Provisional report on diving-related fatalities in Australian waters in 2012

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Abstract
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Introduction: An individual case review of known diving-related deaths that occurred in Australia in 2012 was conducted.
Method: The case studies were compiled using statements from witnesses and reports of 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: There were 26 reported fatalities (four less than the previous year). Only two of the victims were female (one snorkeller and one scuba diver). Fourteen deaths occurred while snorkelling and/or breath-hold diving, 11 while scuba diving and one diver died while using surface supplied breathing apparatus in a commercial pearl diving setting. Two breath-hold divers likely drowned as a result of apnoeic hypoxia. Cardiac-related issues were thought to have contributed to the deaths of at least three and possibly seven snorkellers and four scuba divers.
Conclusions: Pre-existing medical conditions; poor organisation, planning and supervision; equipment-related problems; snorkelling or diving alone or with loose buddy oversight and apnoeic hypoxia were features in several deaths in this series.

Introduction

Each year deaths occur during scuba diving and snorkelling. Analysis of diving-related fatalities indicates that many might have been avoided through appropriate countermeasures. The aims of the DAN Dive Fatality Reporting Project are to:

- educate divers and the diving industry about good, safe diving and snorkelling practices;
- inform 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 2012 that are recorded on the DAN Asia-Pacific (AP) database. When an accident is unwitnessed, it is difficult to determine accurately what had occurred. We have sometimes included considered speculation within the comments to provoke thought about the possible sequence of events. A summary of the possible sequence of events in each of these incidents is shown in Table 3 as part of the discussion.

Methods

Ethics approvals were received from the Victorian Department of Justice Human Research Ethics Committee (to access data from the Australian National Coronial Information System (NCIS)); the Royal Prince Alfred Hospital Human Research Ethics Committee; the Coronial Ethics Committee of the Coroner's Court of Western Australia; and the Queensland Office of the State Coroner. The methodology used for this report was identical to that described previously for the 2004 Australian diving-related fatalities.[1]

Breath-hold and snorkelling fatalities (Table 1)

There were 14 snorkelling deaths recorded, the majority (nine) occurring in the State of Queensland on the Great Barrier Reef (GBR) or associated islands.

BH 12/01

This 64-year-old (y.o.) male was an overseas tourist who was on a day trip to an island on the GBR. He had a history of stage 1 myeloma for which he was being monitored with six-monthly blood tests but not yet receiving treatment. He was taking diclofenac and omeprazole. He was reported to have been a capable swimmer who had dived and snorkelled several times before.

He was using his own mask and snorkel and hired a lycra suit. Although he was wearing bootees, it was uncertain if he had been wearing fins. The weather was sunny with a light wind and the water was calm and clear. He went to an

Table 1

Summary of snorkelling and breath-hold diving-related fatalities in Australian waters in 2012; BMI – body mass index; BNS – buddy not separated; BSB – buddy separated before incident; BSD – buddy separated during the incident; GNS – group not separated; GSB – group separated before incident; IPE – immersion pulmonary oedema; n/s – not stated

BH	Age (y)	Sex	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)	Training	Experience	Dive group	Dive purpose	Depth (msw)	Incident (msw)	Weights On	Weights kg	Disabling injury
12/01	64	M	178	74	23	n/s	Yes	Solo	Recreation	n/s	Surface	n/s	-	Asphyxia? IPE?
12/02	82	M	172	82	28	n/s	n/s	Solo? GSB?	Recreation	n/s	Surface	n/s	-	Cardiac?
12/03	37	M	175	79	26	n/s	n/s	GNS	Recreation	n/s	Surface	n/s	-	Asphyxia?
12/04	62	M	173	85	28	n/s	Yes	GSB	Recreation	n/s	Surface	n/s	-	Cardiac
12/05	68	M	175	101	33	n/s	n/s	GNS	Recreation	n/s	Surface	n/s	-	Cardiac
12/06	26	M	185	60	18	Yes	Yes	GSB	Spearfishing	10–20	n/s	n/s	-	Asphyxia
12/07	70	F	158	64	26	n/s	n/s	BSB	Recreation	n/s	Surface	n/s	-	Asphyxia
12/08	71	M	180			n/s	Yes	BSD	Recreation	n/s	Surface	n/s	-	Unknown
12/09	31	M	190	79	22	Yes	Yes	Solo	Spearfishing	20–25	During ascent	Yes	4	Asphyxia
12/10	64	M	175	104	34	n/s	n/s	Solo	Recreation	n/s	Surface	n/s	-	Asphyxia? cardiac?
12/11	45	M	178	88	27	n/s	nil	GSB	Recreation	n/s	Surface	n/s	-	Asphyxia
12/12	68	M	176	75	24	n/s	Yes	Solo	Recreation	n/s	Surface	n/s	-	Cardiac
12/13	27	M	174	74	24	Yes	Yes	GSB	Spearfishing	15	n/s	Yes	9.5	Asphyxia
12/14	38	M	170	70	24	n/s	n/s	Solo	Hunting abalone	0.5–4	Surface	rescuer off	12	Asphyxia

unsupervised area and snorkelled there alone. Approximately 45 minutes (min) later, he was seen to be floating motionless with his snorkel submerged and only his shoulder blades visible. A lifesaver and an assistant dragged him onto a paddle board, and took him to a nearby vessel. Basic life support (BLS) was commenced by another lifesaver approximately 10 min after he was first seen. After another 5–10 min an automated electrical defibrillator (AED) was attached and repeatedly indicated that no shock was advised. Supplementary oxygen was provided (method unreported). The lifeguard unsuccessfully attempted to insert a supraglottic airway (i-gel). Two doctors (tourists) became involved in resuscitation efforts and implemented advanced life support (ALS). The victim failed to respond and resuscitation was ceased after an hour. One doctor reported that the victim was very cold when she initially assessed him and estimated that he might have been dead for possibly 30 min when found.

Autopsy: (1 day post mortem). The heart weighed 408 g (normal range (n.r.) 295–445 g). There was some concentric left ventricular thickening, redundancy of the mitral valve and 50% narrowing of the coronary arteries. There was frothy fluid in the upper airways, the right and left lungs weighing 926 g (n.r. 410–892 g) and 884 g (n.r. 378–780g), respectively and oedematous. Myeloma was detected in the bone marrow. The cause of death was given as drowning but the possibility of a precursor event related to heart disease or myeloma could not be excluded.

Comments: What caused the victim to become unconscious is unknown. He had mild left ventricular hypertrophy, mild mitral incompetence and a 50% stenosis of the coronary arteries. Generally none of these factors in isolation would be severe enough to cause loss of consciousness. His decision to snorkel alone in an unpatrolled area likely led to a substantial delay in the recognition of a problem and the subsequent rescue. Despite prompt and appropriate post-rescue BLS and ALS, death was likely inevitable because of this delay. An alternate interpretation of the fluid-laden lungs at autopsy could be immersion pulmonary oedema (IPE).

Summary: 64 y.o. male; history of stage 1 myeloma and back pain; capable swimmer; had snorkelled several times before and earlier that day; snorkelling alone; found unconscious in water after probably long delay; AED attached (long delay) but no shock advised; drowning

BH 12/2

This 82 y.o. man was an overseas tourist who was on a day trip to the GBR on a large tourist vessel. He had a history of hypertension, hypercholesterolaemia, stroke and coronary atherosclerosis. His wife reported that he had "*heart surgery twice … with five stents inserted over the past five years*". His prescribed medications included fexofenadine, lisinopril, ezetimibe, simvastatin and sildenafil. He was reported to have been a strong swimmer but his snorkelling experience is unknown. The pre-dive briefing included warnings about the risks of snorkelling with certain medical conditions, including cardiac conditions. Participants were asked to declare any medical conditions but he failed to do so. He had slept well, was in a good mood and appeared confident about snorkelling on the reef.

On arrival at the pontoon, he took a mask and snorkel (it is unclear if he wore fins). He was advised to take a stinger suit and buoyancy aid, such as a lifejacket or 'noodle'. However, he refused. One witness reported that he sounded drunk. The weather was clear with a light wind, the water was calm with a low swell and the current was variously reported to be slight (by staff) to strong (by passengers). The victim entered the water wearing a t-shirt and shorts and his snorkelling gear and was initially observed to be swimming well. However, he soon appeared to be distressed and then motionless, face-down in the water with the end of his snorkel submerged. Another snorkeller went to his aid, found him to be unconscious, and alerted a lifeguard. His mask and snorkel were still in place. With the aid of another snorkeller, he lifted the victim's head out of the water and noted white frothy sputum oozing from his mouth. He was taken by tender to the pontoon, where BLS was commenced by lifeguards and continued for 40 min. It is likely that a defibrillator was attached at some point as the presence of electrode pads were noted at autopsy. However, there were no details about when this occurred and what was indicated.

Autopsy: (1 day post mortem) Examination of the brain revealed an old infarct in the left temporal lobe. X-ray of the chest showed no significant pathology. The heart was heavy, 565 g (n.r. 331–469 g). The coronary arteries showed 80% calcific stenosis of the right and circumflex coronary arteries and near occlusion of a stent in the left coronary artery. There was biventricular hypertrophy. Histological evidence was seen of scarring but not of acute ischaemia. The upper airways contained gastric contents. The right and left lungs weighed 860 g (n.r. 446–880 g) and 782 g (n.r. 348–790 g), respectively, and were oedematous. The cause of death was given as drowning secondary to arrhythmia due to ischaemic heart disease.
Toxicology: Alprozolam < 0.01 $mg \cdot kg^{-1}$; tramadol 0.04 $mg \cdot kg^{-1}$ (therapeutic)

Comments: This elderly man with a history of significant cardiovascular disease had been assessed as medically fit four months earlier although it is not clear what this assessment was for. His failure to declare his conditions to the operator resulted in a lower level of surveillance and support, although this might not have changed the outcome as the other snorkellers appeared to have recognised the problem promptly and reacted appropriately and swiftly. He was obviously overconfident about his capabilities and health and determined to snorkel. The staff repeatedly offered him a buoyancy aid but it is unclear whether this would have prevented what was likely an arrhythmia precipitated by the combination of severe cardiac disease, immersion and exertion.

The authors are not aware of studies of the physiological effects of immersion of elderly individuals taking cardioactive medications. This individual was taking a potent pulmonary vasodilator as well as medication with the potential to alter his renal response to immersion. The effects of such combinations on an individual with impaired cardiovascular reserve secondary to ischaemic heart disease may well have resulted in the sudden onset of an arrhythmia or possibly IPE.

Summary: 82 y.o. male; history of hypertension, hypercholesterolaemia, stroke and coronary atherosclerosis; capable swimmer but snorkelling ability unknown; failed to declare medical conditions; refused buoyancy aids; became unconscious in water; drowning (likely cardiac-related)

BH 12/03

This 37 y.o. male was an overseas visitor with a history of hypercholesterolaemia (medications unreported) and of several episodes of post-exercise hypotension. There was a family history of hypertrophic cardiomyopathy in three of his uncles with a known genetic mutation (MYPBC3 c.1073delC). However, a resting ECG and exercise test done eight months prior to the incident were normal. His swimming ability and snorkelling experience were unknown. He was among a group of nine conference delegates who went snorkelling from the beach of a small offshore island as part of an organised kayak tour. The weather was clear with a moderate wind and there was a surface chop. No information was available about the current. The victim was wearing mask, snorkel, fins and board shorts. He was not using a buoyancy aid.

Sometime later, the victim waved his arm indicating that he was in distress. The tour operator went to his assistance and he was loaded onto a nearby dive boat, unconscious and apnoeic. The boat transferred him to the local water police office (possibly a 10-min trip). Police boarded the vessel and began BLS. Supplementary oxygen was provided (method unknown). Paramedics arrived 20 min later and implemented ALS. The victim was initially found to be in ventricular fibrillation (VF) and so was defibrillated. However, this reverted to asystole and then pulseless electrical activity (PEA) before spontaneous circulation returned. The victim was transported to hospital but died six hours post incident.

Autopsy: (1 day post mortem) There was bruising of the tongue. The heart weighed 354 g (n.r. 331–469 g) and appeared normal. The free wall of the left ventricle was 10 mm and the inter-ventricular septum was 11 mm. The ratio of septal to left ventricular posterior wall thickness was 1.1 (in hypertrophic cardiomyopathy this ratio is greater than 1.4).[2] There was a 50% stenosis of the first diagonal artery of the left anterior descending (LAD) coronary artery. Histologically, there were occasional microscopic foci of myocardial fibre disarray of uncertain significance. The right and left lungs weighed 1014 g (n.r. 446–880 g) and 826 g (n.r. 348–790 g), respectively, and were heavy with haemorrhagic oedema and early aspiration pneumonia. Ante-mortem serum osmolarity was high, 331 $mmol \cdot L^{-1}$ (n.r. 275–295). The cause of death was given as aspiration pneumonia and multi-organ ischaemia secondary to a cardiac arrhythmia (ventricular fibrillation), diagnosed clinically.

Comments: This case strongly suggests some form of cardiac arrhythmia but the exact underlying cause is not clear. While it would be interesting to know whether he had the MYPBC3 c.1073delC mutation, the absence of asymmetric hypertrophy would tend to exclude this as a contributor. A 50% stenosis of a coronary artery would not be regarded generally as sufficient as a cause of sudden death (> 75% stenosis is usually required[3]) although isolated cases during exercise are seen occasionally. The high osmolarity suggests possible aspiration of salt water but could also reflect treatment to reduce cerebral oedema.

Summary: 37 y.o. male; history of hypercholesterolaemia and post-exercise hypotension. Swimming and snorkelling abilities unknown; snorkelling under supervision; indicated distress and became unconscious in water; aspiration pneumonia and multi-organ failure post-drowning

BH 12/04

This victim was a 62 y.o. male interstate tourist who was previously a heavy drinker and smoker. He had suffered a myocardial infarction (MI) five years earlier and had insulin-dependent diabetes, requiring four injections per day. He also was taking diltiazem, ezetimibe, atorvastatin and aspirin. He was a strong swimmer with extensive snorkelling experience, albeit not for the past three years. He and three family members were on a day trip to an island on the GBR. After arrival, the group did a moderately strenuous walk across the island to a beach. On three occasions, the victim had to rest for five minutes after becoming dyspnoeic. Once at the beach, the victim and others had lunch before setting out snorkelling.

The sea was calm with a slight current and a water temperature of 29°C. The victim was wearing a hired mask, snorkel and fins. He snorkelled for a short time before resting on the beach for over two hours. He did not take his scheduled insulin. He and his daughter then decided to snorkel, with the aid of the current, back towards the jetty. The daughter initially swam about 10 m ahead and after a short distance, on reaching shallow water, she stood and saw the victim sitting on a rock. When she asked if he was "*OK*", he answered affirmatively. He began to snorkel towards her but she was soon unable to see him as he was obscured by a large rock. When he failed to appear beyond the rock, she raised the alarm. A search involving several vessels was soon commenced and, after 45 min, the victim was found about 10 m from where he was last seen. He was partly submerged face-down in 30 cm of water between some rocks. His mask, snorkel and fins were in the water

nearby. He was unconscious, apnoeic and cyanotic. BLS was initiated by a crew member of a dive vessel. Supplementary oxygen was provided (method unknown). BLS was continued until a doctor arriving by rescue helicopter advised that resuscitation efforts be ceased. When the snorkelling equipment was examined, no significant issues were found.

Autopsy: (2 days post mortem) The heart was enlarged, weighing 663 g (n.r. 331–461 g) and with scarring and thinning of the apex of the left ventricle. The coronary arteries showed severe calcified atherosclerosis. The right and left lungs weighed 796 g (n.r. 446–880 g) and 573 g (n.r. 348–790 g), respectively, and were mildly oedematous. The cause of death was given as cardiac arrhythmia due to ischaemic heart disease.

Comments: With his history of MI and diabetes and substantial breathlessness on exertion, it is unsurprising that this man encountered difficulties when snorkelling. The effects of immersion and exertion (exacerbated by probable hyperglycaemia) likely combined to cause an arrhythmia and subsequent unconsciousness in the water.

Summary: 62 y.o. male; known history of healed MI and insulin-dependent diabetes; strong swimmer and experienced snorkeller; dyspnoeic during walk to site; missed scheduled insulin injection; separation from buddy; cardiac event

BH 12/05

This 68 y.o. male overseas tourist was visiting the GBR on a cruise. Together with over 200 others, he joined a tour with a snorkel operator to a pontoon on the reef. He was obese (BMI 33 $kg \cdot m^{-2}$) with a history of an MI 17 years earlier. He was taking glyceryl trinitrate and salbutamol. On the morning of the incident he had "*taken antacid for an upset stomach*". He was described as a competent swimmer but there was no indication of snorkelling experience. Although all participants were asked to complete a medical questionnaire, it appears that he had not done so. The sea was smooth and visibility was good but there was a strong current, estimated to be 4–5 $km \cdot hr^{-1}$. One witness noted that some snorkellers were being swept away in the current and needed to be towed back to the pontoon.

The victim was wearing his own mask and snorkel but had hired fins and a stinger suit, and did not take a floatation aid. He was in the water with about 30 others when he was seen 25–30 m distant from the pontoon and signalling that he was in difficulty. A staff member in a tender went to him and he grabbed a rope attached to the tender. When asked if he was okay he did not answer but declined boarding the tender. He held the rope and was towed to the pontoon but became unresponsive. The staff reported that his head did not submerge and his fingers had to be pried from the rope when he was dragged onto the pontoon. Frothy sputum exuded from his mouth. BLS was commenced by staff with the help of two doctors (tourists). An AED was used but no details were provided. Adrenaline was administered but the victim failed to respond and resuscitation was ceased after about 25 min.

Autopsy: (3 days post mortem) The heart was enlarged and weighed 505 g (n.r. 331–469 g). There was aneurysmal scarring of the apex and anterior wall of the left ventricle due to an old infarct. There was occlusion of the LAD coronary artery and severe calcified atherosclerosis of the right and circumflex coronary arteries. The upper airways contained no fluid. The right and left lungs weighed 845 g (n.r. 446–880 g) and 845 g (n.r. 348–790 g), respectively, and were moderately oedematous. The cause of death was given as left ventricular failure. The reviewers believe the cause of death would be more aptly described as cardiac arrhythmia due to ischaemic heart disease.

Comments: In light of this man's very significant cardiac conditions, he was highly predisposed to an exertion-related cardiac event, whether aquatic or terrestrial. It appears that he failed to declare his medical condition to the operator who stated that had he done so he would have been classified as 'high risk' and been supervised more closely. (At least one other passenger had declared a previous MI and was permitted to snorkel). However, it is unlikely that this would have made a difference as his rescue was prompt and apparently appropriate. The operator's wisdom in permitting snorkellers of varying health and abilities to snorkel in such a strong current is questionable.

Summary: 68 y.o. male; history of previous MI and current angina; competent swimmer but unknown snorkelling experience; strong current; signalled for help and became unconscious while being towed to pontoon; AED used (no details); cardiac-related

BH 12/06

This 26 y.o. male had a history of idiopathic epilepsy, with four seizures over the previous three years. He was poorly compliant with his prescribed medication (Valproic acid) and two of the seizures were associated with recent marijuana use. He was otherwise well, a strong swimmer and experienced snorkeller who owned his own equipment.

He and nine others went snorkelling and spearfishing from some rocks at a headland. The weather was clear and warm (28°C) and the water was choppy with a 1 m swell. There was little current, the visibility was 5 m and water temperature 24°C. The depth of the site varied between about 10–20 metres' sea water (msw). One of the group stayed on the rocks while the others snorkelled. The victim was wearing mask, snorkel, fins with bootees, gloves and board shorts. He was the only one not wearing a wetsuit and was warned that he would be cold. One of his fin straps broke prior to entry and was subsequently secured with a wire.

The group snorkelled separately close to the edge of the rocks in what was described as a "*radius of 30 m of each other*". The victim was last seen swimming towards the rocks after about 10 min. When one of the group returned to the rocks after about 40 min and noticed the victim's towel untouched, he became concerned as he had expected him to be the first out from getting cold. The emergency services were contacted and an air and sea search was conducted, followed by underwater searches over the next two days. The victim's body was found floating 200 m offshore three days after he was last seen. He was still wearing his shorts, gloves and one boot but the rest of his gear was missing.

Autopsy: (4 days post mortem) There were early decompositional changes (the body not recovered for three days). The brain was heavy 1618 g (n.r. < 1,500 g) and mildly oedematous but showed, only decompositional change. "*There was a defect on the left posterior aspect of the tongue which could be consistent with decomposition,*"(sic). The heart was normal and weighed 348 g (n.r. 331–469 g). The coronary arteries were patent. The upper airways contained pulmonary oedema and decompositional fluid. The right and left lungs weighed 846 g (n.r. 410–892 g) and 719 g (n.r. 378–780 g), respectively, with 500 ml of fluid in the left pleural cavity and 350 ml of fluid in the right pleural cavity (in early decomposition in salt water drowning fluid can move from the lungs to the pleural cavity).[4] The cause of death was given as drowning *Toxicology*: Alcohol 0.068 g·100 mL^{-1}; Delta–9-THC acid 0.031 $mg \cdot L^{-1}$; paracetamol 3 $mg \cdot L^{-1}$; valproic acid < 10 $mg \cdot L^{-1}$ (sub-therapeutic)

Comments: The victim might have drowned as a result of becoming debilitated by the cold. Apnoeic hypoxia was another possibility as was an epileptic seizure. No specific bruising of the tongue was described but it is unclear to the reviewers whether this defect could be evidence of seizure activity. While the anticonvulsive was noted to be sub-therapeutic, this was not thought to be significant by the coroner. Snorkelling may involve a variety of factors that can reduce the seizure threshold. These include stress, exercise, sensory deprivation, hypercapnia, hyperventilation and hypothermia. This individual was poorly compliant with his medication and had recently taken marijuana, which had been associated with some of his seizures. He would have also been cold while snorkelling. The combination of these factors while snorkelling may have precipitated a seizure. The toxicology is hard to interpret. Alcohol can lower the seizure threshold but some or all of the alcohol detected could be due to decomposition. Metabolites of cannabis were detected but no parent compound, which indicates past exposure but not proximate use.

Summary: 26 y.o. male; history of epilepsy; strong and experienced snorkeller; not wearing wetsuit in relatively cool water; snorkelling with others but with no buddy system; body found three days later; drowning (Epilepsy? Apnoeic hypoxia? Hypothermia?)

BH 12/07

This 70 y.o. woman was an overseas tourist holidaying on the north-west coast of Australia. She had a history of hypothyroidism for which she was prescribed thyroxine. Her last medical consultation was one month prior to her trip and she was reported to have been in good health. There was no information about her swimming or snorkelling ability or experience.

She had snorkelled for an hour without incident in the morning. After lunch and a rest, she and her husband entered the water from a sandy beach surrounded by coral reef. The sea was calm and she wore a mask and snorkel but no fins and was not using a flotation device. They separated on entry as the husband was taking photos. After eight minutes, he snorkelled towards shore and then looked for his wife. He could see her approximately 30 m from shore and called to a person on a nearby boat and asked if she would check his wife. This person noticed that the victim was floating face-down but only moving with the water action. She donned her snorkelling gear, took a flotation aid and swam to the victim. She found her to be unconscious with her head submerged, her mask in place but full of blood and water, and with the snorkel out of her mouth. Blood-stained frothy sputum was visible in the victim's mouth. The rescuer also noticed blood in the water all around the victim. She removed the victim's mask and supported her with the float. She then tried unsuccessfully to detect breathing and a pulse before attempting in-water CPR, but soon abandoned this. With the aid of another rescuer, the victim was towed to shore, which took 2–3 min.

BLS was commenced using a resuscitation mask as a barrier. The victim was rolled onto her side several times to clear blood-stained frothy sputum from her mouth. The ambulance was called some 10–12 min from the time the victim was first sighted and arrived 13 min later. Supplementary oxygen was provided using a manually-triggered resuscitator (MTR) and an AED was attached but no shock advised. She was taken to the nursing post, where her airway was suctioned and an oropharyngeal airway inserted. A defibrillator was attached and indicated asystole, so BLS continued with ventilations given via a bag-valve-mask (BVM) resuscitator. However, a short time later, although the monitor of the defibrillator indicated asystole, it advised that a shock be given, which was done without effect. Resuscitation efforts were ceased after a total of 50 min.

Autopsy: (3 days post mortem) No blood was described on the face at autopsy. The heart was normal and weighed 316 g (n.r. 285–439 g), with mild coronary atherosclerosis. The upper airway was clear, the right and left lungs weighing 680 g (n.r. 305–817 g) and 638 g (n.r. 287–695 g), respectively and with marked pulmonary oedema. Subsequent histology of the lung showed early bronchopneumonia. The cause of death was given as "*consistent with drowning*".

Comments: In the absence of reports about her snorkelling ability and the depth of the water in which she was found, it is unclear why she apparently drowned. What happened to the victim and if she showed any indications of distress before becoming unconscious is unknown. The presence of blood in the mask and in the water around the body is unexplained but could have been secondary to pulmonary oedema.

Summary: 70 y.o. female; history of hypothyroidism controlled by thyroxine; entered water with buddy but separated as buddy pre-occupied with taking photographs; found unconscious; one belated shock with AED; drowning

BH 12/08

A 71 y.o. male, overseas tourist and his wife were among a group of 63 passengers on a large commercial snorkelling/diving vessel on a day-trip to the GBR. He was apparently well and, other than gout and passing a kidney stone three months earlier, had no significant medical history. He was taking unknown medication for nephrolithiasis and gout. He was described as 180 cm tall and of a "*solid build*". On his pre-snorkel declaration, he stated that he was an average swimmer (although he swam daily), but an experienced snorkeller. He owned a yacht and he and his wife sailed regularly.

As part of the pre-snorkel brief, passengers were advised to raise their hand if in need of assistance. The vessel moored about 30 m from the top of the reef and a 'mermaid line' was trailing from the stern to the reef. There was a permanent snorkelling rest station about 20–30 m from the stern. The weather was clear with a gentle to moderate breeze (20–30 km·hr^{-1}). The water was warm (27°C) and choppy, visibility varied from 8–15 m, and there was a strong current. The maximum depth at the site was 20 msw.

The victim and his wife donned masks, snorkels, fins and stinger suits and entered the water. After about 15 min the husband noticed that they had been swept away from the boat and they started to swim back towards it but were unable to make much headway owing to the current. The wife reached the rest station and raised her hand to indicate that she needed assistance. She saw the victim, who was 4–5 m away also raise his hand, before submerging in what she thought was a duck-dive. However, he surfaced and made a "*loud screaming sound*". She then lost sight of him. The wife waited at the rest station for the next 15 min, raising her hand periodically to attract attention. She was distressed and exhausted. There were 20–30 snorkellers in the water and the lookout repeatedly failed to recognise that the victim's wife needed help. The staff only responded after another passenger swam to the wife and returned to the boat to raise the alarm. After another 10–15 min, the crew commenced a surface and underwater search. The emergency services were alerted and a rescue helicopter arrived 50 min later followed several hours later by the water police. The search continued for five days but no sign of the victim was ever found.

Autopsy: Body not recovered.

Comments: In the absence of an autopsy, one can only speculate on what might have occurred based on witness statements. An autopsy provides a lot of information about an older individual, especially in regard to pre-existing medical conditions and injuries. It is probable that the victim was tired from swimming against the current and may have become incapacitated, possibly aspirating some water. Despite the absence of any supporting evidence, it is remotely possible that he was taken by a shark.

The delay in recognising the wife's distress raises substantial concerns about the training and effectiveness of the lookout system. The lookout later opined that, despite the passengers being briefed to raise their hand if needing help, a person in distress would be splashing around and not just raising a hand. This is not necessarily the case and indicates the lack of insight of the lookout. With 20–30 snorkellers to observe (as well as some scuba divers), it can be difficult for a lookout to recognise a problem, especially if they are relatively inexperienced. There is a need to ensure that there are sufficient lookouts, that they are adequately trained in appropriate observation techniques and that they are relieved after relatively short intervals to avoid fatigue or complacency.

Summary: 71 y.o. male; history of gout and nephrolithiasis; otherwise apparently well; average swimmer and experienced and regular snorkeller; strong current; fatigue; submerged, surfaced and made loud scream before vanishing; body not recovered; medical problem?/drowning?

BH 12/09

This 31 y.o. male was a strong swimmer, an experienced spearfisherman and a certified free-diving instructor. No information was provided about his fitness or medical history. He and three friends were spearfishing from a 5.5 m rigid inflatable boat which was anchored by a rocky reef with a maximum depth of around 25 msw. The weather was clear with a light breeze, the surface was calm, albeit with a 2m+ swell, little current and good visibility (15–20 m). He was wearing a mask, snorkel, fins, boots, gloves; a wetsuit with attached hood; a weight belt with 4 kg of weights; a knife and was carrying a speargun.

The group performed about 10 dives up to 25 msw before deciding to move to another site. However, the victim decided to do one more dive, which he did while the others boarded the boat. When he failed to appear after several min, the group became concerned and called for the assistance of some scuba divers in a nearby boat. The divers entered the water and found the victim's speargun, but some aborted the dive after seeing a large shark. Two divers who persisted found the victim lying in kelp (not entangled) at a depth of 24 msw. He was unconscious with blood flowing from his mouth. His weight belt was still in place. While the

divers brought him to the surface, one purged her 'octopus' regulator into his mouth in an attempt to ventilate him.

He was dragged aboard the boat approximately 35 min after he was last seen and BLS was commenced. The victim was rolled onto his side regularly to drain blood-stained sputum and water from his airway. Initially his weight belt had not been removed and stomach inflation was visible. Rescue breaths were supplemented with oxygen via a resuscitation mask with a flowrate of 15 $L \cdot min^{-1}$. When the boat reached land, some 100 min after the victim was recovered, paramedics were waiting and continued resuscitation for 15 min before efforts were ceased.

Autopsy: (4 days post mortem) Post-mortem CT scan showed extensive intra-vascular gas throughout the arterial and venous systemic and pulmonary venous system, large amount of gas filling the left side of the heart but with a relatively small amount of gas present within the right ventricle. The heart appeared to be structurally normal. There was fluid filling the central airways and diffuse, patchy centrilobular airspace changes were present throughout both lungs with some predominantly basal interlobular septal thickening. Only an external examination was performed, which showed petechiae around the eyes and on the conjunctiva and froth in the mouth possibly suggesting drowning. The cause of death was given as "*undetermined*".

Comments: This man should have had a full autopsy to establish the cause of death, especially given the gas seen on CT scan and the undetermined cause of death. The observed gas could have been due to resuscitation artefact from vigorous BLS. It is also possible that the rescuer's purging of her 'octopus' regulator into the victim's mouth during ascent caused some barotrauma and subsequent gas distribution. Although there was no report about his medical history, it is likely that his wife would have mentioned if he had a significant condition such as epilepsy. It is unknown whether or not he practiced hyperventilation – this is a question that investigators should routinely ask companions in such situations. It seems likely that the victim suffered apnoeic hypoxia during ascent as a result of extended breath-holding, with or without hyperventilation, and then sank to the bottom (evidenced by signs of facial barotrauma).

Summary: 31 y.o. male; medical history unknown; strong swimmer and trained and experienced breath-hold diver; deep breath-hold dives (24 msw); did last dive alone; recovered after delay; likely drowning post apnoeic hypoxia

BH 12/10

This 64 y.o. male was obese (BMI 34 $kg \cdot m^{-2}$) and had a history of hypercholesterolaemia and arthritis, but it is unknown what medications he was taking. There was no report of his swimming ability or snorkelling experience. He was an interstate tourist who went snorkelling with family members in a thermal pool, wearing swimming goggles and a snorkel but no fins. After entering the water, he swam upstream for a short time before turning back. He then appeared to have difficulty swimming, began to thrash around in the water and called for help. When rescuers reached him, he was unconscious, apnoeic and became cyanotic. One rescuer attempted to give in-water rescue breaths, but had difficulty due to lack of buoyancy. However, a short time later, the victim began to breathe spontaneously. A rope was tied around his chest and he was towed, floating on his back, across the pool but again became apnoeic and cyanotic. The rescuers hauled the victim onto a platform and began BLS. After a short time, nurses from a nearby clinic arrived, suctioned the victim's airway and attached an AED. No shock was advised on three occasions. Resuscitation was ceased after a total time of around 35 min.

Autopsy: (1 day post mortem) The heart weighed 430 g (n.r. 331–469 g) and was reported as enlarged. The left ventricle showed mild left ventricular hypertrophy and measured 15 mm (n.r. ≤ 14 mm). The coronary arteries showed moderate (50% narrowing) atherosclerosis. The trachea and bronchi contained a small amount of white frothy fluid. The right and left lungs weighed 460 g (n.r. 446–880 g) and 540 g (n.r. 348–790 g) respectively, and were congested, although pulmonary oedema was not described. The cause of death was given as undetermined but the possibility of a sudden cardiac event was raised.

Comments: On the basis of the available information, it is unclear what precipitated the eventual drowning in this victim. However, he had no fins, lacked buoyancy support and was wearing swimming goggles which do not isolate the nose so there was ample potential for aspiration and primary drowning.

Summary: 64 y.o. male; history of hypercholesterolaemia and arthritis; swimming ability and snorkelling experience unknown; snorkelling in thermal spring; became distressed and called for help; in-water rescue breathing attempted unsuccessfully; AED attached (probable 15–20 min delay) but no shock advised; drowning (cardiac-related?)

BH 12/11

This 45 y.o. male was an overseas tourist on a day trip to the GBR aboard a large tourist vessel. He had no medical history and was on no regular medication, although he took one sea-sickness tablet (diphenhydramine) before boarding. He was a non-swimmer and had not snorkelled before. He spoke little English but attended a multi-lingual pre-snorkel/dive briefing which included his native language. He had enrolled in a Discover Scuba Dive.

Once at the pontoon, the victim wearing shorts, a mask and snorkel (it is unknown if he wore fins) and a life-jacket decided to go snorkelling before his scuba dive. The weather

was clear, the water calm and visibility good. There was a slight current. He began to snorkel in a roped area in front of the pontoon, along with 10 snorkellers and with a lookout on duty. After about 15–30 min a lookout noticed a floating object about 120 m distant. When a tender reached the object, the driver found that it was the victim, floating unconscious with his face submerged. When lifted from the water and his mask and snorkel removed, white, frothy sputum was seen coming from his mouth. He was apnoeic and cyanotic and the driver tried to perform chest compressions as he drove the tender to the pontoon.

On the pontoon, BLS was commenced by staff who were assisted by an off-duty nurse and paramedic. It is unknown how long the victim had been unconscious before being seen, but the time from reaching the victim until commencement of BLS was approximately 5 min. The victim had to be rolled on his side to drain stomach contents from his mouth. The rescuers attempted unsuccessfully to insert a supraglottic airway (i-gel) and the victim 'vomited' so suction was used. Supplementary oxygen was provided via a BVM and an AED was attached some 10 min after BLS began. It advised no shock be given, but two shocks were given later without an apparent return of circulation. A rescue helicopter with paramedics aboard arrived about 80 min after the rescue, implemented ALS and transported the victim to hospital. No ambulance report is available so it is unknown whether spontaneous circulation was re-established, but it is reported that he died the next day. A head CT showed a subarachnoid haemorrhage and cerebral oedema.

A subsequent investigation by the local workplace authority resulted in the issuance of two improvement notices, which were: (1) "*To include in the snorkel briefing if passengers cannot swim to advise crew members of the situation*"; and (2) "*To review current snorkelling area to a distance that makes supervision of the area better.*"

Autopsy: (1 day post mortem) Post-mortem examination consisted of external examination, CT scan and toxicology, but no internal examination. The CT scan (on the day of death) confirmed subarachnoid haemorrhage and cerebral oedema. External examination showed superficial abrasions on the back, but was otherwise unremarkable. The cause of death was given as drowning post subarachnoid haemorrhage.
Toxicology: Diphenhydramine 0.04 $mg \cdot kg^{-1}$ (therapeutic).

Comments: Such a large, regular operator should have had processes in place to readily identify a non-swimmer so that suitable supervision is provided, enabling a prompt rescue in the event of an incident. With only 10 snorkellers in the water at the time, the lookout should have more promptly recognised that the snorkeller was in trouble. An important consideration for snorkelling operators to consider is the size of the area under watch and the number of lookouts required to properly scrutinise a large area, especially if there are many snorkellers.

Summary: 45 y.o. male; apparently fit and healthy with no known medical history; non-swimmer; unknown period of unconsciousness in water; 2 shocks with AED; died next day in hospital; Drowning post subarachnoid haemorrhage

BH 12/12

This 68 y.o. male overseas tourist was on a day-trip to snorkel on the GBR on a charter vessel with 32 other passengers. He had been diagnosed with borderline hypertension but was not on medication. He had visited his doctor about two weeks earlier and appeared to be relatively healthy. He was a competent swimmer and had snorkelled on several previous overseas trips.

On the morning of the incident the victim appeared to be well. The conditions were "*fine*" with calm seas, good visibility and a water temperature of 27°C. There was no mention of any current. He and his wife entered the water from the beach of a small coral cay with a guide-led group. He was wearing mask, snorkel and fins and had chosen not to take a life vest. A short time later, after helping his wife with her mask, he seems to have fallen behind the group who were reportedly snorkelling quite quickly. There was one lookout on the beach and another assistant helping guests in the water. It is unclear if there was a lookout on the boat which was moored approximately 50 m from shore. The beach lookout recalled initially noticing the victim snorkelling slowly and making headway. However, possibly 10 min later when she looked again, she noticed that he was stationary and his snorkel was out of his mouth. He was recovered from shallow water (1.2 msw), about 25 m from shore, and brought to the beach. He was apnoeic, cyanotic, his eyes were open and there was froth coming from his mouth.

BLS was initially commenced by the skipper who then stopped and left to fetch an AED and oxygen equipment from the main vessel. It appears that, in his absence, no-one performed any resuscitation as the lookouts were untrained in this. When the skipper returned, possibly 5–10 min later, he attached the AED but no shock was advised. He was soon joined by two passengers who were doctors (one a cardiologist). It appears that supplementary oxygen was provided via a resuscitation mask with oxygen inlet. It was necessary to roll the victim onto his side several times to drain water from his mouth. BLS continued until the arrival of a paramedic on a rescue helicopter. When attached, the cardiac monitor indicated asystole and, given the period of unconsciousness and the appearance of the victim (grey with fixed dilated pupils), resuscitation was ceased.

Autopsy: (2 days post mortem) The heart weighed 432 g (n.r. 295–445 g). There was mild left ventricular hypertrophy of 18 mm (n.r. ≤ 14mm), and right ventricular hypertrophy of 5 mm (n.r. ≤ 4mm). There was moderate coronary atherosclerosis (approximately 50% stenosis) and mild patchy interstitial fibrosis. There was white froth in the

right bronchus. The right and left lungs weighed 723 g (n.r. 410–892 g) and 699 g (n.r. 378–780 g) respectively, and were moderately oedematous and congested. The cause of death was given as drowning with other significant conditions including cardiomegaly and moderate coronary artery disease.

Comments: There was evidence of enough cardiac disease to suggest a possible cardiac-precipitated drowning. The histological evidence of fibrosis in association with left ventricular hypertrophy has been associated with sudden cardiac death and increased incidence of arrhythmias.[5] Despite borderline hypertension, the victim appeared to be healthy, a competent swimmer with some snorkelling experience. He did not appear to have been anxious, the conditions were good and the water was shallow. No-one noticed any indications of distress. However, at least one of the lookouts was inexperienced, another pre-occupied, and the third possibly non-existent, so signs of distress, if any, could have been missed. The outcome may not have been any different had there been an effective lookout and first aid system in place. However, this case again highlights some important considerations for snorkel operators in relation to supervision and first aid provision.

Summary: 68 y.o. male; borderline hypertension (unmedicated); competent swimmer and confident snorkeller; inefficient lookout system; noticed with snorkel displaced; BLS abandoned for extensive period while equipment being retrieved; drowning (cardiac-related)

BH 12/13

This 27 y.o. male, overseas national living in Australia was fit and healthy with no medical history except back pain for which he took herbal medicine. He was a strong swimmer (previously a part-time lifeguard) and an experienced and regular (weekly) breath-hold diver. He had been scuba and breath-hold diving for nine years. He and two friends went spearfishing off a small offshore island with depths up to 20 msw. He had dived there on many occasions, including the previous day. There was a clear sky, no wind, a slight sea and only a weak current; visibility was less than 5 m. He was wearing mask, snorkel, fins, gloves, full length 5 mm wetsuit, weight belt with 9.5 kg of weights, a knife and was carrying a speargun attached to a line and float.

The victim was the last to enter the water and took some time to reach the others. He told them that he had just dived to 15 msw – a personal record. The trio continued snorkelling with the victim swimming about 20 m behind. Before returning to shore, one of the companions looked back and saw the victim's float, presuming that he was diving. At this point it was about 150 m from shore. On reaching shore, one of the companions became concerned that the victim's float had not moved and he was still not visible so he re-entered the water, swam to a nearby boat and asked the driver to take him to the float. On arrival, he pulled in the float with the victim's speargun attached but there was no sign of the victim. The buddy then returned to shore and called the emergency services. Police arrived and a search was commenced. The victim's body was found four days later. He was lying on the bottom at a depth of 15 msw near to where he was last seen. All of his equipment was still in place. It was noted that the quick-release buckle of his weight belt was positioned behind his back, rather than at his front.

Autopsy: (4 days post mortem) The heart weighed 304 g and was normal with right dominant circulation and minimal atherosclerosis apart from myocardial bridging (25 mm long and 5 mm deep) of the LAD artery. Histologically there was no fibrosis. There was no obvious pulmonary oedema in the upper airways. The right and left lungs weighed 947 g (n.r. 410–892 g) and 764 g (n.r. 378–780 g), respectively. They were markedly hyper-inflated and there was 750 ml of red/brown fluid in the left pleural cavity, and 450 ml in the right pleural cavity (common in drowning with a longer post-mortem interval). The cause of death was given as drowning.

Comments: The clinical significance of myocardial bridging is complex and controversial. Bridging is quite common in the LAD artery and is probably only clinically significant if symptomatic, deep and long. It can cause focal proximal atheroma, may cause coronary spasm and is said to be more significant in left-dominant circulations and in cases where there is histological evidence of fibrosis. This bridge at 25 mm long and 5 mm deep was at the boundary between shallow and deep. Given the victim was relatively young with a history of exertional activities, this is unlikely to have been clinically significant. It appears most likely that this victim became unconscious and subsequently drowned as a consequence of apnoeic hypoxia (possibly post hyperventilation).

Summary: 27 y.o. male; fit and healthy with no known medical history; strong swimmer and experienced and regular breath-hold diver; spearfishing; likely intentional separation from buddies; deep breath-hold diving; drowning (probably post apnoeic hypoxia)

BH 12/14

This 38 y.o. male was a slightly-built and apparently healthy foreign national living in Australia. He was reported to have been "*not a strong swimmer*" who had little experience in collecting abalone and little knowledge of Australian coastal conditions. He had driven through the night and set out snorkelling for abalone with three friends at a site with a rocky reef and depths up to 4 msw. There was a one-metre swell, a strong surge and some current. He was wearing a wetsuit (unknown thickness) and a weight belt with four weights (possibly 12 kg), which did not have a quick-release buckle. His snorkel was attached to a three-metre length of garden hose to enable him to dive deeper and "*hold his breath*

for longer". He used an inflated tyre tube as a buoyancy aid which was attached to him by a string. One of his friends told him that he was wearing too much weight but he ignored this. It was not clear if he was wearing fins. After searching for abalone for over two hours he came ashore for a short rest, after which he abandoned the tube and re-entered the water to look for more abalone, apparently standing on submerged rocks. After another two hours, he was heard to call for help before submerging about 30 m from shore.

Two companions located him lying face-up in several metres of water, brought him to the surface after an estimated 4–5 min submersion, and ditched his weight belt. With the aid of others, they dragged him onto rocks where BLS was performed by bystanders and some of the companions. The victim's airway was soiled by white frothy sputum and regurgitated stomach contents. A first responder arrived with an AED about 20 min later. When attached, the AED indicated that no shock was advised. BLS was continued until paramedics arrived about 10 min later. Several shocks were delivered by their defibrillator but the victim remained in asystole and resuscitation was ceased.

Autopsy: (4 days post mortem) The heart weighed 332 g (n.r. 295–445 g) and was normal apart from a focal 50% stenosis at the origin of the LAD coronary artery. There was moderate bloody frothy fluid in the trachea and bronchi. The right and left lungs weighed 940 g (n.r. 410–892 g) and 764 g (n.r. 348–790 g) respectively, and both appeared hyper-expanded with severe pulmonary oedema. The cause of death was given as drowning due to focal coronary atherosclerosis.

Comments: This victim, a relatively poor swimmer and inexperienced snorkeller, was likely exhausted from lack of sleep and several hours of snorkelling. He was overweighted and using totally unsuitable snorkelling equipment which would have caused hypercapnia, possible hypoxia and increased his fatigue and discomfort. It appears likely that he stepped or slipped off submerged rocks on which he was standing and into deeper water. Being overweighted, unable to quickly release his weight belt and without access to his buoyancy aid he submerged and drowned. The pathologist listed moderate focal atherosclerosis of around 50% stenosis as relevant. However, there was no apparent fibrosis and a 50% stenosis is generally not regarded as a cause of sudden cardiac death.

Summary: 38 y.o. male; apparently healthy with no known medical history; weak swimmer; inexperienced snorkeller using snorkel attached to 3 m hose; overweighted; likely slipped off submerged rocks into deeper water; AED attached (20 min) but no shock advised; drowning

Scuba diving fatalities

There were 11 recreational scuba deaths and one occupational, surface supplied death, distributed across most of Australia, with the most (four) in the State of New South Wales (Table 2).

SC 12/01

This 55 y.o. male appeared to be relatively fit and active and his work required strenuous manual labour. However, his medical history included essential tremor (propranolol, insertion of deep brain stimulator); depression (mirtazapine, fluoxetine, citalopram) and sleep apnoea (CPAP). Two months earlier he had fallen and sustained a head injury (no abnormality on head CT) and dislocated shoulder. He smoked 15 cigarettes a day. He certified as an Open Water Diver (OWD) seven years earlier, at which time he had a diving medical assessment. It is unknown if the doctor had any training in diving medicine. He had done approximately 200 dives, although none for nine months prior to the day of the incident.

The victim, his son and a friend set out in the son's small boat to dive for crayfish at a familiar site - an offshore island with undulating reef covered in kelp with a depth of 10–12 msw. The sea was calm with a slight current, the water temperature was 23°C and visibility was 20 m. He was wearing a mask, snorkel and fins; a BCD with 4.9 kg of integrated weights; a scuba unit with an 11.5 L steel cylinder; full 3 mm wetsuit with gloves and boots; a dive computer and he was carrying a 'Shark Shield', crayfish loop and catch bag. The first dive of the day was uneventful, with a maximum depth of 11 msw for 38 min. After some lunch, they moved the boat to a new site and re-entered the water after a surface interval of 58 min. The victim seemed to be in good spirits.

After what he reported to have been about 30 min of diving, the son returned towards the boat, stating that, at this time his father was about 35 m from it. However, after boarding the boat (an unknown time later), he heard his father call to him for help. The victim was on the surface, about 20 m away. The son quickly donned his snorkelling gear and swam to his father, who was unconscious and face-down but with his BCD inflated. The son attempted in-water chest compressions and rescue breaths but this proved too difficult. By now, the friend had surfaced and together they removed the victim's BCD/scuba unit, towed him to the boat and dragged him aboard. He was apnoeic and cyanotic so the son began BLS while the friend alerted the emergency services. A medical team from the island clinic reached the vessel about 15 min later, finding the victim to be asystolic with fixed dilated pupils. ALS was commenced but abandoned after a total of one hour of resuscitation.

When later tested, most of the equipment was found to be serviceable with the main exception being a faulty pressure gauge. When the scuba equipment was recovered, the gauge read 20 bar, although the actual content was 5 bar. Overall, the gauge gave substantially higher readings than actual at pressures lower than about 100 bar. The needle would not go below 12 bar, even without a gas supply. His dive computer was a very old model which did not enable a download of the dive profile, other than maximum depths, dive times and surface intervals. Although the computer indicated that

Table 2

Summary of scuba and surface-supplied diving-related fatalities in 2012; BCD – buoyancy compensator device; BMI – body mass index; BNS – buddy not separated; BSB – buddy separated before incident; BSD – buddy separated during incident; GSB – group separated before; GSD – group separated during; + sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ > 50% full; nad = nothing abnormal discovered; n/a – not applicable; n/i – not inflated; n/s – not stated; PBT – pulmonary barotrauma; CAGE – cerebral arterial gas embolism; IPE – immersion pulmonary oedema

SC	Age (y)	Sex	Height (m)	Weight (kg)	BMI ($kg \cdot m^{-1}$)	Training	Experience	Dive group	Dive purpose	Depth (msw)	Incident (msw)	Weights On/off (kg)		BCD	Remaining air	Equip. test	Disabling injury
12/01	55	M	175	90	29	Yes	Experienced	BSB	Crayfishing	17	Surface	Rescuer off	4.9	inflated	+	faulty SPG	CAGE?
12/02	40	M	184	87	26	Yes	Experienced	BNS	Recreation	4	4	n/s	n/s	n/s	n/s	nad	Cardiac
12/03	40	M	178	97	31	Try-dive	nil	BNS	Training	n/s	Surface	Self off	n/s	removed	+++	n/s	Cardiac
12/04	58	M	184	129	38	Yes	Experienced	BSD	Training	30	14	Rescuer off	n/s	n/s	+++	nad	Cardiac/IPE?
12/05	34	M	181	81	25	Yes	Experienced	BSB	Recreation	20	Surface	n/a	nil	inflated	+	nad	Asphyxia
12/06	25	M	182	97	29	Yes	some	BSD	Cave	24	n/s	on	2.7	n/s	nil	some issues	Asphyxia
12/07	33	M	n/s	n/s	n/s	n/s	n/s	BNS	Crayfishing	8	2	n/s	n/s	n/s	n/s	n/s	Trauma
12/08	42	M	178	100	32	Yes	Experienced	Solo	Crayfishing	5	Surface	Self off	15.1	removed	+	faulty SPG	Asphyxia
12/09	42	F	n/s	n/s	n/s	Yes	some	BSD	Recreation	33	15	on	9.8	n/s	nil	faulty SPG	Asphyxia?
12/10	68	M	185	105	31	Yes	Experienced	BNS	Recreation	12	Surface	Rescuer off	n/s	n/s	++	nad	Cardiac
12/11	45	M	161	81	28	n/s	n/s	Solo	Suicide	3	3	on	n/s	n/s	n/a	99% helium	Asphyxia (He)
SS																	
12/01	22	M	190	89	25	Yes	Limited	Solo	Commercial	16	Surface	on	n/s	not worn	+++	some issues	Asphyxia?/CAGE?

maximum depth of the last dive was 16.5 m for a total time of 62 min, both of the other divers reported that most of the dive was spent at 10–12 msw, which is consistent with charts of the site.

Autopsy: (Within 2 days post mortem) CT scan showed extensive intravascular gas especially within the cerebral arterial circulation, the aorta, the coronary arteries and some abdominal vessels. There was extensive, apparently intravascular gas in the liver, possibly in the biliary tree. There was a small left pneumothorax. (While this may represent pulmonary barotrauma (PBt)/arterial gas embolism (AGE) it is not possible to exclude post mortem decompression artefact or decomposition as a source of the gas). External examination showed surgical scarring on the head and chest related to a neurostimulator device in the right chest wall and leads inserted in the left and right frontal lobes of the brain acting as a deep brain stimulator for control of tremor. The heart weighed 410 g (n.r. 331–469 g) and appeared normal. The left atrium was opened underwater and no gas was detected. There was 40% narrowing of the LAD artery, no hypertrophy of the ventricles and minimal scarring of the myocardium microscopically. The foramen ovale was not described. The lungs were heavy and very oedematous, with the right and left lungs weighing 902 g (n.r. 446–880 g) and 944 g (n.r. 348–790 g), respectively. There were no focal abnormalities. The brain weighed 1660 g (n.r. 1179–1621 g). There was an acute-on-chronic subdural haematoma (100 mm x 80 mm x 8 mm) over the left parietal lobe without features of raised intracranial pressure. There were electrodes in the right and left inferior frontal lobes passing into the area of the thalamus. The pathologist gave the cause of death as drowning but suggested two possible underlying causes: (1) PBt/AGE on history with equivocal evidence at autopsy; and (2) seizure activity due to the acute-on-chronic subdural haematoma (the lesion appeared too small to cause death directly from pressure effects).
Toxicology: Chlorpheniramine < 0.01 $mg \cdot L^{-1}$ (therapeutic); propranolol 0.08 $mg \cdot L^{-1}$ (therapeutic).

Comments: The pathologist suggested the possibility of a seizure related to the acute-on-chronic subdural haematoma. The victim had no history of seizures and there was no evidence of tongue-biting or bite damage to the regulator mouthpiece. However, the incidence of seizures after severe head injury is around 7.1% after one year and the absence of tongue-biting does not exclude the possibility of seizure.[6] The presence of acute haemorrhage in the subdural makes it more difficult to ignore. The acute on chronic subdural haematoma probably arose from a combination of the fall, modified by the effects of neurosurgery and the two electrodes fixing the inferior frontal cortex affecting the interaction between the skull and the brain. It may be that this small subdural haematoma is unrelated to the diving death, but had it been diagnosed in life, it would likely have raised questions about fitness to dive. In any diving death where loss of consciousness is suspected, the pathologist needs to record the heart weight, the left ventricular thickness and whether the foramen ovale is patent or sealed.

It is likely that the victim did a hasty ascent as a result of his low air situation. Although the police testing did not indicate difficulty breathing from the victim's regulator until the air supply was almost depleted, it is possible that the victim did at depth, given that he only had 5 bar remaining. The source of the gas seen on CT is hard to establish since it was not reported how long after death the CT scan was performed. Scans need to be performed in the first eight hours and preferably in the first three hours before post mortem decompression artefact complicates the interpretation of arterial gas.[7] It should be reported by someone with experience of post mortem radiology and diving fatalities. The apparent low air situation and the history of reaching the surface and calling out are consistent with PBt/CAGE but there were no ascent alarms and little gas was detected at autopsy. It is likely that he had a significant dissolved gas load and the gas seen on CT scan is probably at least partly post-mortem decompression artefact, decomposition and possibly resuscitation.

Unfortunately, as the dive computer only recorded minimal details, there was no indication of the actual profile and ascent characteristics. The dive computer model used is very permissive on repetitive dives, more so than most current models. If the profiles were essentially rectangular and 10–12 msw, the victim would have been close to or may have missed a decompression obligation recommended by other decompression guides (which could manifest as gas due to post-mortem decompression artefact). If the depth recording was accurate, it appears that the victim went deeper than the others at some stage during the dive, possibly after separating from his buddy.

Summary: 55 y.o. male; history of essential tremor, depression, sleep apnoea and head injury; experienced; good conditions; intentional separation; unconsciousness on surfacing; drowning (subsequent to CAGE or seizure?)

SC 12/02

This 40 y.o. male had a history of depression for which he was prescribed escitalopram. However, he had reportedly undergone "*a comprehensive medical check and found to be in good health*" although no details were available about this assessment. He was a strong swimmer, an experienced and long-time scuba diver and dive instructor. On this occasion, he took his 12 year-old nephew for a scuba dive from the shore at a sheltered dive site. The sea was calm and there was no mention of any current. There was no report of exactly what the divers wore, other than that the victim wore the only scuba unit and the nephew swam alongside and breathed through the 'octopus'.

After a few minutes at a depth of 3–4 msw, the nephew noticed that the victim was "*twitching*" and his regulator fell from his mouth. The nephew dragged the victim to the surface by the regulator hose and some bystanders who were on the shore nearby jumped in and helped to drag him onto a rock ledge. He was seen to take a couple of gasps (probably agonal respirations) before it was decided that he was apnoeic. BLS was commenced and was accompanied by considerable stomach inflation. An ambulance arrived about 10 min later and paramedics found the victim to be apnoeic with fixed dilated pupils and no palpable pulse. An AED was attached (possibly 25 min post-event) and indicated that no shock be given. The victim was transferred to hospital by ambulance and resuscitation efforts were ceased 90 min after the commencement of the dive.

The equipment was later tested, both on the bench and during a test dive and no identifiable faults were found. The cylinder air met relevant purity standards.

Autopsy: (4 days post mortem) The heart weighed 442 g (n.r. 331–469 g) with left ventricular hypertrophy (LVH) (17 mm, n.r. ≤ 14 mm) and 70–80% stenosis of the LAD coronary artery by atherosclerosis. There was mild, patchy fibrosis but no evidence of acute ischaemia. The atrio-ventricular and sino-atrial nodes were histologically normal. There was gas in the chambers of the heart but no foamy blood. The lungs were heavy and oedematous with the right and left lungs weighing 858 g (n.r. 446–880 g) and 664 g (n.r. 348–790 g), respectively. There was a small amount of mucus and pus in the upper airway. The cause of death was given as cardiac arrhythmia due to ischaemic heart with possible secondary drowning.
Toxicology: Citalopram 0.1·mg·L^{-1} (therapeutic); Delta-9-tetrahydrocannabinol 0.006 mg·L^{-1}; Delta-9-THC acid 0.025 mg·L^{-1}; Carbon monoxide 2% saturation (probably not significant and could be from being a smoker (up to 8%) or possibly low levels of carbon monoxide in the air fill.)

Comments: Anecdotal evidence from a friend suggested that "*he had been under a lot of stress for a long time and drank Red Bull like water*". Both the unrecognised ischaemic heart disease and LVH are independent risk factors for sudden cardiac death.[8] While, the death is most likely due to the 70–80% narrowing of the LAD, it should also be noted that the antidepressant citalopram can cause dose-dependent prolongation of the QT interval,[9] which, combined with the increased risk of arrhythmias associated with LVH, makes this also a reasonable hypothesis.

Summary: 40 y.o. male; history of depression; recently assessed as in good health; experienced diver and instructor; sharing single scuba unit with buddy; good conditions; seen to twitch and become unconscious underwater soon after submerging; BLS attempted; AED indicated no shock; LVH and severe coronary atherosclerosis; cardiac death

SC 12/03

This 40 y.o. male overseas tourist was on a day trip to the GBR and enrolled in an Introductory Scuba Dive. He was obese (BMI 31 kg·m^{-2}) but his medical history was unknown. Nothing was declared on his pre-dive medical questionnaire. There were no reports on the diving conditions or site or of the equipment worn or its functionality. Whilst breathing from his regulator on the surface he lifted his head and said "*I don't think this is for me*". He indicated that he did not wish to continue and exited the water five minutes after entering.

Possibly 5–10 min later, he walked up to the air-conditioned wheelhouse and sat down. The skipper heard him breathe heavily before rubbing his temple and slumping in the chair. His eyes were open but he was unresponsive. A crew member arrived and reported that the victim was drooling with his fingers, hands and forearms clenched, his eyes open and staring and he was unresponsive. Several of the crew placed the victim in the recovery position where he remained unresponsive and with "*abnormal breathing*". His airway was cleared (there was no indication of what) and BLS was commenced (with supplementary oxygen by mouth-to-mask) and continued for 45 min until a doctor arrived by rescue helicopter and implemented ALS. When attached, the defibrillator indicated asystole and adrenalin was administered. ALS was continued for another six minutes before resuscitation attempts ceased. No medications were found in his personal effects and no personal information was available as there was difficulty contacting family or friends after the event.

Autopsy: (1 day post mortem) The heart was heavy and weighed 509 g (n.r. 331–469 g). There was mild concentric LVH, scarring of the posterior wall of the left ventricle and severe atherosclerosis of the right, left circumflex and LAD coronary arteries. Histology showed scarring and subacute ischaemic changes but no neutrophils. The lungs were oedematous and heavy, the right and left lungs weighing 1,096 g (n.r. 446–880 g) and 969 g (n.r. 348–790 g), respectively. The cause of death was given as "*an arrhythmia complicating coronary artery atheroma*".

Comments: In addition to immersion and anxiety, factors such as exertion and salt water aspiration can contribute to the occurrence of cardiac arrhythmia so it is always useful to consider these. Given that the sudden death occurred 5–10 min after immersion, the pulmonary oedema observed was likely cardiac in origin. This victim had very significant and apparently undiagnosed ischaemic heart disease with evidence of old infarction (posterior left ventricle) and more recent "*days to weeks*" ischaemia and, thus, was at risk of a cardiac event in any circumstances.

Summary: 40 y.o. male; declared no significant medical conditions or medications; obese; only breathed scuba on surface for 5 min with no submersion; collapsed unconscious on boat; cardiac-related

SC 12/04

This 58 y.o. male nurse had a past history of anxiety and depression. He was severely obese (BMI 38.1 $kg \cdot m^{-2}$) and his recent history included reflux oesophagitis, atrial fibrillation (AF) and shoulder pain. He was reported to have been non-compliant with his AF medications and had presented to emergency departments on four occasions over the previous seven years with related symptoms, on one occasion requiring cardioversion. There was some evidence of "*light-headedness*" associated with his AF which appeared to be worsening. He suffered twice-monthly episodes of palpitations lasting 1–6 hours. Several months before his death a cardiologist had recommended the fitting of a pacemaker, which had not been done. Although he had previously been prescribed amiodarone for his AF, his current long-term medications were esomeprazole, ibuprofen, metoprolol and tadalafil. He was also reported to have been taking panadeine forte for shoulder pain.

The victim was reported to have been an experienced diver in the past but had not dived for approximately 20 years until very recently, when he participated in some shallow river and shore dives. He had now enrolled in an 'Advanced Diver' course. On the pre-dive medical questionnaire, he indicated that he was taking medications, although he failed to declare that he suffered from a cardiac condition, among other required declarations. Although his declaration of taking medications should have led to an automatic referral to a doctor and subsequent assessment prior to diving, this was not done. He undertook the course and participated in three, shallow, uneventful dives.

The next day, the victim was part of a group of nine divers who participated in the 'deep dive' of the course. The group comprised the instructor, two trainee divemasters (TDM), the victim and four other students. The dive was from a boat at a site with an underwater wall. Conditions were described as calm and sunny with a light breeze. There was a slight swell and the water temperature was around 16°C. Visibility and current were not reported. The victim was wearing mask, snorkel, fins, a 7 mm one-piece wetsuit, a 12 L steel cylinder scuba unit with a BCD with integrated weight pockets (unknown weights) with attached torches and knife and a dive computer.

After diving to 30 msw for about 10 min, the group ascended along the wall. The victim lagged behind and when a TDM went to check on him, he signalled that he was out of air. The TDM checked the victim's gauge which read 130 bar, at which point the victim indicated that he was okay but wished to ascend, (they were at 14 msw at that stage). The TDM released his surface marker buoy and signalled for the victim to swim over and hold onto it. However, after looking away for a moment, he saw the victim ascend quickly past him in a prone position, apparently unable to control his buoyancy. The TDM signalled for him to dump air from his BCD and the victim appeared to attempt this. Believing the victim to be fine, the TDM completed a safety stop before noticing the victim on the surface, floating face-down with his regulator out. He immediately surfaced, swam to the victim, rolled him over and checked for breathing and pulse, both of which appeared to be absent. The victim's jaw was stiff and he was "*bubbling and foaming a brownish liquid from his mouth*". The TDM began in-water rescue breathing and called to the boat operator to assist. Despite dumping the victim's gear, they were unable to lift him into the boat until the instructor joined them. A substantial amount of water and some frothy sputum was drained from his mouth. BLS was begun (soon with supplementary oxygen) and continued until they reached the jetty. Gurgling sounds were heard with each ventilation. Paramedics arrived soon afterwards and initiated ALS. An intercostal catheter was inserted (presumably for suspected pneumothorax). The victim failed to respond and was pronounced dead at the scene.

When later inspected, the remaining equipment was found to be in good condition and fully serviceable. The cylinder contained nitrox with 31.7% oxygen. Although the water content of the gas was high (160 $mm \cdot m^{-3}$; Australian Standard < 50 $mm \cdot m^{-3}$) this, or any equipment fault were not believed to have contributed to the victim's demise.

Autopsy: (1 day post mortem) Post mortem CT scan was not undertaken, making it difficult to assess the possibility of PBt/CAGE. There was bruising of the tongue consistent with biting of the tongue. The heart weighed 506 g (n.r. 331–469 g) with a globose shape with dilatation of the right atrium and both ventricles. There was a 30% stenosis of the LAD artery. Histology of the heart showed mild, patchy subendocardial and perivascular fibrosis and myocyte hypertrophy but no acute ischaemic changes. There was a moderate amount of blood-stained pulmonary oedema fluid in the upper airways and mouth. The lungs were heavy and oedematous, the right and left lungs weighing 930 g (n.r. 446–880 g) and 953 g (n.r. 348–790 g), respectively. The cause of death was given as unexpected death while scuba diving with significant contributing risk factors given as obesity and atrial fibrillation.

Comments: This severely obese man with a history of paroxysmal AF failed to declare this and other relevant conditions as required on the pre-dive medical declaration. However, the fact that he did declare medications should have triggered a medical examination or at least some further inquiry. The dive operator was remiss in not ensuring this. It appears that the declaration was signed just prior to beginning the course and this in itself, at such a late stage, can create a strong temptation to fail to declare relevant conditions so as not to disrupt immediate plans. On the other hand, as a nurse, it is likely that the diver was aware to some extent of the potential dangers his medical conditions posed and, in his determination to go diving, could have set out to deceive.

There was a significant cardiac history with features of a possible dilated cardiomyopathy and a documented cardiac dysrhythmia for which insertion of a pacemaker had been recommended. Given the victim's age and medical history, it is likely that the effects of immersion, exertion and breathing compressed gas (especially with an elevated PO_2) at depth precipitated a cardiac arrhythmia in this susceptible diver. The β-blocker taken to control the victim's AF may have reduced his ability to respond to the physical demands of the dive and contributed to his feeling of being 'out of air'. It is also possible that, if he went into AF, this may have triggered pulmonary oedema in the setting of immersion, evidenced by his difficulty breathing and later by the brown frothy sputum. He was using a 32% oxygen mixture, which at a depth of 30 msw, would produce a PO_2 of around 1.2 bar and it has been suggested that an elevated PO_2 may be a risk factor for IPE.[10] The effect of tadalafil (which may act as a pulmonary vasodilator) in this setting is unknown. Although there was strong evidence of pulmonary oedema at autopsy, this could also have resulted from drowning.

The rapid and uncontrolled ascent may have resulted in CAGE. It is unclear on what basis an intercostal catheter was inserted. However, in the absence of CT scanning (requested but not done) evidence of CAGE is hard to assess.

Summary: 58 y.o. male; little recent experience; severely obese; history of increasingly frequent AF, reflux oesophagitis, anxiety and depression; 'deep dive' (30 msw) on training course; signalled 'out-of-air' despite having 130 bar and functioning equipment; uncontrolled ascent alone; in-water rescue breathing; difficulty lifting victim into boat because of his size; BLS attempted; drowning (cardiac-related?/IPE?/CAGE?)

SC 12/05

This 34 y.o. apparently healthy man had been certified as a diver for two years and dived weekly, having logged around 100 dives. On this occasion he was diving with a regular, albeit less experienced buddy at a site that was familiar to both of them. The victim was wearing mask, snorkel, fins, a BCD with scuba unit with twin 7 L steel cylinders (linked by a manifold with central isolation valve) a drysuit with undergarments, socks and a hood. His equipment weighed 30 kg and he was carrying no additional weights.

At the time, the water conditions were described as "*good*" and they entered the water from the rocky shore. The water temperature was about 22°C. After about 30 min underwater, at an average depth of 12 msw, the buddy's gauge read 120 bar and he signalled to turn back towards shore. They did so and continued for a while, reaching a maximum depth of 20 msw, until the buddy's air ran low and he indicated that he wanted to surface. The buddy spent two minutes at a safety stop and was surprised that the victim did not do so, but was not concerned as he could see him on the surface. On surfacing the buddy joined the victim, who seemed fine, and they began to swim towards shore on their backs. However, this was difficult due to the increasing swell so they re-descended and swam underwater for a short time, at a depth of 5–7 msw. They again surfaced as the buddy was very low of air and again kicked on their backs towards the exit point. However, they became separated as the swell and current pushed the victim towards the rocks.

On reaching shore, the buddy saw the victim struggling to make headway and then heard him scream for help. He left the scene briefly to arrange for someone to call the emergency services. On his return several minutes later, he saw the victim floating on his back and a boat approaching him. A nearby dive boat had heard the emergency call and came to assist. The now unconscious victim was lifted onto the boat and BLS was commenced an estimated 15 min after his cry for help. A life-saver rescue boat arrived and he was transferred onto it and BLS continued as he was taken to shore. Paramedics arrived and implemented ALS and this continued until the arrival of a doctor by rescue helicopter.

On later inspection, there were no significant faults found with his equipment

Autopsy: (3 days post mortem) No CT scan was performed, but no gas was described at autopsy. There were no traumatic injuries apart from a chest abrasion thought to be due to cardiopulmonary resuscitation. The heart weighed 340 g (n.r. 295–445g) and was normal, with no significant coronary atherosclerosis. The left ventricle measured 14 mm (n.r. ≤ 14mm). The right and left lungs weighed 630 g (n.r. 410–892 g) and 842 g (n.r. 378–780 g), respectively, with moderate pulmonary oedema but no frothy fluid in the upper airways. The cause of death was given as drowning. *Toxicology*: Carbon monoxide 2% (probably not significant)

Comments: It is probable that this healthy, experienced diver found it particularly difficult swimming on the surface encumbered by twin cylinders, a drysuit and undergarments in relatively warm water. Although the fins he was wearing provided good propulsion underwater, they were relatively rigid and might not have been as effective on the surface. It is likely that he became exhausted, was swamped by a wave, aspirated and drowned. Adverse sea conditions can be a challenge and divers should never be complacent about this.

Summary: 34 year-old male; healthy; experienced and regular diver; twin tanks; returning to shore on surface with large swell and current; likely exhaustion; drowning

SC 12/06

This 25 y.o. male was an overseas national studying at university in Australia. He was certified as an open water diver (OWD) overseas four years earlier and received an advanced certification shortly afterwards. His logbook indicated that he was not on medication at that time but no subsequent medical history is available. He had logged a

total of 24 dives, three of which were between 24–30 msw. His last dive was a shallow shore dive 19 days earlier.

On this occasion he was diving in more temperate waters. He arrived at the dive centre lodge with three friends at 2–3 am and would only have had a few hours of sleep. He owned his own equipment which had never been used. It included mask, snorkel, fins; a 'wing' BCD; and regulator with 'octopus'. He checked this in at the dive shop prior to departure and all seemed functional. He hired a 5 mm one-piece wetsuit, a weight belt with 2.7 kg of weight, and a 10.5 L steel cylinder. The group's first dive was uneventful. The conditions were described as good and they did a multi-level 'orientation' dive to 15–20 msw. The divemaster (DM) reported that they all performed well, none appearing to have any problems during the dive.

After a surface interval of at least an hour, the group of four and the DM descended to the entrance of a sea cave at 24 msw. Before entering the cave, the DM asked them to check that they all had at least 150 bar of pressure in their cylinders and that their torches were functioning. After this, the group entered the cave with the DM leading, followed by the divers in single file in reverse order of their experience, the least experienced being directly behind him. The victim was the second last and was followed by a friend who was a Rescue Diver with a history of 100 dives.

There are two 'chimneys' near the entrance and the DM swam into the second and waited for the divers. He saw the first two torch beams but, when the third diver didn't arrive the DM descended the 'chimney' and then noticed a torch beam above him in the first chimney near the cave's entrance. He went there and found the victim unconscious, floating prone near the ceiling with his regulator out of his mouth and mask missing. There was no gas escaping from his equipment. He grabbed the victim and dragged him out from the cave and to the surface and then on to the nearby dive boat. The victim was noted to be unconscious, apnoeic and his face was a "*grey colour*". BLS was begun by staff, assisted by some off-duty police officers who were on the vessel, and resuscitation was coordinated by the DM, an ex-paramedic. BLS was continued while other divers were retrieved and throughout the 25-minute boat trip. Supplementary oxygen was available but was not used. Ambulance paramedics were waiting at the jetty and continued resuscitation efforts for a short time before pronouncing the victim to be dead. It was estimated by the operator that the victim had been underwater for a total of around 10 min, was unconscious underwater for possibly 4–5 min of this and was apnoeic for around 10 min before BLS was commenced on the boat.

It was later reported by the diver following the victim that, when she entered the cave, she saw vast amounts of bubbles escaping from the victim's equipment. The victim then inadvertently kicked her in the head, causing her to become disoriented and so to exit the cave.

His equipment was photographed by the dive operator and secured by the police. The 'octopus' second stage was missing and cylinder contained several litres of sea water. Three days later police divers found the victim's mask, one fin and octopus second stage at the accident scene. They reported that the 'octopus' had not been screwed tightly to the hose and had subsequently come undone. No significant fault was found with his other equipment when tested, although there was some visible damage, probably from contact with the cave.

Autopsy: (3 days post mortem) The post mortem examination was confined to external examination. On admission to the mortuary there was a large plume of pulmonary oedema coming from the mouth which had dissipated by the time of post mortem examination. There were bilateral conjunctival haemorrhages, a small laceration on the vertex of the head and minor lacerations to the left upper cheek and right lower lip. Post-mortem vitreous sodium and chloride was 277 $mmol \cdot L^{-1}$ (> 259 is reported to be consistent with salt water drowning[11]) The cause of death was given as drowning. *Toxicology*: Carbon monoxide 2% (see prior comment)

Comments: It appears that the victim's 'octopus' became detached after he entered the cave, causing panic, loss of the face mask and regulator, exhaustion of air supply, aspiration and subsequent death from drowning. It is likely that he had assembled the equipment himself, failed to secure the 'octopus' and it progressively unscrewed. When it separated, he would have been surrounded by a plume of bubbles with a rapidly depleting air supply, his 'octopus' hose would have been whipping around and it would have been difficult to orientate. Being inexperienced, he likely panicked and may have crashed into the cave wall or ceiling, sustaining facial injuries. Given the equipment failure and loss of face mask which make aspiration highly probable, internal examination of the body, though ideal, would probably not have changed the determined cause of death.

Summary: 25 y.o. male; relatively inexperienced with 26 previous dives; entering sea cave single file; octopus separated from hose; bubble plume and fast-depleting air supply; disorientation and panic; probable drowning

SC 12/07

This 33 y.o male was apparently healthy. His diving qualification and experience were not reported. He and his brother went diving for crayfish in the victim's 5 m boat. After a short uneventful dive about 4 km from shore, where visibility was very poor, they moved and re-anchored at another site 1.5 km offshore. The site comprised patches of reef and a depth of 8 msw. There were two other boats anchored 100–300 m away and their occupants were fishing. One of the fishermen later reported that fish had stopped biting and he had observed balls of baitfish and suspected there was a "*predator*" nearby.

The sky was overcast, there was a light wind and the water was choppy. However, the visibility near the surface was 6–7 m and there was little or no current. The divers geared up and rolled into the water, the victim about 3 m ahead of his brother. The victim descended along the anchor line and when he had only reached a depth of about 2 msw, a very large grey shark (with a white underside) reported to be 4–4.5 m long emerged rapidly from deeper water and engulfed the victim's head in its mouth. The shark thrashed around while retaining its grip on the victim. The brother stabbed the shark repeatedly with his knife but it just flicked him off several times, before suddenly discarding the victim and swimming away.

The victim's body was floating on the surface. His head and left arm were missing, his torso was torn open and some internal organs were visible. The brother screamed for help, grabbed the victim's remains, dragged them onto the boat and covered them with a towel. The other boats came alongside and then escorted the brother as he drove the boat to the nearest jetty. The victim's head, left shoulder and left arm and part of a wetsuit were found six days later and approximately 100 km away from the dive site.

Autopsy: (5 days post mortem) Traumatic amputation of the head and left arm and deep injuries to the chest and abdomen. There was no apparent natural disease. The cause of death was given as "*multiple injuries*".

Comments: This diver was in the wrong place at the wrong time. The shark appears to have been a very large Great White Shark (*Carcharodon carcharias*). The divers were not carrying any crayfish and had done nothing to provoke the attack. However, it is possible that the shark was attracted to the area by the nearby fishing. There were no reports that the fishermen had been 'burleying'

Summary: 33 y.o. male; just entered water with buddy; fishing activity nearby; attacked by large shark (probably Great White); multiple trauma

SC 12/08

This 42 year-old man was reported to have been very active and healthy though overweight (BMI 31.6 $kg \cdot m^{-2}$). His partner stated that he was "*fearless*", although a safety-conscious diver. She was not aware of any medical conditions and he was on no medication. He had last seen a doctor for a physical check-up and blood test 18 months prior and no concerns were found. He was a non-smoker but drank 2–3 cans of rum and coke each day. A strong swimmer, he was a keen and relatively experienced diver. Apparently, he did some training when he was much younger and had done some diving before taking a break for many years. His diving began again in earnest a few months earlier, sometimes as often as four times a week. He was a keen crayfish catcher who often dived alone and reportedly had little fear of potentially adverse diving conditions.

Two days before the incident, he had done up to six dives with one to 28 msw to retrieve crayfish pots. Without a dive watch or computer he was unaware of the times of the dives or of any decompression obligations. Following the dive he complained of unusual fatigue and malaise. Despite this, he planned to dive with friends two days later and took amphetamines at some point in the 24–48 hours preceding the dive. He also had a can of rum and coke on the way to the dive site. His friends thought it unusual that he only planned to do one dive this day as he was normally very keen to do more.

The conditions were benign, with little wind or swell. The water temperature was 17°C and visibility about 10 m. There was no mention of current but it is likely that one was present, at least later in the dive. The victim and his two regular buddies were hoping to collect crayfish and abalone and set off from shore at mid-tide and waded across reef to a small island some 100 m distant. They had all dived the site on many occasions. He was wearing a mask, snorkel, fins, wetsuit, hood, gloves and boots, a BCD/scuba unit with 11.6 L aluminium cylinder (no alternate air source), weight belt with 15 kg of weights, torch, knife and carried a catch bag. On arrival, he set off alone to dive on the seaward side of the island while the others dived on the more sheltered, landward side.

After about 40 min the friends surfaced and returned to shore, not initially concerned about the victim. However, some 20 min later he was seen to surface and hold his left arm above his head. He was not waving it or calling out so the friends and another bystander did not think that he was in distress. He then disappeared from view and after 10–20 min they became concerned and began a land and water search.

His body was washed ashore by waves about 500 m from where he was last seen and recovered by fishermen. He was floating on his back, with his mask and snorkel under his chin, and frothy sputum bubbled from his mouth. His BCD/scuba unit and weight belt were missing but his fins were in place. One of the fishermen checked for a pulse without success and tried to clear the victim's mouth, but froth continued to flow. He then gave some chest compressions but soon abandoned these believing them to be futile given that the victim had been in the water for so long (around 60 min). One of the buddies then called the emergency services.

The next day, police divers located the missing equipment where he was last seen and at a depth of 5 msw in an area free of kelp or other natural entrapment hazards. The BCD and cylinder were buoyant but the high-pressure hose and pressure gauge were entangled with the weight belt and pinned to the seabed by it. The pressure gauge read zero and the BCD shoulder straps had not been unclipped. The catch bag was empty and the torch was still on. When tested, most of the equipment functioned correctly although it was noted that the pressure gauge read low, indicating zero when the master gauge showed 8 bar. Analysis of the remaining air

showed that it met relevant purity requirements, other than the likelihood of an elevated moisture content.

Autopsy: (2 days post mortem) Post mortem CT scan of the body showed diffuse pulmonary oedema consistent with drowning. There were patchy, intravascular gas bubbles in the liver and in the coronary arteries but not in the cardiac cavities. There was some bruising on the left side of the neck. The heart weighed 440 g (n.r. 331–469 g) and appeared mildly enlarged with LVH of 20 mm (n.r. < 14 mm). The coronary arteries showed no significant atherosclerosis. There was mild, focal fibrosis in the heart on histology. There was pale, frothy fluid in the mouth and airways. The right and left lungs weighed 870 g (n.r. 446–880 g) and 725 g (n.r. 378–790 g), respectively, and were overexpanded with moderate to severe pulmonary oedema. Histology examination revealed sarcoidosis in the lungs, hilar lymph nodes and liver. There was water in the stomach. The cause of death was given as drowning in an out-of-air situation. *Toxicology*: Ethanol (< 0.01 g·100 ml^{-1}); amphetamine (blood) 1.3 mg·L^{-1}; amphetamine (urine) > 2.5 mg·L^{-1}; cathinone detected in urine (a monoamine alkaloid found in the shrub *Catha edulis* (khat) and is chemically similar to ephedrine).

Comments: It appears most likely that the victim was low on air and may have attempted to ditch his weight belt. Given that it was found entangled with the HP hose, it is possible that the weight belt caught on the pressure gauge and the victim quickly removed his BCD in order to become buoyant. His ability to react appropriately to his situation might have been hampered by fatigue (possibly from DCS from earlier dives), amphetamines and alcohol. While doing so, he probably aspirated water and became unconscious. Without the presence and prompt action of a buddy, he had little chance of survival.

Prolonged use of stimulants can cause left ventricular hypertrophy. It is possible that the combination of amphetamines and left ventricular hypertrophy may have resulted in a cardiac arrhythmia. However, the out-of-air situation and the changes of drowning are probably more significant. The stimulants could impair judgement regarding the safe length of the dive. Amphetamine can be detected up to 46 hours after ingestion.[12]

Summary: 42 y.o. male; overweight but otherwise healthy; little training but recent experience; recent use of amphetamines and alcohol; intentional buddy separation; low on air; surfaced then sank; entanglement of weight belt and scuba unit; drowning

SC 12/09

This 42 y.o., apparently healthy woman had a negative medical history other than a 25 pack-years smoking history, but had stopped four year earlier. She certified as an OWD three years earlier at which time she was assessed as fit to dive by a doctor trained in dive medicine. She subsequently did an advanced course one year before this incident and had logged a total of 55 dives, including five deeper than 28 msw, but only one over 30 msw.

She and her buddy booked two dives with a charter operator. The buddy had done 40 dives over two years, of which nine were with the victim during the previous year. He reported that the victim had consistent problems with buoyancy control, often related to difficulty finding and using the inflator and deflator buttons. The weather was fine and sunny, with a light offshore breeze, and calm sea, described as "*ideal winter diving conditions*", with a water temperature of about 12°C. She owned all of the equipment she was wearing; this consisted of mask, snorkel, fins, 7 mm full wetsuit, hood, boots, gloves, BCD and scuba unit with a 10.5 L steel cylinder, dive computer, fabric weight belt, knife, camera and torch. She was wearing a total of 9.8 kg of weights distributed between her weight belt (3.4 kg), integrated pouches in the BCD (3.4 kg) and her BCD pockets (1.5 kg in each).

The first dive was on a large wall to a maximum depth of 26 msw. There was a strong current and she ran low on air and had an uncontrolled, rapid ascent, missing a safety stop. The buddy grabbed her but was unable to stop her without also being dragged to the surface. Once on board the boat, the divemaster scolded her for missing the stop. She explained that she had had a problem locating her BCD deflator and, after demonstrating that she could now find and use it, the divemaster permitted her to do the next dive. During the 2.5-hour surface interval the victim appeared to be fine and insisted on doing the second dive, despite her buddy being reluctant due to the cold.

The next site was a wreck sitting on a sandy bottom at a depth of 33–35 msw, 4 km offshore. It was sunny the water was calm with very little swell and there was a current of 2–3.5 km·hr^{-1} on the surface. After a briefing from the divemaster and with fresh tanks, the pair descended with 11 others down the shot-line. The buddy held the victim's hand during the descent, as was their usual practice. There was little current on the bottom but the visibility was less than 5 m. The planned maximum depth was 30 msw but the victim exceeded this by landing on the bottom at 33 msw. The buddy subsequently shortened the planned dive time to accommodate this and they began ascending after 15 min. During the dive, several divers had seen the victim and noted that she had poor buoyancy control and finning technique and was swimming near-vertically.

During the ascent, the buddy carefully followed his computer and observed that the victim's ascent rate was variable, at times she was above him and sometimes below, although this was not unusual. On reaching approximately 10–12 msw, the buddy focussed on his gauges for what he estimated was 15 seconds, and, when he looked up to check on the victim,

she was not visible. He presumed that she had ascended before him, again due to poor buoyancy control. When he had last seen her she was 4–5 m below him. He completed his safety stop and, still unable to see his buddy, he surfaced with 20 bar of air remaining, about 8–10 min after last seeing the victim. Once aboard the boat, he asked others if they had seen the victim, which they had not. When she failed to surface and no bubbles were visible, a pair of divers re-descended to look for her, without success. Emergency services were promptly notified of a missing diver. A black object was seen to surface briefly in the distance but was not identified or seen again. An extensive air, sea and land search began and was continued for four days.

The following day the police used a remotely operated vehicle to scan the wreck and its vicinity for the missing diver. The scan showed the presence of a seven gill shark (*Notorynchus cepedianus*) approximately 2 m long around the site. During a search dive the next day, police found some of her equipment lying on the bottom about 50 m from the wreck. This included the victim's BCD/scuba unit, a severed weight belt with damaged pockets, a mask (with several strands of her hair) with a severed strap, snorkel, knife strap, camera, a torch and a slate. The equipment had distinctive damage in the form of rips, tears and fraying, consistent with shark bites. The weight belt was still buckled but had been severed. When the equipment was recovered it was noted that it had a "*distinct unpleasant odour*", consistent with that of bodies recovered post-submersion.

Analysis by a shark expert suggested that the damage was consistent with shark predation of a victim lying on her back on the sea bed, rather than mid-water. The pattern of damage was thought to have been most consistent with the jaw morphology and dentition of one or more Sevengill sharks 2–3 m in length. Her cylinder contained 4.5 L of water, indicating that it had been completely depleted and the pressure gauge read high by 10–15 bar. When tested, no faults were found with her BCD inflator/deflator mechanism.

Autopsy: In the absence of a body, the cause of death was given as drowning. Damage to the equipment suggested post-mortem predation.

Comments: It appears clear that, despite having logged 55 dives and done post-basic training, the victim still consistently had problems with buoyancy control and might have greatly benefitted from some specific training in this. She confided in a friend that she sometimes felt panicky underwater and this likely contributed to her poor buoyancy skills, especially at depth where she appeared to have been grossly overweighted. Ascending along a shot or anchor line provides a good datum in open water, such as this site. However, it appears likely that this pair hadn't done so and this would have contributed to the difficulty of ascent control. She had consumed air much faster than her buddy on the previous dive and probably also did so on this one. It is likely that her demise arose from a combination of low, or lack of air during the last part of the ascent, poor buoyancy control (possibly involving dumping air in error) and failure to ditch her weight belt. The most likely scenario is that she aspirated water, became unconscious and sank. One or more opportunistic sharks then predated on her body.

Summary: 42 y.o. female; no significant medical history; logged 55 dives but still had poor buoyancy control; buddy separation on ascent; not seen to surface; equipment showed signs of predation by large shark(s); body never found; probable drowning followed by post-mortem shark predation

SC 12/10

This 68 y.o. male was an overseas tourist on a day trip to the GBR on a commercial vessel with 30 people on board. His medical history is unknown but he did not declare any conditions or medications on his pre-dive medical declaration and no medications were later found with his belongings. Although only certified as an OWD, he was an experienced diver with a history of nearly 300 dives. He had brought his own mask, snorkel, fins, wetsuit and boots, BCD with integrated weights and regulator with octopus. The operator provided him with a cylinder, and possibly weights. The first dive of the day (around 10 msw for 25 min) was uneventful and the victim appeared to be well and "*in good spirits*". After a large lunch, he and five others (including an instructor) prepared to dive again. There was a moderate wind, the water had a 0.5 m chop, visibility was 10 m and there was what was variously described as a mild to strong current (possibly around 1 $km \cdot h^{-1}$ in places).

The depth at the site was 32 msw but there was no plan go that deep. The group descended the mooring line with the victim at the rear. Finding it difficult to descend and make headway against the current, the victim signalled the instructor for another weight, which he was given. The group then descended to 12 msw. The victim appeared to be competent and relaxed and took photographs. They ascended to shallower water with less current, but, after a total time of 10 min, he signalled that he wanted to ascend and did so quickly. When the instructor reached the surface, the victim told him that he was exhausted and appeared to be wide-eyed and breathless. He returned to the boat unassisted while the instructor re-joined the rest of his group.

The victim reached the dive platform and sat on it. A witness noticed blood-stained, frothy sputum at one corner of his mouth. He passed his camera to that witness before collapsing backwards and floating semi-conscious above the platform. He was quickly dragged aboard the boat, placed in the recovery position and his equipment was removed. Oxygen was administered via a non-rebreather mask. Another passenger, an ED nurse, reported that he initially responded to command but did not speak, was breathing weakly and had a weak pulse. At one point he sat up briefly before collapsing unconscious, apnoeic and without a palpable pulse. The nurse commenced BLS, assisted by

crew members. No AED was available but supplementary oxygen was provided via a BVM. BLS continued until the rescue helicopter with paramedics arrived 30 min later and ALS was implemented, without success.

When tested, all equipment was found to be functional and the remaining air met relevant purity standards. However, the primary demand valve appeared to have a relatively high 'cracking pressure' and showed signs of poor maintenance. Based on the dive computer, the victim's respiratory minute volume (RMV) during the dive was 33.2 $L \cdot m^{-1}$ which was considerably higher than on the previous dive (unreported).

Autopsy: (6 days post mortem) A CT scan (possibly 24 hours post mortem) showed gas in the coronary arteries and a small amount of gas in the left ventricle. There was extensive portal venous gas and diffuse opacification of the lung fields (possibly ante-mortem adult respiratory distress syndrome). The heart was heavy, weighing 492 g (n.r. 331–469 g). Both ventricles showed hypertrophy – the left ventricle measured 18 mm (n.r. < 14 mm), and the right ventricle 7 mm (n.r. < 4 mm).The coronary arteries were all severely narrowed by calcified atherosclerosis. The lungs were heavy and oedematous, the right and left lungs weighed 1,011 g (n.r. 446–880 g) and 930 g (n.r. 348–790g), respectively. The cause of death was given as ischaemic heart disease.

Comments: The victim had significant ischaemic heart disease, although this may have been undiagnosed. It seems likely that the effects of exertion from swimming against the current, and immersion, possibly exacerbated by breathing resistance from the demand valve, triggered a cardiac arrhythmia. He also developed either pulmonary oedema or secondary drowning. While it is possible that he ascended rapidly enough to develop a CAGE, he appears to have had problems before he ascended. The gas found on CT could have been due to either resuscitation or post-mortem decompression artefact. Given his heart disease and pulmonary oedema, gas exchange was probably impaired increasing the amount of decompression artefact. The victim's calcified coronary artery atherosclerosis may have been visible on cardiac CT scan. In a case such as this, with a witnessed collapse with rapid BLS, prompt access to an AED might have been beneficial.

Summary: 68 y.o. male; unknown medical history; experienced; exertion against moderate to strong current; fast ascent; collapsed on boat; prompt BLS but no AED; substantial IHD at autopsy; cardiac-related

SC 12/11

The medical and diving history of this 45 y.o. man were unavailable. A dive shop filled his 7 L cylinder with helium, which he said was to be used for filling balloons for his son's party. He was subsequently reported missing and police found his clothing and mobile phone on rocks at the edge of a dam. A stream of small bubbles was visible 10 m from the water's edge. Police divers located the victim's body the next day. He was face-down, 10 m from shore at a depth of 3.3 metres' fresh water (mfw), with his regulator out of his mouth. In addition to his scuba equipment, he was wearing a one-piece full wetsuit and boots, fins, mask (and presumably weights). When examined, the victim's cylinder was reported to have had a small leak, but still contained 730 L of 99% helium.

Autopsy: (2–9 days post mortem) The body showed early decompositional changes. The heart weighed 349 g (n.r. 331–469 g) and was normal with mild atherosclerosis. The right and left lungs weighed 521 g (n.r. 446–880 g) and 423 g (n.r. 348–790 g), respectively, and were moderately expanded. Based on the gas analysis reporting 99% helium in his cylinder, the cause of death was given as asphyxia by helium inhalation.
Toxicology: Carbon monoxide 1%; paracetamol 5 $mg \cdot L^{-1}$ (therapeutic)

Comments: Suicide by asphyxiation due to helium inhalation is reportedly an increasingly commonly promoted method suggested by 'right to die' advocates.[13] It seems clear that this was the victim's intent

Summary: 45 y.o. male; medical and diving history unknown; cylinder filled with 99% helium; dived alone in dam lake; asphyxiation by helium inhalation; likely suicide

Surface-supplied breathing apparatus (SSBA) fatality

SS 12/01

This fit 22 y.o. male was on no medications. He had surgery the previous year to remedy shoulder dislocations. He was a qualified recreational diving instructor with a history of more than 600 dives, but had no previous training or experience as a commercial diver. He took a job with a large pearling company and was enrolled in a three-day industry-established course in the use of surface-supplied breathing apparatus (SSBA) and other relevant equipment for pearl diving. Although covering a variety of relevant skills, the practical component included only one or two 'bail-out' dives in a pool. He was assessed as being competent.

The weather was poor, so the victim had the opportunity to spend eight days doing a relatively simple job using the SSBA equipment in sheltered conditions checking shells in a pearl farm. He told his parents that he felt much more confident after this. When the weather settled, the victim and eight other divers, five of whom were also novice pearl divers, set out to sea to collect oysters with the rest of the fleet. This is done by a specific mode of drift diving.[14] Booms are secured either side of the boat's stern and weighted shot lines and air hoses (100–150 m long) are suspended from these. Work lines run from the shot lines and drag behind them. Each diver hangs onto his work line and drifts over the sea bed, collecting oysters and placing them in a shell bag

slung over his neck. When this bag is full, the diver swims to the shot-line at the front of his work line and empties the contents into another bag. There are four divers regularly spaced each side of the stern. There may or may not be visual contact, depending on the clarity of the water, which is sometimes poor.

On the first day the victim did nine dives. On the second day he had done seven dives prior to the fatal one wearing a full 1 mm wetsuit, weight belt, hood, gloves, fins and bail-out bottle but no BCD. It appears that in the preceding dives he had at least one incident involving separation from his line in poor visibility. He complained to one of the other divers that the work was exhausting and that at the end of each dive his hands and whole body ached. He also stated that he "*almost drowned*".

The eighth dive of the second day was planned to be 13–15 msw for 45 min with 10 min of decompression. He surfaced after about 30–35 min and waved and shouted for help, possibly submerging briefly before re-surfacing and again calling for help. Two crew members heard his cry and saw the victim to be what was variously reported 40–100 m from the boat. By the time the crew member returned from alerting the captain in the wheelhouse, the victim was no longer on the surface. The skipper slowed the boat and the other divers were recalled and surfaced after completing decompression. A crew member then began to haul in the victim by hand by his hose, standing on the boom to do so. This was difficult as the boat was still moving slowly.

He was hauled to the surface and the skipper and a crew member jumped into the water to try to support him. It appears that the skipper did not have a mask or fins or other means of support and this hampered his efforts. They were unable to keep the victim's head above water and there were no reports of attempts at in-water rescue breathing. There was difficulty in bringing the victim back onto the boat and there appears to have been no specific equipment or procedure for recovering an unconscious diver. As a result, more time was lost. When the victim was finally brought aboard (hand-hauled up a 2 m ladder), one leg was tangled in the air hose. He was still wearing his weight belt and the shell bag (which contained 16 oysters) around his neck and was missing one fin. His bail-out bottle was in place and not activated. There were no apparent signs of trauma on his body.

BLS was commenced by the skipper some 20 min after the victim originally surfaced in distress. This was complicated by regurgitation of stomach contents and water. Although there was a lot of oxygen on board for use with decompression, there was no equipment to provide positive pressure oxygen ventilation. The skipper called a medical consultant some 30 min later for advice on the BLS as the victim was not responding. There was an Epipen available and the doctor suggested that nothing would be lost by injecting some adrenalin (into the thigh). BLS continued for 45–50 min but was unsuccessful. There was no AED available. The boat returned to port and the victim was taken to hospital, arriving over eight hours after the accident.

He had been using his own demand valve (attached to the SSBA) and both lugs were missing from the mouthpiece, appearing to have been bitten off. His dive computer indicated that he had dived to a maximum depth of 16 msw, surfaced for a short time, before re-submerging to a maximum of 9.5 msw for at least 12–29 min, before being hauled to the surface.

Autopsy: (4 days post mortem) The CT scan performed three to four days post-mortem was not reported. There were sub-conjunctival haemorrhages in both eyes, a healed scar on the left shoulder and early decompositional change. The heart weighed 414 g (n.r. 295–445 g) and was normal as were the coronary arteries. There were several large gas bubbles in the left atrium. There was a small amount of frothy fluid in the trachea and bronchi and the lungs were distended and oedematous with the right and left lungs weighing 802 g (n.r. 410–892 g) and 760 g (n.r. 348–790 g) respectively. Both pleural cavities contained dark-coloured fluid (fluid can move from the lungs and accumulate in the pleural cavity post-mortem). Much of the pectoralis musculature on the right side of the chest was absent. The cause of death was given as consistent with drowning. However, after further expert advice the Coroner later revised this to CAGE (mainly on the basis of a probable rapid ascent, followed shortly afterwards by unconsciousness).

Comments: Despite his experience as a recreational diver and instructor, the victim was a novice pearl diver who appeared to be having problems dealing with the unfamiliar equipment, diving techniques and physical requirements of his new job. The physical demands could have been exacerbated by the absence of his pectoralis musculature. It might have been difficult for him to hold onto the line and this could have contributed to his previous incident of separation. He was out of visual contact of the supervising diver (and others) for much of the dive and, in the absence of verbal communication equipment between divers themselves and those on the boat, it is unclear what problem he had underwater that caused him to surface in apparent distress.

It is unknown when the lugs were bitten off the mouthpiece. If this occurred while he was conscious, it would have made it difficult to retain the demand valve which may have fallen from his mouth, causing him to panic and ascend. Although he was trained to use the bail-out cylinder, this skill would not have been embedded and might have been difficult, or overlooked. Even if the mouthpiece was retained, aspiration of salt water would have been likely. It is also possible that the lugs were bitten off as a result of trismus, with or without the pulling from the air hose. However, what is apparent is that there was no standby diver to assist him. There also appears to have been no effective equipment or procedure for rapidly extracting an unconscious diver from

the water. This caused substantial delays to the initiation of resuscitation attempts, making recovery highly unlikely. In addition, there was no oxygen resuscitation capability, unacceptable in such a setting. An AED would likely have made little difference to the outcome in this incident largely due to the delay to retrieval.

The company was charged with and pleaded guilty to failing to maintain a safe workplace environment and was fined $60,000 as a result. This was largely based on the absence of appropriate systems to identify and promptly recover a distressed diver. They were not charged with causing the death of the victim. Improved initial training, better supervision and communication (including the presence of a stand-by diver); appropriate and practiced diver extraction protocols and relevant equipment; the wearing of BCDs; and ready access to suitable oxygen resuscitation equipment and an AED would reduce the likelihood of such an incident and improve the chances of successful rescue.

Summary: 22 y.o. male; absent pectoralis major (Poland syndrome); experienced recreational diving instructor; novice commercial pearl diver; second day of drift diving for oysters; previous incidents of separation from line and distress; poor supervision and no stand-by diver; surfaced and called for help then sank; long delays in rescue; drowning?/CAGE?

Discussion

A summary of the possible sequence of events in each of these incidents is shown in Table 3.

DEMOGRAPHICS

Once again, older males were over-represented in this series. There was only one female victim in each of the snorkelling and compressed gas diving cohorts. The mean (SD) age of the snorkellers was 55 (19) with a median (interquartile range, IQR) of 63 (37, 68). The compressed gas group were younger with a mean (SD) age of 42 (13) and median (IQR) of 41 (32, 48). Eight of the 14 snorkellers were overseas visitors compared to only three of the 11 scuba divers. A large proportion of the snorkel-related deaths were in Queensland, consistent with the high number of snorkellers on the GBR, many of them overseas tourists.

MEDICAL CONDITIONS

Associated with increased age is an increase in co-existing disease, both known and occult.[15–18] Six of the snorkellers and at least two of the scuba divers had a known medical condition which could have affected their fitness to snorkel or dive. These conditions included hypertension, ischaemic heart disease, diabetes, atrial fibrillation and epilepsy. However, three of the snorkellers and five of the scuba divers had no significant medical history, and the history was unknown in one of the snorkel and two of the scuba victims. In five of the snorkelling incidents and two of the scuba incidents, the pre-existing condition was believed to have contributed to the death.

Epilepsy

Although there remains some debate about the safety of diving for those with a history of (apparently) controlled epilepsy,[19] there is no doubt that a diver or snorkeller is exposed to a variety of potential triggers. With his poor compliance with medication, recent intake of marijuana and likely extended apnoea, BH 12/06 put himself at great risk. All epileptics need to be closely watched in aquatic situations, and, with no direct oversight and the associated opportunity for a swift rescue, the outcome is unsurprising.

Failure to declare

It is not uncommon for intending snorkelling or scuba participants to fail to declare current or past medical conditions; this was the case in at least two snorkelling and one scuba incident (BH 12/02, BH 12/05 and SC 12/04). This failure may at times result from a poor briefing by the operator, and/or inattention or misunderstanding by the intended participant, or simply due to time pressures. However, some individuals intentionally withhold information for fear that they will be prevented from participation. Given his medical background and his significant health issues, it appears likely that SC 12/04 would have been aware of an increased risk and may have intentionally withheld information from the dive operator in order to continue with his diving. A candid consultation with a diving physician would have provided the opportunity for an independent risk assessment and might have prevented this fatality.

Had the snorkellers declared their conditions, it is likely that increased supervision would have been offered or insisted upon. However, these events might still have occurred despite closer supervision and, given that some of the rescues often appear to have been relatively prompt, the outcomes might have been the same. Although sometimes appropriate and even necessary for the safety of the individual and/or others, it can be difficult for an operator to dissuade a keen customer from snorkelling or diving, as indicated in SC 12/09. It is worth noting that recent changes have been made to the Code of Practice relating to snorkelling in Queensland. These include strengthening the declaration process, a requirement for snorkellers identified as high risk (according to health or swimming ability) to use a flotation device, use of a clearly-marked snorkel and allocation to a buddy pair. The requirement for commercial operators to carry an AED has also been strengthened.[20] Although supportive of the changes, these authors have reservations about their impact in the absence of better-targeted medical screening and improved supervision, as discussed below.

Table 3
Chain of Events Analysis of snorkelling and compressed gas diving-related fatalities in Australian waters in 2012; CAGE – cerebral artery gas embolism; He – helium; IPE – immersion pulmonary oedema; OoG – out of gas

Case	Predisposing	Trigger	Disabling agent	Disabling injury	Cause of death
BH12/01	Planning	Unknown	Unknown	Asphyxia?/IPE?	Drowning
BH12/02	Health	Environmental/ Exertion	Medical	Cardiac incident?	Drowning
BH12/03	Health	Unknown	Unknown	Asphyxia?	Delayed drowning
BH12/04	Health	Environmental/ Exertion	Medical	Cardiac incident	Cardiac-related
BH12/05	Health	Environmental	Medical	Cardiac incident	Cardiac-related
BH12/06	Health/Planning	Environmental	Medical?	Asphyxia	Drowning
BH12/07	Supervision	Unknown	Unknown	Asphyxia	Drowning
BH12/08	Organisational	Environmental	Unknown	Unknown	Unknown
BH12/09	Planning/Activity	Extended apnoea	Apnoeic hypoxia	Asphyxia	Undetermined (Drowning?)
BH12/10	Equipment	Unknown	Unknown	Asphyxia?/ Cardiac incident?	Undetermined (Drowning?)
BH12/11	Organisational/ Experience/Skills	Exertion	Medical	Asphyxia	Drowning
BH12/12	Organisational/Planning & Supervision/Health?	Environmental/ Exertion	Medical	Cardiac incident	Drowning
BH12/13	Planning/Activity	Extended apnoea	Apnoeic hypoxia	Asphyxia	Drowning
BH12/14	Equipment/Experience/ Skills	Gas supply	Buoyancy	Asphyxia	Drowning
SC12/01	Equipment/Heath/ Supervision	Unknown (gas supply?)	Ascent?	CAGE?	Drowning
SC12/02	Health/Equipment/ Planning	Environmental/ Exertion?	Medical	Cardiac incident	Drowning
SC12/03	Health	Environmental/ Anxiety	Medical	Cardiac incident	Drowning
SC12/04	Health	Environmental	Medical	Cardiac incident/ SDPE?	Cardiac-related
SC12/05	None identified	Environmental	Gas supply	Asphyxia	Drowning
SC12/06	Equipment/Experience	Equipment	Environmental/Equip/ then OoG/Impact	Asphyxia	Drowning
SC12/07	Activity	Environmental	Environmental (shark attack)	Trauma	Trauma
SC12/08	Health	Gas supply	Equipment	Asphyxia	Drowning
SC12/09	Skills/Planning	Buoyancy/ Diver error	Gas supply/Buoyancy	Asphyxia?	Drowning?
SC12/10	Health	Environmental	Medical	Cardiac incident	Cardiac-related
SC12/11	Health/Activity	Gas supply	Gas supply	Asphyxia (He)	Asphyxia (He)
SS 12/01	Organisational/Training/ Experience/Supervision	Unknown	Unknown/Gas supply?/Ascent?)	Asphyxia?/ CAGE	Drowning

APNOEIC HYPOXIA

At least two (BH 12/09 and BH 12/13) and possibly three (BH 12/06) deaths appear to have been associated with apnoeic hypoxia. As is typical, these cases occurred in relatively young, experienced spearfishermen who were diving with others, but with poor oversight. The 'one-up, one-down' breath-hold buddy system was not used and in all cases body recovery was delayed. Unfortunately, the police reports gave no indication of whether or not the divers practiced pre-dive hyperventilation. This should be a routine question of buddies in such investigations as it can provide important educative information.

SEA CONDITIONS

Adverse sea conditions, in particular strong currents, were contributory in at least three snorkelling and two compressed gas fatalities. In some of these, the exertion involved probably precipitated a cardiac event. In others, it likely led to exhaustion with subsequent aspiration and drowning. All divers and snorkellers, even those with considerable experience, should never be complacent about the potential impact of a strong current and should carefully consider how to manage it if they proceed with the dive. Commercial operators need to be mindful of the conditions into which they permit their customers to snorkel or dive.

SUPERVISION

In at least two cases in this series (BH 12/08 and BH 12/11), inadequate supervision in commercial snorkel operations was identified as a concern. This is a recurring theme in these reports. With groups often ranging from 20–30 snorkellers or more to observe, it can be difficult for a lookout to recognise a problem, especially if they are relatively inexperienced, tired or distracted. There is a need to ensure that there are sufficient lookouts to effectively supervise an area, considering the size, shape and geographical features of the site, the prevailing conditions, the number of snorkellers and the effectiveness of the vantage point. These lookouts need to be adequately trained in appropriate observation and monitoring techniques,[21,22] remain vigilant at all times and be relieved at regular intervals to avoid fatigue or complacency.

Lifeguards patrolling pools or beaches are trained in methods to detect a swimmer in distress and these techniques are directly applicable to surface lookouts for snorkelling and diving activities and should be reviewed and adopted by the latter.[23] Prompt identification of a distressed or unconscious snorkeller, together with rapid rescue, will maximise the chances of survival. However, substantial delays in recognition do occur as it can sometimes be difficult to determine whether or not a motionless snorkeller is unconscious or just quietly observing the scene below. It is not uncommon for distressed and exhausted swimmers, snorkellers and divers not to wave or call for help. Lookouts need to be aware of this; it is better to have a high index of suspicion and run the risk of over-reacting. In addition, suitable rescue techniques need to be identified and practiced to ensure that they can be done swiftly and effectively when needed. Of interest, the use of flotation aids by snorkellers can be beneficial but incidents still occur, as evidenced in BH 12/11.

AED USE

AEDs were attached to at least seven of the snorkellers and one of the scuba victims. In six cases, the AED reported that there was no shockable cardiac rhythm. In one case, two belated shocks were advised and given, albeit unsuccessfully. There were no details about the AED advice or action in the other incident. In most cases, it is appears that the AED was attached at least 10 min after the victim was discovered unconscious, so the likelihood of successful defibrillation was low.[24] It would be valuable to collect data on AED use in the diving environment, including the likely timings from unconsciousness to the attachment of the AED, for police and other on-site investigators and details of the advice provided by the AED and any shocks given.

BUDDY SYSTEM

Consistent with many other fatality reports, the lack, or failure, of an effective buddy system may have influenced the outcome in at least six of the snorkelling and at least two of the scuba diving incidents. In some incidents separation was intentional while in others it was unintended. Buddy separation can often occur unintentionally underwater due to buoyancy issues, as evidenced with SC 12/09.

OVERWEIGHTING/BUOYANCY MANAGEMENT

Overweighting was likely a contributory factor in the deaths of BH 12/14 and SC 12/09. Both individuals were described as slightly-built, the weights worn seemed disproportionate and both had problems with managing their buoyancy. It is concerning that SC 12/09 had such poor buoyancy control skills after having completed 55 dives, as indicated by her uncontrolled ascent on the dive prior to her death and the problems described by the buddy on previous dives. Correct weighting and good buoyancy control are important tools for safe diving and need to be mastered early. They are especially important on deeper dives with the associated variations in buoyancy with depth.

EQUIPMENT

Faulty equipment in the form of a poorly assembled alternative air source was the trigger for the death of SC 12/06. It is likely that this relatively inexperienced victim assembled the regulator himself and failed to secure it properly. Although many divers assemble and adjust some components of their equipment, they need to have the

knowledge, skills and care to do this correctly. In the absence of these, it is better to take the gear to their dive shop and have it done by someone with appropriate expertise. Faulty gauges might have contributed to the deaths of SC 12/01 and SC12/08 who were both found with very little remaining air. It is unknown whether or not these divers were aware of their inaccurate gauges. Equipment-related problems are commonly reported to be associated with diving incidents, whether fatal or non-fatal.[25–29] The importance of having well-maintained and correctly functioning diving equipment is obvious.

IMMERSION PULMONARY OEDEMA (IPE)

IPE was discussed by the authors as a possible contributing factor or differential diagnosis in several of the above cases. However, a definitive diagnosis can be elusive in the absence of a clear clinical history, as autopsy findings can readily be attributed to cardiac disease or drowning.

LEFT VENTRICULAR HYPERTROPHY

Eight of the victims in this series were noted at autopsy to have LVH of varying degrees. Up to five of these may have been disabled by an arrhythmia. LVH is a known risk factor for sudden cardiac death and individuals with LVH have an increased incidence of serious arrhythmias.[5,30,31] The cardiovascular effects of immersion may increase the likelihood of an arrhythmia[32,33] and being in the hostile environment will reduce the chances of survival. In a comparative study of matched scuba diving and traffic accident victims, both heart mass and left ventricular wall thickness were greater in the scuba victims.[8] This may suggest that LVH is a risk factor for sudden death while diving. However, most studies on the physiological effects of immersion have been done on relatively young, fit individuals. Further research is needed on more elderly individuals with medical conditions and multiple medications.

Conclusions

There were 26 reported diving-related fatalities during 2012, 14 occurred while snorkelling and/or breath-hold diving and 11 while scuba diving; one diver died while using SSBA in a commercial pearl diving setting. Contributory or causal factors included pre-existing medical conditions (predominantly cardiac); poor organisation, planning and supervision; equipment-related problems; snorkelling or diving alone or with loose buddy oversight and apnoeic hypoxia. With snorkellers, the main disabling injuries were asphyxia and cardiac causes while, in compressed gas divers, asphyxia, cardiac causes and CAGE were identified. There were several cases where IPE was a possibility but there was insufficient evidence to confidently support this. LVH was noted at autopsy in almost one third of the victims, many of whom appeared to have been disabled by an arrhythmia. This is an area deserving further research. Factors that may reduce mortality include routine fitness-to-dive assessments in older divers by doctors with relevant training, improved supervision in commercial snorkelling operations; better assessment of the suitability of sea conditions; improved buddy oversight and avoidance of pushing breath-hold limits, especially without direct supervision with rapid response.

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