The Editor's Offering

It is sad to have to start the year with an apology, but, for reasons quite beyond the Journal's control, we did not get the Journal into the post in time for you to read it for Christmas. We hope for better luck with this issue.

We present another Provisional Report on Australian Diving-related Deaths in Australia from Douglas Walker and a review of his book *Report on Australian Diving Deaths 1972-1993*. As our reviewer, David Elliott, of Bennett and Elliott, makes quite clear this book should be read by all those interested in diving safety. One of the reasons is that the causes of death in scuba divers are the same failures to perform safely as they have been for the last 20 years, in spite of the vastly improved, but much shortened, training available. Running out of, or being low on, air underwater is the first step in the majority of diving deaths, failed buddy breathing or sharing an air supply by using an octopus is a common next step. The survivor of these pairs, and pairs are in the minority in fatal incidents as 80% of the divers died alone, are usually the one who made a bolt for the surface, dropped the weight belt (65% died with their weights on) and inflated the buoyancy vest. Certainly they risked cerebral air embolism, but they usually did not develop it, and equally importantly they survived to give evidence at the inquest.

Do training agencies teach their recruits to look at the contents gauge more often than they look at their depth gauges? Only by drilling this routine, of looking frequently to see how much air is left, into learner divers can any reduction in low or out-of -air incidents be expected.

We have reprinted a paper from DIVER, the major UK diving magazine, about the 22 diving deaths achieved in the UK in 1998. There may be readers who doubt the BSAC's claim that club diving is the safest way to dive, but it makes sense for novice divers to dive with more experienced divers for an appreciable number of dives after qualifying. One group of divers who appear to have contributed very strongly to the deaths are those classified as "orphan divers" by the BSAC. These are the products of recreational diving training bodies who, after qualifying, go diving with a group of recent trainees all with no experience. In the UK it seems that they are figuring largely in the Coast Guard rescue statistics. In fact there are murmurs that recreational divers diving should be regulated in the interests of diving safety. It sounds reminiscent of Queensland where efforts to reduce diving accidents by voluntary codes have been thwarted by the actions of a boat operator who ignored the basic safety requirement of making sure that all passengers were aboard before unmooring for the return journey. It seems that the Queensland Government is considering taking more coercive action. But, as the Diver Article points out, most diving deaths appear to be due to not diving safely, i.e. knowing nothing about how to dive safely or making decisions to do something stupid, like the man who, when his mask dropped into the sea after a dive, jumped in after it, although he had taken off his fins, but not his weight belt, and disconnected his buoyancy compensator's direct feed. He did not survive to explain why he acted so foolishly. The DIVER paper also included a number of boxes in which various UK diving authorities made suggestions as to avoid these deaths. They are reprinted with the paper and uniformly recommend better training of divers in how to avoid the common causes of incidents, lack of knowledge, overconfidence and a lack of understanding the use and problems of equipment.

We published a paper on the performance of ventilators in hyperbaric chambers in June 1998 (Skinner M. Campbell "D-mode" ventilator under hyperbaric conditions. 1998; 28 (2): 71-74) which told of the reduction in pumped volume which occur with increasing chamber pressures. We now publish a paper by Whittle, Butler and Muller on the performance of two mechanical volume measuring devices at three pressures often used clinically in hyperbaric treatments. These two devices appeared many years ago, in the 1960s, and were welcomed by many anaesthetists, though few thought it worthwhile to buy one for their own use (in those days anaesthetists took their own equipment into private hospitals). For the first time one knew the volume that came out of the patient each breath, a vastly better way of estimating adequacy of ventilation than just watching the rise and fall of the chest or relying on the "educated hand of the anaesthetist". It is cheering to read that both volumeters are useful and reliable.

Our last editorial promised further information on the Diving and Hyperbaric Special Interest Group that had just been formed by the Australian and New Zealand College of Anaesthetists. This exciting new initiative will, it is hoped, bring Diving and Hyperbaric Medicine, in time, into an established and nationally recognised position. In 1936 the Australian Society of Anaesthetists was formed with under 20 members. Nearly 20 years later anaesthesia was sufficiently developed for the successful formation of the Faculty of Anaesthesia under the wing of the Royal Australasian College of Surgeons. Forty years later the Faculty became the College. Diving medicine is now where anaesthesia was in Australia in the late 1940s, looking for a system to improve teaching and standards of knowledge and equipment. This is not to say that individual SPUMS members, and others, have made no such efforts. They have and without their efforts SPUMS would not have come so far in its endeavours to improve diving safety. For evidence see the pages where the requirements for the Diploma and the various courses are printed. So please read pages 17 and 18 and write letters of comment to the Editor.

ORIGINAL PAPERS

PROVISIONAL REPORT ON AUSTRALIAN DIVING-RELATED DEATHS IN 1995

Douglas Walker

Key Words

Accidents, deaths.

Summary

This review reports on four (4) persons swimming using snorkels, nine (9) scuba divers, three (3) who were using surface supply and two fatalities which are of interest although not strictly falling within the usual field of this investigation. Attention is directed to the apparently inappropriate overconfidence shown by some who achieve an "advanced diver" qualification after minimal diving experience.

Breath-hold and snorkel-using swimmers

BH 95/1

While staying with compatriots during a back-packing holiday this man decided to try snorkelling with them. He borrowed a mask with a fitted snorkel and joined them and other swimmers. He was reputed to be a poor swimmer and to avoid venturing into water where he was out of his depth. The water chosen was only up to the top of his chest. After a while his friends left the water but he remained. They watched him as they sat on the rocks, though not continuously. When, about 5 minutes later, they could no longer see him they walked along the beach to look for him. They became worried and asked for help from the nearby surf club. This search was also unsuccessful. His body was found floating 42 hours later, in the area where he had last been seen. Nobody had noticed any signs of him being in any trouble. It is assumed that he panicked and drowned, not thinking to remove his mask and stand up.

FIRST USE OF SNORKEL. SHALLOW WATER. POOR SWIMMER. LACKING CONFIDENCE. SILENT DROWNING. SNORKEL ATTACHED TO MASK. SEPARATION.

BH 95/2

The sea was calm and visibility good when this experienced spear fisherman was diving solo about 50 m off the beach. His wife watched his snorkel at the surface and only became alarmed when he failed to return at the arranged time. She then realised that the buoy he had attached to his spear gun had remained in the same area for far too long. She saw another spear fisherman and asked him to check. He found the victim beneath the buoy. The water was too shallow (3 m) to require him to hyperventilate to assist his hunting efforts, though he possibly did so and suffered a blackout. There was no health reason for him to drown. There was a history of asthma but this appears non-contributory.

EXPERIENCED SPEARFISHER. SOLO. SEA CONDITIONS GOOD. RELATIVELY SHALLOW WATER. ASTHMA HISTORY. DROWNED.

BH 95/3

The reason for this death is similarly unexplained as he was snorkelling in waist deep water watched by his wife and a friend in a nearby dinghy. He was seen standing in waist deep water when he called out for help and then collapsed. The pathologist was unable to identify the cause of death as his coronary arteries were healthy and there was no evidence of a "stroke". Possibly a cardiac arrhythmia, which leaves no evidence, was the reason for his death.

SNORKELER. SUDDEN UNEXPLAINED DEATH. STANDING IN SHALLOW WATER.

BH 95/4

Despite his disabilities (a spinal lesion and operations on both shoulders and one hip which left him with restricted function of his left upper limb and weakness of his lower limbs) he was described a being a good swimmer. He and his wife were among many others making the day trip in a boat to a pontoon moored off a reef. He was last seen alive as he pulled himself back towards the pontoon along a rope after losing one fin. There were no signs of distress and other swimmers were close by. When next seen he was floating quietly, face down and did not respond when a small wave passed over him. There was an efficient surface watch and he was reached rapidly and brought back to the boat, but resuscitation efforts failed. Although his coronary arteries were patent this was clinically a cardiac type of death. He was taking many medications but they do not appear to have contributed to his death.

SNORKELER. SILENT SURFACE DEATH IN CROWD. GOOD SWIMMER DESPITE DISABILITIES.

Scuba divers

SC 95/1

A Resort Dive two years before had led him to join this course to learn to scuba dive. The pre-course diving medical check passed him as fit to learn to scuba dive, but he was advised that he was too heavy and his age (59 years) was a matter for caution when considering taking up an active sport. The first dive of the course was to 4 m. He died on the second dive. There were five pupils in the care of an instructor and his assistant. After a safe, planned, dive for 23 minutes at 9-18 m they made a controlled ascent together when one of the pupils' contents gauge showed it was time to ascend.

At the surface they all gave "OK" signals. A check showed that two of the pupils had enough remaining air for a short further dive and the instructor descended with them while his assistant had the task of returning to the shore with the remaining three pupils, a surface swim using snorkels. After only a short distance the victim complained of feeling tired so the assistant started to tow him. Although initially alert he soon ceased to respond and the assistant started in-water resuscitation. It was rapidly apparent that this was not effective so he resumed his tow. At first witnesses on the shore though they were watching a practice of rescue but swam out to assist when they realised the truth. On at least one occasion the victim became submerged during the rescue effort.

The pathologist requested a pre-autopsy X-ray performed but failed to recognise the significance of the finding of air in the right side of the heart, arch of the aorta, blood vessels in the neck, and hepatic veins. He was later persuaded by a more experienced pathologist to give pulmonary barotrauma as cause of death, with drowning the final element. He also added that he had found "small air-filled cysts in association with haemorrhage at the top of the lungs", a fact omitted from his formal autopsy report. The suggested course of events was that he suffered a small cerebral arterial gas embolism (CAGE) during the (apparently) normal group ascent and this blunted his level of consciousness and he drowned at the surface. The resuscitation efforts may have forced more air to enter the circulation, but this is only supposition. He had adequate remaining air but may have been troubled at the surface by being overweighted.

PUPIL IN CLASS. NORMAL GROUP ASCENT. COLLAPSE DURING SURFACE SNORKEL RETURN TO BEACH. RAPID CORRECT MANAGEMENT OF INCIDENT. OVERWEIGHTED. ADEQUATE AIR. CAGE.

SC 95/2

This man's buddy, who owned the boat they were using, had loaned him the scuba equipment. Being aware that he was untrained and making only his 4th scuba dive, the buddy remained close by him for about the first 15 minutes as they spearfished at 20-24 m depth. Then the buddy indicated that they should return to the anchor and ascend. Unfortunately the buddy then saw a good sized fish and darted away to spear it. When he returned to the anchor there was no sign of his friend, so he ascended, but found he was not in the boat so descended again. His search was limited because he suffered some sinus barotrauma. He called out to some divers in a nearby boat and one of them dived, using his scuba equipment, locating the victim on the sea bed. There was insufficient air remaining to inflate the victim's buoyancy vest. The buddy had obviously used far less air as there was sufficient remaining to support this search. There was evidence of a mask squeeze and it was suggested this occurred as he sank after ascending solo while his buddy was hunting the fish. It is not known whether the two divers began with tanks which contained similar amounts of air. Certainly at one stage the victim had returned an "OK" response after he was given a sign to check his contents gauge, but it is not known whether he was aware of the significance of whatever reading he noted, and his buddy (an experienced diver) did not check the gauge.

The victim was using a borrowed 96 cu ft cylinder and there was no declaration that it was checked before the dive by either the victim or by his buddy (its owner) although this may have occurred. Possibly, being inexperienced and likely to over-ventilate, he ran out of air more rapidly than his buddy expected. But the more likely explanation is that he was ignorant of the significance of what the gauge showed. Cause of death was given as drowning, no evidence of a health factor or CAGE being present.

UNTRAINED. 4th USE OF SCUBA. SPEARFISHING. SEPARATION WHEN BUDDY SAW AND HUNTED FISH. SOLO OUT OF AIR ASCENT. FAILED TO DROP WEIGHTS. NO AIR TO INFLATE BUOYANCY VEST. PROBABLY UNAWARE OF SIGNIFICANCE OF CONTENTS GAUGE REMAINING AIR READING.

SC 95/3

This was a wreck dive, a popular one with local divers, the sea bed being at 28 m and the upper side of the wreck at 18 m. The victim had been trained for 20 months and had made 20 dives, including a night dive and one to at least 30 m. He was paired with a diver who appeared to be more experienced and they entered the water with another pair but separated during descent as the victim was slow descending. As they had planned, they first swam to the stern close to the sea bed, then ascended and began to swim forward on the upper side of the wreck towards the bow. It was there that the ascent line was attached. The current was significant and, although his buddy was able to swim forward without holding onto the wreck, the victim needed to pull himself forward. The buddy now realised that he was getting low on air (41 bar) so they ascended obliquely towards the line. The buddy saw the victim descend again to join a trio of divers; an instructor, his son and a relatively inexperienced diver. They were just approaching the wreck to start their dive.

PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience Victim	Buddy	Dive group	Dive purpose	Depth in metres Water	Incident	Weights On	kg
BH 95/1	26	No training No experience	No training Some experience	Group Separation before incident	Recreation	1.5	Surface	None	-
BH 95/2	64	Trained Experienced	No buddy	Solo	Spear fishing	3	Not stated	On	Not stated
BH 95/3	53	Training and experience not stated	No buddy	Solo	Recreation	1	Surface	None	-
BH 95/4	66	No training Experience not stated	Training and experience not stated	Buddy Separation before incident	Recreation	Not stated	Surface	None	-
SC 95/1	59	Some training No experience	Trained Experienced	Buddy No separation	pupil	18	Surface	Buddy ditched	15
SC 95/2	30	No training No experience	Trained Experienced	Buddy Separation before incident	Spear fishing	24	Not stated	On	Not stated
SC 95/3	43	Trained Some experience	Trained Experienced	Buddy Separation before incident	Recreation	27	15	Off	Not stated
SC 95/4	36	No training Experienced	No buddy	Solo	Recreation	30	Not stated	On	12
SC 95/5	42	Trained Experienced	Trained Experienced	Group Separation during incident	Recreation	5	Surface	On	Not stated
SC 95/6	29	Trained Some experience	Trained Some experience	Buddy Separation before incident	Recreation	38	38	On	Not stated
SC 95/7	44	Trained "Experienced"	Trained Experience unknown	Group Separation before incident	Recreation	21	21	On	Not
SC 95/8	28	Trained Some experience	Trained Experienced	Buddy Separation before incident	Club dive	3	Surface	On	7
SC 95/9	29	No training No experience	No buddy	Solo	Abalone poacher	Not stated	Surface	On	13
H 95/1	27	Some training No experience	Trained Experienced	Buddy Separation before incident	Work Pearl diver	3	3	On	Not stated

DIVING-RELATED DEATHS IN 1995

Buoyancy vest	Contents gauge	Remaining air	Equipment		Comments
			Tested	Owner	
No	Not applicable	Not applicable	Not applicable	Borrowed	Separation at surface. Drowned silently.
No	Not applicable	Not applicable	Not applicable	Own	Solo. Spearfishing.
No	Not applicable	Not applicable	Not applicable	Own	Stood up and died. Cause unknown. "No asthma for 25 years".
No	Not applicable	Not applicable	Not applicable	Hired	Surface death. Possibly cardiac. "had disabilities but not disabled".
Not inflated	Yes	Low	Adequate	Dive shop	Pupil in class. All made a normal ascent. At surface complained he was tired and died. CAGE.
Not inflated	Yes	None	Adequate	Borrowed	4th dive. Under water separation when buddy left to spear fish. Out of air. Drowned.
Not inflated	Yes	None	Some adverse comments	Hired	Inexperienced. In a current so air used fast. Low air. Buddy breathing attempt led to CAGE.
Not inflated	Yes	None	Adequate	Own	Short dive then surfaced out of air. 2nd dive same tank ? Solo. CAGE. History of cannabis use.
Not inflated	Yes	++	Adequate	Own	Sudden wave hit trio divers during water entry. Cold water. Kelp caught regulator. Unfit. CAGE ?
Not inflated	Yes	++	Adequate	Own	Unexplained underwater separation. Adequate air. Middle ear haemorrhage. Atrial septal defect. CAGE.
Not inflated	Yes	None	Adequate	Own	Group of "advanced divers" but had inadequate experience. Current. Separation CAGE ?
Not inflated	Yes	None	Signifigant fault	Hired	Overweighted. Some current. Night dive. Separation. Snorkel surface swim. Vest difficult to inflate.
Not inflated	Yes	Adequate	Some adverse comments	Borrowed	5th scuba dive. Dangerous water. Entered water with tank valve closed. Solo. Abalone poacher.
No vest	Not applicable	Not applicable	Not tested	Employer	Inexperience with hookah. Panic ascent? Drowned. Ill health factors?

PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience Victim	Buddy	Dive group	Dive purpose	Depth in metres Water	Incident	Weights On	kg
H 95/2	29	Trained Experienced	No buddy	Solo	Work Abalone	8	Not stated	Not stated	Not stated
H 95/3	40	Trained Experienced	No buddy	Solo	Work	4	4	On	Not stated

He appeared to tap one of them, a boy aged 15, on the shoulder and indicate he wished to buddy breath and this diver signalled to his buddy (father) that a diver was wanting air. When the father looked round he failed to see the victim, although he saw the victim's buddy who showed him his contents gauge. Although low on air he seemed to have sufficient for a safe ascent and these two divers watched him ascend before the boy saw the victim lying on the sea bed a short distance away, regulator out of his mask and gasping. Unfortunately, due to his intellectual condition, this did not seem remarkable to him and he did not attract his father's attention to what he had seen. The body was found later on the sea bed. A massive air embolism was shown by a pre-autopsy CT scan but the pathologist decided to be cautious and declared this was a drowning death. The accounts given by the instructor and his son of what occurred differ in some particulars and it is uncertain whether the victim attempted to use the boy's octopus regulator before drifting away.

The victim's buddy had reportedly made over 30 dives to this depth on previous occasions All the divers on this boat had to declare their training and experience but there is no evidence that log books were viewed. Although the victim and his buddy agreed to dive with another pair of divers, who had requested this because of their inexperience, this arrangement did not eventuate.

SEPARATION WHEN LOW AIR AND ABOUT TO ASCEND. LEFT BUDDY TO APPROACH OTHER DIVERS FOR AIR. MADE INEFFECTIVE REQUEST TO BUDDY BREATHE. FAILURE OF ANOTHER DIVER TO RECOGNISE THE VICTIM WAS IN TROUBLE. CAGE NOT DIAGNOSED BY PATHOLOGIST AFTER BEING CLEARLY DEMONSTRATED.

SC 95/4

This man always dived solo, a practice he had followed during his 20 years of diving. He had never received formal training. On this occasion he had collected his two newly filled tanks from the dive shop the day before setting out in his boat with his brother-in-law, who was not a diver. After his dive, which lasted 30 minutes, he remarked that it had been a deep dive but did not state its depth. The next day two more friends came with them in the boat and, once again, he has the only one diver. The water depth was 30 m by the depth sounder. They were surprised when he reappeared at the surface some distance from the boat after only 15 minutes. When they reached him it was apparent there was something seriously wrong with him. They pulled him into the boat and started CPR but realised after 10 minutes that he was dead.

Autopsy was preceded by an X-Ray examination but there is no record of what, if anything, this showed. During the autopsy a few gas bubbles were seen to escape from the right pleural cavity when it was opened, and a small quantity escaped from the aorta and vessels at the base of the brain and in the mesentery. There was some focal coronary atheroma but no vessels were stenosed. Subpleural focal air trapping was noted but no pleural lacerations. The cause of death was given as drowning but clinically CAGE had occurred. He appeared to have made an emergency, out-of-air ascent and had not ditched his weight belt. His buoyancy vest leaked but it is unknown whether he had tried to inflate it at any time. One possibility (unchecked) was that he mistakenly used the same cylinder for both dives and omitted to check the contents before diving.

EXPERIENCED BUT UNTRAINED. SOLO. SUDDEN ASCENT SOON AFTER STARTING DIVE. BUOYANCY VEST LEAKED. FAILED TO DITCH WEIGHT BELT. OUT OF AIR EARLY IN DIVE. POSSIBLY FAILED TO CHECK AIR GAUGE BEFORE STARTING DIVE. CLINICALLY CAGE.

SC 95/5

The trio of divers consisted of the victim and a 16 year old, both with Advanced Diver certificates gained during the previous 12 months, and a second 16 year old youth who was making his 4th scuba dive. He was part way through his basic open water training course. There were waves but they chose the sheltered side of the point for their water entry. The two youths entered by walking backwards, the victim walking directly into the water. Just before they were hit by a large wave the victim was heard

DIVING-RELATED DEATHS IN 1995 (Continued)

Buoyancy vest	Contents gauge	Remaining air	Equipment Tested	Equipment Owner	Comments
No vest	Not applicable	Not applicable	Not tested	Employer	Shark attack. Abalone diver..
No vest	Not applicable	Not applicable	Adequate	Employer	Unsafe work situation.

to call out. After it had passed they could no longer see him. They were both washed back onto the beach and there they removed their equipment before returning to look for the missing diver from some high ground before seeking help. A surf rescue swimmer retrieved the body after a fin was seen to break the surface. There was no response to resuscitation efforts. A piece of ribbon kelp was found round the regulator, which led to a suggestion that he had attempted to swim underwater beyond the surf line but lost his regulator. This, combined with the water power, is believed to have resulted in his drowning.

TRIO HIT BY WAVE AS ENTERING WATER. EXPERIENCED DIVER. KELP ROUND REGULATOR. WATER POWER. DROWNED.

SC 95/6

Although the victim was more experienced (30 compared with 11 dives) and had obtained Advanced and Rescue diver qualifications, his buddy was the dive leader. The reason for this was probably that he was following the request made by the instructor that he “keep an eye on his buddy” as he was the more experienced diver. He had some difficulty in equalising but managed to reach the sea bed at 30 m and followed as his buddy pointed out a crayfish and a stingray. The buddy looked back from time to time and observed no sign of his companion having any problem. He started the return swim when his gauge showed he had used about half his air and was surprised soon after this to find he was alone when he next looked back. A 360 degree visual search was unavailing so, after a short wait, he surfaced. There was no sign of the missing diver at the surface and after 20 minutes the dive group (the buddy and three other divers who had dived separately) returned to the shore. Three instructors from the dive shop returned to the dive area and made a line abreast search, taking care to examine all crevices. They found him at 35 m with all equipment in place, except that the regulator was out of his mouth, and brought him up carefully with his head back. The autopsy showed evidence of bilateral inner ear haemorrhage, a perforated left ear drum, and of CAGE. Of interest, and not mentioned in any previous autopsy reports, was the presence of a small atrial septal defect. As he had adequate remaining air no reason can be advanced for his sudden ascent let alone making this in a manner which resulted in him suffering pulmonary barotrauma and cerebral air embolism.

TRAINED. 30 DIVES EXPERIENCE. SUDDEN SEPARATION. INNER AND MIDDLE EAR HAEMORRHAGE AND PERFORATED EAR DRUM. ADEQUATE REMAINING AIR. CAGE.

SC 95/7

Dive trip organisations may experience problems in ensuring the safety of their clients for many reasons but a major one is where a group is not only non-English speaking but have a different scuba diving philosophy, as in this case. There is heightened importance in such circumstances in having an experienced and safety-orientated crew in charge of the diving. There was a interpreter with this foreign group but it is probable that he did not understand the instructor’s pre-dive briefing, and did not pass on to the members of the group that there was a current and that they should commence their dive with a snorkel swim till they reached the bommie where they were to dive.

A significant additional adverse factor for safety was the presence of two dive master trainees on board. They were trading service for experience and, being unpaid, were technically not covered by regulations which governed professional divers. They had not been formally advised of their responsibilities and appear to have either been lacking in motivation or fearful of speaking out of turn. This resulted in them omitting to inform the diving instructor of their observation that the victim had a habit of surfacing with an empty tank, appeared anxious, had poor diving skills, and seemed to be very inexperienced for someone who had an “advanced diver” certification. This was a qualification held by many of this group. He, like most of the group, tucked in the end on his weight belt, making its quick release difficult. The dive philosophy of the group was to dive as a group rather than as buddies, a matter which the instructor found he was unable to change. The true diving experience of members of the group, not being written in English, was unknown to the diving instructor and had to be taken on trust as being indicated by their certificates of training. The two trainee dive masters failed to regard it as their responsibility to alert the divers about the strength of the current.

The dive boat was anchored in an area off a reef, sheltered from the strong currents. The currents varied with the depth and locality, the reason for recommending the surface swim before descending and information probably not passed on to the divers. This was the fourth dive of the live-aboard trip and they descended as a group of six but soon became separated by the current. The victim assisted one of the group for a time but after she rejoined the others they never saw him again. The watch from the boat saw him surface, heard him call out (but naturally could not understand what he said), then observed his head fall forward. When reached he was unconscious, floating face down, his tank empty. He failed to respond to resuscitation efforts although showed an initial response.

The autopsy failed to reveal any signs of air embolism but this was clinically a "text book" example.

TRAINED. "ADVANCED DIVER" BUT APPEARED INEXPERIENCED. HABIT OF ENDING DIVE OUT OF AIR. UNSAFE DIVE HABITS OF GROUP MEMBERS. LANGUAGE PROBLEM DESPITE INTERPRETER. FAILURE OF TRAINEE DIVEMASTERS TO ALERT INSTRUCTOR OF OBSERVATIONS. CURRENT CAUSED GROUP SEPARATION, BUT DIVE CONTINUED. SURFACE SIGNAL THEN COLLAPSED. CLINICALLY CAGE.

SC 95/8

The majority of the divers making this club night dive had been trained by the club president, a dive instructor. He remained in the boat as safety diver during the dive. The boat was anchored in the calm water within a crescent of stone blocks set in the open sea, a popular dive site. The victim and her buddy were the last pair to enter the water. They swam underwater towards the entrance of the crescent but soon realised they were taking too long to reach it so they surfaced and then snorkelled to the entrance. The buddy led on each occasion, on each finding himself well ahead. When he reached the rocks at the entrance he shouted an "OK?" to the victim, then allowed himself to drift in the current along the outer wall of the crescent in the belief that the other was following him. After a short delay he heard her call for help so he climbed the rocks and called for the dive boat to come. During the short time this took the victim was lost to view. A surface search was about to start when two divers surfaced supporting the body of the missing diver and said they had found her on the sea bed, led there by seeing a torch. Resuscitation efforts were unavailing.

No reason could be given for her to drown, but there were the factors of anxiety because this was a night dive, separation, and failure to drop her (excessively heavy) weight belt or inflate her buoyancy vest when in trouble. Its inflation button was described as difficult to reach. She had been using her snorkel when she drowned and might well have survived had she resumed use of her scuba regulator. Her weight belt carried 12 kg, probably 3-6 kg in excess of what she should have required. She had made 26 previous dives, including two night dives

TRAINED. NIGHT DIVE. SURFACE SNORKEL SEPARATION. CALM SEA. FAILED TO DITCH WEIGHT BELT. POSSIBLY EXCESS WEIGHTS. FAILED TO INFLATE BUOYANCY VEST. INFLATOR BUTTON DIFFICULT TO REACH AND TO OPERATE. DROWNED.

SC 95/9

There were several significant adverse factors present and operative in this fatality. The diver was untrained and making his 5th scuba dive, using borrowed equipment. He was a successful and highly regarded "cockatoo", a look out for illegal abalone poachers, but inexperienced in being the diver. The nature of this work required the dive to be conducted unobtrusively and in conditions which inspectors would deem adverse to such activities. This resulted in him diving solo, his "helper" leaving the scene with his clothing as soon as he was ready to enter the water, it being his responsibility to return at the appointed time to meet the diver and spirit away his catch. The sea was rough and entry was from rocks. The safest method was to jump in and immediately descend and swim to deeper water. For this reason the helper was not surprised to see no sign of him after he jumped in.

When the diver failed to make his expected return the helper was alarmed but phoned the person who supplied the equipment, who was, naturally, in complete ignorance of the purpose of the intended dive although known to be involved in such activities. The advice he received was to shine his torch out to sea in the hope that the missing diver was waiting to be reassured that there were no fisheries inspectors about. Only after this was unavailing were the police informed.

The tank, battered, was washed ashore before the victim's body was found. The valve on the tank was closed so it was suggested that he checked it was full then turned it off while walking across the rocks and forgot to open it again. If he entered the rough water without air his fate was certain drowning. Earlier notification of the police would not have altered the outcome.

UNTRAINED. 5th DIVE. ROUGH WATER SOLO DIVE. ABALONE POACHER. DELAYED NOTIFICATION OF HIS BEING MISSING. AIR TURNED OFF WHEN ENTERED WATER. WEIGHTS ON. DROWNED.

SC 95/X

This case is reported because of its unusual nature. During her overseas holiday she had injured her leg while boarding the dive boat after a dive. No particulars are available but she was able to fly home as arranged, a flight which took about five hours. About a month later she became breathless and sought medical advice. By a process of exclusion a diagnosis of asthma was made, there being no evidence of cardiac failure and her blood pressure and ECG were normal, although there was no real evidence to support the diagnosis. A fortnight later she became suddenly breathless and failed to respond to emergency care. At the autopsy organised thrombus was found in both pulmonary arteries but no source of the thrombus could be found in her leg. She never reported having any chest pain.

MINOR LEG INJURY BOARDING BOAT WHILE SCUBA DIVING. BREATHLESSNESS DEVELOPED FOUR WEEKS LATER. CAUSE NOT IDENTIFIED. SUDDEN FATAL HEART FAILURE 2 WEEKS AFTER THIS. NO PAIN. BILATERAL ORGANISING THROMBUS IN PULMONARY ARTERIES. SOURCE OF THROMBUS NOT FOUND.

Surface Supply (Hookah) divers

H 95/1

The pearling industry off Western Australia and the Northern Territory has traditionally been serviced by those divers who survived their introduction to diving, although this situation is now being regulated and replaced by training schemes.

There is still, on occasion, a divergence between what the regulations set as procedure and actual practice. Such was the case here. This youth was interested in becoming a diver and was given permission to have a trial period on a pearl lugger before a decision was made to sign him on. This was to commence after he passed a basic medical examination, but he actually started before this was performed. He was permitted to make a few dives under the supervision of a licensed diver. On this day he was with a possibly inexperienced diver and diving from a dinghy in an effort to find an area worth a drift dive for pearl shell by the full team. It was revealed later that the skipper had forbidden him to dive, having watched how he managed the equipment and formed the opinion that he was far too inexperienced, although he held an Advanced Diver certificate as a scuba diver and was probably experienced with scuba. Unfortunately another person gave him permission to dive when he and his "teacher" were in the dinghy away from the boat. This person acted as their tender and communicated with the pearl boat concerning their reports on the amount of pearl shell on the sea bed in the area.

He was seen to surface several times in an area of shallow water, at least initially keeping near to the licensed diver. The other person in the dinghy, who was in charge of their hoses, was distracted for a time while watching the approach of another pearling boat which appeared initially to be on a collision course with their boat. When he next looked he saw that the victim's hose had gone tight, then that there were no bubbles. He pulled the hose in and brought the unconscious victim to the surface. He failed to respond to resuscitation efforts. Drowning was the cause of death. There had been no interruption to the air supply. Post-accident checks showed that harnesses were not used so the air hose was attached to the weight belt. There was no bail-out bottle. He was still wearing his mask and weight belt when pulled to the surface.

Through error it was only while the victim was in transit to join the boat that it was noted that he had not yet had a medical examination, but it was thought reasonable to let him join the trip and obtain the certificate on their return. As he had a history of taking medications for depression and hypertension and other unspecified conditions and was a user of cannabis, he would probably have "failed" his medical. However this was his first use of the hookah equipment and he had not impressed the skipper with his approach to the equipment and the only "training" he had received was a few words on emergency ascent as he was about to start his dive. He had been told to hold onto the other diver's line and watch his actions but evidently separated from him, although the latter apparently remained unaware of this until he surfaced.

1st HOOKAH DIVE. NO TRAINING. NO INSTRUCTION IN ITS USE. ESCAPED PRE-DIVE MEDICAL CHECK. EXPERIENCED "ADVANCED" SCUBA DIVER. INEXPERIENCED APPROACH TO HOOKAH APPARATUS. SEPARATION FROM TEACHER/BUDDY DIVER. ON MEDICATION FOR HYPERTENSION AND DEPRESSION. CANNABIS ? ON DIVING ASSESSMENT BEFORE EMPLOYMENT. DROWNED.

H 95/2

This abalone diver disliked using a cage while working but was aware that this was a dangerous time for period for shark attacks because the seals and whales were calving. Like the other local licensed abalone divers he was required to dive in controlled locations and defined times; restrictions which the divers consider to be unwise and unsafe. The shark attack was unexpected and lethal. The tender in the boat found it beyond his strength to pull the victim's body back into the boat and it was lost during the trip back to shore, though later recovered.

ABALONE DIVER. HIGH RISK AREA. SHARK ATTACK.

H 95/3

The "can-do, must-do" ethic of small commercial diving firms is based on the (correct) assumption that there are plenty of others willing to take on any job which might require too troublesome an attention to safety regulations and procedures. Such factors operated in this case. The task was to clear rubbish from within a water inlet tunnel which supplied several pumps, and to check the filter. This task was infrequently performed and, unlike most procedures at this works, there was no pre-prepared job protocol. As the work was not performed in-house, and the successful tenderer was using a sub contractor, the stage was set for each level to assume that another group had clarified safety practices. The diving firm employed had previously undertaken this job and were aware that they should check with the pump attendant that the relevant pump was closed down, and this they did. But they were unaware that another intake pump was also taking water from this passage.

The three man team were advised not to park their truck too close to the pit which gave access to the tunnel because there was risk from a nearby coal heap. When the work diver entered the tunnel his tender, with a safety line attached, kept hold of his air hose. Suddenly he felt a pull and than found the hose was no longer attached to the diver. He quickly descended and found a part of the torn hose but not the victim or his weight belt (found later). Greatly distressed, he reported his findings. A police rescue unit attended and one of the officers, realising there was still a slight chance the missing man might be alive, donned the spare set of hookah equipment and descended to search for him. This was particularly brave, but stupid, as he had never previously dived. By this time all the relevant pumps had been turned off. He managed with great difficulty to drag the victim from the pump impeller into which one foot had been drawn, and brought him back to the surface. CPR was sufficiently successful for him to reach hospital and there one leg was amputated, but he later died from the anoxic brain damage he had suffered. The dive team had not been made aware of the design of the water intake system and the works' safety officer had not adequately checked the plans for this work.

COMMERCIAL HOOKAH DIVER IN WATER INLET TUNNEL. ONE PUMP ALLOWED TO CONTINUE WORKING WHILE DIVER IN TUNNEL. HEROIC RESCUE EFFORT BY NON-DIVER POLICEMAN. TRAUMA. DELAYED DROWNING DEATH. INADEQUATE PRE DIVE SITE DESIGN INFORMATION AVAILABLE TO DIVERS.

SW 95/1

This fatality is included for its information value although it cannot strictly be considered to come into any of the above categories. This man was taking part in a dive master course and their boat was anchored only 150-200 m from another dive boat. It was suggested that this man and another have a swimming race to the other boat and back, in part a fitness test. The victim reached the other boat first and exchanged a few words with a person he knew aboard it. He was the faster of the two swimmers and was not puffed by the swim, unlike his fellow swimmer. He then led during their return swim. They were watched from both boats and when the other swimmer was seen to be going off course, due to swimming back stroke, all attention was on him until he corrected his course and completed his swim. Then it was noticed that there was no sign of the victim.

He had been swimming strongly and completed about half of the return swim when last seen. One of the divers immediately dived in and swam to where he had last been seen and was able to see him lying on the sea bed 12 m below. He was unable to breath hold dive so deep and called out for help. As soon as the victim was brought to the surface, by one of the instructors wearing scuba, and his 1-tooth dental plate had been removed, EAR was commenced.

It was later established that he had a history of epilepsy but had neither taken medication not suffered any known fits for many years. He had probably assumed he was totally free from fits. He had been a scuba diver, without any problems, for 8 years and was an experienced diver. No reason can be advanced for him to suffer a fit at this time other than over-vigorous swimming. He drowned during the short time he was unobserved but the outcome could well have been the same even had the delay before he was rescued been shorter.

SCUBA DIVER. SWIMMING TEST DURING DIVE MASTER COURSE. SILENT DROWNING AT SURFACE. EPILEPTIC FIT AFTER MANY YEARS WITHOUT FITS.

Discussion

It is a matter of repeated observation that death can come silently to some of those who are using a snorkel, even while they are leisurely swimming at the surface in apparently safe conditions. Such was the case in three of the four fatalities in this report. As no adequate reason for such fatalities is readily apparent, a sudden reflex inhibition of cardiac function following inhalation of salt water is invoked as the critical factor in the absence of any significant coronary artery disease. In BH 95/1 it is highly probable that poor swimming ability and a fear of being out of his depth played a part, aggravated by this being the first time he had used a snorkel and he was separated from his friends. Even the shallowness of the water offered no safety in the presence of such factors. In cases BH 95/3 and BH 95/4, sudden death occurred in persons with healthy coronary arteries. It is hard to see how even improved supervision of a crowd of swimmers could prevent this type of fatality. While the disabilities for which the swimmer/ snorkeller was taking medications are unlikely to have been a factor in his death, too few details of his medical condition are recorded to be certain whether this is so. In case BH 95/2, the reason for the tragedy is even more elusive as even the possibility of blackout post-hyperventilation appears unlikely.

The problem of understanding the reason for one person suffering CAGE while another does not is highlighted by case SC 95/1. While it is convenient to believe that the victim failed to exhale correctly during his ascent, such a conclusion would be the consequence of extrapolation from theory rather than one based on evidence of witnesses to this incident. There must be innumerable occasions where divers fail to exhale “correctly”, but few pay with their lives. The delay in symptom onset should be noted. Two other victims were untrained and grossly inexperienced (SC 95/2 and SC 95/9). Both were using borrowed equipment. In case SC 95/4 the diver also was untrained, but he was experienced. As he was solo diving there is no witness to what occurred.

In case SC 95/3 the victim broke the primary rule that if one is becoming low on air, ascent is imperative before running out of air. This diver, who claimed to have made 20 dives, including one to 30 m (100 ft), swam deeper in an ineffectual attempt to find an air donor when aware, rather belatedly, that he was nearly out of air. A critical “loading” factor in this incident was a strong current, which had required him to use most of his air supply. Failure to monitor the contents gauge adequately can be fatal. Four of the fatal episodes were associated with low/no-air situations. Two (SC 95/3, SC 95/7) included the factors of excess use of air due to currents while SC 95/4 appears to have omitted to check his contents gauge before he entered the water and probably chose, mistakenly, to use the tank he had used the previous day. In case SC 95/2 the victim should never have been taken diving by his buddy.

The night dive fatality occurred at the surface while using a snorkel. As the victim had an almost full tank of air, and was in no danger from surface conditions, her death is hard to explain. Adverse factors may have been the wearing of excessive weights, anxiety resulting from separation from her buddy, and the difficulty in reaching the inflation button on her BCD.

Water power was obviously critical in SC 95/9 but it was also important in three additional instances. In case SC 95/3 the victim probably used much of his air fighting a current, in SC 95/5 the rough water led the diver to attempt to swim through kelp, which apparently entangled his regulator and pulled it from his mouth, while in SC 95/7 the current was apparently greater than the group had previously experienced in their home country (and their range of diving experience is unknown).

There were four instances where pulmonary barotrauma was either probable or was demonstrated at autopsy as CAGE. It is to be noted that in two instances (SC 95/1, SC 95/3) the doctor who performed the autopsy was aware of the need for either an X-Ray or CT before commencing but appeared to be unaware of how to interpret the findings.

The critical factors in the three hose-supply diver fatalities were strikingly different In H 95/1 the youth was making his first such dive and was doubtless keen to show his abilities in the water after failing to impress the skipper of his alertness in learning. His scuba diving ability is not known but his health history would probably have proved a block to his being taken on as a trainee. Unfortunately the undoubtedly kindly meant offer of a chance for him to dive proved fatal in this instance.

The shark attack of H 95/2 was made possible by the diver’s dislike of working from a shark cage combined with a severe financial imperative to work in known dangerous conditions and blamed, rightly or wrongly, on the regulations which governed licensed abalone divers.

There is probably always an interplay between divers and those for whom they work. In H 95/3 the apparent reluctance of the works’ safety officer to recognise the necessity for stopping all pumps which worked on the passages which the divers were to enter, and their ignorance of the true anatomy of the tunnel system, conspired fatally. There can only be praise for the policeman who recovered the victim, though his inexperience could have resulted in this becoming a double tragedy.

Finally, to demonstrate the element of chance which can influence the occurrence of an “incident”, and indeed its outcome, consider SW 95/1. This experienced scuba diver had a forgotten history of epilepsy and, even had this been known, it is unlikely he would have been forbidden to swim, though he would not have been accepted for scuba training without an assessment by a neurologist.

Absolute safety is an impossible dream, so always keep alert and follow safe diving rules at all times. Remember the one rule which follows no rules is Murphy’s Law !

Acknowledgments

This investigation is an attempt to increase diver safety by indicating problems which others have not survived. It would not be possible without the unstinting and continued support of the Justice/Law/Attorney-General’s Departments in every State, their Coroners and Police Departments. This invaluable assistance in this safety project is greatly appreciated.

PROJECT STICKYBEAK

All who are interested in improving diver safety are asked to assist by sending information concerning fatalities (personal reports or news cuttings) because even events receiving great local publicity may be unknown to the compiler of this report. Please write (in confidence) with information to :-

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Dr D G Walker is a foundation member of SPUMS. He has been gathering statistics about diving accidents and deaths since the early 1970s. He is the author of REPORT ON AUSTRALIAN DIVING-RELATED DEATHS 1972-1993 which was published in 1998 (see Book Reviews on page 24). His address is PO. Box 120, Narrabeen, New South Wales 2101, Australia. Fax + 61-02-9970-6004.

FUNCTIONAL CHARACTERISTICS OF THE WRIGHT RESPIROMETER AND THE DRÄGER VOLUMETER UNDER HYPERBARIC CONDITIONS

John Whittle, Christopher S Butler and Ray Muller

Summary

An accurate and reproducible method for measuring minute volume under hyperbaric conditions is desirable for the safe conduct of assisted ventilation in the hyperbaric chamber. The Wright respirometer and Dräger 3000 volumeter were compared under normobaric and hyperbaric conditions (1, 2 and 3 bar or 101, 202, 303 kPa) to determine their precision and accuracy at physiologically relevant flow rates.

Although both devices demonstrated a high degree of precision, the accuracy of the Wright respirometer varied with both gas-flow rate and pressure. In contrast the accuracy of the Dräger 3000 volumeter was dependent on flow rate but independent of pressure. Both instruments are suitable for hyperbaric use so long as their limitations are understood.

Key Words
Equipment, hyperbaric research, treatment.

Introduction

Standard testing of commonly used volumeters under normobaric conditions has demonstrated an accuracy approaching +/- 5%.[1,2] Some published data exists on the functioning of the Wright respirometer under hyperbaric conditions, indicating over-reading by up to 18%.[3,4]

The high partial pressure of oxygen in the hyperbaric chamber imposes safety limitations on equipment such that devices requiring mains electrical power, heated wires or using touch button controls are unsuitable for use in the chamber. This excludes the majority of commonly used flow and volume meters leaving only mechanical meters (e.g. Wright respirometer and the Dräger volumeter) suitable for use. Sidestream end tidal CO_2 measurement, outside the chamber, may in future prove a useful alternative.[5]

Increases in gas density lead to reduced performance of ventilators, particularly if fluid logic controlled.[6] The reduction in the delivered tidal volume of set volume under hyperbaric conditions can lead to hypercarbia. As the Wright respirometer has been noted to over-read under hyperbaric conditions, this error is potentially compounded. The monitoring of ventilation with volumeters must therefore be conducted with an understanding of their limitations.

The Wright respirometer contains a light mica vane which rotates within a small cylinder (Fig 1). The wall of the cylinder is perforated with a number of tangential slits so that the air stream causes the vane to rotate. The rotation of the vane activates a gear chain which in turn drives the pointer around the dial. Calibration is performed using a sine wave pump to adjust the relationship between the number of rotations of the vane and the volume of gas which has passed through the meter.[7] This system has an inherent inertia so that the meter tends to over-read at high tidal volumes and flow rates. The instrument is suitable for use in conditions of high relative humidity (>60%) and temperatures up to 50° C.[1]

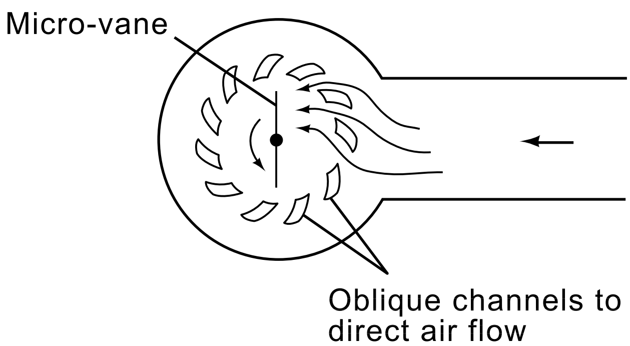

Figure 1. Wright Respirometer in cross-section (reprinted, with permission, from Sykes, Vickers and Hull[7]).

The Dräger range of volumeters register volume using two light interlocking dumb-bell-shaped rotors (Fig 2), which are set in motion by the passage of moving air at a speed dependent on the flow rate.[2] This movement is transferred to a pointer by means of a gear mechanism.

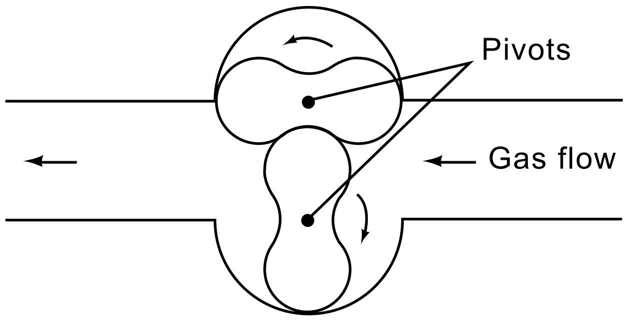

Figure 2. Dräger Volumeter in cross-section (reprinted, with permission, from Sykes, Vickers and Hull[7]).

The aim of this study was to assess and compare the accuracy and precision of the Wright respirometer and the Dräger volumeter, over a range of gas flows and chamber pressures used clinically, in order to determine the most suitable and reliable instrument for hyperbaric conditions.

Materials and methods

The Dräger Volumeter 3000 Adult and the Haloscale Wright respirometer were tested in the hyperbaric chamber against a standard calibrated one-litre syringe. The meters were tested at 1 (sea level), 2 and 3 bar and at flow rates of 20 and 50 l/min. To achieve reproducible flow rates over a series of measurements, the driving force for the syringe was provided by a rubber bicycle inner-tube. Outflow resistance to achieve the required flow rates from the calibrated syringe was achieved using an adjustable clamp applied to the outflow tubing. Mean flow rates were determined from these results. To demonstrate the reproducibility of the system at 1 bar a Vitalograph was employed to measure the output (Fig 3). During testing at 1 bar the volumeters were also tested with the Wright respirometer next to the pump. There were no noticeable differences in these readings from those obtained with the configuration used at higher pressures.

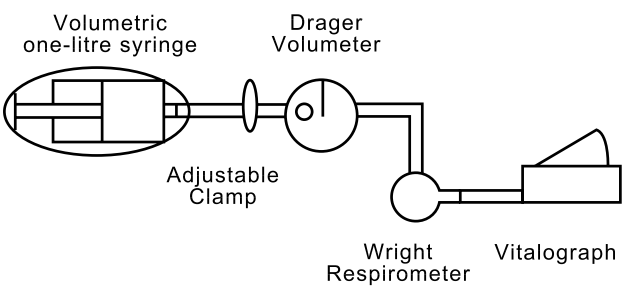

Figure 3. The configuration of the volumeter testing equipment at 1 bar. **Note.** Reversing the position of the volumeters did not alter their readings.

Due to the increased resistance to flow under hyperbaric conditions, the settings of the adjustable resistor had to be altered once the test pressure was reached. A stop watch was employed in the chamber to calculate flow rates because the Vitalograph was electrically powered.

Twenty readings from each meter at 20 l/min and at 50 l/min at each pressure (1, 2 and 3 bar) were performed to assess the meters' accuracy and precision. Throughout the study, chamber temperature was held at 25+/-2 C° and relative humidity was held at 85+/-5%. The composition of the chamber gas (air) did not alter and the hyperbaric chamber was located at sea-level.

Results

Table 1 (page 14) shows the Accuracy and Precision of all tests. Accuracy was calculated as the mean percentage difference from one litre as measured by the standard volumetric syringe. Precision was calculated as the mean percentage difference from the mean measured volume. In order to increase comparability across the test settings, the latter percentages were expressed as a proportion of the known volume (i.e. one litre) as opposed to a percentage of the measured means.

Discussion

The accuracy of the Wright respirometer was affected more by flow rate than chamber pressure. The two effects were additive so that at 3 bar and 50 l/min the meter readings were about 10% above the delivered volume. The precision of the meter was high with <1% mean difference from the mean measurement for all measurement conditions.

The precision of this instrument allows a correction to be made for flow rate and chamber pressure. However this correction factor is not linear and requires testing to be performed against a standard calibration syringe as described above. A solution to this problem is to have a number of meters each calibrated to a particular flow rate and chamber pressure.

In contrast, the performance of the Dräger 3000 volumeter was not greatly affected by altering chamber pressure. The meter was consistently inaccurate, over-reading by 8% at the lower flow rate of 20 l/min and by 14% at 50 l/min. Accuracy can be improved by recalibration. The importance of this finding is that a tidal volume

TABLE 1

MEAN AND MEDIAN READINGS WITH PRECISION AND ACCURACY CALCULATIONS

Meter	Chamber pressure	Flow rate	Mean reading [litres]	Median reading [litres]	Precision [percent]	Accuracy [percent]
Wright	1 bar	20l/min.	0.96	0.96	0.3	3.9
		50l/min.	1.03	1.03	0.5	3.2
	2 bar	20l/min.	1.03	1.03	0.5	2.5
		50l/min.	1.07	1.07	0.4	7.2
	3 bar	20l/min.	1.04	1.04	0.4	3.8
		50l/min.	1.10	1.10	0.3	10.1
Dräger	1 bar	20l/min.	1.08	1.08	0.4	7.9
		50l/min.	1.14	1.14	0.5	14.2
	2 bar	20l/min.	1.08	1.08	0.4	8.25
		50l/min.	1.13	1.13	0.5	13.5
	3 bar	20l/min.	1.09	1.09	0.4	8.7
		50l/min.	1.13	1.13	0.4	13.1

Precision is calculated as the mean percentage difference from the mean whilst accuracy is taken as the mean percentage difference from 1.

measured by the Dräger 3000 volumeter in a ventilated patient at 1 bar is the same volume at 2 and 3 bar. This allows monitoring of ventilation parameters to continue with confidence under hyperbaric conditions .

This study has demonstrated the contrasting performance characteristics of two readily available mechanical volumeters. The accuracy of both meters is affected by altering flow rate. However whilst the Wright respirometer becomes progressively less accurate with increasing pressure, the Dräger 3000 volumeter's performance is relatively independent of pressure. As such, we could recommend the Dräger 3000 volumeter for measuring tidal and minute volume in the ventilated patient under hyperbaric conditions. The proviso is that one must remember that the minute volume shown on the Dräger is higher than that delivered at all pressures. The Wright respirometer is also suitable if calibrated specifically for a set chamber pressure.

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This investigation was carried out in the Department of Anaesthetics and Intensive Care Townsville General Hospital, Eyre Street, Townsville, Queensland 4810, Australia when Dr Whittle was a registrar in the department.

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THE WORLD AS IT IS

NOT IN FRONT OF THE CHILDREN, PLEASE !

Douglas Walker

Key Words

Diving medicine, medicals, research, training.

It is probably common to all cultures for certain matters to be regarded as not for the ears of the young, or those who are still uninitiated. This is true not only in family situations but also in all trades and occupations, even the medical fraternity. It is a common criticism of the Learned Professions that they frequently fail to explain matters fully to lay persons when they discuss their problems with them and give advice. There are a number of reasons for this including inability to communicate easily with those whose understanding of the topic is limited. However the least noble is attempting, consciously or otherwise, to keep the expert's lack of exact knowledge and understanding from becoming too obvious. While there are dangers in setting aside the aura of omnipotence and mystery which so greatly enhances the effect of utterances from Authorities there is more danger to the recipient if expert advice is too uncritically accepted as irrevocably correct. All Authorities are human and can make mistakes. While this is possibly most evident in connection with legal opinions, it can occur even in the medical environment. This essay is an attempt to define some of the matters in which, just possibly, criticism could be levelled at the involvement of doctors in Diving Medicine.

There has always been an uneasy relationship between divers and the medical profession. The former wish to obtain advice to make their diving practices safe, but do not welcome any restrictions. What is undeniable is that some conditions make diving more hazardous. Some are medical conditions, others are environmental or equipment caused and some are due to the diver's inability to dive safely. The parties were at loggerheads for many years because of the tendency for those regarded as Authorities in diving medicine to assume they had an absolute understanding of the problems of divers, married to which was their assumption that any discrepancy between fact and theory was the result of the untruthful and unreliable nature to the divers' reports. This was particularly noticeable in the field of decompression sickness (as it was then the practice to call it), as the Experts "knew" that the dive tables, being constructed by mathematicians and tested on naval divers, were safe and therefore "safe" dives never resulted in symptoms. These beliefs held back progress for decades and it probably still lingers on because divers naturally seek to put the best gloss on their activities they can, and have certainly have no greater desire to reveal their mistakes than do any other group of people.

The medical profession was, in some ways, hoist by it's own petard when diving problems were taken under its wing. When medical supervision of diving was limited to naval divers, the results of medical disqualifications, excellent training and careful supervision appeared to back the experts beliefs. However, it became obvious that medical disqualification had little influence on diving accidents in recreational divers. But because diving medicals had been promoted as a means of reducing diving accidents, diving organisations and lawyers rapidly accepted the medical claim to be able to decide whether or not a person is "fit to dive" as a way of avoiding any blame arising from a diving accident. The present vogue for requiring evidence-based medical decision making may in time mitigate this.

It has never been, nor will it ever be, true that the medical profession could decide that a person was fit to dive because there are so many interacting factors in any misadventure and the strictly medical ones are only rarely the most significant. However, the fact that different countries have been long known to have radically different views on the matter of diving medical standards without evidence of differing diver morbidity has not noticeably influenced opinions or led to questioning of shibboleths. Dick Smith has talked of "affordable safety" in relation to aviation (and was howled down by the unthinking) and similar choices exists in regards to every human activity, including the degree of restriction divers are willing to accept, whether it be in relation to health factors, gas mixtures, choice of tables, or any other matter, in order to make their diving activities safer.

It is a stated purpose of our Society "to promote and facilitate the study of all aspects of underwater and hyperbaric medicine. To provide information on underwater and hyperbaric medicine". How completely do we fulfil this noble objective? The Society's Committee has in the past made pronouncements on the inclusion of out-of-air ascents as being essential in basic training without any evidence that these do in fact improve the student's chances of survival when they run out of air. There are no statistics, nor is there any likelihood of any, as about half those who die from running out of air die alone. What we need is the collection of reports of low/out-of air events, ranging from those so adequately managed that there was no problem to those where morbidity occurred. These should then be analysed to ascertain why the situations arose, how they were managed and the outcomes. But that is a pipe dream as medical diving training guidelines (Australian Standards) are regarded as having validity, in a Court of Law, as being what an informed and careful medical practitioner would do.

In Australia there is, unlike the situation in the UK, no way to formally question or challenge the Standard except through a duel between competing expert witnesses in a Court of Law. While the Standards are good guidelines, they are too rigid to be a binding rule because they fail to take into account the imprecision of our information. Indeed personal experience and gut feelings still appear to wield far greater sway in the decision making process than does appeal to actual case data in these two important opinion areas (value of out-of-air ascent practice in the present basic training courses and validity of our Medical Standards for safe diving). SPUMS made a welcome change to its medical advice, by recommending giving the diving applicant advice on possible medical risk factors rather than stating baldly that he/she is medically fit/unfit to scuba dive, in 1995. But the legal fraternity will take much convincing before it releases doctors from the assumption that they have given a yes/no decision on the medical fitness to dive of the person they have examined. Doctors are often forced to make decisions based on inadequate data and are influenced in reaching their decisions on management by a necessary reliance on protocols which may themselves be based on insufficient data. We should always remain aware of this factor when we are giving advice or stating our opinions.. It is time that it was clearly recognised that the morbidity expectation of any given diver could possibly often be better predicted by Tarot cards than the medical findings. Unfortunately no financing body has provided funds to make this hypothesis the subject of a rigorous double blind investigation!

To be serious, it is time for systematic collection and analysis of the range of factors present in the many types and degrees of diving misadventures. We do not know the "natural history" of divers with asthma (and this label itself has a wide range of definition and significance in practice), or diabetes, or cardiac conditions. We do not know because nobody has taken the trouble (and it will indeed be a difficult task requiring the involvement of many Society members) to obtain the data. Few, so far, have been willing to accept the odium associated with investigating factors which "so very obviously" preclude acceptance as compatible with safe diving. At the present time, in general, we know only of instances where the medical condition and some misadventure coincide, rarely indeed do we hear of those persons who have some "adverse" condition but in whom no misadventure has occurred.

In the matter of reaching a reasoned conclusion on the value of out-of-air ascent practice, there is need to create a wide ranging collection of data describing incidents where an out-of-air situation has occurred in order to identify why it occurred, what was the response, and what the outcome. My investigations have been limited to where the outcome was fatal and have therefore failed to address the problem adequately. Here is a situation where co-operation between the diving fraternity, instructor organisations, and those collecting data on diving incidents could lead to a pooling of resources to the benefit of all divers. Similarly there is a need to have an impartial and medically confidential assessment of why cases of DCI, and even deaths, sometimes occur during training. Although the Queensland Workplace Health and Safety (diving) inspectors are attempting to investigate misadventures in divers their work is hampered by the perception, true or false, that they are have a police function and are seeking crimes to prosecute. This perception results in delayed and probably gross under-reporting of problems.

It is time the diving industry recognised the value and importance of research into factors associated with misadventures affecting their clients, even if they are not too worried by such matters affecting their members. The "don't dob in" mentality in the Australian diving industry has undoubtedly contributed to the occurrence of the recent double fatality, the loss of the Lonergans while diving, with others from a commercial dive boat, on the Great Barrier Reef. The aviation industry has a scheme for reporting-without-retribution (unless the law has been seriously breached) and such a scheme would be of great value to the diving industry. Indeed it is long overdue.

One problem with obtaining data is partly due to the efficiency of the equipment used when diving. Another is the commercial imperative to minimise any comments on the possible dangers in order to encourage members of the public to dive. These combine to make safety appear far too easy to maintain. There is also the fear of rocking the boat by revealing that there exist some serious differences of opinion, that questions have been ducked which cast doubt on accepted dogma. Inexperience is without doubt a critical factor in the safety equation and some divers appear to be dangerously unaware of their true level of ability. It is time we diving doctors made it clear to both divers and potential divers the limits on our knowledge and the narrowness of the safety margin. It is time for us, both members of the Society and others in the diving community, to research the above critical factors and to speak more honestly about both the limits of our medical ability to prevent morbidity and the fact that we cannot always completely reverse DCI damage. It is time to share our information and to talk honestly to general diving community, the "children" we seek to keep in ignorance about the limits of our knowledge, and enlist them in our continuing search for accurate information, the foundation on which to build to improve diver safety.

Dr D G Walker is a foundation member of SPUMS. He has been gathering statistics about diving accidents and deaths since the early 1970s. He is the author of REPORT ON AUSTRALIAN DIVING-RELATED DEATHS 1972-1993 which was published in 1998 (see Book Reviews on page 24). His address is PO. Box 120, Narrabeen, New South Wales 2101, Australia. Fax + 61-02-9970-6004

THE DIVING AND HYPERBARIC MEDICINE SIG

John Knight

Key Words

Diving medicine, hyperbaric oxygen, qualifications, training, treatment, standards.

Readers who are not anaesthetists may well ask what is a SIG? Some years ago the Australian and New Zealand College of Anaesthetists (ANZCA) had many requests to provide a forum where those who worked in the field of pain relief could meet and discuss their problems and solutions. A place where like minded people could meet and learn from each other. So the College's first Special Interest Group (SIG) was born. Others followed, all in some way closely connected with anaesthesia.

By chance anaesthetists have come to dominate the medical staffing of Australian hospital hyperbaric units, most of which come under the umbrella of a Department of Anaesthesia or of Anaesthesia and Intensive Care. As an aside the Executive Committee of SPUMS has always had a high proportion of anaesthetists. One year they were all anaesthetists except for one retired GP. Even in these enlightened days there are five anaesthetists listed inside the front cover of the Journal as Officers of the Society.

Years ago the Treasurers and Secretaries of SPUMS got fed up with letters being addressed to them in their official capacities for years after they had left the job because they used their home addresses. In 1990 SPUMS contracted with a high profile secretariat in Sydney, which was to provide a permanent address for SPUMS, for their services. These turned out to be far more expensive than quoted and the contract was terminated within six months. The Royal Australasian College of Surgeons (RACS) was not interested in being our postal address and so we tried the newly formed College of Occupational Medicine who accepted our request. However they decided to become a Faculty of the College of Physicians about the time that the Faculty of Anaesthetists (FA) RACS turned themselves into ANZCA. As Anaesthetists were the largest group of doctors in SPUMS we were able to persuade the new College under their wing.

Bob Wong (Dr R M Wong) used his Chairmanship of the College Education Committee and a spirit of change in the College Council to bring forward the idea of a SIG for Anaesthetists connected with Hyperbaric and Diving Medicine which he had suggested in 1994. But his ideas went far wider than that. He wanted to see come into existence a body open to all doctors who were interested in diving or hyperbaric medicine. A body which would hold meetings at the Annual Scientific Meetings (ASMs) of Anaesthetic bodies, which would offer more opportunity for discussion than the well filled programs of the SPUMS ASMs and provide for close-to-home discussion of the joys and sorrows of daily hyperbaric life. With a smallish group, the number of doctors involved in full and part time hyperbaric medicine is well under 100, it would be easier to arrange and carry through co-operative research projects.

Bob drew his colleagues attention to the vast improvements in the training available since the formation of the FA and its publication of training standards and the much faster rise in the standards of anaesthetic and ancillary equipment provision when the College updated the requirements for anaesthetic training accreditation and the safe administration of anaesthetics. There are no agreed performance and training standards for hyperbaric units available to interested people. Who was to take the lead in producing such standards? There are two groups involved, doctors and supporting staff (technicians and nurses). Neither group can do the job on their own.

Some people have suggested that SPUMS should pull its socks up and step into the breach. After all it is the biggest diving medical organisation. But the proportion of its members who are expert, or want to be, in hyperbaric medicine is only about 5%. It is a much better idea to let the hyperbaricists sort their problems out. The chances of getting a good result are much higher. But the only hyperbaric medicine society is the Australian and New Zealand Hyperbaric Medicine Group (ANZHMG) which was formed by the Directors of the various Australasian hyperbaric units.

The big snag for the ANZHMG to become a standard setting body is that standards have to be enforced and the AMZHMG are all hospital employees, in a bad position to say to management "You must change the way you do things". However the ANZCA, which is a body well removed from hospital managements, has been able to insist on hospitals upgrading equipment and buying new devices which improve the safety of patients.

Bob's idea was to use the SIG as a start for the process of accreditation of hyperbaric units, hospital and free standing. Not a bad idea, making sure that the plant (equipment) is of the right standard and that the doctors are properly trained, the nurses are properly trained and the technicians, without whom the chambers would not work, have a proper training. These are tasks quite beyond SPUMS.

Australian standards exist for recompression chambers in the diving world, but the non-diving world in Australia is still running on the Compressed Air Code published by the Australian Standards Association in 1970. This was mostly to cover workers in compressed air in tunnels but it is all there is to cover nurses tending patients in compression chambers! Standards Australia is producing a new standard which will have two sections, one for treatment chambers and one for tunnels and caissons. Bob Ramsay of the Hyperbaric Technicians and Nurses Association has produced a well thought out series of proposals (HOTFIG) which will be going before appropriate Standards Committee in the very near future. Australian Standards (nowadays they are ANZ Standards) have no force unless they are adopted by government legislation. So to get one standard adopted Australia-wide legislation has to pass through six State, one Federal and three Territory parliaments. And those acts should be updated every time the standard is updated, but they are not. At the inquest on an occupational diver who died in 1997, Western Australia's legal standard for occupational diving safety was AS 2299/79, a far cry from state of the art, two revisions (1990 and 1992) and 19 years out of date. It is only where an Australia wide organisation inspects and maintains standards that this sort of thing can be avoided. The medical Colleges are the ones to maintain medical standards.

The only qualification in Hyperbaric Medicine which is available in Australasia is the SPUMS Diploma of Diving and Hyperbaric Medicine. It involves a little bit more than my DObstRCOG and my DA did in the 1950s. The requirements are a basic and an advanced course and six months full time experience, with a thesis for publication in the SPUMS Journal. It was introduced in 1974 when SPUMS could not find a University willing to give it a bed. Diplomas were not for Universities we were told then. So, as there was a need for a qualification, SPUMS pushed the boat out. In those days there were two multiplace chamber units in Sydney (HMAS PENGUIN and Prince Henry Hospital), a monoplaces at the Royal Adelaide Hospital, Prince Henry's Hospital, Melbourne and the Royal Perth Hospital.. Five medical chambers for all Australia. The Diploma is just that, a basic qualification in Diving and Hyperbaric Medicine. Now that Australia has 12, New Zealand has 2 and PNG has one medically supervised chamber units listed on the back cover of *Offgassing*, the Journal of the Hyperbaric Technicians and Nurses Association, a higher qualification is needed.

Who should administer such a higher qualification? Certainly not SPUMS which does not even have a centralised administration. Efforts to get Schools of Public Health interested in running even the Diploma all ended in failure when they realised they would have to set up a program and administration for students numbering one to three a year!

With anaesthetists being medically responsible for most hyperbaric units in hospitals it seems to me quite sensible to use the SIG format to form a body with diving doctor-anaesthetists and proceed to work on standards and the requirements of a proper length training, as many holders of the Diploma honestly admit that they learnt much more in the next two years of hyperbaric work.

The ANZCA constitution required the Executive of the SIG to be members of the College. But the draft constitution for SIGs allows the SIG to set its own criteria for membership of the group. Ordinary members have to be FANZCA, or Ordinary members of the ASA or NZSA, interested in Diving and Hyperbaric Medicine. That covers every anaesthetist. Those with a special interest in Diving and Hyperbaric Medicine who are not entitled to be full members can be Associate Members. At its meeting, on December 8th 1998, the Executive decided that they would limit Associate Membership, at present, to medical practitioners which makes it possible for full members of SPUMS to be admitted. Once we see how things are going consideration will be given to widening the scope of Associate Membership, but new SIGs, just like babies, should walk before they try to run.

For those who feel that SPUMS is being left out of the SIG the composition of the SIG, like most College Committees, has membership from each State with current interested groups represented. I represent SPUMS and Mike Bennett represents the ANZHMG, which has the status of a sub-Committee of SPUMS. Bob Wong (Chairman) represents WA, Ian Unsworth NSW, Chris Lourey Vic, Chris Acott SA, Margaret Walker Tas and David Griffiths Qld. All except one of the members is a member of SPUMS and the non-member was President of SPUMS from 1976-1979. Two members are SPUMS Life Members and three are Ex-Presidents. A very solid SPUMS overlap.

The first meeting of the executive dealt with the draft constitution and membership qualifications, outlined the role of the SIG, discussed the accreditation of hyperbaric facilities and the requirements for an adequate education in Hyperbaric and Diving medicine and how it can be provided. These two matters were delegated to sub-committees to produce documents for consideration in May 1999. Other matters which got a natter were HOTFIG, qualifications for medical directors of hyperbaric units and hyperbaric oxygen treatment (HBOT) for sporting injuries. No decisions were reached but views were clearly aired.

Applications to join the SIG, which means being proposed and seconded (and there should be no problems there), should be addressed to the Diving and Hyperbaric Medicine Special Interest Group at the Australian and New Zealand College of Anaesthetists, 630 St Kilda Road, Melbourne, Victoria 3004, Australia. The College has a website, where it is hoped to construct a home page for the SIG. To access a SIG website from the College website requires a password. For the moment letter or phone (03 9510 6299) is going to be more use to those wanting more information about the SIG

Dr John Knight FANZCA, Dip DHM, has been a Committee member, Secretary and President of SPUMS as well as Assistant Editor and, since 1990, Editor of the SPUMS Journal.

SPUMS NOTICES

SOUTH PACIFIC UNDERWATER MEDICINE SOCIETY

DIPLOMA OF DIVING AND HYPERBARIC MEDICINE

Requirements for candidates

In order for the Diploma of Diving and Hyperbaric Medicine to be awarded by the Society, the candidate must comply with the following conditions:

1 The candidate must be a financial member of the Society.

2 The candidate must supply documentary evidence of satisfactory completion of examined courses in both Basic and Advanced Hyperbaric and Diving Medicine at an institution approved by the Board of Censors of the Society.

3 The candidate must have completed at least six months full time, or equivalent part time, training in an approved Hyperbaric Medicine Unit.

4 All candidates will be required to advise the Board of Censors of their intended candidacy and to discuss the proposed subject matter of their thesis.

5 Having received prior approval of the subject matter by the Board of Censors, the candidate must submit a thesis, treatise or paper, in a form suitable for publication, for consideration by the Board of Censors.

Candidates are advised that preference will be given to papers reporting original basic or clinical research work. All clinical research material must be accompanied by documentary evidence of approval by an appropriate Ethics Committee.

Case reports may be acceptable provided they are thoroughly documented, the subject is extensively researched and is then discussed in depth. Reports of a single case will be deemed insufficient.

Review articles may be acceptable only if the review is of the world literature, it is thoroughly analysed and discussed and the subject matter has not received a similar review in recent times.

6 All successful thesis material becomes the property of the Society to be published as it deems fit.

7 The Board of Censors reserves the right to modify any of these requirements from time to time.

Key Words

Qualification

1999 SPUMS ANNUAL SCIENTIFIC MEETING

will be held on the island of **Layang Layang**, Malaysia

Friday April 30th to Sunday May 9th 1999

The Guest Speakers will be Dr Richard Moon (USA), who was a guest speaker at the 1997 ASM at Waitangi in New Zealand, and Dr Alf Brubakk (Norway), who attended the 1998 ASM in Palau.

The Convener of the Annual Scientific Meeting is Dr Chris Acott. The provisional title of the theme of the meeting is *Gas bubble injury and its treatment*.

To present papers contact:

Dr Chris Acott
Hyperbaric Medicine Unit, Royal Adelaide Hospital,
North Terrace, Adelaide, South Australia 5000
Telephone +61-8-8222-5116. Fax +61-8-8232-4207.
E-mail guyw@surf.net.au

Speakers at the ASM must provide the printed text and the paper on disc to the Convener before speaking.

The Official Travel Agent for the meeting is:
Allways Dive Expeditions
168 High Street, Ashburton, Victoria, Australia 3147
Telephone + 61-(0)3-9885-8863.
Toll Free with Australia 1-800-338-239
Fax +61+(0)3-9885-1164.
Email: allways@netlink.com.au

THE

SPUMS

HOME PAGE,

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SPUMS JOURNAL INDEX 1971-1998, IS AT

http://www.SPUMS.org.au

CONSTITUTIONAL AMENDMENTSS

The Committee will be presenting the changes below to the Annual General Meeting in Layang Layang in May 1999.

The reasons are as follows.

1 To emphasise the honorary position of the Committee Members of SPUMS. The Editor is paid an honorarium (much less than would be charged by an outside publisher for the same work) for the many hours of work required to produce the Journal and the Society's other publications. As a condition of the honorarium he is obliged to attend the ASM. As there has never been an election for the position of Editor since SPUMS was founded, the Committee considers that this should be an appointed position with a tenure of 3 years like elected Committee Members.

2 The Public Officer has to live in Victoria, as SPUMS is incorporated in Victoria. This limits the choice of Public Officer to Victorian members. The Public Officer's main duties are to provide reports of the Annual Financial Reports and any motions passed at the Annual General Meeting of the Society to Office of Fair Trading within a month of the meeting. The two persons who have been Public Officer were both instructed by the Committee to stand for election, in neither case has there ever been another candidate. Given this history, the Committee considers that this should be an appointed position with a minimum tenure of 3 years.

2 The Committee has been co-opting the Chairman of the Australian and New Zealand Hyperbaric Medicine Group, a sub-committee of SPUMS, to its meetings and wishes to continue to have access to this person's advice. This position is not by election of the SPUMS membership so cannot be an elected position.

3 The same logic applies to the position of the representative of the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated.

4 There was no mention in the constitution of the Board of Censors which is a body appointed by the Committee.

5 To correct a failure to change rule 2 when the end of the financial year was changed to 31st December some years ago.

The changes proposed are

Under the heading **Definitions**

Alter rule 2.(a) by changing the words *30th June* to *31st December*.

Under the heading **Committee**

Insert new rules

21.(d) The Australian and New Zealand Hyperbaric Medicine Group is a Sub-Committee of SPUMS.

21.(d) (i) Its members must be members of the South Pacific Underwater Medicine Society Incorporated.

21.(d) (ii) Its Chairman shall have a place on the Committee.

Under the heading **Officers of the Committee**

Alter rule 22.(a) by adding the words, *the Chairman of the Australian and New Zealand Hyperbaric Medicine Group* after the words the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated

22.(a) will then read

The Committee shall consist of a President, Immediate Past President, a Secretary, a Treasurer, Public Officer, the Editor of the Journal, an Education Officer, a representative appointed by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated, *the Chairman of the Australian and New Zealand Hyperbaric Medicine Group* and three other members of the Association entitled to vote.

22.(b) to be renumbered 22. (d)

22.(d) will then read

Each officer of the Association shall hold office until the annual general meeting three years after the date of that person's election but is eligible for re-election.

22.(c) to be renumbered 22. (e)

22.(e) will then read

In the event of a casual vacancy in any office referred to in sub-clause (a), the Committee may appoint one of the Association's members entitled to vote to the vacant office and the member so appointed may continue in office up to and including the conclusion of the annual general meeting next following the date of that person's appointment.

Insert new rule

22.(b) All officers of the Association, except those detailed in 22.(c), shall be elected by postal ballot if the number of candidates exceeds the number of vacancies.

Insert new rule

22.(c) The Editor, the Public Officer, the representative of the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated and the Chairman of the Australian and New Zealand Hyperbaric Medicine Group shall be appointed to their positions. The first two by the Committee, the others by the New Zealand

Chapter of the South Pacific Underwater Medicine Society Incorporated and the Australian and New Zealand Hyperbaric Medicine Group respectively.

Under the heading **Publications and Publicity**

Alter rule 41 by adding the words *The Chairman of the Australian and New Zealand Hyperbaric Medicine Group is the Association's official spokesman on Hyperbaric Medicine matters.* after the first sentence

Rule 41 will then read

Public statements in the name of or on behalf of the Association shall only be made by the President, Secretary or by another member of the Association specifically designated by the Committee to speak on any particular matter. *The Chairman of the Australian and New Zealand Hyperbaric Medicine Group is the Association's official spokesman on Hyperbaric Medicine matters*.

Insert new heading

Board of Censors

Under the heading Board of Censors

Insert new rules

42. The Committee shall appoint a Board of Censors.

42.(a) The Board of Censors shall be composed of the Education Officer, the President of the Society and a Director of a Hyperbaric Medicine Unit in Australia or New Zealand.

42.(b) The role of the Board of Censors is to advise the Committee on all matters of education in diving and hyperbaric medicine.

42.(c) A Diploma of Diving and Hyperbaric Medicine may be awarded by the Society, on the recommendation of the Board of Censors, to a member who fulfils the requirements set down by the Board and published in the SPUMS Journal from time to time.

Cathy Meehan
Secretary of SPUMS

ROYAL AUSTRALIAN NAVY
MEDICAL OFFICERS' COURSE
IN UNDERWATER MEDICINE

November 22nd to December 3rd 1999

The course concentrates on diving physiology, fitness to dive, and emergency management of diving injuries.

Practical involvement includes opportunity to dive with different types of equipment and a recompression chamber dive.

The course fee for 1998 was $1,330.00. The 1999 fee is expected to be about the same but is yet to be determined.

For information or to enrol contact

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LETTERS TO THE EDITOR

THE 1997 ANNUAL SCIENTIFIC MEETING IN WAITANGI, NEW ZEALAND

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6/1/99

Dear Editor

Now that all the 1997 SPUMS ASM papers have seen the light of day, thanks to the Editor's patient cajoling of the authors (including this writer!), I wish to make a few comments as Scientific Convenor.

I had three goals as Convenor. First, to make this one of the very best scientific meetings that SPUMS has had. That this was achieved is clearly seen from the large diverse and high quality set of publications that have appeared in the Journal over the past year or so. What this does not tell non-attendees, though, is the high standards of the actual presentations by almost all the speakers (even those who left their slides behind).

Our visiting speakers, Richard Moon and James Francis, were outstanding. James' paper on mechanisms of spinal decompression injury[1] will stand as ***the*** definitive review of this important field of research for the next decade. That such a paper should appear in a non-indexed journal like ours is a considerable mark of respect for SPUMS.

Secondly, we Kiwis were determined to show the doubting Ozzies that northern New Zealand has world class diving rivalling anywhere in the world. In this we were fortunate to have excellent weather. I doubt if anyone will forget the three wonderful days at the Poor Knights. I knew we had succeeded in this goal when Chris Acott graciously admitted he had had a wonderful time!

Finally we wished this meeting to be a financial success for the Society. In this we were disappointed. It was only due to significant sponsorship that the meeting came close to breaking even. Registrations were only about 75% of what we had hoped for, and the support from New Zealand members was particularly disappointing. They missed out on the most outstanding diving medicine meeting there is likely to be on this side of the Tasman in 20 years.

From the comments I have received many have a misconception of the costs involved in running an international meeting with world class speakers. Likewise the Australian response could have been better. For all those who did attend, thank you very much for making this one of the most enjoyable and satisfying experiences (even if it was incredibly busy) of my professional life.

I would like to acknowledge some important contributions. Des Gorman ensured the meeting's success by setting up Richard and James as our visitors and negotiating successfully with the Accident Rehabilitation and Compensation Insurance Corporation (ACC) for major financial support.

Other financial support came from NorthPower and PADI International for the workshop. SPUMS is especially indebted to Paterson Industries for the considerable support with equipment and teaching personnel for the very successful first aid workshops on board "Tiger IV". Nicholas Roberts from Auckland would be the best paramedic instructor I have come across. Dr Rees Jones gave me considerable support and encouragement behind the scenes.

Thank you one and all to all SPUMS speakers. Bill Day's cheerful company throughout the week and his atmospheric after dinner talk on the General Grant expedition are special memories for me.

My last thought has to go to Conference Manager, Tania Townsend (of Fullers and then the Waitangi Resort) who, with her blend of youth, professionalism and sunny personality proved the most unflappable front-of-house person one could wish for.

Times like these are what SPUMS is all about. I can only encourage more members to attend meetings. Attendance by less than 10% of members is a poor showing and unfortunately the rest do not know what they are missing. The Editor is the lucky one, his job demands he go to every meeting!

Michael Davis
Medical Director, Hyperbaric Unit

Reference

1 Francis J. Mechanism of spinal cord injury in DCI. *SPUMS J* 1998; 28 (1): 29-41

Key Words
General, letter, meeting.

STIRRING THE POSSUM - UK STYLE

PO Box 120
Narrabeen
New South Wales 2101
15/1/99

Dear Editor

The ancient art of "stirring the possum" is far from dead. It has recently been resuscitated in the UK in the disguise of *Pressure Point*, a news sheet produced by Dr Ian Sibley-Calder.

Having been fortunate enough to receive copies of the first two issues, I can confirm that this Editor has jumped into the dangerous arena of questioning, where diving medical orthodoxy seeks to make questioners ashamed to proclaim their doubts, refuses them publication opportunities, or tries to drown them with indifference and silence. Government Departments are not the only places which practice a policy of quietly ignoring correspondence on matters they do not wish to admit require a reasoned response.

In its first issue *Pressure Point* states that its aim is to encourage ongoing education, debate, and discussion in the fields of diving and hyperbaric medicine. There will be an attempt to review articles and gather stories, particularly those of an interesting or controversial nature. The first issue raises the matter of whether "obesity" (those with a BMI > 30) should automatically be regarded as reason to refuse a "fit-to-dive" certificate to a commercial diver. Remember, this is a UK publication and there the medical examination system for occupational divers is more advanced than in Australia, having a medical committee to deal with all appeals where a professional diver feels the "fail" decision to be unjust.

As readers will realise, the BMI is a crude measure indeed and should not be treated as the sole criterion of health. The author asks for correspondence, a request which deserves a good response. There are also brief references to the possible benefits of exercise during decompression, a no-no by present beliefs if ever there was one. As this is a report of an article by Dr Jankowski[1] in *Undersea and Hyperbaric Medicine* it should not be too readily discounted. An additional borrowing from *Undersea and Hyperbaric Medicine* records the work by Edge, Grieve, Gibbons et al. with diabetic divers.[2] This is a subject which is not discussed here in Australia. Finally, there is a brief commentary by Dr David Elliott on the resumption of diving after a diving incident. It will be interesting to read the papers presented at the UHMS meeting on this topic, held at Cozumel in 1997, when it is published.

The second issue was no less informative, including a reference to the use of hyperbaric treatment where a Jehovah's Witness refused transfusion despite critical anaemia from antepartum haemorrhage. This is especially interesting in view of a current case being appealed to the High Court of Australia[3] where the husband reluctantly gave assent to a transfusion after three days and everyone even remotely involved is being sued by the fully recovered patient and other cases,[4,5] where the patient's wishes were granted and deaths resulted. There are brief notes about exploding teeth, a problem which can affect commercial divers while welding underwater, and comments about the diving methods chosen for the search to find and recover fragments of the TWA plane which crashed off Long Island a few years ago. The poor caisson workers get a mention too, with the comment that modern tunnelling methods have reduced their risks, but also their employment chances.

The further issues of this news sheet are awaited with interest. There do not seem enough Holy Cows left to identify for slaughter to support a long publishing life, but there probably are!

Readers are encouraged to contact Dr Ian Sibley-Calder at Westfield, Westwood Avenue, Hornsea, East Riding, HY18 lEE, UK, for details of how to subscribe to *Pressure Point*. For those who have out of date atlases, East Riding was part of Yorkshire in the days before I moved to Australia.

Douglas Walker

References

1 Jankowski LW, Nishi RY, Eaton DJ and Griffin AP. Exercise during decompression reduces the amount of venous gas emboli. *Undersea Hyperbaric Med* 1997; 24 (2): 59-65
2 Edge CJ, Grieve AP, Gibbons N,O'Sullivan and Bryson P. Control of blood glucose in a group of diabetic scuba divers. *Undersea Hyperbaric Med* 1997; 24 (3): 201-207
3 *The Australian* 1998; Nov 24: 1,2
4 *The Australian* 1998; Aug 22: 2,4
5 *The Australian* 1998; Dec 11: 1,15
6 *The Australian* 1998; Nov 26: 3
7 *The Australian* 1998; Dec 1: 12,15

Key Words
Letter, underwater medicine.

BOOK REVIEWS

REPORT ON AUSTRALIAN DIVING DEATHS 1972-1993

Dr Douglas Walker
Edited by Dr John Knight, Dr David Pescod and John Lippmann
1998 ISBN 0 9587118 1 X
Published by J L Publications and DAN S E Asia-Pacific. Available from DAN SEAP PO Box 384, Ashburton, Victoria 3147, Australia.
Price from the publisher $35.00 plus postage and packing.

Essentially this is a volume which should become compulsory reading not just for diving doctors but for those who call themselves divers. In particular, it is a must for all those who teach diving. This is a case-by-case account of what is known about the circumstances of each one of more than three hundred diving deaths in Australian waters. Apart from shark attack, suicide and sudden ilnesses most of these deaths, with hindsight, were totally avoidable.

The report is predominantly the output of "Project Stickybeak", a voluntary task begun and continued by Dr Douglas Walker on behalf of SPUMS in 1972, the year of the Society's foundation and still continuing. In his "Introductory paper, 1972", announcing the proposal and requesting information and assistance, Dr Walker does not explain how this curious title was chosen. It could be an early example of using an odd name merely to catch public attention or maybe it is derived from some intricate thought process incomprehensible to those who are not Australian but, but either way, what is remarkable and important is that, over these years of data collection, Stickybeak has maintained momentum. It has kept a modest profile with interim reports published in the SPUMS Journal and elsewhere. I have found the collected results to be compulsive reading, perhaps for much the same reasons as a Shakespearean tragedy is addictive, you know that some characters are going to die but who and where and how and why? And, as you continue to read, you know that inevitably it will happen all over again. Why this repetitive pattern? How can so many fail to learn from the ultimate examples provided by others?

This is a sombre story spread over 22 years and is a story which does not get better as one moves on from one year to the next. Each time one turns the page, one expects that some safety lesson has been learnt, that a stupid omission or short-cut has now been rectified, perhaps by highlighting the potential for error in manuals or traing and that divers have begun to recognise their own technical and physiological limitations. If so, the pattern of fatality should change over the years, but no the theme is repetition. As Carl Edmonds reminds us in the Foreword, "He who does not know history, is doomed to repeat it".

Any early optimism about the ability of individual divers to learn from the errors of others soon disappears because one has only to compare the first few years of this extended review with the final years and, alas, there seems to be no detectable improvement. For example, in the analyses to be found in Part Two, one of the largest groups is headed "Gross inexperience or no recent diving". One must acknowledge that the process of retrieving information about fatalities, the total numbers of divers being trained and, no doubt, other relevant factors will have changed during the intervening years. Nevertheless 6 of the 10 deaths among scuba divers in 1973 were in this misguided category and so also were 6 of the 9 in 1992.

This report is not in quite the same style as those on recreational diving accidents from other sources. For example the annual reports of the British Sub-Aqua Club include not only the fatalities but also cover every known diving incident in the UK. Nor is it in the same style as the annual reports from DAN in the USA which include fatalities but which also focuses on the more frequent cases of decompression illness. The diving deaths in these other reports are therefore overshadowed numerically by the many non-fatal diving incidents with a result that the lessons to be learned from the fatalities receive only a portion of the spot-light. Thus, by confining itself to analysing only diving deaths, the Australian report has a greater potential with this type of accident for making an effective impact upon training and safety.

The analyses in Part Two tell their own story. In a few incidents there may ave been some valid reason for non-compliance with safety training, but not in the majority. Most of us know that many scuba divers fail to drop their weight belts in an underwater emergency or when in trouble at the surface, but here are the actual data. It is shown that 65% of these fatalities did not drop their weights. One teaches the importance of the buddy system, but in this series 80% of the divers died alone. More than 50% were low on air or had none at all. In only 12% did the victim inflate a buoyancy aid. Et cetera, et cetera. Hard, tragic data. However this documentary volume merely records and analyses these deaths and it is not its function to make wider recommendations.

By providing the circumstances of each of these 300 or so fatalities within a single volume, an opportunity has been created to use their deaths to enhance health and safety. The patterns of death revealed here should stimulate the recreational training agencies to review and revise their bassic approach to diver training. Individual case histories might even be suitable for classroom teaching, although that approach is not likely to be welcomed by those who in their instruction of novices wish to emphasise the safety of sport diving. Nevertheless, it would surely be a positive step for this book to become part of the official curriculum of all would be instuctors.

Finally but not least, this volume, by reproducing a selection of covers from old SPUMS Journals, is also a tribute to the skills of the cartoonist, the late Peter Harrigan, whose sharp drawings, such as "Mickey Mouse Medicals" (not included here) and "Come on in ... anyone can do it" (to be found on page 82) did so much to highlight the successful campaign by SPUMS for proper fit-to-dive medicals and the appropriate training of the doctors conducting them. Many any of his cartoons remain relevant to the teaching of diving safety today and the publication of some of them here should also help to reduce future diving deaths.

Compulsory reading on the beach, before the next dive.

David Elliott

Key Words

Book review, data, deaths, diving accidents, safety, training.

SIMPLE GUIDE TO REBREATHER DIVING

Steve Barsky, Mark Thurlow and Mike Ward

Best Publishing Company, P.O.Box 30100, Flagstaff, Arizona 86003-0100, U.S.A.

Price from the publishers $US 26.95. Postage and packing extra. Credit card orders may be placed by phone on +1-520-527-1055 or faxed to +1-520-526-0370. E-mail divebooks@bestpub.com .

This well illustrated book is exactly what it claims to be. It should be read by all divers wishing to use a rebreather, before they use one, as it takes the reader on a simple walk through the advantages, disadvantages and dangers of rebreather diving and the need for learning about their new equipment.

It emphasises the need for the potential rebreather diver to regard him or herself as a novice once again. There is a lot to learn before one can use a rebreather safely. Unfortunately many rash rebreather users have given up diving, permanently and with no chance of recommencing again. This self selection has meant that successful rebreather users have learnt to accept the need for self discipline, keen concern for depth maintenance, knowledge of the risks of oxygen toxicity and of hypoxia on ascent.

All types of rebreather get a mention, semi-closed and closed, oxygen and mixed gases. The need for training and careful maintenance and self discipline in learning about all that can go wrong and how to cope successfully with the problems which are likely, and unlikely, to arise are emphasised.

The authors are to be congratulated on their clear and easily understood contribution to diving safety.

John Knight

Key Words

Book review, equipment, rebreathing, training.

THE CALIFORNIA ABALONE INDUSTRY: A PICTORIAL HISTORY

A L. "Scrap" Lundy

Best Publishing Company, P.O.Box 30100, Flagstaff, Arizona 86003-0100, U.S.A.

Price from the publishers $US 39.95. Postage and packing extra. Credit card orders may be placed by phone on +1-520-527-1055 or faxed to +1-520-526-0370. E-mail divebooks@bestpub.com .

The recorded history of the abalone industry in California certainly predates that of Australia, but examination of the aboriginal middens around Cape Otway and at other places along the south coast gives good evidence that abalone formed part of the diet of the local tribes going back several thousand years. There is probably evidence along the Californian coast that the native Americans also made abalone part of their diet, although this does not rate a mention in Lundy's book.

The narrative begins with the influx of Chinese labourers to the Californian goldfields in the 1850s. Many of these had been "shanghaied" from coastal villages so they tended to gravitate back to the familiar environment in the new country. I found it fascinating that these fishermen collected their catch from boats, using viewing boxes and long poles to lever the shellfish off the rocks. They never actually entered the water and the abalone escape rate must surely have been high.

The author has done an enormous amount of personal research with the result that it is written very much as a personal narrative. This has resulted in frequent repetition of facts, which I found rather galling after a while.

It was not until the Japanese entered the industry in a big way around the turn of the century that the abalone collector actually got into the water. Apart from a few divers who followed the Ama tradition of breathhold diving in thin cotton clothes the temperature of the water led most divers to adopt hard hat and formal diving dress. This meant that many more abalone came within reach of the divers and it is reported that a diver could collect 40 to 50 dozen abalone a day. With the introduction of larger motorised boats and power driven compressors, larger catches became the norm and the export market flourished.

The advent of World War II resulted in most of the Japanese fishermen being interned, which left the field open for many more Caucasian Americans to enter the industry. At the same time, areas formerly closed to abalone fishing were opened up and market forces required that species other that the traditional red abalone were also collected.

The author also tells of the devastation that the sea otter colonies caused down the coast. These animals, protected after their near extinction by fur traders, pay no heed to catch sizes or species whereas divers were restricted to taking only mature shell. As a consequence the sea otter caused total denudation of the shellfish stocks with no hope of their return at a later date.

On his return from active service as a US Navy diver, Philip Widolf soon discarded the heavy traditional (standard) diving helmets and used the US Navy lightweight rig and a light weight Desco constant air flow full-face mask held on by an elastic spider, still with surface supply. This too was cumbersome so he discarded all but the mask and wore several layers of long underwear and used swim fins, which gave him vastly increased mobility. Then he designed and made a covering suit of rubber sheet to prevent the rapid onset of hypothermia in the cold water and the new mobile dry suited diver was born. The Desco mask was not comfortable to wear for extended periods because of its shape and tendency to float up as it filled with air. This led to his designing a new mask made of bronze with air control and exhaust valves. This meant that if a diver got into trouble on the bottom, for the first time, he could readily ditch his gear and return to the surface making his way of life much safer.

In the 60s, Bev Morgan and Ramsey Parks modified this Widolf mask by inserting the second stage from a single hose SCUBA regulator through the glass port, opening the way for the later development of the now famous Kirby-Morgan band mask. This meant that the compressor on the boat could be much smaller as the divers air requirements were much reduced. Morgan was also responsible for the development of the neoprene foam wet suit.

Many of the divers who later went on into the fledgling oil industry in California and the Gulf of Mexico were introduced to diving on the abalone beds of the California coast. They took with them the equipment, the skills, the experience and the innovations which allowed the oilfield divers more latitude and versatility than those divers who had come directly from the rigid techniques, schedules and equipment of the Services.

It is a pity that the text and most of the photographs were printed in sepia ink on cream paper, which made reading quite difficult in all but an extremely good light. With this colour combination one loses a lot of the contrast and definition and many of the photographs become almost worthless. This situation improved to a certain extent later in the book where colour photographs appear.

Lundy's book is a goldmine for the serious student of diving history and a fascinating read for those, like myself, who have been actively involved in the abalone industry. He has recorded interviews with many of the people who actually participated in the industry. With good editing it could have been a lot easier to read with much less repetition. The poor reproduction of the photographic material certainly detracts from the quality of the work.

David Davies

Key Words

Book review, equipment, history, marine animals, occupational diving.

A VENOMOUS LIFE

Struan Sutherland.

ISBN 1 86447 026 7.

Hyland House Publishing, 387-389 Clarendon Street, South Melbourne, Victoria 3205, Australia.

Price from the publishers $Aust 29.95. Postage and packing extra ($Aust 5.00 in Australia).

This book is worth every cent of its price. While there is not a laugh on every page there are enough to make reading the book a pleasure. Combine that with a fascinating account of a life devoted, very successfully, to venom and antivenom research which has brought the author world-wide fame as well as much credit and commercial success to his long term employers Commonwealth Serum Laboratories (now privatised as CSL Ltd) and you have a very interesting book.

Professor Sutherland's early years, the country boy making good, were interesting and he must be almost the only person with an MD, a DSc and the Fellowships of Colleges of Physicians and Pathologists who had to repeat the first year of the medical course!

After his early hospital appointments Dr Sutherland held a Short Service Commission in the Royal Australian Navy. Those readers who, like the reviewer, served with the RAN, or the Naval Reserve, in the 1960s will recognise and remember the characters who appear in the amusing anecdotes of service life.

It seems that Dr Sutherland, almost accidentally, tumbled into his life's work by chance. He saw an advertisement for a Commonwealth Medical Officer, applied, liked the idea of the work and got the job. This led, over the years, to much research on toxins and venoms and the production of antivenoms.

All Struan's work has been based on a desire to use his knowledge and special skills for the benefit of his fellow humans. This book is full of examples and I will mention two. His studies of the "treatments" used for first aid for snake bites led to the pressure-immobilisation method that is now the recommended method of first aid. The envenomed extremity is wrapped in firm bandage, tight enough to compress the lymphatics and small veins but definitely not tight enough to be a tourniquet. Then the limb is splinted and the patient carried to somewhere where antivenom can be administered. For a better description of the procedure see pages 371-373 when you buy the book. This firm bandaging prevents movement of the venom or toxin until the bandage is undone. This should wait until an intravenous drip has been set up as deterioration can occur rapidly. If this occurs the bandage can be reapplied while antivenom administration is readied.

Another advance was the production of a snake venom detection kit which enabled the treating doctor to know which venom had been injected. As most snake antivenoms are made in horses their potential for anaphylaxis and serum sickness is high. Multiple antivenoms required larger volumes than single venoms so using a specific antivenom has less risk of side effects as well as being more effective.

Research could be frustratingly slow, for the very powerful venoms were present in tiny quantities in each insect. As one should expect some projects did not succeed but the isolation of Sydney Funnel-web spider venom, which can be fatal to primates but very few other mammals, and the production of its antivenom was a success. Testing the antivenom, produced in rabbits, was also very difficult as ethical considerations prohibited testing a known lethal venom in humans and financial considerations limited the number of rhesus monkeys which could be used.

It is clear that Dr Sutherland has been fully aware that he could be difficult to get on with. It is not often that prominent researchers are suspended by their employers for objecting to staff cuts in their laboratory. This happened to Dr Sutherland in 1981. His story is unbelievable, in a rational, co-operative world, but it happened. There are court records to prove it. Buy the book and draw your own conclusions as to why CSL management were so keen to do without his services.

Struan also discusses the effects of the privatisation of CSL, which included vast paper profits for senior executives granted share options and notes that, not quite four years later, no Tiger snake antivenom was available on 19/1/98 (the first time this had happened in sixty years), are discussed. The various Commonwealth governments appear to have decided that it is the patient's worry if he or she gets bitten by a snake, certainly not theirs to see that the public is protected.

The outlook for venom research in Australia, the world leader in the venomous snake stakes, has luckily been improved, not by the Commonwealth Government but by the formation of the Australian Venom Research Institute within the Department of Pharmacology in the University of Melbourne with Associate Professor Struan Sutherland as the Foundation Director. This is the work of Professor James Angus and various generous benefactors including the Victorian Government. The Commonwealth Department of Health has kept away.

One episode in Struan's life has been left out of the book. In 1985 he was a guest speaker, with Carl Edmonds, at the SPUMS Annual Scientific Conference held on Bandos Island in the Maldives. Besides enlightening us about toxins and the treatment of snake bites and allergies, he led us through the intricacies of hydroponics.

Struan has fought for what he believed in all his life. This book, a celebration of a life spent improving treatments and helping animals as well as humans, was written while Parkinson's disease had interfered with his voice and hand control. It is full of lessons for all medical personnel and anyone interested in how the world goes round.

John Knight

Key Words

Book review, envenomation, general interest, history, toxins.

SPUMS ANNUAL SCIENTIFIC MEETING 1998

EARLY DECOMPRESSION EXPERIENCE: COMPRESSED AIR WORK

David H Elliott

Key Words

Decompression illness, history, osteonecrosis, working in compressed air.

Introduction

Although there must be more than 100 divers at this meeting, I doubt if many have been exposed to compressed air in a civil engineering project. One of the last major such projects in the Southern hemisphere that I am aware of was the construction of the Auckland Harbour Bridge some 40 years ago but of course since then there have probably been many smaller contracts for sewage outfalls, bridges and tunnels. So what, if anything, does the history of compressed air work have to do with recreational diving in the South Pacific today?

The answer lies in studying these pioneering exposures to pressure in order to find observations which might improve our understanding of today's pressure-related illnesses and their prevention. The development of these early engineering procedures was associated with a gradual realisation that these achievements also led to some adverse medical consequences for those who were exposed to raised environmental pressure. Methods for decompressing the workforce did not exist at the beginning of this industry, and written procedures of around 100 years ago are scarce. The history of this era deserves more study than this summary can provide. Clinical examination in those days could be detailed but some of the terms are difficult to interpret and many of the therapeutic approaches are, with hindsight, totally inappropriate. Over the same period of some 50-60 years there were parallel developments in diving with similar lessons to be learned from diving case histories, but the total number of persons in diving were many fewer. The exposures in compressed air workings are generally very much longer and this difference is associated with some differences in clinical presentations and long-term effects from which useful conclusions can also be made.

Recognition of a new medical problem

Professor Trouessart in his report to the Industrial Society of Angers in 1845 is quoted by Paul Bert[1] as attributing the concept of the caisson to Denis Papin who said in 1691 that if fresh air were pumped constantly into a bell on the sea-bed by strong leather bellows, the bottom of it could be kept almost entirely dry and one could work on the sea or river bed just as effectively as at the surface. There was no industrial need to develop Papin's practical idea for working in compressed air until 1839 when coal deposits were found 20 metres under the quicksands and alluvial deposits of the river Loire in France. Although Sir Thomas Cochrane, had some 10 years previously patented the concept of using compressed air in water-laden ground for constructing shafts and tunnels, the credit for making such ideas work in caissons goes to M. Triger. A complete account of the caisson he developed for opening up this coalfield was presented to the French Academy of Sciences in 1841 and published in 1845. [2]

The technical aspects of these developments do not concern us here but, as they provided some of the very first observations of the effects of raised environmental pressure upon man, it is worth mentioning what was reported at the time. Triger noted the increasingly nasal quality of speech with increasing depth and, on reaching around 3 atmospheres, the loss of the ability to whistle. Though not the first to do so, he also described pains in the ears associated with compression and decompression and further said of the workmen that ... *they become much more tired when working in compressed air than in open air. We think that this is the result of the very great humidity ...., which hampers the insensible perspiration and promotes the more rapid secretion of sweat in those who have to exert their physical powers ... . Perhaps this humidity would also explain the somewhat severe pains in the articulations experienced by some workmen a few hours after leaving the shaft ... .*

He also describes the case of two workmen who, after .... *seven consecutive hours in compressed air, experienced rather keen pains in the articulations, half an hour after leaving the shaft. ... Rubbing with spirits of wine soon relieved this pain in both men; they kept on working the following days.*

As Paul Bert commented some years later, Triger gave no details about the duration of the decompression, only that they opened the cock gradually.

The method developed by M. Triger was then used to open coal mines in Northern France where, as reported by M. Blavier,[3] the engineering problem of penetrating permeable limestone was much greater than that of penetrating soft quicksand. After his own exposure to around 2.6 to 3 atmospheres on 5 December, he reported that the next day .... *keen pains appeared in the left side, and we felt a rather severe painful discomfort for several days afterwards. ... After we were quite free from these pains, 28 December, we were anxious to try the experiment again*

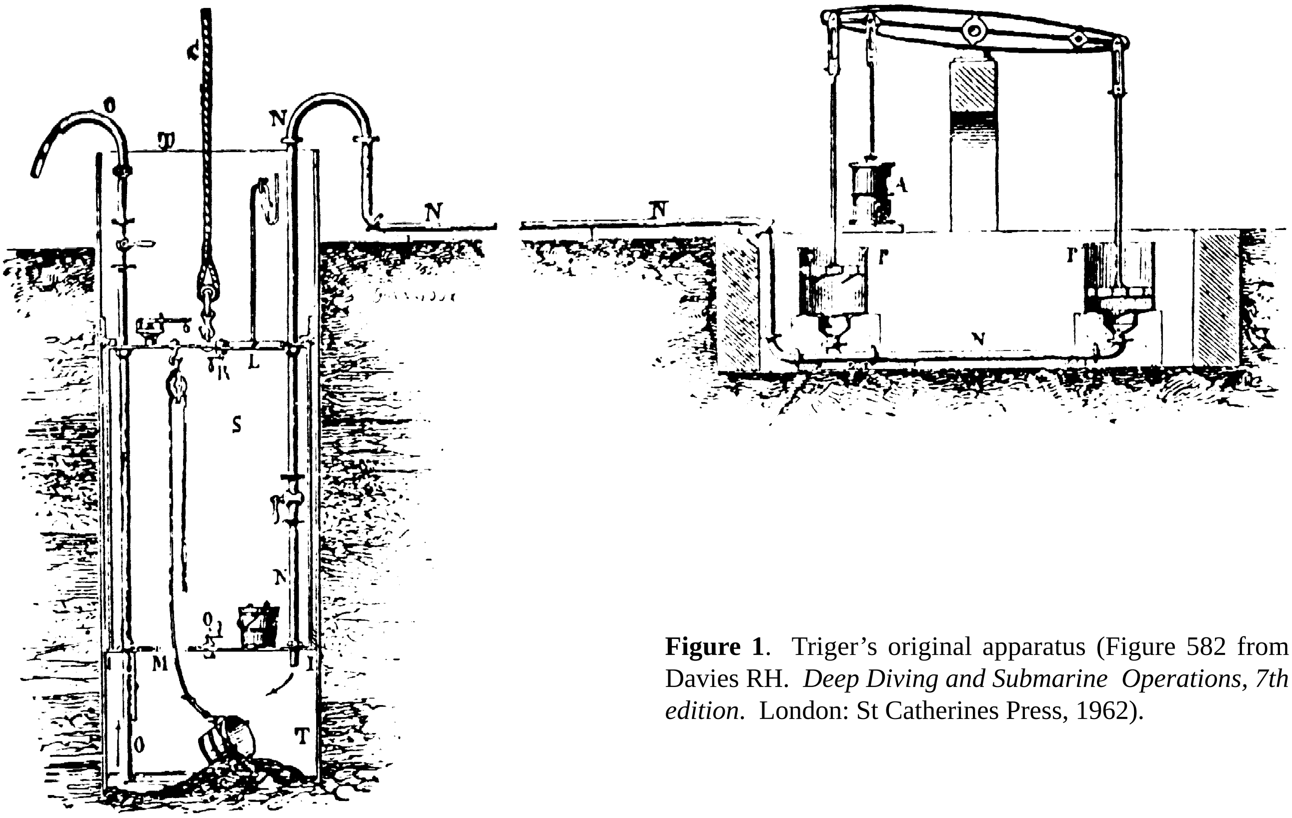

Figure 1. Triger's original apparatus (Figure 582 from Davies RH. *Deep Diving and Submarine Operations, 7th edition.* London: St Catherines Press, 1962).

... at the same hour, that is, 20 hours after our exit from compressed air, we felt in the right side pains just like the former ones, which kept us numb for four or five days.

The maximum pressure there was 4.25 atmospheres (32 m) with shifts twice daily of around 4 hours, each with a 45 minute compression phase, and each followed by a 30 minute decompression. The Superintendent of the mine in Douchy had assured Blavier that the various symptoms of the workmen, *heaviness in the head or pains in the legs*, almost always coincided with some excess committed by them between shifts. *Only one of them experienced complete paralysis of arms and legs for 12 hours.* Of the 64 workmen there, 2 died.

Dr Pol and Dr Watelle went to these mines in order to examine these phenomena but their study, upon their own admission, was not designed for publication. It was a collection of *observations made without plan.*[4] Nevertheless from their observations they deduced that "*The danger does not lie in entering a shaft containing compressed air; nor in remaining there a longer or shorter time; decompression alone is dangerous; pay only when leaving*".

As one reads through their case descriptions from among the men employed there, one is struck by decompression experiences which, hopefully, are now only rarely encountered and, if they do occur, would be managed differently. For example, Case 1-V:

One day, an hour after leaving the shaft,... he complained of distress; when placed in bed he lost consciousness. Pulse full and rapid, face congested, respiration short and stertorous; obscure sound everywhere ... bled, purged, plastered. After 4 hours, return to consciousness. In 3 days, cured.

From among the 10 or so serious cases, i.e., those with more than just musculo-skeletal pains, one notes a curious absence of what might be termed "spinal" manifestations. The observed symptoms were attributed by them not to bubbles but to "*superoxygenation and congestion*". Nevertheless, they said that one is justified in hoping that a sure and prompt means of relief would be to recompress immediately, then decompress very carefully. Indeed,[1] at another mine in Belgium, some workers with severe attacks of articular pain were completely relieved by returning to work, but then found that the *pains returned after leaving the apparatus*. To put these developments into chronological perspective, the paper by Pol and Watelle[4] was published in 1854, the same year that Florence Nightingale went to the Crimean War.

With the subsequent use of caissons in bridge building around Europe and then around the world, illness among the workforce was reported time and time again. For example, symptoms[5]... *were much worse when the change was made from caisson to the open air: serious, even fatal, symptoms appeared then.*

And another case .... *completely prostrated ... unable to walk, hands and feet cold and without sensation. Was seated with his feet in the fire, so that several of his* *toes were burned without feeling the heat... Two days later he was cured except for his burns.*

During the building of a bridge in Bayonne,[1] a 20-year old engineer decompressed in 4 or 5 minutes after 60 minutes at 4 atmospheres. Within a few minutes he had dizziness followed by unconsciousness. When he regained consciousness after 3 hours he was paraplegic with also loss of sensation in the arms. After bedsores and other complications, function began to return after seven weeks. Twelve years later he could climb one flight of stairs with difficulty. Bert[1] also quotes a mining student's own description of his decompression manifestations. *During the decompression I felt a discomfort which I attributed to the cold. After I had come out, when I wished to raise my right arm, I could not make it reach a definite point. My sight was affected, and I saw ... much as one perceives objects after whirling around several times. The paralysis grew worse .. I could not walk.. I was dazzled and my eyes refused to serve me at all. My eyes were dull and glassy, they told me, and perceived only a white vaporous light. I recovered first the use of my leg, then of my arm; ... and I saw distinctly for longer periods. Finally ... my headache disappeared in the open air and I went home, having nothing but fatigue to remind me of my former experiences.*

Many similar clinical observations continued to be made and were accompanied by various explanations of the underlying patho-physiology many of which can now be dismissed as fanciful. In the absence of any facts, these were vehemently argued and used by some to justify the apparent need for a slow decompression but with a totally incorrect logic.

At the same time, there were others[1] who did not consider the rate of decompression to be important but said, for example, that the major factor was chilling during decompression....*if the thick and icy mist, which is sure to appear, seems to be penetrating you, make haste!*

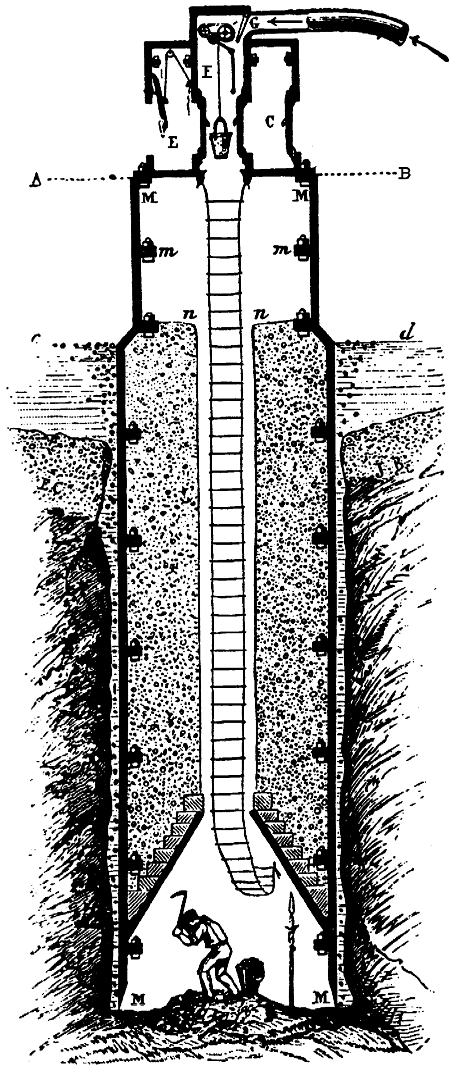

Figure 2. One of the first caissons used in France by Foley (Fig.6 from Paul Bert[1]).

But a few curious clues did emerge. For example, M. Bucquoy[6] in 1862 watched the use of dry cupping-glasses placed around a workman's painful knee. The cups had been applied properly by a skilful orderly but, repeatedly, after a certain time they fell off. He concluded that the elimination of free gases explained the prompt disappearance of the knee pain through repeated application. He went on to conclude that the gases of the blood are increased in quantity, and ...*at the time of decompression, these gases tend to be liberated again, just as the carbonic acid escapes from charged water when the stopper is removed from the bottle containing it.*

Another comment, possibly based on Hoppe-Selyer's observation in 1857 that decompression to altitude had caused bubbles in the heart and blood vessels of a rat,[7] was made by a Danish physiologist, Panum[8] who, after studying dogs' blood pressure at depth in order to disprove some other fanciful hypothesis, said that the symptoms of decompression ...*result from the fact that the air which has suddenly been liberated in the blood vessels ... forms embolic obstructions in different vascular regions.*

An engineering report,[9] based on some 10 locations around France, stated that the diseases caused by these accidents could be prevented by the use of the means which they specified...

- *woollen garments in the lock chamber*
- *not to open the cock too quickly... M. Triger requires that the decompression last 7 minutes, and states that then the symptoms disappear completely. It seems to us that this time should vary with the constitution of the workman.*

No thoughts about depth and duration of exposure yet, though in Belgium around that time M. Barella suggested a decompression rate of 10 minutes per atmosphere.[10]

One of the first bridges to be constructed in the United States using work in compressed air was over the Mississippi at St Louis where a large number of workmen was exposed to pressure (34 m at the East pier; 4.4 bar). With decompression in 3 to 4 minutes, 30 of the 352 men were seriously affected and 12 died. The clinical report on some of these cases is interesting but not relevant to the prevention of decompression injury.[11] The report by the engineer, Captain Eads[12] after whom the bridge is named, describes the use of 'galvanic rings' of zinc and silver which were worn by the majority of the workmen to stop attacks of paralysis or pains. He also mentions that the physician at the site was severely affected after 2 hours at 90 feet (27m) and, in Dr Jaminet's own words,[13] *...We were only three minutes and a half in the air-lock to return to the shaft or normal atmosphere. ... epigastric pain ... dizzy ... . I reached home ... three quarters of an hour after leaving the caisson. The last effort brought me to my office where in a few minutes I became paralysed...* in both legs and left arm and also had transient aphasia. Within 10 hours or so his paralysis had gone though he felt weak for another week or so.

Some physicians, Eads says, ... *maintained that a slower return to normal pressure would have been less dangerous; others blamed too rapid compression ... ... we believe that the real cause lies in the long duration of the stay in this air ... at pressure, and not the rapid changes to which it is exposed.*

This belief appears to be based not on nitrogen uptake but on a 30 to 50% reduction of respiratory rates at pressure, and thus is a reaction *...against the introduction of oxygen in a proportion 2 to 3 times greater than in normal atmosphere.*

As Eads stated elsewhere in his report *...The duration of stay in the air chamber was gradually shortened from 4 hours, to 3, to 2, and finally to 1 hour* after which there were no more fatalities.

Many of these are among the observations and reports which formed the background to Paul Bert's experimental work,[1] the real importance of which is that he reported evidence in 1878 to suggest that on decompression ... *all the symptoms, from the slightest to those that bring on sudden death, are the consequences of the liberation of bubbles of nitrogen in the blood, and even in the tissues when compression has lasted long enough.*

He made no hypotheses concerning the dynamics of the dissolved gases but concluded: "*The great protection is slowness in decompression; ... from 3 to 4 atmospheres, one hour ... ... The longer the workmen remain in the caissons, the more slowly they should undergo decompression, for they must not only allow time for the nitrogen to escape from the blood, but also allow the nitrogen of the tissues time to pass into the blood*".

These rates are between 0.5 m and 1 m per minute, similar to those proposed later by von Schrotter,[14] 20 minutes per atmosphere. Bert also proposed that if a workman becomes stricken one should return him to a pressure greater than that from which he came, then make decompression very slowly.

Frustrated beginnings of decompression theory

Paul Bert's clear conclusions in 1878, together with his pioneering work on oxygen toxicity, mark the start of the scientific approach to hyperbaric physiology. One might expect such logical recommendations to be adopted by the doctors who had responsibilities for compressed air workers, but not so. Dissemination of knowledge and the subsequent conversion of non-believers took time and in the meanwhile much preventable morbidity continued.

The name "bends" for the musculo-skeletal variety of decompression illness was adopted from the name of a then fashionable ladies' posture, the Grecian Bend, by the men who were working on the Mississippi bridge at St Louis and those working on Brooklyn Bridge in New York. In 1870 the Brooklyn workings were at 20 m (79 ft) and, although Dr Smith[15] at that location also recognised that re-exposure to compressed air would alleviate the symptoms, recompression was not made available for the 110 cases of serious decompression injury that did occur. Dr Smith rejected the intravascular bubble theory because Bert's experimental work had been from a greater pressure than that experienced by tunnel workers and because he attributed the illness to the long-standing hypothesis of vascular congestion due to vasomotor paralysis

When the construction of a tunnel under the Hudson was resumed in 1879, it reached 30 pounds [per square inch] (about 20 m depth) and at the beginning provided some of the worst recorded decompression risks ever encountered in industry. In 1882 there was a mortality of 25% of the workforce there in one year but, fortunately for the tunnellers, insufficient funds caused work there to cease.[16]

When work on the Hudson tunnel restarted in 1890, *an air compartment like a boiler was made in which the men could be treated homeopathically, or re-immersed in compressed air. ... The medical lock should be used at once, as it does not appear to have much effect after some time has elapsed.*

By introducing the lock,[16] the deaths were reduced to only two in fifteen months, 1.5%.[17]

In the year that Marconi patented radio, 1896, tunnelling was being carried out extensively in London and other great cities in response to the increasing demands of urban development, Sir Ernest Moir[16] made his address on *Tunnelling by Compressed Air* to the Society of Arts and Snell[18] published his book on *Compressed Air Illness: Blackwall Tunnel.*

It may have been an era of major civil engineering throughout Europe and North America, but not everyone involved necessarily understood the physics of pressure. In the early 1890s when the Blackwall Tunnel had completed a significant phase of its construction, the builders threw a champagne party for dignitaries at pressure but, because of the raised ambient pressure, they could not get the corks out! When at last they succeeded, by drilling holes through the champagne corks, they found that the champagne was flat. After all that effort to keep the party going, they drank it anyway. There were some reports about their subsequent decompression experiences in the press but, alas, no detailed account by any of the party-goers.

In 1904, just a year after the Wright brothers had flown the first aeroplane, the Hudson river tunnel was completed after more than 30 years work and many deaths. In decompression theory, this brings us to the time when Professor Haldane,[19] in addition to working on decompression tables for the Admiralty, was preparing tables for compressed air work. The principle was to decompress rapidly to half the absolute pressure in 3 min and then continue at a specified linear rate to the surface. For example, after working in compressed air at 40 psig (27 m) for 6 or more hours exposure, ascend from 13 psig at 9 minutes per pound (about 2 hours decompression). The response of employers in the construction industry[20] could have been anticipated ...

... are these times practical?
... out of the question ...
... it quite appals one to think of taking so long.

Between 1906 and 1908 more tunnels were built under the East River in New York with twice daily exposures to pressures up to 42 psig (28 metres) and Dr Keays, the doctor there, reported[21] more than 3,600 bends, including 20 fatalities. He described the association of abdominal girdle pain with serious spinal cord injury and many other clinical features. Also, from a total of more than half a million decompressions, he analysed the bends percentages in the first shift (0.35%) and the second (0.72%) of the two 3-hour shifts in one day (i.e., cumulatively 1.07%), and also in more than 10,000 single eight-hour shifts (0.62%) clearly suggesting that one decompression might be better than two. However the "split shift" continued for many more years.

It then became necessary to raise the pressure in the East River tunnels to 40 psig. The shifts were 3 hours, twice daily with a 3-hour interval between them (though it is not clear if this was a true surface interval or if it included the previous decompression time). Because prolonged decompression stops were not welcomed by the workers, the response of the contractor[20] was to install an intermediary lock at 28 psig, in which the workmen had to spend 5 min, and another chamber at 12 psig in which they had to spend 8 min and then take 15 min for the final decompression to surface. The intermediate stop time which was necessary was introduced without it being noticed because the two chambers were some 1,000 ft (300 m) apart in the length of the tunnel and, by the time the stragglers walking from one chamber to the next had been rounded up, the total decompression time became 48 min. They used 330 men for this deep phase, none new but only experienced workers. At first the workmen rebelled against the final 15 minute decompression, but then agreed and no fatal or serious cases resulted thereafter.

In 1912, Sir Leonard Hill published his book on *Caisson Sickness and the Physiology of Work in Compressed Air*[20] which was another landmark in the application of good physiological science to a complex environment. He despaired of the many *astounding hypotheses* that still abounded more than 30 years after Bert's work. He methodically demolished each of the hypotheses that he reviewed and presented experimental evidence in disproof of some. He particularly deplored the slowness of many doctors around the world to accept *the magnificent work of the French school*. Hill also reviewed the solution of the respiratory gases at pressure into the blood and their uptake into the tissues and argued the importance of duration under pressure as a factor. He also emphasised the close concordance between the results of his own experimental work and those of Haldane but was concerned that the advantages of stage over continuous decompression might not be as great as Haldane had suggested.

Hill had hoped to recoup some of the expenses of his own team's decompression work with pigs by *a sale of the victims* but found that bubbles in the fatty tissues prevented bleeding the pigs to ensure the whiteness of the meat and that, because of the pink fat, *no butcher would take a second pig from us at any price*. Hill then used two experimental subjects, Major Greenwood and himself, to achieve pressures up to 7 atmospheres (62 m, more than 200 feet) but the decompression profiles are not detailed in his book. His experiments led Hill to believe in the value of moderate exercise during decompression and, on his suggestion at the construction of the Greenwich tunnel, the men were made to climb the ladder out of the shaft immediately after decompression to atmospheric pressure.

The development of safer tables for compressed air work has continued since then in parallel with, but independently from that for diving tables, the nature of the workmen's prolonged exposures creating some distinct problems. So, for a final illustration of the relevance of compressed air workers' decompression safety to that of diving, I will turn to an aspect of decompression injury that was first reported at the same time that the Sir Leonard Hill published his book on compressed air work.

An occupational health hazard

Decompression sickness was now recognised as a hazard of exposure to raised environmental pressure because the illness was acute and it could be attributed to a recent decompression. But, in 1911, two papers were published, each reporting a new and more subtle threat to health.

Bassoe,[22] under the auspices of the Illinois State Commission on Occupational Diseases, reported 11 caisson workers with chronic joint pain and stiffness and showed an x-ray typical of arthritis deformans. Bornstein and Plate[23] reported 3 cases of necrosis in men who had worked in compressed air during the construction of the Elbe tunnel in Hamburg and x-rays had been taken of the symptomatic joints. (There had been one earlier report of necrosis in compressed air worker by Twynam,[24] but in retrospect this is considered to have been osteomyelitis not osteonecrosis.[25]) In the subsequent years there were many more similar papers each reporting cases of articular collapse and pain in compressed air workers who had been investigated because of their crippling joint symptoms.

The significance of this tale is that, some 40 years after these first reports, the Medical Research Council began to screen compressed air workers on major contracts in the UK in order to try and diagnose necrosis before the joint surface collapsed and so be able to remove susceptible workers from further exposure to hazard. To do this, they defined standardised radiographic procedures and used internationally agreed diagnostic criteria.

They also used the results of these surveys to monitor expected improvements in morbidity when, from time to time, the decompression schedules were changed.

The importance to divers of these extensive studies on compressed air workers, which are discussed in detail elsewhere,[26] is to demonstrate the application of the basic principles of occupational health to the hyperbaric environment. First, it is necessary to recognise that an injury is probably related to some occupational hazard (in this case pain due to joint collapse and a history of exposure to compressed air). Then it is necessary to assess the risk of this condition to the apparently healthy exposed population, to control the hazard perhaps by improving the decompression procedures and finally to monitor the outcome by health surveillance. For bone necrosis in compressed air workers this became a successful epidemiological investigation and the study was continued later with divers.[27] Although for the individual who develops dysbaric osteonecrosis it may affect the quality of life, the risk to the individual workman or diver of acquiring necrosis was assessed by these studies as relatively small .

The significance of the original reports[22,23] to today's diver is that what started with a clinical problem of chronic pain in compressed air workers was followed by good epidemiology and led to measures aimed at control.

In contrast, there are other more recent studies which appear to have been started not because of a known clinical illness but maybe as interesting or speculative research using procedures accepted for clinical investigations in hospitals. The results, such as of some brain scans of divers, may indeed show some abnormalities (assuming, of course, that the limit of normality has been defined by appropriate controls) but these abnormalities are not correlated with recognised clinical manifestations. These findings, which have caused much concern among divers, are perhaps *"dubious deficits in search of an unknown disease"*.

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A HISTORY OF CEREBRAL ARTERIAL GAS EMBOLISM RESEARCH: KEY PUBLICATIONS.

Des Gorman and Simon Mitchell

Key Words

Air embolism, history.

Introduction

In 1982, Dr Tom Shields was asked to assemble the key references in cerebral arterial gas embolism research for the Undersea Medical Society. He did so and it is remarkable how many of these remain the key references for this subject.[1]

Only six key publications are chosen here. Each is discussed in the context of precedent and consequent research. One, our own, is chosen because it is the only prospective, controlled, blinded clinical study.

Van Allen CM, Hrdina LS, Clark J. Air embolism from the pulmonary vein. *Arch Surg* 1929; 19: 567-599[2]

Van Allen, Hrdina and Clark were surgeons, at the University of Chicago and Iowa respectively, who were interested in air embolism of the pulmonary vein as a complication of lung surgery. They recognised 2 mechanisms for arterial gas embolism (AGE): direct infusion into the pulmonary vein and arterialisation of venous bubbles via a patent *foramen ovale* (PFO). The authors cited 2 key earlier references. Bichat (1808) caused pulmonary venous air embolism by blowing air into the lungs of a "living animal" at a sustained pressure greater than maximal respiratory effort. Ewald and Kobert (1883) claimed that such embolism arose through distended normal stoma and not through ruptured alveolar septa. This was thought to explain the findings of air in the left heart chambers of people who had died from drowning and hanging and in infants who had died after unsuccessful resuscitation. It was also considered a possible explanation of the brain injury seen occasionally after whooping cough.

The paper is prefaced by a series of clinical cases of iatrogenic air embolism. A series of experiments in dogs are described. Air was introduced into the pulmonary vein by way of a surgical broncho-venous fistula. The major findings are as follows.

1 The distribution of bubbles was determined by posture (buoyancy).
2 Air traps were used to show that bubbles passed from carotid arteries via the brain capillaries to the jugular veins and to the right heart. "The capillaries hinder but

do not prevent passage."

3 Bubbles were trapped in the pulmonary arterioles and expired. "No air succeeds in traversing the pulmonary capillaries …….. gradually disappearing by excretion into the alveoli."

4 Although the cause of death in these dogs was not clearly identified, mortality was related to portal of entry (50 times more air needed if injected into the jugular vein or descending aorta as compared with the pulmonary vein) and posture (1-5 ml/kg into the pulmonary vein was lethal in head-up dogs, compared to about 15 and 30 ml/kg in horizontal and head-down dogs respectively).

5 Initial increase in systemic blood pressure with embolism. Together with air bleeding (bubbling from a stab) considered diagnostic of air embolism.

6 Spontaneous air embolism from fistula prevented by positive pressure ventilation and injection of epinephrine and ephedrine (as long as blood pressure was maintained).

These experiments were replicated in rabbits and the results reproduced almost 60 years later by Gorman and his naval research team at the University of Sydney.[3] Subsequent work by the same group at the University of Adelaide identified the following related phenomena.[4-6]

1 Infusion of air into a carotid artery causes ipsilateral embolism of the middle cerebral artery.

2 As bubbles traverse the cerebral arterioles, there is a loss of both blood flow and spontaneous and evoked brain electrical activity.

3 Most bubbles clear to the jugular vein. Clearance is usually accompanied by both a restoration of blood flow and function to normal levels. However, over the next 30 to 180 minutes, brain blood flow progressively fails and function deteriorates. These latter events are prevented by reducing the circulating number of white blood cells.

4 Bubbles that are trapped in the cerebral arterioles either do so in communicating vessels (anastamoses) or are of sufficient volume that the surface tension pressure acting on the advancing bubble interface exceeds that at the trailing interface by more than systemic blood pressure. Trapping is greatly enhanced by hypotension and is often lethal.

Polak B, Adams H. Traumatic air embolism in submarine escape training. *US Nav Med Bull* 1932; 30: 165-177[7]

Polak and Adams were US Navy medical officers involved in early US Navy submarine escape training. They drew attention to the difference between neurological decompression sickness and AGE secondary to a lung injury. Subsequently, Neuman and Bove have presented cases that show the 2 pathologies can co-exist[8] and Francis and Smith have suggested that the distinction between decompression and AGE may be somewhat artificial.[9]

Polak and Adams used a small series of dogs to measure the intratracheal pressure required to "rupture the stretched alveolar walls and drive air into the circulation." A critical pressure of about 80 mmHg was reported. The authors also showed that air embolism could be prevented by use of abdominal and thoracic binding.

These results were confirmed in 5 human cadavers 29 years later by two physicians, Malhotra and Wright, at the Royal Navy's Physiological Research Laboratories.[10] Like Polak and Adams, their interest was stimulated by submarine escape morbidity. They cite from their own experience of cases of "burst lung" in members of a submarine crew escaping from 40 fsw (12 m). Whereas intra-tracheal pressures of 73 and 80 mmHg resulted in lung trauma in 2 cadavers with either no or abdominal binding only, pressures of 190, 190 and 133 mmHg were necessary to cause such injury in 3 cadavers with both abdominal and thoracic binding.

About the same time, the critical nature of the intra-tracheal pressure was challenged by naval medical officers led by Schaefer at the US Naval Medical Research Laboratory in Connecticut.[11] The motivation for this group was common to those above and they cite low survival rates in genuine escapes from submarines. The authors also noted fatal air embolism in submarine escape trainees despite normal ascents and no indication of breath-holding. Their experiments employed dogs that were compressed (over 2.5 and 4 minutes) to 100 (30 m) and 200 fsw (60 m) in a recompression chamber (RCC), kept at pressure for 1 minute and then decompressed to the surface over I minute. Interstitial pulmonary emphysema and AGE were seen in dogs that had their trachea occluded by either a solenoid valve or a scissors clamp. These events were again encountered beyond intra-tracheal pressures of 80 mmHg. Both the lung injury and the AGE could be prevented by thoracic and abdominal binders despite increases in intra-tracheal pressures in excess of 180 mmHg. It was shown that, while these binders did not prevent this increase, they did maintain both trans-pulmonic (intra-tracheal minus intra-pleural pressure) and trans-atrial pressure (intra-tracheal minus intra-atrial pressure). Both the latter pressures are considered to be measures of lung distension and hence were argued to be the critical determinants of injury. A threshold of about 60 mmHg for both was measured. Twenty years later this concept was reinforced by Professor Colebatch at the University of New South Wales.[12] His findings are cited in more detail below.

The equivalent British experience with AGE in submarine escape training has been described many times, but the report by Elliott, Harrison and Barnard is still the definitive report.[13] This report showed that many of those trainees who suffered AGE did not have any real evidence of lung injury and some AGE victims who appeared to recover after recompression subsequently relapsed. The cause of such relapses is still controversial. More recently, in a prospective study at the same facility, Brooks and his Royal Navy colleagues could not identify a good correlation between lung function as measured by spirometry and risk of AGE.[14]

Macklin M, Macklin CC. Malignant interstitial emphysema of the lungs and mediastinum as an important occult complication in many respiratory diseases and other conditions. An interpretation of the clinical literature in the light of laboratory experiment. *Medicine* 1944; 23: 281-358[15]

Madge and Charles Macklin wrote and described what is an exhaustive review and study of lung disease resulting in extrapulmonary release of gas. Their concern was based on patients who developed such a state, usually after some chest infection. They suggested that toxins of some infectious diseases (and especially influenza) predisposed to lung injury. Other patients were thought to have a constitutional weakness of their alveolar walls.

The Macklin's proposed 3 causes of pulmonary injury resulting in escape of air.

1 Atelectasis of some part of the lung followed by hyperinflation in adjoining regions of the same lung or in the opposite lung.
2 General over-inflation with or without increased intra-alveolar pressure.
3 Reduced blood supply to the pulmonary vessels either with increased intra-alveolar pressure or with hyperinflation.

Air was considered to become entrapped in lung tissue by escaping through ruptured alveolar bases into the sheaths of the pulmonary vessels. Such air was then though to have the following eventual destinations.

1 Retroperitoneum and peritoneum.
2 Mediastinum.
3 Subcutaneous tissues of the face, neck, chest, axillae and body.
4 Thoracic cavity.
5 Pericardium.

Although the Macklin's did not specifically address air escape into blood, their theories are still considered central in arguments about the likely pulmonary lesion in divers and submariners who suffer AGE.

Whereas the mechanism of lung injury causing AGE in chest surgery and after some chest infections can be obvious, the type of lung lesion that underlies AGE after decompression or as a consequence of mechanical ventilation remains controversial. Risk is not well predicted by simple lung function[14] and many victims of AGE after a decompression were seen to ascend normally and to not hold their breath.[11,13] One suggested mechanism for such lung injury, which is consistent with the Macklin's proposals, is that lung may tear as a result of shearing forces generated within tissues of heterogeneous compliance.[12] This is most likely in inspiration and is supported by a recent observation that apparently normal lungs can rupture during a sustained deep breath.[16]

de la Torre E, Meredith J, Netsky MG, Winston-Salem NC. Cerebral air embolism in the dog. *Arch Neurol* 1962; 6: 307-316[17]

A neurosurgeon, two cardiac surgeons and a neurologist from the US Public Health Service were stimulated to study AGE because of the multiplicity of different surgical procedures that are complicated by such embolism. They noted the high tolerance for venous air embolism because of the filtering capacity of the pulmonary circulation and suggested an important role for any PFO. They also remarked on the importance of posture with respect to distribution of arterial bubbles.

Air and other gases were injected directly into the carotid artery of dogs. Their key results are as follows.

1 Whereas about 0.4 ml of air, helium or nitrogen gas infusate was lethal, 1 ml of oxygen and 2 ml of carbon dioxide were needed to kill the dogs.
2 No effect was noted for this type of infusion on the ECG.
3 Ischaemic infarcts were seen in the ipsilateral (to the infusion) distribution of the middle cerebral artery. "The physiologic and anatomic effects are generally less with air than solid emboli in part because air bubbles can enter the venous system by passing through the capillaries and because air is less damaging to blood vessels."
4 Morbidity and mortality increased with increased volume of air foam infusate.
5 The factor that correlated best with outcome was the degree of increase in the cisternal pressure. "Death occurs within 48 hours from increased intra-cranial pressure."

These relative risks for different gases were subsequently confirmed in studies on rabbits at the University of Sydney.[3]

Ischaemic infarcts at the junction of the grey and white matter of the brain, along with punctate haemorrhages, were also demonstrated in more recent but similar experiments in dogs at the United States Navy's Medical Research Institute (NaMRI).[18]

However, there is now considerable evidence from both NaMRI and the University of New England (Australia) that bubbles have a significant deleterious effect on the endothelium and blood, and cause a temporary loss of the blood-brain barrier.[19,20] There are no data to show any correlation between a consequent increase in brain water content (brain oedema) and outcome in either animals or humans after AGE. However, there are data from both North American and Australian groups that show outcome (restoration of blood flow and evoked brain responses) is greatly enhanced if white blood cell behaviour is modified after AGE.[4,21]

Waite CL, Mazzone WF, Greenwood ME, Larsen RT. *Cerebral air embolism: 1. Basic studies*. USN SMRL Report 493, 1967[22]

These US Navy officers used a canine model to identify an effective treatment pressure for AGE. Their report is prefaced with a review of the risks of AGE after the different types of escape practised in the US Navy (see Table 1).

TABLE 1

Technique	1930-1953 SEA Momsen lung	1942-1957 Free ascent	1957-1965 Buoyant ascent	1963-1965 Steinke Hood
Number of ascents	193,000	17,583	130,679	32,679
Morbidity	0.004%	0.09%	0.009%	0.015%
Mortality	0.0005%	0.01%	0.0008%	0

The experimental model was based on anaesthetised dogs with surgically implanted cranial windows. The type of anaesthesia used was not described and no data were provided about the dogs' blood pressure. Air (1 to 7 ml) was injected into the carotid artery. Five dogs were kept at sea-level. Two died and 3 were left with sequelae. Three dogs were embolised at sea level and then compressed in a RCC to 165 fsw (50 m). The final 3 dogs were embolised at 2 atmospheres absolute (10 m) decompressed to sea-level and then compressed to 165 fsw (50 m). After 10 minutes at this pressure, the dogs were decompressed in accordance with a US Navy standard air diving table (170 fsw for 10 minutes). One of these dogs showed complete clearance of bubbles from the field of view before compression beyond 60 fsw (18 m), 3 by 80 fsw (24 m)and the remainder by 100 fsw (30 m). Five survived without sequelae. The sixth had a brain haemorrhage and suffered sequelae. Other observations from the dogs that were not compressed included the following.

1 Circulatory arrest occurred in small arterioles (30 to 60 µ).

2 "In other small arteries there was a slow pulsating progression of the bubble in response to the systolic pressure peaks."

Other observations from the dogs that were compressed included the following.

"In every instance, there was evidence of a change in bubble size and partial restoration of the circulation just beyond 33 feet (10 m). In none of the experiments were intravascular bubbles seen to persist after pressure equivalent to four atmospheres (30 m) was reached. Equally important, in no instance was there a reappearance of bubbles during or after decompression….."

All these observations were subsequently confirmed by Gorman and his colleagues at the University of Sydney.[3,23] First, many trapped bubbles were seen to be cleared from brain arterioles by systolic pressure and especially during the period of systemic hypertension that usually follows AGE. Second, bubble clearance from the brain during recompression occurred with the first doubling of pressure and there was no real difference in efficacy in this context between compressions to 2 ATA, 2.8 ATA, 4 ATA, 6 ATA and even 11 ATA.

Cerebral protection by lidocaine during cardiotomy. Mitchell SJ, Pellett O, Gorman DF. *Undersea and Hyperbaric Medicine* 1998; 25 (Suppl): 22.[24]

The preservation of neuroelectrical function in cats premedicated with the class Ib antiarrhythmic agent lignocaine (lidocaine in the USA) prior to experimental AGE was first described by Evans and his research group at the NaMRI in 1984.[25] The same group later demonstrated a similar benefit when lignocaine was administered "therapeutically".[26] This work was extended by others using in vivo models of AGE, focal, and global brain ischaemia. Lignocaine in standard antiarrhythmic doses was variously demonstrated to preserve neuroelectrical function and cerebral blood flow, and to reduce cerebral oedema and infarct size. Possible mechanisms for this cerebral protection by lignocaine were reviewed by Mitchell as a preface to the principal study described here and include: deceleration of ischaemic ion fluxes, reduction of cerebral metabolic rate and modulation of leucocyte activity.[27] Subsequent to that review, lignocaine has also been reported to reduce ischaemic excitotoxin release.[28] Several case reports have been published which claim benefit from lignocaine in decompression illness.

Patients undergoing cardiac surgery involving cardiopulmonary bypass often suffer post-operative neuropsychological (NP) impairment and several studies have implicated cerebral arterial emboli as the primary cause. We investigated the effect of lignocaine on brain function in patients undergoing left heart valve surgery; a group known to have a high incidence of post-operative NP impairment and where the elective nature of the surgery allows comprehensive pre-operative assessment. Consequently, patients were used as their own controls.

Fifty five patients completed 11 pre-operative NP tests, a self rating inventory for memory and inventories measuring depression and anxiety. These were repeated 10 days, 10 weeks and 6 months post-operatively. Patients received a 48-hour double-blinded infusion of either lignocaine in a standard anti-arrhythmic dose or placebo, beginning at induction of anaesthesia. The difference between each patient's pre and post-operative scores was calculated. A deficit in any test was defined as decline by ≥ 1 standard deviation of the pre-operative group mean for that test. Pre-operative scores were also normalised and sequential post-operative percentage change scores were also calculated for each patient in all tests and inventories.

Significantly more placebo patients had a deficit in at least one NP test at 10 days ($p < 0.025$) and 10 weeks ($p < 0.05$). The lignocaine group performance (sequential changes in normalised scores) was significantly "better" in 6 of the 11 NP tests ($p < 0.05$) and the memory inventory ($p < 0.025$). There were no group differences in the remaining NP tests or the depression and anxiety inventories. No important confounding differences between the groups were identified. In particular, there was no difference between the groups in terms of total operative emboli exposure or hypotension.

These data show persistent cerebral protection by lignocaine, which is unrelated to any effect on depression or anxiety, and is at a level that is noticed by the patients.

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THE DIVING "LAW-ERS" A BRIEF RESUME OF THEIR LIVES.

Chris Acott

Key Words

History, physiology.

Introduction

Early diving and diving medicine researchers were not necessarily involved with diving, some were mathematicians, philosophers, scientists and astronomers while others were physiologists and medical clinicians. Hence the history of diving and diving medicine has involved many seemingly unrelated disciplines. However, many of the researchers lives and research work were intertwined. As an example, John Dalton, an astronomer, after whom Dalton's Law was named, first published on colour blindness (which is why it was originally called 'Daltonism'). The genetics of this disorder were first studied by J B S Haldane (the son of J S Haldane). JBS Haldane was involved with both the Royal Navy Admiralty's Deep Diving Units (the first with his father and the second with L Hill, R Davis and K Donald). J S Haldane designed the first "safe" decompression tables.

A menagerie of animals, divers, "volunteers" and self experimentation were used by the early diving medicine researchers. Boyle used a viper; Bert used birds, dogs, cats and many other animals; J S Haldane used goats; L Hill used frogs but was also involved in self experimentation; K Donald used naval divers and other "volunteers". Much of the actual original diving/diving medicine research demonstrated ingenuity, lateral thinking and unique observation skills.

Unfortunately, many of the original documents are impossible to find and reliance is therefore on second hand interpretation.

This paper is a brief outline of the lives of the originators of the physical laws of diving (Archimedes and Pascal's Principles; Poiseuille and Laplace's equations; the Laws of Boyle, Henry and Dalton).

Archimedes (287-212 BC)

Archimedes was the pre-eminent Greek mathematician and inventor, who wrote important works on plane and solid geometry, arithmetic and mechanics. He was born in Syracuse, Sicily (the exact date is not known, however, popular belief has it as 287 BC) and was educated in Alexandria, Egypt. In pure mathematics he anticipated many of the discoveries of modern science, such as the integral calculus. He published his works in the form of correspondence with the principal mathematicians of his time. He spent the majority of his life in Sicily, in and around Syracuse. He did not hold any public office but devoted his entire lifetime to research and experiment. During the Roman conquest of Sicily several of his mechanical devices were used in the defence of Syracuse (the catapult and the legendary mirror system for focusing the sun's rays on the invading boats and igniting them). After the capture of Syracuse during the second Punic Wars, Archimedes was killed by a Roman soldier who found him drawing a mathematical diagram in the sand. It is said that Archimedes offended the soldier by being so absorbed in his work that he remarked to the soldier, "Do not disturb my diagrams."

He is credited with the invention of the pulley and the hydraulic screw for raising water. However, he is best known for his discovery of the law of hydrostatics, often called **Archimedes Principle**, which states that a body immersed in fluid loses weight equal to the weight of the amount of fluid it displaces. The story that he ran naked through the streets of Syracuse shouting "Eureka" ("I have found it") is a popular embellishment.

Several of his works on mathematics and mechanics survive, including "Floating Bodies, The Sand Reckoner, Measurements of the Circle, Spirals" and "Sphere and Cylinder".

Jean-Louis-Marie Poiseuille (1799-1869)

Poiseuille, a French physiologist and physician, was born in Paris on the 22nd April, 1799 and died in Paris on the 26th December, 1869. He received his medical degree in 1828. His interest in the circulation of blood led him to conduct a series of experiments on the flow of liquids in narrow circular tubes. He formulated the mathematical expression for non-turbulent (laminar) flow of fluids in 1839. This equation is known as the Hagen-Poiseuille equation, because it was also described independently by a German hydraulic engineer, Gotthilf Heinrich Ludwig Hagen in 1840.

Blaise Pascal (1623-1662)

Pascal was born on 19th June, 1623 at Clermont-Ferrand, France and died on the 19th August 1662. A mathematician, physicist, religious philosopher and master of French prose who laid the foundation for the modern theory of probabilities. He formulated **Pascal's Principle** of pressure (probably about 1654).

In 1644 he conceived and constructed the first digital calculator to assist his father in his work as a Tax administrator. He laid the foundations for the calculus of probabilities.

He invented the syringe and constructed a hydraulic press. His work with the mercury barometer confirmed the experimental work of Torricelli.

His two major religious works were "Les Provinciales" (1657) and "Pensees" (1670).

He died a painful death from meningeal carcinomatous secondaries from a gastric carcinoma.

Robert Boyle (1627-1691)

Boyle was born in Lismore, Ireland. He was the 14th child of rich, influential parents. He was educated at home by private tutors, at Eton (1635-38) and in Geneva (1639-1644). A devout Protestant, who throughout his life was an earnest student of theology, he was interested in missionary work and subscribed to societies which were for the propagation of the Gospel.

In 1644 he returned to England after he inherited his father's manor of Stalbridge, Dorset. In 1645 his interest in science was influenced by the Philosophical College (which later became the Royal Society) and, until he visited Ireland in 1652, he specialised in chemistry. During his stay in Ireland (1652-53) he studied anatomy.

In 1654 he settled in Oxford and erected a small laboratory. At this time he was the leader of a small scientific society. About 1659, assisted by Robert Hooke, he invented the "machina Boyleana" which was the forerunner of the modern air-pump.

His achievements were numerous. He recognised the differences between compound and mixtures, acids, bases and salts. He introduced colour testing for acidity and alkalinity. He formulated the Atomic Theory which challenged the Aristotelian concept of the four elements. His book "The Skeptical Chymist" was the foundation of modern chemistry and he is often referred to as the "Father of modern chemistry". His experiments with air showed that air was necessary for combustion, respiration and sound transmission. He was the first to isolate and collect gases. He was one of the founding members of the Royal Society of London. He was the originator of the "experimental method". His work influenced many others including Newton and Jonathan Swift.

In 1662 Boyle's Law was published. He showed that a reduction in pressure caused bubbles in tissues. His description of the viper with the bubble in its eye was the first of an animal with decompression sickness. He described the cause of decompression sickness as: "The little bubbles...by choking up some passages, vitiating the figure of others, disturbe or hinder the due circulation of blood." This was ignored until the work of Paul Bert.

Pierre-Simon Laplace (1749-1827)

Born on the 23 March, 1749, in Beaumont-en-Auge, Normandy he died in Paris on 5 March, 1827. He was a mathematician, astronomer and physicist who is best known for his investigations into the solar system.

He was the son of a peasant farmer. Little is known of his early life except that he was educated at a military school in Beaumont. He did not have strong political views and so escaped execution during the French revolution, not so his friend A Lavoisier.

In 1780 with the help of Lavoisier he showed that respiration was a form of combustion. His scientific work laid the foundations for the study of heat, magnetism and electricity. In 1796 he published "The System of the World" ("Exposition du systeme du monde") which strongly influenced future thought on the origin of the solar system. In 1814 he described the mathematical model for the prediction of probabilities that a particular event will occur in nature. He also aided in the organisation of the metric system and help found the Society of Arcueil, a French scientific society. He was created a Marquis for his scientific work.

John Dalton (1766-1844)

Born on the 6th September 1766 in Eagesfield, England and died in Manchester on the 27th July 1844. He was the son of a Quaker weaver and received his early education from his father. He retained his Quaker faith throughout his life. He was a recluse with few friends and dedicated his life to scientific research. He never married.

His scientific life began in 1787. He is known as one of the fathers of modern physical science. His homemade equipment was crude and his data and record keeping were not exact, hence the dates for some of his work are unknown. His early studies on gases led to the publication of his gas laws in 1801 (his first law is now known as Charles' Law and his second was the law of partial pressures and is now known as Dalton's Law).

Dalton began a series of meteorological observations in 1787 that he continued for 57 years. His interest in meteorology led him to study a variety of phenomena as well as the instruments to measure them. He was the first to prove that rain was due to a decrease in temperature and not a change in atmospheric pressure.

He suffered from colour blindness and published, in 1794, the first scientific paper on it called the "Extraordinary facts relating to the vision of colours". He attributed colour blindness to a discolouration of the eye's aqueous humour. Colour blindness was known as Daltonism for many years.

Dalton's most important contribution to science was that matter is composed of atoms. In 1804 he published his table of atomic weights. He also proposed the "Law of definite proportions" and the composition of ether.

He was a Fellow of the Royal Society, from whom he received a gold medal in 1826 and was also a co-founder of the British Association for the Advancement of Science.

Unfortunately all his documents were destroyed during the bombing of London in World War II (the Blitz).

William Henry (1775-1836)

Henry was born on 12th December 1775 and suicided on the 2nd September 1836. As a chemist he studied hydrocarbon gases and is best known for the discovery of the solubility of gases. Henry's Law was published in 1803.

In 1807 he graduated from the Edinburgh Medical School. Ill health forced him to retire from medical practice. He was made a Fellow of the Royal Society in 1808.

Jacques-Alexander Charles (1746-1823)

Charles was born on Beaugency, France, in 1746 and died in Paris in 1823. A mathematician, physicist and inventor he was the first to ascend in a hydrogen balloon in 1783. He discovered his gas law in 1787 but did not publish it until after Dalton had published it. He also invented the hydrometer and improved Fahrenheit's aerometer.

Robert Hooke (1635-1703)

Hooke was born on the Isle of Wight on 18th July 1635 and died 3rd March 1703. He was educated at the University of Oxford and is known for his study of elasticity (Hooke's Law of the spring). He made other original contributions to many other fields of science. While at Oxford he served as an assistant to Robert Boyle. He helped Boyle develop the air pump and aided him in his experiments on the properties gases. He also demonstrated that air was necessary for respiration by intubating and ventilating a dog with a set of bellows - he was the first to do so.

Hooke's Oxford friends formed the nucleus of the Royal Society in London and they appointed him curator of experiments in 1662.

Hooke's 'Micrographia' indicated the great potential of the microscope. He was the first to use the name "cell" and initiated the study of insect anatomy. He considered fossils to be remains of organic creatures and suggested the mutability of species when fossils bear no resemblance to living creatures.

His work in orbital dynamics influenced Newton. Both corresponded with each other although there was a large degree of animosity between them. After the Great Fire of London he was appointed surveyor of London and designed many buildings including Montague House and Bethlehem Hospital.

Edmond Halley (1656-1742)

Edmund Halley was an astronomer (a comet is named after him) and mathematician. He was born in Shoreditch on the 8th November, 1656 and died in Greenwich on the 14th January, 1742.

In 1684 he met Sir Isaac Newton. He was one of Newton's major supporters. He funded and published Newton's 'Principia' in 1687. He was a Fellow of the Royal Society at the time of Hooke, Boyle and Wren.

In 1686 he published the first world map showing prevailing winds over the oceans. In 1701 he published the first magnetic charts of the Pacific and Atlantic oceans.

In 1690 he designed his first diving bell, which had an atmospheric air supply. He subsequently improved this design in 1716. The air supply was replenished by 2 thirty six gallon barrels lowered below the bell and connected to the bell by a hose. Divers used this bell to depths of 18 m and apparently stayed submerged for up to 1.5 hours with no recorded cases of decompression sickness.

He developed life expectancy charts in 1693 which were the first attempt to relate mortality and a population's age. These charts were used for insurance purposes (the first modern life insurance policy was issued in England in 1583) and are still the basic model used by Insurance companies today.

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DIVING BELLS THROUGH THE CENTURIES

John Bevan

Key Words

Bell diving, equipment, history.

Abstract

One of the oldest, successful and most enduring forms of diving involves the use of a diving bell. This paper traces the history of the applications and development of the diving bell over a period in excess of 2,000 years. Setting off in pre-Christian times in the Middle East, the story travels all over Europe, with occasional expeditions to the Americas, and closes with the appearance of the modern "transfer under pressure" bell, first introduced by the Royal Navy and now universally adopted.

Introduction

Alexander the Great is credited with the first recorded bell dive in 332 BC.[1] Legend has it that he descended in a bell called "Colimpha" at the Siege of Tyre. Aristotle described how his pupil, Alexander the Great, peered out of his bell to observe underwater sheep and dogs and even one gigantic creature that took three days to pass by! But before we credit Alexander the Great with being the first saturation diver as well, we have to consider that his bell was probably an atmospheric observation bell since it was referred to as a glass case, covered with asses skins and provided with a door made fast with chains. Another version describes the bell as constructed of wood, fitted with glass windows and a lid impregnated with resin, wax and other substances to make it water tight. Whilst the accuracy of any of the accounts is questionable, it may at least be reasonable to presume that Alexander the Great made some sort of a dive in some sort of a bell.

The 16th century

Surprisingly we have to wait nearly 2,000 years for the next and more reliable account of a bell dive.[2] An Italian by the name of Gulielmo di Lorena came up with a design for a bell in AD 1531. The diver had little freedom of movement because he was strapped into a frame inside the bell. The specially interesting aspect of this design is that it was a bottom-orientated bell which allowed diver to walk on the sea bed. So whilst the bell was raised and lowered by a lifting rope to the surface, it had the important ability to move laterally over the sea bed. In 1535 Francesco da Marchi dived in Lorena's bell and claimed to have remained underwater for one hour surveying Caligula's pleasure galleys sunk in lake Nemi near Rome but no mention is made of how the air was replenished within the bell. As with all these early diving bell designs, there was no facility to replenish the air inside the bell. In reality dive durations would therefore have been severely limited and the bell would have been raised periodically to provide a supply of fresh air at the surface. Interestingly this account also records the first time a diver used a red hat. Marchi stated after returning to the surface from one of his bell dives: *Moreover I had a hat of crimson silk, with a quantity of white feathers which were as dry as they had been when I went into the lake, and my companions each took one from me as a souvenir.*[2]

Today's diver's red hat may not be made of silk and the white feathers would be a little over the top, but a red hat seems to have become the enduring uniform of the diver.

The importance of the Mediterranean Sea as the field centre for the earliest diving experiments is confirmed by many subsequent accounts of underwater exploits.

Two Greek divers were reported by Taisner in AD 1538 to dive in a "large inverted kettle" and rise up again without getting wet.[3] The authenticity of this particular account is fairly reliable since the demonstration dive was carried out at Toledo, Spain, in the presence of King Charles V and several thousand spectators.

On 27 February 1582, the Spanish got into the news with a bell diving operation at Palermo, Sicily.[4] José Bono used an elaborate and magnificently cast, bronze bell to demonstrate his underwater prowess. The use of a heavy metallic construction is particularly well demonstrated in this design, the bell itself being sufficiently heavy to sink itself without the addition of extra weights. The disadvantage of this arrangement was that if the bell was lowered too far, or if it fell to the sea bed, the diver would be trapped inside.

The 17th century

Not to be out-done, the Italians, this time with military ambitions in mind, were back on the scene with a basic bell design provided by Buonaiuto Lorini in the year 1609.[5] Lorini's bell was built as a rectangular wooden chest, fitted with glass ports and reinforced with an iron frame. A large flat, stone counterweight fixed below the bell also doubled at a platform for the diver to stand on. This arrangement had the important advantage of the provision of a stand-off facility so that if the bell was lowered all the way to the sea bed, the diver could not be trapped within the bell. Provision was made for lifting the heavy bell by the use of a block and tackle arrangement. The military aspect is worth noting because many of these diving techniques were in fact quite secret at the time in view of their potential application during a war. Presumably their main use would have been to salvage sunken vessels and cargo.

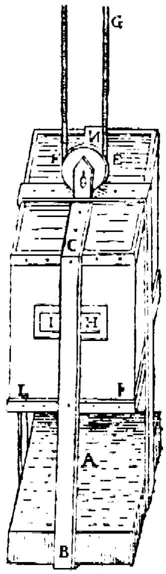

Figure 1. Lorini's bell redrawn from illustration 564 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

The French were next on the scene when a priest by the name of Gaspart Schott described another bottom-orientated or "portable" bell in 1664.[6] This bell was used in 1616 by Franz Kessler. It was constructed from a metal frame covered by leather and fitted with small ports. A metal counterweight was slung underneath and the diver was secured inside the bell by a leather harness. The buoyancy was arranged to be just a little on the negative side so the diver could lift the weight off the sea bed and walk about. In this respect it was similar in mode of operation to Lorena's bell of 1531 but different in that it did not appear to be provided with a hoisting facility. Perhaps it was therefore intended to be walked out to depth from shallow water. Apart

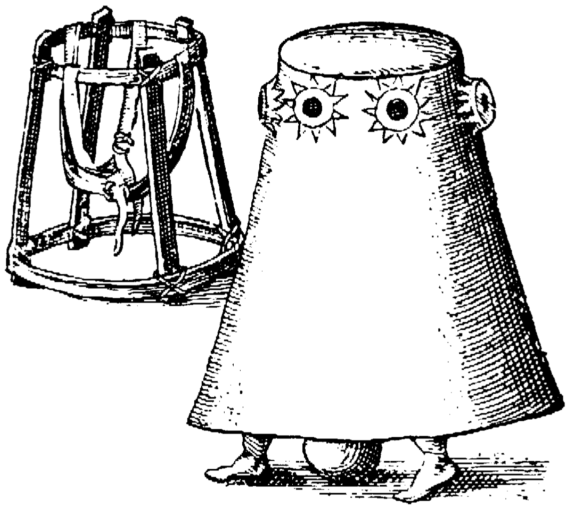

Figure 2. Kessler's bell redrawn from illustration 566 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

from the limited endurance of the system, it would seem that the design was operationally viable.

Sweden was the next country to learn the art of bell diving, necessity being the mother of plagiarism. There had been a naval incident of catastrophic proportion at Stockholm harbour when the magnificent man-of-war *Vasa* sailed out on her maiden voyage. The main problem was that she sank. Not surprisingly, this took everyone by surprise. The vessel was bristling with state-of-the-art cannon which were now doing no good whatsoever at the bottom of the harbour. This is when Hans Albrecht von Treileben and Andreas Peckell, both Swedes, appeared and offered to salvage the valuable cannon using their revolutionary diving bell. It was 1.25 m high and shaped like a church bell. Between 1663 and 1664, the two Swedes raised no less than 53 of the *Vasa*'s guns, each weighing 1.5 tons.[7]

Bell diving technology appears to have eventually reached Britain around 1665 when a gentleman from Greenock named Archibald Millar salvaged at least three cannon from a Spanish Armada ship wrecked at Tobermory in Scotland.[8-10] The bell, suspended in a chain bridle, was of cast metal weighing 260 lb (118 kg), beneath which a metal platform weighing 130 lb (59 kg) was suspended by more chains. It is likely that the weighting and buoyancy arrangements were such that if the bell's underslung platform landed on the sea bed, the bell would maintain its "stand-off" through being positively buoyant, and thus not trap the diver inside. Indeed it is likely that this was the normal mode of operation.

We now come to the most successful bell diving operation ever carried out, at least in financial terms. An ambitious carpenter, born to a blacksmith in Boston, USA, named William Phipps, had raised himself to the status of a ship's master. During his seagoing travels, he had heard incredible stories of Spanish shipwrecks which had carried untold quantities of gold and silver to the sea bed. He tried unsuccessfully on several occasions to recover such treasures, but mutinous crews had thwarted his efforts. He eventually ended up in London, seeking financial backing for yet another attempt. In 1667 he mounted his next expedition from England. His ship, manned by a reliable crew, sailed off down the Thames and this time it was carrying a diving bell consisting of a square wooden box bound round with iron bands and furnished with small windows. A stool was fixed inside for the convenience of the diver. To cut a long story short, the following year he sailed back up the Thames carrying treasure to the value of £300,000, recovered from a Spanish shipwreck off the island of Hispaniola.[11,12] The arrival of such wealth into the country, all in one go, shook the financial markets to their foundations. Phipps himself was paid £16,000. He was knighted by King James II. He was given the Governorship of New England and returned as Governor to Massachusetts.

According to a Doctor Panthon of Lyons, France, writing in 1678, a French diver named Jean Baptiste was, around 1677, successfully salvaging money lost in two wrecks near Cadaques, Spain.[13] Baptiste's diving bell was a departure from conventional bell design thinking, in that it was a massive structure. Most, if not all previous bell designs had been intended for single occupancy. But Baptiste's multi-occupancy bell was 13 ft (3.9 m) high and 9 ft (2.7 m) in diameter at its base. It was made of wood and was strengthened with iron hoops. Iron ballast weights, each weighing between 60 to 80 lb, were suspended all the way around the base. Several divers could operate from the bell at the same time and the large volume of enclosed air would have provided a higher than usual endurance capability. Endurances of 1 to 2 hours were claimed. The handling of such a huge diving bell would have presented novel engineering problems and Baptiste's illustration helpfully includes details of how the bell was operated from a robust crane arrangement fixed between two surface vessels. The divers collected coins from the wrecks and their method of remuneration was novel to say the least. Each diver was allowed to keep as much of the money he salvaged as he could hold in both his hands and mouth!

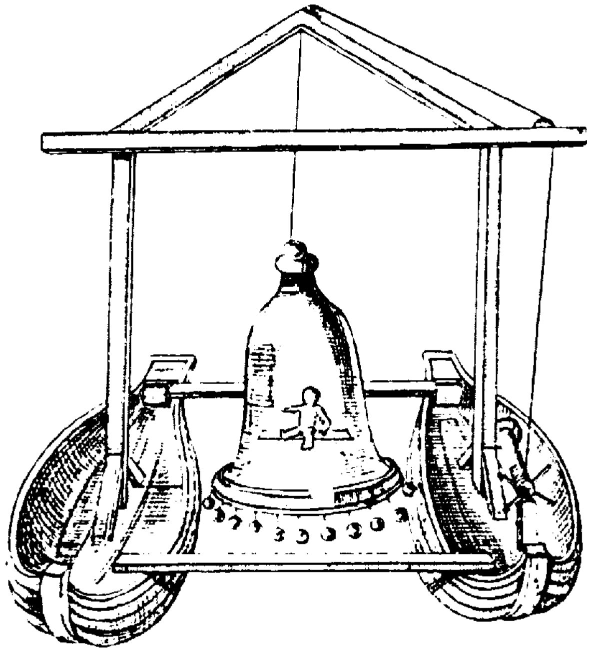

Figure 3. The Cadaques bell redrawn from illustration 568 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

Remaining in France, a most important proposal was made by Dr Denis Papin in a letter he wrote to Colonel du Rossy in 1689:[14,15] *Fresh air could be injected constantly into the diving bell by means of a strong leather bellows furnished with valves, by a tube passing under the bell and opening into its upper part. And so, since the bell would always remain empty and rest entirely on the ground, the bottom in this place would be almost dry and one could* *work there just as if he were out of the water, and I have no doubt that it would save much expense when construction must be carried on under water. Moreover, in case the leather bellows were not strong enough to compress the air as much as would be necessary at great depths, one could always meet this difficulty by using pumps to compress the air.*

This is a remarkable statement that was way ahead of its time. The suggested technique would not see the light of day until 89 years later when John Smeaton first applied a pump to a diving bell in England.

The Phipps experience had the effect of concentrating many minds on get-rich-quick-schemes. One of these minds was that of Sir Edmund Halley who was at the time suffering from a singular lack of success in making comet-watching pay.

With treasure-hunting foremost in his mind, Halley designed and built an improved diving bell incorporating for the very first time a brilliantly simple means of supplying air to the bell whilst it remained at work on the sea bed. His bell was constructed of wood coated with lead. It was 3 ft (0.9 m) in diameter at the top and 5 ft (1.5 m) in diameter at the bottom. There was a glass window at the top to admit some light coming down from the surface. Three weights, of 1 hundredweight (51 kg) each, were suspended 3 ft (0.9 m) below the bottom edge of the bell. The bell had an internal volume of 60 cubic feet (1,699 litres or 1.699 m^3) and would have accommodated two men in reasonable comfort. Surface communications was provided by a lead plate onto which appropriate messages could be scratched using an iron nail and the plate would then be sent up or down as required. A lump hammer served the function of an eraser. But the really novel feature was in the extra 36-gallon (162 litre) barrels, heavily weighted, which could be lowered down, air-filled, to the bell and the air allowed to escape into the bell via a short leather hose. The "used" warmer air inside the bell, which collected at the top of the bell, was vented through a valve at the top of the bell. This represented a quantum leap forward in bell diving technology. The bell could now work for extended periods without the need for frequent excursions back to the surface. Halley's first diving expedition was to Pagham harbour on the Sussex coast, England, in July 1691, where he demonstrated the ability to remain 1 hour and 15 minutes at a depth of 10 fathoms (60 feet or 18 m).[16] These numbers should start to ring bells in the minds of those with a hyperbaric medicine bent (there is an unintentional clue hidden in the pun). On 7 October 1691 Halley together with wealthy colleagues Sir Steven Evance, Francis Tyssen and John Holland, who undoubtedly shared Halley's treasure hunting ambitions, took out a patent for the ingenious life support system.[17] Halley formed a salvage company in 1692, which ran at least until 1696, the shares of which were available on the market. The stated maximum operating depth of the company was 10 fathoms (60 feet or 18 m).. Perhaps for tax reasons, little more is known about the success or otherwise of Halley's salvage company.

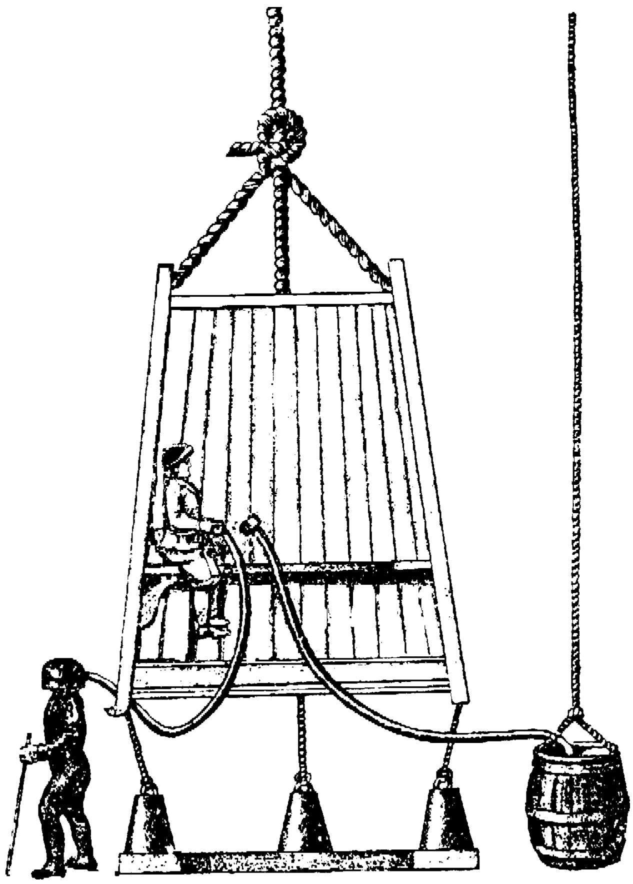

Figure 4. Halley's bell redrawn from illustration 570 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

The 18th century

The military reappear on the scene in 1728 when Marten Treiwald, Captain of Mechanics and Military Architect to King Frederick of Sweden, proposed a new twist in bell life support systems.[18] Treiwald's bell was made of copper loaded with lead weights at the rim and had a heavy iron plate suspended by chains beneath. The bell was for a single diver and supplied with air according to Halley's system. But Treiwald's improvement was a spiral tube that wound its way around the inside of the bell. His idea was that when the air in the bell was becoming exhausted, the diver, whose head would be near the top of the bell (where the warmer, exhaled air collected) could inhale through the tube and thereby use the fresher, cooler air at the bottom of the bell. The importance of this will be better appreciated when one remembers that the water temperature around the Baltic could be uncomfortably low so the diver would be keeping as much of his body out of the water, and as high in the bell, as possible. Treiwald referred to his bell as a

"Campana Urinatoria". Roughly translated this means a bell for hunting gold. Bell divers were referred to as Urinatores, meaning gold hunters though other interpretations have been proposed.

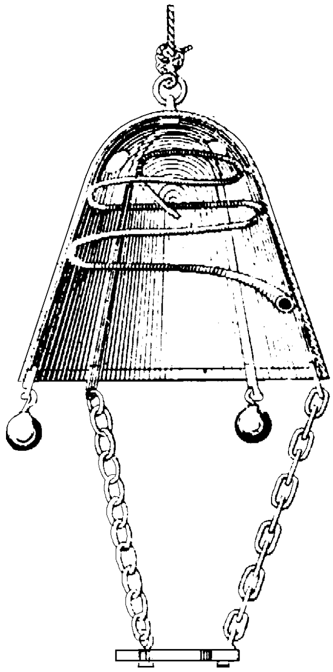

Figure 5. Treiwald's bell redrawn from illustration 571 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

So far we have seen diving bells being used principally for salvage operations, more or less on an opportunistic basis. The time was fast approaching when a more "professional" and perhaps respectable application was established. No less a person than the "father of civil engineering" was responsible for turning the diving bell into an engineering tool. John Smeaton, often referred to as the first true civil engineer, was founder of the Smeatonian Club for civil engineers which later evolved into the Institution of Civil Engineers in 1818. Smeaton is probably best remembered for his brilliant and enduring design for the Eddystone Lighthouse (1759-1882), all previous designs having fallen prey to the elements. Less well known are his efforts to underpin the bridge at Hexham, in the north of England in 1778. But it was here that he was the first to use a diving bell in a civil engineering construction function. Not only that but it was at Hexham that he also employed the force pump to deliver air into the bell for the first time (as first suggested by D Papin in 1689). This bell was a strong chest, 3 ft 6 ins (1.05 m) long, about 4 ft 6 ins (1.35 m) depth and about two feet (0.6 m) wide. The air pump was actually fixed to the top which protruded above water level.[19] Perhaps the reason Smeaton kept this project at a low profile was because the bridge fell down three years later. Undeterred, Smeaton went on to greater things and on 6 July 1779 he first used a new, cast iron bell which he had designed and built to carry out much of the underwater preparatory work at Ramsgate harbour which he was responsible for building. This bell weighed 50 cwt (2,545 kg). It was 4.5 ft (1,35 m) high, 4.5 ft (1,35 m) long, 3 ft (0.9 m) wide and had room for 2 men though they must have been a little cramped. Because the bell was to be used fully immersed the air was supplied by force pump through an umbilical air hose, the first time this technique for supplying air was used. The bell was intended to be lowered all the way to the sea bed and pumped dry so the divers could observe and work on the sea bed in relatively dry conditions. The main application of the bell was to remove stones from the sea bed before construction work commenced. About 100 tons (101,818 kg) of stones were removed by Smeaton in this way.

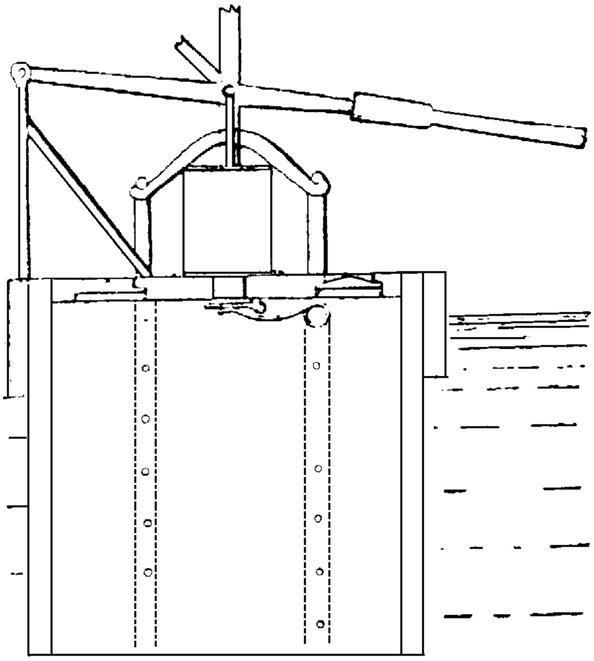

Figure 6. Smeaton's bell redrawn from illustration 573 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

Our next unlikely hero is a confectioner from Edinburgh in Scotland. Charles Spalding suffered a financial blow when a consignment of raw materials he had bought was lost, along with other valuable merchandise, in a wreck on the Farne Islands off the east coast of England. Being a bit of an unstoppable character, he was commissioned by his colleagues who had interests in the lost cargo to go and get the cargo back. So Spalding set about designing a diving bell to do the job. This he built and in 1775 off he went to recover his cargo. This was when he discovered the difficulties of operating a diving bell off a small boat and he returned empty-handed. He went back to the drawing board and redesigned his bell. This time he introduced some revolutionary improvements. His new bell had an air chamber at its top which could be either filled with air from the bell or flooded with water from outside the bell. In addition, he incorporated a weight slung inside the bell which could be raised or lowered at will. By this means, Spalding was able to control the degree of negative buoyancy of the bell and the height of the bell off the sea bed. The bell was 200 English gallons (900 litres) capacity. The top compartment was of 25 wine gallons. The bell required 16-20 cwt (815 to 1,018 kg) to sink it. The air was supplied using Halley's plan and air vessels of 40 wine gallons each. For normal operations the bell would be used in its heavy mode. The internal weight could be lowered a few feet below the bell to provide a useable stand-off distance from the sea bed. Alternatively the bell could be made less negatively buoyant, the internal weight adjusted to just below the edge of the bell and in this configuration, Spalding could stand on the sea bed, lift the weight (and bell) and move the whole bell laterally over the sea bed.[20-23]

One account of Spalding's successful bell diving operations stated "Mr Spalding, impelled by curiosity and intrepidity of spirit, and a genius for mechanics, made several attempts to remain for a considerable time in deep water under the bell which was always crowned with success. He at length became such a proficient in the aquatic art, that he could remain if necessary for a whole day in water of 12 or 14 fathoms deep" (72 to 84 ft or 22 to 25.5 m)![24] We are looking here at no less than the first saturation dives. And yet another first for the Spaldings was related in the same journal *His (Charles Spalding's) acquaintances having so many proofs of the trifling danger with which this wonderful visitation of the deep was attended, many of them ventured at different times to accompany; nay, an Amazonian lady, belonging to Edinburgh went down with him, where she remained upwards of half an hour.*

This must be the first account of a lady bell diver and it surely has to be the very first ever Amazonian bell diver!

Spalding's most successful diving operation was in September and October of 1782 when he raised 9 brass and 6 iron guns from the wreck of HMS ROYAL GEORGE sunk at Spithead, near Portsmouth, England. The following year he was employed to salvage the cargo from the East Indiaman *Count Belgioso* sunk just outside Dublin harbour, Ireland. Here he achieved yet another first which sadly has to be covered in the Diving Accidents paper.

The next bell diver appeared the following year on the same wreck where Spalding came to grief. This was Adam Walker of Manchester, England, a lecturer on natural philosophy.[25] He too had been commissioned to design a bell to recover the rich cargo of the *Count Belgioso*. Walker described his bell as follows:[26] "I recommended a conical tub of wood, three feet diameter at bottom, two and a half at top, and three feet high; so loaded with lead, at bottom, as just to sink itself; with a small seat for the diver; a small metal tube was attached to the in and out-side of the bell, as a, b, c, with a stop cock at a; and a flexible leathern tube or hose to the other end at c; this tube terminated in a forcing air-pump, fastened to the side of the ship; a solid piston actuated by a lever ... With this bell on his head, he can walk about several yards in a perpendicular posture." Walker's bell was perhaps the first time that a diving bell involved in an offshore salvage operation had been supplied by air by a force pump. The only previous example of this arrangement for the air supply had been Smeaton's application in harbour construction.

The 19th century

The use of diving bells in marine civil engineering took a major step forward in the early 1800s. John Rennie took over the improvements to Ramsgate harbour in 1807, some 15 years after the death of John Smeaton. He made further improvements to the use of the diving bell in actual construction activities including an overhead gantry bell handling system and the ability to hoist large building blocks under the bell and then into position underwater.[27] The cast iron bell was 5 tons (5,091 kg) in weight, 6 ft (1.6 m) high, 6 ft (1.6 m) long and 4.5 ft (1.35 m) wide. There were solid glass, cast "bull's eyes" on the top to admit light. The technique was later exploited in harbour construction works all over the world. His son Sir John Rennie, who later took over the business along with his brother George, became the principal manufacturer of diving bells in Britain. By the 1840s their bells had been supplied to all of the Royal Navy's dockyards around the world as well as to most of the major harbours and dockyards around Great Britain.

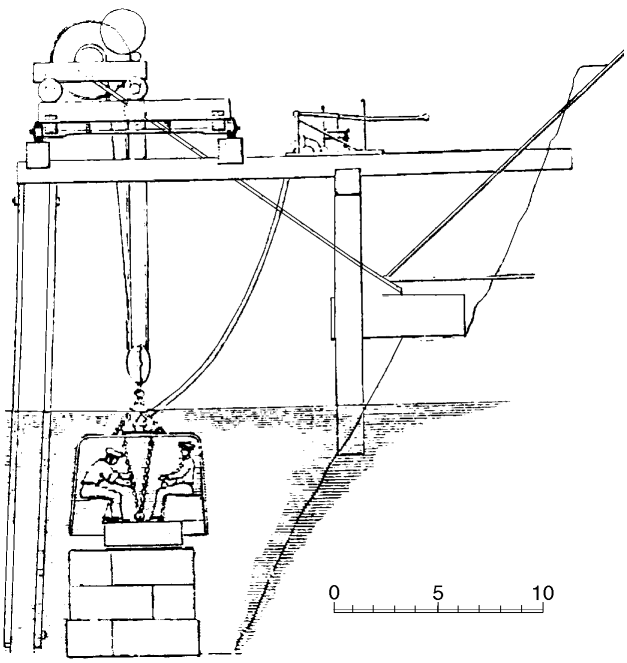

Figure 7. Rennie's bell redrawn from illustration 574 in Sir Robert Davis' book *Deep Diving and Submarine Operations* (7th Edition, reprinted 1969).

Staying briefly in Ireland, we next meet Thomas Steele, a rich land owner from County Clare. Steele was a colourful character who became politically obsessed, losing most of his family's fortune in a bungled attempt to send armaments to the revolutionaries in the civil war in Spain. He took out a patent for a unique diving bell in 1825.[28] The novelty lay in the inclusion in a cast iron bell of a separate compartment which remained at atmospheric pressure.[29-31] Whilst technically feasible, it was never a practical option. Steele later became a friend of the Deane brothers who invented the diving helmet and after a tempestuous political career associated with Daniel O'Connell, sadly took his own life in 1848 by throwing himself into the Thames from Waterloo Bridge.

By the early 1840s, the Rennie cast iron diving bell was the standard. When Colonel Charles Pasley of the Royal Engineers decided to move into the diving business he logically chose such a bell. In 1838 he attempted to use a Rennie bell, borrowed from the local dockyard, to clear the wreck of the brig *William* which was obstructing navigation of the Thames at Gravesend. It was not successful because the water current played havoc with the bell handling requirements. The job had to be completed by helmet divers. The following year Pasley began work on clearing the wreck of the ROYAL GEORGE at Spithead, Portsmouth. This time he decided to modify the diving bell to overcome the problem of tides causing the bell to be thrown violently about. His idea was to give the bell a hydrodynamic profile by the addition of "boat-ends". His prototype was built at great expense but the resulting structure was so large, heavy and unwieldy that it took over 40 men to operate it. Following the abortive trial on 14 May 1839 from HMS ANSON in the Medway, just off the Thames, Pasley was forced once again to revert to helmet divers and that was the end of his bell diving episode.[31]

Still with the military, the Crimean War (1854-1856) became the theatre for some firsts for underwater activities. The main underwater interest lay in the problem posed by the Russians when they sank a line of battle ships at the entrance to Sebastopol harbour to block access to the allied British and French fleets. John Deane was commissioned to blast a channel through these ships but that story belongs in another paper. Back in England, another brilliant mind applied himself to the problem. This was Charles Babbage, famous for inventing the computer, who proposed a unique diving bell design which could approach the sunken ships underwater and allow lock-out divers to place explosive charges against the hulls of the block-ships.[32] Fortunately the idea was never taken up so Babbage was spared to do more important work.

The Crimean War did however spawn one new diving bell design which at least made it into the water. This was the Nautilus Bell first patented by J H Tuck in 1855. The bell was ultimately built by Rottermund & Hallett for the newly-formed Nautilus Submarine Company and funded by the British government. A whole variety of top engineers were involved in its final design and construction. Amongst these were John Scott Russell, Major H B Sears and a Wilhelm Bauer of Austria. Even Augustus Siebe appears to have been helping on the sidelines, quite possibly with the plumbing, pumps, pressure gauges and valves. The bell was quite ahead of its day in concept and incorporated several unique advances, notably the ability to adjust its own buoyancy and move itself around the sea bed.[33] Sadly for the developers, the Crimean War ended before they had finished their project so they had to look elsewhere for a customer. In 1857 the rusting bell was spotted in Victoria Docks, London. The following year a desperate attempt was made to commercialise the project when the bell was demonstrated in the river Seine at Port Royal, France. But the absence of any further news on the subject suggests that it had joined the growing pile of failed diving bell designs.

The late 1800s and early 1900s saw a huge increase in harbour-building projects in and around Britain. One of these was a major harbour development which started in Dublin, Ireland in 1870. Yet another clever new concept was introduced to the diving bell for this operation. The engineer responsible had the colourful name of Bindon Blood Stoney. His diving bell was no less than 20 ft (6 m) square at roof level and 6.5 ft (1.95 m) high. But the innovative aspect was a vertical pipe, 3 ft (0.9 m) in diameter and 37.5 ft (11.4 m) long which was connected to the top of the bell. At the top of this pipe was built an air lock, 6 ft 6 ins (1.95 m) high. The total height of the system was 44 ft (13.3 m) and it weighed 80.5 tons (81,9 tonne). The brilliance of the idea was that the bell no longer needed to be raised to the surface every time the workers within needed to be changed and consequently slow down the operation. By the use of the air lock, the workers could commute in and out freely, at will. Surprisingly, one of the major problems encountered within the bell by the workers was that it became oppressively hot inside, despite being surrounded by water at about 10°C. At times, the men could not work more than 30 minutes without rest.[34] Bell buffs can still have guided tours around this bell which stubbornly refuses to rust away on the quayside at Dublin harbour.

The 20th century

Meanwhile on the south coast of England the harbours at Dover and Folkestone were being expanded. At these the Rennie system of placing large building blocks on the sea bed with great precision with the use of diving bells was heavily exploited. The expanding Siebe Gorman company grew even more successful through their design and manufacture of the large diving bells required for the works. In 1904 the Admiralty extended their pier at Dover harbour and Siebe Gorman built the diving bells for Messrs Pearson & Son Ltd. The bells were 17 ft (5.15 m) long, 10 ft 6 ins (3.2 m) wide and 6 ft 6 ins (1.95 m) high inside.

The bells came complete with lights, signalling gear and a "loud-sounding telephone apparatus". The latter was one of the first attempts at an electric telephone for underwater use. The bells were specifically designed to have flush sides so they could be placed very close to the quay walls. To permit this, the ballast weights were fitted inside the bell.[35] Siebe Gorman built more bells like these for harbour works in Devonport and Folkestone, England, and for Gibraltar. The Folkestone development which started in 1905 and was carried out by Messrs Coode, Son & Co, used two of Siebe Gorman's bells. Each bell was 12 ft 9 ins (3,9 m) long, 10 ft (3 m) wide and 6 ft 6 ins (1.95 m) high and weighed 26 tons (26,473 kg).[36]

The Royal Navy's interest in underwater operations grew in the 1900s, not least as the result of two world wars. Surface orientated helmet diving had been the mainstay of the navy's diving operations for generations but the technique was found to be severely limited when deeper diving was needed. The penalty of protracted decompression times demanded a new approach to deep diving. The next step in diving bell development is inextricably interlaced with decompression table development and I have to be careful not to stray too far into Dr David Elliott's territory. Suffice it to say that special diving bells were needed to provide the operational capability for divers to carry out hitherto undreamt of lengthy decompressions. The first step was a bell which could be sealed at depth and the divers brought to the relative safety of the ship's deck inside the bell, there to carry out the remainder of their decompression schedule. This was christened the Submersible Decompression Chamber (SDC) by its inventor, Sir Robert Davis. The Royal Navy first used a bell of this type, designed and built by Siebe Gorman, in 1931 when they reached over 300 ft (90 m) depth in Loch Lyne, Scotland. The system was stretched to its limit when the diver was surfaced from a pressure equivalent to 30 ft (9 m) inside the bell and he walked to a waiting deck compression chamber, there to be recompressed and again slowly decompressed (a sort of surface decompression procedure). This was the procedure adopted when Bollard reached a depth of 535 ft (162 m) from HMS RECLAIM in 1948, when he was able to find time to have a cigarette on his way from the SDC to the deck chamber. It was used again when Lt George Wookey reached 600 ft (182 m) from HMS RECLAIM in a Norwegian fjord on 12 October 1956. This time however both the diver and his attendant (R Clucus) were suffering from pain bends as they made their way over to the deck chamber.

This procedure was acceptable for the initial increase in diver depth capability, but the bell was too small for very long decompressions and the surface decompression procedure was often accompanied with unacceptably high bends incidence. So somehow the divers had to be transferred from the diving bell into larger pressure chambers on board the surface support vessel. Sir Robert Davis, the then managing director of Siebe Gorman & Co Ltd, had patented the solution in 1931[37] and illustrated the application in subsequent editions of his acclaimed book, Deep Diving and Submarine Operations.[38] The Navy, true to its traditional reputation for conservatism and scepticism, took a quarter of a century to acknowledge the merit of Davis's transfer-under-pressure (TUP) chamber. A TUP diving system was eventually commissioned on board HMS RECLAIM in 1957 immediately following the embarrassment at the bends suffered on the 600 ft (182 m) dive.

Davis's TUP bell was an immediate and unqualified success. It heralded the birth of deep diving on a world wide scale.

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SCUBA DIVING AND THE MENSTRUAL CYCLE: INTERIM DATA FROM THE SECOND YEAR OF A FOUR YEAR PROSPECTIVE STUDY OF DIVING WOMEN

Marguerite St. Leger Dowse, Phil Bryson, Alex Gunby and William Fife.

Key Words

Physiology, recreational diving, women.

Background

The majority of medical recommendations concerning females in recreational scuba diving are based on data from fit young men and animals and not from females who may be menstruating, menopausal or pregnant. The effects of increased pressure, resulting from scuba diving, on the menstrual cycle, or the effect of the menstrual cycle on a woman's ability to dive safely are not well documented.

Aerospace studies have attempted to evaluate any relationship between the menstrual cycle and altitude decompression illness (DCI).[1,2]

Studies of changes in the menstrual cycle in airline stewardesses have been carried out and have shown changes in menstruation, though some of these effects may be attributed to time zone changes.[3,4] In addition, separate studies of Chinese and South American non-diving female populations, living at various altitudes, have demonstrated changes.[5,6] Differences in abdominal pain, length of menstrual phase and hormone profiles were observed.

Only one formal preliminary study has so far attempted to address the issue of whether scuba diving affects the menstrual cycle.[7] This study acknowledged that more precise information and more subjects were necessary to expand on the results which showed that the dives, carried out in the hyperbaric chamber on two women, had no gross effect on the menstrual cycle.

Recently Doyle found that data from the Divers Alert Network (DAN) data base showed women taking the oral contraceptive pill were more likely to experience DCI if they dived whilst menstruating.[8]

Comparative studies, between males and females,[9-12] have attempted to assess the relative risk of diving DCI. The most recent is the "Men and Women in Diving" (MWD) study carried out by the Diving Diseases Research Centre (DDRC).[13] Studies have differed in their findings. Zwingelburg and later both Fife studies found no difference between males and females in the incidence of DCI. Bangasser's study showed that there was a 3.3 fold increase in the incidence of DCI amongst women compared with males in the study. The MWD study showed, that when other factors such as number of dives and years of experience were taken into account, males had a higher rate of incidents of DCI than females per thousand dives.

In addition to the current "Scuba Diving and the Menstrual Cycle" project, the DDRC is collaborating with the Defence Research Evaluation Agency (DERA) gathering data in which the incidence of DCI in female divers is being observed in relationship to the phase in the menstrual cycle. This paper presents preliminary data from that study.

Methods

As a result of the findings and comments of the Men and Women in Diving study, the present prospective study was launched in May 1996 and was designed solely to expand on our knowledge of women, diving, contraception and the menstrual cycle.

The study uses a combination of questionnaires and charts. Initially, each respondent is required to fill in a preliminary comprehensive background questionnaire covering personal details, diving history, any previous DCI incidents, medical and reproductive history, and any effects they have experienced whilst diving.

The dive/menstrual cycle charts are designed to record the cycle, type of bleeding, depth/diving profiles and any *diving* incident experienced. The women record the required information on the charts for the next three consecutive years, returning the charts on a six monthly basis. A time period of three years was chosen in an attempt to gain a reasonable overview of each woman's diving career and menstrual history. An interim questionnaire, which records any changes in the woman's health, personal status and diving status is also returned with the charts. Respondents then continue with the next six month's record keeping. The first group of women commenced in November 1996 and completed the first year of record keeping in November 1997, they will finish the project in November 1999. The fourth group of women commenced in January 1998 and will complete in January 2001. Women who are not menstruating, for whatever reason, have also been encouraged to take part in order that the rate of diving incidences in the women who *are* menstruating may be compared with women who are *not*.

A data base has been developed to enable all dive profiles, menstrual histories and diving incidents to be evaluated and compared.

The logistics of managing and tracking a large number of women with the resources of a small research team on a very limited budget are considerable, but every attempt is being made to encourage the women to complete the project. In the last eighteen months 12% of women have changed addresses, and of that group, 8% have moved more than twice, confirming the need to keep in constant touch with the respondents.

Results

Data from the DDRC *retrospective* MWD study indicated some women *perceived* there was an effect of diving on the menstrual cycle, challenging previous diving studies.

Women who dived whilst menstruating reported the following *perceived* problems of tiredness, cold, rapid temperature drop, slower reactions, impaired reactions and decreased confidence. There were also reports of light headedness and dizziness, feelings of panic, a general feeling of loss of control and feeling physically weaker. Some reported a *perceived* tendency to be more susceptible to nitrogen narcosis.

The women also reported that diving whilst experiencing period pains actually reduced their pain quite noticeably. Other signs reported were the early onset of menstruation, increased bleeding both during and after a dive, and spotting during consecutive day diving.

Still from the MWD study, 76% of the women who reported using a diaphragm or cap had dived with it in place. There were reports of it becoming impacted and difficult to retrieve. Useful advice was given concerning the removal of the impacted item by the women who responded, but highlighted the need for diving physicians to offer women advice on diving when using a diaphragm or cap to ensure that pelvic infection does not result from such an occurrence and that they are aware of the trauma caused by impaction and a diaphragm or cap's unconventional removal.

Also in the retrospective study 34% of all the respondents either regularly or sometimes suffered impaired reactions; 71% of all the respondents regularly or sometimes reported suffering from pre-menstrual tension.

From the current prospective study, to date a total of 956 women, collectively recording 199,861 dives, and with an age range of 14 -69 (mean of 35) have so far reported an average diving experience of 4.75 years each. 114 of the women are over the age of 45 years.

Tables 1 and 2 show the distribution of the menstrual state and the methods of contraception used from a sample of 620 women who have returned the appropriate data in the last eighteen months.

Increasingly, women are inquiring about the relationship between hormone replacement therapies (HRT) and scuba diving, therefore the study is also gathering data

TABLE 1

DISTRIBUTION OF WOMEN MENSTRUATING AND NOT MENSTRUATING

	Total	%
Menstruating	511	83%
Hysterectomy	32	5%
Peri or post menopausal	77	12%
Total	**620**	**100%**

concerning HRT and the methods of delivery used by the respondents.

From the sample of 620 women, those who have had a hysterectomy or are peri- or post-menopausal, 30% have so far reported using HRT, oral use being the most popular method. Few women use HRT implants or patches, however one respondent with an implant has questioned how the effects of pressure could alter the delivery system.

Preliminary data from the background questionnaires show that 48% of women so far *perceive* an effect of diving on the menstrual cycle or that they *perceive* the menstrual cycle affects their ability to dive safely. Fifteen percent of women said they felt exercise affected their menstrual cycle in some way. When asked if they considered diving affected the heaviness of their period 18% said yes. The data received back from the dive/menstrual cycle charts will enable the frequency and heaviness of the bleeding to be evaluated against the dive profiles and the frequency of dives made. Twenty percent have reported an effect on the pain they experienced when diving while menstruating. Eighteen percent perceived the menstrual cycle affected their ability to dive safely and reported feelings of panic or loss of control, with anxiety being the most commonly observed. Some respondents did not feel that the menstrual cycle affected their ability to dive safely even though they had experienced feelings of panic or anxiety on occasions. Some respondents reported more than one effect. Again, the design of the charts will enable any relationship between the frequency of diving accident and the phase in the menstrual cycle to be observed. These data will be compared with the women who are not menstruating. As in the MWD study, number of dives and years of diving experience of the women will be taken into account when analysing these data.

Discussion

Preliminary results of the *prospective* study support the *retrospective* study and suggest some women *perceive* their ability to dive safely during the menstrual cycle may be impaired, and that scuba diving may alter the menstrual cycle in some women. The *prospective* data gathered from three consecutive years of diving and menstrual histories

TABLE 2

METHODS OF CONTRACEPTION REPORTED BY 511 WOMEN

Methods of contraception	
Oral contraceptive pill and injectable contraceptive	38%
Condom	24%
Sterilised male partners	11%
Female sterilisation	9%
Natural methods	9%
Intrauterine device	5%
Diaphragm/cap	3%
None	20%

from recreational scuba diving women, will be analysed in an attempt to qualify and quantify these perceived problems. With the *retrospective* study data there was no way to quantify changes in diving risks due to menstruation, or changes in menstruation due to diving. This was due to lack of a suitable control group. With the *prospective* data it will be possible to study these changes objectively using statistical methods of survival analysis and relative risk models. Many of the problems of identifying closely matched control groups and the problems associated with selection bias will be avoided. Estimates of the prevalence of diving diseases will be feasible. Estimates of the relative risks of diving diseases due to the menstrual cycle should also be possible. Although it is acknowledged that there will be a proportion of women who will not complete the three years commitment to the project, it is anticipated these data will provide a greater knowledge base concerning the effects of scuba diving on the menstrual cycle and the effect of the menstrual cycle on a woman's ability to dive safely.

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Dr William Fife is a retired Professor of Hyperbaric Medicine well known for his pioneering research. He initiated early research into the effects of diving on pregnancy and the fœtus, has been responsible for the only two workshops relating to women and diving.

The team as a whole were the recipients of the 1994 "Duke of Edinburgh's Prize for the British Sub Aqua Club" for their work on the first project, Men and Women in Diving.

The 117 page publication of the results of the first project, MEN & WOMEN IN DIVING, is available from the DDRC.

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ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

TWENTY TWO UK DIVING DEATHS IN 1998

Brendan O'Brien

Key Words

Accidents, deaths.

Why was there such a huge increase in the number of diving fatalities last year and what can be done to prevent such tragedies happening again?

It is the start of the dive season**.** You have just arrived at a dive site and you are excited at the prospect of getting back in the water. You know what pre-dive procedures should be carried out, but you choose to ignore them.

The dive is going well until disaster strikes. As you sink deeper into the incident pit, you realise that this time you will not be able to pull yourself out. Your breathing becomes erratic as your mind is thrown into chaos. You feel your heart pounding in your chest as the adrenalin rushes through your veins. You realise you are in your worst nightmare and you hear your inner voice asking why it is all going horribly wrong?

You feel alone and scared. Your thoughts are drawn to the visions of a future you will never see. You imagine your funeral, the crying of grieving friends and relatives and the soul-destroying burden of guilt carried by your dive buddies. Are you sure that it will never happen to you?

Weighing up the risk

There were 22 diving-related fatalities in the UK in 1998, the highest recorded figure for 26 years. However, when you compare the number of dives made every year with the number of fatalities, the risk is estimated to be about one in 200,000.

Surely this statistic is proof that diving is essentially a safe pastime, no different from any other adventure sport?

That may be the case, but do not forget that these people were just like you and me. Now they are dead. Do you believe their friends and relatives care about how safe the sport is when the one they loved is now part of these statistics?

I would suggest not. I would go as far as saying that figures such as these are irrelevant. They seem to be quoted year after year by training organisations. Are we trying to comfort ourselves? Or are we perhaps trying to fool ourselves into believing that there is an acceptable number of fatalities?

So why is the number 22 so important? Brian Cumming, the BSAC's Safety and Incidents Adviser, explains: "Twenty-two deaths is a lot, but if people had been following the right guidelines there would, by my reckoning, only have been between two and four fatalities."

This statement is by no means extraordinary. In 1997, the Health and Safety Executive (HSE) published *Scuba Diving: a quantitative risk assessment.* In this report, the Paras Research Group collated several years of incident records from the BSAC and the Divers Alert Network (DAN).

The results were shocking. To establish the true nature of diving incidents, the team excluded from the figures all fatalities involving divers who would not have passed a diving medical.

Of the 286 fatalities left, the investigation discovered that all but eight of them were avoidable.

In other words, 278 deaths could have been prevented. The report concluded that all these deaths were "avoidable by a well-trained, intelligent and alert diver, working in an organised structure".

Procedural problems

So what happened in 1998, and why aren't we learning from these incidents? Colin Bryan, National Diving Officer of the Sub-Aqua Association (SAA), suggests that "these fatalities seem to be down to procedural error, for example: diving alone; not being trained for the environment or in equipment use; air management; and decompression diving".

These views are echoed by Brian Cumming: "When you look at our safe diving practices and then look at these incidents, I guess more than 90% transgress one or more of the recommendations in them."

When the circumstances of the majority of the fatalities are examined, it becomes very clear that these are major transgressions: diving solo; diving too deep; diving beyond their level of experience; diving in a three or even a five; re-entry recompression; and inexperience with equipment.

Should we need to say anything about diving solo? It appears so, as five of the fatalities involved divers going it alone. There are those who believe it is OK to dive solo, either for the whole or for part of the dive.

Serious consideration has even been given to it being a safe practice in certain conditions. But what about splitting up from a group of three to explore a cave at 57 m when your buddies are above you at 40 m?

Or, after a dive to 26 m, jumping back in to recover a dropped mask with only 50 bar in your tank, with no fins and without a direct feed attached? Unfortunately, the divers who did these things cannot explain to us what they were thinking when they bypassed well-established safe-diving practices.

In deep trouble

Three of this year's fatalities involved diving to depths exceeding 50 m. One has already been mentioned, the other two were using tri-mix at depths of 75 m and 85 m.

The exploits of serious technical divers are widely covered by the diving press. However, the increase in the popularity of deep technical diving has not come without some major concerns being raised. What is worrying is that these concerns are being ignored by those who really need to take notice.

Mike Harwood of the HSE's diving group has this to say on the issue of technical diving: "Those that carry out dives on the likes of the *Britannic* do an impeccable job. However, there appears to be an emerging group of divers who believe that they are bulletproof."

The Coastguard and Maritime Agency sees the results of reckless and over-ambitious technical divers. Reg Hill, the CMA's diving officer, is very concerned: "I have seen it myself. They believe that they are experts, having been on a two-day course. The technology and gases involved are widely available. Then they try to copy the real experts. They are going way over the top."

The SAA is the only UK training agency to be affiliated to the International Association of Nitrox and Technical Divers (IANTD) and Technical Diving International (TDI). Colin Bryan of the SAA believes that technical diving can be safe if the guidelines are adhered to. "These pioneers have been carrying out technical diving for years," he says. "Hours of planning go into their projects, with build-up dives, numerous equipment checks and safety divers on stand-by. However, there are those who think: 'I can do that'. With the money to purchase the equipment and a course under their belt, they believe they are ready for deep dives. Eventually they are going to kill themselves."

Brian Cumming effectively summed up the issue of deep diving at the 1998 Underwater World conference in Harrogate. "This year we have seen six incidents at 50 m plus and three of these were fatalities. Amateur divers need to realise that if you have an incident at these depths it is going to be very serious."

Rebreather reality

The subject of rebreathers has received a vast amount of attention recently. However, in examining their use it is worth mentioning the circumstances of the three rebreather fatalities as reported in the BSAC's *Incidents Report 1998*.

The first involved the 75 m dive where the deceased was conducting a tri-mix rebreather dive as part of a group of three. The second involved another group of three where there was a separation on a wreck dive to 34 m. In the third, the deceased deliberately separated from his two buddies towards the end of the dive to recover a piece of dropped equipment.

In all these dives, there have been two common denominators: the use of the rebreather and a decision to ignore safe diving practices. Could the latter be the prime cause of these fatalities? The extent to which this may be true is not clear, because at the time of writing these fatalities are still awaiting the results of inquests. However, this hasn't stopped those involved in the industry passing comment.

The SAA offers what it believes to be the best training in the world for this equipment. Colin Bryan adds an important rider to this: "You may be a good technical diver, but you will not be ready for the same dives on a rebreather. It is very much like going from a car to a high-powered superbike."

He goes on to say: "One of our members has had a closed-circuit rebreather for several months. He did his course at the same time as one of the divers who later died using the same type of rebreather on a deep dive. Although he is an accomplished technical diver, he is still practising 20m dives with his rebreather. I believe that there may be some gung-ho divers out there who are allowing themselves to be pushed into dives they are not ready for."

Brian Cumming gives the BSAC's opinion on the closedcircuit rebreather: "It is a very complex piece of equipment, both mechanically and electronically. There is clearly the potential for problems with maintenance, manufacturing, design and usage."

Could it be the usage that is the problem? Like any piece of equipment, safe diving practices need to be adhered to. This includes becoming fully competent in the use of any new equipment. Is it the case that we are not learning from the rise in fatalities whenever a new type of equipment or procedure is introduced, as was the case with the increased use of drysuits in the ’70s?

Clubbing together

The subject of “orphan” divers was raised again by Brian Cumming at the 1998 Diving Officers’ conference. This is the phrase that he has used over the past few years to describe a growing group of UK divers.

But what exactly does he mean when he refers to an orphan diver? “They are responsible for some of the shallow-water fatalities. They have done a short diving course, so they know a little bit. Then they want to go diving. As they learnt together, they do the easiest thing, which is to go to a quarry, jump in and go diving. They do not have support from more experienced people, so they get themselves into trouble.”

Brian Cumming uses this group of divers and others to support the view that you are far safer diving in a club environment. Indeed, every year the BSAC compares the number of fatalities among BSAC and non-BSAC divers. This year, there were six BSAC fatalities out of the 22. In 1997, the ratio was four BSAC to 12 non-BSAC. Do these non-BSAC statistics include BSAC members diving outside branch activity or ex-BSAC members? “I’m fairly certain that none of them were BSAC or exBSAC members,” claims Brian. “Certainly the bulk of them had nothing to do with the BSAC.”

Brian also compares the statistics from the past two years to previous years. “For non-BSAC fatalities we expect an average per year of about six, what we are seeing now is almost three times that. Do you honestly believe that 70 per cent of the diving in this country takes place outside the BSAC? This indicates that you are safer inside a club environment.”

Mark Caney, the UK managing director of PADI International, the world’s largest diver training organisation, questions the BSAC’s use of these figures: “Trying to say that these fatalities are BSAC or that these are PADI is not very productive, and in any case we would not agree. Our records certainly do not indicate figures anything like this.” Mark later informs me that seven of the fatalities had been PADI trained.

“We would agree that it is safer to dive with an organisation and to follow safe diving practices,” he continues. “In relation to what Brian calls orphan divers, if they are doing this they are not following what we reinforce constantly in our training. We do have some examples of this. As a result, we are trying to reinforce through magazines, our instructors, the PADI Dive Society and with notices at popular dive sites that any change of environment or equipment, such as drysuits, needs local training.”

It is clear that urgent action must be taken to halt the rising number of orphan divers. Reg Hill of the Coastguard and Maritime Agency is becoming increasingly concerned: “These people are drifting around with no direction, the depth of knowledge is not there and they are not capable of planning dives. We even see groups of trainee divers from the same dive school going diving without any experience in their ranks. There is a need to belong to a group where there is experience that you can learn from, such as the BSAC or SAA.”

But what effect is this increase having on the Coastguard and Maritime Agency? “The senior officers in my organisation are beginning to take note of the number of diving incidents and the strain they are creating on our resources,” replies Reg Hill.

Is the raising of these issues at this level the precursor to regulatory legislation being introduced to make the sport safer?

With the increase in the media’s reporting of diving incidents, this must be seen as a distinct possibility.

Learning lessons

So what of this year’s increase in fatalities? There is nothing in the BSAC’s Incidents Report to suggest that this was an unlucky year. Could the figures have been a lot higher?

Colin Bryan believes so. “We have been very lucky in previous years. We just continue to get away with it. Every incident is potentially lethal,” he claims.

Brian Cumming is prepared to quantify what he calls the near misses. “There could have been another dozen fatalities, but that is not unusual.”

Despite all of this, there are still those who choose to disregard the lessons that need to be learned from these deaths.

Margaret Baldwin from Stoney Cove dive centre has experienced the aftermath of several fatal incidents. She cannot believe the recklessness of some divers. “We discovered that there was a man, diving solo with a rebreather, in the water. We did not know where he was or what he was doing. After he surfaced, we spoke to him about this practice. We could not believe it, he wanted to go back in and do another solo dive! This is the sort of behaviour that causes the incidents.” she says.

Maybe you are new to diving and have heard your diving companions talk of numerous near-misses. Or perhaps you are one of those divers who has had some lucky escapes? Think about your behaviour in the past. Diving is a great experience, but do not let it be your last.

HOW TO REDUCE THE RISKS OF DIVING

Various UK authorities give their views

Brain Cumming, BSAC Safety and Incidents Adviser.

"We are publicising the Incidents Report as much as we can, so that people can avoid making the same mistakes. We have also launched a program inviting any diver to BSAC branches to join in refresher courses so that they can improve their diving and rescue skills. We are throwing the doors open, they do not have to be BSAC members or join the BSAC. Use the branch structure and the experience of other club members and stick to the safe diving practices of your training organisation."

Mark Caney, UK Managing Director, PADI International.

"We are constantly reviewing our training and looking for any trends that would indicate a need for change. Last year we launched out Safe Diving in the UK program to reinforce the need for additional training to prepare for the UK's conditions. We are also meeting with the BSAC to see if there is anything we can do in joint co-operation. We are always reinforcing the message to keep within safe diving practices."

Colin Bryan, National Diving Officer of the Sub-Aqua Association (SAA),

"We are working with CMAS to produce and annual incident report that will look at worldwide trends in incidents. We are also pushing the club environment, where a progressive training atmosphere exists. We will be running build-up dives in the pool for March/April where I would hope to see all divers testing their equipment and practising rescue skills. I would like to remind all divers that this is a risk sport. If you do not respect the water, it will kill you. We have to take the appropriate precautions and risk-assess every dive. I would suggest that at the moment 80% of divers do not even formulate any kind of risk assessment prior to a dive. There is a lot to be learnt from the HSE and their Safe Diving at Work Regulations. I am recommending to our diving officers that we follow many of the commercial divers' codes of practice. Keep practicing your drills, what you learnt 10 years ago may not save you now. Remember you are in a hostile environment and need to constantly assess your situation."

Glynne Pusey, Manager of Horsea Island Dive Centre.

"We are running a Sunday dive-experience program for refresher training. Generally, I would say that standard of the divers we see here is very high. However, that should not mean that you should slack off. I would recommend that people keep training in their drills, just like paramedics do. Do not dive beyond your experience."

Commander Ralph Mavin, RN (retired), HSE Chief Inspector of Diving.

"If the pre-dive plan conditions cannot be met, then do not dive. If things are not as planned, have the sense and courage to admit it. If in doubt, do not dive or abort the dive. It is far better to live to dive another day. Follow the advice of the recreational agency whose qualifications you hold. Remember, holding a particular diving qualification does not mean you are going to remain a competent diver at that qualification level unless you practice the skills on which you were assessed. Putting it bluntly, do not let your ego exceed your talent."

Reg Hill, Diving Officer, Coastguard and Maritime Agency.

"Most incidents are caused by people exceeding their capabilities, technically or physically, or simply being reckless. They could have been avoided if those people had been capable of carrying out their dive within the codes of practice of their organisation."

Margaret Baldwin, Manager of Stoney Cove Dive Centre.

"We have introduced the divers registration scheme, which pushes people towards safe diving practices. If people stayed within these, we would not have nearly as many problems. In the future, if anyone insists on carrying out any unsafe practices, we will, with the registration scheme, be able to refuse access to Stoney Cove. Most of these incidents could have been avoided. We see the end result and the relatives coming on the anniversaries of the deaths with flowers. This is what most people do not see and we would like to work towards avoiding in the future.

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TOURISM

Tourists as inpatients in Queensland regional hospitals

Nicol J, Wilks J and Wood M. *Aust Health Rev* 1996; 19 (4):55-72

Abstract

This study analysed medical record data from seven regional hospitals in Queensland to determine the types of medical conditions and injuries that resulted in overseas and interstate tourists being admitted to hospital. From a total of 135,128 admissions to the participating hospitals, 695 (0.51%) were identified as overseas tourists and 3,479 (2.57%) were from interstate. The main reasons for admission of overseas tourists, based on principal diagnoses, were injuries and poisonings (37.6%), circulatory disorders (11.7%), digestive conditions (9.8%), and genito-urinary disorders (8.8%). For interstate tourists, the main reasons for admission were genito-urinary disorders (19.8%), injuries and poisonings (15.4%), neoplasms (11.4%) and circulatory disorders (10.6%). These findings are discussed in relation to current literature in the field of travel medicine, emphasising the burden of care placed on the admitting hospital's resources, and the growing number of visitors to Queensland needing health care.

Key Words

Medical conditions and problems, tourism.

Working in paradise: health services provided for staff at island tourist resorts

Wilks J, Walker Wood M, Nicol J and Oldenberg B.
J Occup Health Safety Aust NZ 1996, 12(1): 41-48

Abstract

Employment at a tropical island resort is generally perceived as glamorous and exciting. Even in such an idyllic setting, employers have specific duties of care to protect and promote the health and safety of their staff at the workplace. As part of a Best Practice Demonstration Program, the present study reports a detailed profile of health services provided for staff at three tropical island resorts. A total of 1,123 clinic visits were analysed; 912 (81%) concerned medical conditions, while 211 (19%) were related to injuries. Health services consisted mainly of medication, specialist nursing care and first aid. Comparisons with other studies of service industry employees highlight the unique health needs of staff in remote locations and the critical role of the resident nurse. Study findings also demonstrate the advantages of using an internationally accepted classification system for primary health research.

Key Words

Health, tourism.

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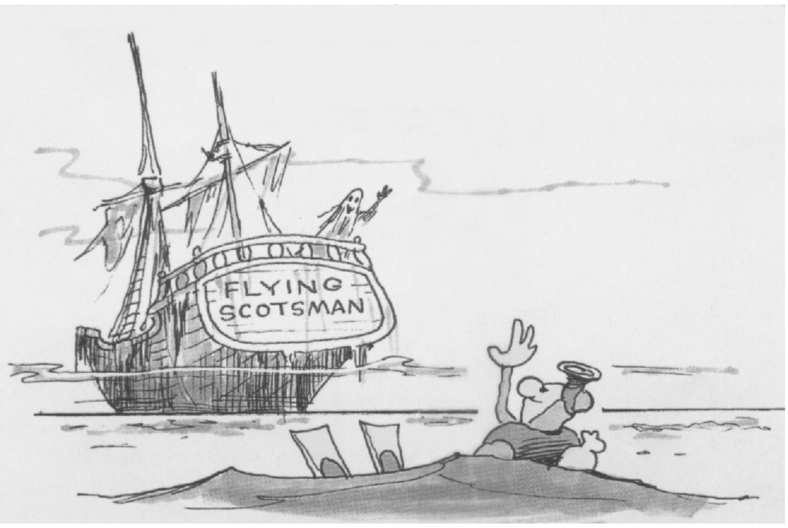
THE SEA PEOPLE'S GUIDE TO DIVERS

By RICO

Humans say that to see themselves as others see them is a great blessing. Imagine then what a blessing it would be to see themselves as other species see them. If only we could find a way of giving them a Sea People's view of themselves. Well, actually, we can...

Thanks to the kindness of Rico, the cartoonist, and of Bernard Eaton, the Editor of DIVER, who have agreed to allow this series of typical divers to be reproduced in the SPUMS Journal. Although the featured diver types originated in the UK, we believe that most of them, at one time or another, have attended a SPUMS Annual Scientific Conference.



Mayday Drifter

A diver with a chronic disability is the Mayday Drifter. Although unaffected in everyday life, he is the victim of a selective word blindness. Only in the diving world does this special dyslexia become apparent: he cannot comprehend the words "tide" and "current".

He surfs the raging currents of major estuaries and shipping lanes; he scoffs at rip tides and gale warnings. If he surfaces in sight of land, this man feels lost.

To the Coastguard and the Search and Rescue forces he is an old friend you invite to retirements and bravery awards. Most helicopters carry a monogrammed rescue harness just for him.

Moss Bros

The Moss Bros are the underwater naturalists of dive clubs. They are as at home in a mossy rock pool or muddy creek as on a spectacular wreck. Seaweed is the garnish of their paradise. While others shun the tenacious tangles of the kelp forest, they embrace its bondage. While other divers choke and drown alongside their cover boat, trying to recover their unmouthed regulators, the Moss Bros will hold them firmly from the boat while they tenderly remove a hitch-hiking feather star from their BC. While others admire a porthole, the Moss Bros will identify the barnacle on the deadlight dog as *Eliminius modestus*, an immigrant species brought over by foreign shipping during the Second World War and which really should be kept on as a conversation piece.

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