Provisional report on diving-related fatalities in Australian waters 2004

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

Abstract
(Walker D, Lippmann J, Lawrence CL, Houston J, Fock A. Provisional report on diving-related fatalities in Australian waters 2004. *Diving and Hyperbaric Medicine*. 2009;39(3):138-61.)
Introduction: An individual case review of diving-related deaths reported to have occurred in Australia in 2004 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 are provided, and also details from the post-mortem examination, where available.
Results: In total, there were 22 reported fatalities, all male. Nine deaths occurred while snorkelling and/or breath-hold diving, 10 while scuba diving, one just prior to scuba diving, one while using surface-supply breathing apparatus and one while diving with a rebreather. In this series, cardiac-related issues were thought to have contributed to the deaths of five snorkel divers and three scuba divers, and in one person who was about to go diving. Three of the deaths in breath-hold divers were likely to have been associated with apnoeic hypoxia blackout.
Conclusions: Pre-existing medical conditions, inexperience, time away from diving, inadequate supervision, and diving without appropriate training were features in several scuba deaths in this series.

Introduction

Diving is a potentially dangerous recreational activity. 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 of these fatalities might have been avoided through better education, greater experience, appropriate medical screening, better equipment maintenance and design, or a modicum of common sense.

The aim of the DAN Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and the diving industry and inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future. This report includes the diving-related fatalities between 1 January and 31 December 2004 that are recorded on the DAN Asia-Pacific (AP) database.

Methods

As part of its ongoing research into, and reporting of diving fatalities in Australia and elsewhere in the Asia-Pacific region, DAN AP has obtained ethics approval from the Human Research Ethics Committee, Department of Justice, Government of Victoria, Australia to access and report on data included in the Australian National Coronial Information System (NCIS). A comprehensive search was made of NCIS to identify all diving-related cases that were reported to various State Coronial Services for the year 2004. The other major source interrogated was the DAN AP dive fatality database for scuba diving fatalities occurring in 2004. DAN AP staff routinely monitor a variety of internet sites and newspapers for diving and snorkelling fatalities. DAN sometimes also receives reports from the diving community when a fatality has occurred.

The process followed in the investigation and analysis of each case involved the following steps:

- Two of the research team (DW and JH) reviewed the police reports, witness statements and coronial reports and independently prepared a summary of each incident.
- Another researcher (JL) reviewed the two reports, investigated any discrepancies and prepared edited incident summaries.
- The incident summaries, coronial and autopsy reports were independently reviewed by three medical practitioners (DW, CL and AF), one of whom (CL) is a pathologist with extensive experience in diving autopsies.

Researchers at DAN America have recently applied the process of root cause analysis (RCA) to the investigation of diving fatalities with the aim of improving understanding of the sequence of events associated with such an accident.[1] Categories include trigger, disabling agent, disabling injury and cause of death. Sometimes the disabling injury can be more relevant to the assessment of a diving fatality than the cause of death. An example of this is a situation in which a diver suffers a cerebral arterial gas embolism (CAGE), becomes unconscious in the water and subsequently drowns. The cause of death, in this case drowning, may not provide as good an insight into the accident as the fact that the diver suffered from CAGE. We have applied this process to each case in this series.

Snorkelling and breath-hold diving fatalities

CASE BH 04/01

This victim, a 30-year-old male, was reported to have been in good health and was an experienced breath-hold diver and spear fisherman. He was spear fishing with two friends with whom he had dived for years. After a time diving near a headland, the group moved to an area off a small island where there was a reef. There was a strong current, estimated at 6 to 7 knots, and a calm sea. Visibility was described to be "*a good 10–15 metres if not more*". The dive plan was for one to remain in the boat and the other two to drift over the reef, one each side of the drifting boat. On the fourth drift, the friend in the boat noticed that the victim had not surfaced from a dive after 90 seconds; he became alarmed and alerted his other companion in the water. They pulled up the victim's float, which had his spear gun attached. It had been fired and there was a fish on the spear. The water was 15–20 metres' seawater (msw) deep and slightly murky but they thought they should be able to see the red handle of the missing man's knife if they looked down. There was no sign of the victim. He was known to have adjusted his weights in order to be negatively buoyant deeper than 10 msw.

An extensive search followed involving a police diving team who happened to be in the vicinity at the time. After two to three hours the body had not been found and the search was abandoned due to deteriorating weather. Two surfers found the victim's body floating on the surface four days later and some 50 km from where he was last seen. All of his snorkelling equipment was in place, including the weight belt with 4.2 kg of weights.

Autopsy: The body was not recovered for five days and there were severe decompositional changes. Only mild atherosclerotic changes were present in the coronary arteries (maximal 30% narrowing). Histology revealed a mild increase in interstitial fibrous tissue in the heart, of uncertain significance. He had injured his ribs the day before this dive but no chest wall injury was noted at the autopsy. The cause of death was given as drowning.
(Height = 189 cm; Weight = 71 kg; BMI = 19.9 $kg.m^{-2}$)

Comment: This is likely to have been a case of apnoeic hypoxia, with or without hyperventilation. Although it was reported that two whaler sharks were present while the group were spear fishing, and that on one occasion a two-metre shark came in very close as a fish was speared but showed no interest, the autopsy report included no mention of trauma to the victim's body. The reviewing pathologist would give the cause of death as drowning due to apnoeic hypoxia with or without hyperventilation with other significant factors including negative buoyancy.

Summary: Experienced breath-hold spear fisherman; breath-hold diving with friends to 15–20 msw; strong current; failed to surface; drowning (probably due to apnoeic hypoxia).

CASE BH 04/02

The 20-year-old male victim had multiple years of breath-hold diving and spear fishing experience, and was paired on the day of this accident with a buddy with whom he had dived over the previous two to three years. The two friends took a boat out to spear fish near to a wreck site about 28 km off the coast. The depth at this site was 20–22 msw and visibility around 15 metres, and no sharks were seen in the area. There was a mild current, which presented no problem. The victim wore a 'long-john-style' wetsuit and top with fitted hood, and used a weight belt with quick-release buckle. He wore fins, mask and snorkel and carried a spear gun with a length of rope attached to a float. The buddy later said that their usual practice was to dive one at a time "*to keep an eye out*". The victim did not appear to be having any difficulty with the dives and they managed to spear several fish.

The buddy dived to the wreck to look for an anchor that he had seen caught up there. The victim was on the surface where he appeared to be fine. When the buddy re-surfaced he saw the victim's float about 50 metres behind their boat. He waited for the victim to re-appear but when he did not do so, the buddy became alarmed. He made several unsuccessful attempts to search for the victim, both underwater and from the boat. He collected the victim's float and found the victim's speargun discharged at the end of the line. He dropped his boat anchor at this point as a reference, and released the float into the water in order to determine the direction of the current and hence the possible location of his friend. By then, he realised that the victim's chance of survival was very low. The buddy then undertook appropriate emergency call-out action and contacted authorities. A search was initiated, which lasted for three days and covered 1,140 square km but the body was never recovered.

Later checks with the family revealed that the victim had had asthma problems in the past but, although he carried and used an inhaler in earlier years, they were not aware that he had had to do so for at least a year prior to the fatal event. The family doctor had nothing on record of this, nor had he any report of the victim using an asthma inhaler.

Comment: There was no evidence of marine animal involvement, however, with no body for autopsy this cannot be excluded. This may well have been a case of apnoeic hypoxia. The victim had reported to his buddy on prior occasions that he sometimes felt dizzy after surfacing from some of his breath-hold dives. The buddy had specifically warned him not to stay on the bottom too long and to time his reserves to always be able to get back to the surface. The buddy also reported that he had never seen the victim hyperventilate prior to diving at any time.

Summary: Experienced breath-hold diver; apparently healthy; spear fishing with friend; failed to surface; no sharks sighted; body never recovered; probable drowning (possibly associated with apnoeic hypoxia).

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

ID BH	Age	Training	Experience	Dive group	Dive purpose
04/01	30	n/s	yes	BSB	Spear fishing
04/02	20	nil	yes	BSB	Spear fishing
04/03	33	trained	yes	Solo	Solo practice
04/04	61	n/s	some	BSB	Recreation
04/05	69	n/s	n/s	BSB	Recreation
04/06	60	nil	nil	BSB	Recreation
04/07	38	n/s	yes	GSB	Spear fishing
04/08	58	n/s	some	GNS	Recreation
04/09	47	nil	nil	BSB	Recreation

CASE BH 04/03

This healthy 33-year-old male overseas visitor was training to become a diving instructor. He was seen entering a swimming pool area at a residential complex and was wearing mask and snorkel. He had been swimming alone and was found unconscious on the bottom of the pool late in the evening, wearing his mask and snorkel and lying "*with his arms wrapped around a landscape rock*". Basic life support (BSL) was attempted but was unsuccessful, which is unsurprising as it was later estimated he had likely already been dead for four hours. It was reported that the victim regularly tested his breath-holding ability and had been observed practising this in the pool at his accommodation on two occasions in the preceding month. Suspicious circumstances were ruled out.

Autopsy: This confirmed he was otherwise healthy. No defensive markings were found. Condition of the skin indicated he had likely been in the water for several hours. The lungs weighed 746 g and 689 g. There was abundant pink frothy material in the trachea and main bronchi consistent with drowning. The heart weighed 368 g and was normal. No signs of drug use were noted. Toxicology results were negative for all tests performed. The cause of death was asphyxia (sic) due to drowning.
(Height = 177 cm; Weight = 76 kg; BMI = 24.3 $kg.m^{-2}$)

Comment: The reviewing pathologist would give the cause of death as drowning due to post-hyperventilation apnoeic hypoxia. Ironically, the victim had been present at a lecture two days earlier during which a diving safety officer had presented a talk on diving fatalities, stressing the point that in all the recreational diving work fatalities he had investigated there were two common factors. Firstly, that the person had disobeyed some of the basic rules of diving that instructors spend their time relying to others and, secondly, in each case the death occurred in a situation where the person was alone. The presentation had included the quote "*don't let the sole purpose of your life be to serve as a warning to others*".

Although in this case there was no history of syncope, the negative autopsy does not rule out the possibility of long QT syndrome as a cause of cardiac arrhythmia and loss of consciousness during breath-hold diving. This cannot be detected at autopsy and if there was any past history suggestive of syncope, the only way to exclude this possibility would be to screen the remaining family for long QT by electrocardiogram (ECG).

Summary: Trainee scuba instructor; alone in pool; likely practising prolonged breath-holding; drowning (possibly due to post-hyperventilation apnoeic hypoxia).

CASE BH 04/04

This 61-year-old male was described by his wife as a proficient swimmer who had snorkelled many times before. He and his wife, both visitors from overseas, went snorkelling on a coral reef in water about 3 msw deep. The water was described as clear and with a temperature of about 23°C. There was no apparent current and it was calm. On finding an area of abundant marine life, the victim called to his wife to come over to have a look. She was swimming towards him and was about 10 metres away when she saw him suddenly go limp, his head slumping to

in Australian water in 2004; all cases were male
separated before; n/a – not applicable; n/i – not inflated; n/s – not stated

Depth (msw)	Incident (msw)	Wt belt	Wts (kg)	BCD	Cause of death
15	15	on	4.2	nil	Drowning, ?hypoxic blackout
21	n/s	n/s	n/s	n/s	Drowning, ?hypoxic blackout
n/s	n/s	nil	n/a	n/i	Drowning, ?hypoxic blackout
2.5	surface	nil	n/a	nil	Cardiac
n/s	surface	nil	n/a	nil	Cardiac, drowning
n/s	surface	nil	n/a	nil	Cardiac
18	n/s	on	n/s	nil	Trauma, shark
n/s	surface	nil	n/a	nil	Cardiac
n/s	surface	nil	n/a	nil	Cardiac

one side and his snorkel becoming submerged. She found him to be unconscious and so she took him to shore. BLS was commenced immediately on shore, with assistance from other beach users, and was pursued vigorously for 45 minutes without success.

Autopsy: The heart weighed 438 g and there was multifocal atheroma, which varied from 70% to 30% narrowing along the major coronary arteries. The lungs weighed 658 g and 588 g and were hyperinflated, but the upper airways were clear. There was no evidence of marine animal activity or bites. The cause of death was given as coronary atherosclerosis.
(Height = 180 cm; Weight = 88 kg; BMI = 27.2 kg.m^{-2})

Comment: The victim was a competent swimmer with no previous medical history, and no evidence of bites or stings. This death from ischaemic heart disease while snorkelling could have occurred during any form of exertion.

Summary: No history of health problems; silent death occurring in the vicinity of others while snorkelling; vigorous but unsuccessful BLS attempts; coronary atherosclerosis.

CASE BH 04/05

This 69-year-old male, who was a visitor from overseas, had a history of hypertension, for which he was taking amlodipine besylate, and angina, for which he was prescribed nitroglycerine. Despite this, he showed no outward signs of being unfit and was reported to have been a competent swimmer. It is unknown if he had any snorkelling experience. He and his wife joined a trip to see the Great Barrier Reef (GBR). There was a talk on snorkelling during the outward trip and passengers were asked to report any health or medication factors that might affect their safety. There is no record of him reporting his medical condition.

They were snorkelling in the roped area around the pontoon moored at a reef. He was wearing a thin wetsuit and the snorkelling equipment provided. Three lookouts watched those in the water in the roped area, ready to help anyone requiring assistance. The victim and his wife were separated at times due to choppy sea conditions. A short period of separation occurred and when next seen, the victim was floating face-down against the boundary rope and not moving. A rescue swimmer and a tender were immediately dispatched to him and he was dragged into the tender. He was apnoeic and pulseless. He was taken to the pontoon where BLS was commenced, without success.

Autopsy: The heart weighed 480 g. There was left ventricular hypertrophy (18 mm thickness, normal <15 mm). The only significant coronary atheroma was in the left anterior descending (LAD) coronary artery, whose lumen was reduced to approximately 50% by a plaque 10 mm from its origin. The heart muscle histology showed myocyte hypertrophy and some interstitial fibrosis in some areas but no myocarditis. The lungs were heavy, weighing 1220 g and 1053 g. There was a large amount of frothy fluid in the larynx and bronchi and the lungs were extremely moist with watery fluid suggestive of salt water drowning. The cause of death was given as drowning, other significant conditions were coronary artery stenosis due to atherosclerosis.
(Height = 187 cm; weight = 87.5 kg; BMI = 25.0 kg.m^{-2})

Comment: The reviewing pathologist would give the cause of death as drowning due to ischaemic heart disease (50% LAD) and left ventricular hypertrophy while snorkelling. At autopsy, there are no pathognomonic findings of drowning. The diagnosis is based on the circumstances of the death, plus a variety of non-specific anatomical findings like pulmonary oedema, which may also be caused by cardiac failure. As in cases BH04/04 and BH04/08, the degree of coronary artery stenosis reported was 50%, below the 75% stenosis usually held to be clinically significant. The left ventricular hypertrophy could be the significant other factor. The fact that he was prescribed nitroglycerine is a strong indicator of clinical ischaemic heart disease. The occurrence of a cardiac event was possibly high at any time, but of particular importance in the water especially in choppy sea conditions and/or a current.

Summary: History of angina; appeared to be otherwise 'fit'; unpredictable event occurring whilst, but not necessarily as a consequence of, snorkelling; silent death in presence of others; drowning (possibly due to cardiac arrhythmia).

CASE BH 04/06

The victim was a 60-year-old male, an overseas tourist who had come with his family to holiday on the GBR. He had a history of Parkinson's disease for which he was taking a variety of medications, including levodopa, selegiline, tolcapene, benserazide hydrochloride and adamantine.

The usual introductory information and films were shown on the outward boat trip to a pontoon on the reef. The victim omitted declaring his health condition and medications on the pre-snorkel medical questionnaire. Although he was an active swimmer, it is not known if he had snorkelled before and the family was apparently surprised by his decision to do so. He began snorkelling with his son who then exited the water briefly to have his mask adjusted. At this time, the lookout noticed that the victim was about 4 to 5 metres away and appeared to be struggling to reach out to the outer yellow float line. Another swimmer was seen to lift the line to allow him to swim under it. After appearing to regain his composure, the victim was thought to have continued to snorkel, although there were no visible signs of him kicking. He was then noted by a ship's lookout to be face-down and not moving. The lookout immediately dived in and swam to assist the victim who was now approximately 30 metres away. The victim was found to be unresponsive, with staring eyes, and did not appear to be breathing. The victim was brought to the pontoon where BLS was commenced. A doctor, present by coincidence, assisted. Despite advanced life support (ALS), the victim failed to respond.

Autopsy: Autopsy revealed the presence of a small skull defect about 20 mm across in the right mid lateral portion of the skull and a small area of compression of the anterolateral right hemisphere. Both were long-standing and indicated a past surgical procedure. The heart weighed 408 g and there was no left ventricular hypertrophy. There was no macroscopic scarring and histology revealed only small patches of predominantly subendocardial fibrosis. The coronary arteries showed 80-85% stenosis of LAD coronary artery and 50% stenosis of the other two major coronary arteries. The lungs were heavy, weighing 855 g and 689 g and exuded haemorrhagic fluid. The cause of death was stated to be "*acute cardiac failure due to atherosclerotic stenoses of the coronary arteries due to atherosclerosis*".
(Height = 183 cm; Weight = 78 kg; BMI = 23.3 $kg.m^{-2}$)

Comment: Although the victim was taking several medications to manage his Parkinson's disease, he was not apparently taking any cardiac medication. There is no information concerning the reason for the skull surgery or whether he had previously reported any cardiac symptoms. Why he became determined to leave the designated snorkelling area is unknown. This cardiac death was not necessarily related to his snorkelling and could have likely occurred in other circumstances.

Acute cardiac failure is a 'mode' of death and not an acceptable 'cause' of death according to a report from the Australian Bureau of Statistics,[2] although it is used on occasions in coroner's findings. The reviewing pathologist would give the cause of death as ischaemic heart disease due to severe narrowing of the LAD coronary artery while snorkelling. Another significant condition contributing to death may have been Parkinson's disease as the movement problems caused by this disease would probably significantly impair the victim's ability to save himself.

Summary: Overseas visitor on multiple medications for Parkinsonism; active swimmer with no known history of cardiac symptoms; unknown reason for skull surgery long ago; separation; silent death; acute cardiac failure.

CASE BH 04/07

This 38-year-old male had 15 years of spear fishing experience and was thought to be generally of good health, although he was taking medications for high cholesterol (simvastatin) and depression (paroxetine hydrochloride). He was spear fishing with two friends on the outer GBR and continued to spear fish when his two friends returned to the boat for lunch. One of the friends looked up and noticed the victim vertically upright in the water, then heard him scream. He had been snorkelling about 60 metres from the bow of the boat. No shark was sighted at any stage of the event.

Realizing that something was wrong, the friends quickly weighed anchor and went directly to him. He was surrounded by a pool of blood about 3 metres in diameter and his spear gun floated nearby, although they did not notice whether it had been fired. They quickly pulled him into the boat. The victim had a large bite wound down to the bone on his inner left thigh and involving his femoral artery. He was still conscious when pulled aboard but was extremely pale.

The friends tried to pack the wound to stop the bleeding and talked to keep him calm and prevent him from trying to get up. Emergency services were contacted by mobile phone when efforts on marine radio failed. Whilst returning to land, the victim slipped in and out of consciousness. About 10 minutes before an emergency helicopter arrived, his pulse could no longer be felt, although his eyes were open. His death was confirmed by the paramedics. It was reported that the victim had a 'bait pouch' attached to his weight belt.

Autopsy: No teeth were found in the wound but examination of the incision marks on the victim and on his wetsuit indicated that he was attacked either by a bull shark or a black whaler. Experts at James Cook University suggested its probable size to have been 1.8 to 2.2 metres. The wound showed no tearing so it was thought to be a single bite.
(Height = 174 cm; weight = 70 kg; BMI = 23.1 kg.m-2)

Comment: The presence of blood from fish that the divers had speared, and the 'bait pouch' attached to the victim's belt are likely to have encouraged the shark to attack. The manner in which the friends attempted to stop the bleeding is not clear so it is unknown whether or not more effective first aid would have made any difference to the outcome. The reviewing pathologist would give the cause of death as shark bite of left thigh while spear fishing.

Summary: Experienced spear fisherman; bait pouch on weightbelt; location far from shore hence distant from medical care; shark attack; exsanguination.

CASE BH 04/08

This victim was a 58-year-old male, with unknown previous snorkelling experience. He had recently arrived from overseas and was on a three-day cruise on the GBR with his daughter, who was a scuba diver. He was obese, with a BMI of 34.6 $kg.m^{-2}$, and had a history of hypertension for which he was taking atenolol 25 mg, enalapril maleate 10 mg, calcium aspirin 100 mg, hydrochlorthiazide 25 mg and isoride dinitrate 5 mg. It was reported that the victim had visited his doctor in the weeks preceding his journey "to have his blood pressure checked" and was assured that he was fit to undertake his forthcoming trip.

Prior to being permitted to snorkel, the victim was required to complete a medical declaration, which he chose to do in his native language, but in a manner that was comprehensible to the dive operator. The waiver he had signed contained warnings about the risks of snorkelling for people with certain health conditions, such as heart disease. It is unknown whether or not he reported his health conditions.

On the first day of the trip, he remained on board the vessel, appeared well and ate normally. Mid-morning on the second day, the victim prepared to go snorkelling with an organised group. He hired mask, snorkel and fins, donned a wetsuit top but refused an extra buoyancy aid that he was offered. After boarding the tender, he was taken approximately 30 metres from the vessel. The conditions were described as suitable to allow the victim and others to snorkel in the area and to return to the main vessel "with the aid of the wind and the surface chop". The victim requested to be taken back to the main vessel after only a few minutes in the water, stating that he felt tired. He was taken back promptly and after several minutes on board, he became breathless, vomited and collapsed. The crew immediately initiated BLS, which continued until the arrival of a rescue helicopter. Paramedics implemented ALS procedures but the victim failed to respond.

Autopsy: The autopsy revealed no injuries. The heart weighed 475 g and was mildly enlarged. The left ventricle was reported to measure between 20 and 28 mm in thickness (normal < 15 mm), There was an area of 50% narrowing in the right coronary artery. The more distally placed coronary vessels showed widespread areas of luminal narrowing but no signs of complete occlusion. Histology of the heart showed advanced ischaemic pattern fibrosis and severe atheromatous narrowing of the smaller coronary arteries. The weight of the lungs is not given and there is no comment about the presence or absence of pulmonary oedema fluid in the upper airways, making it difficult to assess whether drowning may have occurred. Histology also showed renal arterial and arteriolar nephrosclerosis, an indicator of background raised blood pressure. The cause of death was given as acute cardiac failure, coronary arterial atherosclerotic narrowing, cardiomegaly and myocardial fibrosis.
(Height = 183 cm; Weight = 116 kg; BMI = 34.6 $kg.m^{-2}$)

Comment: Fatalities occurring during exercise are observed with narrowing of between 50% and 75%, especially when there is severe atheroma in the smaller coronary arteries or left ventricular myocardial hypertrophy. The histology is very suggestive of past ischaemic fibrosis. Where there is hypertrophy of the left ventricle greater than 15 mm, there may be some problems with diastolic perfusion. In this context, it seems reasonable that a subcritical stenosis with left ventricular hypertrophy during exercise might cause myocardial ischaemia and trigger a lethal arrhythmia.

As with BH 04/06, cardiac failure is a mode, not a cause of death, which is more correctly described as due to ischaemic heart disease and left ventricular hypertrophy while snorkelling. Another significant condition contributing to death may have been hypertension. This death could have occurred in a variety of other circumstances and the victim was either unaware of the degree of his ill health, or concealed its presence.

Summary: Obese; hypertension on medication; pre-trip medical check found victim fit to travel but unknown if snorkelling was discussed with doctor; became breathless shortly after entering the water to snorkel; collapse soon after exiting water; ischaemic heart disease (death could have occurred at any time, especially with exertion).

CASE BH 04/09

The victim was a 47-year-old, apparently healthy, male who was visiting Australia with his brother and was on a day trip to the GBR. During the cruise out on the vessel, they attended the safety talks and the victim decided to undertake a 'resort dive'. He completed a medical questionnaire, reporting no ill health. He said to his brother that his doctor had told him the previous year that he was fine.

While awaiting the appointed dive, the two men joined others snorkelling. The current was reported to be fairly strong. Seven crewmen were tasked to look out for any people in distress or fatigued. Four were on the observation deck and three were in boats either inside, or close to, the marked area. The two brothers snorkelled together, the victim taking pictures. After talking about the strength of the tide and "*stinging going on in the seawater*" they took pictures of each other. There were no signs that the victim was suffering any difficulty. However, he said that he was a little tired and he would return to the pontoon to rest before his scuba dive. At this stage, they were 15–20 m from the boat. The brother then made several dives to photograph giant clams but checked and saw the victim swimming towards the pontoon each time he surfaced. Nothing seemed out of the ordinary.

Later, on returning to the pontoon, he was unable to locate his brother. One of the lookouts noticed the victim floating face-down and immobile. When a rescuer reached him, he was found to be unconscious, apnoeic and cyanotic. He was dragged into the boat where BLS was commenced. This continued for a further hour on the pontoon before the attempt was abandoned. It was estimated that about 30 minutes had elapsed from the time he entered the water until he was found.

Autopsy: There was significant ischaemic heart disease with a pinpoint narrowing of the ostium of the right coronary artery by atheroma and the left coronary and the left circumflex arteries with 50% stenoses. Histology showed similar narrowing of some small vessels but no evidence of myocarditis, significant fibrosis, or of recent infarction. Cause of death was given as myocardial ischaemia as a consequence of coronary artery stenosis due to atherosclerosis. No suspicious circumstances were noted. (Height: 170 cm; weight: 88 kg; BMI = 30.4 $kg.m^{-2}$)

Comment: While this death occurred during immersion, it was clearly an event that could have happened at any time. It is likely that the exertion of snorkelling was significant in this death due to ischaemic heart disease, as during vigorous exercise the risk of sudden death is 56 times greater than at rest in sedentary individuals and 5–25 times greater in fit individuals based on the underlying level of fitness.[3]

Summary: Apparently healthy; snorkelling in strong current; reported fatigue; silent death despite several lookouts; myocardial ischaemia.

Scuba diving deaths

CASE SC 04/01

This victim was a 44-year-old male, who was working on a luxury yacht that was visiting the GBR from overseas. He was said to be a qualified and competent diver although the level of his training was not reported. The yacht's anchor became stuck in water at a depth of 23 msw and the victim and his buddy were sent to try to free it. The divers did an initial survey dive to assess the situation and to formulate a plan. After waiting on the surface for equipment to be lowered to them, they dived again about 15 minutes later. This time they went down with a heavy line and shackle to attach to the anchor chain, which they did.

About one hour later, after having refilled their air cylinders using the ship's compressor, they dived again to free the anchor. The victim injured his right hand but it is unclear exactly how this occurred. However, the injury resulted in the victim making an immediate solo rapid ascent without warning. Observers on the vessel noted that he arrived at the surface looking unwell, although he was initially conscious. He seemed to try to speak and then began to vomit. At this point, two of the crew dived in and assisted him back to the vessel. Once on board, he was apnoeic and pulseless. BLS was immediately commenced. An emergency services helicopter arrived within the next half an hour and ALS procedures were implemented. Resuscitation attempts were halted approximately one hour after the victim was removed from the water. He was pronounced dead shortly thereafter at a mainland hospital.

Another witness, apart from the buddy, who was an experienced diver had observed the dive plan and watched the equipment prepared and had seen no fault in any of this. The victim had seemed at ease with his task as he had appeared to be during dives on previous occasions.

Autopsy: Autopsy revealed subcutaneous emphysema of the upper chest and significant amount of gas within the right side of the heart and adjacent major vessels, and the vessels of the circle of Willis together with hyper-inflated lungs strongly suggested massive air embolism. Radiological imaging showed changes in the vessels of the brain, neck, thorax and pelvis. Toxicology showed no other findings. Cause of death was massive gas (air) embolism due to diving.
(Height = 185 cm; Weight = 88 kg; BMI = 25.7 $kg.m^{-2}$)

Comment: This is a classic description of an incident of pulmonary barotrauma/cerebral arterial gas embolism (PBT/CAGE) following rapid ascent, in this case following injury while scuba diving, and sudden loss of consciousness upon reaching the surface. Although the victim was reported to have been a competent diver, it appears that he panicked when injured and is likely to have ascended rapidly without breathing adequately. The extent of the injury to his hand

or arm is unclear but it was a trigger for an unsafe ascent. Although the victim and his buddy performed three 23 msw dives in a short period of time, decompression sickness was not believed to have been a factor in his demise.

Summary: Buddy pair attempting to free a jammed ship's anchor; victim cut hand/arm; probable panic; rapid ascent; BLS and ALS unsuccessful; CAGE.

CASE SC 04/02

The victim was an apparently healthy 41-year-old male tourist from overseas. He registered for a 'resort' dive with a group visiting the GBR. He completed the required medical declaration, stating that he had no known medical conditions prohibiting him from undertaking a scuba dive. There was a talk by an instructor covering the main matters the group of four resort divers needed to know before their first scuba dive. After the instructor checked their equipment, they entered the water and assembled at a bar in the water near the stern of the boat where they practised equalizing, mask clearing, and regulator recovery. Each individual demonstrated these skills before descending to a lower bar to be photographed. Sea conditions were described as moderate with a slight current and visibility of around 15 metres.

They then linked arms and swam over towards the reef whilst slowly descending to the bottom. After about 30 minutes, one diver's air contents gauge was indicating 60 bar so it was time for him to ascend. Another pupil indicated a desire to surface also. The instructor thought the dive was rather short so offered the other two the option of continuing. To his surprise the victim decided to ascend at this time, though he had seemed to be managing well, so the instructor escorted three divers to the surface while the fourth diver remained on the bottom. The depth of the water at this time was variously described as 3–8 msw.

At the surface, the victim and one of the others mentioned having experienced some trouble breathing from their regulators. The instructor ascribed this to their being nervous and to the effort of swimming, believing this to be quite common among 'resort dive' pupils. After noting that the lookout on the boat, some 20–40 meters away, had seen the group on the surface, and that the wind and tide would assist their return, the instructor asked the three whether they were able to return together on the surface to the vessel before re-descending to the fourth student. The victim and his companions then commenced their return swim. A short time later, the victim was located on the surface by another crew member. He was unconscious and cyanotic, with neither snorkel nor regulator in his mouth. Although his weightbelt was in place, he was quite buoyant as his buoyancy compensating device (BCD) was inflated. The victim was brought back aboard to the boat where BLS was commenced. A doctor and paramedic who were on a nearby vessel came over to assist and took over the resuscitation efforts. Oxygen and an automated external defibrillator (AED) were available but it is unknown whether or not these were used. Resuscitation efforts were continued for approximately 35 minutes but the victim failed to respond.

Autopsy: The heart weighed 381 g and showed mild left ventricular hypertrophy. There was severe ("pinpoint") atheromatous stenosis of the origin of the left circumflex coronary artery and moderate stenosis of the ostium of the right coronary artery. Ischaemic changes were seen in the myocardial fibres but no acute infarction. There was diffuse fatty change in the liver. The cause of death was ischaemic heart disease.
(Height: 177 cm; Weight: 79 kg; BMI = 25.2 $kg.m^{-2}$)

Comment: This death resulted from pre-existing ischaemic heart disease due to severe atherosclerosis and could have occurred in many circumstances, unrelated to diving, although the exertion was probably significant. The abandonment by the instructor on the surface breached recognised training protocols.

Summary: Apparently healthy man; 'resort dive'; abandoned on surface by instructor; silent death at surface; significant but apparently unknown coronary artery disease; ischaemic heart disease.

CASE SC 04/03

The victim was a 31-year-old male who was uncertified and inexperienced, having only completed around six to eight dives in total. He had learned what he knew about diving from a friend who had reportedly been diving more than 20 years and claimed to have completed between 200 and 300 dives. The victim was described as safety-conscious and competent and, although it had been suggested to him by others with whom he had dived previously (including the person with whom he had 'trained'), that he should do a formal diving course, he had not done so. The pair went diving for crayfish from a private vessel. Another friend, who had no knowledge of diving, tendered the boat whilst the two dived. He had been told to look out for them when they resurfaced. It was reported that the victim's buddy, the diver who had 'trained him', had set up and checked the victim's gear, which included air cylinders charged to 270 bar.

There was a delayed start to the dive as the victim was initially under-weighted and an additional 1.3 kg weight was placed in each pocket of his BCD. The sea was calm and visibility around 15 metres. They descended and followed the bottom out to a depth of about 15 msw, staying together for about 30 minutes. They then became separated but soon reunited when the victim's buddy found him with his head in a hole trying to extract a crayfish. The buddy swam off about 25 metres and when he returned there was no sign of the victim and he presumed that his friend had swum off in search of other crayfish and so was not concerned. About 10 minutes later, he heard a boat's motor and believed that

Table 2. Summary of scuba, rebreather and surface-supply diving-related
BNS – buddy not separated; BSB – buddy separated before problem; BSD – buddy separated during; GSB – group separated before; GSD – group separated during; expcd – experienced; tnd = trained;

ID SC	Age	Training	Experience	Dive group	Dive purpose	Depth (msw)
04/01	44	trained	expcd	BSB	Work	23
04/02	41	nil	nil	GSB	Resort	8
04/03	31	some	slight	BSB	Crayfish	15
C04/04	32	trained	some	BSB	Recreation	3
04/05	26	trained	some	GSB	Recreation	13
04/06	53	trained	some	GSD	Recreation	30
04/07	55	trained	nil	BNS	Recreation	18
04/08	37	some	nil	GSB	Class	3.3
04/09	36	some	nil	GSB	Class	10.5
04/10	32	trained	some	GSB	Recreation	12
RB						
04/01	55	trained	expcd	GSB	Recreation	46
SSBA						
04/01	24	some	some	GSB	Crayfish	30
Pre-SC						
04/01	65	n/s	expcd	BNS	Recreation	n/s

this indicated that the victim had surfaced and was being picked up. Noticing that he had 70 bar of air remaining, the buddy began a slow return to shallower waters but after about 5 to 10 minutes he saw the victim lying face-down on the bottom at a depth of 12 msw. He was unconscious with regulator out of his mouth and mask missing. After being unable to inflate the victim's BCD as there was no remaining air supply, the buddy inflated his own BCD and brought the victim to the surface. The buddy then commenced in-water rescue breathing while he waited for the boat to pick them up. Rescue breathing was continued until they reached shore where they were met by an ambulance and a local doctor. BLS attempts were unsuccessful.

The equipment was later found to be in good working order apart from the lack of air in the tank. The dive computer indicated that the ascent alarm had been triggered; however, the dive profile could not be downloaded.

Autopsy: The pathologist did not obtain a CT check prior to autopsy but did inflate the lungs underwater (no air escaped), noting the absence of subpleural emphysema, then aspirating the ventricles. He obtained 20 ml of gas from the right ventricle and 60–80 ml from the left. Gas was found in the inferior vena cava, the aorta, and the left and right atria (with less in the right). There was mediastinal emphysema. The coronary arteries showed minimal atherosclerosis, and the foramen ovale was probe patent. Cause of death was given as pulmonary barotrauma/cerebral arterial gas embolism due to an out-of-air situation while scuba diving.
(Height: 172 cm; Weight: 77.8 kg; BMI = 26.3 $kg.m^{-2}$)

Comment: Given that the victim was discovered dead on the bottom, it is possible that the gas detected at autopsy represents post-mortem off-gassing. Unfortunately, the ascent was not witnessed, hence one of the best diagnostic criteria for PBT/CAGE was absent.

fatalities in Australian waters in 2004; all cases were male
problem; n/a – not applicable; n/i – not inflated; nad – nothing abnormal discovered; n/s – not stated;
+ sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ >50% full; CAGE – cerebral arterial gas embolism

Incident (msw)	Wt belt	Wts (kg)	BCD	Remaining air	Equip test	Cause of death
23	n/s	n/s	n/s	+++	nad	CAGE
surface	on	n/s	infl	++	n/s	Cardiac
12	on	7	n/i	nil	nad	CAGE
3	on	10	infl	+++	nad	Cardiac?
ascent	on	n/s	n/i	+++	fault	CAGE
5	on	11	n/i	nil	nad	Drowning
surface	on	n/s	n/i	++	nad	Cardiac, post dive
3	on	11.2	n/i	nil	faults	Drowning
ascent	on	n/s	n/i	+++	faults	CAGE
surface	on	18	n/i	+++	faults	Drowning
46	on	3	nil	ok	faults	Drowning
n/s	on	2	nil	++	faults	Drowning
surface	n/a	n/a	n/a	n/a	nad	Cardiac, pre dive

Summary: No formal training; some instruction; inexperienced; hunting crayfish; separated; out-of-air situation with probable rapid ascent; PBT and CAGE.

CASE SC 04/04

This 32-year-old male was obese and had a history of HLA B27 spondyloarthritis. He was a trained open water diver but had "not dived for quite some time" and was keen to get back into diving. The dive was planned with a group of work colleagues, one of whom was to be the victim's dive buddy as they had dived together previously. Prior to the outing, the victim hired a tank and weight belt.

The chosen location required a 50-metre walk down a steep path, which the victim appeared to manage without any problems. The group rested for 10 minutes, then checked each other's equipment before entering the water. The entry point was off a rock ledge requiring judgment of the optimal point of the surge before jumping in. Conditions were choppy, visibility was described as 10–15 metres and there was an incoming tide that would tend to carry them towards the planned exit point.

The first group of three divers entered the water from the ledge and swam off. The victim was the next to enter the water, just before his buddy. He descended two to three metres, then ascended again very shortly after, reaching the surface before his buddy had submerged. He removed his regulator and said "*I'm not feeling good*" and that he "*wanted to go in*". By this time they were about 15 metres from the rock shelf. When they reached this shelf the victim found he could not climb out as it was too steep and waves were knocking him onto the rocks. His buddy thought he was beginning to panic and saw him pulling at his exposure suit as if it was too tight. As they swam to find an easier place

to exit, the victim pulled his mask off. His buddy urged him to continue to use his regulator and saw that there was some air in his BCD. The buddy later said it would not have been possible to exit onto their water entry ledge as it was too high.

The buddy swam with the victim, holding his tank and pulling him along on his back. He encouraged him to relax and to keep breathing from his regulator. When the regulator fell out of the victim's mouth, the buddy replaced it, then removed his mask and snorkel from his hand. On reaching the lower ledge the victim and his buddy tried in vain to exit the water. This required significant exertion for both divers and the victim began to panic when he was unsuccessful. The buddy then realized he needed to release his friend's weights before he would be able to pull him out of the water, which he did. At this time the victim seemed to be relaxed, floating with his head out of the water. He then developed a blank look with his eyes open and distant, and he spat out the regulator. The buddy kept the victim's head above the water and called for help, which soon arrived. He attempted to pull the victim from the water but this was only achieved when more helpers arrived and four were needed for this task as the victim was so heavy.

The buddy placed the victim on his side and "*about a cup-full of water and yellow matter came out of his mouth*". He was then rolled face-up and BLS was commenced. Another diver soon arrived and together they maintained BLS until ambulance paramedics arrived. Shortly after this, a rescue helicopter arrived carrying a doctor who, together with the paramedics, implemented ALS. However, the victim failed to respond.

It was only later, at work, that the buddy learned that his friend had been unwell with arthritis the previous week. They had dived together three times in the past, the last occasion three years prior. The buddy thought that the victim had put on a lot of weight since last wearing his semi-dry suit. In his opinion, it had been too tight. He later suggested that the victim should probably not have been diving that day. Later examination of the victim's diving equipment found it functioned correctly and the air was suitable for use.

Autopsy: The autopsy revealed no evidence of subcutaneous emphysema, pneumothorax, or serious coronary disease and a 'cause undetermined' finding was recorded. Although there was 2 cc of small air bubbles in the right atrium, ventricle, and pulmonary arteries, this was ascribed to post-mortem changes – the heart was opened underwater. Toxicology tests show that he had used cannabis in the recent past and had taken rofecoxib and pseudoephedrine. There was 3% carbon monoxide saturation of the blood, which was consistent for that of a smoker. There was no evidence of trauma beyond minor grazes probably sustained when he was pulled from the water. The maximum coronary lumen stenosis was 10%. Histology showed delicate focal scarring in the anterior wall of the left ventricle but there were no changes in other locations. The liver showed mild macrovesicular steatosis. No comment was made concerning arthritis or his obesity. The cause of death was not determined at autopsy.

Subsequent review of the case by a physician and a pathologist with diving medicine experience suggested that cardiac arrhythmia was the most likely cause of death. Features of concern were the presence of pseudoephedrine on toxicology, the HLA B27 spondyloarthritis with a possible hypercoagulable state associated with the arthritis just before death, minimal recent diving experience, recent weight gain and a tight wetsuit. Screening of the family for long QT was recommended even though ECGs of the diver had not demonstrated a long QT interval. The cause of death was given as cardiac arrhythmia.
(Height = 174 cm; Weight = 105.5 kg; BMI = 34.8 $kg.m^{-2}$)

Comment: At the time of this case, there was publicity about the potential cardiac risk for those taking rofecoxib and the victim had been taking this, in addition to other medications, for his chronic arthritic disease. His family brought this to the Coroner's notice and in consequence his medical records were reviewed. These showed a long history of arthritis, diagnosed in 1995 as Reiter's Syndrome. He was intermittently on various non-steroidal anti-inflammatories, salazopyrin, prednisolone, and atropine eye drops for episodes of uveitis. Opinions were obtained from a cardiologist and a pathologist with a special diving-medicine interest. They noted the medications, his obesity and lack of fitness, the structural changes in the heart, the strenuous activity in reaching the water's edge and the tight-fitting semidry suit. It was noted that physical evidence of a myocardial infarction takes time (at least four hours) to develop. Various suggestions, such as coronary thrombosis due to platelet aggregation associated with the spondyloarthritis, a long QT Type 1 or a 'small-vessel disease' syndrome, were made, and it was suggested the family be investigated for some of these conditions. Both specialists agreed this was probably a cardiac arrhythmia death. This case demonstrates the difficulty of diagnosis of a functional abnormality, for example cardiac arrhythmia, at autopsy when there is no structural abnormality.

Summary: Trained but no recent experience; obese with long history of medication, including rofecoxib for spondyloarthritis; tight semi-dry suit; difficult access to dive site; reported feeling unwell immediately on entering water; buddy rescue attempt; probable cardiac arrhythmia.

CASE SC 04/05

This 26-year-old male came from overseas on a diving holiday with three friends. He had obtained his open water diving certification at home some months earlier and, although described as an enthusiastic diver, he was thought to have done only six dives prior to this trip, the deepest being to 18 msw.

The trip was for three days on a live-aboard vessel in tropical

GBR waters. The victim aborted a dive on the first day as he was grossly under-weighted and had exhausted himself trying to stay underwater. He reported feeling tired and seasick. On the second day, he decided not to join the first dive as it was too early in the morning, but dived later that morning with two friends and a dive guide.

The vessel was anchored in water 10 to 12 msw deep. Conditions were described as "good", with visibility of around 20 metres, no swell and only a small surface chop. Underwater, the divers swam into a slight current. After about five minutes, one of his friends saw the victim standing on his fins on the sandy bottom and wrote on his slate telling him not to kick up the sand. The victim made some sort of a signal in response, possibly a hurried 'OK' before swimming, his kicking appearing to be weaker than expected. It was a further few minutes before his absence was noticed and the dive leader, who was a divemaster-in-training, started to ascend to look for the missing diver and noticed the victim on or near the surface above him. He was face-up and sinking from the surface, the regulator was not in his mouth and his mask and snorkel were missing. The leader grabbed the victim by his BCD, placed the regulator back into his mouth, inflated his own BCD and they both ascended to the surface from a depth of 4–5 msw. The leader described this as a struggle as the victim was heavier than him. On reaching the surface, he removed the victim's weight belt, enabling him to remain buoyant.

Meanwhile, the look-out on the boat had seen the victim surface briefly and then disappear. The rescuer in the water called and signaled for help then checked for, and found no, signs of life so he began in-water rescue breathing while the tender came to their aid. The victim was brought aboard the tender and quickly taken to the main vessel where BLS was commenced. Supplemental oxygen was provided (15 litres per minute via a resuscitation mask). Initially a lot of water was drained from the victim's mouth. Ventilation was complicated by the fact that the victim had clenched teeth as well as continuous frothing and regurgitation of water and stomach contents. Bloody fluid was noted coming from his ears. A doctor and nurse (tourists themselves) arrived from another vessel and continued with the BLS. After a total of some 90 minutes the doctor ceased resuscitation attempts.

The victim's dive computer indicated a maximum depth of 13.8 msw and a dive time of 12 minutes. There was 110 bar of air remaining in the cylinder. The rented equipment was reasonably serviceable except for the contents gauge which was inoperable, stuck at a constant reading of 90-100 bar. The cylinder air was found to be "suitable for use" when tested.

Autopsy: The autopsy was performed two days after death. The CT of the head and neck revealed gas in both internal carotid and vertebral arteries as well as within the basilar artery and within branches of those vessels. Extra-axial air was seen anteriorly in each middle cranial fossa. The hard palate was high-arched and the left side canted up laterally. The findings suggested repair or part-repair of a cleft palate. The CT of the trunk showed intra-cardiac gas and gas within the origins of the great vessels of the aortic arch and a small amount in the mid-descending thoracic aorta. An air-fluid level was seen in the distal trachea and within the right and left main bronchi. There was no pneumothorax. In the abdomen, there was also gas in the aorta and major arterial branches and in the spleen and liver, neither of which was enlarged.

The heart weighed 330 g, the coronary arteries were small in calibre and showing no significant atheroma. There was gas in the ventricles, especially the left ventricle, and in the arch of the aorta. There was a comment that histology of the heart revealed "chronic myocarditis", although the extent, and hence, the possible significance of this change is not clear. The lungs weighed 700 g and 600 g and had the appearance and consistency of "e*mphysema aqueosum*", typically associated with drowning. The liver had a number of pale areas, chiefly subcapsular, suggestive of impending necrosis due to ischaemia (likely due to obstruction of peripheral blood supply from blockage by bubbles). The cause of death was given as cerebral and generalized gas embolism with drowning due to probable uncontrolled ascent during a scuba diving accident.
(Height = 185 cm; Weight = not recorded; BMI = unknown)

Comment: The cause of death as PBT/CAGE was probably due to a rapid ascent. Other significant factors may have been feeling unwell prior to the dive and a faulty contents gauge giving misleading information. Because this autopsy was completed two days after death, it is possible that some of the gas seen could be due to post-mortem off-gassing or decomposition. The descriptions of the liver and spleen are suggestive of either off-gassing or decomposition. There are some features that do not completely fit the diagnosis of CAGE: (1) the diver may have been unwell prior to ascent, (2) there are changes consistent with drowning, and (3) there was microscopic chronic myocarditis. One of the other passengers noted afterwards that he saw the victim before he entered the water and "*he didn't seem relaxed. I think it might be best to call him tense*". His actions as described by his buddy cannot be readily explained; he had adequate air even should he have believed the contents gauge rather than the ease of his air supply. Panic appears to have overwhelmed him, possibly in consequence of anxiety concerning his diving ability and exacerbated by his residual ill health.

Summary: Prior sea sickness and fever symptoms; trained but very inexperienced; appeared anxious before dive; strange behaviour, then separation and solo ascent; seen to sink from surface; weights not ditched; adequate air but faulty contents gauge; comment that histology of the heart revealed "chronic myocarditis" although the extent and hence the possible significance of this change is not clear; CAGE.

CASE SC 04/06

This victim was a 53-year old male described as a "big man". Although he reportedly suffered from migraines, tinnitus and impaired vision, he had no history of cardiovascular disease. He gained his open water diver qualification three years earlier and his logbook noted only four dives since then, although it is likely that he had made several more, including two confirmed dives with his former instructor to 23 and 34 msw respectively. This instructor had advised him to always use a large (2800 to 3360 L) cylinder because of his "enormous" air consumption, especially on deep dives. On this occasion, the victim borrowed a smaller cylinder (2240 L) of air at a pressure of 220 bar. He also borrowed a regulator and BCD. He was wearing a 5 mm wetsuit and had approximately 11 kg of weight on his belt.

A group of seven divers boarded a chartered vessel and were taken to a dive site with a maximum depth of 30 msw. Other, shallower, sites had been discussed but were apparently rejected by the boat skipper. Sea conditions were described as choppy and several people on board were reportedly sea-sick, although the victim was not one of these. It was reported that the dive briefing, delivered by the skipper, was scant and a dive leader was hastily selected just prior to entry.

The divers entered the water (the victim made a head-first water entry for some unknown reason) and separated into two groups once they reached a ledge at 24 msw depth, the victim being in a group with two other divers. Visibility was reported to be limited until reaching the bottom where it was possibly 10 metres. There was a current and at least one diver later described the water as cold. The victim became separated from his buddies at one point before they retrieved him. One of the victim's buddies kept a watch on his contents gauge after noticing his use of air was far more than his own, and, after they had been diving about 20 minutes, he noticed that the victim's gauge was reading 110 bar and initiated their return to the anchor rope. When they reached the anchor, one of the buddies realised it was the wrong one but decided that they should ascend up it anyway. The victim's gauge now read 60 bar. When they had reached about 10 msw depth they came to end of the rope and realised that it had been cut previously and was floating free. Both his buddies decided to make a 5-metre safety stop and inflated their delayed surface marker buoys (DSMB). However, the victim continued to the surface and did not re-descend even after one of his buddies reached him and tugged at one of his fins. They stated later that they saw him start to fin towards the dive boat some 20–30 metres away.

The skipper noticed him at the surface, low in the water, facing towards the boat in the choppy water, and then turned to watch the other divers as they surfaced alongside their DSMBs. He concentrated on picking up the other divers, none of whom attempted to swim back to the dive boat in the choppy water. When he next looked he could no longer see the victim and assumed that he had chosen to re-descend, either to make a safety stop or to return below the surface to avoid the rough water. Some time passed before any concern was expressed at the victim's continued absence and a visual check made of the surface. Nobody considered performing an underwater search. After about 20 minutes a call was made and a police boat arrived soon after. An intensive search was made but it found only one of the victim's fins before the conditions deteriorated and the search was called off. His body was found by divers the next morning, lying on the sea bed. All his equipment, except for one fin, was present, his BCD was deflated and his cylinder empty. No faults were found with the equipment when later tested.

Autopsy: X-ray of the head and neck showed some air in neck vessels (it was not identified whether arteries or veins) but none in the heart. At autopsy, the heart weighed 420 g. There was no atherosclerosis of the coronary arteries. The lungs were heavy, weighing 1240 g and 1120 g and there was frothy fluid in the upper airways. There was bruising in the right and left trapezius muscle at the back of his neck at autopsy, which may have been due to a blow from his tank when he made his head-first water entry. Cause of death was given as consistent with drowning.
(Height = 192 cm; Weight = 118 kg; BMI = 32.0 $kg.m^{-2}$)

Comment: This appears to have been a drowning following an out-of-air situation while scuba diving. Other significant conditions contributing to death were excessive air consumption, loss of a fin and negative buoyancy. There were many safety-adverse factors present but ultimately the lethal one was likely to be the failure to drop his weight belt and use his snorkel after he surfaced in somewhat rough water some distance from the dive boat. Adverse factors included the omission of a dive leader and a subsequent absence of checking on the experience of those intending this deeper dive. He was using borrowed equipment and neither asked for nor received advice on its use although the dive organizer, its owner, was aware that he was relatively inexperienced. His history of excessive air use was not disclosed, and the use of a smaller cylinder than he was used to led to an out-of-air situation. His two buddy divers undertook an appropriate monitoring role, but observed no signs of nitrogen narcosis or panic or of his being over-weighted. His medical history of migraine, tinnitus, and some visual impairment was not considered significant.

The skipper failed to recognize the need to monitor the diver he saw "at the surface, low in the water" and could be criticized for not picking him up sooner, but there were soon other divers requesting collection and he could not have known that this diver was out of air. It is apparent the buddies could not have prevented his omitting the safety stop and he failed to indicate at the surface that he was in need of assistance.

Summary: History of migraine, tinnitus and impaired vision; trained but inexperienced; heavy air user; borrowed equipment with smaller cylinder than used to; site changed

prior to dive; careful buddies in group of three; omission of safety stop; separation and alone at surface; probable out of air; failure to signal for assistance, release weight belt or inflate BCD; loss of a fin; lack of trip/dive leader; incorrect role of commercial skipper; drowning.

CASE SC 04/07

The victim was a 55-year-old male who was visiting Australia and holidaying with his wife at the GBR. They both had a medical examination prior to the trip and were both declared to be fit to dive. He was taking valsartan for mild hypertension and bupropion hydrochloride to help him stop smoking. He had been certified to dive for approximately 12 months but it is unknown how many dives he had done.

They were on the first day of a three-day trip on a live-aboard vessel on one of the outer reefs. The couple dived with a group to a depth of 18 msw when the wife had a mild panic attack and indicated to the dive leader she wanted to surface. They soon surfaced and found that the boat was a long way off and had to swim the long distance to the boat. About 10 minutes after boarding the boat, the victim felt sick and vomited. His wife had noticed that "*he was really sweaty*" and told him to go to the upper deck. A short time later he collapsed on the deck and had a seizure. The crew attempted to help him and when they discovered him to be unconscious and apnoeic with no palpable pulse they began BLS with oxygen supplementation, apparently using a bag-valve-mask. An air ambulance arrived and paramedics implemented ALS while the victim was being airlifted to hospital, although he died en route. All of his dive gear was tested by water police and found to be in working order. His air supply was satisfactory.

Autopsy: The heart weighed 375 g. There was an unstable plaque in the right coronary artery with haemorrhage into a plaque and thrombus formation as well as 50% narrowing of the coronary arteries by atherosclerosis. There was focal subendocardial fibrosis. No intravascular gas was detected on CT scan. The lungs were heavy, weighing 1177 g and 1137 g, with haemorrhagic fluid in the distal airway and cut surface of the lung. There was renal arterial and arteriolar nephrosclerosis. The cause of death was given as acute cardiac failure as a result of thrombus in the right coronary artery due to atherosclerosis of the coronary arteries.
(Height = 174 cm; Weight = 74 kg; BMI = 24.4 $kg.m^{-2}$)

Comment: The actual mechanism of death in this man was probably ventricular fibrillation (VF) due to myocardial ischaemia in a person with undiagnosed coronary artery disease. There may also have been secondary drowning due to loss of consciousness from the arrhythmia based on the lung findings.

Summary: Overseas tourist on first day of live-aboard dive trip; significant exertion during long surface swim to boat; had undergone diving medical prior to trip and had been passed fit to dive; collapsed soon after exiting water; probable cardiac arrhythmia due to myocardial ischaemia.

CASE SC 04/08

This 37-year-old male open-water student had no significant medical history and had passed a dive medical examination. He was described by one of his family as a non-swimmer. As part of his training, he was required to do a 200-metre survival swim without aids. There was no time limit on the swim and he struggled to do it, reportedly taking some 30 minutes. He was also supposed to tread water for 10 minutes but was too exhausted to attempt this. On a subsequent day, before completing the pool swim test, he participated in two open water dives at a pier in calm conditions and completed these without any apparent problems.

On the day of the accident, the victim did another dive at the same location as his previous dives. A different instructor was leading this dive and the instructor was apparently unaware that the victim had not completed the treading water test. The conditions on the day were windy, with a surface chop of 0.5–1 metre. Visibility was variously reported to be 5–10 metres, and the depth at the site approximately 5 msw. Some witnesses described the prevailing conditions as very unsuitable for open-water trainees; however, the instructor assessed it to be safe and went ahead with the dive, despite some warnings from at least one bystander who was also an instructor.

There were four students, including the victim and his buddy, and a certified diver joined the group in order to gain some additional dive experience. It was reported that the victim's pressure gauge read 220 bar prior to the dive. The 12.3L cylinder had a capacity of 2700 L at this pressure. The group did a high-water entry from the pier. On entry, the victim's octopus regulator free-flowed and his cylinder slipped down in the BCD mount. These problems were remedied by the instructor. The instructor also needed to assist the victim in venting air from his BCD. After a short time, the group submerged to practise controlled emergency swimming ascents. The victim appeared to have problems re-descending after this ascent and was last seen apparently trying to vent air from his BCD. The instructor then assessed the trainees sharing air with their octopus regulators. The depth was just over 3 msw. He assessed the first buddy pair and then signaled to the next two divers to perform the skill, believing these divers to be the victim and his buddy when in fact one of them was the certified diver. After this skill was done, the instructor realised that a diver was missing and surfaced to search for the missing diver.

There was no sign of the diver on the surface so he re-descended at the shot-line and soon located the victim face-down on the bottom. The BCD was deflated and neither of the BCD-integrated weights had been released. When the instructor turned the victim over, he noticed that his mask and regulator were still in place but he was unresponsive

and apnoeic. He was unable to inflate the victim's BCD so he inflated his own to bring them both to the surface. The victim's mask and regulator appear to have been displaced during this time. Once on the surface, the instructor called for help and was soon assisted by bystanders. The rescuers towed the victim to shore and commenced BLS but ventilations were complicated by froth and regurgitation of water and stomach contents, and by seaweed in the airway. Two trained rescuers continued BLS until paramedics arrived but the victim failed to respond.

When examined, the cylinder was empty. The first stage line pressure was slightly high and the breathing resistance of the second stage regulator was slightly lower than specified. In addition, the low pressure inflator did not function smoothly. However, none of these minor faults was thought to be sufficient to cause substantial problems.

Autopsy: The heart weighed 304 g and the coronary arteries were widely patent. No gas was detected on dissection or radiology. The lungs were heavy, 1146 and 1022 g, the upper airways contained a moderate amount of frothy fluid and the lungs appeared hyperinflated and concealed the cardiac outline. All lobes showed florid congestion and oedema. The cause of death was stated as "*finding in keeping with drowning*."
(Height = 182 cm; Weight = 76 kg; BMI = 22.9 $kg.m^{-2}$)

Comment: The phrase "*finding in keeping with drowning*" reflects the difficulty of diagnosis of drowning at autopsy, as drowning has no pathognomonic features. The diagnosis is based on the circumstances of the death, plus a variety of non-specific anatomical findings such as pulmonary oedema. The reviewing pathologist would give the cause of death as drowning due to poor swimming skills and low air supply while scuba diving.

This trainee was a very poor swimmer and had failed to tread water for the time required. He should not have been allowed to attempt the open water dives prior to completing the pool swimming tests satisfactorily. However, there appears to have been a communication failure within the dive operation and information about the victim's lack of completion of required tests was not conveyed to the instructor who took the victim on these dives. As a result, the victim was permitted to dive. In addition, it is likely that the conditions on the day of this fatal dive were unsuitable for trainees, especially one with such poor aquatic skills. His cylinder reportedly contained approximately 2700 L of air initially and was empty when the victim was found. Given the maximum depth of 5 msw and a dive time of approximately 16 minutes, it is highly unlikely that he breathed all of this gas but rather that substantial air must have escaped from the equipment. Whether this was prior to or after the victim became unconscious is unknown. However, an anxious diver can consume air very quickly. He had not released his integrated weights.

Summary: Open water student; very poor water skills possibly incompatible with safe diving; incomplete water skills assessment; rough surface conditions; separated from group; found unconscious on seabed; BCD deflated and weights on; BLS unsuccessful; drowning.

CASE SC 04/09

This victim was a 36-year-old obese male who had suffered from an embolic stroke from an unidentified source 16 years earlier. He reported minimal residual problems but did suffer from migraines, sometimes with vomiting and visual field losses. He was assessed as 'fit to dive' by a doctor trained in diving medicine and was explained the risks of diving with his medical history. He agreed to accept the doctor's advice that he never dive deeper than 18 msw or make more than two dives in any day, that he always ascend slowly, and always make a safety stop.

He was undergoing open water diver training and on the day before the accident he completed two open water pier dives without incident. He completed another shallow, incident-free pier dive earlier on the day of the accident. Although he told his buddy that he was exhausted, sunburned and did not feel like diving, he persisted. The victim, his buddy, the instructor and some additional divers and divemasters undertook a boat dive at a popular dive site – an annulus of rocks in a current-prone area. The maximum depth in the area was approximately 11 msw. Surface conditions were described as choppy with visibility of 5 metres. The group entered the sheltered water inside the annulus and planned to swim around the rocks, initially swimming with the current. A bystander noticed that, on the surface prior to diving, the victim was breathing erratically and "*fiddling with his equipment*". The divers submerged and swam around the end of the rocks. The victim was grouped with his buddy and the instructor, as part of the larger group. The instructor was in front, followed by the buddy and then the victim. The buddy reported that the victim did not appear to be having any problems. However, when they again encountered the current, this time against them, the victim disappeared from view. His buddy quickly pointed this out to the instructor who then surfaced to locate the victim.

Observers on a nearby boat saw the victim surface rapidly. After a short time he waved to the people on the boat and called for help, complaining that he couldn't breathe and thought he was going to die. Staff on the boat acted quickly to remove him from the water, assisted by the instructor who had surfaced and swum over to assist the victim. The victim was floating on his back, apparently unconscious with his regulator out and water coming out from his mouth. On board, he was apnoeic and pulseless so the instructor began BLS. Water and regurgitated stomach contents made it difficult to attain a clear airway for ventilation and it was several minutes before it was possible to give proper ventilations. Once the boat arrived at the jetty, paramedics applied ALS but the victim failed to respond.

When tested, the victim's second stage regulators were noted to have a much lower breathing resistance than that specified by the manufacturer. This could lead to air surging from the demand valve if the user attempted to breathe deeply. The BCD inflation hose connection was faulty. However, there is no evidence that equipment issues contributed to this accident. The dive computer indicated that he had done a rapid ascent. There was still 110 bar of air remaining in the cylinder.

Autopsy: The heart weighed 440 g and the coronary arteries were widely patent. There was 10–15 ml of gas in the right ventricle when opened underwater, consistent with the diagnosis of PBT/CAGE. There was a patent foramen ovale with a small oval window 5 x 3 mm. Examination of the brain revealed gas bubbles in the circle of Willis, consistent with CAGE. The brain showed no macroscopic damage from the previous stroke. Cause of death: cerebral arterial gas embolism (CAGE).
(Height = 191 cm; Weight = 111 kg (clothed in diving suit); BMI = 30.4 $kg.m^{-2}$)

Comment: Although it is unknown whether or not this victim's previous stroke had impacted on this accident, given the autopsy findings, this seems unlikely. Although his buddy was aware that the victim was feeling unwell prior to the dive, it is unclear if the instructor was aware of this. Despite the prevailing currents at this dive site, it is one that was commonly used for training. It is likely that when the victim encountered difficulty swimming against the strong current, he panicked and ascended rapidly.

Summary: Open water student; previous cerebrovascular accident but assessed fit to dive by diving physician; strong current; separated from instructor and others; surfaced rapidly; unconscious shortly after surfacing; prompt BLS complicated by regurgitation; CAGE.

CASE SC 04/10

This reportedly apparently healthy 32-year-old male had learned to dive in tropical waters about 18 months earlier, the course consisting of four open water dives. He had not dived since. His buddies booked him on a boat dive in temperate southern waters with a dive charter operator. He hired a scuba cylinder, BCD and weight belt. He had planned to conduct a shallow shore dive earlier that day to re-orientate himself to diving and familiarise himself with the equipment but was too buoyant and aborted the dive. He returned to the dive operator's store and obtained extra weights and a different regulator. He now had 18 kg of weight, which included one 2 kg weight in each pocket of his BCD. He did not attempt the shore dive again.

The victim and his friends later joined other divers on the dive charter boat and were taken to a popular 'slack water' dive site. However, on arrival at the site, some witnesses asserted that the divers had to hurry into the water as the current had already begun to run. The site was an underwater hole, beginning at a depth of 12 msw and dropping to a maximum 34 msw. The victim, the last diver to enter the water, initially tried to jump in without his fins on, telling a crew member that he would put them on in the water. He was told to put his fins on in the boat, which he then did then entered the water over-weighted, with his mask on his forehead, his BCD inflator hose unattached and BCD deflated, and without his regulator in his mouth.

He submerged briefly, re-surfaced and struggled for a short time on the surface, apparently attempting to inflate his BCD, before sinking. His buddies (who had been waiting for him several metres down the shot-line) found him unconscious with his mask off on the sea bed at about 12 msw depth and brought him to the surface. His total time underwater was approximately five minutes. When he was brought aboard the dive boat there was froth coming from his mouth but there were some initial indications of breathing and pulse. However, these soon ceased and BLS was commenced, without a response. The rescuers had difficulty using unfamiliar oxygen equipment: a bag-valve-mask for which the rescuers were untrained.

Inspection of the equipment indicated that both first and second stage regulators were in need of servicing, the scuba feed was 'sticky' and that it would have likely been difficult for an inexperienced diver to attach the scuba feed hose to the buoyancy compensator. Despite this, the coroner concluded that "*the equipment was in reasonable condition and unlikely to have contributed to the death of an experienced diver*". The dive operator was subsequently prosecuted by the State Workcover Authority for breaches of the Workplace Health and Safety Regulations and was fined $200,000. The operator subsequently went into liquidation and the fine was not paid.

Autopsy: The autopsy was performed two days after death. The brain was mildly heavy, weighing 1670 g. There was a 10x10x7 mm oligodendroglioma in the right basal ganglia of the brain. The heart weighed 465 g which is normal for his weight. The left ventricle was 15 mm in thickness and there was a bicuspid aortic valve without significant aortic stenosis. The coronary arteries showed 60% stenosis of the LAD coronary artery. Gas was detected in the right but not the left ventricle. The pathologist concluded that the oligodendroglioma, the bicuspid aortic valve and the 60% coronary artery stenosis were probably incidental to the death. The cause of death was given as drowning.
(Height = 182 cm; Weight = 108 kg; BMI = 32.6 $kg.m^{-2}$)

Comment: The cause of death was likely to have been drowning due to equipment problems (i.e. mask and regulator not in place during entry, negative buoyancy (buoyancy compensator not connected and BCD uninflated)). The role of the other pathology in the death is unclear.

Many factors conspired to cause this rather predictable

accident. The diver was inexperienced, had not dived for an extended period, was diving in more difficult conditions than those under which he was trained and was reportedly rushing to get into the water. His buddies did not assist him with gearing up or check him prior to entry, instead waiting for him to meet them underwater. In addition, the divemaster, who was unaware of the victim's lack of diving experience, failed to properly check his equipment prior to his entry. This incident might not have occurred had his buddies or the divemaster taken the time to ensure his equipment was in place and functional prior to entry.

Summary: Inexperienced; rushing to get ready; poor communication by dive operator and poor supervision by divemaster; no buddy check prior to entry; entered with mask on forehead, regulator out of mouth, BCD deflated and hose unattached, and over-weighted; buddies waiting underwater; ventilations attempted using unfamiliar oxygen equipment; drowning.

Rebreather diving death

CASE RB 04/01

This 55-year-old male had begun diving seven years earlier. He had completed numerous diving specialty courses, including the use of a rebreather, and dived regularly and often, having logged over 250 dives in his first two years since certification and diving regularly since, often using his rebreather.

The victim and four others set out to dive on a wrecked barge about two kilometres offshore on a sandy bottom at about 50 msw. Conditions were said to be "ideal" – calm, little current, no surge and with around 15 metres visibility. Each diver had done his own breathing gas preparation, calculated his own dive profile and looked after his own gear, There was a mix of gear in use – some divers, including the victim, used rebreathers and others used twin-tank open-circuit scuba. As is fairly common practice in deep technical diving, the divers descended with no particular buddy system. The barge had a small cabin at both bow and stern, entry being through a hatch, which covered each opening and was significantly more restricted over the bow cabin. One of the last divers to see the victim alive was moving towards the bow of the vessel when he saw the victim backing into the tight bow cabin hatchway, feet first at a depth of 46 msw. Despite being a very tight fit, one that the other divers would not attempt, the victim managed to enter the cabin without having to remove any of his gear in the process. As there was no room for anyone else in the bow compartment this diver waved to the victim and swam off elsewhere.

This group's practice was that each diver would leave a marker (strobe light) at the bottom of the ascent line. As each diver left the bottom, he collected his marker and, on this day, the agreement was that the last diver would ensure the release of the anchor line. Concern was raised when, at least 10 to 15 minutes after all the other divers had surfaced, they realised that the victim had not released the anchor from the wreck. He should have surfaced or at least have been decompressing by this time. However, there was no sign of the victim on the surface, so one of the divers re-descended to the wreck and quickly found the victim. He was floating upside down (the air in his drysuit having gone to his feet), separated from and above his equipment, which was lying on the deck of the wreck. He was still attached to the gear by his dry-suit inflator hose, with no mouthpiece in his mouth. He was unconscious and apparently lifeless. Knowing that the victim had very likely been in the water for too long to survive and being aware that he did not have sufficient gas supply to recover the victim, this diver returned to surface. The boat skipper and another diver then descended to recover the body.

The victim had been diving with a rebreather. The diluent cylinder was found to be empty. It appeared that he had removed his gear to exit the wreck through the tight opening. Most of his diving weight was in the rebreather with very little on his belt. On releasing his gear, the buoyancy of his drysuit may have caused him to float above his gas supply and it is probable that he would not even have been able to reach the sling bottle used as back-up gas.

Later testing of the rebreather unit revealed that it operated appropriately according to the operating manual. One concern related to the type and status of the soda lime used in the rebreather. Evidence implied that this may have been of low quality or had perhaps been used already in an earlier dive. If so, then some degree of carbon dioxide intoxication was a possibility. It was officially concluded that efficacy of the equipment used was unlikely to have contributed to the fatality. The official conclusion about the tragic turn of events was that:
"*It was the aforementioned factors: poor decision by (the victim) to enter the hatch, the need to remove the rebreather prior to exiting the hatch, the fact that the deceased had embraced a lone diving policy, and the sudden and unrecoverable change in the deceased's buoyancy, that have combined to produce the ultimately fatal result*."

Autopsy: The autopsy was performed three days after death. The heart weighed 460 g and the coronary arteries showed 50% narrowing of the LAD coronary artery. There was mild myocardial perivascular fibrosis. Gas bubbles were detected in the vessels on the surface of the brain, the basilar artery and the pia mater, and within the heart ventricles. However, it could not be determined whether this was due to post-mortem off-gassing from bringing the body to the surface from depth, or decomposition from the three day post-mortem interval. The lungs weighed 1000 g and 800 g and there was frothy fluid in the upper airways. There was a 10 mm laceration on the posterior scalp. Toxicology was negative for alcohol and all drugs tested. Carboxyhaemoglobin level was 1%. The cause of death was given as drowning.
(Height = 186 cm; Weight = 85.5 kg; BMI = 24.7 $kg.m^{-2}$)

Comment: Removal of a CCR in order to attempt a difficult exit following penetration of a wreck is a very dangerous manoeuvre, leading in this case to death. The role of the 50% stenosis of the LAD is hard to evaluate but in a hypoxic situation could be the difference between survival or death. The small laceration on the scalp could have resulted from an impact during the attempted exit.

The diver who had seen the victim trying to squeeze through the hatch had signaled "you're mad" but the victim had just shrugged his shoulders and gone through. The witness did not think anyone wearing a rebreather would attempt this as it was too tight an opening. He considered the victim "*a bit of a loner*" who would "*go off by himself and attempt to negotiate tight places others would not attempt*" and said he had seen him on previous dives trying and failing to enter this cabin. The critical factor in this fatality appears to be the diver's personality, his desire to push his limits and break the safety rules. Removing his equipment while alone at depth in order to exit a narrow hatch was a predictably dangerous action in the absence of any buddy to assist him safely complete the manoeuvre.

Summary: Well-trained and experienced technical diver using a closed-circuit rebreather; diving separately in group on deep wreck; most weights worn on rebreather; removed rebreather to exit wreck; too buoyant without rebreather and lost and then floated above gas supply; drowning.

Surface-supply death

CASE SS 04/01

The victim was an apparently healthy 24-year-old male who was a 'backpacker' from overseas. He held an advanced diver certification and was reported to have made 70 dives, the deepest to 45 msw. He had answered an advertisement in the local paper to become an ocean harvester, collecting sea cucumbers or crayfish off the ocean floor. However, there is no evidence he had ever used surface supply (hookah) equipment, or performed drift diving to collect sea cucumbers, before the fatal dive.

On the day of the accident, there were four other similarly inexperienced divers on the boat who were to be introduced to the work. The five new employees were given an operations manual to read. They then signed an employee declaration stating they agreed to accept these standards. Their induction into the work involved a demonstration of the equipment, information on how to manage it, how to respond to loss of work-line, use of the bail-out bottle and decompression procedure. They did not use any of the equipment. However, a short demonstration dive was made by the nominated head diver.

That afternoon, after the introductory session, a working dive was conducted. The group consisted of one of the 'experienced' crew divers (who were not recorded as holding any occupational diving or harvesting qualifications) and two of the neophytes. It appears that the intention was harvesting rather than training or observation of their performance. Indeed, it is doubtful whether they would have been able to readily observe the actions of the two new employees because of positioning and other tasks involved. The weather was calm with a strong current running, visibility underwater a maximum of 15 metres and water temperature 29^{o}C.

The first of these dives passed without incident, with two of the new divers involved in its topside management. The victim participated in the second of these dives and the boat skipper was the experienced diver in the trio at depth. It was later reported that the victim looked a bit nervous and vague as he prepared for the dive and had required assistance to correctly don and position his equipment. He chose not to wear a wetsuit, only a tee-shirt and shorts (although this was in breach of the employer's policy), reducing his weights accordingly. He required help to clip his hose to his weightbelt, a difficult task wearing gloves.

The second dive was planned for 25 minutes' bottom time and a maximum depth of 35 msw. Nitrogen narcosis problems were expected to be mild. One of the new divers, acting as the on-deck tender, later reported that the victim had commenced his dive by swimming through the hoses of the diver next to him, contrary to their instructions, and causing the hoses to become entangled. He stated that he did not think this would have caused a problem and did nothing about it. This on-deck tender had only been trained that day. Two of the divers surfaced at the planned dive time, after a decompression stop. One of them brought up the victim's air hose and regulator and only then was it realised a diver was missing. The hope was that he had ascended using his pony bottle but a surface search was unsuccessful. The catch bags were raised and the victim's bag was found to also contain his neck bag (a small catch bag carried by the diver), indicating that he had at some stage swum back to reach it.

During the dive, none of the others divers or tenders had seen him. When the diving equipment and lines were retrieved, it was noted that the victim's line and air hose appeared to be in a knot and when his regulator was examined, the mouthpiece was missing. It is usual for it to be held in place by a plastic cable or a metal clamp and one witness stated there was a plastic tie around it before the dive commenced. A later check of the rest of the equipment revealed two without the essential cable ties, and on some others the cable ties were too loose to ensure retention. It was noted that there was no evidence of an attempt to use the bail-out bottle.

A formal search of the dive area the next day found the body on the sea bed. All of the victim's equipment was in position except for his mask. The victim's bail-out bottle had not been turned on and its regulator was still stowed in position. Massive tissue damage of his upper chest and face was present, which was later attributed to post-mortem shark action.

Autopsy: The autopsy was performed 5 days after death. The pathologist noted there was evidence of post-mortem changes and damage from both shark and sea lice. There was no evidence of physical injury or health factors as the cause of death. The heart weighed 275 g and the coronary arteries showed only a focal 30% narrowing in the LAD coronary artery branch. The lungs weighed 310 g and 264 g and showed decompositional changes. The cause of death was stated as drowning.
(Height = 183 cm; Weight = 86 kg; BMI = 25.7 $kg.m^{-2}$)

Drift diving procedure

The drift diving procedure was for the boat to maintain a slow (1 knot) forward speed using a drogue to maintain steerage as it towed from two to four divers. There was a boom extending from each side of the boat, each one held the working lines, air lines and oxygen (for use at the decompression stop), all of which were controlled from the vessel. Each working line, two from each boom, consisted of a down-line weighted by chains which were kept just above the sea bed. A large catch bag was attached to this and a 50-metre line trailed back above the sea bed from it. Each diver worked his own line, pulling himself along the line or swimming back to the bag as he caught his quarry. Each of the air-lines had a Tema brand end connection. A non-locking karabiner was whipped to the hose at the diver's end. Separate hoses were used for the oxygen delivery system. Two divers shared a single delivery hose.

Each diver's weight belt had a stainless steel 'D' ring to serve as the attachment point for the air hose karabiner. His regulator then connected to the quick-connect fitting of the hose and a bail-out or pony bottle was worn in a backpack. To use this, the diver had to reach back with his left hand to turn the cylinder on, and, with his right hand behind his back, pull the regulator free from its restraining cable ties. As the cylinder was worn inverted, it effectively required a reversal of the usual rotation direction needed to open the valve. This procedure requires practice. It was possible for the karabiner to be accidentally released if the lines or hoses were twisted over the karabiner gate. Also, the weight belt could not be easily released independently of the air hose, which would create a problem if the diver needed to ditch the weight belt quickly and ascend using his usual air supply from the hose. As there were several 'D' rings on the harness which held the bail-out bottle, a safer attachment area was available but not used. All of the divers wore half-face masks but none had the safety factor of a head strap to retain the mouthpiece if it became displaced.

Comment: It is especially difficult to diagnose drowning in the presence of decomposition as the typical lung changes are lost, but the most likely cause of death was drowning following loss of the diving regulator due to an inadequate harness system while surface-supply diving.

This fatality was investigated by a local Workplace, Health and Safety Inspector and the report listed numerous serious breaches of the regulations governing diver safety. The victim was untrained in the use of surface-supply diving equipment. He had never practised the use of a bail-out bottle air supply or of the oxygen decompression procedure. He was wearing a half-face mask without strap to retain it should he lose consciousness. He had his line and air hose attached to his weight belt rather than to a backpack holding his bail-out bottle. There was no communication with the surface or a stand-by diver at the surface. The regulator mouthpiece was not securely attached. He was not wearing a wetsuit or other protection, putting him at risk of avoidable injury. The karabiner was non-locking and could be easily detached. The anxiety of this first dive, and the probable presence of some nitrogen narcosis, would further reduce any safety margin. Following the investigation, the company was prosecuted and despite imperfect legislation at the time, was fined AUD$6,000. The skipper, who was part owner and supervising diver on the day, was fined AUD$10,000. This was the third occasion this company had been prosecuted.

Summary: Experienced recreational diver; no known health problems; using hookah for first time and inadequately trained in its use; first dive as commercial sea harvester; inadequate supervision; air hose entangled and regulator mouthpiece likely to have been loose and become detached; mask may also have become detached; out of sight of other divers; nitrogen narcosis possible factor; body found following day; drowning.

CASE PRE-SC 04/01

This victim was a 65-year-old male who was an experienced and active diver over many decades. He and two friends were in a small, inflatable boat and heading out to go diving at one of their regular dive sites, leaving the shore late in the morning. After about 20 minutes, the victim fell forwards in the boat and was found to be unconscious and apnoeic. The friends headed back to shore, which took twenty minutes, attempting BLS en route. On reaching shore, BLS was continued on the beach, with supplemental oxygen, by various bystanders including some doctors and nurses. Paramedics arrived after approximately 30 minutes but the victim failed to respond to ALS.

Autopsy: The autopsy showed severe ischaemic heart disease. The heart weighed 470 g. There was severe focal calcific atherosclerosis with stenoses of the left main LAD, left circumflex and right coronary arteries. In addition there was a thrombus in the right coronary artery. Histology showed a healed sub-endocardial infarct and contraction band necrosis but no neutrophil infiltrate. Cause of death was given as ischaemic heart disease.

Comment: It was unknown whether or not the victim had recently seen a doctor or was on any medications. However,

his buddy stated that the victim had been complaining of constant "indigestion" and that, lately, he had seemed lethargic. This death could very likely have occurred at any time. Although this incident did not occur during a dive, and is therefore not strictly classified as a diving death, it is included here to highlight how an existing medical condition can be implicated in a diving accident. Had this person become unconscious in the water a short time later, it would have been classified as a diving death, and, unless an appropriate autopsy was conducted, which is unlikely in many parts of the world, the cause of death may well have been attributed to drowning.

Summary: Experienced diver; pre-existing ischaemic heart disease; collapsed prior to dive; unstable plaque in right coronary artery.

Discussion

BREATH-HOLD DIVERS AND SNORKEL USERS

In previous Project Stickybeak reports , there were several deaths which were most likely attributable to apnoeic hypoxia.[4–10] Despite this phenomenon being well described and discussed both within and outside of the freediving community many young breath-hold divers still seem to fail to realize the dangers of pre-dive hyperventilation and pushing their apnoeic times to the limits. That this problem is also relatively common amongst the 'elite' breath-hold divers who are often highly educated on these matters is probably an indication that education alone will not see this problem disappear. Equally, as will be discussed later with regards to one of the technical diving deaths, experience may well work against these individuals as, the more often they "get away with it" the more likely they are to push the limits further. Blackout with little or no warning can occur before, during or soon after ascent. Unless a rescuer is immediately at hand, drowning will be the most likely result. Even the relative safety of a swimming pool can prove dangerous if there is no supervision, as was the case with BH 04/03.

CARDIAC-RELATED DEATHS

Cardiac-related issues appear to have been instrumental in the deaths of five snorkel divers (56%) and four of the compressed gas divers (31%) in this series. Of these nine divers, only four were known to have been undergoing treatment for cardiovascular conditions (BH 04/05, BH 04/06, BH 04/08 and SC 04/07). The victim in Pre-SC 04/01 appears likely to have been suffering cardiac symptoms over recent times but there is no evidence that he had visited a doctor for this. BH04/08 represents another case where an individual has significant medical conditions but would appear to be able to conduct normal activities of daily life, only to die with the relatively minor challenge of snorkelling in tropical waters, whilst, in BH04/06, the severity of the atheromatous lesions apparent on autopsy would generally be considered to be non-critical clinically.

This phenomenon of almost silent cardiac death without what would usually be considered clinically significant coronary lesions in divers and snorkellers would appear to be a recurring theme in diving fatalities. Dysrhythmias, sudden death and pulmonary oedema are becoming increasingly recognized in the setting of immersion.[11–13] As with many unobserved diving-related deaths, the exact agonal sequence of events in many cases will never be known with certainty and we can but speculate on the exact cause of death.

Given the high incidence of cardiac-related diving fatalities in 'older' snorkellers and divers, it seems reasonable to suggest that, over the age of about 45 years, they should be strongly encouraged to have their cardiovascular health periodically assessed by a doctor, preferably one who is well aware of the cardiovascular stressors associated with diving and snorkelling. However, even a full cardiac evaluation may not reveal the presence of a risk that should have precluded these in-water activities.

REFRESHER DIVES / SUPERVISION OF DIVERS

Diving accidents in divers who have just returned to diving are not uncommon. Any diver who has not dived for an extended period needs to have the opportunity to re-orientate to diving by undertaking an appropriate refresher dive(s) under favourable circumstances. This is especially important for an inexperienced diver, divers in whom dive fitness is a potential issue, and/or for one who is planning to dive in more demanding conditions than previously experienced.

Although the victim in SC 04/10 had conducted a brief, unsupervised 'orientation' dive prior to the fatal event, without suitable supervision and education from a qualified person, this was of little value as the problems that it highlighted were not adequately addressed. When required to enter the water quickly for the subsequent dive, he was totally unprepared. The events during the subsequent dive raise the difficult issue of duty of care of the dive operator and divemaster in the setting of an ostensibly qualified diver. There is an ongoing debate about the relative responsibilities of qualified divers and the dive professionals with whom they dive. Some argue that a qualified diver must take full responsibility for themselves and accept any and all risks associated with their diving activities. Others, including most of these authors, believe that those who take others diving, whether within a commercial setting or otherwise, owe a duty of care to the divers, and that the level of this duty is inversely proportional to the experience of the diver.

Had the divemaster been aware of this victim's inexperience, he may well have more carefully observed him and, hopefully, would have ensured that he had his mask on, regulator in his mouth (air on) and that his BCD was functional and inflated prior to entry. However, one would have thought that the victim's lack of experience was evident by his behaviour, and it is rather alarming that the divemaster or skipper did not prevent him from entering the water with

his gear as it was. Had this been done, this accident may well have been prevented. Equally, one may question how a diver of this experience was allowed on the boat in the first place without the operator conducting a 'check out' dive under suitable supervision.

A divemaster, by acting as the 'gate-keeper' prior to entry, has a good opportunity to prevent some avoidable mishaps. The divemaster in this case was not made aware of the victim's lack of experience as this information had not been relayed from the dive shop staff to the boat staff, in breach of the dive operator's own written procedures. This failure to follow appropriate procedures led to the prosecution of the dive operator by the local workplace authority. The successful prosecution led to an audit of all local recreational dive operations by the workplace authority. Operators were required to produce evidence of having appropriate procedures in place, regular documentation of the checks included within these procedures and safe, regularly serviced equipment, along with a variety of other requirements.

Inadequate supervision also appears to have been a factor in SC 04/06. This situation can often arise with a so-called 'bare-boat charter' where a boat and non-divemaster skipper are chartered by a dive group and no-one in particular is appointed to oversee the divers. As a result, an inexperienced diver can miss out on required supervision.

An instructor must be constantly vigilant and maintain close contact with his or her students at all times. This can sometimes be difficult to achieve, especially in poor conditions and / or with many students. It was unfortunate that the instructor in SC 04/08 initially failed to realise that the student was missing from the group until it was too late. Extra certified divers with a student group should be clearly identifiable and well-briefed on appropriate separation from the students in order to avoid a mix-up, as occurred here. The victim in SC 04/02, who was undertaking a resort dive, was also separated from his instructor at what appears to have been the considered decision of the instructor. This turned out to be a poor decision, although the victim may well have died despite the immediate presence of the instructor.

POOR AQUATIC SKILLS

Diving is an aquatic sport, and a minimal swimming capability would appear to be fundamental. There is no logic to having a swimming test then allowing a student who fails this test to proceed to open-water dive training. SC 04/08 is a tragic example of just such a student diver who was unprepared for diving in the circumstances into which he was taken. He was described as a "non-swimmer" and had failed to complete the required basic aquatic skills tests. He should not have been taken on this dive, especially into conditions that were described by several other instructors as relatively rough and inappropriate for open water students.

LACK OF APPROPRIATE TRAINING

Dive fatality reports not infrequently include cases of divers who were untrained, or inadequately trained for the diving activities undertaken. The victim in SC 04/03 was uncertified and inexperienced. Learning from a friend who is not a trained instructor is inadequate as there is a lack of the usual 'checks and balances' required when being trained and certified by a licensed instructor. The employer of the victim in HH 04/01 obviously failed to provide adequate training and supervision and these actions no doubt contributed greatly to the victim's demise.

BUDDY SYSTEM IN TECHICAL DIVING

Technical diving is increasing in popularity. Technical divers are taught to be self-sufficient, a laudable attribute; however, divers who dive alone or without a reasonable buddy system continue to be well-represented in diving death statistics.[14] Overconfidence and a history of 'having got away with it' often encourages such individuals to push their limits a little further each time until a situation becomes unrecoverable. The 'same ocean' buddy system where divers know who is about but do not specifically stay close to one another is common practice amongst technical divers. As well demonstrated here, unless there is a proper close buddy system, there is in reality no buddy system at all.

The victim in RB 04/01 was well known for penetrating tight spaces. As an experienced diver he should have been aware of the buoyancy issues surrounding taking off his gear at depth, His decision to use the small gas supply in his CCR rather than that in his 'bail-out' cylinder is also an interesting point. In the post-event analysis of this diver's equipment there was some suggestion that the CO_2 canister may have been near exhaustion. Discussion of this finding with the dive operator revealed that the victim was due to leave on holiday after this dive and was unlikely to have had a freshly charged CO_2 scrubber. Whether this was an influencing factor in his decision to remove his equipment to extricate himself rather than wait for assistance must remain a matter of speculation. Even highly competent, self-sufficient technical divers should be aware that not all situations are self-recoverable. The authors would suggest that even for this group, buddy diving makes for a more enjoyable and safer experience.

CARRYING OF BAIT BAG OR TETHERING FISH TO BODY

It was reported that the victim in BH 04/07 was wearing a bait pouch. The practice of carrying bait bags and/or tethering fish near to the body was relatively commonplace many years ago. However, having captive marine life in one's possession underwater does appear to increase the likelihood of shark attack, and, when this became better

known, its popularity waned.[15] It is a practice that should continue to be discouraged.

FAMILIARITY WITH OXYGEN / RESUSCITATION EQUIPMENT

It is not sufficient to have fulfilled the criteria of having emergency equipment available if there is no one who is trained or available to use it. This was vividly demonstrated in the case of SC 04/10. The victim was reported to be initially breathing when brought aboard the boat and given that he was relatively young, apparently healthy and had only been submerged for several minutes there may have been a brief window of opportunity where a successful resuscitation was possible. Unfortunately, the staff who were present did not appear to have been sufficiently familiar with the operation of the resuscitation equipment available, nor was the diving instructor who came aboard from another dive boat to perform the resuscitative efforts. The unit available was a bag-valve-mask device with a mask of a type that is difficult to obtain a seal with during positive pressure ventilation in inexperienced hands. In addition, the rescuer was also unable to use this type of mask for mouth-to-mask ventilation when he tried to revert to this.

Failure to achieve an adequate mask seal and perform effective ventilations is common with bag-valve-masks devices when used by infrequent operators, and especially when used by a single operator.[16–18] Studies suggest that it is more effective to provide oxygen-supplemented rescue breathing using a resuscitation mask with oxygen inlet.[16,19,20] It is important that oxygen equipment is chosen carefully so that it is not only effective, but is relatively simple to operate by those who are likely to use it. Dive leaders should be appropriately and thoroughly trained and well-practised in the equipment they are likely to be required to use in an emergency. Rescuers should also be prepared to quickly abandon equipment if they are having trouble using it and to revert to basic rescue breathing while equipment issues are resolved by others, if possible.

POST-MORTEM FINDINGS OF PULMONARY BAROTRAUMA / CEREBRAL ARTERIAL GAS EMBOLISM

There were four deaths in the scuba divers attributed to PBT/CAGE making it the single most common cause of death apart from drowning. It is difficult to distinguish the cause of gas found at autopsy between CAGE, post-mortem off-gassing, decomposition and resuscitation. The reviewing pathologist is increasingly restricting this diagnosis of PBT/CAGE to cases where there is a witnessed history of rapid ascent to the surface followed by loss of consciousness. In the absence of this history, especially where there is a delay in imaging or autopsy, these cases should probably be classified as possible or probable PBT/CAGE. The CT scan needs to be done within the first eight hours post mortem to be of value.[21]

PROBLEMS WITH DIAGNOSING DROWNING AT POST MORTEM

The contribution of drowning to the death of people with schaemic heart disease can be difficult to assess, in part due to the non-specific nature of the pathology of drowning. For this reason, it is important to include such information as the macroscopic appearance of the lungs, the weight of the lungs and the presence or absence of pulmonary oedema in the upper airways.

ROOT CAUSE ANALYSIS

A summary of the root cause analysis is shown in Table 3.

Snorkel and breath-hold divers

Unsurprisingly, exertion was suspected to be the major 'trigger' in all five of the cardiac-related snorkelling fatalities. Other potential triggers to a cardiac event might include a tight wetsuit and possibly aspiration of water through the snorkel. The disabling injury was thought to be the same as the cause of death in all but BH 04/05 where it is believed the victim may have become unconscious as a result of a cardiac event and subsequently drowned.

Compressed gas divers

Again, exertion appeared to be a key trigger in the cardiac-related incidents. Loss of air supply and negative buoyancy were major triggers in the drownings. In the incidents involving diving using compressed gas, it is believed that the disabling injury was the ultimate cause of death in all cases reviewed. The main disabling injury and cause of death was drowning (five of 12 cases), followed jointly by CAGE (four cases) and cardiac-related deaths (three cases).

Conclusions

- There were 22 reported diving-related fatalities during 2004, which include nine deaths while snorkelling and/or breath-hold diving, 10 while scuba diving, one shortly prior to scuba diving, one while using a closed-circuit rebreather and one while using surface-supply breathing apparatus.
- Causal factors associated with these deaths include apnoeic hypoxic blackout from extended breath-hold diving; cardiac disease, whether diagnosed or not; lack of training; inexperience or lack of recent diving experience; poor supervision and poor aquatic skills.
- The main disabling injury with snorkellers was a cardiac incident (five of nine cases). With scuba divers, the main disabling injuries were CAGE and asphyxia (each with four of 12 cases) and cardiac incidents (three cases).
- Factors that may reduce mortality in the future include improved medical screening of older divers; cessation of the practice of hyperventilation prior to breath-hold diving; closer supervision of inexperienced divers,

Case	Trigger	Disabling agent	Disabling injury	Cause of death
BH				
04/01	Extended breath-hold	Sudden loss of consciousness	Asphyxia	Drowning
04/02	Extended breath-hold	Sudden loss of consciousness	Asphyxia	?Drowning (body not recovered)
04/03	Extended breath-hold	Sudden loss of consciousness	Asphyxia	Drowning
04/04	Exertion	Cardiovascular disease (coronary atherosclerosis)	Cardiac incident (probable cardiac arrhythmia due to myocardial ischaemia)	Cardiac-related (ischaemic heart disease)
04/05	Exertion	Cardiovascular disease (coronary atherosclerosis; left ventricular hypertrophy)	Cardiac incident (?cardiac arrhythmia)	Drowning
04/06	?Exertion; ?water inhalation via snorkel	Cardiovascular disease (coronary atherosclerosis)	Cardiac incident (probable arrhythmia due to myocardial ischaemia)	Cardiac-related (ischaemic heart disease)
04/07	Bait on belt; dying fish	Shark attack	Trauma (transection of left femoral artery)	Trauma (shark bite of left thigh)
04/08	Exertion; ?tight suit; ?anxiety	Cardiovascular disease (coronary atherosclerosis; left ventricular hypertrophy)	Cardiac incident (ischaemic heart disease; left ventricular hypertrophy)	Cardiac-related
04/09	Exertion in current	Cardiovascular disease (coronary atherosclerosis)	Cardiac incident (probable arrhythmia due to myocardial ischaemia)	Cardiac-related (ischaemic heart disease)
SC				
04/01	Trauma (hand/arm injury)	Rapid ascent	CAGE	CAGE
04/02	Exertion; stress	Cardiovascular disease (coronary atherosclerosis)	Cardiac incident (probable arrhythmia due to myocardial ischaemia)	Cardiac-related (ischaemic heart disease)
04/03	Insufficient gas	Probable rapid ascent	CAGE	CAGE
04/04	Exertion; tight semi-dry suit	Other medical condition (HLA B27 spondyloarthritis; ?hypercoagulable state)	?Cardiac incident (?cardiac arrhythmia)	?Cardiac-related (?cardiac arrhythmia)
04/05	?Anxiety (feeling unwell; faulty contents gauge)	Rapid ascent	CAGE	CAGE
04/06	Out of air; negative buoyancy	Loss of air supply	Asphyxia	Drowning
04/07	Exertion from long surface swim	Cardiovascular disease (coronary atherosclerosis)	Cardiac incident (probable cardiac arrhythmia due to myocardial ischaemia)	Cardiac-related (ischaemic heart disease)
04/08	Unknown (?loss of air supply; ?lack of buoyancy)	Loss of air supply	Asphyxia	Drowning
04/09	Panic (feeling unwell; current; separation)	Rapid ascent	CAGE	CAGE
04/10	Buoyancy problem (negatively buoyant); disabled BCD; regulator out	Loss of air supply	Asphyxia	Drowning
RB				
04/01	Separation from gas supply	Loss of air supply	Asphyxia	Drowning
SS				
04/01	Separation from gas supply	Loss of air supply	Asphyxia	Drowning

Table 3. (opposite page)
Root cause analysis for 21 diving fatalities in Australian waters in 2004; BH – breath-hold diver; SC – open-circuit scuba diver; RB – rebreather diver; SS – surface-supplied diver

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out-of-practice divers or divers who are inexperienced in the particular environment; better screening by dive operators and better communication within dive operations and between buddies.

Conflict of interest

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

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REFERENCES

1 Denoble PJ, Caruso JL, de L Dear G, Vann RD. Common causes of open-circuit recreational diving fatalities. *Undersea Hyperb Med* 2008;35(6):393-406.
2 Information paper "*Cause of death certification*" Australia. Cat No. 1205.0.55.001. Canberra: Australian Bureau of Statistics; 2004.
3 Siscovick DS, Weiss NS, Fletcher RH, Lasky T. The incident of primary cardiac arrest during vigorous exercise. *N Engl J Med*. 1984;311:874-7.
4 Walker D. *Report on Australian diving deaths 1972-1993*. Melbourne: Divers Alert Network Asia-Pacific; 1998.
5 Walker D. *Report on Australian diving deaths 1994-1998*. Melbourne: Divers Alert Network Asia-Pacific; 2002.
6 Walker D. Provisional report on diving-related fatalities in Australian waters 1999. *SPUMS Journal.* 2005;35(4):183-94.
7 Walker D. Provisional report on diving-related fatalities in Australian waters 2000. *Diving and Hyperbaric Medicine*. 2006;36(1):62-71.
8 Walker D. Provisional report on diving-related fatalities in Australian waters 2001. *Diving and Hyperbaric Medicine*. 2006;36(3):122-38.
9 Walker D. Provisional report on diving-related fatalities in Australian waters 2002. *Diving and Hyperbaric Medicine*. 2008;38(1):8-28.
10 Walker D, Lippmann J. Provisional report on diving-related fatalities in Australian waters 2003. *Diving and Hyperbaric Medicine.* 2009;39(1):4-19.
11 Cochard G, Arvieux J, Lacour JM, Madouas G, Mongredien H, Arvieux CC. Pulmonary edema in scuba divers: recurrence and fatal outcome. *Undersea Hyperb Med*. 2005;32(1):39-44.
12 Slade JB Jr, Hattori T, Ray CS, Bove AA, Cianci P. Pulmonary edema associated with scuba diving: case reports and review. *Chest*. 2001;120(5):1686-94.
13 Choi G, Kopplin LJ, Tester DJ, Will ML, Haglund CM, Ackerman MJ. Spectrum and frequency of cardiac channel defects in swimming-triggered arrhythmia syndromes. *Circulation*. 2004;110(15):2119-24.
14 Pollock NW, Vann RD, Denoble PJ, Freiberger JJ, Dovenbarger JA, Nord DA, et al. *Annual Diving Report*. Durham, NC: Divers Alert Network; 2007.
15 http://www.sharkresearchcommittee.com/statistics.htm
16 Elling R, Politis J. An evaluation of emergency medical technicians' ability to use manual ventilation devices. *Ann Emerg Med*. 1983;12:765-8.
17 Lawrence PJ, Sivaneswaran N. Ventilation during cardiopulmonary resuscitation: which method? *Med J Aust*. 1985;143:443-6.
18 Harrison GA. *A manual of skills for the use of devices for oxygen administration and/or ventilation of the lungs in emergencies*. Melbourne: Australian Resuscitation Council; 1996.
19 Stahl JM, Cutfield GR, Harrison GA. Alveolar oxygenation and mouth-to-mask ventilation: effects of oxygen insufflations. *Anaesth Intensive Care*. 1992;20(2):177-86.
20 Palmisano JM, Moler FW, Galura C, Gordon M, Custer JR. Influence of tidal volume, respiratory rate, and supplemental oxygen flow on delivered oxygen fraction using a mouth to mask ventilation device. *J Emerg Med*. 1993;11:685-89.
21 Fact File – Autopsy and the investigation of scuba diving deaths. Surry Hills: The Royal College of Pathologists of Australasia; 2008.

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