

## ORIGINAL PAPERS

### PROVISIONAL REPORT ON AUSTRALIAN DIVING-RELATED DEATHS IN 1988

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#### Summary

There were nine diving-related fatalities identified in this year, two being breathhold divers, four using scuba, and three with hookah air supply. In each tragedy there may be found some factor or factors which adversely influenced the course taken by events. One breathhold diver demonstrated the need for exhaling during ascent after taking a breath of air from a friend who was using scuba. The other died while spearfishing, the result of a post-hyperventilation blackout. The scuba divers died from a diverse series of causes, one being medical in nature, another an illustration of the danger of believing one is really an advanced diver after 9 dives, whatever a certificate may state. There is an important lesson to be found from examination of the three hookah diving fatalities, that many commercial diving operations continue to be performed in a "she'll do" manner not conducive to safety.

#### Case Notes

##### Case BH 88/1

The victim was an experienced spearfisherman who was on holiday with some friends. On this day he was with two others, one remaining in the boat while he and the third man spearfished. They remained initially within 9 m of each other so as to act as buddies but later became separated after the buddy noticed the current had moved them to an area where the water was deeper, which the victim liked but the buddy disliked. The buddy returned to shallower waters, expecting that his friend would join him but failed to check he had done so. It was 20 minutes before he realised he had not seen his friend for some time and approached the boat to find that the man left there was now similarly worried, till then having assumed the divers had been together. The body was located next day lying on the sea bed, weight belt on and a fired speargun nearby. This is a scenario typical of a post-hyperventilation blackout in a diver intent on hunting a fish. The only unusual fact was that in this incident the fish appears to have escaped the hunter's spear just before the latter lost consciousness. There was no medical reason for him to lose consciousness other than hypoxia.

EXPERIENCED SPEARFISHERMAN. SEPARATION. FOUND WITH WEIGHT BELT ON. HAD FIRED SPEARGUN. POST-HYPERVENTILATION BLACKOUT TYPE FATALITY.

##### Case BH 88/2

Of this trio of divers two were intending to breathhold spearfish while the other was to scuba dive. On their way to the dive they visited a dive shop and while the scuba diver was hiring scuba gear the victim bought an additional two weights. The victim was keen to try using scuba and it was agreed that he would dive down and join the scuba diver when the latter reached 4-5 m depth. There they were to share the use of the regulator. This they managed to perform successfully, and indeed ascended together buddy breathing to the surface. The victim was enthusiastic with this experience and asked to be allowed to dive using the equipment. This was denied but after they had lunched he was allowed to repeat the morning's dive-down-and-share adventure, the other friend declining an offer to try the same experience. The scuba diver advised the victim of the need to breath out when ascending before the morning dive and the successful dive must have confirmed in his mind a belief that there was no danger in this sharing.

The victim had carried a camera for the morning dive and had taken a photo of his scuba buddy before they ascended. On the afternoon dive he brought his speargun. They came together as arranged at 4.5 m depth but after five exchanges the victim saw a fish a little below them and dived after it. As he began making his ascent the buddy tried to indicate to him the need to exhale, but it is unknown whether he saw or understood these signals. The buddy thought he could see his friend reach the surface but could not see clearly because of his ascending bubbles and the somewhat poor visibility. He therefore assumed the victim was spearfishing when he was unable to see him after he surfaced.

Nobody saw the victim reach the surface, though there is no proof that he failed to reach it. The first awareness of anything untoward was when two divers returning to shore happened to look down and saw the victim lying on the sea bed, his weight belt on. It was back to front so the quick release was out of his reach, although it is not known whether it had slipped round or he had chosen to wear it thus. The body floated up after the weights were dropped. The autopsy confirmed the diagnosis of air embolism which clinical grounds suggest. Surgical emphysema was found both in the neck and mediastinum and air was noted in the aortic arch. Despite this clear evidence of pulmonary barotrauma with probable cerebral arterial gas embolism, the Coroner decided that the cause of death was "anoxia when he accidentally drowned".

BREATHHOLD DIVER SHARED SCUBA BUDDY'S REGULATOR. UNTRAINED IN USE OF SCUBA. SPEARFISHING. SOLO ASCENT. WEIGHT BELT ON. PULMONARY BAROTRAUMA. AIR EMBOLISM.

**AUTOPSY EVIDENCE OF SURGICAL EMPHYSEMA IN NECK AND MEDIASTINUM PLUS AIR IN AORTA IGNORED IN CORONIAL VERDICT.**

**CASE SC 88/1**

This case illustrates the danger which can result if a diver on completion of a course of instruction fails to realise that without the maturing effect of experience he is a novice and likely to find it difficult to translate the information recently acquired into appropriate responses to new situations. The victim and his buddy had recently completed, one after another, a basic scuba course and then an Advanced Diver course. Indeed it was probably the first unsupervised dive this victim had made and his buddy was possibly making his second such dive. But they could show the documentation (card) to confirm their being Advanced Divers, which was associated with conversation seemingly confirming their being also experienced. Unfortunately nobody thought to check this.

The two men were visiting another State and obtained an introduction to a diver there. When they hired equipment their certification was checked at the dive shop but there was no check of their experience, in particular whether they had made any dives to significant depths. Had the dive shop been running the dive it would have been routine to ask such questions but in this case, as a private person had hired the boat and boatman, there was no such questioning, though an additional hire charge was considered to be appropriate for the boat.

There were six divers in all, the others being locals and experienced divers. The two visitors were paired together for the dive, their talk of wreck diving leading the others to believe they were experienced. The wreck was broken into pieces and lying on the sea bed at 43 metres depth. Although visibility was called good the victim and his buddy were unable to find the anchor when they became low on air and decided to ascend. So they had to start an open water ascent. As was apparently their practice during the courses they had taken, the buddy came up a little ahead of the victim at this time but he was aware of the ascending bubbles which were evidence to him that the latter was close. When the buddy reached about half way to the surface he realised that he was very nearly out of air so inflated his vest and started finning to assist his ascent rate. He was in some distress when he surfaced so was very quickly got aboard the dive boat, placed in the head low position, and given oxygen. The victim failed to surface, which indicated to the others that he had died. When another boat responded to their calls for assistance the boatman and a diver from this boat dived using equipment from the second boat as the dive boat's only extra tank had been hung on the anchor line and used by the divers for their decompression stop. They soon located the victim lying on the sea bed, all equipment in place, buoyancy vest part inflated. There was no further inflation on pressing

the vest inflation button but on ditching the weight belt the body became buoyant. They allowed it to ascend while they made a precautionary decompression stop.

Autopsy confirmed that death resulted from drowning, but the presence of bubbles in the tissues led the pathologist to diagnose early decomposition changes which appears to indicate that his understanding of diving medicine was limited. The tank was shown to contain a little air but the pressure was inadequate for inflating the buoyancy vest at this depth and probably had seemed to the victim to be an out of air situation. It was shown on test of the vest in a chamber at this depth that it inflated slowly and quietly even when connected to a full tank so a wearer would not gain any rapid effective buoyancy and would readily believe there had been an inflation failure. It is reasonable to suppose that a very inexperienced diver, alone, low on air, unable inflate his vest and excessively weighted (he probably carried 15.5 kg (34 lbs), affected to some degree by nitrogen narcosis and cold, might panic, forget to drop his weight belt and perhaps hold his breath as he tried to swim up. Unconsciousness from anoxia due to exertion using his available oxygen, or from cerebral arterial gas embolism (CAGE) would cause the regulator fall from his mouth. Drowning would be very likely to occur.

JUST TRAINED "ADVANCED DIVER". FIRST UNSUPERVISED DIVE. BUDDY SAME STATUS. DEEP DIVE. CERTIFICATION CHECKED BUT NOT EXPERIENCE. UNABLE LOCATE ANCHOR LINE. LOW AIR SO OPEN SEA ASCENT. SEPARATION AT START OF ASCENT. BUDDY WAS NEAR. DEVELOPED NO-AIR STATUS WHEN HE INFLATED BUOYANCY VEST AND MADE FINNING EMERGENCY ASCENT. QUICK SURFACE RESPONSE TO MISSED DECOMPRESSION. VICTIM HAD PART INFLATED VEST. NO/LOW AIR STATUS. EXCESS WEIGHTS. FAILED TO DROP WEIGHT BELT. INFLATION OF VEST VERY SLOW AND QUIET AT DEPTH. NITROGEN NARCOSIS. GROSS INEXPERIENCE. PROBABLY PANIC. ANOXIA DUE TO EXERTION OF FINNING ASCENT POSSIBLY LED TO UNCONSCIOUSNESS AND DEATH. CAGE ALSO POSSIBLE.

**Case SC 88/2**

The dive shop on this resort island ran Resort Courses for visitors and organised boat dives for these new divers and those who wished to snorkel or were certificated scuba divers. This day the dive location was a bay on a nearby island. The instructor, on the boat to take the "resort diver" group, checked that all those wishing to scuba dive had been trained. They chose to dive as one group of five but shortly after descending the victim was seen to leave the group and ascend. The group leader followed him and saw him reach the boat, then he descended again and rejoined the three others and they made their planned dive. The victim, an underwater photographer carrying a camera, was an experi-

## PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training/Experience		Dive Group	Dive Purpose	Water Depth m	Incident Depth m	Weight Belt		Contents Gauge
		Victim	Buddy					On	lbs	
BH1	25	Trained Not stated Experienced	Trained Not stated Experienced	Separation Buddy	Spearfishing	18	Not stated	On	Not stated	Not applicable
BH2	16	Trained Not Stated Some experience	Trained Some experience	Separation Buddy	Recreation	6	4.5	On	Not stated	Not applicable
SC1	43	Trained 9 dives	Trained 9 dives	Separation Buddy	Recreation	43	24	On	34	Yes
SC2	52	Trained Experienced	Not stated	Not stated	Recreation	15	3	On	Not stated	Yes
SC3	26	Trained Inexperienced	Trained Inexperienced	Separation Buddy	Recreation	12	Not stated	On	Not stated	Yes
SC4	20	Trained Inexperienced	Trained Experienced	Separation Buddy	Recreation	45	13.5	On	Not stated	Yes
H 1	46	Trained Experienced	Not applicable	Solo	Work	7.5	3	On	Not stated	Not applicable
H 2	25	Trained Inexperienced	Not applicable	Solo	Work	15	15	Off	32	Not applicable
H 3	54	Trained	Not applicable	Solo	Work	24	24	On	35	Not applicable

enced scuba diver but was wearing a new backpack and his tank had come loose. To assist him the instructor gave him one of the shop units in exchange for his backpack unit and indicated where bubbles showed the location of the others. However poor visibility prevented him from finding them even after a second attempt to dive on the bubbles. He chose to continue solo and only surfaced when frustrated by malfunction of his camera. The instructor admonished him for this behaviour.

There was a second dive, in the afternoon, and on this occasion no separations occurred. When one of the group noted that he had acquired a decompression requirement according to his decompression computer the group leader buddied him with the victim and dispatched them both to make a 14 minute stop at 3 m, this to be made in open water as there was no line. The other three surfaced a short time later and were picked up by the surface cover inflatable. The

driver of this boat returned them to the dive boat and then returned to the place where he expected the remaining pair to surface after their decompression time was completed. But only one diver surfaced.

The buddy described how they had been floating close to and facing each other for 12 minutes, then the buddy turned his head to look at his gauges. When he looked up the victim had gone. He turned around to check all directions, then surfaced and looked in all directions without seeing any sign of his companion. There were waves but the man in the boat was certain that he would have seen the diver if he had been at the surface. After he had picked up the buddy and made a local surface search he took the buddy to the dive boat and returned to make a wider search. They were in a bay and he noticed something floating near the headland, this he recognised was a backpack. He drove the boat towards this object but the engine swamped when he was round the point

**DIVING-RELATED FATALITIES OF 1988**

<b>Remaining Air</b>	<b>Vest</b>	<b>Equipment Check</b>	<b>Equipment Owner</b>	<b>Significant Factors</b>
Not applicable	No	Not applicable	Own	Spearfishing, separated, post-hyperventilation blackout.
Not applicable	No	Not applicable	Own	Breathhold dived then shared buddy's scuba. Solo ascent. CAGE.
Low	Partly inflated	Satisfactory	Hired	Separation started open water ascent. Buddy no/low air "Advanced Divers".
None	Partly inflated	Some adverse	Own	Shop backpack. Decompression stop separation. Faulty contents gauge. Acute Myocarditis. CAGE?. No Inquest.
Yes	Not inflated	Satisfactory	Dive Shop	First post-course dive. Separation but continued dive. History of epileptic fit.
Low	Not inflated	Equipment lost	Own	No Inquest. Body not found. Low air. Failed buddy-breathing. Panic, became unconscious.
Had air	No	Yes	Employer	Part obstructed grid caused unsuspected strong current. Previous refusal to dive ignored.
Lost air	Not stated	Some adverse	Employer	Unsafe/unorthodox cylinder change method. Supply hose had faulty non-return valve. Backup system failed. CAGE.
Had air	Not inflated	Some adverse	Employer	Unconscious while trying to ditch equipment. Tied to water-jet gun by belt sucked into casing. No tender. No effective leader.

and his signals for assistance were only seen when he drifted back around the point and into view of the dive boat. He resumed his journey, having restarted the engine, before another boat reached him after receiving a radio call for assistance sent from the dive boat. By this time he had found that the object was the part inflated vest of the backpack and that it was supporting the victim, unconscious, in a vertical position, his head forwards and face underwater. His first action was to raise the victim's head out of the water, then he commenced giving EAR. However he was not able to pull the victim into the boat unaided. When help arrived, the victim was got aboard and taken back to the dive boat, resuscitation being continued throughout.

The victim was brought back to the resort, then flown to the mainland. There he was pronounced dead. The autopsy showed no evidence of pulmonary barotrauma or air embolism but there was histological evidence of an acute

viral myocarditis and a chronic hepatitis. The contents gauge needle was found to be loose and it showed 3 bar (45 psi) when the tank was empty. Whether he ran out of air, or was aware that this was imminent, then attempted to inflate his buoyancy vest, cannot be known. As the coroner considered there to be no need for an Inquest there was never any official discussion of the reasons for his death. It is possible that he had suffered from an air embolism, or his diseased heart may have suddenly gone into failure when stressed by the low/no air situation. The delay before the body was seen at the surface may be because it floated lower than a surfaced diver would and so remained unobserved till it floated into the calmer waters outside the bay.

EXPERIENCED DIVER. SEPARATION AT DE-COMPRESSION STOP 3 M DEPTH. DELAY BEFORE SEEN AT SURFACE. PART INFLATED BUOYANCY VEST. VERTICAL IN WATER WITH FACE SUB-

MERGED. WEIGHT BELT ON. CONTENTS GAUGE FAULTY SO PROBABLY LOW-AIR BECAME OUT-OF-AIR. NO AUTOPSY EVIDENCE OF CAGE. EVIDENCE OF ACUTE VIRAL MYOCARDITIS PLUS CHRONIC HEPATITIS. NO INQUEST.

#### Case SC 88/3

The diving course had been conducted from a schooner from which the two divers had made their required four dives. They had successfully completed the course despite poor visibility and now were making their first unsupervised dive. The boat was lying off a reef, unanchored because there was no current. The buddy pair of novices entered the water together but then one regulator started to free flow and when this was resolved it was found that the victim was no longer at the surface. Despite the strong advice in their course that separated divers should resurface he did not do so. The buddy was directed to where bubbles were seen breaking at the surface and dived, but was unable to locate him so returned to the boat. After 80 minutes it was realised that he must have used all his air and could no longer be considered to be diving.

A search was made but was unsuccessful. The body was found the next day lying on the sea bed, all equipment in place. A check showed he had plenty of air remaining and his buoyancy vest inflated efficiently. Information from a friend revealed the most probable reason for this fatality, that he recently suffered a fit of some type but had declined further investigation because there was this planned and desired holiday trip due.

JUST TRAINED. FIRST POST COURSE DIVE. SURFACE SEPARATION. PROBABLY HAD EPILEPTIC FIT WHILE DIVING SOLO.

#### Case SC 88/4

This diver was so keen to view the Barrier Reef that she took a scuba course and this was her first unsupervised dive, indeed her first dive since completing her course. The boat which took them out to the reef carried a diving instructor who checked that all those intending to scuba dive were trained, though he did not check their actual diving experience. He paired the victim to a diver who had been trained for three years, unaware she had only made 12 dives in this time. The dive platform was a pontoon and the reef was reached by following a rope down from a nearby buoy. The instructor told them that the best coral was in the shallow areas rather than below 15 m depth, but if they chose to dive deeper a decompression stop was advised.

There was some current but this was against them for their outward swim along the reef. They surfaced once to check on their position as the rope guide ceased where it reached the reef and they felt unsure of whether they were going in the correct direction. When their contents gauges

each showed 100 bar, half full, the return swim was commenced in accord with the instructor's advice. They had been swimming at 12-13 metres depth for about 10 minutes and then the victim showed her contents gauge to her buddy: it was indicating 50 bar and the buddy had very little more so they knew they should start to ascend. The buddy realised her companion was starting to ascend too rapidly and restrained her gently. However she then appeared to become agitated, let the regulator fall loose from her mouth, and signalled that she was not able to breathe. The buddy gave her her second (octopus) regulator, which she guided to her mouth but failed to purge. Her buddy offered it back, purged twice, but it was spat out and the victim then kept her mouth very firmly closed. She then began to struggle and clutched her buddy, who naturally began to panic as they began to sink deeper.

The buddy attempted to inflate the victim's buoyancy vest and drop her weight belt but failed. She managed to get free and saw that the victim had become quiet, probably unconscious, and was sinking. She became breathless from overbreathing, panicky, and drained of energy so ascended rapidly, recognising that she was in real danger herself. At first her yells and waving arms failed to attract attention, then a snorkeller on the reef noticed her and he managed to alert staff on the pontoon. It was recognised that her rapid ascent without any decompression stop placed her at risk of decompression sickness so she was given oxygen and was put in a head low position after return to the pontoon. Search of the locality was unsuccessful and this was expected as there was some outflow current and a deep channel where they had stopped to make their ascent. The body was never recovered so it is unlikely that the buoyancy vest was inflated.

The sequence of events as described is suggestive of an inexperienced diver becoming anxious in a mid water situation, believing an out-of-air situation was occurring (which could be a consequence of anxiety effecting the respiratory rhythm), followed by a flustered management of the offered regulator, leading to the final panic, aspiration of water and sudden or rapid death.

One problem which emerged from this tragedy was that of management of a diving emergency in the presence of non-divers, as occurred here. The boat which took these divers to the pontoon also carried visitors for a glass-bottomed boat view of the reef. Though these people were aware that some accident had taken place they were told nothing and mistook the attempts made by the staff to shelter them from involvement for lack of a feeling of urgency in responding. They saw the boats and planes searching but failed to experience an awareness of the intense activity around them or feel involved. This is obviously a public relations problem which requires consideration by those involved in commercial boat trips to the Barrier Reef.

TRAINED. GROSS INEXPERIENCE. FIRST

POST-COURSE DIVE. BUDDY HAD LIMITED EXPERIENCE BUT ACTED VALIANTLY. DIVE BOAT CHECK OF CERTIFICATION BUT NOT OF EXPERIENCE. FAILED TO DROP WEIGHT BELT. FAILED TO INFLATE BUOYANCY VEST. ANXIETY/PANIC AIR HUNGER SYNDROME. BODY NOT RECOVERED.

#### Case H 88/1

The commercial diver who died in this accident was a victim of a set of circumstances whose potential danger to divers went unrecognised till too late. Although another diver had noted the adverse diving conditions and declined to dive, there is no reason to believe he anticipated the true degree of danger posed by this job, the clearing of a trash grid in a concrete canal carrying the water supply into a power plant. This task was usually performed by a machine but it was out of action and being repaired. Failure of communication between diving supervisor and works engineer was a critical factor in the chain of events.

The diver entered the water from a ladder a little upstream of the grid, wearing hookah, and descended. A short time later, when his tender realised there was no response to line calls, there was a sudden realisation that all was not well. The second diver then kitted up and entered the water, almost immediately finding he was torn from the ladder and onto the victim on the grid. It was with difficulty that he was able to regain the surface after the water flow had been stopped. The water had forced the victim so rapidly onto the grid he would have been stunned, and even had he retained his regulator the water power would have prevented him making any respiratory excursion. The second diver was fortunate to survive.

Although the speed of the water flow was far greater than on other occasions this diving company had worked here, there was a more important and less obvious factor involved. Because of the build up of weed on the grid the channel was reduced to a small available cross section at the grid. This greatly increased the power and flow rate in the immediate vicinity of the clear part of the grid while the flow was slow and weak in front of the remainder of the grid. The diver was suddenly caught in a powerful (and unexpected) current and flung onto the grid.

This tragedy, however, arose in the first instance out of a failure to follow recognised safe diving procedures, probably in an effort to please the client. Although the water flow should have been stopped before the divers entered the channel it appears that this would have required taking two generators out of action at a time when others were not ready to take over. The consequent loss of power generation would have adverse consequences on the public conception of the Authority involved, and the diving company would lose a powerful client. Such thoughts would occur to those making decisions on the spot even if not actually spoken or discussed.

SOLO. HOOKAH. PARTLY OBSTRUCTED GRID NARROWED EFFECTIVE WATER CHANNEL SO THERE WAS A RAPID AND POWERFUL CURRENT. DIVER FORCED AGAINST GRID. RESCUE DIVER ALSO AFFECTED BUT SURVIVED. FAILURE STOP WATER FLOW BEFORE ENTRY. POSSIBLE REASONS FOR BREACHES OF SAFE DIVING PRACTICES.

#### Case H 88/2

The circumstances of this tragedy may appear to many as beyond belief in a world where commercial diving is apparently subject to over cautious regulations overseen by strict Government Inspectors much more interested in the wording than the spirit of such regulations. The victim was a newcomer to commercial diving, an experienced scuba diver (49 dives) who has never undertaken a hookah dive till he joined this firm two weeks before. Since then he had dived three times using hookah to familiarise himself with an unusual method they employed when changing to a new air cylinder. When the diver was warned there was to be a change over he turned on his bail-out bottle and used this while the empty cylinder was removed and the fresh one connected.

The job was to survey an old pipe, marking its course at intervals with floats. The dive boat was 1 km from shore, the water depth was 15 metres. The victim swam to the float which indicated how far the previous diver had travelled, then descended. His rate of descent was slow as he had difficulty equalising his ears, this being known because he was wearing a Kirby-Morgan band mask which had direct communication with the surface. He appeared to be calm and normal when advised that a cylinder change was to take place. Delay occurred after the cylinder was turned off and the line had been vented, disconnection requiring the use of a shifting spanner before this was accomplished and the fresh cylinder connected. It was a surprise to everyone when the victim was seen to surface as there was no warning of his intention to do so. His mask was off, held in his hands. He appeared to say "I thought I was dead", then lost consciousness and floated on his back at the surface. He may have been wearing his weight belt when he surfaced and dropped it as he lost consciousness.

He was brought onto the dive boat and everyone there realised that he had suffered an air embolism. He was placed in a left lateral head-down position, oxygen commenced, and a radio call made to shore for an ambulance to meet their arrival. He appeared to have difficulty with breathing, it being rasping and irregular, his pulse was weak and rapid, and jaw was clamped tightly shut. He then started fitting, was agitated and thrashed about so that they were unable to maintain him in the approved lateral position. The ambulance took him to the local hospital and there there was some discussion as to who should transport him to which centre capable of providing recompression treatment. It was decided to transport him by air and before he left the hospital

for the airport he was apparently sufficiently recovered to understand and answer simple questions. However his condition deteriorated again and he had to be taken to a hospital on the route. There he was put onto a drip of dextran and a transportable recompression chamber reached him. It was now 4 1/2 hours from the time he surfaced. Although he did reach the hyperbaric treatment unit alive he died four days later from the cerebral damage he had suffered.

It is not known why the victim failed to communicate his intention to ascend but it is reasonable to suggest that this was because he was making an instinctive response to an emergency situation, tearing the mask off his face indicating his feeling of being suffocated. Examination of the equipment showed it was very possible that the non-return valve in the air hose might not have worked reliably. The bail-out bottle was shown to contain air and to be turned on. It was suggested that when the air lines vented, prior to removing the in-use cylinder, the faulty non-return valve allowed the venting of his mask to the surface and the air supply from the get-home tank may have been insufficient to maintain air in his mask. In a diver grossly inexperienced with hookah diving, as this man was, the loss of mask air (not merely cessation of the air supply) would be a panic creating situation. It would require any diver to make an emergency ascent in order to survive.

There was no legal requirement for any recompression chamber to be on site, and though there was a chamber ashore which could have been used it would have taken several hours to make it ready for use. It is uncertain whether there was anyone available with training in its use. Naturally the delay before commencing a recompression of the victim greatly reduced his survival chances, which were probably minimal from the time he surfaced.

SCUBA EXPERIENCED. UNTRAINED (FOURTH USE OF HOOKAH) AS "COMMERCIAL DIVER". UNUSUAL TOPSIDE CYLINDER CHANGE METHOD REQUIRED USE OF BAIL-OUT BOTTLE. POSSIBLE FAILURE OF NON-RETURN VALVE IN AIR HOSE CAUSED VENTING OF KIRBY-MORGAN MASK TO SURFACE. EMERGENCY PANIC ASCENT. PLACED IN TRANSPORTABLE RCC 4 1/2 HOURS AFTER HE SURFACED. LOCAL RCC NOT AVAILABLE FOR IMMEDIATE USE. CEREBRAL ARTERIAL GAS EMBOLISM. DEATH DELAYED 4 DAYS.

### Case H 88/3

The task was to remove the concrete cladding round a pipe to enable it to be inspected. There were four divers working from the dive boat, a democratic group who shared tasks, the diving supervisor taking his turn with the rest to dive and none of them formally acting as tender or backup diver. Indeed each was quite free to decide whether to make a decompression stop or not. There was one other person aboard, the mechanic whose responsibility was the pump

supplying the water jet gun.

The inlet of the water pump became blocked so it had to be put on idle while this was cleared. In order to utilise the diver's available no-decompression dive time fully the supervisor decided to bring up the diver until the water-jet was functioning again. It was at this time that it was noticed that there were no bubbles ascending, and a line call went unanswered. The air supply had not failed as the air compressor was separate from the water-jet pump. The supervisor descended to discover what had happened, choosing to use the second air compressor. He found the diver was lying on the sea bed with his equipment partly ditched. The mouth piece of the regulator was out of his mouth (he was not using any retaining strap) and no air was escaping. The rescuer tried first to bring the victim up by orally inflating his vest (no reason is given for not attempting to use the hose supply inflation system) but this failed. He then noticed that the heavy water jet gun lay across the diver's thigh and was retained attached to the body by the fact that the buoyancy vest belt had been sucked into the jet gun's retro nozzle casing. After it was cut free the body floated up to the surface. Other divers had noticed the annoying habit of loose portions of equipment to be sucked into the casing but this had been treated as a nuisance, not a danger.

There are several unanswered questions in connection with this fatality. The air supply for the diver was said to have been uninterrupted so there was no reason for him to attempt this ditching of equipment. He was an experienced diver who had a bail out bottle and buoyancy vest, so there is no obvious reason why he could not have calmly cut himself free. Possibly he drowned while trying to recover his regulator mouthpiece, suffering sudden groin pain when stretching for it. This could occur because he had been jumping into the water from the upper part of the boat during the mid day meal break and had suffered some groin pain following one of his water entries. The mid day break served two purposes, being a surface interval period between the morning and afternoon dives and also when the tide change made the visibility very low. It is not known why he attempted to ditch his equipment rather than cut the strap connecting him to the jet-gun. He was experienced in the ditch and recovery of equipment because he was a well known local diving instructor. Indeed his knife was used to cut the strap.

Resuscitation attempts were unavailing: very probably he was dead when located. None of the three divers knew about EAR but the engineer who controlled the water pump was trained and he performed the resuscitation attempt. Death was due to drowning.

EXPERIENCED. UNREGISTERED COMMERCIAL DIVER. ATTEMPTED TO DITCH BACK PACK BEFORE HE DIED. NO DIVE TENDER. FAILURE TO DEFINE TOPSIDE DUTIES. FAILED TO DROP WEIGHT BELT. FAILED TO INFLATE BUOYANCY VEST. VEST

STRAP SUCKED INTO WATER JET-GUN'S CASING.  
NO REPORTED DEFICIENCY OF AIR SUPPLY. DI-  
VERS IGNORANT OF RESUSCITATION METHODS.

### Discussion

The death of an experienced breathhold spear fisherman is commonly a consequence of pre-dive hyperventilation and this is the almost certain reason for the death of the diver in the first case described. The second death was unusual as the practice here described of a breathhold diver descending to join a scuba diver and then buddy breathing is probably rare nowadays. Although this tragic example of the reason for exhaling during ascent after the breathing of air at a higher ambient pressure is both instructive and predictable it is apparent that the scuba diver had failed to adequately appreciate the potential danger of the sharing his air with a breath hold diver.

There were a number of critical factors which had an influence on the scuba diver fatalities, with the most significant one being the factor of inexperience. Any just-certificated diver who thinks her or she is more than in a novice category has obviously been inadequately instructed in their skill status, and the use of the term "Advanced Diver" for someone who has performed only nine dives, all under supervision, should cease immediately. This is in part because such people may well believe they have acquired a diving ability rather than a diving certification. Possibly there should be a probationary period of a minimal number of supervised and logged dives before this certification is confirmed. There is also a warning to those who operate dive trips that it is wise to make a routine check of the experience as well as certification when signing up clients for dive trips.

An examination of Case SC 88/2 shows several factors worth consideration. The faulty contents gauge (probably owned by the victim but this is not directly stated) played a part in this incident if the victim was unaware that it was unreliable, however it was not stated whether the gauge was likely to have given some reading when greater pressure was in the line or whether it would have been obvious that it was faulty. Special significance should be paid to the basic reason for this fatality, the need for one of the group to make a decompression stop. That an experienced diver should accumulate a decompression requirement of 14 minutes taken at 3 m depth in open water and the matter be treated as not being noteworthy may indicate an attitude to decompression safety which is leading to so many cases for the hyperbaric units to treat. In this case visibility was poor and the divers were neither holding onto a line or onto each other. They were at double jeopardy, from separation (which occurred) and failure to maintain a correct and constant depth during the decompression stop. It is probable that the victim, who did not require the decompression stop, became very short of air and ascended rapidly, using the last of his air in an attempt to inflate his buoyancy

vest. The partially inflated vest unfortunately allowed his head to fall forwards and be submerged. This is a failing of modern buoyancy control devices (ADV's) which have little buoyancy in front on the surface and do not tilt unconscious divers onto their backs. The described events support the suggestion that he suffered from a cerebral air embolism during his 10 feet ascent rather than the postulated cardiac attack.

Two fatalities occurred in divers making their first dive following completion of their basic scuba training. One case involved an epileptic who possibly declined to accept that he had such a condition and required investigation and medication. He ignored the advice given to dive with a buddy and surface if separated. There was therefore nobody near to rescue him when he (it is assumed) suffered a fit. A similar event is known which ended more happily because of the presence of an instructor. Epileptics should not dive. In the other case there was panic which the buddy attempted valiantly to reduce, placing herself at real risk in the process.

The remarkable fact concerning the commercial diving fatalities is that in these seemingly over-regulated days so many ill managed diving operations continue. This is more a matter for education than regulation, though the latter response is far more likely. Reading the incident resumes will indicate which critical adverse factors were most important in each case. In the first of the cases described there was a failure to insist that the water flow be stopped, or at least monitored, before the diver entered the channel. The significance of another diver's refusal to dive here was not appreciated by the engineers and possibly unknown to this diving company. The "Can Do" tradition of commercial divers must surely be given some of the blame for this fatality.

The power of flowing water is easy to underestimate, or fail to consider in advance. This is particularly important in calm or slow moving water where there is a restricted outlet such as a pipe. In this case the partial obstruction of the grid was a cause of the channel suffering sudden reduction in cross section. This was not visible from the surface appearance of the water and neither diver was aware of this till in front of the unobstructed portion of the rubbish grid, when the flow was irresistible.

While a change over from one air cylinder to another while the diver is underwater is an entirely reasonable practice, a method which requires venting of the supply lines and a removal of one cylinder before a fresh one can be connected up is unusual and unsafe. That such a method had been apparently followed for some time without significant misadventure gave no guarantee that it was safe, and this victim's gross inexperience proved too great an additional factor when the non-return valve failed while the air line was venting to the surface. The air supply rate from his get-home bottle was insufficient to offset this venting so he made an out-of-air ascent, unfortunately suffering air embolism.

The third case is hard to understand because in this



incident the diver was experienced in ditch-and-recovery from his work as a scuba instructor. If the evidence is correct that there was no failure of his air supply, there must have been another, not identified, reason for his actions. While there was entrapment of his buoyancy vest's belt in the water jet-gun this machine had been turned off about the time he died. Possibly he misjudged the danger of his situation and inhaled water while he was attempting to ditch his equipment.

### Acknowledgements

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### Project Stickybeak Divedata Databank

The objective of this on-going project is to identify factors which influence the safety of divers, whether recreational or commercial divers. Reports are requested concerning incidents of all types and severity, particularly where there has been a successful outcome. MEDICAL CONFIDENTIALITY is given to every communication received. Address for correspondence:-

Dr D Walker  
P O Box 120, Narrabeen  
New South Wales 2101  
Australia.

### DEVELOPMENT AND USE OF THE OXYGEN-BREATHING MINIMAL-RECOMPRESSION TREATMENT OF DECOMPRESSION SICKNESS

Geoffrey Gordon

### Introduction

When man ventures into a hyperbaric or hypobaric environment, his excursions are occasionally complicated by the development of decompression sickness (DCS) and arterial gas embolism (AGE). To treat the occurrence of these illnesses, recompression therapy is used either according to a standard treatment table or to a depth that brings relief. This approach to treatment is not based on experimental evidence, but on the empirical application of theoretical concepts.<sup>1,2</sup> Old protocols were superseded when it was felt that the results were unsatisfactory, rather than when case analysis indicated poor treatment outcomes.

Analysis of the effectiveness of treatment regimens needs to be conducted if, in any meaningful way, we are going to be able to improve our effective treatment opinions. That a solution will be developed to benefit every case is a naive idea, but have the current "minimal recompression oxygen breathing tables", developed in 1965, filled a void, or are they just another attempt at treating a disease process that is still incompletely understood?

### The history of treatment tables

It was not until 1847 that Pol and Wattle<sup>3</sup> first recognised that there was a relationship between the onset of DCS symptoms and the depth, bottom time and rate of ascent. This was 28 years after Siebe developed the first practical deep-sea diving outfit and 6 years after the production of the first large capacity compressors that permitted large numbers of men to work at raised ambient pressures. Although this work established recompression as the primary treatment modality, the manner of its application was unclear. It was not until 1878 that Bert<sup>4</sup> demonstrated that liberation of nitrogen in the form of bubbles was the cause of DCS. He also recommended recompression and went on to expound that treatment with oxygen should be effective. No decompression rates were specified, and as pure oxygen was both scarce and very expensive it was little used. In 1897 Zuntz<sup>5</sup> utilised oxygen in conjunction with recompression to increase the gradient for nitrogen elimination and hasten bubble resolution. However, due to the development of oxygen toxicity, the use of this adjunct proved unpopular and was not widely used again for many years. Air recompression therapy for DCS was subsequently developed.

In 1937 Behnke and Shaw<sup>6</sup> re-investigated the use of oxygen in the treatment of DCS. They hoped to utilise the increased gradient for nitrogen elimination to improve treatment outcomes. In experiments using a dog DCS model, they observed that severe cardiopulmonary DCS responded well to recompression to 30 msw regardless of whether air or oxygen was breathed. On subsequent decompression however, those treated on air had recurrences of cardiopulmonary DCS of pretreatment severity. Those treated with oxygen showed a minimal return of symptoms, indicating better inert gas clearance when an oxygen atmosphere was breathed. Yarbrough and Behnke<sup>7</sup> two years later, documented a 50% recurrence of symptoms in divers treated by recompression to depth of relief plus 10 metres of seawater, the procedures published in the US Navy (USN) Diving Manual of 1924. This protocol probably did not achieve resolution of all the gas in bubble form despite the pressure applied. In an attempt to achieve complete bubble elimination, they empirically developed guidelines limiting recompression depth to 50 msw with a minimum time at this depth of 30 minutes. In modifying the Haldanian type decompression, 100% oxygen was breathed from 18 msw to the surface. The process of gas diffusion from bubbles and tissues was thought to be slow, and so administration of