

## Provisional report on diving-related fatalities in Australian waters 2006

John Lippmann, Douglas Walker, Chris Lawrence, Andrew Fock, Thomas Wodak and Scott Jamieson

### Key words

Diving deaths, scuba, breath-hold diving, closed-circuit rebreathers, diving accidents, case reports

### Abstract

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**Introduction:** An individual case review of diving-related deaths reported as occurring in Australia in 2006 was conducted as part of the Divers Alert Network Asia-Pacific (DAN AP) dive fatality reporting project.

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

**Results:** In total, there were 16 reported fatalities (eight fewer than 2005), all involving males. Ten deaths occurred while snorkelling and/or breath-hold diving and six while scuba diving, one of which involved the use of a closed-circuit rebreather. One death resulted from an encounter with a stingray and two involved scuba divers diving alone after an extended absence from diving. Cardiac-related issues were thought likely to have contributed to the deaths of six snorkel divers and one scuba diver.

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

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### Introduction

Each year in Australia, there are deaths associated with snorkelling and diving using compressed gas (i.e., scuba or surface-supplied breathing apparatus). Although some accidents are unavoidable, many might be avoided through better education, appropriate medical screening, greater experience, common sense, improved supervision or better equipment maintenance and design. The aim of the Divers Alert Network Asia-Pacific (DAN AP) Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and the diving industry and to inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future and of detecting, in advance, those diving candidates who may be at risk. This report includes the diving-related fatalities between 01 January and 31 December 2006 that are recorded on the DAN AP database. When an accident is unwitnessed, it is often difficult to determine exactly what has occurred. We have sometimes included considered speculation within the comments to provoke thought about the possible sequence of events.

### Methodology

As part of its ongoing research into, and reporting of diving fatalities in Australia and elsewhere in the Asia-Pacific region, DAN AP has obtained ethics approval from the Human Research Ethics Committee, Department of Justice, Government of Victoria, Australia to access and report on data included in the Australian National Coronial

Information System (NCIS). In addition, ethics approvals have been sought and obtained from various coronial offices in certain Australian States and Territories. The methodology used for this report was identical to that described previously for the 2004 Australian diving-related fatalities.<sup>1</sup>

### Snorkelling and breath-hold diving fatalities

BH 06/01

Although the coronial papers about this incident are unavailable (at the request of the victim's family), some of the media reports combined with other enquiries provided useful details.

This victim was a 44-year-old male who was apparently fit and healthy and an experienced snorkeller. His death occurred while he was making a documentary film about marine life. He was snorkelling and, at the time of the incident, was reportedly standing on, or floating above the reef in water of a depth of about 1.5 metres' of seawater (msw). He was very near a large stingray (bull ray), reportedly with a wingspan of approximately one metre. He was positioned to enable a nearby cameraman to film both the stingray and himself in the same frame. The cameraman was in front of the stingray and the victim was behind and above the ray when the ray turned around, rose and flicked its barbed tail, hitting the victim forcefully to the left of his sternum. He was seen to pull the barb out but then collapsed. Resuscitation was attempted on the boat and continued on shore, but was unsuccessful.

*Autopsy:* There is no autopsy report available but other sources report that death was found to have resulted from cardiac tamponade.

*Comment:* A tragic death resulting from the victim positioning himself too closely over and above a stingray and likely causing it to feel threatened and trapped. The shallow depth placed the victim within range of the stingray's barbed tail. Removal of an embedded stingray spine is generally discouraged in the first-aid setting, as it is likely to further increase the trauma caused by the rear-facing serrations, and 'unplug' the wound. However, it is unknown whether this act made any difference to the outcome of this incident.

*Summary:* 44-year-old male; experienced; snorkelling in shallow water close to large stingray; penetrating injury of the chest caused by a stingray barb; trauma causing death from cardiac tamponade

#### BH 06/02

This 55-year-old male overseas visitor went snorkelling with a group off an island resort on the Great Barrier Reef (GBR). No details are available relating to his health, swimming and snorkelling experience, the water conditions, whether he or his group received any instruction or advice prior to snorkelling, or whether any buddy system was supposed to be in place.

The victim was noticed floating motionless by lifesavers and was quickly reached, found to be unconscious, and brought ashore. It is unknown how long he had been unconscious. He was unresponsive, apnoeic and there was no palpable pulse, so basic life support (BLS) was commenced while awaiting the arrival of oxygen (O<sub>2</sub>) equipment and an automated external defibrillator (AED). Oxygen-supplemented ventilations were soon provided using a bag-valve-mask. When the AED was attached, no shock was advised, indicating the likelihood of asystole. Resuscitation was ultimately unsuccessful.

*Autopsy:* A pre-autopsy CT was performed after the absence of trauma or evidence of marine stings was noted, and it revealed no significant pathology. At the autopsy, the heart (296 g; normal range 150–400 g) had a normal appearance and weight. The right coronary artery was unusually small (maximal diameter 1 mm, with 40% narrowing by atheroma) and the left anterior descending (LAD) coronary artery was up to 60% narrowed by atheroma. There was no evidence of any old or recent myocardial infarction and the histology showed patchy ischaemic-type fibrosis and some fat infiltration in the myocardium of the left ventricle. There was severe fatty change in the liver. His BMI was 25 kg cm<sup>-2</sup>. The lungs (right (Rt) 558 g, left (Lt) 508 g; normal range for combined weight 600–1000 g) showed gastric contents in the upper airways. The stomach was full of food. There were several rib fractures due to vigorous resuscitation efforts.

The cause of death was given as coronary atherosclerosis.

*Comment:* It is unknown how long the victim was unconscious before being noticed and, therefore, how long the delay prior to BLS and attempted defibrillation. It is pleasing to note the availability of high-concentration O<sub>2</sub> equipment and an AED, which are becoming increasingly available at dive sites on the GBR, a valuable model for other diving destinations.

A narrowing of the LAD of only 60% would normally be considered to be borderline as a cause of clinical symptoms (i.e., less than 75%). However, the pathologist commented that the right coronary was unusually small, which may represent congenital hypoplasia of the right coronary artery. The combination of an LAD stenosis and a small right coronary artery with atheroma may have produced apical ischaemia in this case.

*Summary:* 55-year-old male; solo or separated snorkeller of unknown experience; found unconscious on surface; atherosclerosis; cardiac-related death

#### BH 06/03

This 70-year-old male had no history of medical problems and was taking no medications. He and his wife went snorkelling from a commercial vessel on the GBR. While he had stated that he could swim, there is no record of whether he had snorkelling experience. All passengers intending to snorkel were offered a 'noodle' flotation aid, which the victim took. He used his own mask. The boat was anchored to windward of the chosen reef and there was a strong current running off the reef towards the boat and the conditions were described as "quite rough". The victim and his wife took an opportunity for a short practice snorkel before his wife left on a supervised tour. His wife reported that he managed to use the fins after an initial period of uncertainty.

When the guided tour started, the victim remained in the designated snorkelling area between the boat and the reef. A lookout was on duty to watch those in this area. When his wife returned from the guided tour and enquired about her husband's whereabouts, it was eventually realised he was missing. Another boat in the area was alerted and its captain found the victim about 300 metres further from the reef, floating face down and unconscious, with his mask and fins in place and supported by the 'noodle'. He was brought back to the boat where BLS was commenced. When an AED from the other vessel was attached, no shock was advised, indicating the likelihood of asystole. The victim failed to respond to BLS, which was terminated after about 35 minutes on medical advice via radio.

*Autopsy:* The autopsy revealed his heart was healthy (395 g), with only mild atheromatous changes and widely patent coronary arteries. His lungs (Rt 710 g, Lt 624 g) were

**Table 1**  
**Summary of snorkelling and breath-hold diving-related**  
**BSB – buddy separated before problem; GNS – group not separated; GSB – group separated before;**

ID BH	Age	Sex	Height (cm)	Weight (kg)	BMI	Training	Experience
06/01	44	M	n/s	n/s	n/s	trained	yes
06/02	55	M	165	68	25.0	n/s	n/s
06/03	70	M	177	70	22.3	nil	nil
06/04	74	M	176	81	26.1	nil	nil
06/05	61	M	196	95	24.7	n/s	n/s
06/06	69	M	175	71.5	23.3	n/s	n/s
06/07	26	M	182	78	23.5	nil	nil
06/08	23	M	187	66	18.9	n/s	n/s
06/09	76	M	173	74	24.7	n/s	n/s
06/10	41	M	177	75	23.9	n/s	n/s

oedematous and congested. There was a recent haemorrhage in the mediastinum adjacent to the Lt hilum, and fractures of the Rt ribs 2–3 and Lt 2–6, in the mid-clavicular line, consistent with resuscitation attempts. Histology showed mild interstitial fibrosis of the heart, and atheromatous narrowing of up to 50% was noted in the epicardial arteries. The cause of death was given as drowning.

*Comment:* Despite the presence of a ‘safety watch’ the victim drifted, possibly unconscious, some 300 m from the designated snorkelling area. As he was wearing a bright yellow shirt which was highly visible, the company received an ‘infringement notice’ for having failed to adequately watch over those in the designated swimming area. As this death was unwitnessed, it is unknown what led to his drowning. However, inexperienced snorkellers often have trouble clearing a snorkel and aspiration of salt water can cause drowning through a variety of mechanisms. The cardiac fibrosis seen on microscopic examination of the heart raises the possibility of some cardiac precipitant in the drowning. Since the flotation noodle was still under his arms death is unlikely to have been caused by asphyxia of ascent. It is not known how close the other boat was anchored or whether persons snorkelling or swimming from it were close to the designated swim area of the victim’s boat. This factor could have compromised the efficiency of supervision.

*Summary:* 70-year-old male; no history of medical problems and not on medication; snorkelling alone but supposedly under supervision; discovered unconscious; drowning

#### BH 06/04

This 74-year-old male overseas tourist joined a day trip to visit a pontoon moored on the GBR. There were 428 passengers and a crew of 40. He was reported to have been active and apparently healthy, although taking ramipril daily for mild hypertension. He had been a lifeguard in the past so was presumably a competent swimmer, although it is

unknown what previous snorkelling experience he had.

A safety talk was given and a video on snorkelling was shown during the outward trip. An information leaflet in multiple languages, including the victim’s primary language was also available. When they arrived at the pontoon, the tour leader gave instructions, at which the victim was present, on how to fit and use the snorkelling equipment. Sea conditions were reported to be rough due to a moderate wind, with a slight current. Water temperature was 27°C. The victim was wearing mask, snorkel, fins and a Lycra suit, without any additional buoyancy aid.

On this day, there were three designated lookouts/lifeguards with responsibility for those in the buoy-defined, designated swimming area. At the time, there were approximately 25 swimmers in the water, although the victim was snorkelling alone. Minutes after the first passengers had entered the water, one of the lookouts saw the victim floating slightly submerged just outside the buoyed area. When she went to him in the safety dinghy, she found him unresponsive; however, being unable to lift him into the dinghy unaided, she returned to the pontoon to get another lifeguard. They returned to the victim, who was now 70 metres from the pontoon. His eyes were open but he remained unresponsive. Although his mask was in place, it was full of white froth and his snorkel was out of his mouth. He was brought aboard the dinghy where it was noted that he was cyanotic, apnoeic and pulseless. He was taken to the pontoon where BLS was commenced with supplemental oxygen provided via a resuscitation mask with O<sub>2</sub> inlet. When an AED was attached, no shock was advised, indicating that he was likely to have been in asystole. BLS was continued for 70 minutes until paramedics arrived and declared the victim dead.

*Autopsy:* The heart weighed 477 g and showed a dilated left ventricle. The coronary arteries showed generalised atherosclerosis with significant stenosis of the LAD (70%). Sectioning of the myocardium revealed a degree of circular

**Table 1 (cont.)**  
**fatalities in Australian waters 2006**

n/a – not applicable; n/i – not inflated; n/s – not stated

Dive group	Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	BCD	Disabling injury
GNS	filming	2	n/s	n/s	n/s	n/s	Trauma (Stingray)
Solo	recreation	n/s	surface	n/s	n/s	n/s	Cardiac
BSB	recreation	n/s	surface	nil	n/a	nil	Asphyxia
GSB	recreation	n/s	surface	nil	n/a	nil	Cardiac
GSB	recreation	n/s	surface	nil	n/a	nil	Cardiac
GSB	recreation	15	surface	nil	n/a	nil	Cardiac
BSB	recreation	2	surface	nil	n/a	nil	Asphyxia
Solo	spearfishing	n/s	surface	n/s	n/s	nil	Asphyxia
Solo	recreation	n/s	surface	nil	n/a	nil	Cardiac
BSB	recreation	n/s	surface	n/s	n/s	n/s	Cardiac

hypertrophy of the left ventricle and a well-defined extensive area of old infarction (maximally 20 x 45 mm) at the apex of the left ventricle, which histology showed was nearly full-thickness scarring of the myocardium. The lungs were heavy (Rt 1,100 g, Lt 970 g), markedly congested and clear haemorrhagic fluid oozed from the cut surfaces. The formal finding was death from cardiomegaly, coronary artery atherosclerosis with stenosis of major vessels and pulmonary congestion changes.

*Comment:* It appears that the previous myocardial infarction may have been silent as there was no indication that the victim had been treated for this. The reviewing pathologist would give the cause of death as ischaemic heart disease due to generalised atherosclerosis. The mechanism of death could have been a cardiac arrhythmia due to the atherosclerosis or ventricular dilatation, with terminal drowning due to loss of consciousness. The inadequate (single lifesaver in safety boat) response delayed retrieval but was not thought to have influenced the outcome. The operator's revised response rules now require the safety boat response involve two crew members.

*Summary:* 74-year-old male; unknown experience; history of hypertension; snorkelling with others but without buddy in patrolled area; silent death; atherosclerosis and cardiomegaly; cardiac-related

BH 06/05

This 61-year-old male was visiting from overseas and touring the GBR on a large cruiser. He had a history of polycystic renal disease and was on multiple medications: minoxidil 10 mg, frusemide 40 mg, ibesartan 15 mg, omeprazole 20 mg, gaviscon suspension, cephalixin 250 mg and escitopram 15 mg.

On the previous day, there had been a presentation to passengers on safety procedures when snorkelling. It is

unknown whether the victim had reported his health status to the cruise operator. He was reported to have been a competent swimmer, but it is unknown whether or not he had snorkelled before. On this day, the vessel was moored off an island resort and the group were ferried ashore, given a mask, snorkel, fins, and a life vest to wear, the last of which the victim appears to have declined. Then they entered the water from the beach, whilst a safety boat with lookouts was present. The weather was reported to be clear, with a moderate wind and waves of less than one metre high, but it is unclear whether there was a significant current. The snorkelling area was apparently not clearly marked.

After about 45 minutes, two of the group noticed the victim floating at the surface, face down and motionless, with the tip of his snorkel bobbing below the surface. On approaching him, they found him unresponsive and cyanotic. Despite believing him to be dead, one rescuer attempted in-water rescue breathing but was hampered by his own safety vest. The tender soon arrived and took the victim aboard, and BLS was initiated as they returned to the cruise boat. Resuscitation continued with the assistance of the resort nurse until the arrival of a doctor who declared the victim to be dead.

*Autopsy:* The heart was large, weighing 570 g, with dilatation and concentric hypertrophy of the left ventricle. The coronary arteries showed some atheroma but no significant atherosclerotic stenoses. The Rt and Lt lungs weighed 780 g and 800 g respectively. Cystic hepatic disease was present with cysts of various sizes scattered in a random manner. The typical changes of polycystic kidney disease were confirmed. The Lt kidney weighed 3,000 g, the Rt 2,760 g and each was 35 cm long with no normal renal architecture. The pathologist considered the deceased was to be regarded as being only a short time from developing full renal failure, though histology showed residual intact glomeruli and tubules throughout. There was some patchy myocardial fibrosis in the heart. The coroner found cause

of death to be acute cardiac failure, cardiomegaly, and polycystic renal disease.

*Comment:* The reviewing pathologist would give the cause of death as hypertensive heart disease due to polycystic kidney disease while snorkelling. As the pathologist described this 61-year-old man as 'elderly' it is probable his ill health was apparent to others. His disease was first identified when he was aged 25. He was under the care of a kidney specialist whom he had last attended about two months previously. This was a seriously ill man who died silently not far from others while gently snorkelling.

*Summary:* 61-year-old male; long history of kidney disease; snorkelling with group but without buddy; found by other snorkellers but unnoticed by safety lookout; cardiomegaly; cardiac-related

#### BH 06/06

This 69-year-old male was an overseas tourist of unknown prior snorkelling experience who was on a sailing vessel visiting several GBR resort islands. He was described as appearing healthy and had not reported having any ill health on the pre-snorkelling questionnaire. No medications were later found in his luggage.

The victim and other passengers had been provided with snorkelling equipment and were swimming or snorkelling between the vessel and the beach, some 20 metres away. The water depth was about 15 msw and the conditions described as good. Those in the water were monitored by crew on the vessel. The alarm was raised when two of the passengers saw a pool of blood under the water. The safety tender quickly found the victim floating and unresponsive with blood in his mask. He was quickly returned to the vessel where BLS was attempted without success.

*Autopsy:* The heart weighed 383 g, and appeared normal macroscopically. There was generalised severe atherosclerosis of all the coronary arteries, with a pinhole lumen in the LAD artery, 10 mm from its origin. Histology showed patchy subendocardial fibrosis in the left ventricle. The trachea and bronchi contained a large amount of watery, blood-stained, frothy fluid. The lungs showed congestion and pulmonary oedema (Rt 825 g, Lt 696 g). There was approximately 700 ml of blood-stained fluid in the left pleural cavity. The findings were of myocardial ischaemia, coronary artery stenosis and atherosclerosis.

*Comment:* An apparently fit man who was gently snorkelling and died silently. The lookouts reported that only 5–6 minutes earlier the victim had been seen to look up, smile, and give a 'thumbs-up' signal indicating that all was well. The reviewing pathologist would give the cause of death as ischaemic heart disease due to triple vessel atherosclerosis. It is possible this caused him some symptoms but his medical

history is unknown. This is the first occasion in the long history of these reviews where a cardiac failure has involved blood staining the water. This was an unpredictable 'natural death' event.

*Summary:* 69-year-old male; no known medical history; apparently healthy; experience unknown; silent death while snorkelling in calm conditions; cardiac failure; cardiac-related

#### BH 06/07

The victim was a 26-year-old male overseas visitor with no known health problems. He and his girlfriend hired mask, snorkel and fins to go snorkelling from a popular, although unpatrolled, beach. Both were weak swimmers and the victim had not snorkelled before.

The water was calm and clear with only a slight current. The sea bed dropped steeply and the depth reportedly reached 2 msw only 10 metres from shore. The couple entered the water off a beach, and the victim appeared to be managing well and enjoying it. He chose to remain in the shallow water when his buddy went further out into the deeper water. When she looked back she saw him standing up with the upper half of his body out of the water and thought he may have waved to her. She decided to swim back to him and, alarmed not to find him, she alerted others, and a search was made. The victim was found on the sea bed about 45 minutes later at a depth of 2 msw and approximately 10 metres from shore. He was unconscious, cyanotic and apnoeic. BLS was commenced by a bystander and continued by a nurse. Airway management was complicated by the presence of copious amounts of blood-stained sputum and water. There was no response and efforts were ceased after 10–15 minutes.

*Autopsy:* There was frothy blood-stained fluid in the trachea and bronchi and 300 ml of blood-stained fluid in each pleural cavity. The lungs (Rt 920g, Lt 890g) showed pulmonary congestion and oedema. The heart and the cardiovascular system were normal. The cause of death was given as drowning (immersion).

*Comment:* The buddy had described how, when in shallow water, they both went towards shore to stand and clear their snorkels on previous occasions. It is possible that the victim inadvertently stepped into deeper water and was unable to clear his snorkel. Aspiration from a snorkel can trigger laryngospasm and subsequent silent drowning.

*Summary:* 26-year-old male; poor swimmer; first use of a snorkel; separated; drowning

#### BH 06/08

This 23-year-old male had a history of epilepsy and was described as 'poorly compliant' with his medication. He was

an experienced snorkeller and spear fisherman.

On this occasion, he donned a mask, snorkel, fins and a wetsuit and was spearfishing beside a long pier while his friend motored quietly in a boat nearby. The victim was observed to be snorkelling gently alongside the jetty for around an hour and was about 150 metres from the shore when his friend in the boat noticed that he was motionless. When the friend came alongside, he found the victim to be unconscious and, with difficulty, pulled him into the boat. He was apnoeic and pulseless. BLS was initiated and a faint pulse was detected after the victim vomited some water. A witness on the pier was alerted and called an ambulance. Paramedics arrived and provided advanced life support (ALS). He was taken to hospital where he died two days later.

*Autopsy:* The cause of death was listed as post-immersion cerebral anoxic changes with terminal bronchopneumonia. His heart (weight 400 g) was healthy on both macroscopic and histological examination. Brain and lung changes were consistent with the diagnosis. Toxicology tests showed the presence of phenytoin within the therapeutic range (approximately 16 mg L<sup>-1</sup>), methamphetamine (0.1 mg L<sup>-1</sup>), and lignocaine and propofol, consistent with his hospital management. The cause of death was found to be hypoxic brain damage due to drowning in a person with a history of epilepsy.

*Comment:* It would appear likely that this man lost consciousness and drowned. Possible mechanisms include:

- Epileptic seizure followed by drowning.
- Cardiac arrhythmia followed by drowning. A link between sudden cardiac death and epilepsy has been described previously.<sup>2</sup> This may be related to the presence of long QT syndrome during swimming in susceptible epileptics.<sup>3</sup>
- The presence of methamphetamine at autopsy is difficult to attribute to his hospital management. Methamphetamine has been associated with cardiac arrhythmias and may also alter the seizure threshold in epilepsy.

*Summary:* 23-year-old male; history of poorly-managed epilepsy; experienced snorkeller; spearfishing alone with observer in boat nearby; drowning (possibly as a result of a seizure)

BH 06/09

This 76-year-old male was reported to have been “*in generally good health but had recently been complaining of a tightness in his chest*”. It is unknown whether he had consulted a doctor about this.

He had first been seen walking up and down the beach

with a metal detector, wearing bathers and a vest and with a mask and snorkel. Some 15 minutes later, a lifesaver taking part in training activity saw him floating, apparently unconscious, on the surface of the water, near to the beach. He was brought ashore unconscious and apnoeic and BLS was commenced. Paramedics arrived several minutes later and ALS was administered without success.

*Autopsy:* The heart weighed 460 g. There was 476 ml of blood in the pericardial sac and a rupture of the lateral wall of the left ventricle due to a recent (3–5 days) myocardial infarct. The coronary arteries showed generalised, severe atherosclerosis, with at least 90% stenosis in the first 1 cm and 50% to 70% more distally, but no thrombotic occlusions were seen. The kidneys showed granular changes. No other pathology was noted. The cause of death was given as cardiac rupture causing cardiac tamponade, secondary to a recent, unreported myocardial infarction.

*Comment:* This death could have occurred anywhere and at any time and just happened to occur while the victim was snorkelling. It seems surprising that three to five days after an unrecognised myocardial infarct this man felt well enough to go snorkelling.

*Summary:* 76-year-old male; recent myocardial infarction; recent chest symptoms; snorkelling alone; cardiac-related (sudden death from cardiac rupture).

BH 06/10

This victim was a 41-year-old male with a history of alcoholism and unreported snorkelling experience. He and his wife were snorkelling from a friend’s boat off a popular island in temperate waters. The sea conditions were not reported.

The victim had snorkelled earlier that day without apparent problems. However, during this second snorkel excursion, the victim told his wife that he was “*not feeling well*” and swam back to the boat. He was seen to hold on to the side before his head slumped forward and he floated away face down. He was quickly dragged into the boat and rescue breathing was commenced en route to the jetty where the island nurse was waiting. BLS was unsuccessful.

*Autopsy:* His heart (462 g), showed concentric hypertrophy of the left ventricle. The LAD artery was noted to be almost completely occluded in the first 1 cm from its origin but thereafter had minimal atheroma, while the other coronary arteries had minimal atheroma. No thrombotic occlusion was noted. There was pallor of the posterior basal myocardium. There was nicotine staining of the fingers. The lungs (Rt 650 g, Lt 642 g) were plum-coloured, oedematous and congested. The formal finding of the coroner was “*coronary atherosclerosis in a man engaged in a marine activity*”.

**Table 2**  
**Summary of scuba (SC) and rebreather (RB) diving-related**  
**BSB – buddy separated before problem; BSD – buddy separated during problem;**  
**GSB – group separated before; trng (com) – commercial diving training;**

ID	Age	Sex	Height (cm)	Weight (kg)	BMI	Training	Experience	Dive group	Purpose
<b>SC</b>									
06/01	52	M	180	76	23.5	trained	experienced	solo	work
06/02	72	M	172	97.5	33.0	trained	experienced	GSB	recreation
06/03	35	M	167	73.5	26.4	trained	some	BSB	trng (com)
06/04	64	M	176	107	34.5	trained	some	BSD	recreation
06/05	40	M	175	89	29.1	trained	some	solo	work
<b>RB</b>									
06/01	31	M	181	104	31.7	trained	experienced	BSD	recreation

*Comment:* Only the police summary of witness statements is available and there is no information concerning his recent health.

*Summary:* 41-year-old male; history of alcoholism; unknown experience; felt unwell while snorkelling; cardiac-related

### Scuba diving fatalities

#### SC 06/01

This victim was a 52-year-old male with a medical history of hypertension, although he was not taking any medication for this. He was an experienced diver who had been scuba diving since his early twenties, but he had dived rarely over recent years.

On this occasion, he decided to clean the hull of his boat, which was moored in a sheltered inlet, and a friend remained on board to assist with various ropes. He was wearing a wetsuit but no weight belt; however, he placed four weights (a total of 9.8 kg) in his BCD pockets. The depth was 3 msw and visibility less than one metre.

He was seen to surface very shortly after his water entry. He then redescended, before surfacing again about 5 metres from the boat, this time without his mask and with the regulator out of his mouth. He called out for help and his friend threw him a rope, but he had already submerged again. The friend entered the water and attempted to locate him, but he failed to see him in the muddy water. Police divers were called and they located him two hours later about 20 metres from where he had last been seen. His mask and snorkel were nearby and one fin was missing.

The equipment was tested and described as being in poor condition. The contents gauge showed the tank (which was out of test) was filled to 230 bar, slightly over its correct pressure, indicating the victim had taken few breaths from it after entering the water. The weights in the BCD pockets

were excessive and could not be ditched in an emergency. The lost fin was recovered and its buckle strap noted to be undone, while the other was capable of easily dislodging. The fins were described as too floppy to provide effective thrust. The low-pressure corrugated hose had snapped off the BCD but it is unknown if this occurred while the victim was alive or during the retrieval of his body.

*Autopsy:* The heart weighed 400 g, and there was a focal 60% narrowing of the proximal LAD artery. The left ventricular wall thickness was 16 mm, possibly associated with the victim's hypertension, which was of unknown severity. The lungs were overinflated and heavy (Rt 1,080 g, Lt 1,040 g) and the upper airways contained frothy fluid consistent with drowning. No CT-scan imaging was done, though occasional bubbles were detected in the aorta but not in the pulmonary or coronary arteries. An area of blotchy red discolouration was noted over the left side of the forehead, and irregular areas of loss of skin surface on the dorsum of the left hand. A carboxyhaemoglobin level of 10% was detected in his blood. The cause of death was given as drowning.

*Comment:* The sudden loss of mask, regulator and fin may have led to drowning and there were injuries on the left forehead and left hand that may have been the result of contact with the hull of the boat. Carboxyhaemoglobin levels of 10% can occasionally be observed in heavy smokers. Gas analysis of the cylinder was normal for carbon monoxide (< 0.0002%), indicating that there was no contamination of the compressed air in the tank. Of the possible explanations, the most likely cause of death was drowning due to loss of equipment. This was possibly exacerbated by an impact with the boat and an inability to ditch weights. This victim appears to have had little or no recent experience, was using poorly maintained equipment and was grossly overweighted according to police. Although the sequence of events is uncertain, it appears likely that his regulator became dislodged and he was unable to achieve positive buoyancy due to weights in the BCD pockets, the loss of a fin and/or possible BCD malfunction.

**Table 2 (cont.)****fatalities in Australian waters in 2006**

**BCD – bouyancy compensation device; + sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ >50% full;  
nad – nothing abnormal discovered; CAGE – cerebral arterial gas embolism**

Depth (msw)	Incident (msw)	Weight belt	Weights (kg)	BCD	Remaining air	Equip test	Disabling injury
3.5	surface	nil	9.8 (in BCD pocket)	defective	+++	defective	Asphyxia
17	ascent/surface	off	not stated	removed	not stated	nad	Asphyxia
12	12	nil	7.25 (integrated)	not inflated	nil	nad	Asphyxia
12	5	on	7.5	inflated	++	nad	CAGE
11.5	surface	on	11	not inflated	++	nad	Asphyxia
76	surface	not stated	not stated	not stated	+	nad	Asphyxia

*Summary:* 52-year-old male; experienced but likely little or no recent experience; poorly maintained equipment; weights in BCD pocket and broken fin; overweighted and unable to achieve buoyancy on surface; drowning

## SC 06/02

This very experienced 72-year-old male had conducted over 1,000 dives in 30 years and continued to dive regularly. He was obese (BMI 33), had a residual limp from polio as a child, and history of six idiopathic nocturnal seizures eight years earlier. These were eventually ascribed to work stress and he subsequently retired. He was prescribed carbamazepine but it is uncertain whether he was still taking this at the time of the incident. No further seizures were recorded. Mild hypertension had been noted at the time of the seizures.

The victim made a boat dive with six of his usual dive group. They initially remained roughly together while inspecting the rocky area at a depth of about 17 msw. After about 30 minutes, they ascended to a depth of 9.5 msw, where there was a passage under a large boulder. A strong surge passed through this archway and then upwards, and four of the group, including the victim, decided to allow the surge to take them through it. The victim was last seen alive as he entered the arch. A witness on another boat later told of seeing the victim surface and look around as if to get his bearings. He was showing no signs of distress and the witness left the location – which was close to where the victim's body was later found floating – unaware of any problem.

When the victim failed to rejoin his friends, they searched for him and soon found two packets of his integrated weights and then one fin at a depth of 5 msw. However, when they could not locate the victim they notified the police. About an hour later his backpack and cylinder were found floating by a lifesaver on a surf ski, and the body was then seen floating unconscious and apnoeic about 50 metres further away. Subsequent BLS was unsuccessful.

*Autopsy:* An X-ray was taken before commencing the autopsy, and there was no evidence of any significant air in the heart or any other injuries. The heart weighed 440 g and appeared normal. There was atherosclerotic narrowing of the LAD and right coronary arteries of about 30%, and the left circumflex had about 50%. The trachea and bronchi contained frothy fluid and the lungs showed congestion and oedema. The histology showed moderate liver steatosis, the stomach had evidence of a gastrointestinal stromal tumour, and there was mild perivascular fibrosis and thickening of the walls of the intramural vessels in the myocardium. There was diverticular disease in the lower colon. There were scars anteriorly on both shoulders and a vertical scar on the lower abdomen of unknown origin. The cause of death was given as drowning.

*Comment:* There is insufficient information to determine why this man drowned. Whether the loss of a fin had any influence on the course of events is uncertain, and it is unknown when and why he ditched his weights and BCD. Seizures can lead to drowning but there is no evidence to support it in this case and the clinical history is vague. There was no evidence of any trauma to his head other than a small (2 mm) laceration over his right temple.

*Summary:* 72-year-old male; experienced; history of polio, seizures, hypertension; dived through underwater passage with strong surge; ditched weights; later found floating on surface; drowning (from unknown cause)

## SC 06/03

This 35-year-old male had undergone rescue diver training four years earlier and logged 18 dives during the previous year, although it is not known how much overall diving experience he had. He was apparently in good health, with no known history of medical problems, and appeared to be very fit.

He was undertaking a commercial diving training course in a fresh-water quarry in which there was very low visibility

and a muddy bottom. The victim and another student were practising locating and raising a concrete-filled drum at a depth of about 12 metres' fresh water. He and his buddy were each wearing a full-face mask, suit, harness and lifeline with voice communications. His air supply was from a 2,500 L cylinder, with a 700 L pony bottle attached valve-down as a reserve supply. The victim's reserve was configured so that his primary air supply could be almost exhausted prior to accessing the reserve. However, the buddy's configuration was such that he would need to access his reserve supply when his primary supply fell to around 60 bar.

The victim and his buddy commenced the dive and located the drum. However, when they tried to inflate the lift bag they found that there was no air in the dedicated inflation cylinder and returned to the shore to report the situation. At that point, the victim's contents gauge read 110 bar and the buddy's 120 bar.

The instructor advised them to abort the lift, but to tie a marker buoy to the drum and return. They set out to do this, but after a short time and a 30-metre surface swim the buddy needed to activate his reserve. He reported this to the instructor and was told to return to shore, which he did. The victim was also called back as his buddy was returning and he agreed to do this. However, when the handler of his lifeline was pulling in the 'slack' as the victim returned, he felt a resistance. When he again pulled, the victim asked him to stop pulling and the handler fed back additional slack on the line. Within 20 seconds there was an urgent, but barely intelligible call for help and the sound of water entering the mask.

The instructor dived straight into the water with a mask and knife, but was unable to locate the victim. Eventually, another person located the victim, who was not wearing his mask, and managed to lift him to the surface after some initial resistance from the attached and entangled lines.

It was estimated that a period of 7 to 12 minutes elapsed from the cry for help until the diver was brought to shore. BLS was promptly commenced by trained staff and continued until the ambulance arrived shortly afterwards. Paramedics provided ALS, although defibrillation was not attempted as the victim was in asystole. The paramedics noted palpable gas within the subcutaneous vessels. He was transferred to hospital where he was soon pronounced dead.

Police divers later checked the equipment, which was found to be functional. While the primary tank was empty, the pony bottle was almost full (190 bar) but was turned off. It was difficult to reach and open the valve of the reserve, particularly if it had been firmly turned off. The victim was wearing a borrowed BCD with 7.25 kg of integrated weights.

*Autopsy:* A CT scan was performed at the local hospital within 4 hours of death. This was reported to show gas filling the arterial system. Review of this CT scan showed a large amount of gas in the left ventricle and arch of the aorta, and in the carotid, cerebral and subclavian arteries. There was less gas in the right ventricle. There was gas in the vessels of the liver. There was some gas in the chest wall and arms but this was probably in blood vessels. The preponderance of gas in the arterial system is not typical for post-mortem off-gassing and suggests cerebral arterial gas embolism (CAGE). X-rays taken prior to autopsy the next day also showed significant intra-arterial gas, but also more gas in the right ventricle.

The pathologist noted an absence of interstitial emphysema. When he opened the pericardial sac the distended heart bulged out and when a needle was inserted, clear gas was aspirated from both ventricles. The heart weighed 420 g. There was minimal coronary atheroma. There was a small amount of frothy, lightly blood-tinged fluid in the trachea and bronchi and more blood-stained fluid in the lower bronchial tree. The lungs (Rt 960 g, Lt 740 g) were well aerated and moderately oedematous. The pathologist attributed the gas seen mostly to peri-mortem "*extra-alveolar air syndrome*" caused by rapid ascent of the unconscious diver with a closed upper airway during recovery, possibly with some post-mortem off-gassing. However, the cause of death was attributed to drowning in an out-of-air situation when the mask had been lost.

*Comment:* The finding of large amounts of almost entirely intra-arterial gas so soon after death is not typical of post-mortem off-gassing and is difficult to explain with the history as given. Whilst laryngospasm secondary to aspiration has been reported, this ceases with increasing hypercapnia and hypoxia, leaving the airway open.<sup>4</sup> This diver was recovered after approximately 7 to 12 minutes, so he would have been deeply unconscious and hypoxic at the time of the recovery attempts. One would have to postulate positional airway obstruction during the ascent rescue efforts to explain the arterial gas if it was generated during the recovery. Whilst the finding of arterial gas is suggestive of barotrauma, the history of entrapment and the difficulty experienced by the rescuer in releasing the victim would tend to militate against this hypothesis. The presence of large amounts of arterial gas at autopsy could represent a peri-mortem CAGE after drowning due to an out-of-air situation. In the end, whether the death was the result of drowning or gas embolism is a moot point compared to the larger issues surrounding his inability to deploy his emergency gas supply.

It is likely that the victim exhausted the supply in his main cylinder and was insufficiently experienced to manage the reserve air unit he was wearing while dealing with the added stress of his lifeline being snagged. Zero visibility and entanglement would likely have exacerbated the out-of-air situation. It is also possible that his mask might

have become dislodged while he was attempting to reach and open his pony bottle. Practice in managing a situation such as this was an important element in the course being conducted, but being trapped may have led to panic and subsequent drowning. The instructor's decision to tell the divers to make a second dive on the available air supply proved to be costly.

*Summary:* 35-year-old male; healthy and fit; some experience; undertaking commercial diver training; entanglement; out of air; apparently unable to open reserve; mask dislodged; drowning

SC 06/04

This 64-year-old male from overseas, was a guest on a liveaboard dive vessel on the GBR. Although he had completed more than 100 dives since being certified 20 years earlier, it appears that he had dived infrequently, if at all, during the past three years. He declared that he had no medical conditions and was described as "looking fit", reportedly doing vigorous exercise for 1½ hours daily. However, he was obese and his luggage was later found to contain several medications which included doxazosin 2 mg, naproxen sodium 250 mg, finasteride 5 mg, cetirizine hydrochloride and montelukast sodium 10 mg.

This was the first dive of the trip. There were to be four divers in the group; the instructor, two inexperienced divers, and the victim, who was wearing full scuba gear, including a wetsuit and weight belt with 7.5 kg. There was a slight swell and current. Early in the dive, one of the inexperienced divers had a problem and the instructor assisted her, while the victim and the other diver continued for a short time together. After reaching a maximum depth of approximately 12 msw, the victim signalled to turn back and they slowly ascended to 5 msw where the victim knelt down and grasped the coral for a couple of minutes. He appeared to be mildly confused or distressed and possibly also clutched at his chest before inflating his BCD and ascending rapidly to the surface.

When his buddy surfaced 30 seconds later, the victim's eyes appeared glazed and he soon fell face down in the water. The buddy rolled him onto his back, found him to be unresponsive and alerted the dive boat some 60 metres away. A tender was quickly sent, but the crew were unable to drag the victim on board immediately because of the inherent difficulties bringing an unconscious diver on board a vessel. After another few minutes, and with additional assistance, he was successfully brought onto the tender and was assessed to be unconscious and apnoeic, with a faint, erratic pulse. Rescue breathing was commenced and this was replaced with CPR with supplemental O<sub>2</sub> once on board the main vessel. BLS was continued by crew and two guest doctors for 40 minutes, prior to ALS being provided by a paramedic who was air lifted to the vessel. However, resuscitation attempts were unsuccessful.

*Autopsy:* A total body CT scan was done within 24 hours of retrieval, which was reported to indicate gas embolism in the heart and major vessels. At autopsy, some gas was found in the right atrium, less in the right ventricle, but no surgical emphysema or any other intravascular air or pulmonary pathology was noted. The heart showed cardiomegaly, weighing 533 g with concentric hypertrophy of the left ventricular wall. There was generalised coronary arterial atherosclerosis but no occlusions, the maximal narrowing of the lumen being 40% in the LAD branch. Histology of the heart showed widespread ischaemic fibrosis. He was obese, BMI 34.5. Several ribs had been fractured during the resuscitation efforts. The cause of death was given as cardiac air embolism due to barotrauma. The pathologist considered that a cardiac event related to the enlargement of the heart and ischaemia could have precipitated the uncontrolled ascent.

*Comment:* The police summary includes an unsourced note of the victim possibly clutching his chest before inflating his BCD, his buddy's statement only mentioning his apparent confusion or distress. The clinical picture is consistent with his experiencing anginal pain and responding with a panic ascent, resulting in CAGE. The pathology would fit with this, despite the lack of a critical coronary occlusion. It is important to note that it is often difficult to bring an unconscious diver aboard a vessel. Divers and boat operators should have a pre-planned and, ideally, well-practised system to do this, taking into consideration the number of people likely to be able to assist, as well as the size of and access to the vessel.

*Summary:* 64-year-old male; experienced although few or no dives for past three years; taking medications for hypertension, asthma, allergy; cardiomegaly and atherosclerosis; aborted dive early and made a rapid ascent to surface; CAGE (possibly precipitated by cardiac event)

SC 06/05

The victim was a 40-year-old, apparently healthy male who was the skipper of a crayfishing boat. He had certified as a recreational diver 28 years earlier but his subsequent diving experience is unknown.

He was planning to dive to retrieve his boat's anchor, which had been lost at sea several days earlier at a depth of approximately 10–12 msw. After hiring scuba equipment at a local dive store, he set out to the site. The conditions were described as calm. A shot-line was dropped where he believed the anchor to be. Prior to entering the water, the victim shackled a rope to his BCD. The plan was to attach this rope to the anchor and use it to drag it up when back on the boat. He appeared to be very anxious prior to entering the water. His crew member remained on board to manoeuvre the boat as required. The victim submerged and the crew member watched the rope feed out as the victim descended.

The boat drifted away from the shot-line several times and the crew member repositioned it.

After what he estimated was 10–20 minutes, the crew member noticed that the victim had surfaced and appeared to be “*in serious trouble*”. He drove the boat to the victim who appeared to be unconscious and had partly submerged by then. He managed to hook the victim’s BCD with a gaff and dragged him to the side of the boat although he was unable to bring him fully on board. He then dragged the victim to the rear of the boat and eventually, with the use of a winch, managed to lift the victim onto the transom where he attempted BLS, without success.

The equipment report indicated that the equipment was functioning adequately and had no major faults. The remaining air was 120 bar, the maximum depth reached was 11.5 msw, and the recommended ascent rate had been exceeded (this indicator is activated at any rate faster than 9 m min<sup>-1</sup>, so the actual rate is not known). The victim had worn a sleeveless full-length wetsuit, a weight belt with 8.2 kg, and carried an additional 2.7 kg of weights in the pockets of his BCD.

*Autopsy:* The management of this death was unusual in that, after the victim was brought ashore and declared to have died, the body was taken to a hospital and CT scan of the chest was performed. This did not show the presence of intravascular gas. A further radiographic check later, pre-autopsy, confirmed this. The heart weighed 390 g and coronary arteries showed no significant narrowing. The lungs were over-expanded and heavy (combined weight 1,589 g) and oedematous, and there was oedema in the larynx, trachea and bronchi. The cause of death was given as drowning.

*Comment:* The clinical history in this case is suggestive of CAGE, but this appears to be excluded by the negative CT scan. This incident was investigated by the local workplace authority as a workplace-related death. The management of the investigation by the local police was criticised for the failure to follow a protocol, which required involvement of a diving medicine expert at the autopsy. Neither health nor equipment factors can be faulted but inexperience may have led to a panic ascent.

*Summary:* 40-year-old-male; no known medical history; certified diver for 28 years but unknown experience; hired equipment; diving alone to retrieve anchor; surfaced and became unconscious; drowning

### **Rebreather fatality**

RB 06/01

This report lacks vital details because the victim’s family refused permission for access to the full coronial documentation. However, some key witnesses provided

important information. The victim, a 31-year-old male, was an experienced technical diver with extensive experience in open-circuit trimix diving. He had 20 years’ diving experience with 75 dives in the past year. He cycled regularly, went to the gym twice-weekly for weight training, and was described as “*fit and healthy*”, without any known medical conditions.

He had trained in the previous year on a ‘PRISM’ electronic closed-circuit rebreather (CCR) using air diluent. However, due to the unreliability of this unit he had recently retrained in the use of an ‘Inspiration’ CCR. This rebreather differs from the former in a number of key areas, including the direction in which the gas circulates around the breathing loop and the placement of the O<sub>2</sub> and diluent cylinders and their manual injection buttons on opposite sides. The victim had reputedly had these differences highlighted to him during the retraining and had been encouraged to gain experience with the unit conducting air dives only. He had apparently conducted several dives in the 40–50 msw range on the unit after the course.

The victim and two friends were planning to dive from his boat, with another friend remaining on board as boat operator. The dive site was a wreck at a depth of 75 msw located 5 km offshore. Conditions were choppy and, as the victim was suffering from seasickness, it was decided that he would enter the water first in an attempt to alleviate his symptoms. A shot-line with an attached ‘mermaid’ line was dropped at the site and the dive boat was anchored. The victim was assisted in gearing up and entered the water with one of his buddies. The victim soon complained that he felt nauseous and decided to abort the dive. As the boat had now drifted some distance away, the pair decided to wait at the shot-line buoy until it returned to drop off the third diver.

The buddy turned to watch the approaching boat and then turned again to check on the victim, only to find him underwater at about 5 msw, apparently unconscious and sinking rapidly. He immediately tried to descend but had to return to the surface as, in his haste, he had failed to allow sufficient air out of his drysuit. He called to the other diver on the boat and when he entered the water, the two descended to try to reach the victim. After descending to 55 msw without sighting the victim and with visibility rapidly deteriorating, they decided to ascend as the second diver was now experiencing problems with his CCR. The buddies ascended, boarded the boat and notified the emergency services.

A subsequent search using boats and aircraft failed to locate the victim. His body was eventually found by a diver eight days later at 75 msw depth with all equipment in place.

*Autopsy:* The autopsy reported the cause of death as drowning following loss of consciousness from an unknown cause.

*Comment:* The use of hypoxic diluents with CCRs makes the possibility of becoming unconscious particularly likely at the surface. Because of this, CCR divers are usually encouraged to purge the unit with oxygen if they are on the surface while waiting to return to the boat, exerting themselves or feeling unwell. The fact that the unit that the victim was using on this occasion had the diluent and oxygen manual addition buttons on opposite sides to that of the unit on which he had originally trained may well have contributed to his death as, if he had flushed with diluent ( $150 \text{ L min}^{-1}$ ), it is unlikely that the electronic controlled injection of oxygen would have kept up. Why no alarms were heard by his buddy remains a mystery, although one possible explanation is that the 'buzzer' on the CCR was underwater and hence the sound was not transmitted across the water/air interface.

Another theory that has been put forward to explain this death is that the unit, an early production 'Inspiration' units, may have suffered from battery 'bounce' as the victim rolled backwards into the water from the boat, resulting in the electronics turning off and back on into 'no-dive mode', in which case the CCR would no longer automatically add  $\text{O}_2$ . While this was a known problem with early 'Inspirations', a factory fix had been available for several years. There is no mention whether this 'fix' had been applied to this unit. In any case, correct procedure and vigilance by the victim should have avoided either of these scenarios.

The combination of stress, motion sickness and task loading would appear to have distracted the victim and resulted in him failing to adequately monitor his  $\text{O}_2$  partial pressure; hence he became hypoxic and lost consciousness. Once the mouthpiece had fallen from his mouth, the subsequent loss of buoyancy as the CCR flooded resulted in him sinking rapidly. It is interesting that the buddy was shocked by how quickly these events unfolded. The issue of vigilance when using a CCR and the importance of correctly retraining experienced open-circuit divers about the differences between open-circuit scuba and a CCR cannot be understated.

*Summary:* 31-year-old male; apparently fit with no known health conditions; experienced technical rebreather diver; recent change to different rebreather type; probable seasickness; possibly breathed hypoxic mix by mistake; became unconscious and sank; drowning

A summary of the possible sequence of events in these 16 fatalities is shown in Table 3.

## Discussion

The main purpose of these ongoing fatality reports, as stated in the introduction, is to highlight problems so that similar events can be minimised in the future. This report again details potentially avoidable diving accidents, but also some cardiac-related deaths that were likely to have been unavoidable and could have occurred in non-diving circumstances.

BH 06/01 was one of the deaths that was likely to have been avoidable. Stingrays are generally relatively placid and attacks on divers, snorkellers and swimmers are rare and usually the result of the creature trying to escape or defend itself, rather than attacking without provocation. There are only 17 well-documented deaths due to stingray injuries up till 1996, although there are likely to have been many more that were not adequately documented.<sup>1-5</sup> Such fatalities are usually due to trauma, severed arteries, or infection and rarely from the direct effects of the venom. This was the third recorded stingray-related fatality in Australia, the others being in 1945 and 1989.<sup>6-8</sup> All three deaths resulted from chest penetration by the barb.

Unlike the two previous annual reports, there were no breath-hold fatalities in 2006 thought to have been associated with apneic blackout. Among the snorkelling group, chiefly identified from the GBR area, five of the ten victims were overseas visitors. Once again, there were a number of cardiac-related deaths, mainly in snorkellers, 55 years or older, with pre-existing cardiovascular disease, whether previously identified or not. These included BH 06/02, BH 06/04, BH 06/05, BH 06/06, BH 06/09 and BH 06/10. In only one (BH 06/05) was there any reason to have suspected ill health and in none was strenuous exertion a factor. One scuba diver (SC 06/04) possibly suffered cardiac pain prior to a rapid ascent during which he sustained a CAGE. Of interest, in three of these cases that occurred on the GBR, AEDs were available (BH 06/02, BH 06/03 and BH 06/04). The availability of AEDs on dive boats in Queensland is encouraged by the local Workplace Health and Safety Regulations and has the potential to save lives in the right circumstances. However, in all these cases, the AEDs indicated that no shock was required, so it was likely that ventricular fibrillation had not occurred or, more likely, had already ceased by the time the AEDs were attached.

The main factor determining the chances of survival after many cases of cardiac arrest is how quickly sinus rhythm can be restored. CPR plus defibrillation within 3–5 minutes of cardiac arrest can produce survival rates as high as 49–75%.<sup>9</sup> Therefore, the inevitable delays in recognising that a victim has become unconscious in the water, bringing them to boat or land, commencing CPR and retrieving and attaching an AED all reduce the likelihood of success. Such delays occurred in each of these cases, so the likelihood of a successful outcome was low.

In three cases (BH 06/04, SC 06/04, SC 06/05), there were great difficulties and delays in bringing the victim aboard the boats. This can often be a problem, depending on the size of the victim, the amount and type of equipment worn, the number of rescuers available and the type of boat. It is important to have a pre-planned, time-efficient, effective and adequately practised system in place to deal with such a situation. There are commercially made devices specially designed to facilitate the easy removal of a diver from the

**Table 3**  
**Root cause analysis of diving-related fatalities in Australian waters in 2006**

<b>Case</b>	<b>Trigger</b>	<b>Disabling agent</b>	<b>Disabling injury</b>	<b>Cause of death</b>
BH06/01	Startling stingray	Stingray barb injury	Trauma	Cardiac tamponade Cardiac-related
BH06/02	Unknown (exertion?)	Cardiovascular disease	Cardiac incident	Cardiac-related
BH06/03	Unknown	Unknown (cardiac?)	Asphyxia	Drowning
BH06/04	Unknown	Cardiovascular disease	Cardiac incident	Cardiac-related
BH06/05	Unknown (exertion?)	Cardiovascular disease	Cardiac incident	Cardiac-related
BH06/06	Unknown	Cardiovascular disease	Cardiac incident	Cardiac-related
BH06/07	Unknown (water inhalation from snorkel?)	Sudden loss of consciousness (laryngospasm?)	Asphyxia	Drowning
BH06/08	Unknown (epilepsy?, methamphetamine?)	Sudden loss of consciousness	Asphyxia	Drowning
BH06/09	Previous myocardial infarction	Cardiovascular disease	Cardiac incident (cardiac rupture fr. recent infarct)	Cardiac-related
BH06/10	Exertion	Cardiovascular disease	Cardiac incident	Cardiac-related
SC06/01	Unknown (loss of equipment/panic?)	Loss of regulator/mask due to mild trauma?	Asphyxia, ascent-related?	Drowning
SC06/02	Unknown (epilepsy?)	Unknown	Asphyxia	Drowning
SC06/03	Entrapment, gas-supply-related	Gas-supply-related	Asphyxia	Drowning
SC06/04	Unknown (exertion?)	Ascent-related, cardiovascular disease	CAGE	CAGE
SC06/05	Unknown (anxiety/panic?)	Ascent-related	Asphyxia	Drowning
RB06/01	Seasickness	Equipment-related	Asphyxia	Drowning

water by a single rescuer, ideally in the horizontal position (e.g., Jason's Cradle™).<sup>10</sup>

Two drowning deaths occurred in individuals who had a history of epilepsy (BH 06/08 and SC 06/02). It is unknown whether or not epilepsy contributed to these deaths, but this is always a consideration in an aquatic environment. Epilepsy is regarded as a contra-indication to breath-hold and scuba diving.<sup>11</sup>

Failure to gain adequate buoyancy quickly in an emergency is often identified as an issue in dive fatality reports, and this year was no exception. SC 06/01 was excessively overweighted and carried all his weight in his BCD pockets, from where it could not be readily ditched. It is also possible that his BCD was not functioning adequately and that his fins provided little thrust. Had he been able to attain and maintain positive buoyancy when he initially surfaced, there should have been a greater likelihood of survival. It has been

claimed that divers who manage to reach the surface promptly in an emergency, whether conscious or unconscious, have a greater chance of survival than those who need to be sought out and retrieved from underwater.<sup>12</sup>

Once again, solo diving, coupled with lack of recent experience, may well have contributed to the deaths of two scuba divers (SC 06/01 and SC 06/05). It is important that divers have ready assistance available throughout the dive. It is also important that divers without recent experience return to diving in appropriate circumstances, with adequate supervision and support.

Commercial diver training inherently involves teaching participants how to prevent, as well as how to deal with, potential problems while using commercial diving equipment and performing various tasks underwater. Case SC 06/03 likely highlights the importance of not only having a redundant gas supply, but being able to quickly and easily

access it. Course participants vary greatly in diving training and experience and close supervision is always important, especially early in the training while they are familiarising themselves with their equipment. This case also highlights the importance of having a standby diver appropriately equipped and ready to enter the water with minimal delay in the event of an emergency.

The problem of whether to make a diagnosis of CAGE in the absence of physical evidence is noted in one case. (SC 06/05). Many dive sites are remote, and it may be difficult to get a CT scan of the body within 8 hours of death, although this remains the most useful test for CAGE. Problems with decomposition and post-mortem off-gassing make scan results unreliable after this time. The history of a rapid ascent followed by loss of consciousness is a very important factor in the diagnosis of CAGE, but if a CT scan has been done and is negative it is hard to justify the diagnosis of CAGE.

Technical diving and, in particular, rebreather diving are rapidly growing areas of recreational diving. CCRs are complex pieces of equipment with a number of potential failure modes that are not necessarily familiar to even the experienced open-circuit scuba diver. An open-circuit scuba failure will usually result in the diver being unable to breathe. In contrast, a diver using closed or semi-closed rebreather scuba will often still be able to breathe despite a failure in the unit, which may result in a non-life-sustaining gas mixture being delivered. The subtle onset of such failures can result in a loss of consciousness with little to no warning. As such, these divers must be ever vigilant as to the partial pressure of O<sub>2</sub> they are breathing.

Case RB 06/01 highlights the importance of divers being thoroughly familiar with the CCR that they are using, including the gas mixes utilised on a particular dive. It also highlights that CCR divers should inflate other buoyancy devices when on the surface and not rely on their counterlung as a primary buoyancy device.

It was noted during the preparation of these case reports that the practice of police reporting a summary of the evidence, rather than including copies of the witness statements significantly degrades the value of the reports as a complete resource for research and the subsequent discussion of critical factors in fatal dives, even though there may be valid reasons for doing this.

### Conclusions

In 2006, there were 16 reported diving-related fatalities, which included 10 deaths while snorkelling, five while diving on open-circuit scuba and one while using a CCR. Causal or contributory factors associated with these deaths included cardiac disease or other co-existing illnesses, inexperience or lack of recent experience, and injury from a stingray.

The main disabling injury with snorkellers was cardiac-related episodes (six of ten cases), followed by asphyxia leading to drowning (three cases). With scuba divers, the main disabling injury appears to have been asphyxia, leading to death by drowning in five of the six cases. CAGE was identified as the likely disabling injury in the other death, although it is thought that there may have been a cardiac-related disabling agent to this incident. A summary of the possible sequence of events in these 16 fatalities is shown in Table 3.

Factors that may reduce mortality in the future include improved medical screening of older divers, improved supervision of snorkelling activities, avoidance of close contact with potentially dangerous marine creatures, such as stingrays, increased adherence to the buddy-diving system and attention to the integrity of and familiarity with the equipment being used.

### Conflict of interest

John Lippmann is the Executive Director of DAN AP. DAN is involved in the collection and reporting of dive accident data and provides evacuation cover and dive-injury insurance to recreational divers.

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*John Lippmann, OAM, BSc, Dip Ed, MAppSc, is the Executive Director of Divers Alert Network (DAN) Asia-Pacific.*

*Douglas Walker, MB, ChB, MM, is a retired general practitioner, former Editor of the SPUMS Journal and Project Stickybeak researcher.*

*Chris Lawrence, MB, BS, FRCPA, is Director, Statewide Forensic Medical Services, Royal Hobart Hospital, Tasmania.*

*Andrew Fock, MB, BS, FANZCA, Dip DHM, is a senior specialist for the Hyperbaric Services, The Alfred Hospital, Melbourne.*

*Thomas Wodak, LLB, is a retired County Court judge with an interest in litigation involving medical matters, and a past dive instructor.*

*Scott Jamieson is a researcher for DAN Asia-Pacific.*

**Address for correspondence:**

*John Lippmann*

*PO Box 384, Ashburton*

*VIC 3147, Australia*

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

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

**E-mail:** <[johnl@danasiapacific.org](mailto:johnl@danasiapacific.org)>

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