

Provisional report on diving-related fatalities in Australian waters 2005

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Key words

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

Abstract

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Introduction: An individual case review of diving-related deaths reported as occurring in Australia in 2005 was conducted as part of the DAN Asia-Pacific dive fatality reporting project.

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

Results: In total, there were 24 reported fatalities, comprising four females and 20 males. Fourteen deaths occurred while snorkelling and/or breath-hold diving, nine while scuba diving, and one while using surface-supply breathing apparatus. Four deaths from large marine animal attacks were recorded. Once again, cardiac-related issues were thought to have contributed to some deaths: five snorkel divers and at least two but possibly up to four scuba divers. Three of the deaths in breath-hold divers were likely to have been associated with apnoeic hypoxia blackout.

Conclusions: Pre-existing medical conditions, trauma from marine creatures and snorkelling or diving alone were features in several deaths in this series.

Introduction

Tragically each year in Australia (and elsewhere), there are numerous fatalities associated with compressed-gas diving and snorkelling. Some of these accidents are unavoidable. However, many fatalities might have been avoided through better education, greater experience, appropriate medical screening, better equipment maintenance and design or common sense. The aim of the DAN Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and the diving industry and to inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future and of detecting, in advance, those who may be at risk. This report includes the diving-related fatalities between 1 January and 31 December 2005 that are recorded on the DAN Asia-Pacific (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.

Methods

As part of its on-going 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 Coronal Information System (NCIS). The methodology used for this

report was identical to that described previously for the 2004 Australian diving-related fatalities.¹

Snorkelling and breath-hold fatalities

BH 05/01

The victim, a 60-year-old female overseas visitor, was with a group but unknown to any of them. While on a day trip to an island she hired mask, snorkel, fins and a floatation vest and went to an unsupervised section of the beach, to swim alone. She was found floating face-down about 100 metres from the beach. When seen, she was initially thought to be snorkelling, but witnesses then thought she seemed to be in trouble. No details of what they observed are reported. Staff were alerted and, after a delay, one entered the water and brought the victim back to the beach. She had the snorkel in her mouth when she was reached but was unconscious and cyanotic. Resuscitation efforts by staff, including semi-automated defibrillation, and advanced life support (ALS) by paramedics, were unsuccessful.

Autopsy: Autopsy revealed oedematous lungs (R 768 g, L 606 g) consistent with a diagnosis of drowning; the right pleural cavity was almost obliterated by fibrous adhesions. The heart weighed 276 g and was normal with mild coronary atherosclerosis. The cause of death was given as drowning due to salt water immersion.

Comment: Nothing is recorded of her health, swimming ability or experience in the use of a snorkel prior to the

Table 1. Summary of snorkelling
BNS – buddy not separated; BSB – buddy separated before problem; BSD – buddy separated during problem;
n/s – not stated;

ID BH	Age	Gender	Height (m)	Weight (kg)	BMI	Training	Experience	Dive group
05/01	60	F	1.62	60	22.9	n/s	n/s	Solo
05/02	26	M	n/s	n/s	n/s	trained	yes	GSB
05/03	63	M	1.78	81	25.6	nil	nil	GNS
05/04	40	M	1.93	87	23.4	nil	yes	Solo
05/05	37	M	1.80	77	23.8	trained	yes	BSB
05/06	51	F	n/s	n/s	n/s	n/s	n/s	Solo
05/07	42	M	1.77	75	23.9	trained	yes	Solo
05/08	21	M	1.87	71	20.3	trained	yes	Solo
05/09	59	M	n/s	n/s	n/s	nil	nil	BNS
05/10	30	M	1.65	56	20.6	nil	nil	BSD
05/11	59	M	1.72	70	23.7	nil	nil	BNS
05/12	65	M	1.83	83	24.8	nil	yes	BSB
05/13	76	M	1.80	112	34.6	n/s	n/s	BSB
05/14	35	F	1.59	54	21.4	n/s	n/s	Solo

incident. The float vest failed to prevent her from floating face-down and drowning. She was wearing a bathing costume so it is probable the water was not cold. It is likely that she aspirated water through the snorkel and subsequently drowned. She was not snorkelling with a buddy and was not directly supervised.

Summary: Solo snorkelling in calm water; unknown experience; wore floatation device but floated face-down when unconscious; drowning (possibly due to inexperience with snorkel use).

BH 05/02

This victim was a 26-year-old male, an experienced snorkeller and scuba diver, working as skipper of a luxury charter boat on its maiden voyage. The vessel was anchored at one of a group of offshore islets where the water depth rapidly increased from 5 metres' seawater (msw) close to the shore to 50 msw. Some of the passengers and crew were fishing but it is unclear whether this was done directly from

the boat or elsewhere. After completing some tasks on the boat, the victim and four of the crew snorkelled close to the boat; two drifted away and two left the water, leaving the victim alone. Some staff on the boat then saw the white underbelly of a large shark and a cloud of blood in the water. The victim had been bitten in half and the shark had carried away the lower portion of his body. His torso floated away, but the shark returned and appeared to make a strike about 100 metres from the boat, after which the torso could no longer be seen. One of the crew, a shark fisherman, thought it was a great white shark and estimated it to be about six metres or more in length. None of the victim's remains were recovered. No berley had been put into the water by the fishermen and none of the snorkellers were spear fishing. It was, however, the start of the crayfishing season when sharks are known to frequent the area.

Autopsy: The body was not recovered. The coroner found that the victim died as the result of an attack by a great white shark and that death occurred by accident. The cause of death was given as multiple injuries due to shark attack.

and breath-hold diving-related fatalities

GNS – group not separated; GSB – group separated before; n/a – not applicable; n/i – not inflated; reocrn – recreational dive

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	BCD	Disabling agent
reocrn	n/s	surface	nil	n/a	nil	Asphyxia
reocrn	n/s	surface	nil	n/a	nil	Trauma (shark)
reocrn	n/s	surface	nil	n/a	aid	Cardiac
reocrn	12	n/s	nil	n/a	nil	Asphyxia ?hypoxic blackout
reocrn	n/s	surface	nil	n/a	nil	Trauma (crocodile)
reocrn	n/s	surface	n/s	n/s	n/s	Cardiac
abalone	4	n/s	on	5.5	nil	Asphyxia ?hypoxic blackout
reocrn	1.5	1.5	on	n/s	nil	Asphyxia ?hypoxic blackout
reocrn	0.5	surface	nil	n/a	float	Cardiac
reocrn	2.5	surface	nil	n/a	nil	Asphyxia
reocrn	n/s	surface	nil	n/a	aid	Cardiac
spearfishing	n/s	surface	on	5.5	nil	Asphyxia
reocrn	n/s	surface	nil	n/a	nil	Cardiac
reocrn	n/s	n/s	nil	n/a	nil	Asphyxia ?hypoxic blackout

Comment: Although it was known that sharks frequented this area during the crayfish season, there was no evidence that the victim had collected crayfish or precipitated this shark attack in any way. It is possible that the nearby fishing might have attracted a shark to the area, but this is speculative.

Summary: Sudden lethal shark attack on snorkeller close to deep-water drop off.

BH 05/03

This overseas visitor was a 63-year-old male who had suffered a myocardial infarction (MI) 10 years earlier and had undergone regular medical checks since then. He was taking three unidentified medications but had not been advised of any restrictions to his activities. He was a weak swimmer and had never snorkelled before. He and his wife were on a commercial snorkelling day trip to the Great Barrier Reef (GBR). During the outward trip the passengers were briefed on snorkelling safety, in which health risks were mentioned. There was also a poster about medical

risks on display. The victim did not report his health issues. The weather was fine, with only a slight surface chop. After the vessel moored at the reef, the passengers were issued lycra suits, mask, fins and snorkel, and 'noodles' (floatation devices). The victim was given three noodles, one under each arm, the third to be held in front of his body, then snorkelled close to the vessel with his wife. He had some problems breathing through his snorkel and was advised that he did not have to use it but could hold his breath and look down, looking up to breathe as required. After about 15 minutes, he returned to the vessel and sat on the duckboard where his wife and several other snorkellers were sitting.

Several minutes later the victim said that he felt unwell and collapsed backwards. He was unconscious, apneic and had no palpable pulse. Basic life support (BLS) was commenced using a bag-valve-mask until oxygen equipment was brought from another vessel. Resuscitation was continued until the rescue helicopter arrived and the paramedics pronounced him dead.

Autopsy: The autopsy showed his heart weighed 439 g and there was severe triple-vessel atherosclerosis with complete occlusion of the left anterior descending coronary artery and an extensive old scar in the anterior apical left ventricle (55 x 25 x 2 mm) due to the previous acute myocardial infarction. The lungs (R 912 g, L 725 g) were oedematous and congested with pulmonary oedema fluid in the bronchi. The cause of death was given as cardiac arrhythmia in consequence of myocardial fibrosis the result of severe coronary artery atherosclerosis. Only the official summaries of witness depositions are available, not their statements, so his actual health status is unknown.

Comment: The cause of death was clearly ischaemic heart disease. The lung changes were similar to cases where a diagnosis of drowning was made; however, he was out of the water when he collapsed. Nothing in his history would suggest he experienced salt water aspiration. This highlights the nonspecific pathological changes of drowning. A person with a previous infarct and this degree of ischaemic heart disease is clearly at risk of sudden death during exertion despite being declared fit to travel.

Summary: Previous heart attack; recent medical assessment as fit to travel, but no information on recent health; short period of snorkelling in non-stressful conditions, left water then reported feeling unwell and died; cardiac incident.

BH 05/04

This victim, a 40-year-old male overseas visitor, was a guest on a liveaboard vessel offering diving and snorkelling on the GBR. He stated he had no medical problems, was able to swim 5 km and that he could breath-hold dive to 10–20 msw and hold his breath for up to 2–4 minutes. The pre-snorkelling talk emphasised the dangers of hyperventilation and the importance of always diving with a buddy. On the first day, he spent 45 minutes snorkelling with others, and then took a Resort Scuba Dive after completing another medical questionnaire.

On the second day, there was another briefing, after which the victim told one of the supervisors he intended to breath-hold dive down to join the scuba divers when they were at 18 msw. He was told that would be unsafe and that he should remain in the shallower areas. He was later seen within a few metres of them at 15 msw. Following this he was seen free-diving alone near the stern. Possibly five minutes later two scuba divers surfaced and reported seeing a person on the sea bed below. The instructor immediately donned scuba gear, dived and brought the victim to the surface from a depth of 12 msw. His mask was in place but there was no snorkel. In-water rescue breathing was followed by on-board BLS with supplemental oxygen, but there was no response. Although the crew held oxygen-provider certifications, they were untrained in the use of the bag-valve-mask equipment carried on the boat. However, there is nothing to suggest that this influenced the outcome.

Autopsy: Autopsy revealed heavy oedematous lungs (R 877 g, L 856 g) consistent with drowning. The heart weighed 425 g (normal, given his size) and there was mild coronary atherosclerosis. The story is typical of post-hyperventilation apneic hypoxia. The cause of death was given as drowning due to probable apneic hypoxia following hyperventilation.

Comment: This again highlights the risks of extended breath-hold diving, especially without a vigilant buddy nearby.

Summary: Experienced breath-hold diver; solo breath-hold diving to at least 12 msw against advice; drowning (possibly due to post-hyperventilation apneic hypoxia).

BH 05/05

Although locals were well aware of the presence of numerous crocodiles and the danger they constituted, it was common practice, even by members of the local police, to swim in the waters off this beach. This victim, a 37-year-old male, had lived in the area for about six months and had been warned of the danger, but also was aware of the local practice. On this day, he was intending to snorkel with a friend while their wives remained on the beach. He was reportedly an avid scuba diver and strong swimmer. Although the two men became separated, this was not noticed as being of any significance until some time later when, after searching up and down the beach for him without success, his buddy became concerned and informed the police. The victim had been swimming close to the beach when last seen, but a full-scale search, involving air, sea, and beach searchers, was unsuccessful. The next day his body was found near a large saltwater crocodile, approximately 1.5 km from where he had been snorkelling. The crocodile was shot by the police.

Autopsy: The autopsy revealed the presence of numerous lacerations and punctate tricorn wounds on the face, scalp, trunk and shoulders, and fractures of the frontal and right temporal bones, a midline skull fracture and multiple fractures of the mandible. There was little associated haemorrhage and no intracranial haemorrhage or damage to the brain. The trachea, bronchi and stomach contained sand and gravel. The pathologist concluded that the cause of death was multiple injuries due to crocodile attack but noted a relative lack of haemorrhage associated with the fractures. This can occur due to leaching of the blood and decomposition during immersion. The mechanism of death could have been blood loss, asphyxia or terminal drowning. However, despite the presence of sand and gravel in the airways, lungs and stomach, the pathologist found no evidence that drowning was the primary cause of death.

Comment: A notice had been posted 10 days before this fatality, warning of the sighting of a crocodile in the wharf area and that there was increased risk from crocodiles with the approach of the wet season.

Summary: Snorkelling in area known to have a risk from crocodiles; local tolerance of the risk; lethal trauma.

BH 05/06

A 51-year-old overseas tourist and her husband were staying at a small island resort and decided to snorkel from the beach. She was wearing a wetsuit. After a time, her husband felt cold and swam back to the shore. He looked back, and saw his wife waving her arms in the air as if in trouble. He ran to get a kayak and to raise the alarm. She was said to have been caught in a strong current and required to swim vigorously just before she signalled for help. Meanwhile, another person (a doctor) staying at the resort saw the victim's trouble and swam out and brought her back to the beach. Initially she was gasping for air and cyanotic but when brought ashore was soon unconscious and apneic. BLS was unsuccessful.

Autopsy: The autopsy showed that "*the condition of her heart was not good*"; the cause of death was given as a coronary artery occlusion. Her medical history and specific autopsy findings are unknown as this was a 'natural' death and so did not require coronial notification.

Comment: The cause of death may have been from ischaemic heart disease but drowning may also have contributed. Such cases are usually reported to the coroner so that it can be established if the death was natural, i.e., due to ischaemic heart disease, or accidental, i.e., due to drowning or a combination of the two.

Summary: Health history unknown; snorkelling; buddy went ashore due to cold water; strong current; cardiac incident.

BH 05/07

The victim, a fit 42-year-old male, was an experienced snorkeller who usually dived alone. He called his wife to tell her that he was going spearfishing. When he failed to pick up his child from school, she became concerned. After finding his car where he usually parked it when diving, she called the police. The police found his backpack and clothing on a rock near where he would likely have entered the water, and later retrieved a buoy, with his catch bag and spear gun attached, about 50 m from the shore and close to a reef. By this time it was too dark to continue their search. The next day police divers found his body at a depth of 4 msw, about 50 metres south of where the buoy had been and 30 metres from the beach. He was on the sea bed in a sandy area close to a rock that nearly broke the surface: Visibility was 3–4 metres. There was thick kelp in the area. He was wearing two wetsuits, neoprene hood and booties, a weight belt, mask and snorkel, and two pair of gloves. The water temperature was reported to be 9°C.

Autopsy: The pathologist noted that his weight belt was old fashioned and its clasp had no quick release. There was evidence of mask squeeze with some blood around the face.

The lungs were over-expanded and oedematous (R 1022 g, L 836 g) with pulmonary oedema in the upper airways and bronchi consistent with drowning. The heart weighed 340 g and there was a 50% stenosis of the right coronary artery (generally insufficient to cause death). He had a history of asthma and had histological changes consistent with asthma, which had reportedly not troubled him for years. There was no evidence of any asthma factor in his death. The cause of death was given as drowning while snorkelling.

Comment: His wife reported he had not gone snorkelling during the previous four weeks because of URTI symptoms. He had been taking long-term medication since a workplace accident resulted in him developing a hernia, which had not been operated upon. He drowned, but the precipitating factors for drowning are unclear. Possible factors include no quick release on his weight belt, possible hypoxic blackout of ascent as he had been diving for abalone in 4 msw, entanglement in kelp (although his body was not entangled when found), cold water (9°C), the 50% coronary artery stenosis, or other unknown factors.

Summary: Experienced, solo breath-hold diving for abalone and fish; cold water; depth insufficient to require prolonged apnea unless determined to target a fish; drowning.

BH 05/08

This healthy 21-year-old overseas male was visiting his grandmother in Australia. He was a scuba diver with a keen desire to improve his breath-holding ability, which he claimed was three and a half minutes. He practised in his grandmother's swimming pool each morning and evening. His grandmother found him lying motionless on the pool bottom, wearing goggles and a weight belt. She called for help and her next-door neighbour arrived before she collapsed from an acute myocardial infarction. The victim was removed from the pool, but no resuscitation was attempted prior to the arrival of paramedics. He did not regain consciousness and life support was turned off three days later. His dive watch indicated that he had been underwater for over 19 minutes before he was discovered.

Autopsy: No autopsy was performed at the request of the parents. The cause of death was stated to be "*hypoxic brain injury due to near drowning*".

Comment: This was very likely a drowning due to post-hyperventilation apneic hypoxia.

Summary: Scuba diver; alone in pool, training to increase breath-hold; weight belt on; delayed drowning death (possibly due to post-hyperventilation apneic hypoxia).

BH 05/09

Minimal details are available concerning the fatality of a 59-year-old man with a history of hypertension and cardiac

disease. He was visiting Australia with his wife and took a day trip to the GBR. During the outward trip, the passengers were given written advice on snorkelling and advised to report any medical conditions, advice that he followed. They were taken to an island and the victim, with two others, started to snorkel off the beach. A short time later a crew member on safety watch saw him being assisted in very shallow water. He was cyanotic and coughing up water. He was assessed to be unconscious, apneic and pulseless and BLS was attempted without success. In view of his medical history, there was no referral to the coroner and no autopsy was performed. No further details of his medical condition or medications are available.

Comment: The likely cause of death was ischaemic heart disease while snorkelling, with exertion triggering a lethal arrhythmia. There may have also been terminal drowning.

Summary: History of hypertension and cardiac disease; snorkelling in shallow, calm water; cardiac incident.

BH 05/10

The tragic death of this 30-year-old male overseas visitor on his honeymoon occurred during a day trip to an island on the GBR. He was described by his wife as an adequate swimmer who had snorkelled on two or three previous occasions. After a seemingly large lunch, the couple hired masks, fins and snorkels and began to snorkel in an unsupervised area approximately 30–40 metres from shore. They were wearing normal bathing costumes. The weather was fine, sea calm and there was reported to be no current. The water depth was approximately 2.5 msw. Possibly 20 other swimmers and snorkellers were in the water, but none were close to them. When out of their depth, the victim began to panic, grabbed his wife and nearly drowned her as she attempted to help him. She later reported that he may have swallowed water and was attempting to keep his head above the surface by trying to climb on top of her. She tried to calm him and they separated briefly as she signalled for help. She became exhausted and briefly became unconscious.

At this time, the resort manager noticed one of the people in the water behaving strangely, seeming to swim backwards in circles, and he instructed two staff members to swim out to assist. The victim's wife was motionless in the water, but breathing and she was brought back to the beach where oxygen was administered. Thirty minutes later an interpreter found that she had been trying to tell the staff that her husband had been swimming with her. A search was immediately made for him in the water and his body was found floating above the sea bed close to where she had been found. BLS was commenced but the rescuers were hindered by frequent regurgitation of stomach contents. Despite this, resuscitation was continued for 45 minutes until paramedics attended and declared the victim dead.

Autopsy: Autopsy showed oedematous lungs (R 690 g, L 687 g) consistent with drowning, a heart that weighed 304 g with no atherosclerosis. The cause of death was given as drowning following inhalation of water, and panic.

Comment: His wife said he was not scared of water and could swim; the probable reason for his panic was his reaction to water unexpectedly inhaled via his snorkel. Although there was a notice warning that there were no lifeguards on the beach, it was in English, which the couple did not speak. Although the woman waved her arms to attract attention, she did not call out, delaying the rescue response.

Summary: Minimal snorkelling experience; calm water; possible aspiration of water through snorkel, causing sudden panic exacerbated when found water too deep to stand up in; buddy at severe risk from victim's actions; drowning.

BH 05/11

This 59-year-old male overseas tourist had suffered an asymptomatic MI many years previously but had led an active life with no apparent cardiac symptoms. He was taking medication of unknown type for hypertension and high cholesterol. He and his family were visiting the GBR and had joined a day trip to go snorkelling. It is not known if he had prior snorkelling experience. During the trip out, a talk on snorkel use was given to the passengers. According to the local Code of Practice, cautionary advice should have been provided specifically for older persons or for those with heart conditions. An information form, usually available for this purpose, was not used on the day. Passengers were asked to tell the staff if they were poor swimmers or had any other possible problems, but health factors were not specifically mentioned. Poor swimmers were advised to wear a wet suit and use a floatation device.

The boat, carrying nine passengers, anchored and put its two tenders in the water. Passengers were offered the use of wetsuits, along with mask, snorkel and fins, which the victim accepted. A dive master member of the crew watched from the stern as the passengers entered the water. She asked the victim if he was a good swimmer and he replied that he was okay, although his wife later claimed that earlier that day they had told a crew member they were not strong swimmers and needed assistance. In fact, the dive master noted he had a 'noodle' (floatation device) and was not managing the current, so gave him a ring to hold and towed him to the shallows over the reef. When they had gone about 25 metres, his wife asked him how he was going and he replied "*this is different*" (from a swimming pool), and agreed that he would like to return to the boat. When they were about 10 metres away from the boat, the victim raised his head, lifted his mask, dropped face first into the water and let go of the ring. She turned him on his back to keep his face above water and called for help. She noticed that his jaw was clenched, his tongue was between his teeth and he appeared to "*jolt a couple of times*". Other crew entered

the water and brought the victim aboard the vessel, where BLS with supplemental oxygen was promptly commenced, assisted by doctors and a nurse who were passengers on board. An emergency helicopter arrived, but the victim was dead and his body was transported to hospital.

Autopsy: A CT scan revealed no evidence of barotrauma. The heart weighed 404 g with severe triple-vessel atherosclerosis, with 75–90% stenosis. There was evidence of old infarction with scarring of the apical-posterior left ventricle and interventricular septum. There was no evidence of trauma. The cause of death was reported as acute cardiac failure.

Comment: The history of a ‘silent’ MI raises the question as to whether the victim failed to recognise angina symptoms or had atypical symptoms. It is unlikely that he did not have some symptoms with such severe coronary artery disease.

Summary: History of a ‘silent’ MI many years earlier; taking unidentified medication for hypertension and for cholesterol control; appeared fit; poor swimmer using floatation aid; current; severe coronary artery disease; cardiac incident.

BH 05/12

The uncertainty in reconstructing circumstances where there are no witnesses to critical events is well illustrated in this incident. The victim, a 65-year-old male, with a history of epilepsy, was an experienced spear fisherman who was fishing with a friend in an area with which they were familiar. They had been in the water approximately 1.5 hours when the buddy indicated he was going back to shore to clean his catch; the victim said he would follow shortly.

A fisherman on the rocks had first noticed two men on the surface, one swimming towards the shore as the other dived. He did not see this diver return to the surface so assumed he had surfaced beyond the headland. There was reported to be a submerged rock close to where the victim was last seen. A small boat came into view about 100 metres out. The driver of this boat later reported that he had been travelling at a speed of about 4 knots. The sea was described as calm but with a strong current. The buddy said it took him 20 minutes swimming from when they separated until he reached the beach and left the water.

It was only when the buddy had finished cleaning his catch, about 30 minutes later, that he noticed his friend had not returned. He could not see him from the beach, but when he walked along the headland he could see something floating in the water about 100 metres from the shore. He saw it was drifting towards an anchored boat from which another man was spear fishing. He called out and managed to get his attention, and that of another person in the boat, who then saw the victim’s body moving in the strong current. The spear fisherman swam to the victim and, with assistance, pulled him aboard. It was obvious that the victim was dead. After picking up the buddy, they brought the body back to shore.

When found, the victim was wearing his mask, snorkel, wetsuit, weight belt, fins and also a net catch bag attached by a rope. Although a search was made, his spear gun was never found. He was not using a float or dive flag.

Autopsy: At autopsy a laceration was observed on the back of the head with a 100 mm bruise under the scalp. There was also an abrasion on the bridge of the nose probably caused during retrieval of the body. There was no skull fracture, intracranial haemorrhage or damage to the brain. The heart was slightly enlarged, weighing 390 g. Mild atheroma was present in the right coronary artery only. The cause of death was given as drowning.

Comment: Three possible underlying causes for this drowning can be considered:

- Superficial head injury from impact with rocks or a boat could have led to altered consciousness and/or inhalation of water. The cause of the head injury is uncertain. If he had been hit by a boat there would probably have been more extensive injury, especially if struck by the propeller. The two boats known to have been in the area were not thought to have been implicated.
- Seizure activity: There was a history of six grand mal episodes in 1998, for which he had been fully investigated and no cause found. He had had no further seizures, was retired and now taking regular carbamazepine (at autopsy blood level was therapeutic, 3.4 mg L⁻¹). There was no direct evidence, such as biting his tongue, to suggest this condition played any part in his death.
- Apneic hypoxia of ascent, with or without hyperventilation.

The spear fisherman who recovered the body was an off-duty police officer and had seen many dead bodies. He estimated that the victim appeared to have been dead for about an hour when the body was recovered.

Summary: Experienced spear fisherman; solo after buddy swam to land; on medication for epilepsy; evidence of fresh head injury; no dive flag; boats in area; drowning.

BH 05/13

The victim was a 76-year-old male with a history of aortic valve replacement, coronary bypass and cardiac stent insertion. Although he was taking medication for hypertension and hyperlipidaemia, there was no record of his recent health. He and several friends went snorkelling from a boat. After 5–10 minutes, he signalled that he wished the boat to pick him up and started to swim towards it. When he climbed aboard he was breathless, and said he was feeling tired, which was the reason for his return. About 10–15 minutes later a crew member found him slumped over, unrousable, apneic and pulseless. BLS, with supplementary oxygen, was commenced while the boat headed ashore, transferring him en route to another boat

**Table 2. Summary of scuba and surface-supply diving-related
BNS – buddy not separated; BSB – buddy separated before problem; BSD – buddy separated during problem;
GNS – group not separated; GSB – group separated before; GSD – group separated during;
CAGE – cerebral arterial gas embolism**

ID	Age	Gender	Height (m)	Weight (kg)	BMI	Training	Experience	Dive group
SC								
05/01	71	M	1.70	104	36.0	trained	expcd	GSB
05/02	52	M	1.84	98	28.9	trained	some	BNS
05/03	39	M				trained	expcd	GSB
05/04	45	M	1.88	120	34.0	trained	nil	GNS
05/05	30	F	1.64	n/s		trained	some	BNS
05/06	23	M				trained	expcd	BSD
05/07	67	M	1.60	57	22.3	trained	expcd	GSB
05/08	45	M	1.83	87	26.0	trained	expcd	BSD
05/09	51	M	1.68	83	29.4	trained	expcd	BSB
SS								
05/01	55	M	1.70	92	31.8	trained	expcd	BSB

with a defibrillator. On arrival, ALS from waiting paramedics was unsuccessful.

Autopsy: Autopsy revealed a large heart (780 g) with left ventricular hypertrophy and a porcine aortic valve graft showing calcification. There was severe narrowing of the native coronary arteries by atherosclerosis, with a recent thrombus in the left anterior descending and a stent in the circumflex. Venous bypass grafts showed sclerosis. The cause of death was given as acute coronary artery thrombosis due to ischaemic heart disease and aortic stenosis (surgically treated).

Comment: This event could have occurred in many different circumstances, with or without exertion.

Summary: History of aortic valve and coronary arteries bypass surgery; reportedly now 'fit and active'; became breathless while snorkelling; cardiac incident.

BH 05/14

A 35-year-old female overseas tourist was staying at a hostel or similar accommodation with a residents' swimming pool. A man was sitting beside the pool, looking after his two children swimming in the pool. He noticed a towel and some clothing on a chair. Thinking it indicated that someone else must be in the pool but seeing no-one on the surface, he

became curious, walked to the poolside and saw the victim lying face-down on the bottom of the pool with her arms folded across her chest, wearing goggles and snorkel. He thought she was training to hold her breath but soon realised she had been holding her breath far too long. He jumped into the pool and nudged her. When there was no response he grabbed her, brought her to the shallow end of the pool and pulled her out. He then phoned for help. Resuscitation was commenced only after the arrival of an ambulance a few minutes later, and she failed to respond.

Autopsy: Autopsy revealed oedematous lungs (R 808 g, L 725 g) with some pulmonary oedema fluid in the trachea and bronchi consistent with drowning. The heart weighed 304 g and was normal with minimal coronary arteriosclerosis. Toxicology showed no trace of alcohol or recreational drugs. Nothing is known of her personal history. There is no evidence concerning how long she had been in the pool before being discovered. The cause of death was drowning, possibly due to post-hyperventilation apneic hypoxia.

Comment: The sparse documentation of this fatality is devoid of details of the victim's personal history although the ascribed cause of her death is almost certainly correct.

Summary: Found dead in a swimming pool; drowning (probably as a result of post-hyperventilation apneic hypoxia).

fatalities in Australian water in 2005

++ 1/4–1/2; + sufficient air (to surface safely); expcd – experienced; recrn – recreational dive;
 n/s – not stated; nad – nothing abnormal discovered; dns – defect not significant; n/a – not applicable;
 n/i – not inflated;

Dive purpose	Depth (msw)	Incident (msw)	Wt belt	Wts (kg)	BCD	Remaining air	Equip test	Disabling injury
recrn	32.5	ascent	on	n/s	part infl	low	n/s	CAGE? cardiac?
recrn	20	ascent	on	n/s	inflated	++	nad	CAGE? cardiac?
cray	21	n/s	off	n/s	inflated	nil	nad	CAGE? asphyxia?
class	53	surface	n/a	n/a	n/a	n/a	dns	DCS
recrn	5.2	3.6	on	5.4	n/i	++	nad	Asphyxia? CAGE?
work	18	5	on	n/s	n/i	+	nil	Trauma (shark)
recrn	25	surface	off	n/s	n/s	low	nil	Cardiac
recrn	9	ascent	on	8	fail infl	nil	n/s	CAGE? asphyxia?
crayfish	n/s	surface	off	n/s	inflated	+	nad	Cardiac
work	n/s	n/s	on	n/s	n/s	n/a	n/s	Trauma (crocodile)

Scuba fatalities

SC 05/01

The victim, an obese but apparently fit 71-year-old male overseas visitor, was on a liveaboard dive vessel on the GBR. He had a history of 300 dives, although he had not dived during the previous two years. He claimed to have obtained a 'diving medical' within the previous three months and reported no adverse health conditions although he was taking an unidentified medication.

The victim was dressed in a wetsuit jacket and bathing costume and was using his own equipment, other than the tank, weight belt and dive computer, as his was found to be faulty. The sea was described as 'a bit choppy', visibility 'not good', and there was some current. The victim was buddied with two other divers who were judged to have a similar level of diving experience. The dive plan was for them to swim on the surface to the reef, and then start their dive. However, shortly after the trio entered the water, the victim dived and the other two followed. Although he had been told not to dive deeper than 18 msw on this dive, the dive computer he was wearing later showed a maximum dive depth of 32 msw.

The trio found they were over a sandy sea bed and could not locate the reef so, after 13 minutes, they began their ascent. Although the victim's ascent rate alarm sounded

on two occasions, indicating that his ascent rate exceeded 10 m min⁻¹, there is no indication that his rate of ascent was excessive. He spent two minutes at a safety stop at 7 msw before surfacing, the ascent alarm being triggered again during this final ascent.

At the surface, the three divers exchanged 'OK' signals. They were several hundred metres from the boat and decided to swim back on the surface although a tender was sent to pick them up. After collecting two other groups of divers and returning them to the vessel, the tender driver noticed the victim lying on his back, mask and snorkel missing, BCD partly inflated and weight belt and fins in place. He was unresponsive and cyanotic, with froth coming from his mouth. The tender driver was unable to lift the victim into the tender so he returned to the vessel for assistance. The victim was lifted into the tender and BLS commenced. It was continued on the dive vessel until the staff received medical advice to cease. The air contents gauge was noted to show 55 bar.

Autopsy: A CT scan performed two days after death showed the presence of gas in the vasculature throughout the body. The autopsy revealed a large heart, 529 g, with left ventricular hypertrophy (18 mm) and right ventricular hypertrophy (5 mm) but no significant coronary atherosclerosis. The lungs (R 677 g, L 605 g) were oedematous and there was pulmonary oedema fluid in the upper airways. There was no description at autopsy of the gas seen on CT. The cause of

death was given as cerebral arterial gas embolism (CAGE) due to pulmonary barotrauma. The pathologist commented that “*anyone with a heart weight of over 450 g was at increased risk of sudden death*”.

Comment: The results of the CT scan are difficult to evaluate since the examination was performed two days after death. This pattern of gas could be due to decomposition or even post-mortem off-gassing rather than CAGE. While his dive computer indicated two ascent alarms, the alarms were triggered at a rate of only 10 m min⁻¹ so the rate may not have been excessive or uncontrolled. This is supported by the fact that he completed a safety stop at 7 msw. The victim apparently signalled that he was okay at the surface and was only later found unconscious. Another possible explanation for what happened is that during the swim back to the boat he drowned after experiencing a loss of consciousness due to a cardiac arrhythmia triggered by his enlarged heart.

Summary: Trained, experienced, no dives for two years; obese and on unidentified medication; separation during surface return swim; CAGE or cardiac incident.

SC 05/02

This 52-year-old male overseas visitor had been scuba trained in his home country. He had made only 20 dives, the most recent about two years before. He was reported to have been taking several medications, including a statin for hypercholesterolaemia, SSRI for depression, hydrocortisone spray for allergic rhinitis, and esomeprazole magnesium for reflux. The dive shop was aware of his lack of recent dives and that he was overweight, and decided that the dive master taking the three customers for this dive would buddy him. He was shown and practised the use of the equipment he had hired before leaving the dive shop. Another customer heard him say that he was a doctor and very much aware of the risks involved in diving, although this witness thought the victim “*wasn't in very good physical condition*”.

The dive was on the wreck of a scuttled warship about two km offshore. Water depth was 30 msw, the deck at 20 msw. No details of the weather or sea conditions are noted. The dive master (instructor) briefed them, checked their equipment and then observed them as they entered the water and descended to the wreck's foredeck. The dive master had the victim tighten his weight belt before they swam along the vessel's side to the stern. Some minutes later the victim gave a ‘low air’ signal. His buddy, the dive master, checked and found he had sufficient air (130 bar), so wrote on his slate “*Is it your chest?*” and got the answer “*Yes, slight cough*”, so he decided to abort the dive and to take him slowly to the surface. Only 14 minutes of the planned dive had elapsed.

The dive master linked arms with the victim to ensure they stayed close together as they slowly ascended. When they reached shallower water, the victim appeared to panic and began to inflate his BCD to increase his ascent rate. The dive

master quickly ‘dumped’ the air from the BCD and guided him to the surface. There he ditched their weight belts and signalled for assistance from the dive boat. Before it reached them, the victim removed the regulator from his mouth and said “*I'm dying. It's my heart*”. He appeared distressed and was clearly unwell. He went rigid and stopped breathing. The dive master removed the victim's BCD and supported his head above the water till the dive boat reached them. Resuscitation efforts were unrewarded.

The equipment was examined and tested by police divers to 20 metres and worked correctly. Though the weight belt was retrieved and given to the police, neither its weight nor the amount of air remaining in his tank was recorded.

Autopsy: A CT scan three days after death showed gas throughout the arterial system. Observable gas bubbles were noted in the blood and the anterior mediastinum during the autopsy. When the heart was opened underwater numerous bubbles were noted in each chamber. The heart was moderately enlarged (540 g) with some dilatation of each of the chambers, with left ventricular wall hypertrophy up to 20 mm thickness. The coronary arteries showed atherosclerosis but the degree of narrowing is not described. The presence of fibrous scarring on histology suggested ischaemic heart disease.

The lungs (R 750 g, L 650 g) were hyper-expanded and bulged forward when the chest was opened. Palpable crepitus was noted on the cut surfaces of the lungs, which had multiple, dark red-coloured areas several millimeters in size, and some pale areas, giving a mottled appearance. There were no obvious sub-pleural haemorrhages or large collections of gas. There were bubbles in the pulmonary vessels. No other pathology was noted.

The cause of death was given as CAGE, with coronary atherosclerosis as a contributing factor. The pathologist considered that the coronary atherosclerosis was insufficient to cause death, and was not abnormal in degree for a person of this age, most of whom have no ill-effects from its presence.

Comment: The victim was a trained but unfit diver making a dive while closely and efficiently monitored by his buddy, an instructor. He suffered chest discomfort underwater. There is histological evidence of ischaemic heart disease. Whether the death was related to a cardiac event due to the ischaemic heart disease, or as a result of CAGE from a stressful ascent as suggested by the pathologist, is difficult to assess because of the post-mortem delay of three days and the potential for decomposition and post-mortem off-gassing.

Summary: Trained; no dives for two years; overweight and unfit; on unidentified medications; probable chest discomfort underwater; possible short period of fast ascent; CAGE or cardiac incident.

SC 05/03

This 39-year-old male victim was an experienced diver who swam regularly and was reportedly fit, albeit a little overweight. He joined three friends for a recreational dive from the boat one of them owned. He “*had been his usual chirpy self and had appeared fairly fit*” before the dive despite having a few drinks and being out until 4 am. After anchoring over a reef about 2 km offshore, they all descended the anchor line. The water was calm and visibility good. They met at the anchor and, having checked that their equipment was okay, moved off together. One diver (not the victim), who was only recently qualified, was the main focus of the others’ attention for safety considerations on the dive.

The victim was last seen alive swimming alone down the reef, and appeared to be chasing a crayfish. At about that time, his contents gauge had shown 100 bar. He was diving solo, as was the diver who last saw him. When the other two divers reached the boat, one asked the other solo diver where the victim was. On scanning the surface, the victim’s BCD was seen floating about 30 metres away. One of the group thought that it was initially partly on the victim, who also appeared to have his mask on his forehead. However, when one of the divers swam to the victim, the fully-inflated BCD was several metres away and the victim was unconscious, with no mask, fins or weight belt, and floating with the aid of his wetsuit. He towed the victim to the boat and pulled him aboard, where he was pulseless. A Mayday call was made, the anchor rope cut, and the group made a hurried and bumpy drive back to the marina. Apparently what had occurred had so shocked them that none of the friends attempted to effectively resuscitate the victim. The ambulance crew initiated resuscitation as soon as the boat docked but the victim was pronounced dead shortly afterwards.

Examination of the equipment showed there was a ‘sticky’ inflator valve, the BCD taking 10 minutes to fill and re-inflating itself. No other adverse findings were made. His GP reported that, apart from some relatively minor periodic ailments and arthritis and ligament damage in one leg, he had been generally in good health.

Autopsy: Only a summary of the autopsy findings was available. In this, the pathologist noted the absence of excessive fluid in the lungs and stomach. An abrasion of 1 x 2 cm consisting of three parallel lines each approximately 4 mm wide was also noted to be present on the right side of the deceased’s forehead. A CT scan, performed many hours after death, showed the presence of gas in the heart and great vessels although the origin of this gas was not determined.

Comment: This case once again demonstrates the limited utility of CT when performed with significant delay post mortem. While gas was said to be present in the heart and great vessels, this could be due to putrefaction, post-mortem off-gassing, or method of specimen collection prior to

autopsy and while it may have resulted from CAGE these results in themselves are unhelpful in providing evidence to support that hypothesis. The abrasions on the deceased’s forehead were consistent with the markings of the aluminium tread plate of the decking, making it likely that he struck his head on the deck. It was suggested that he had ascended rapidly (as indicated by his dive computer) possibly due to being out of air (his cylinder was empty though the BCD inflated). He possibly reached the boat before the other divers ascended and part removed his BCD/backpack when he slipped or passed out and hit his head on the decking and was unconscious when he fell back into the water and drowned. This unproven estimation of the series of events has much to commend it. Whether CAGE occurred is uncertain, as is whether, if it occurred, it affected the course of events. A part-ditched back pack/BCD would have impaired any attempt to avoid drowning even if he had not first hit his head on the boat.

Summary: Experienced; solo; found floating on surface without gear on; cylinder empty; possible rapid ascent; lacerations on forehead; possible CAGE and/or head trauma followed by drowning.

SC 05/04

The victim, a 45-year-old male, was a highly educated and skilled professional who had taken up diving 19 months earlier and had since done numerous training courses and logged 127 dives. He had a history of hypertension, later found to be Conn’s syndrome, obesity (BMI 34), severe headaches, chest pains, and sleep apnea. The chest pains were relieved by activity and, after investigation, were considered to be ‘non-cardiac’. The headaches were considered to be exercise-induced and reduced after a neurologist suggested a NSAID be taken before strenuous exercise. He was taking diclofenac to prevent headaches, amiloride for hypertension, and diphenhydantoin to prevent seasickness. He underwent a commercial diving medical with a doctor trained and experienced in diving medicine prior to a technical diving course. He was assessed as ‘fit to dive’, although no tests were conducted by the examining dive physician to investigate the implications of the sleep apnea and Conn’s disease on his diving. Both of these diseases had been thoroughly investigated by his treating physicians, but it is unclear whether the results of these investigations were provided to the diving physician.

On an open-circuit-scuba, technical-diving training weekend, he completed three incident-free dives. On the previous day, he dived to 42 msw and 40 msw, and the first dive on the day of the accident was to 43 msw. After a surface interval of about three hours the victim planned to dive to 50 msw. Decompression was planned on decompression software with little conservatism built into the calculations. The victim was carrying twin cylinders filled with air, as well as two sling tanks for decompression. One contained pure

oxygen for use at the 6 msw and 3 msw stops. The other was supposed to contain a nitrox mix with 50% oxygen but was subsequently analysed as 59%.

The victim, his buddy, and their instructor entered the water and descended uneventfully, although two minutes faster than the dive plan calculated; they also exceeded the planned bottom depth by 3 msw before returning to the correct depth. No in-dive allowances were made for these departures from the dive plan. Once at the sea bed, they performed several training drills before beginning the ascent after a bottom time of 25 minutes. There is no indication that substantial exertion was required underwater. The initial stop was at 27 msw with subsequent stops every 3 metres thereafter. EAN50 was used for the stops from 21 msw to 9 msw and 100% oxygen at the 6 msw and 3 msw stops.

The victim was described by the instructor as “*calm and relaxed and met the requirements for diving perfectly*”. He reached the boat’s stern 59 minutes from starting the dive, passed up the sling cylinders then climbed onto the boat up a small ladder while still wearing the backpack main cylinders and other equipment. He slipped on the ladder and was helped to prevent him falling. He then walked along the deck, and it was as they started to remove his equipment that the victim was noticed to be unwell. He looked uncomfortable and complained of “*really burning*” chest pains and difficulty breathing. He was given oxygen from his sling tank, but his condition deteriorated rapidly with shallow, laboured breathing, groaning between breaths, pallor and he appeared to be in severe pain. When he became unable to hold the regulator mouthpiece, a full face-mask was used to provide oxygen, but the tank was not full and the supply was soon depleted. The victim soon became unconscious and pulseless and BLS was commenced and continued on the boat for about 90 minutes. Paramedics arrived and, despite ALS, the victim died en route to hospital.

His equipment was checked and no faults were identified apart from the tank supposedly containing 50% oxygen in reality containing 59% oxygen. The breathing apparatus alone weighed 47 kg.

Autopsy: A CT scan performed two days after death showed intravascular gas in four chambers of the heart (fluid level in left atrium) the internal carotid and basilar arteries, aorta, pulmonary trunk, jugular veins and cavernous sinus. There was also gas in the parapharyngeal and facial soft tissues. There was opacification of the trachea and major bronchi (pulmonary oedema/gastric aspirate). No bullae, pulmonary lesions, pleural fluid, or pneumothorax were seen. There was extensive gas throughout the liver, portal vein, and superior mesenteric vein (decomposition).

The heart weighed 560 g, partly reflecting a body mass of 120 kg; left ventricle wall thickness was 13 mm, right 3 mm. The coronary arteries showed less than 20% narrowing.

The pathologist initially attributed the death to CAGE but amended this to decompression sickness (DCS) following input from several diving medical experts.

Comment: The investigation of this technical diving fatality was extremely thorough with input from numerous diving medicine experts, albeit with some differing opinions. The coroner’s ‘finding’ comprised a 21-page summary of the 10 cm-thick file of documents; a thoughtful, thorough and well-crafted exposition of facts.

The diagnosis of death from DCS is very difficult at autopsy. This is especially so after a long, deep dive where large amounts of nitrogen are absorbed by the body tissues and released into the blood and tissues post-mortem, in addition to any gas that is present ante-mortem (e.g., from CAGE or DCS). This may be further complicated by gas due to putrefaction, which can occur in eight hours and could be widespread by two days. Deaths during technical diving are more complex and investigation of the cause of death should properly be undertaken by collaboration between a pathologist with experience of diving autopsies and a diving physician with knowledge of technical diving. Multiple unusual physiological issues, such as decompression time and oxygen toxicity at depth, need to be considered.

Many salient points arose from the investigation of this fatality. Some deserve brief comment here and warrant on-going discussion by diving medical practitioners and others.

The coroner and several expert witnesses expressed concern about the dive medical examiner’s failure to further investigate the victim’s sleep apnea. This dysfunction can cause pulmonary hypertension, leading to increased risk of right heart failure, atrial arrhythmias and possibly a reduced capacity of the lungs to filter venous bubbles.²⁻⁴ Without the results of the investigation of the victim’s co-existing disease, it is impossible to provide adequate advice on the risks of undertaking this type of diving. The issue was raised about the role of the dive medical examiner when conducting a dive medical – whether it is to determine a definitive pass/fail, or to provide a risk assessment and advise the individual. From the perspective of the individual requesting the medical, the discussion is generally more focused on risk assessment and understanding rather than acceptance or rejection. However, from the perspective of the dive industry, there is a requirement for a pass/fail answer.

Concerns were reasonably expressed about the lack of validation of the decompression algorithms routinely used by technical divers, including the inclusion of deep decompression stops, and it was perhaps cavalier that a student diver with some obvious risk factors was allowed to build in so little conservatism to his planned profile. There was some debate about the fact that reverse-order depth dives were conducted and the potential effect this could have on

decompression. This issue remains somewhat controversial. No allowance was made in-dive for the departures (fast descent and deeper dive) from the dive plan.

That the victim was carrying 59% oxygen in his sling tank rather than 50% oxygen was a matter of concern. Although it did not cause harm in this particular case, there was an increased potential for oxygen toxicity. The dive operator was held to account by workplace authorities and received a large fine as a result of this and other breaches.

The victim was not wearing a weight belt, and even without this his equipment weighed 47 kg. Technical divers and those who take them diving need to consider the substantial weight of the equipment often used and should take precautions to minimise the exertion required by divers when exiting the water, so reducing the likelihood of precipitating a decompression or cardiac event, or musculoskeletal injury.

Forensic pathologists are becoming increasingly aware of the potential cardiovascular effects of obstructive sleep apnea and its possible role in sudden death due to arrhythmia. However, functional abnormalities like cardiac arrhythmias cannot be detected at autopsy. This is amply demonstrated in the present case where extensive investigations performed pre-morbidly showed cardiac abnormalities and rhythm disturbances. The contribution of these to the final outcome will never be known.

Complex medical conditions such as Conn's disease result in patients being on a variety of medications, the effects of which cannot always be predicted with immersion. Whether the victim's medications contributed in this case is unknown, but prolonged immersion, exposure to high PO₂ mixes and medications that alter fluid and salt balance in the body pose a risk of unknown proportions especially in the unfit and overweight.

Summary: Experienced; undergoing technical diving training; history of severe headaches, 'non-cardiac' chest pain, Conn's syndrome, obstructive sleep apnea; hypertension, seasickness, and obesity; dive plan lacking conservatism profile; collapsed and died soon after exiting water; fulminating decompression sickness.

SC 05/05

The victim was an apparently healthy 30-year-old female overseas visitor on a dive trip to a GBR resort. She had done only 15 dives, two of these conducted in the 24 hours prior to the incident dive. The victim, who spoke enough English to hold a basic conversation, was paired with a companion from her country of origin, as part of a group of four divers, accompanied by a dive master. She was using equipment hired from the resort.

After a briefing, which was later reported by the victim's buddy as incomprehensible to her as it was delivered in English only, the divers entered the water from the shore and then swam a short distance on the surface to a mooring buoy to commence the dive. Current was flowing at 1–2 knots, depth was 3–4 msw, with visibility between 5 and 10 metres. The four divers were split into two buddy teams. One of the other pair had difficulty during the descent and the dive master stopped to assist. When he looked for the other pair of divers, he could see only one of them, who was also having some difficulty in descending. When the other divers were on the bottom an exchange of signals indicated that none of them knew where the victim was. After only one minute, the dive master signalled for the group to ascend, telling them to hold onto the buoy and watch for bubbles or anyone at the surface while he descended and made an underwater search down-current for 20–30 metres for about five minutes, without success. He then brought the three divers back to shore, where he reported that a diver was missing and initiated a broader search.

After about 50 minutes, the victim was found lying on her back unconscious on the bottom at about 5 msw and approximately 120 metres from the original dive location. Her regulator hose was initially trapped in coral but was easily freed and she was brought to the surface after inflation of her BCD and release of her weight belt. Pink, frothy sputum was coming from her mouth and an attempt was made to clear this and perform in-water rescue breathing until the victim was brought aboard the rescue boat. BLS, including the use of a resuscitation mask and oxygen, were hampered by frothy sputum and vomit. A rescue helicopter arrived but further resuscitation attempts by the paramedic were unavailing.

The equipment was found to be in serviceable condition. The air cylinder contained at least 170 bar. The cylinder air was analysed five months later and no impurities were found. The profile recorded on the victim's computer was 50 minutes at 5.2 msw, with no indication of ascent prior to the body recovery. The victim was wearing a 3 mm wetsuit and 5.4 kg of weight on her weightbelt, similar to that which she had worn on the previous dives without apparent problems.

Autopsy: The autopsy, performed two days after death was preceded by a CT scan but no report of the scan is on file. There was evidence of mask squeeze and petechiae on the conjunctivae. Small bubbles were present in small vessels over the cerebral hemispheres and a few in the Circle of Willis vessels. There was a small amount of air in the right pleural sac and bubbles were seen in the upper descending thoracic aorta near the isthmus. There was gas in the left ventricle and multiple small bubbles were seen in the inferior vena cava. The lungs (R 700 g, L 600 g) were voluminous with the appearance of emphysema aqueosum (over-expanded with prominent rib markings) and were boggy with frothy

fluid exuding from cut surfaces. There was some interstitial air and haemorrhages in the lung parenchyma. There were also 20–25 mm bruises on the frontal and occipital scalp. The pathologist concluded that she suffered CAGE while attempting to ascend and then drowned.

Comment: This is ultimately a drowning but the precipitating factor is not clear. The autopsy was performed two days after death and the gas seen at autopsy is likely to be a combination of post-mortem off-gassing and decomposition, rather than a result of CAGE. The CT scan could have resolved this issue if it had been performed early post mortem. As there was at least 170 bar of air remaining in the cylinder, it is obvious that the victim stopped breathing early in the dive. The profile recorded by the dive computer during the 50 minutes was more consistent with a body being gently moved by the water motion rather than a conscious diver swimming.

It is important in the forensic examination of diving deaths that there is a good understanding of the limitations of any dive-profile recording equipment worn by the victim. Although the dive computer print-out of the victim's dive profile indicated that she descended directly to around 5 m and stayed at that depth for almost 50 minutes before being brought to the surface by the rescuer, this could be misleading. This computer samples depths at 20-second intervals, recording only the maximum depth reached within that interval. If the victim had made a rapid ascent at the start of the dive when she became separated from her buddy, this may not have been recorded. It is possible, therefore, that she made a rapid ascent, suffered a CAGE, lost consciousness and sank to the seabed within 20 seconds, and remained there for 50 minutes prior to being found. The presence of mask squeeze and petechiae indicate inadequate equalisation on descent, which is likely if the victim became unconscious and sank, but could also have occurred as a result of inattention and/or panic. Given that this event was unwitnessed, other scenarios such as hitting her head on one of the other diver's tanks or on coral in the current and entrapment are also possible but again unproven.

Summary: Trained; some experience; apparently healthy; separation on descent; became unconscious shortly after descent and found 50 minutes later; questionable evidence of CAGE; drowning.

SC 05/06

The tragic death of this 23-year-old male marine scientist, an experienced diver, occurred while he and a buddy made a safety stop at 5 msw after a dive to 18 msw collecting cuttlefish eggs for research purposes. Visibility underwater was estimated to be 3–5 metres. From the dive boat, others saw a large shark approaching the two divers. The buddy said he had felt something bump into him with sufficient force to rotate him in the water. He then saw the shark, estimated to be about 5 m long and believed to be a great white, directly approach his buddy who struck it on the snout, causing it

to retreat momentarily. However, it came back, took the victim's leg in its jaws and dragged him deeper. He was seen to surface momentarily, surrounded by a pool of blood, before disappearing underwater. The buddy surfaced and was soon picked up by the boat. Although some of the victim's equipment, including intact and undamaged BCD and tank, was later recovered, his remains were never found.

This area, an artificial reef 5 km offshore, was known for sharks although no sightings had been reported that day. A number of fishing boats were in the area as there were plenty of fish running. There were unconfirmed reports that berley was used by some fishermen in the area although this was not mentioned in the coronial documents.

Comment: Although shark-repelling devices were present on the boat, the divers did not use them and were unaware that they were available. At the inquest, various expert witnesses were consulted on both the behaviour patterns of large sharks and on the use of shark-repelling devices. It was noted that the divers were employed by an educational institution that owed the divers a 'duty of care'. This raises the question whether it should have been deemed safe to dive in that area at that time. There was much discussion of the reasons for and against the use of shark-repelling devices, why they were not used and whether they might have deterred this particular attack if they had been, with no definitive conclusions being reached.

Summary: Marine biologist collecting cuttlefish eggs; substantial fishing activity nearby; attacked by 5 m shark; probably died from massive blood loss.

SC 05/07

A 67-year-old, highly experienced, male diver visited Australia with seven of his compatriots and dived from a liveaboard boat on the GBR. He declared a medical history of a CVA, hypertension and diabetes (NIDDM) for which he took a variety of medications including glimepiride, metformin, amlodipine, cilostazol, diphenhydramine, aspirin, and KH1010 (for unknown reasons). He stated he was fit to dive and made two uneventful dives before the fatal one. One of his companions thought he was looking tired, but he had not reported feeling unwell.

Safety information was given in the visitors' own language and, although they were advised to dive as buddy pairs, they chose to dive as a group. The dive was without incident but one of the victim's companions was surprised when, after only 20 minutes, the victim's contents gauge read 50 bar. He and two others ascended separately, in a normal manner, the victim making a safety stop at 10 msw. The safety watcher on the boat saw them on the surface soon after and they indicated to him that they were okay. They started to swim back to the boat, the victim in the rear, but it is uncertain whether they were using scuba or snorkel. The victim appeared to stop, as if waiting for the remainder of

the group to reach him, and seemed to be paying attention to his snorkel. The alarm was raised when these following divers reached him and found him unconscious, floating face-down, with mask, snorkel and weight belt missing. He was quickly turned face-up and the safety tender summoned. BLS was commenced and continued until paramedics arrived by air and declared life extinct.

There is no record of his equipment being tested, but a note was made that the depth gauge gave a maximum depth for the dive of 25 metres for a total dive time of 23 minutes and remaining air at 20 bar. There is no record whether his BCD was inflated when he was found.

Autopsy: There was no visible evidence of trauma, brain pathology, or barotrauma noted at the autopsy. The heart weighed 340 g and appeared macroscopically normal apart from a stenosis of the anterior interventricular branch of the left coronary artery, confirmed histologically as 70% occluded. There was patchy myocardial interstitial fibrosis suggesting previous ischaemia (possibly due to small vessel disease from his diabetes). The lungs (R 711 g and L 611 g) were oedematous and there may have been agonal drowning. A finding was made of death from ventricular arrhythmia resulting from myocardial fibrosis due to severe coronary artery atherosclerosis.

Comment: There was no information about this victim's functional health beyond his claim to be fit. Although he was a man with severe health problems, as evidenced from his medical history, this dive was not considered to be overly strenuous. There was no explanation for his apparent excessive use of air. He made no comment about feeling unwell. The possible hypotheses for his death include cardiac arrhythmia or a hypoglycaemic event, causing him to become unconscious and drown.

Summary: Experienced; history of CVA, NIDDM, angina but apparently fit; excessive air usage during dive; unconscious during relatively non-stressful surface swim; probable cardiac incident.

SC 05/08

This 45-year-old male victim was 'instructing' his girlfriend to scuba dive and this was her third dive. He had obtained an open-water certificate nine years earlier but his diving experience is unknown, although it appears that he was not a registered instructor. They planned to dive in a waterway much frequented by vessels but also popular with snorkellers and scuba divers and commonly used by local dive schools for scuba instruction. The southern wall of this waterway had a concrete platform on which the victim and his buddy donned their equipment. There were numerous other people in the water, some snorkelling and others scuba diving. The water conditions were described as initially calm with visibility of 15 metres. However, there was a strong inflowing tidal current that later reduced visibility substantially. The

current was described by the victim's buddy as stronger than when they last dived there, a day earlier.

The pair entered the water and swam out underwater for about 40 metres to where the depth was 9 msw. They were about mid-channel at this time and when the victim looked at their contents gauges he saw it was time for them to return to the shallow area close to the wall rather than surfacing where there was risk from vessels. Before they reached the wall he signalled that he was out of air and both ascended. When his buddy looked round she saw him struggling to remain at the surface and frequently swallowing water, so she called for help. When both divers began to sink, she felt him pushing her up from below and a swimmer who had come to assist her pulling her from above. A search was begun after her buddy failed to re-surface. A short time later he was located on the sea bed, unconscious with mask in place but regulator out of his mouth. His weight belt was difficult to release because of a poor release mechanism. He was brought to the surface and taken ashore aboard a surf ski. He was apneic and pulseless. BLS was attempted, initially by a bystander, then by a rescue service volunteer, prior to the arrival of a paramedic. Unfortunately there was no response.

The buddy was taken to hospital where she recovered from the incident. She reported that she believed their tanks were full at the start of the dive. The equipment was sent for checking. There is no report on the findings, but there is no suggestion of any equipment problem except for the weight belt release and being out of air.

Autopsy: A whole body CT scan was performed one day after his death and the autopsy was performed two days after death. The CT scan showed gas in the internal and basilar arteries, less in the anterior and middle cerebral arteries and some other small vessels. A large amount of gas was noted in the right ventricle with a fluid level in right atrium, a small amount in the left ventricle, with the ascending aorta and aortic arch totally gas-filled and gas throughout the proximal arterial tree. Gas was also detected in the soft tissue of the orbit and face. There was an air fluid level in the sinuses, commonly seen in drowning. The portal vein and its intra hepatic branches also contained gas.

Autopsy revealed very heavy lungs (R 1050 g, L 940 g) with distention and pulmonary oedema. The heart weighed 490 g and appeared slightly dilated, with up to 50% narrowing of the left anterior descending coronary artery. Histology of the brain showed decompositional gas formation in the brain. In the coronary arteries, described as 'basically healthy', a slightly less than 50% concentric narrowing of the proximal left anterior descending artery was present, which was accepted by the pathologist as a non-contributory finding. The pathologist suggested that he suffered a severe PBT/CAGE as he made his final attempt to reach and stay at the surface. The cause of death was given as air embolism due to, or as a consequence of, pulmonary barotrauma.

Comment: The CT scan was performed more than eight hours after death and there is some decompositional gas present at autopsy. There is a history of rapid ascent and there may well have been a PBT/CAGE. However, given the out-of-air situation, strong current and the heavy weight belt this may simply represent drowning. It was suggested that the buddy's fatigue and panic affected her ability to stay afloat. Being unable to inflate his BCD as his tank was empty, and unable to ditch his weight belt, the victim had no chance of maintaining himself at the surface. He probably sank and drowned. Inexperience on the part of both divers was apparent. The victim failed to properly monitor his air and took an untrained, extremely inexperienced diver into open water subject to a strong current and potential boating hazard. The reportedly poor release mechanism on his weight belt would have made it more difficult to ditch and might have contributed to the outcome of this incident. Though the buddy had some remaining air, she failed to realise the value of trying to inflate her BCD or of ditching her weights. This incident also highlights the value of assessing one's buddy as being competent to provide assistance in adverse circumstances. 'Training' dives should be planned and conducted in safer conditions than those encountered on this dive and should be done by a qualified instructor.

Summary: Trained; some experience and recent diving; apparently healthy; out-of-air ascent; weight belt difficult to release and BCD deflated; struggled on surface then sank; CAGE or drowning.

SC 05/09

The victim, a 51-year-old male, had been scuba diving for over 12 years. His only health factor was raised cholesterol level for which he took atorvastatin and had regular medical checkups. On a dive to catch crayfish they used the buddy's boat at a site approximately 500 metres offshore. The victim had dived here before, unlike his buddy, and so was the leader for this dive. There was a strong current and the wind was estimated at around 15 knots. The victim was a strong swimmer and, once underwater, the buddy "*could only just keep up*" with him. After about 30 minutes, the buddy checked and found his contents gauge read 105 bar and the victim's 95 bar, and they decided it was time to begin their return. Both surfaced to determine the boat's location, then descended to about 10 msw depth to start their underwater swim of approximately 200–250 metres. As the victim was swimming faster, he was soon lost to sight. When the buddy reached the boat he saw the victim was about 40 metres away. They exchanged OK signals. After boarding the boat and removing his equipment, he saw that the victim was swimming into the strong current and wind. They again exchanged OK signals and the buddy decided to take the boat to pick him up. It took him several minutes to free the anchor, and when he reached the victim, he was floating face-down with his regulator out of his mouth, BCD inflated and weight belt missing. The buddy jumped into the water to assist him and attempted some in-water rescue breathing by the side

of the boat. After ditching the BCD and tank, he managed to pull the victim into the boat. He sent a radio distress call and continued resuscitation efforts while returning to the boat ramp where the efforts were continued by bystanders and then a paramedic, without success.

Although the victim's equipment had floated away, it was later recovered and was found to perform correctly. The dive computer showed that the victim's dive duration was 31 minutes whereas the buddy's computer indicated 48 minutes. This was taken to indicate that the victim had surfaced and started a surface return swim very shortly after they both commenced their underwater return.

Autopsy: The heart weighed 485 g and there was multi-focal atherosclerosis with a 70% stenosis at the origin of the diagonal branch of the left anterior descending artery. The lungs (R 914 g, L 810 g) showed significant oedema and there was watery fluid in the upper airways and stomach. There was no apparent evidence of either trauma or CAGE. The formal cause of death was drowning and associated multifocal coronary atherosclerosis.

Comment: This was an apparently healthy man who underwent regular medical checks. The only indication of a potential medical problem was elevated cholesterol, managed by prescribed medication. It is likely that the level of exertion required in swimming to the boat against a strong current and wind caused a cardiac event. He appears to have become unconscious and drowned despite apparently ditching his weight belt and inflating his BCD. In the context of this review, the death is regarded as being due to cardiac factors.

Summary: Experienced; apparently healthy; swimming against strong current and wind; gave no warning that he required assistance; cardiac-related.

Surface-supply fatality

SS 05/01

This 55-year-old victim and his employee were experienced commercial divers, diving on a remote reef, collecting fish for salt-water aquariums. They were diving from a dinghy with an air compressor supplying the two hoses for their hookah system. The victim's 10-metre fishing vessel was moored nearby. On surfacing, the buddy saw the other hookah hose was at its full length and noticed a large shape floating at the surface about 100 metres away. Becoming concerned, he investigated by pulling the hookah hose gently and then more firmly. He pulled it in until he saw a large crocodile with what he recognised as his employer's dive gear. He got out of the water, contacted police by satellite phone and marked the spot with an emergency locating beacon. Searchers found the victim's body five hours later in the mouth of a large saltwater crocodile, which then let it go and disappeared. The body was then recovered.

Autopsy: There were lacerations to the face, neck, and scalp, and compound comminuted fractures of his right temporal bone and zygoma, as the main injuries with some subarachnoid haemorrhage. The cause of death was given as blunt head trauma from crocodile attack.

Comment: The population of saltwater crocodiles in this region has increased to 75,000 since they were declared to be a protected species 33 years ago. This fatality occurred only five days after the death of a snorkel swimmer (BH 05/5) in a similar attack, though not in the same area.

Summary: Experienced commercial diver; diving in remote area with potential for crocodiles; lethal crocodile attack; trauma.

Discussion

Once again, 2005 saw a number of tragic and some potentially avoidable accidents. A summary of the possible sequence of events (root cause analysis) in these incidents is shown in Table 3. Despite the well known hazards of apneic diving and apneic hypoxia, several deaths can be attributed to this (BH 05/04, BH 05/08 and BH 05/14), some possibly involving hyperventilation. It is important, if extended breath-holding is attempted, that there is a vigilant buddy present in order to quickly rescue the person. This is necessary even in shallow, sheltered waters such as a swimming pool.

Some of the victims in this series came to grief while diving, snorkelling or breath-holding alone (BH 05/01, BH 05/04, BH 05/08, SC 05/03). Some divers dive alone through preference while others do so through lack of a companion. In any case, when a problem occurs with a solo diver or snorkeller, the reality is that there is no-one close at hand to assist. Diving with a buddy certainly does not guarantee their immediate awareness and assistance, but does increase the likelihood of a helping hand should it be required.

This series includes two cases involving attacks by crocodiles (BH 05/05, SS 05/01) which occurred within a week of each other, both in locations known to be frequented by large saltwater crocodiles. Both victims were said to have been aware of the potential presence of crocodiles in the area in which they dived, but had chosen to do so despite this.

The victims of the shark attacks (SC 05/06 and BH 05/02) were both diving in areas known to be frequented by great white sharks. However, the likelihood of an attack would have been increased with the substantial fishing activity and probable presence of berley in the area with SC 05/06, and possibly the fishing from a nearby boat with BH 05/02. It would be common sense to modify diving plans where there is the potential for increasing shark activity. Perhaps a more laissez faire attitude to dangerous marine creatures has developed due to the preponderance of television programmes depicting presenters interacting with such creatures, even outside of a cage. Standing his ground and

behaving in a suitably aggressive manner, did not save the victim in SC 05/06. These creatures are large apex predators and suitable respect should be exercised at all times.

It was noted in the analysis of the technical diving fatality (SC 05/04) that, during previous dives, additional decompression stops appeared to have been added without recalculation of the decompression profile for the final dive. Similarly, there has been a trend in recent times in recreational diving towards adding extra 'safety stops' at 10 msw and 5 msw for what would otherwise be no-decompression dives. The addition of any time in the water must be included in the decompression planning. The assumption that these extra stops occur during the ascent and therefore are adding to the safety is not necessarily correct and can, in some cases, actually result in inadequate decompression being conducted.

Similarly, the presence of co-existing disease and its associated medication may have unpredictable effects in the setting of immersion and diving. While the death in case SC 05/04 was attributed to fulminant pulmonary decompression illness, this is a very rare event especially in the apparent absence of grossly omitted decompression. In this individual, the combination of multiple medical conditions may have played a significant part in his ultimate demise. While the effects of immersion in young healthy individuals has been well studied, and is known to cause considerable physiological effects, the effects in the setting of co-existing disease and in the presence of medications that affect fluid balance and vascular tone are unknown. The decision of fitness to dive in such individuals must therefore be made cautiously with as much information as possible available. Cross referral to specialists with experience in the affected areas and suitable investigations are essential if there is to be any meaningful discussion with the candidate with regard to risk and risk acceptance.

The concept of risk acceptance in diving has led to some individuals being passed as fit to dive with co-existing diseases that were previously considered contraindications. These include diabetes and asthma. The debate over fitness to dive with these conditions is beyond the scope of this paper, but divers who decide to dive with these conditions must be cognizant of the correct management of their disease and the effects that immersion and the hyperbaric environment will have on it. In case SC 05/07, there was no mention in any of the witness statements that the diver took appropriate steps prior to the dive to check his blood glucose, nor that he had on hand a source of glucose should he develop a hypoglycaemic event during the dive.

The investigation of deaths associated with diving is always difficult. Delays in autopsy, often caused by the remote locations in which many accidents happen, compound these difficulties. Although pre-autopsy CT scans were conducted on several of the scuba divers, these were often delayed for more than eight hours, so reducing their reliability.

Table 3
Root cause analysis of diving-related fatalities in Australian waters in 2005
PBT – pulmonary barotrauma; CAGE – cerebral arterial gas embolism; DCS – decompression sickness

Case	Trigger	Disabling agent	Disabling injury	Cause of death
BH 05/01	Unknown	Water aspiration from snorkel?	Asphyxia	Drowning
BH 05/02	Fishing activity?	Shark attack	Trauma	Trauma
BH 05/03	Mild exercise / salt water aspiration?	Cardiovascular disease	Cardiac incident	Cardiac related
BH 05/04	Extended breath-hold	Loss of consciousness (sudden)	Asphyxia	Drowning
BH 05/05	Presence of crocodile	Crocodile attack	Trauma	Trauma
BH 05/06	Exertion in strong current	Cardiovascular disease	Cardiac incident	Cardiac related
BH 05/07	Extended breath-hold / entrapment?	Loss of consciousness (sudden)	Asphyxia	Drowning
BH 05/08	Extended breath-hold	Loss of consciousness (sudden)	Asphyxia	Drowning
BH 05/09	Mild exercise / salt water aspiration?	Cardiovascular disease	Cardiac incident	Cardiac related
BH 05/10	Water inhalation from snorkel / panic?	Laryngospasm?	Asphyxia	Drowning
BH 05/11	Mild exercise	Cardiovascular disease	Cardiac incident	Cardiac related
BH 05/12	Contact with boat?	Head injury?	Asphyxia	Drowning
BH 05/13	Mild exertion	Cardiovascular disease	Cardiac incident	Cardiac related
BH 05/14	Extended breath-hold	Loss of consciousness (sudden)	Asphyxia	Drowning
SC 05/01	Exertion / rough water	Ascent related?	PBT / CAGE? Cardiac-incident?	CAGE? Drowning?
SC 05/02	Chest discomfort	Ascent related / cardiac related?	CAGE? Cardiac incident?	CAGE? Cardiac related?
SC 05/03	Gas-supply related?	Ascent related / head trauma?	CAGE? Asphyxia?	CAGE? Drowning?
SC 05/04	Inadequate decompression	Bubble formation	Fulminating DCS	Fulminating DCS
SC 05/05	Unknown	Unknown	Asphyxia? CAGE?	Drowning
SC 05/06	Presence of fish eggs / fishing?	Shark attack	Trauma	Trauma
SC 05/07	Unknown	Cardiovascular disease / diabetes	Cardiac incident	Cardiac related
SC 05/08	Current / gas-supply related?	Ascent / buoyancy related?	CAGE? Asphyxia?	CAGE? Drowning?
SC 05/09	Exertion against strong current and wind	Cardiovascular disease	Cardiac incident	Drowning
SS 05/01	Presence of crocodile	Crocodile attack	Trauma	Trauma

Where divers have had a significant nitrogen uptake into their tissues ante-mortem, gas will be released into both the tissues and intravascularly, independent of gas present at the moment of death, confusing the diagnosis of gas embolism. Furthermore, gas may be created by putrefaction and intravascular gas may result from prolonged CPR attempts. Where possible, a pre-autopsy CT scan should be conducted within eight hours of death to minimise artifacts and gas sampling may be of value to determine the origin and composition of the gas.⁵

Given that drowning is a diagnosis of exclusion and that unrecognised ischaemic heart disease is common, the recent trend for fewer or less extensive autopsies may reduce our ability to understand the causes of diving deaths and undermine efforts to improve preventative strategies.

Conclusions

There were 24 reported diving-related fatalities during 2005, which include 14 deaths while snorkelling and/or breath-hold diving or shortly thereafter, nine while scuba diving, and one while using surface-supply breathing apparatus.

Causal factors associated with these deaths included apneic hypoxic blackout from extended breath-hold, cardiac disease or other co-existing illnesses, attacks from sharks and crocodiles and inexperience diving in adverse conditions.

The main disabling injury (Table 3) with snorkellers was asphyxia (seven cases), followed closely by cardiac involvement (five cases). With scuba divers, the main disabling injury appears to have been CAGE, which was possibly associated with five cases. Cardiac causes were thought to have been the disabling injury in at least two, but possibly up to four, scuba fatalities.

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; avoidance of diving in areas and/or times of increased crocodile or shark activity; and improvement of, and increased adherence to, the buddy system.

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