic with the regulator still in her mouth. He brought her to the surface and onto a police boat where BLS was

performed by police for 15–20 minutes on the way to the boat ramp. There, ambulance paramedics took over resuscitation and continued en route to hospital, where the victim was pronounced dead on arrival.

On inspection the regulator mouthpiece was found to be perforated, potentially enabling water aspiration.

The instructor was charged with manslaughter and, at the committal hearing, representatives for the police and WHS, among others, argued that the victim was over-weighted, that her regulator was poorly maintained and that the instructor erred in taking a group of four totally inexperienced divers diving in such poor visibility. However, the magistrate determined that the evidence was insufficient to support charges of unlawful killing and the charge was dismissed.

Autopsy: Unavailable.

Comments: This was likely a very avoidable tragedy. Although the standards under which the instructor was operating allow a maximum ratio of four students to one instructor on this programme, the instructor is advised to reduce this ratio in the event of adverse conditions, including poor visibility, rough water and/or current. Had this instructor done so, it would have been easier to monitor fewer students. The conduct of such a dive with the instructor swimming in front of the students can increase the likelihood of separation. Introductory dives are better conducted with participants holding hands, linking arms, or by swimming in formations that enable the instructor to see all of the divers at all times. It appears that the student was likely to have been over-weighted and this would have made it difficult for her to remain on the surface without inflating her BCD and/or ditching her weight belt, something that she would have had little or no training in. Even if she had been told about weight-belt ditching, it might well not have been absorbed, given all else that was happening, possibly magnified by a language problem.

Although the actual timings were unavailable to these reviewers, it would be interesting to know how much time was spent in the shallows learning and practising the basic skills prior to setting off on the actual dive. It seems that it might have been minimal. It is important to provide adequate time to enable the students to learn and practice the essential skills and to feel comfortable enough to participate further. Language difficulties may also have affected the briefing and training adversely in this instance. Finally, if the perforation in the mouthpiece caused the victim to aspirate water, it would likely have increased anxiety.

Summary: Apparently healthy; weak swimmer; introductory scuba dive; some chop and current and poor visibility; ratio of four students to one instructor; relatively little training/orientation time; over-weighted; perforation in mouthpiece; separation; probable drowning or CAGE

SC 09/04

This 59-year-old male was an overseas tourist who went on a day trip on a large dive charter boat to dive on the GBR. There were 100–120 passengers on board. He had been certified as an Open Water Diver three years earlier and had logged a total of 30 dives. He appeared to be healthy and, although his medical history remains unknown, he did not declare any medical conditions on the pre-dive medical questionnaire. The victim was grouped with two other divers and was provided with equipment, including wetsuit, BCD, regulator with ‘octopus’, dive computer, 8 L tank (filled to a pressure of 200 bar), and weights. The sea was reported to be calm and visibility about 15–20 metres. No mention was made about the presence or strength of any current.

The group entered the water and the victim and one buddy descended to a maximum depth of 14 msw and waited for four minutes for the other diver to join them. When he failed to do so, they surfaced briefly before re-descending. They met the other buddy underwater and dived for about 15 minutes before the victim lost sight of the others and surfaced again. His buddies soon surfaced and the three descended again and dived for another five minutes before the victim again surfaced. His buddies ascended to find him holding onto the boat’s mooring line and breathing from his ‘octopus’. He told them that he was “OK”, and did not appear to be in any distress, but he wanted to swim back to the boat (60–70 metres away) on the surface. The divers signalled to the lookout on the boat that everything was okay. After one of them (an off-duty paramedic) checked the victim’s gauge (which read 100 bar) and helped to place the victim’s primary regulator into his mouth, the others descended to return to the boat underwater.

The victim was initially seen to swim ‘freestyle’ for a few metres before rolling onto his back and finning towards the boat. The lookout anticipated that it would take the victim about five minutes to reach the vessel. However, after a while the lookout became concerned that the victim was no longer making headway and was not responding to his calls to confirm he was fine. When the victim was about 25 m from the boat, he did signal that he was okay, but now appeared to be swimming aimlessly and making no effort to return to the boat. In fact, he then turned and began to swim away from it.

On returning from the dive (approximately 15 minutes after leaving the victim), one buddy expressed concern that the victim was not on board, prompting the crew to send a tender to retrieve the now partly submerged victim. When approached by the tender driver, the victim was floating on his side, unconscious, with a grey appearance and foamy discharge coming from his nose. The tender driver dragged him aboard and he was taken to the boat where he was confirmed to be apneic and cyanotic with dilated pupils and frothy sputum coming from his mouth and nose. BLS was commenced by one of the buddies (the paramedic), variously

assisted by an ex-nurse, some crew and a passenger who was a doctor. The victim was rolled onto his side several times in order to clear regurgitated material from his airway. After about 50 minutes, a rescue helicopter arrived and a doctor and paramedic were winched onto the boat. When a defibrillator was attached, it indicated that the victim was asystolic and resuscitation was ceased shortly after.

There was 50 bar of air remaining in his tank and the valve was noted to have been turned on fully. When later tested by the police, the equipment was found to be in good working order and the remaining air met appropriate purity standards.

Autopsy: A CT scan performed 6 hours after death showed “*intravascular gas is noted in the cerebral vessels... There is fluid in both maxillary sinuses and both sphenoidal sinuses. There is fluid noted within the trachea and in the main bronchi. There is extensive air space shadowing throughout both lungs consistent with the presence of fluid in the alveoli. There is gas noted within the pericardium. Intravascular gas is noted in the legs and the vessels in the liver as well as throughout the abdomen.*” The gas pattern could be early decomposition or post-mortem decompression artefact.

The heart weighed 349 g (NR 370 +/- 75 g). There was some calcific thickening of the margins of one of the mitral valve leaflets but no vegetations or areas of perforation were identified. The coronary arteries showed severe focal calcific atheroma, with greater than 75% luminal narrowing of the left main, the mid-course of the LAD and right coronary arteries. Histology showed some oedema and wavy fibres but no acute infarction. There was some focal scarring around the AV node. The trachea and major bronchi showed unremarkable mucosal surfaces but contained frothy fluid. The lungs appeared to be hyper-inflated, with contact between the medial aspect of the lungs anteriorly. The right and left lungs weighed 1,013 g and 887 g respectively (NR 651 +/- 241 g, 579 +/- 221 g). On section there was marked congestion and expressible oedema. The cause of death was reported to be ischaemic heart disease with secondary drowning.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹); carbon monoxide 6%.

Comments: It is likely that this man developed a cardiac arrhythmia or angina either during the dive or swimming on the surface, became disorientated and then unconscious, and subsequently drowned. It is unfortunate that his plight was not recognised and acted upon earlier as it is possible that he might have survived. However, it can be difficult for a lookout to assess the seriousness of such a situation. This case again highlights the importance of buddies staying together throughout a dive, and the potential, although rare, adverse consequences of allowing a diver to return to the boat or shore alone. Although the residual air in the cylinder tested met specifications, the blood carbon monoxide level was 6%. This would be consistent with a smoker, although

there is no information to confirm whether or not the victim had recently smoked.

Summary: Appeared healthy; no significant medical history declared; some experience; intentionally separated from buddies to return to boat; observed on surface by lookout but no distress evident; ‘silent’ unconsciousness; drowning (cardiac-related)

SC 09/05

This victim was a 50-year-old male who certified as a diver five years earlier and had logged approximately 75 dives, mostly shore dives in temperate waters. He also held Advanced Open Water and Nitrox certifications. The victim suffered from lumbo-sacral spondylosis as a result of a work injury and was being treated for hypertension and proteinuria, managed with telmisartan. He was taking rabeprazole sodium for reflux. He also suffered from idiopathic lymphoedema, being hospitalised on three occasions for cellulitis in his legs. He had given up smoking two years earlier and now went to the gymnasium about four times a week to help manage his spondylosis, swam regularly and appeared to be relatively fit although “*solid-looking and carrying a bit of fat*”. An ECG taken after an episode of chest pain a year earlier indicated “*normal tracing other than bradycardia*” (48 bpm). He had been certified fit to dive three months earlier by a doctor trained in dive medicine. This medical was sought as he was planning to upgrade his diving qualifications and was keen to eventually become an instructor.

He was now enrolled in a Rescue Diver course and was participating in some surface rescue drills. The group consisted of an instructor, an assistant instructor and four students. It was windy (gusts of up to 40 knots) but they dived from the shore in an area sheltered by a long breakwater and where the water was relatively calm. The victim was wearing mask, snorkel and fins, a semi-dry suit, hood, boots and gloves, BCD with 10.5 L cylinder, a regulator with ‘octopus’, dive computer and gauge and a weight belt with six weights (weight unreported). The water temperature was 12°C.

The group was in the water approximately 50 metres from shore and had been doing surface rescue tows for about 20 minutes. The depth was 2–3 msw. The victim had acted as both the rescuer (required to tow another diver about 30 metres), and the rescuee, which was the last role he had undertaken. He had not submerged at any time during the exercise. Shortly after completing a briefing, the instructors heard thrashing in the water and realised that it was from the victim, who was about 2 metres distant floating on his back. One of the other students turned to him and asked if he was “OK”, which he said he was. However, he then began thrashing and turning over in the water before becoming motionless, face-down. When one of the instructors went to him and rolled him over, he was unresponsive with

froth coming from his mouth, although he appeared to be breathing. While the instructors and another diver towed the victim towards the rocks he appeared to have a seizure and became apneic and cyanotic. One of the rescuers commenced mouth-to-mask rescue breathing as they towed the victim. Once they reached shore, the instructors began BLS while one of the students went to call an ambulance. When the ambulance arrived 16 minutes later, the paramedics initially had considerable trouble drying his chest sufficiently for the defibrillator pads to adhere. When this was achieved, the victim was found to be asystolic. An intravenous line was established and he was intubated and given 5 mg of adrenaline intravenously (5 x 1 mg). After about 15 minutes, a shockable rhythm appeared and he was given three shocks and transported to hospital where he was later pronounced dead.

When tested, his equipment was found to be functioning correctly, his cylinder was full, and the air met appropriate purity standards.

Autopsy: The heart weighed 498 g (NR 400 +/- 69 g) and had a normal external contour. There was an area of congestion in the posterior basal left ventricular wall. The left and right ventricular myocardium measured 16 mm (concentrically) and 6 mm in thickness, respectively. There was severe atherosclerosis with up to 80% stenosis of the LAD coronary artery, 90% stenosis of the first diagonal branch and 90% stenosis of the left circumflex coronary artery. The right coronary artery showed mild atheroma. The upper and lower airways were free of debris and foreign material. The lungs were congested. The right and left lungs weighed 914 g and 647 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). The brain weighed 1,365 g (NR 1,423 +/- 161 g) and was normal. The right and left kidneys weighed 157 g and 141 g respectively (NR 169 +/- 37 g, 174 +/- 35 g) and appeared unremarkable macroscopically. Histology of the heart showed widespread vacuolation of the myocytes but no acute infarction or fibrosis. Renal histology showed occasional sclerosed glomeruli, a patchy interstitial lymphocytic infiltrate and slightly hypercellular intact glomeruli consistent with the history of previous renal disease. The cause of death was given as ischaemic heart disease (likely cardiac arrhythmia). Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: It is likely that the substantial exertion of the rescue exercises triggered an arrhythmia in this susceptible diver. What this case highlights is that, even those middle-aged divers who ostensibly have a good exercise tolerance and who exercise regularly can have occult severe coronary disease. The role of screening tests in divers of this age remains controversial because of the high false positive rates and complications of the invasive investigations.^{10,11} One hopes that new technologies such as MRI angiograms may enable non-invasive evaluation of the coronary vessels in individuals such as this. The rescuers acted swiftly and

appropriately, unfortunately to no avail.

Summary: History of spondylosis, hypertension, proteinuria, reflux, idiopathic lymphoedema and cellulitis; experienced diver; exercised regularly; recent dive medical; doing rescue training on surface; suffered seizure and became unconscious; cardiac death

SC 09/06

This 52-year-old male, a non-smoker and social drinker, was an active and competitive wood-chopper who was described as fit and healthy, although “*a bit overweight*”. His doctor regularly prescribed perindopril for hypertension, pravastin for hypercholesterolaemia, and naproxen periodically for musculoskeletal pains. Five months earlier, following an episode of what his doctor believed to be musculoskeletal-related chest pain, he had undertaken an exercise stress test. This concluded that “*the deceased displayed good exercise tolerance and no evidence of inducible ischaemia or symptoms at the prescribed workload.*” He had last seen his doctor two months earlier to monitor his hypertension and was reported to have been in good health.

He had been certified as a diver for eight years and had logged 65 dives, although he had not dived for over three years. His tank was tested several days before this incident. He had also recently bought a new mask and snorkel, which he had used the day before, complaining that he was unable to get a good mask seal and, although not flooding, the mask leaked just enough to be annoying. He and two friends were on a fishing trip and planned to scuba dive from one of the friend’s five-metre boat. On the day before the dive, the victim was reported to have drunk four beers and shared a bottle of wine and appeared to be well.

On this day, after abandoning fishing because of a strong wind, the group anchored the boat in the lee of a small island where the depth was around 4 msw. When assembling his gear, the victim initially tried attaching his regulator upside down before asking for help from one of his friends. The plan was for the victim to buddy up with one friend, an inexperienced diver, and to stay close together. The other would dive alone for the others’ safety, as he had a speargun. The wind was reported to be moderate (15 knots), the sea calm with no significant current or swell, water temperature 22°C and visibility 10–15 m.

The victim was wearing mask, snorkel and fins, a two-piece wetsuit, BCD, 11.5 L cylinder (filled to 250 bar), regulator, octopus and gauge, a knife and a weight belt (with an unconfirmed amount of weight, possibly 20 kg). He entered the water last and appeared to be relaxed underwater. However, on at least two occasions the buddy saw the victim kneeling on the seabed, clearing his mask, the last occasion being about 20 minutes into the dive. After his ‘OK’ signal was returned by the victim, the buddy swam off

to continue diving. However, after a few minutes, the buddy realised that he could not see the victim and commenced a cursory search before returning to the boat alone. On the way, he found the victim's mask and snorkel and became concerned when he surfaced and could not see the victim on the surface or in the boat, some 50–60 m away. He returned to the boat. His computer indicated that he had a dive time of 44 minutes. After a further 20 minutes, the other diver returned and radioed for assistance, to which two nearby vessels responded.

The crew on one vessel located the victim floating face-down on the surface approximately 200 m away from the dive boat. He was unconscious, his regulator was out of his mouth and he was not wearing his weight belt. He was brought aboard and his equipment removed. Breathing and pulse were noted to be absent. He was cyanotic and there was no discharge coming from his mouth or nose. Some rescue breaths were given and the victim was soon transferred to the other, larger vessel where there was oxygen equipment and an AED. The AED was attached but no shock was advised so the crew commenced BLS with supplemental oxygen until the vessel arrived in port approximately 45 minutes later. Waiting paramedics pronounced him dead.

When later examined by police, the equipment was found to be functioning in accordance with manufacturers' specifications and was maintained in good order. The victim's cylinder still contained air at a pressure of 170 bar and this air met most of the purity standards, although carbon dioxide (CO₂) was slightly higher than recommended (500 ppm – maximum allowable under AS2299.1:2007 is 480 ppm). His maximum depth indicator read 4.5 msw.

Autopsy: The heart weighed 510 g (NR 400 +/- 69 g) and showed concentric hypertrophy and dilatation of the left ventricle. The aortic valve was functionally bicuspid with fusion of two of the valve cusps. The trachea and bronchi were clear. The right and left lungs weighed 740 g and 618 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). Both lungs were inflated and were plum-coloured and markedly congested. There was no description of intravascular gas at autopsy. The coronary arteries showed advanced complicated stenotic atheroma on histology. The cause of death was given as immersion in a man with aortic valvular disease.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: The reviewing pathologist (CL) would describe this death as the result of the combined effects of ischaemic and valvular heart disease. The victim possibly became stressed by his leaking mask and this may have precipitated a cardiac event. It is likely that he surfaced and ditched his weight belt before losing consciousness. Unfortunately no one was available to help him because of buddy separation. In the absence of CT scan or description of gas present at autopsy it is impossible to evaluate the possibility of PBT/CAGE. It is unlikely that the slightly elevated carbon dioxide content in his air contributed to this death.

Summary: Hypertension, hypercholesterolaemia, episode of chest pain with negative stress test; bicuspid aortic valve, severe atherosclerosis and left ventricular hypertrophy; experienced but no diving for 3 years; leaking mask; separation; cardiac death

SC 09/07

This victim was a 53-year-old male. Despite a strong family history of heart disease, he appeared to be very fit and healthy and was not known to be taking any medications. It was reported that "*he avoided doctors*". A diver for 39 years, he had qualified as an instructor 20 years earlier and had logged over 2,000 dives. He was a paying passenger on a dive charter vessel on a day trip in sub-tropical waters. The 19-metre boat was carrying 13 passengers and eight crew. He did not declare any medical conditions to the operator prior to diving. The victim was wearing a mask, snorkel and fins, a wetsuit, BCD with integrated removable weights of 5.5 kg, and an 11.5 L cylinder with regulator and octopus, dive computer and pressure gauge. The sea was calm, water temperature 24°C with a current of approximately 0.5 knots. He was paired with an inexperienced buddy and they made an uneventful 40-minute drift dive to a maximum depth of 16.4 msw. After a surface interval of 85 minutes, they entered the water for another dive on a wreck sitting on the seabed at a depth of around 25 msw.

The victim led his buddy around the wreck for about 40 minutes, at which time the buddy indicated that he was low on air and wanted to surface, which they did. The buddy described the ascent as controlled and calm, but at a rate slightly faster than usual. They did not do a safety stop. They had ascended up the anchor line of another boat, and, after speaking with its skipper, the victim decided that he and the buddy should swim to their own boat, variously reported as 50–200 m away. Initially, the buddy was unable to swim unaided against the current so the victim towed the buddy for several minutes until the buddy was able to make headway unaided. After swimming what was likely around 100 m, the divers reached the mermaid line from the boat and began to pull themselves along it. However, when the buddy reached the boat he (and others on the boat) noticed that the victim was floating away, face-down and motionless.

One of the crew swam over to the victim and found him unconscious with his mask in place and with the regulator in his mouth. A tender came over to assist, the victim was dragged aboard and BLS was commenced. Once on the main vessel, BLS was continued, with supplemental oxygen provided during the 10- to 15-minute transit to a nearby resort. Once there, resuscitation efforts were continued by a paramedic, without success.

When tested later, the equipment was found to be functioning correctly. The cylinder still contained air at a pressure of 65 bar. However, the CO₂ content of the air was found to be higher than recommended (559 ppm), as was the water

content. The dive computer indicated that the victim had dived to a maximum depth of 24.6 msw with a dive time of 40 minutes.

Autopsy: A full body CT scan (performed 18 hours after death) showed extensive gas present in the left side of the heart extending through the arterial system to involve the aorta and its major branches both inferiorly and superiorly, in the carotid, vertebral and cerebral arteries, as well as the proximal coronary, subclavian and common iliac arteries, extending into the legs. There was a small amount of gas in the right side of the heart and frothy blood in the inferior vena cava. There was a large amount of gas in the liver and mesenteric vessels and in the thigh muscles, possibly in vessels. There was no pneumothorax. Gas was noted in the hip joint and eye. The brain weighed 1,410 g (NR 1,423 +/- 161 g) and showed numerous air bubbles within the surface vessels. Focal haemorrhage was noted in the petrous temporal bone. Gas was able to be aspirated from the aorta and left ventricle and atrium. The lungs were oedematous and the right and left lungs weighed 880 g and 760 g respectively (NR 651 +/- 241 g, 579 +/- 201 g). There was frothy fluid in the trachea. The heart weighed 360 g (NR 370 +/- 75 g). There was severe coronary atherosclerosis with 90% narrowing of the proximal LAD coronary artery and 95% narrowing of the right coronary artery. There was extensive old scarring of the posterior left ventricle. Histology shows focal haemorrhage in the atheromatous plaque in the right coronary artery and old infarction and eosinophilia suggesting early acute ischaemia in the myocardium without a neutrophilic infiltrate. The cause of death was given as arterial gas embolism with coronary atherosclerosis as contributory findings.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹).

Comments: The interpretation of the finding of gas at 18 hours postmortem is complex. The gas in the liver and mesenteric vessels is probably decompositional and post-mortem decompression artefact, and the gas in the eye, hip and thighs is almost certainly post-mortem decompression artefact. There does appear to be more gas in the arterial system than in the venous system which could be interpreted as PBT/CAGE. However, in a diver dying of a cardiac arrhythmia due to ischaemic heart disease, one might expect that normal off-gassing of nitrogen via the lungs would be compromised and that post-mortem decompression artefact would therefore be increased. The gas may all be due to post-mortem decompression artifact; however, in the experience of the reviewing pathologist (CL), it is unusual to see so much in the arterial system and so little in the venous system but it is probably unreliable to try to interpret a CT scan done 18 hours after death. The reviewers believe that the cause of death was more likely to have been ischaemic heart disease than CAGE, given the description of the incident.

Although this highly experienced diver appeared to be fit and healthy, his substantial (presumably asymptomatic) cardiovascular disease may well have led to an arrhythmia,

triggered by the heavy exertion of swimming and towing his buddy against a current. Older divers, especially those with a known significant medical condition and/or relevant family history (such as this victim), are advised to have periodic health checks.¹¹ This victim, although thought to have been in good health, was reported to have “*avoided doctors*”. It is interesting to contemplate whether a medical review might have raised concerns, or whether his significant cardiovascular disease might have remained undetected as in some other cases in this series.

Summary: Strong family history of cardiovascular disease; apparently fit and healthy; highly experienced diver and instructor; exertion against current; cardiac death

SC 09/08

This 33-year-old male, overseas national currently living in Australia, was apparently reasonably fit, had no known health problems and was on no medications. He had undergone a diving medical one month prior to being certified as an Open Water Diver two months earlier. He had undertaken only three open water dives. His swimming competency was not reported.

On this occasion he went diving for crayfish with three friends, two of whom were also inexperienced divers. The victim was wearing a 5 mm one-piece wetsuit with boots and gloves, mask, snorkel and fins, BCD with integrated weights system and 2.7 kg of weights, a 15 L cylinder (filled to around 240 bar), regulator, demand valve and ‘octopus’ and a dive computer. He was carrying a camera.

They dived from rocks in a relatively calm bay, a site about which they had little knowledge, although one of the group had dived it before. Although their entry point was sheltered from the wind and looked calm from their vantage point, there was a strong wind (gusting up to 25 knots) and a two-metre swell and strong current on the other side of the rocks, some 100 metres distant, beyond a sheltered canal. The water temperature was about 22°C and visibility was 10 m. Following a thorough briefing including selecting an exit point, they geared-up on the rocks and entered the water.

After an underwater time of 33 minutes at a maximum depth of 17 msw, the divers surfaced. They had planned to do a five-minute safety stop but abandoned this after two minutes because of the strong surge. They surfaced on the seaward side of the rocks where the conditions were rough, with breaking waves and a strong current. Unable to access their pre-determined exit point, they swam towards the nearest rocks, reaching them about 20 minutes later. Two of the divers managed to scramble onto the rocks, while the victim and one friend struggled against the waves and current. The victim managed to climb onto the rocks but, while attempting to stand, was knocked over by a breaking wave and fell backwards into the water. He had swallowed some water and was coughing and struggling in the water and calling

for help. One of the divers told him to put his regulator back in his mouth, which he did, before disappearing under the breaking waves without his mask on. A diver tried to jump in to help but was smashed against the rocks by the waves and retreated, losing his mask and fins in the process. Some of the others also lost equipment, and one sustained a fractured finger. The divers waited for a short time in the hope that the victim might surface away from the waves. However, when this seemed unlikely, they called the police.

Police arrived about 40 minutes after the victim was last seen and began a search, utilizing boats and a helicopter. The victim's body was seen from the surface by one of the searchers, close to where he had last been seen. He was lying face-up at a depth of 11 msw; his mask was missing and his regulator out of his mouth but his other equipment was still in place. When the searchers dropped a weighted line to mark the spot, it wrapped around the victim's arm enabling them to pull him to the surface. No attempts were made to resuscitate him.

When examined later by police, the equipment, which looked near-new, was found to be functioning in accordance with the manufacturers' specifications. The cylinder valve was fully closed which caused some initial concern. However, this was thought likely to have been done inadvertently by one of the searchers, although none admitted to doing so. When tested, the air met most of the required standards. The air pressure was 80 bar. However, the CO₂ content (500 ppm) was slightly higher than recommended, and the water content, at 160 mg m⁻³, was well above the recommended 50 mg m⁻³ (although this was not believed to have been contributory).

Autopsy: The post-mortem examination and CT scan were performed five days after death. A post-mortem CT scan showed fluid within the facial sinuses. There was no evident intracranial, intravascular or other compartment gas or evident trauma to the head or neck area. There was a column of fluid filling the trachea from the sternal notch to the carina. There were superficial bruising and abrasions on the face, arms and legs. There were petechiae on the conjunctivae. The heart weighed 266 g (NR 342 +/- 58 g) and was normal, with no coronary atherosclerosis. The lungs showed bilateral pulmonary oedema. The right and left lungs weighed 472 g and 448 g respectively (NR 670 +/- 249 g, 593 +/- 224 g). There was a small amount of frothy fluid in the upper airways. However, there was 600 ml of pale red fluid in the right pleural cavity, 500 ml in the left pleural cavity and 278 g watery fluid in the stomach. There were bilateral middle ear haemorrhages. The lung changes of drowning were obscured by decomposition; a prolonged post-mortem interval makes diagnosis harder, but some of the fluid appears to have moved into the pleural cavity. The cause of death was given as drowning.

Toxicology: alcohol detected 0.01% (probably from decomposition).

Comments: Through insufficient local knowledge and inexperience, these divers grossly underestimated the sea conditions that they would encounter when diving beyond the sheltered area where they entered. Had the victim inflated his BCD and ditched his weight belt, he might have survived. His inexperience and/or incapacitation from being swept back into the sea and aspirating and swallowing water likely hampered his ability to deal with these circumstances. Some divers find it difficult to breathe from a regulator underwater without a mask in the best of circumstances, much less under such adverse conditions. This is a skill that all divers should refresh periodically.

Summary: Healthy; recently certified and inexperienced; surfaced into rough conditions; swept from rocks; drowning

Surface-supply breathing apparatus (SSBA) diving fatalities (Table 2)

SS 09/01

This victim was a 36-year-old male who was described as fit and healthy. He had a history of bipolar affective disorder, although he was reported to have been happy and in good spirits at the time prior to this accident. Two years earlier, he had suffered what had been reported as a possible seizure, but there had been no known subsequent events. He had been a recreational diver for 13 years but his experience was unreported. He was assessed as fit to dive by a qualified diving medical examiner five months earlier when he began working at a pearl farm.

On this day, he was tasked to spread some pearl shell panels across the ocean floor and was diving from a tender. There were two other divers in the water doing different tasks, and a supervisor remained on board the tender, which was tethered to a platform. The victim was wearing a mask, fins, a two-piece wetsuit with undergarments, a weight belt (weight unreported) and was using a tow-line SSBA. He had positioned one set of panels about 30–40 m away and was returning towards the tender at a depth of 8 msw when, after a bottom time of 8 minutes, he ascended directly to the surface (rate approximately 18 m min⁻¹, indicated by his dive computer). On surfacing, he ditched his weight belt and was seen to wave for help before sinking to the bottom. The supervisor recalled the other divers and pulled the victim onto the platform by the airline. His mask was removed and there were froth and stomach contents coming from his mouth.

BLS was begun by the others and supplemental oxygen was added when the equipment was brought to the vessel. Resuscitation attempts continued for an hour, in consultation with a doctor by phone, until that doctor advised that efforts should be abandoned.

When tested, the equipment was found to be functioning adequately. There was a slightly elevated CO₂ content (500 ppm) in the air in his cylinder. A subsequent WHS inspection of the operation found some non-compliance issues but nothing that was believed to have contributed to this death.

Autopsy: The heart weighed 420 g (NR 400 +/- 69 g) and was reported to have appeared to be enlarged. The left ventricular wall measured 15 mm (NR < 14 mm). The coronary arteries showed minimal atheroma. The upper airways contained small quantities of frothy mucoid fluid. The lungs showed oedema and congestion. The right and left lungs weighed 850 g and 790 g respectively (NR 663 +/- 217 g, 569 +/- 221 g). There were petechiae on the conjunctivae. The brain weighed 1,640 g (NR 1,423 +/- 161 g). The cause of death was given as drowning.

Toxicology: alcohol undetected (< 10 mg 100 mL⁻¹); carbon monoxide 5% (consistent with a chronic smoker).

Comments: The pathologist suggested that the heart was enlarged and that cardiac causes could have contributed to the drowning. However, the heart weight is within the normal range for his BMI, and the reviewing pathologist (CL) has questioned whether the heart was in fact enlarged. Although it is unknown what caused this diver to ascend and call for help, several possible factors could have precipitated unconsciousness and subsequent drowning. These include a cardiac arrhythmia (as suggested by the examining pathologist), which could have resulted from exertion underwater; or a PBT/CAGE. As there was no imaging of the body and no description of gas found at autopsy, it was not possible to evaluate PBT/CAGE on this autopsy.

Given his history of what was thought to have been a seizure, it is possible that he had another seizure and subsequently drowned. It is also possible that he simply aspirated water inadvertently, although this seems to have been unlikely. It appears that about eight minutes elapsed from the time he surfaced and waved for help to when he was dragged onto the platform. Although longer than ideal, this indicates a relatively rapid rescue under the circumstances and one can speculate whether or not an AED might have been beneficial in this case.

Other than a comment by a family member, no information was available about the possible seizure suffered by the victim several years earlier. It is probable that this information was withheld from the diving medical examiner as, otherwise, it is unlikely that the victim would have been given a medical clearance to dive. Unfortunately our research team was unable to view all of the relevant documents for this case so some pertinent information might have been missed.

Summary: Apparently fit and healthy although history of seizure and bipolar affective disorder; certified for 13 years but experience unknown; recent dive medical; diving alone

on commercial pearl farm; some exertion; surfaced and called for help; ditched weights but sank; drowning

Root cause analysis

The root cause analysis for each case reported is summarized in Table 3.

Discussion

APNEIC HYPOXIA

It seems likely that three of the victims in this series (BH 09/07, BH 09/09 and BH 09/10) died as a result of apneic hypoxia (often referred to, incorrectly, by the lay community as “*shallow water blackout*” but, perhaps, as suggested by one author (JL), better described as “*breath-holding blackout*”). All of these victims were young and apparently fit and healthy, which is consistent with many previous cases.¹²⁻¹⁶ Pushing one’s breath-holding limits is a potentially dangerous practice and sudden unconsciousness can occur with or without hyperventilation. Ascent from depth increases the likelihood of this as a result of the rapid reduction in ambient pressure and consequent drop in partial pressure of oxygen in the blood and tissues. However, as is likely with BH 09/07, sudden unconsciousness can occur as a result of extended breath-holding with minimal ascent. DAN AP Australian data indicate that, between 2004 and 2009, four snorkellers died while practising extended apnea in a swimming pool.¹⁷ In the absence of a readily available rescuer this practice can carry unacceptably high risks.

BUDDY SYSTEM / SUPERVISION

A recurring theme in dive fatality reports is the absence, or breakdown, of the ‘buddy system’.¹²⁻¹⁹ This series is no exception. Only seven of the 21 victims (33%) were with their buddy or under close supervision when the accident occurred. Four of the victims had dived solo, five had intentionally separated from their companions during the dive, three were under indirect supervision, and two victims had accidentally separated from their buddies. It is important to remember that an unconscious, apneic diver needs to be rescued and resuscitated swiftly in order to have a chance of survival. This is extremely unlikely in the absence of a vigilant buddy or close supervision, and sometimes impossible even if present.

In commercial snorkelling situations there are often too few lookouts relative to the number of snorkellers and this makes adequate supervision difficult. A snorkeller who appears to be fine one minute can suddenly and silently become unconscious soon after, and several minutes may elapse before this is recognised by a lookout who is required to monitor what often becomes a dispersed group. The use of relatively few lookouts might be valid in ideal conditions. However, increased vigilance (usually including more lookouts) is necessary where conditions are less

Table 3
Root cause analysis of diving-related fatalities in Australian waters in 2009

Case	Trigger	Disabling agent	Disabling injury	Cause of death
BH 09/01	Exertion?	Ischaemic heart disease	Cardiac incident	Drowning
BH 09/02	Exertion? Immersion?	Ischaemic heart disease	Cardiac incident	Cardiac-related
BH 09/03	Strong current	Buoyancy-related	Asphyxia	Drowning
BH 09/04	Unknown	Ankylosing spondylitis?	Asphyxia? Cardiac incident?	Drowning
BH 09/05	Exertion	Cardiovascular disease	Cardiac incident	Cardiac-related
BH 09/06	Immersion? Aspiration?	Cardiovascular disease?	Cardiac incident?	Drowning
BH 09/07	Prolonged breath-holding	Apneic hypoxia? Cardiac (fibro-muscular dysplasia)?	Asphyxia? Cardiac incident?	Drowning
BH 09/08	Inexperience/panic? Postural effect on brainstem?	Aspiration? Sudden unconsciousness?	Asphyxia	Drowning
BH 09/09	Prolonged breath-holding? Dragged under by shark?	Apneic hypoxia? Buoyancy-related?	Asphyxia	Drowning
BH 09/10	Prolonged breath-holding	Apneic hypoxia	Asphyxia	Drowning
BH 09/11	Feeling unwell? Current?	Aspiration	Asphyxia	Drowning
BH 09/12	Immersion? Aspiration? Asthma	Aspiration? Cardiac disease?	Asphyxia? Cardiac incident?	Drowning
SC 09/01	Epilepsy? Rough water?	Unconsciousness from seizure? Impact with rocks?	Asphyxia	Drowning
SC 09/02	Unknown	Aspiration? Rapid ascent?	Asphyxia? CAGE?	Drowning
SC 09/03	Unknown	Unknown	Unknown	Unknown
SC 09/04	Immersion? Exertion?	Cardiovascular disease	Cardiac incident	Drowning
SC 09/05	Exertion	Cardiovascular disease	Cardiac incident	Cardiac-related
SC 09/06	Leaking mask?	Cardiovascular disease	Cardiac incident	Cardiac-related
SC 09/07	Exertion	Cardiovascular disease? Ascent-related?	Cardiac incident? CAGE?	Cardiac-related? CAGE?
SC 09/08	Rough water	Aspiration	Asphyxia	Drowning
SS09/01	Exertion?	Cardiovascular disease? Epilepsy? Ascent-related?	Cardiac incident? CAGE? Seizure?	Drowning

than optimal, and rigor is required when deciding whether conditions are suitable for novice snorkellers.

Tragically, one of the victims (SC 09/03) was doing an introductory scuba programme under the supervision of an instructor in circumstances where it was arguable that the instructor-student ratio was inappropriate.

EPILEPSY

Although diving with epilepsy is still the subject of ongoing debate,⁸ the South Pacific Underwater Medical

Society recommends that “a candidate with a history of fits (apart from childhood febrile convulsions), or unexplained blackouts should be strongly advised against diving. Any condition associated with fits or blackouts will be a grave risk to life during diving.”²⁰ Diving and/or snorkelling may involve several factors that can reduce the seizure threshold, such as stress, exercise, sensory deprivation, hypercapnea, hyperventilation and hypothermia. Seizures can occur while taking anti-epileptic medication or may recur many years after the cessation of medication.⁹ Two of the victims in this series had a reported history of epilepsy (SC 09/01, SS 09/01). Given that there were no witnesses to these accidents

(both divers were diving solo), and the inability to detect medical evidence of a seizure at autopsy, it is impossible to confirm whether or not a seizure contributed to these deaths. However, these authors believe people with a history of or current epilepsy are well advised to refrain from scuba diving and to snorkel only if closely supervised.

GAINING POSITIVE BUOYANCY IN AN EMERGENCY

It was necessary to conduct an underwater search to locate the bodies of three of the divers in this series (SC 09/02, SC 09/03 and SC 09/08). The need to locate a diver, especially underwater, prevents early resuscitation efforts and it is far better for an unconscious diver to be at the surface, rather than to have to be searched for and recovered from depth. This is evidenced by a Canadian report of the outcomes of 37 scuba diving accidents.²¹ Of 13 divers who failed to surface and for whom a search was required, 12 died and only one survived. Of the 25 divers who managed to reach the surface after getting into difficulties, 22 survived, despite some requiring resuscitation and/or recompression.²¹ Sometimes a stricken diver simply does not have the opportunity to gain positive buoyancy by inflating his BCD and/or ditching his weight belt or integrated weights. However, this is an important educational message and training drill, which needs to be practised, embedded and periodically re-visited.

OVERWEIGHTING OF TRAINEE DIVERS

In SC 09/03, the student appears to have been over-weighted. Divers are advised that they should adjust their weights so that they are 'neutrally buoyant' on the surface (or at their safety stop). Despite this, it is common practice for instructors to make their students negatively buoyant as it usually makes them less likely to inadvertently float to the surface during a dive without the instructor's knowledge. Although this is not ideal, it generally achieves the stated goal. An additional factor is that many novice divers breathe at a larger lung-volume range than in normal, relaxed breathing, thus increasing their positive buoyancy (body buoyancy being most dependent on that created by the gases in the lungs). As they learn to relax with increasing experience, this changes and a concomitant reduction in weighting is needed, but is often not made. Unless the student or instructor adjusts the student's buoyancy properly using their BCD (students are purposely not trained to do so while underwater in an introductory dive), they tend to swim in a semi-upright position, which increases resistance through the water, or drag themselves along the bottom, so stirring up sediment, damaging reef and reducing visibility. This has the potential to cause fatigue. Additionally, and of important relevance to SC 09/03, over-weighting can make it very difficult for the diver to ascend and remain on the surface unless they sufficiently inflate their BCD and/or ditch their weight belt. The importance of the relationship of lung volume to correct buoyancy is generally not well explained.

CARDIAC-RELATED DEATHS

In this series it is again apparent that cardiac-related factors represent a major disabling injury in both snorkelling and compressed-gas diving incidents. These appear to have contributed to at least six, and possibly up to 12 of the 21 fatalities for this year. Australian fatality data from 2004 to 2009 inclusive indicate that, between 34 to 46 of the 120 diving-related fatalities (28–38%) appear to have been caused by a cardiac incident.¹⁷ This is reasonably consistent with DAN America data from 1992 to 2003 which yielded a rate of 26.4%.¹² However, it is far higher than the 18% of apparent cardiac-related deaths reported for Australia between 1972 and 2005.¹⁸ The difference is undoubtedly partly owing to the increasing participation of older divers, with the likely associated occult cardiac disease. It is also likely owing in part to the increasing awareness of examining forensic pathologists of the potential impact of diving on a person with cardiac disease.

Increasing age and obesity are known indicators of increased risk of a cardiac incident.^{22,23} In this series, the ages of the six victims who likely died from a cardiac cause ranged from 50 to 63 years. Their BMIs ranged from 24.2 to 32.3 kg m⁻¹. One victim who was classified as a possible cardiac-related death was morbidly obese, with a BMI of 42 kg m⁻². A poor swimmer, she failed to declare various medical conditions and associated medications and was 'an accident waiting to happen'. A snorkel operator is faced with a conundrum when dealing with such a customer. While the declaration of a medical condition may provide an avenue of refusal, one must be careful not to be discriminative on the basis of obvious obesity. If there is pressure from the individual to be allowed to participate, which is often the case, then the ideal situation is to allocate a guide to accompany the person, possibly on a one-to-one or one-to-two basis to enable the provision of rapid response and support if required. However, staff numbers often do not enable this, or the individual may not agree to pay any extra associated costs. In such circumstance, dive operators need to show the courage to decline such individuals on safety grounds based on their risk assessment.

The issue of medical screening of the ageing diver is a large subject in its own right. The likelihood of occult coronary artery disease increases with age, and this seems to be reflected in these mortality reports. The difficulty facing the diving medical examiner is selecting which diver candidates to investigate further, and what are the most appropriate

* **Footnote 2:** DAN Asia-Pacific has recently launched an awareness campaign in an attempt to better educate the diving community of the potential danger of diving with cardiac disease. A poster can be downloaded at: <http://www.danasiapacific.org/main/_images/DAN_Cardiac_Poster.jpg>.

investigations to choose. All investigations have a cost and an associated risk, and are prone to false positive and false negative results. This matter represents a current conundrum in diving medicine.

INTRODUCTORY DIVE RATIOS

Training agencies have standards to which their instructors are obliged to adhere, and these include guidelines on training, instructor-to-student ratios, equipment and various other factors. Ratios are set for ideal conditions and should be reduced accordingly if conditions are less than ideal. Despite the general safety of diver training, unforeseen circumstances, medical factors, human error, carelessness, ignorance and occasional negligence may intervene and a student come to serious harm. In an extensive 2010 paper based on PADI worldwide training data, it was reported that between 1999 to 2008 there were 24 recorded deaths in a total of 2,104,366 reported Discover Scuba Dives (i.e., introductory dives); a death rate of 1.14 per 100,000 dives.²⁴

It is questionable whether introductory dive programmes should be conducted at all in poor environmental conditions, based on consideration of participant pleasure with the consequent future potential to take up diving and on safety grounds. From a safety perspective, with an introductory dive such as the one reported here as SC 09/03, it may be more sensible for an instructor (and their employer, if relevant) to consider a ratio starting point of one or two students, and work upwards if the conditions are considered suitable, rather than starting from the maximum and working down. The mindset is subtly different and might help to err on the side of safety. However, this suggestion is likely to be unpopular commercially.

CARBON DIOXIDE CONTENT OF BREATHING GAS

In four fatalities (SC 09/06, SC 09/07, SC 09/08, SS 09/01), the analysis of the breathing gas demonstrated carbon dioxide levels of approximately 500 ppm, slightly in excess of the current Australian Standard (AS2299.1) of 480ppm. In each case, this was thought to be non-contributory to the fatality. It is interesting to note that the current standard for the Royal Australian Navy (RAN) is 800 ppm and for the US Navy, 1000 ppm. Furthermore, AS2299.1 is presently under review, and it is likely that the new standard will allow for a higher level of CO₂ (Ian Millar, personal communication, 2013). A CO₂ of 500 ppm does not necessarily reflect air-supply contamination as the CO₂ in the 'urban dome' (inner city) can often exceed 550 ppm, depending on the time of year and location.²⁵

The American Conference of Industrial Hygienists allows for a continuous exposure of 5,000 ppm (i.e., USN standard @ 40 msw) with a short-term exposure limit of 30,000 ppm (50,000 ppm produces intoxication and greater concentrations may produce unconsciousness). Thus, the

present AS 2299.1 is very conservative even allowing for the effects of pressurisation. In all likelihood, the levels seen in these gas samples were the result of environmental CO₂. Whilst the slightly elevated carbon dioxide and water vapour in several cases was non-contributory, it is a timely reminder that air compressors must be meticulously maintained, and commercial operations have a testing and certification obligation.

Limitations of the study

As with any uncontrolled case series, there were inevitable limitations and uncertainties associated with our investigations. These included:

- Incomplete case data. Fatalities were sometimes unwitnessed, and reports provided by any witnesses and by police varied in their likely reliability, as well as the content and expertise of the investigators.
- Autopsy reports can sometimes be unreliable as a result of 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 arrhythmias, among other factors. Care must be taken to critically examine the available evidence and minimise speculation when determining the likely disabling injuries.
- Classification of cases into a sequence of four events (trigger, disabling agent, disabling injury, cause of death) using root cause analysis (Table 3) requires a single choice for each component event, which may omit important factors in some cases because, at each level, multiple factors rather than a single one may be at play.²
- Limited annual case data. Twenty-one deaths are too few to reliably determine trends.

Conclusions

In 2009, there were 21 reported fatalities, including 18 males and three females. Twelve deaths occurred while snorkelling and/or breath-hold diving, eight while scuba diving, and one using SSBA. Apneic hypoxia continues to be a problem with breath-hold divers and appears to have caused the demise of three victims. Cardiac-related issues, particularly in older divers, were thought to have been the disabling injury in the deaths of at least three snorkel divers and at least three of scuba divers and may have been contributory in several others. One of the victims in this series was a student who became separated from her instructor on an introductory scuba dive in poor visibility. Other causal factors associated with these deaths that may have been contributory included inexperience, non-existent or poor buddy systems, inadequate supervision and diving in rough conditions.

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John Lippmann^{1,2}, Chris Lawrence³, Andrew Fock⁴, Thomas Wodak⁵, Scott Jamieson⁶

¹ Executive Director, Divers Alert Network (DAN) Asia-Pacific.

² Doctoral candidate, Deakin University, Melbourne.

³ Director, Statewide Forensic Medical Services, Royal Hobart Hospital, Tasmania.

⁴ Senior specialist for the Hyperbaric Service, The Alfred Hospital, Melbourne.

⁵ Retired County Court judge and a past dive instructor.

⁶ Researcher, DAN Asia-Pacific.

Address for correspondence:

John Lippmann, OAM

P O Box 384

Ashburton VIC 3147, Australia

Phone: +61-(0)3-9886-9166

Fax: +61-(0)3-9886-9155

E-mail: <johnl@danasiapacific.org>