

being battered against rocks and losing or damaging equipment.

There were 2 who died because they were trapped and drawn into a **pressure outlet** (a valve) in a fresh water dam. It was not appreciated that the outlets in dams, although not very deep, nevertheless cause a considerable pressure difference. In both cases the body was drawn into the outlet pipe. Although the flow of water was not great in either case, the pressures were excessive once the divers body had been drawn onto and had obstructed the orifice.

The effect of depth in contributing to 12% of the deaths, is probably an underestimate. In many other cases it may have contributed, because of the influence on nitrogen narcosis, consumption of air supply, resistance to breathing, ascent problems, panic, etc. In no case in this series was depth related to decompression sickness, as the latter disease was not a cause of fatalities.

There is a tendency to belittle the importance of marine animals, and in many such injuries the pathologist would be unlikely to observe even a fatal injury ( e.g. from a cone shell or blue ringed octopus bite).

Fresh water cave diving was not particularly common in this geographical area, and in 4% of the deaths the caves were ocean caves, in which the customary cave diving procedures were not followed.

It was clear from the lack of experience in the cases in which the environment contributed to the death, that training in that environment was usually inadequate. It was not readily appreciated by many of the divers who succumbed, or by many of their companions, that training for one diving environment does not necessarily translate to others.

These cases confirmed, again, that diving is carried out in a potentially hazardous environment, and this can be unforgiving when adequate precautions for safety are not taken.

## REFERENCES

- 1 Edmonds C and Walker D. Scuba diving fatalities in Australia and New Zealand. Part 1. The human factor. *SPUMS J* 1989; 19: (3) 94-104
- 2 McAniff J J. United States underwater diving fatality statistics 1970-79. Washington DC: US Department of Commerce, NOAA, Undersea Research Program, 1981
- 3 McAniff JJ. United States underwater diving fatality statistics 1986-87. Report number URI-SSR-89-20, University of Rhode Island, National Underwater Accident Data Centre. 1988
- 4 Walker D. Reports on Australian and New Zealand

diving fatalities. Serially presented in the *SPUMS J* 1980-88.

- 5 Edmonds C, Lowry C and Pennefather J. Diving and subaquatic medicine. Sydney: Diving Medical Centre, 1981

*Dr Carl Edmonds is Director of the Diving Medical Centre, Sydney. His address is 25 Battle Boulevard, Seaforth, New South Wales 2092, Australia*

*Dr Douglas Walker. MB, BS. is the Originator and Collator of Project Stickybeak. His address is P.O.Box 120, Narrabeen, New South Wales 2101, Australia.*

## DIVING ACCIDENT CASES TREATED AT THE H.M.Z.N.S. PHILOMEL RECOMPRESSION CHAMBER IN 1988

Allan Sutherland

### Summary

This report on diving accident cases treated at the Philomel recompression chamber during 1988 shows that the cerebral effects are more refractory than previously thought when assessed by general practitioner observation, family observation and scientific assessment at a Post-Concussion Clinic.

### Cases treated

A group of six doctors, the Philomel Recompression Chamber Roster, provided the Diver Emergency telephone advice and treatment for decompression sickness (DCS) and arterial gas embolism (AGE) during this period. Thirty cases required treatment in the recompression chamber. One was an Indonesian aviator under training with the Royal New Zealand Air Force and the remainder resulted from sport diving accidents. Of the thirty cases, twenty-three have been contacted subsequent to discharge, and of those 23, eight are permanently and significantly damaged as a result of their diving accident, and five are unable to return to normal employment.

Two follow ups were conducted, one at six months and the second at two years. Three of the cases are still consulting me on a regular basis, but all are functioning at a cerebral level much below that before their diving accident. The usual symptoms occur intermittently, headaches one day per week or two, thought blocks, poor concentration, muddled thinking, dropping things, falling, altered sensation, limb weaknesses, getting lost, etc. The presentations have marked similarities to post viral, or chronic fatigue/ME syndromes.

I arranged for the post-concussion clinic at the Auckland Public Hospital, run by neurophysiologist Dr Dorothy Gronwell, to assess these cases. Regrettably the follow up information is not available on all cases, but three were assessed at thirty per cent deficit for higher cerebral function by this clinic, and a similar assessment would probably apply to the other three more severely affected patients who were not tested. By the very nature of their disease these patients become unreliable. Appointments are made with neurologists, post-concussion clinics and clinical psychologists, but the patients do not turn up, or turn up at the wrong time; further, as they are geographically distributed through the North Island, follow up is particularly difficult.

### The worst cases

W had a Skipper's ticket and was an entrepreneurial gentleman until his diving accident. He now works intermittently relieving as a taxi driver, frequently getting lost and confused whilst working. W was assessed as having a 30% deficit. He appears punch drunk and he is certainly functioning at a much lower level than before the diving accident and his enjoyment of life is much impaired. He has been treated with tricyclic anti-depressants and this seems to have improved his mood and adaptation to life.

M, a welder, took six months to return to work, changed jobs three times, had much domestic difficulty, and was assessed by the Accident Compensation Commission medical insurance (ACC) as having a permanent disability of 30% after one year. He was treated with tricyclic anti-depressants for that year but is no longer on any treatment. Now, after two years, he has returned to welding and is much improved, but is not as he was before the diving accident. Both he and his wife describe a personality change.

E, a diabetic, hypertensive Maori, who would dive six times a day to 100 feet, possibly taking illegal shellfish. His lifestyle, after his diving accident, has markedly changed to his own distress. He is not getting on with his family, is giddy and has joint pains, and his whole personality has changed. Attempts to get this man to attend for a neurological assessment or head injury assessment have been unfruitful. He was encouraged to make contact with the ACC, and follow up attempts have been unsuccessful.

T sustained two decompression accidents. He suffered with severe back pain and intermittent "head problems". This man clinically had spinal and cerebral bends. He presents as punch drunk and came into conflict with the ACC and received no final assessment or payment. He has recently had three lumbar vertebrae fused by an orthopaedic surgeon. This man believes that his personality has changed and that he is permanently disabled from his diving accident. This is confirmed by the neuropsychological report.

D suffered with dyslexia as well as having a diving accident and this certainly accentuated the symptoms. This encourages me to believe that people with a major cerebral deficit should be advised against diving, or be made aware of the slightly greater risks should a diving accident occur. This person lost two jobs and has become considerably depressed, with difficulties adjusting to a less responsible job, taken since the diving accident.

B, the aviator, who was decompressed rapidly and sustained an air embolus, was deemed unfit to continue his flying training. Follow up has not been possible, but there is little doubt that he is permanently cerebrally damaged.

It has not been possible to contact two other patients at two years, but they were contacted at six months and neither was in the same employment as they had been before the accident and both were having domestic and work problems which they attributed to the diving accident.

These were eight of the 23 patients followed up to 6 months and of 30 patients in all.

### Less serious cases

On assessment after treatment ten patients had persisting minor symptoms which had mostly resolved before the six month follow up. The remaining twelve cases claimed to be totally normal at discharge.

### Conclusions

This interim report demonstrates the great problems involved in following up this particular group of people, who may well have been difficult before the diving accident, but who were certainly very difficult to find and follow up following the diving accidents. This confirms the statement by Curley et al<sup>1</sup> that the cerebral recovery from DCS and AGE is more refractory than previously thought.

A full study of this group would make a good research project for someone with plenty of time and detective skills.

### REFERENCES

- 1 Curley MD, Schwrtz HJC and Zwingelberg KM. Neuropsychologic assessment of cerebral decompression sickness and gas embolism. Undersea Biomed Res 1988; 15 (3): 223-236

*Dr Allan Sutherland is the coordinator of the Philomel Recompression Chamber Roster. His address is P.O. Box 31-144, Milford 9, Auckland, New Zealand.*

## DIVE COMPUTERS AND FLYING AFTER A DIVE TO 39 M FOR 10 MINUTES

John Lippmann

An interesting report by Balldin<sup>1</sup> describes an experiment in which 10 healthy, male divers or military helicopter pilots simulated a rectangular profile dive to a maximum depth 39 m for a bottom time of 10 minutes in a hyper/hypobaric chamber. The ascent rate was 18 m/minute and no decompression stops were performed, in accordance with the US Navy Tables. After an interval of 3 hours at 1 ATA, the pressure in the chamber was reduced to simulate an altitude of 3,000 m which is similar to the maximum cabin pressure that occurs in some commercial airliners. A Doppler ultrasonic bubble detector was used to monitor the divers in the pre-cordial position. Bubbles were detected in 30% of the divers, however no cases of decompression sickness (DCS) were diagnosed.

Many dive computers indicate the surface interval required before flying in a commercial aircraft after a dive or series of dives. These surface intervals vary greatly between computers, depending on the decompression model on which the computer is based and the parameters and criteria used within the model. Curious to discover what surface intervals various dive computers would require before flying after a dive to 39 m for 10 minutes bottom time, I collected a variety of units and tested them in a pressure chamber.

The chamber was pressurised to 4.9 ATA over one minute, maintained at 4.9 ATA for 9 minutes and then gradually released over 4 minutes to simulate an average ascent rate of approximately 10 m/minute, as specified by most of the computers. The only computer that indicated the need for a decompression stop was the "Micro Brain Pro Plus" which required a stop of 45 seconds at 3 m. Table 1 shows the results.

The results caused me some concern. Three of the five computers indicated surface intervals considerably shorter than the 3 hours after which Balldin found substantial gas phase formation.

One would hope that the slower ascent rate recommended by the computers would reduce the degree of gas phase formation below the level that occurred in Balldin's subjects, but, to my knowledge, this has still not been proven. In any case, despite the very useful ascent rate indicators incorporated in most dive computers, many divers still, at times, find it difficult to maintain such a slow ascent rate, especially if no ascent line is available. If ascent is too rapid, substantial bubbling may occur, and this will very likely slow down gas elimination. The current computers do not adequately account for any delayed off-gassing due to a rapid ascent and will give exactly the same surface intervals before flying (as well as identical repetitive dive times) as when

Table 1

## INTERVALS BEFORE FLYING FOR VARIOUS DIVE COMPUTERS

Dive computer	Interval
Aladin Pro (US Divers Monitor 2)	36 min
Datamax Sport	3 hr 25 min
Micro Brain Pro Plus	0 hr
Skinnydipper	5 hr
Suunto SME-ML (R1)	2 hr

the ascent rate has been adhered to. In a similar experiment to the above, an ascent rate of 18 m/minute gave almost identical results on the dive computers despite their recommended ascent rates having been greatly exceeded. The only difference was that the "Micro Brain Pro Plus" required a decompression stop of 70 seconds at 3 m. It still indicated that it was safe to fly immediately after the dive.

We can never really be sure exactly when it becomes "safe to fly" after a dive as it will depend on the degree of gas phase formation and for how long it persists. There is a gradual reduction in risk with time. Many authorities now recommend that a diver waits at least 24 hours before flying after any air dive, but a substantial number of divers have suffered from DCS after having waited far longer than 24 hours before flying. Flying as long as 5 days after extensive diving has resulted in symptoms.

Most dive computers are continuing to improve as the manufacturers realise their shortcomings and modify their programs accordingly. However, it appears that they still have some way to go. By the end of 1988, 121 cases of bends in divers using computers had been reported to the US Diver Alert Network (DAN,) 77 of these occurring in 1988 alone.<sup>2</sup> In the USA, computer-related DCS increased from 14% of the total DCS cases in 1987, to 36.6% in 1988.<sup>3</sup> Divers should not blindly follow their computers but should add substantial safety margins to the times allowed by their units.<sup>4</sup> This advice seems very relevant to flying after diving.

Interestingly enough, despite the worrying short intervals often given by the "Aladin Pro" and "Micro Brain Pro Plus" for flying after diving, these two dive computers are generally more conservative than the other brands for most diving situations and are, in my opinion, the best dive computers currently available.

## REFERENCES

- 1 Balldin U.I. Venous gas bubbles while flying with cabin altitudes of airliners or general aviation aircraft 3

- hours after diving. *Aviat Space and Environ Med* 1980; 51: (7) 649-652.
- 2 Bennett P.B. Personal correspondence 1988, 1989
  - 3 Report on 1988 Diving Accidents. North Carolina.: Divers Alert Network, 1989
  - 4 Lippmann J.M. Dive Computers. *SPUMS Journal*; 1989; 19: (1) 5-10

© 1989 John Lippmann.

*John Lippmann is a diving instructor. His address is 24 Frogmore Road, Murrumbeena, Victoria 3163, Australia.*

## SCUBA TRAINING FOR THE OUT-OF-AIR SITUATION

Douglas Walker

By far the most contentious subject to raise with those who instruct scuba divers is whether practice in making an out-of-air ascent should be prohibited, permitted if performed under very strictly controlled conditions, or be made an integral part of the training course. This paper discusses dispassionately some of the background to the controversy and records the manner in which the main instructor organisations in Australia have chosen to resolve the conflict between the risk factors of the alternative possible courses of action. Tables 2 to 9 are constructed from information in the Divedata Databank (Project Stickybeak) files. These files are accessible to any interested person or organisation.

### Historical Background

Until pumps had been developed capable of supplying air in sufficient volume to maintain a man underwater the only way to dive was in the breath-hold mode, although some records state that Greek divers in ancient times may sometimes have used air lowered to them in cauldrons by people in boats.<sup>1</sup> The problem of supplying air to keep the water from rising too high within diving bells as they descended was solved by sending air down in weighted barrels on a line, a method described by Halley<sup>2</sup> which remained in use till a sufficiently effective air pump was developed and users changed to this method of replenishing the bell air. He later designed a hookah system which was supplied by the pressured air within the bell. The mortality and morbidity among the workers is unknown but it is probable that accidents occurred when the workers were faced with a ne-

cessity to reach the surface or drown, with some suffering air embolism. In those rough, tough days their deaths would be accepted as due to drowning as the very existence of such a condition as air embolism had yet to be recognised.

As soon as it was realised that a man could be supplied with a continuous flow of air while wearing a helmet, which was in essence a mini-bell, the commercial possibilities were recognised. Now workers were free to move on the sea bed, no longer limited to the area immediately below the bell. The occupation of commercial diver came into existence, hardy, brave labourers who seemingly had a philosophical (or resigned) attitude to the dangers of the work they performed. The early suits were of a helmet and jerkin type, so filled with water if the wearer bent too far forwards, a design soon replaced by the standard suit (except among pearl and sponge divers). The open suits could be discarded by the wearer should necessity or panic make him desire an emergency surfacing.<sup>3</sup> It was such untrained divers who first made "free ascents", luck deciding the outcome of the ascents, although the reason why the fatalities occurred was not discovered until the US Navy introduced practice out-of-air ascents for submariners and some died.

The first recorded instance of a "for real" free ascent from a submarine was that of Corporal Bauer and his two crew from 18 msw depth in 1851. William Bauer must have been an exceptional man because while trapped in the damaged "Sea-Diver" listening to anchors trying to engage themselves in the submarine's structure, intending then to pull it to the surface but more likely to break one of its portholes, and watching water seep through the damaged joints on the hull plates, he managed to think clearly. In this he was helped by the remarkable composure of his crew. His knowledge of physics enabled him to recognise that the hatch was kept firmly closed because the water pressure was greater outside than in the submarine but that he could equalise the pressures by opening the sea-cocks to allow water to enter. That he persuaded his crew that this course of action was safe says much for his personality. All three ascended successfully despite each first taking a last deep breath before opening the hatch. The success of their response to the life or death situation was without benefit of prior training or, as far as is known, planning for such an emergency.<sup>4</sup>

That their survival was not a unique event can be given credence by the findings of the British Submarine Escape Mission, set up by the Admiralty to investigate known cases of escape from actually sunk submarines of all nations.<sup>5</sup> This noted that most of the successful escapes were made without the use of the equipment designed for use in such circumstances "but rather by free ascent or buoyant-assisted free ascent (buoyant ascent)... a result of the malfunctioning (equipment) and/or poorly-trained crews". There is relevance in this comment to the subject of the training of scuba divers and especially to attempts to perform a buddy-breathing ascent unless both divers are well trained and have sufficient air available.