Original articles

Provisional report on diving-related fatalities in Australian waters 2003

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

Abstract

(Walker D, Lippmann J. Provisional report on diving-related fatalities in Australian waters 2003. *Diving and Hyperbaric Medicine*. 2009;39:4-19.)
An individual case review of the diving-related deaths that were reported to have occurred in Australia in 2003 was conducted as part of the combined Project Stickybeak / DAN Asia-Pacific dive fatality reporting project. The case studies were compiled using reports from witnesses, the police and coroners. In each case, the particular circumstances of the accident are provided, as well as details from the post mortem examination, where available. In total there were 22 reported fatalities, 18 men and four women. Twelve deaths occurred while snorkelling and/or breath-hold diving, nine while scuba diving and one while using surface-supply breathing apparatus. Cardiac-related issues were thought to have contributed to the deaths of six snorkel divers (50%) and four scuba divers (44%) in this series. There were three deaths in breath-hold divers likely to have been associated with apnoeic hypoxia blackout. Inexperience, time away from diving and lack of common sense were features in several scuba deaths.

Introduction

Diving is a potentially dangerous recreational activity and each year in Australia (and elsewhere) there are fatalities associated with it. Some of these accidents are unavoidable. However, many of these fatalities could have been avoided through better education, greater experience, appropriate medical screening, better equipment maintenance and design, a sounder attitude and common sense. The aim of the DAN Asia-Pacific Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future.

Douglas Walker has reported on Australian diving fatalities since 1972 through Project Stickybeak, which has arguably been the most thorough on-going investigation of diving fatalities anywhere in the world.[1–6] The Divers Alert Network Asia-Pacific (DAN AP) is now collaborating with Dr Walker to ensure that these investigations and reports continue well into the future.

This report includes the diving-related fatalities between 1 January and 31 December 2003 that are recorded on the DAN AP database.

Methods

As part of its on-going research into, and reporting of, general diving fatalities in Australia and elsewhere in the Asia-Pacific region, DAN AP has obtained ethical approval from the Human Research Ethics Committee, Department of Justice, Government of Victoria, Australia to access and report on data included in the Australian National Coronial Information System (NCIS). A comprehensive search was made of NCIS to identify all diving-related cases that were reported to various State Coronial Services for the year 2003.

The other major source interrogated was the DAN AP dive fatality database for scuba diving fatalities occurring in 2003. DAN AP staff routinely monitors a variety of internet sites and newspapers for diving and snorkelling fatalities. DAN sometimes also receives reports from the diving community when a fatality has occurred.

Snorkelling and breath-hold diving fatalities

CASE BH 03/01

The victim, a 23-year-old male, was on a day trip to the Great Barrier Reef (GBR) as part of a large group. After stating that they were strong swimmers and experienced snorkellers, the victim and another person were permitted to snorkel independently from the rest of the group. Sea conditions were reported to be good.

After diving at a first site without mishap, the group moved to another area of reef where some of the scuba divers later reported seeing a breath-hold diver at 7–8 msw, swimming in a normal manner. When they later passed this area again, they noticed the victim lying on the coral at the edge of the reef drop-off, with his weight belt still in place. He had

reportedly been underwater about two minutes before being brought back to the surface. Attempts at resuscitation (basic life support, BLS) were unsuccessful.

Autopsy: The autopsy confirmed drowning in an otherwise healthy man.
(Height = 192 cm, Weight = 81 kg, BMI = 22)

Comment: This victim was seen to do multiple breath-hold dives to around 6 msw including horizontal swimming at depth. Although he wasn't seen to hyperventilate, it is possible that he was a victim of apnoeic hypoxia with or without hyperventilation.

Summary: Experienced; multiple breath-hold dives alone; unconscious on the sea bed; drowning.

CASE BH 03/02

Two days before starting his vacation to Australia, this 68-year-old man arranged a 'check up' by his doctor, who was controlling the treatment of his mild Parkinsonism and the follow-up of his cerebrovascular accident four years ago and two TIAs two years ago, from which he had residual limitation of his speech and mobility. A year prior, he successfully underwent surgical closure of an atrial septal defect (ASD). He was advised that it was safe for him to make this trip.

After a briefing, the group was taken out to the GBR to stay on a moored boat. On arrival, they were each issued mask, snorkel and fins. The victim also obtained a foam-type floatation device to wear round his waist because he was not a confident swimmer. Although the dive organization later mentioned that he had not stated his health problems on the medical questionnaire, he had a significant disability that was obvious to all.

Obeying the advice to swim with a buddy, the victim entered the water with his wife and then swam around for about 15 minutes. There was a slight current and they drifted about six metres apart. When he failed to respond to her call, his wife swam to him and found him face-down and unconscious. She turned him face-up and called for assistance. One of the crew reached them and started in-water rescue breathing whilst the victim was taken back to the boat. Despite the arrival by helicopter of paramedics, resuscitation was unsuccessful. His wife revealed his medical history and that he was taking warfarin sodium, sarbidopa-levodopa, pramipexole dihydrochloride, and rasagiline, the latter being an experimental drug for Parkinsonism.

Autopsy: There was no evidence of trauma, jellyfish stings, or drowning. Examination of the lungs and intracranial cavity showed no abnormalities apart from some atheromatous changes in the cerebral arteries (40% stenosis). The heart was enlarged, 478 grams, and slightly dilated; the surgical repair to the ASD appeared unremarkable. There were significant atheromatous changes in the anterior descending (70% stenosis) and circumflex branches (90% stenosis) of the left coronary artery. The right coronary artery was only 50% patent. Histology revealed patchy fibrosis of the left ventricle. Both the description of the incident and the autopsy supported a diagnosis of a cardiac death.
(Height = 170 cm, Weight = 75 kg, BMI = 26)

Comment: This appears to be a death that could have happened at any time, as the coronary artery disease would have put him at high risk of an acute ischaemic event triggered by exertion, although this risk is somewhat reduced by the fact that he was anti-coagulated. This event may have been an acute myocardial infarction (AMI) or possibly an immersion dysrhythmia. Rasagiline and pramipexole (associated with falling asleep during driving and other activities of daily living) are known to alter vascular activity and how this is affected by immersion is unknown. The type of buoyancy aid provided assisted him when alert but was potentially lethal when consciousness was lost, floating him face down. The effect of Parkinson's disease in movement and swallowing function should not be overlooked and his fitness for undertaking snorkelling activity is questionable.

Summary: History of cardiovascular disease; atrial septal wall closure and Parkinson's disease; wore floatation device as not confident swimmer; silent unconsciousness; probable cardiac death.

CASE BH 03/03

The victim, a 28-year-old male who was reportedly a healthy, competent swimmer and divemaster, was with friends on a boat anchored about 80 metres from shore in water about 16 metres deep. During lunch, the victim was noted to consume about four gin-and-tonics but did not appear to be adversely affected by them. When the others took the tender to the fringing reef, he remained aboard the boat for about 15–20 minutes, and then swam out to join them, a distance of 60–80 metres. It is not known whether he had continued to drink alcohol in the interval. He was using a mask and snorkel but no fins. The sea conditions were reported to be good.

The water over the reef, which was about 20 metres from the beach, was approximately 3 msw deep. After about an hour, the victim said he was going to swim back to the boat. The water was calm and the current minimal. When the others returned to the boat about 20 minutes later they were surprised not to find him there. He had not been seen to dive below the surface during his return swim on the occasions anyone had looked towards him. After checking that he was not on any of the other boats anchored nearby, the police were notified and a search commenced. A little over two hours from when he was last seen, his body was found on the sea bed in 15 msw; his mask was in position, clear of water. BLS was attempted for a short time after he was brought ashore.

Table 1. Summary of diving-related fatalities (BNS – buddy not separated, BSB – buddy separation before incident,

ID BH	Sex	Age (years)	Training	Experience	Dive group	Dive purpose
03/01	male	23	n/s	experienced	solo	recreation
03/02	male	68	nil	nil	BSB	recreation
03/03	male	28	yes	experienced	GSB	recreation
03/04	female	66	n/s	n/s	BNS	recreation
03/05	male	25	n/s	experienced	solo	recreation
03/06	male	51	nil	nil	BSB	recreation
03/07	male	54	n/s	nil	GSB	spearfishing
03/08	male	61	nil	experienced	BSD	crayfishing
03/09	male	85	nil	nil	GSB	recreation
03/10	male	35	yes	experienced	GSB	spearfishing
03/11	male	65	nil	some	GSB	recreation
03/12	male	31	n/s	experienced	solo	recreation

Autopsy: The cause of death was determined to be drowning and no disease was present. The coronary arteries were described as being 'normal'.
(Height = 175 cm, Weight = 73 kg, BMI = 24)

Comment: The blood alcohol level was found to be 150 mg per 100 ml blood. Surprisingly the pathologist omitted mention of this finding from his formal report. Alcohol may have been a contributory factor to this death. The victim was not wearing fins and this would have impaired his swimming ability and also may have been an adverse factor.

Summary: Experienced; reportedly healthy; ingested substantial amount of alcohol prior to snorkelling; found dead on sea bed; drowning (possibly alcohol-related).

CASE BH 03/04

The victim, a 66-year-old overseas tourist, was due for review by her cardiologist when she returned home and expected to then be advised to have a cardiac operation. It was later revealed she had atrial fibrillation (AF), an ASD, pulmonary stenosis and asthma (her dominating concern). Her doctor had reportedly cleared her to travel on this holiday but it is unknown whether she had mentioned her intention to snorkel.

The victim and her companion were staying at a resort island and went snorkelling in front of their unit. After hiring equipment from the dive shop, they swam in the waist-deep water about 20 metres off the beach, looking at the coral. After about 10 minutes, the victim suggested that they return to the beach but when they were 10 metres from shore, she stood up and asked for help. Her friend noticed her breathing was laboured and lips blue. After helping her ashore, she sat her down upright and fetched her 'Ventolin' inhaler. The victim was scarcely able to depress the inhaler or to inhale, and was gasping. Help and oxygen were quickly brought from the resort's medical centre. Although the victim was unable to answer any questions, her friend was sure that she had not swallowed any water. Her condition initially appeared to improve and she was moved to the medical centre. A radio call was made for medical advice and assistance and paramedics were dispatched by helicopter. A doctor holidaying on the island attended her, but she became unconscious and failed to respond to BLS.

Autopsy: No autopsy was conducted given her known medical problems. The death certificate stated that death was due to cardiac arrhythmia associated with an ASD and pulmonary stenosis.

Comment: This victim was at risk of a cardiac event at any time during her normal activities. There is nothing to suggest

in Australian waters in 2003, snorkel and breath-hold incidents
BSD – buddy separation during incident, GSB – group separation before incident; n/s – not stated)

Depth of water (msw)	Incident depth (msw)	Weight belt	Weights (kg)	Floatation device	Cause of death
15	n/s	yes	4.5	no	drowning, ? hypoxic blackout
n/s	surface	no	n/a	yes	cardiac
15	unknown	no	n/a	no	drowning, ? alcohol-related
1	surface	no	n/a	no	cardiac
20	ascent (presumed)	no	n/a	no	drowning, ? hypoxic blackout
9	surface	no	n/a	no	? cardiac
2	surface	off	n/s	no	cardiac
n/s	surface	off	n/s	no	cardiac
n/s	surface	no	n/a	yes	cardiac
25	ascent (presumed)	yes	6	no	drowning, ? hypoxic blackout
n/s	surface	no	n/a	no	drowning, ? cardiac
n/s	n/s	no	n/a	no	unknown

her swimming required more than mild exertion. This death could have been a result of immersion arrhythmia or salt-water-induced asthma. An autopsy would have been of benefit in assessing the most probable cause of death.

Summary: History of AF, ASD, pulmonary stenosis and asthma; respiratory distress while snorkelling; cardiac failure, possibly resulting from cardiac arrhythmia.

CASE BH 03/05

The victim was a 25-year-old male who was an experienced breath-hold diver and the skipper of a charter vessel on the GBR. He challenged a divemaster to a breath-hold diving competition which the divemaster refused. After donning mask, snorkel and fins, the victim entered the water and began to hyperventilate before diving. The divemaster was heard to advise him to stop hyperventilating, but was ignored. After he failed to surface, an unsuccessful underwater search was made. The body was never found. On the basis of the witness statements, it was decided his death had likely resulted from post-hyperventilation apnoeic hypoxia leading to drowning.

Summary: Experienced; last seen hyperventilating prior to breath-hold diving; body never found; probable drowning due to post-hyperventilation apnoeic hypoxia.

CASE BH 03/06

The victim was a 51-year-old male who had never previously used a snorkel. He was aboard a friend's charter boat. The sea was somewhat choppy on the trip out and he became unwell, this being thought to be sea sickness. He said he was feeling better when they anchored at a reef, and even ate a little food. The skipper provided the victim and a companion with mask, snorkel and fins. Before they entered the water, the victim told his buddy that he had never previously used a snorkel. The water was still choppy, enough to occasionally enter a snorkel as one swam along. After they reached a coral bommie about 30 metres from the boat, the victim told his buddy he was managing better without using the snorkel. He seemed well to his buddy, who then dived to photograph fish. After he had finished taking pictures, he saw his companion was no longer close to him but was about a third of the way back to the boat, swimming freestyle. He appeared to be alright. The buddy decided that he would also swim back. They had only been in the water 10–15 minutes. When he soon overtook his friend, he noticed he had slowed down and his arm movements were sluggish. The buddy then saw they were being taken further from the boat by the current but that the crew was pulling up anchor. He reached the boat before its engine started and was taken aboard.

The skipper had watched them as they swam around the bommie. He saw the buddy dive and the victim start swimming towards the boat. He called out to the latter to wait to be picked up, and indicated this with his hand. He saw him stop swimming and lie quietly face-down at the surface, his snorkel sticking out of the water. While the buddy was coming aboard, the skipper had continued watching the other swimmer and became concerned when he realized he was too still so he quickly went to him. When they got him aboard they saw he was pallid with no signs of life, so commenced BLS. Despite the arrival of a doctor and some advanced life support (ALS) procedures, he could not be resuscitated.

Autopsy: The autopsy report notes there was blood in the pericardium, a fractured sternum, and blood in the mediastinum, and traumatic injury to the right ventricle, the result of vigorous BLS. There was early coronary atherosclerosis with 25% narrowing of both proximal and distal vessels, which, combined with the clinical story, was the basis for attributing death to cardiac arrhythmia.
(Height = 180 cm, Weight = 83 kg, BMI = 26)

Comment: It is probable the victim was unaware of the degree of his ill health and incorrectly ascribed his condition to sea sickness. The 25% narrowing of the coronary arteries should not be haemodynamically significant and the diagnosis of arrhythmia would appear rather speculative. His total inexperience in the use of a snorkel can be considered a significant adverse factor.

Summary: First use of snorkel; feeling unwell; swam against current; separation; silent unconsciousness; possible cardiac arrhythmia.

CASE BH 03/07

This victim was a 54-year-old male with a history of hypertension, profound deafness and surgery to both shoulders which had left him unable to raise his arms higher than his shoulders. He went spearfishing with two friends, who were also deaf, and had been loaned a wetsuit and all the other equipment except fins, which were his own. His spearfishing experience was not recorded but he was reported to be a good swimmer and had apparently done some scuba diving. The three men swam out in relatively calm conditions to where the water was about two metres deep. After about five minutes, the victim said he was going back to the beach. He gave no reason and showed no sign of having any problems, giving an 'OK' sign when asked. They saw him swim towards the beach and a few minutes later stand up and give another 'OK' signal. Believing that he was safely on the beach, the other two continued spearfishing for 20–30 minutes. As the victim was not on the beach when they returned, they thought that he had gone to their camp. It was only after they asked his wife where he was, and noticed that none of his gear was around, that the alarm was raised.

A man fishing off the rocks saw the three men enter the water and swim out past his line. A short time later, he saw one of them swimming freestyle back to the beach, the other two continuing away from the beach area. The solitary swimmer seemed to stand up, or float upright, when about 100 metres offshore. When he next looked, possibly 10 minutes later, he saw this swimmer was now 50 metres from him and floating away in the current and swell. He couldn't see his snorkel, or any kicking movements. This worried him and he called another fisherman nearby to come over and give his opinion. However by the time he came the person could no longer to be seen, then this man said he could see three heads out to sea and the two fishermen believed there was no cause for worry and so took no action. A search of the island and the water lasting several days was unsuccessful beyond recovery of his hand spear. The body was washed ashore 10 days later.

Autopsy: Moderately severe coronary atherosclerosis was reported, the left anterior descending showing 70–80% narrowing, the right coronary 60–70%. The pathologist stated his opinion that this was normal for someone of his age. The histology showed "*Autolysis 3+ myofibrosis, coronary artery - severe atherosclerosis*". The cause of death was recorded as being due to severe coronary atherosclerosis.
(Height = 162 cm, Weight = 85 kg, BMI = 32)

Comment: It is unknown whether the outcome would have been any different if the victim's buddies had escorted him to shore. However, it is important to establish and maintain a good 'buddy system' while snorkelling.

Summary: History of hypertension, deafness and bilateral shoulder operations; some experience; spearfishing; separation; last seen standing in shallow water; severe coronary artery disease, cardiac death.

CASE BH 03/08

The victim was a 61-year-old male who was an experienced spear fisherman. He was overweight, with hypertension, hyperlipidaemia, and liver changes. He had been prescribed ramipril and xenicol, but only took these sporadically. He had also undergone bilateral hip replacements successfully three years prior.

His buddy described how they knew this dive area well, that there was a relatively easy walk to a rock ledge, a requirement because of the victim's portly nature and residual hip disability. The buddy had to put his friend's fins on for him because he had difficulty in reaching down while standing on the slippery rock surface. They had donned their wetsuits in their car and carried their equipment to the water's edge. After entering the water they swam out to calm water beyond the turbulent area near the rocks, about 20–25 metres, where they stopped to adjust their equipment and load their spear guns. The victim was wearing a new weight belt with which his buddy saw he was having trouble. He

removed it and handed both it and his speargun to his buddy and started to swim back to the area where they had entered the water. The buddy was used to being given the task of holding his friend's equipment and followed him back.

The current had carried them a little, so where they reached the reef its edge was about 2.5 metres vertically above the partially submerged ledge on which the victim rested, gripping its edge and seeming to be working his way along it. The buddy found an easier exit area a short distance away and deposited their equipment on rocks out of the water. He looked round and saw the victim floating 20 metres away and thought he saw him swimming but when he swam out to him he realised the victim's mask was on his forehead, he had lost one fin and was unconscious, floating with his mouth and nose out of the water. The buddy towed him back to the rocks keeping the victim's face out of the water and calling for help. People on the rocks helped pull the victim out of the water and BLS was commenced and continued for a time after ambulance officers arrived, but was unsuccessful.

Autopsy: Autopsy measurements confirmed his obesity. There was no evidence of either old or recent ischaemic myocardial damage. The right coronary artery was widely patent with only mild atherosclerosis. However, the anterior descending and circumflex branches of the left coronary artery showed approximately 70% and 50% narrowing respectively. Atherosclerosis was only mild in the distal aorta but the circle of Willis was more severely involved. The wall of the right ventricle measured 5 mm, the left 20 mm, thick. Histological examination showed severe fatty changes in the liver and there were scattered areas of fibrosis in the myocardium. The pathologist gave severe ischaemic heart disease due to coronary atherosclerosis as the cause of death. (Height = 183 cm, Weight = 124 kg, BMI = 37)

Comment: The victim was unfit, reportedly neglected to follow the medical treatment prescribed for him, and failed to appreciate the physical demands of his activity. If the loss of a fin occurred while the victim was conscious it would have reduced his swimming ability and increased exertion.

Summary: Obese; history of hypertension, hyperlipidaemia, some disability following bilateral hip replacements, fatty liver; spearfishing; silent unconsciousness; some coronary narrowing; cardiac death.

CASE BH 03/09

The victim was an 85-year-old male who exercised daily and was reported to have no health problems and to be generally fit and mobile for his age. He and his wife had travelled interstate to visit the GBR. While on the boat out to the reef, a talk and demonstration on snorkelling were given, and he completed a medical questionnaire. He had initially intended to scuba dive but was told that, due to his age, he would first be required to obtain a diving medical. There was another briefing on snorkel safety before passengers entered the water.

He entered the water wearing a shirt and bathers, mask, snorkel, fins and a floatation vest, all provided on the boat, he and his wife being among the last to enter the water, his wife before him. Shortly after entering the water, his wife heard a whistle blast and a shout and heard talk of an incident involving an elderly man. The victim was noticed to be floating face down in the water, not moving and with the snorkel submerged. The alarm was given and the lookout jumped into the water and swam to the victim who was about 10 metres away. BLS was unsuccessful.

Autopsy: Significant coronary atheroma was present, particularly on the left anterior descending artery, which had up to 70% narrowing caused by eccentric atheroma, with up to 65% in its circumflex branch. There was also 50–60% narrowing in the right coronary artery. There was no evidence of past or recent myocardial infarction. Mild left ventricular hypertrophy was noted; heart weight 396 gm. There was also evidence of an old cerebral haematoma, 2.5 cm greatest diameter, in the right frontal pole, with adjacent contusional damage; there is no information concerning this old injury. "*The lungs demonstrate pulmonary oedema with what appears to be terminal agonal aspiration of sea water*." Cause of death was diagnosed as a heart attack (with severe coronary atherosclerosis).

Comment: Even the apparently healthy aged can have hidden, high-risk health problems. There was significant coronary stenosis but no evidence of an infarct.

Summary: Apparently fit; elderly; inexperienced; wearing buoyancy vest; silent unconsciousness; severe coronary artery disease; cardiac death.

CASE BH 03/10

As well as being an experienced spear fisherman known locally to be a promoter of safety in that sport, the victim, a 35-year-old male, was also a scuba instructor and worked as a professional abalone diver. On this day, he was spearfishing from a boat with his girlfriend and a friend who was also an experienced spear fisherman. The friend was teaching the sport to the victim's girlfriend while the victim was spearfishing solo on the other side of the boat. After four hours, the others returned to the boat and noticed they could not see the victim come to the surface, and that his float was stationary. They attempted to pull it up and found that it was firmly attached to the sea bed. The friend dived down to find why this was so and found that the spear was through a fish and stuck in the bottom. He surfaced to relay this information and they visually checked around in the hope that the missing man had surfaced and been washed away. The friend then dived again and found the body in 25 msw near the spear, weight belt, which did not have a quick release buckle, in position. BLS was unavailing.

Autopsy: The autopsy revealed petechial haemorrhages in the conjunctivae, "intense" pulmonary oedema and right middle ear mucosal congestion. The pathologist noted an arteriovenous malformation in the brain and suggested that this had caused an epileptic seizure and possible cardiac arrhythmia (although this pathology does not appear in the autopsy report). The victim had no history of fits or ill health. The cause of death was reported to be "*immersion following an epileptiform seizure*".
(Height = 178 cm, Weight = 59 kg, BMI = 18.6)

Comment: Pulmonary oedema in a young person may arise from straining against a closed glottis (e.g., after laryngospasm). The finding of the petechial haemorrhage and pulmonary oedema raises the possibility that the victim overstayed his time underwater and drowned. The ear barotraumas are likely to have occurred as the body sank. This death may have occurred as a result of post-hyperventilation apnoeic hypoxia, rather than as a result of an epileptic event as suggested by the pathologist. The autopsy report contains no evidence that an epileptic event had occurred.

Summary: Very experienced spear fisherman; solo; no quick-release on weight belt; drowning (? seizure, ? apnoeic hypoxia).

CASE BH 03/11

The victim was a 65-year-old male, regarded as being in good health, who had recently retired after a lifetime of physical labour. After a light snack on the beach, the victim swam out about 15 metres. He then stood up in waist-deep water and said that there were things in the water biting him, before returning to the beach. Later, he joined others in the boat to check on set crab lines. He entered the water wearing loaned mask, snorkel and fins but handed back the snorkel a short time later. For some unexplained reason his daughter, who had remained in the boat, became worried and encouraged another relative to swim to check whether he had any problems. He mentioned seeing some crabs and then gave his fins to the relative who had swum to him. They swam back to the boat and, when they were about five metres from it, he ducked his head under the water then raised it and blew out. At first his relative thought he was being amusing, and then became alarmed at his expression. He was quickly brought into the boat and BLS commenced, but this was unsuccessful.

Autopsy: There was evidence of drowning and some particles of sand in the trachea but the heart and the coronary arteries were free of disease. The pathologist declared drowning as cause of death. He noted without any comment the presence of a small amount of quinidine in the blood.
(Height = 174cm, Weight = 83kg, BMI = 27.4)

Comment: The description of the incident, combined with the finding of quinidine in the blood, suggests that he may have had some form of cardiac arrhythmia, possibly initiated by inhalation of some water. There is no evidence of contact with his GP to ascertain his true health as he may have concealed this from his family. There was also a possible history of marine envenomation although the pathologist's report included no evidence of this. Either of these factors could have contributed to the drowning, but this is speculative.

Summary: Apparently healthy; sudden unconsciousness while swimming close to buddy; drowning; possible cardiac arrhythmia (taking a Class 1 antiarrhythmic agent, quinidine).

CASE BH 03/12

The victim was a 31-year-old male who went missing while snorkelling in rough water. His body was recovered the next day. No further details are available at the time of writing.

Scuba diving fatalities

CASE SC 03/01

The victim, a 51-year-old male, was on a cruise of the GBR. On his medical form he had reported he was taking medication for hypertension (analapril maleate) and that his doctor said he was fit to dive. Although he did not produce any documentation, his word was accepted. He failed to reveal he was also taking dothiepin hydrochloride for depression and that he had a history of alcoholism, suffering two 'post alcohol withdrawal' fits two years earlier. He claimed to have done over 1,000 dives over a 40-year period. Some passengers later expressed the view that the victim had boasted too much about his abilities and had expressed concern that he was uncertain if he was 'up to' doing the dive.

Four scuba divers and a divemaster were taken by tender to the dive location. Before they entered the water, they were all checked to ensure their equipment was in order, air turned on, the regulators purged, and BCD inflation and deflation tested. The victim had some problem locating his deflator and the divemaster helped him, prior to descending together hand over hand down their mooring line. Unexpectedly, at about 5 msw, the victim let go of the line and sank in an uncontrolled manner to the sea bed at about 9 msw. The instructor immediately descended after him and found that he was moving around in an uncoordinated manner and had a wide-eyed distressed stare. All his equipment was in place and he was breathing. He sat him down and tried to calm him without getting any response, but he was still breathing so he grabbed him and started to take him to the surface. However, when about half-way up, the victim grabbed the mooring line and would not let go, then grabbed the regulator from the instructor's mouth and held onto it while breathing from his own. As the divemaster started using his alternative regulator, the victim collapsed and let go of everything. The

divemaster quickly ditched the victim's weight belt and took him to the surface, applying pressure on his sternum to ensure he exhaled. The whole dive had lasted only three to four minutes.

The victim was unconscious, cyanotic and not breathing when pulled into the safety boat. His airway was checked and rescue breathing with supplemental oxygen was commenced. The return to the boat only took a minute, and a radio call was made for the emergency helicopter. BLS was successful but he remained unconscious and fitting. He was airlifted to hospital where life support was withdrawn three days later with evidence of irreversible brain damage.

Equipment checks showed it was serviceable and there was adequate remaining air but that some maintenance was necessary before it was next issued.

Autopsy: The autopsy report is limited, merely stating that there was an enlarged cirrhotic liver, enlarged heart, coronary atherosclerosis, congested lungs, and skin lesions of psoriasis. There is also a simple notation that hypertension and ischaemic heart disease were noted. No supporting details were supplied. The cause of death was reported to be congestive heart failure and cerebral hypoxia.

Comment: The autopsy report is inadequate to determine the cause of death with any certainty. As no formal inquest was held there was no discussion concerning the observed actions of the deceased. While panic was probably an important factor, it is possible a cardiac factor was present, though "*delayed drowning death, cerebral anoxic damage*" was the actual final factor. It is notable that a four-year absence from scuba diving destroyed the confidence built up over 40 years. Statements of past diving experience should not be accepted uncritically.

Summary: History of hypertension, depression and alcoholism; trained and claimed 40 years' experience; no dives in past four years; anxious; probable panic; possible cardiac event underwater; initial resuscitation successful; delayed death; congestive cardiac failure and cerebral hypoxia.

CASE SC 03/02

This victim, a 22-year-old female, was visiting Australia with her mother and brother. They joined one of the trips to a pontoon on the GBR. The siblings signed up for a 'resort dive experience', the first dive for her but her brother had scuba dived previously. The chief instructor gave a standard briefing on the basics of scuba diving, with a knowledge review at the end of the presentation. The victim was obviously nervous before the dive and she admitted to the instructor to having a claustrophobia problem. The instructor said she would accompany her for the descent, and if she felt too nervous they could abort the dive.

While sitting on the pontoon's snorkelling platform at about one metre depth, the victim practised some basic skills, such as mask clearing, under the instructor's supervision. The victim had initial difficulties with breathing but, after practising, was able to continue. At this point, and soon thereafter, the instructor had not regarded the victim's anxiety level as more than that she often noted in those making their first scuba dive. The instructor held onto the victim's hand and regularly signalled 'OK' to her and each time she indicated that she was all right.

After they had dived for 20 minutes looking at their coral surroundings, her brother noticed that she had some water in her mask and was looking anxious as she failed in her attempts to expel it. She seemed to forget to breathe. Her instructor tried to help her, but she failed to breathe out through her nose and her mask became pushed up, allowing water to enter her nostrils. She reacted by turning to a vertical position, tore off her mask in panic, and started a rapid ascent from 9 msw with her eyes closed, so was unaware of her instructor's proximity. The instructor tried to guide the victim to the ascent lines to hang on there while clearing her mask, but she ripped it off after again failing to clear it of water. The instructor held onto her trying to slow her ascent and she seemed to be breathing the whole time as bubbles were coming from the regulator's exhaust. They came to the surface together and there the instructor inflated the victim's BCD and rolled her on her back. She responded when asked how she was, but had wheezy breathing. The instructor signaled for assistance, then saw the victim's eyes roll back in her head before her arms went rigid and she became unconscious. They were near the pontoon and help soon arrived. The victim appeared to have no signs of life and BLS using supplemental oxygen was commenced after minimal delay. An automated external defibrillator (AED) was available and was attached to the victim but no shock was indicated. However, despite this, a shock was given, as was an injection of adrenalin into her heart by a doctor; all to no avail.

An investigation found no fault with the equipment or in the conduct of the instructor. There was adequate remaining air.

Autopsy: Pre-autopsy X-rays showed extensive opacification of both lung fields and bilateral pleural effusion. Surgical emphysema was present around the heart, extending up into the mediastinum and the soft tissues of the neck. There was some evidence of gas within the portal venous system of the liver, possibly due to putrefaction. The pathologist reported finding oedematous congested lungs with extensive recent alveolar haemorrhages and no other disease. The cause of death was reported to be pulmonary barotrauma.
(Height = 167 cm, Weight = 56 kg, BMI = 20)

Comment: Although the autopsy makes no mention of intravascular gas, in this witnessed event, there is sufficient

Table 2. Summary of diving-related fatalities in Australian waters in 2003, scuba and surface-supply incidents
BSD – buddy separation during incident, CAGE – cerebral arterial gas embolism

ID	Sex	Age	Training	Experience	Dive group	Dive purpose	Depth (msw)
SC							
03/01	male	51	yes	experienced (4-year gap)	BNS	recreation	9
03/02	female	22	no	nil	BSB	resort	9
03/03	female	26	yes	slight	BSD	recreation	30
03/04	male	47	no	nil	GSB	resort	6
03/05	male	29	yes	experienced	BSB	abalone	n/s
03/06	female	46	yes	experienced	BNS	recreation	29
03/07	male	56	yes	experienced	BSD	recreation	15
03/08	male	39	yes	experienced	GSD	recreation	15
03/09	male	25	partial	experienced	BSB	scalloping	10
SSBA							
03/01	male	25	no	nil	BSB	crayfishing	5

evidence to support the conclusion of cerebral arterial gas embolism (CAGE).

Summary: First resort dive; history of claustrophobia; anxious; mask flooded causing panic; collapsed and died on surface; pulmonary barotrauma (probably leading to CAGE).

CASE SC 03/03

The victim was a 26-year-old woman who was an inexperienced, recently trained diver. She and her husband, a more experienced diver, dived from a dive charter vessel in a moderately strong current on a wreck lying in 30 msw. Because the husband has been charged with the murder of the victim, no further details of this death can be reported at present.

Summary: Trained but inexperienced; first ocean dive; moderate current; reported panic separation; drowning; homicide investigation.

CASE SC 03/04

The victim, a 47-year-old male who was described as 'looking elderly and thin', was an overseas tourist on a day trip to the GBR. He completed a health questionnaire before being accepted to do a 'resort dive' along with three other people. During their outward trip to the GBR, there was a briefing on some of the basics of scuba diving. Concern was later expressed by the victim's companions that no advice was provided about buoyancy control and of the importance of correct breathing in the event of a rapid ascent. The company stated that it was its policy not to mention control of buoyancy, the instructor being responsible for making any necessary adjustments.

After an uneventful first scuba dive, including practising mask clearing and regulator recovery, the victim and some others went for a short snorkel before lunch. The boat was then moved to another reef and the same four did a second dive with the same instructor. They entered the water before making 'a fair swim' underwater to reach the reef, the instructor leading but turning to look back at them, initially frequently. They followed him in line at about 5–6 msw depth with the closest about five metres behind him. One diver noticed it seemed rather long since the last check and when he looked behind he saw only two divers. He waited a short time then checked again as the instructor had not yet looked back, and again could see only two others. He swam hard to reach the instructor to gain his attention. The instructor signaled for them to ascend, though one did not see this and followed only when he saw the others ascending.

A witness, snorkelling about 100 metres from the boat saw a diver at the surface about 25 metres from him and he also saw a tender leaving the boat. He reached the victim at the same time as the tender. The victim sank just before they reached him and the skipper, who was driving the tender, dived in and brought him to the surface. He was not breathing; his

(BCD – buoyancy compensation device, BNS – buddy not separated, BSB – buddy separation before incident, GSB - group separation before incident; depths and weights rounded

Incident (msw)	Weight belt	Weights (kg)	BCD	Remaining air	Equipment test	Cause of death
5	ditched by buddy	6.2	n/i	++	nad	drowning, ?cardiac
on ascent	on	n/s	n/i	++	nad	pulmonary barotrauma
12	on	n/s	n/i	++	nad	drowning
6 on ascent	on	n/s	n/i	++	nad	? cardiac
n/s	off	n/s	n/i	nil	multiple faults	pulmonary barotrauma and CAGE
6	on	n/s	n/i	n/s	equipment lost	? cardiac
7	on	n/s	n/s	+	nad	? cardiac, ? CAGE
15	on	13	n/i	++	nad	drowning, ? head trauma
n/s	off	≥10	n/i	n/s	lost	? drowning
n/s	on	8	nil	++	nad	drowning

mouth and face were cyanotic. The victim was lifted into the tender and brought back to the boat where BLS was commenced. There was a quick response by the emergency services, but the paramedics declared him dead shortly after they arrived.

Autopsy: Pre-autopsy X-rays showed no abnormalities. No air was found in either the blood vessels or the tissues. The heart was slightly enlarged (422 gm), the left anterior descending coronary artery had a 70% narrowing close to its origin, the circumflex and right coronary arteries showing less severe, patchy narrowing. There was no evidence of either past or recent myocardial infarction, but histology confirmed the presence of minor areas of subendocardial fibrosis. It was concluded the victim died from coronary insufficiency due to stenosis of a major coronary artery. Beyond his declaration that he had no medical problems nothing is known concerning his health history. It was concluded that "*the likely cause of death was myocardial ischaemia as a result of undiagnosed coronary artery disease but that the possibility of CAGE as the precipitating event cannot be excluded*".
(Height = 178 cm, Weight = 86 kg, BMI = 27)

Comment: This incident highlights the importance of close supervision of all trainee divers by the supervising instructor. This problem is expanded upon in the discussion.

Summary: Second resort dive; separation from instructor and group; inadequate supervision; no instruction on use of BCD or ditching weight belt; surfaced but became unconscious and sank; probable cardiac death

CASE SC 03/05

Two friends were to scuba dive as they usually did, that is, independently. The victim, a 29-year-old male, was described by his buddy as being experienced, having qualified 12 years earlier and with about 24 dives over the past two years. However, he had taken a break from diving although no details of the length of this break are available.

The two scuba divers swam out from a beach to beyond the zone of rougher water near the beach. They separated early in the dive and the other diver returned to shore alone. He was not at first worried by his friend's absence, as they had dived 'together' previously about a dozen times and the victim had always swum back to shore using his snorkel when out of air. However, after half an hour he became anxious at his friend's continued absence. Sometime later, after a boat joined the search, the victim was found floating face down 100 metres from shore, weight belt off and BCD deflated. It is uncertain whether his mask was missing when he was found or was lost while he was being pulled into the boat. An attempt was made to resuscitate the victim but was soon abandoned.

When examined, the equipment was in poor condition and had been assembled incorrectly. The cylinder valve was an old 'J-valve' type which, being in the 'up' position, should

have prevented access to the final 35 bar of air in the cylinder. However, there was insufficient air in the cylinder to register on the contents gauge. The BCD inflator button was stuck 'on', causing a free-flow and it had several obvious leaks. The first-stage regulator had widely fluctuating intermediate line pressures, the second stage free-flowed and the mouthpiece had several holes in it. The report concluded that the holes in the mouthpiece would result in a fine spray of salt water with each inhalation, and BCD malfunctions would have made it difficult for the diver to control buoyancy.

Autopsy: Pre-autopsy full-body CT scan showed gas in the cerebral arteries and a large amount in the ascending aorta and left ventricle, a small amount in the right ventricle and the inferior vena cava, quite a large amount in the liver, some in the anterior spinal region, a small amount in the psoas muscle and prostatic plexus, but none in the major leg muscles. The heart and coronary arteries were healthy. It was found that "*the deceased died as a result of drowning, following a CAGE due to pulmonary barotrauma*". (Height = 182 cm, Weight = 69 kg, BMI = 21)

Comment: The combination of a small cylinder, equipment in poor condition, a habit of diving until the cylinder was empty, the J-valve in its 'closed' position, and solo diving, was a prescription for trouble. Unfortunately the CT scan was performed three days after death. Delays of greater than eight hours are likely to result in post mortem off-gassing. Gas in the psoas suggests post mortem off-gassing.

Summary: Trained; experienced; little recent diving; planned separation; multiple equipment faults; weight belt off; BC deflated; drowning as a result of CAGE.

CASE SC 03/06

The victim, a 46-year-old woman, had been diving for two years, taking several further courses and completing 123 dives since her basic course. She had also gained 12 kilos in weight. There had been no adverse comments at her diving medical concerning her weight or health, but now she had a BMI of 42. A friend later reported that she had become breathless on exertion on a number of occasions while getting ready for dives. However, she had recently made several dives on an overseas diving holiday without obvious problems.

She and three friends had joined a boat charter to dive a 60 msw deep wall, their dive plan being a 30-minute bottom time to a maximum depth of 30 msw. They planned to dive as a group of four, but just before they entered the water they were asked to accept a fifth diver. They swam to the shot line and descended to 29.4 msw, where they noticed that one of the group was missing. They separated into two buddy pairs, one pair ascending to find the fifth diver. Visibility was 6 metres and there was a weak downwards current. The victim and her buddy swam at about 27 msw for about seven minutes along a wide ledge until the buddy indicated they should commence a slow ascent up the wall. The victim appeared to be having no problems. When they reached the top of the wall the buddy indicated that he wanted to swim away from the shot line but the victim signaled that she wanted to ascend. At about 10 msw her buddy indicated to her that the shot line was behind her and she swam to it and used it in her ascent, her buddy utilising the reel from his surface marker buoy which he had deployed. They made a safety stop at 5–6 msw, but after only two minutes she continued her ascent to the surface.

She was seen to surface at the shot line and spent some time holding onto the buoy in the relatively strong current. Her buddy surfaced shortly after her and the boat collected him first. The skipper got no response from her but noted she still had the regulator in her mouth and mask in position. A rope was thrown to her and she relinquished the buoy and swam the 5–10 metres to reach it. She was pulled to the boat but was unable to climb the ladder. There was blood or vomit on her chin and the regulator was out of her mouth. It was necessary to ditch her equipment before it was possible to pull her aboard. The equipment was never recovered. She was not breathing at this time and her face was cyanotic. Rescue breathing was commenced and was complicated by regurgitation of the victim's stomach contents. BLS was started when no pulse could be palpated. A radio call was made for assistance while the dive boat returned to land. Paramedics met the boat on arrival at the jetty but ALS was unsuccessful.

Autopsy: The autopsy revealed moderate cardiac enlargement and greater than 90% stenosis of the diagonal branch of the left anterior descending coronary artery. The pathologist suggested a sudden lethal arrhythmia occurred in the context of the exertion of this dive, and noted that her obesity was a significant factor. No evidence of any pulmonary barotrauma or CAGE was found. (Height = 171cm, Weight = 123kg, BMI = 42)

Comment: This diver was very obese and reportedly easily breathless; scuba diving was, therefore, contra-indicated as an activity.

Summary: Trained; experienced; obese; previous reports of breathlessness; severe coronary stenosis in one vessel; cardiac death.

CASE SC 03/07

The victim was a 56-year-old experienced male with a history of acute myocardial infarction (AMI) some 20 years earlier but who apparently had had no problems since that time, despite being very overweight. He was on a club dive with 13 divers, all trained and experienced, travelling in several boats.

They made an uneventful first dive before relocating to a flat,

calm area for an unhurried lunch. The victim and two others then did another dive, descending the anchor line to the sea bed at 14.6 msw, then swam deeper in line abreast with the victim in the middle. The visibility was 5–7 metres and one of the trio soon became separated while the victim helped his other buddy to refasten one of his fins. When this was done, they noticed that the other diver was missing and agreed to ascend. As they were ascending, the buddy again found the strap on one fin had come free and the victim helped him thread the strap through its buckle. As they ascended, they became separated at 6–8 msw depth. It was only when the buddy boarded the boat that he saw his friend floating face down about 100 metres away.

The victim was seen at the surface by several people in the boats, lying motionless on his side. When it was realised that he was unconscious, one person jumped into the water and started to give rescue breathing while others ditched his weights and pulled him into one of the boats. He did not respond to BLS or ALS once ashore.

Examination of the equipment showed the remaining air pressure was 134 bar and that the equipment was functional when test dived, though on dry land the valve on the BCD tended to stick open. This fault was thought to be the result of the presence of salt and not to have happened during the ascent.

Autopsy: The significance of coronary atheroma, which was producing some areas of 25 to 50% narrowing, was uncertain. There were no haemorrhages, plaques, or thrombi occluding their lumen. The right side of the heart showed distension by gas and both ventricles contained a very limited amount of frothy blood. There were a number of rib fractures due to the resuscitation efforts. Histology showed focal fibrosis in the left ventricle but no acute ischaemic lesions were identified. The victim was described as being moderately obese. The liver weighed 2,530 gm and it was diffusely enlarged without evidence of mass lesions or cirrhosis, histology showing mild macrovesicular steatosis.

The pathologist, who was familiar with the diving factors in such fatalities, consulted with several colleagues but the differential diagnosis could not be resolved between a cardiac event, CAGE, or possibly the reflex response to inhalation of cold water (the water temperature was 17°C). (Height = 172 cm, Weight = 120 kg, BMI = 41)

Comment: The history is not overly suggestive of CAGE (other than sudden loss of consciousness on surfacing) or AMI, although the latter may have been silent. The autopsy shows no evidence of AMI, the coronary lesions are not haemodynamically significant and there is no evidence of clot formation. Gas was seen in both ventricles, which may well have been a post mortem artifact, and no gas was seen in the cerebral circulation. As the pathologist states, there is really insufficient evidence to confidently determine the cause of this death.

Summary: Experienced; AMI 20 years earlier; separation during apparently normal ascent; unconscious at surface; adequate air and equipment functioning; obese; moderate coronary atherosclerosis; possible cardiac death or possible CAGE.

CASE SC 03/08

The victim, a 39-year-old male, was an experienced diver who was described by friends as being very safety conscious. He was visiting the area to take a technical course to add to the wide range of diving qualifications he already held. This dive appears to have been booked at the last minute, as on the previous day he had told his girlfriend that he had intended to dive but had cancelled the dive because the water was too rough.

It is unknown whether any note was made of the experience of the four divers in the group before they were accepted for this unsupervised cave dive. One had only made 30 dives over 10 years; one had a divemaster certification, but had been diving for only five months, the victim had wreck-dive training but no cave-diving experience and the experience of the fourth diver is not stated. One of the dive shop owners acted as the coxswain and there was a diving instructor with three students on board. When they arrived at the dive location, a cave passage through a rock, they were given a dive briefing. The sea was described as calm, swell slight and visibility good in the open water. The victim was the only one among his group who wore a drysuit and required an 11.7 kg weight belt and 1.29 kg ankle weights. They all carried torches. After they entered the water, the boat took the others to an open-water dive location, and then it returned to the cave area to await the return of the four divers.

The cave entrance was visible from the boat in a depth of 15 msw to the sea floor. There was no dive leader to lead them through and there was some confusion about how the group was to swim through the cave. When about to enter the cave, they felt the surge pulling them in. The passage was apparently large because one diver described how, when deep in the cave and trying to locate the side passage through which they were to exit, he felt a water surge lift him 4–5 metres and he had to vent his BCD in order to descend and so avoid hitting the passage roof. The floor was at about 8 msw depth when they were 15–20 minutes into their dive and in the upper half of the cave the water was turbulent.

After this big surge, they discovered that one person was missing and, after trying unsuccessfully to locate him, the remaining three divers exited the cave. They advised the coxswain what had happened and he reassured them that the missing diver was so experienced he would be all right. Seeing bubbles bursting, he felt confirmed in his belief, but they came from the last diver to return. His advice was for them to continue diving around the passage's other entrance. This they did, surfacing about 10 minutes later and returning to board the dive boat.

The coxswain now believed that a diver was missing. After he had collected the instructor and his pupils, the boat returned to the cave entrance area. Not having any diving equipment of his own with him, the coxswain borrowed the instructor's equipment and, after arranging for an emergency service call to be made, dived to search the cave. He was unsuccessful and surfaced after 20 minutes. After a call to the dive shop, his own equipment was brought out. Both groups of divers were returned to shore, and he and another diver re-entered the cave. After about 12 minutes, the missing diver was located floating above them head-down with his mask under his chin. Both regulators were working, and the contents gauge showed 127 bar, but his tank had slipped from the tank band on which its valve was caught. Some cuts were noted on his nose and face. The body was recovered with difficulty three hours after the victim had started his fatal dive. Police examination of the equipment revealed no faults.

Autopsy: Pre-autopsy scans excluded pulmonary barotrauma. There was no evidence of CAGE. Superficial abrasions and bruising of the scalp were noted in the report summary but there was no evidence of skull fracture or brain trauma. The coronary arteries appeared healthy; the foramen ovale was probe-patent, and blood tests negative. The cause of death was given as drowning, likely as a result of a blow to the head.
(Height = 180 cm, Weight = 60.2 kg, BMI = 18.6)

Comment: Appropriate consideration was given to the potential for CAGE given the description of the incident, although this was rejected due to the presence and characteristics of other injuries and expert knowledge of the location that provided what appears to be a sound explanation of the circumstances.

Summary: Trained; experienced, although not in cave diving; strong wave surges in cave; separation; head trauma; drowning, probably as a result of a blow to the head.

CASE SC 03/09

The victim, a 25-year-old male, had never completed a scuba training course but was reported to have been diving for seven years. He was described as a good swimmer in good health.

On this occasion he, his brother, and two friends, were intending to collect scallops in a current-prone area, diving from a private boat. After anchoring the boat and placing two buoyed shot lines, the victim and his brother dived first. Despite advice and the coldness of the water (15°C), the victim declined to wear a wetsuit. It was later reported that he was wearing about 10–20 kg on his weight belt. The conditions were just beginning to become choppy and visibility was reported to have been in excess of 6 metres.

The two men entered the water with inflated BCDs, deflating these when they reached the shot line. During the descent the two became separated and the brother, after a short wait, surfaced to check if the victim had returned to the boat. A surface search was unsuccessful. About one hour later they notified the police but surface searches both then and over the following days failed to find any sign of the missing man or his equipment. His body, without any equipment, was found floating off a beach 24.5 km from the dive site five days later.

Autopsy: The condition of the body limited autopsy investigation to a finding of a possibility that "*exhaustion and hypothermia may have been significant factors in the ultimate mechanism of death*". The possible cause of death was given as drowning. No disease factors were discovered.
(Height = 179 cm, Weight = 96 kg, BMI = 30)

Summary: Untrained; experienced; dived without wetsuit but with substantial weights in cold water; separation during descent; body washed ashore five days later; equipment never found; hypothermia possible factor; probable drowning.

Surface-supply breathing apparatus

CASE SS 03/01

The victim, a 25-year-old male, was diving with a friend from a boat about 500 m from shore. Sea conditions were described as perfect and the ocean floor visible about 5 m below. They were using a home-made surface-supply breathing apparatus (SSBA, 'hookah').

The victim was wearing a 5 mm short wetsuit and about 8 kg of weights. He had never dived before so his friend instructed him on how to release the weight belt if needed, and how to ascend to the surface. Initially, the friend remained on the boat and watched the victim while he swam on the surface breathing from the 'hookah'. Once he was satisfied that the victim appeared to be coping, the friend entered the water and, using the other hose, dived below the victim looking for crayfish. He had expected that his friend would remain on the surface at this time. After about five minutes trying to catch a crayfish, the friend looked up and could not see the victim. He noticed that the other hookah hose had sunk and followed it to find the victim lying face up and motionless on the seabed without the regulator in his mouth. After determining that the victim was unconscious, the friend brought him to the surface, attempted some in-water rescue breathing and eventually managed with difficulty to bring him aboard the boat.

The friend commenced BLS without a response. After calling the police and being told that assistance would be delayed, the friend drove the boat to shore, stopping every four minutes or so to apply BLS. Prolonged ALS on shore was unsuccessful.

The SSBA was 'home-made' and the air filter had been recently modified. It had reportedly been used by the buddy and another diver a week earlier with no apparent problems. When tested, the SSBA was found to deliver an air flow rate below that required under Australian Standards, and the air supplied had an excessively high water content. This would have made it difficult to breathe from, especially when two people were using it. The air was free from contaminants.

Autopsy: Toxicological analysis showed evidence of prior use of amphetamines and cannabis; however, the levels detected were not believed to be clinically significant. Carbon monoxide saturation was reported to be four per cent. Neurohistology was conducted and the pathologist stated that "*microdysgenesis is a microscopic cortical malformation considered to have the potential to act as a substrate for seizures. Although non-specific, the presence of white matter gliosis, subependymal gliotic nodules and subpial gliosis suggests there has been some previous old insult to the brain*".

It was suggested that the victim may have had an increased potential for seizures and that the scarring of the brain suggested that there may have been prior seizures of which the victim may not have been aware. It was stated that the victim's carboxyhaemoglobin level of 4% may partly or wholly have been the result of recent tobacco smoking, of which there was evidence. The cause of death was found to be drowning as a result of a seizure underwater.
(Height = 179 cm, Weight = 72 kg, BMI = 22.5)

Comment: No injuries to the tongue were noted. Although the pathologist suggested that the drowning may have resulted from an underwater seizure, there was no evidence to support this suggestion.

Summary: Untrained; first dive; using homemade 'hookah' which was not functioning correctly; separation; victim initially on surface and buddy underwater; found unconscious on sea bed; drowning (possibly as a result of a seizure).

Discussion

BREATH-HOLD DIVERS AND SNORKEL USERS

Hyperventilation prior to breath-hold diving is known to be associated with apnoeic hypoxia and loss of consciousness and has been reported to be associated with a substantial number of breath-hold fatalities in Australia in the past.[7,8] Despite this knowledge, the practice remains common and appears to have taken its toll once again. Anecdotal reports indicate that unconsciousness may occur without warning during breath-hold dives without hyperventilation, and there is evidence of this in the presence of sustained exercise.[9] Unless a buddy is immediately at hand to provide rescue, death is a likely result.

In this series, there were three deaths likely to have been associated with apnoeic hypoxia blackout. In one case (BH03/05) the victim was definitely seen to be hyperventilating prior to diving. One may simply have struggled for too long to free his spear gun on the seabed.

There was a clear difference between critical factors in deaths associated with breath-hold diving and those associated with the use of a snorkel as a swimming aid. The former were generally young and healthy and experienced in breath-hold diving, while the latter group tended to be older and lacking in experience and often carried a load of occult coronary artery disease.

ABSENCE FROM DIVING

A recurring theme in diving accident reports is experienced scuba divers getting into difficulties after an extended absence from diving. Diving is not like 'riding a bike'; diving requires re-familiarisation under controlled conditions and equipment requires appropriate inspection and servicing, especially after not being used for an extended period as corrosion and deterioration can occur. The victims SC03/01 and SC03/05 were both said to be experienced divers who had taken a break from diving.

Diver SC03/01 appears to have panicked when his mask flooded (as did the first-time diver SC03/02), something that regular divers should be less likely to do. The associated stress may have contributed to or precipitated the cardiac event that proved fatal. However, managing a flooded mask is an important skill that should never be taken for granted and should be practised regularly by all divers, especially those without recent experience.

LACK OF EXPERIENCE IN THE ENVIRONMENT OR CONDITIONS

Diving in different environments may require specific skills. Sometimes specialised training is required, on other occasions appropriate supervision will suffice, while on others a thorough briefing and orientation may be adequate. As an example, diving in caves or wrecks requires carefully controlled buoyancy and if there is a strong surge, the situation can be substantially more demanding. Although victim SC03/08 had received some basic training in wreck diving, it is not known how much relevant experience he had prior to this fatal cave dive.

Victim SC03/03 had only ever done one dive in the ocean prior to her fatal dive. Given that her training and most of her previous dives were conducted in a fresh water quarry, she would have had little or no exposure to currents, diving from a boat, wreck diving or exposure to marine life. Whether or not her death was accidental, it is unlikely that it would have occurred had she been appropriately supervised. In fact, the dive operator was charged with breaches of local diving

workplace regulations for disregarding its own standards in permitting the inexperienced victim to dive without having a prior dive site orientation with one of its staff.

Dive planning should always include an allowance for the operation of 'Murphy's Law' – a long history of trouble-free practice of a procedure is no guarantee – 'familiarity breeds contempt'. Divemasters and instructors should always remember when giving instructions or a dive briefing that the listeners may be interpreting what one is saying against an entirely different background of experience.

SCUBA EXPERIENCE / RESORT DIVING

It is likely that very large numbers of scuba experience dives are conducted each year worldwide with relatively few reported accidents. However, two cases (SC03/02 and SC03/04) in this series involved divers who died while participating in such dives.

It is important to select dive sites, the diving conditions and instructor/student ratios carefully, given the often total lack of experience of participants. Instructors should remain very close to the divers at all times so that they can intervene without delay when necessary. However, even though the instructor may have immediate access to the novice and may act appropriately, not all problems can be managed successfully, as appears to be the situation with SC03/02. With case SC03/04, there were significant differences in the accounts given by the instructor, who claimed to have swum on his back so as to observe the novices and to have seen the victim ascending, and by the other divers, who denied this version of events completely.

One of the divers in the group in SC03/04 later complained that he had wanted to ascend but had not been shown how to adjust his buoyancy and therefore had difficulty in doing so. The group also reported that they were not told how to ditch their weight belts. Adjustment of buoyancy and the ditching of weight belts may not be necessary if the instructor is immediately at hand, but will occasionally be necessary if separation occurs, as in this case.

An interesting challenge with resort diving is to determine the minimum skills a diver should be taught in the limited time available under these conditions. Various scuba training agencies have standards that address this problem, and dive operators are required to meet these standards. In addition, there is currently a draft ISO standard for scuba experience diving. Most such standards do not include removal of weight belt and use of the BCD underwater as required skills.

COMMON SENSE

Safe diving requires common sense. It is difficult to imagine, for instance, how the victim SC03/09, who was reported to have been an experienced diver, would attempt a dive in 15^{O}C water without an exposure suit and with substantial weight on his weight belt; an obvious recipe for disaster. There are several other examples of extraordinary lack of common sense in this series of fatalities from 2003.

CARDIAC DEATHS

Cardiac-related issues were thought to have contributed to the deaths of six snorkel divers (50%) and four scuba divers (44%) in this series. Diving can add additional stressors in the form of exertion; heavy, and sometimes restrictive equipment; increased respiratory effort, salt-water aspiration and anxiety, among others. This can be a potent recipe for precipitation of a cardiac event in someone with pre-existing cardiovascular disease, whether diagnosed or not. Sometimes such deaths could have occurred with or without exertion in a variety of situations and just happened to occur while diving. We are becoming increasingly aware of the danger of cardiac arrhythmias, such as the long QT syndrome, in diving. Any history of syncope or drop attacks should be thoroughly investigated before a person is cleared to dive.

In cases BH03/02, BH03/04, BH03/08, SC03/01 and SC03/07, the victims were aware of pre-existing conditions, although possibly unaware of the potential implications with diving. However, with BH 03/06, BH03/07, BH03/09, SC03/04 and SC03/06 there was no reported evidence that the victims were aware of their existing cardiovascular disease. It is important that divers and physicians are made well aware of the increasing incidence of cardiac-related deaths in diving so that appropriate health monitoring strategies can be put in place. Since older recreational divers are not required to be assessed medically on a regular basis, and the diving industry appears unlikely to introduce this, such health surveillance could only be achieved through appropriate and effective education programmes or, if this is unsuccessful and it is considered to be a substantial enough problem, through legislation.

ALCOHOL

Alcohol and any form of diving do not mix. Whilst international drowning statistics incriminate alcohol as a contributing factor in many drownings, especially in young males, this appears uncommon in snorkelling and scuba diving. However, alcohol and drug screening is not routinely performed by pathologists as part of diving autopsies. For instance, in the 1980 to 2000 New Zealand series, only 72 of 173 snorkellers and scuba divers whose bodies were recovered had a blood alcohol level measured.[10] This was positive in five of 24 snorkellers and four of 48 scuba divers.

CORONER'S AUTOPSIES

The information obtained from autopsies of scuba fatalities

is often incomplete, as many are performed incorrectly.[11] Despite the promulgation by the Royal College of Pathologists of Australasia of new and detailed guidelines on how to conduct diving fatality autopsies, these are frequently not followed and some pathologists are clearly unaware of the likely pathologies to look for. The same is still true in some areas of New Zealand.[10] There is a need for a significant improvement in the standard of conduct of coroner's autopsies in scuba fatalities in Australasia. In cases where the investigation reveals that the victim had a pre-existing medical condition, every effort should be made to obtain relevant information about this.

Conclusions

There were 22 reported diving-related fatalities during 2003, which include 12 deaths while snorkelling and/or breath-hold diving, nine while scuba diving and one while using surface-supply breathing apparatus (SSBA).

Causal factors associated with these deaths include cardiac disease, whether diagnosed or not; inexperience or lack of recent diving experience, diving in an unfamiliar diving environment and lack of common sense.

Factors that may reduce mortality in the future include improved medical screening of older divers; cessation of the practice of hyperventilation prior to breath-hold diving; closer supervision of inexperienced divers; out-of-practice divers or divers who are inexperienced in the particular environment; and closer communication between dive buddies.

In the investigation of diving fatalities, there is a need for more consistent documentation by investigating authorities such as the police, and improved standards for the performance of scuba diving fatality autopsies by pathologists.

Conflict of interest

John Lippmann is the Executive Director of Divers Alert Network (DAN) Asia-Pacific. DAN is involved in the collection and reporting of dive accident data and provides evacuation cover and dive injury insurance to recreational divers.

Funding

This study is funded by DAN Asia-Pacific.

Acknowledgements

We acknowledge Monash University National Centre for Coronial Information for providing access to the National Coronial Information System (NCIS) and Marde Hoy for assisting with this. State and Territory Coronial Offices, various police officers, dive operators and divers provided information on these fatalities. We thank Dr Andrew Fock for his review of, and comments on, the autopsy reports, and the staff at DAN Asia-Pacific who have worked on this project.

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Submitted: 15 October 2008
Accepted: 22 December 2008

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