DIVING FATALITIES IN AUSTRALIA

ILLUSTRATIVE CASES

by

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In recent years there has been a tremendous increase in underwater swimming and this has led to the occurrence of special medical problems (Weeth, 1965; Davies, 1962; Duffner, 1961; Leaphier, 1957). Unfortunately, the lack of knowledge of these problems on the part of divers and their attendant medical practitioners has resulted in considerable morbidity, and the occasional fatality, among both commercial and recreational divers. The ultimate cause of death in underwater accidents is usually drowning, although in reported series of diving deaths (Denney and Read, 1965; Macfie, 1964; Miles, 1962) cases are described in which such conditions as pulmonary barotrauma, oxygen poisoning, inhaled false teeth and coincidental illness or injury have either caused death or else been an important contributing factor.

The aim of this communication is to describe some illustrative cases from 25 diving fatalities that have occurred in Australia in the past decade. Accurate figures on the incidence of fatal accidents in diving are very difficult to obtain, as there is no recognised authority governing civilian diving on a national basis. The following cases have been selected from records made available by the forensic pathologists in Commonwealth and State Departments of Health in the capital cities of Australia. Unfortunately, in some of the cases it has not been possible to clarify the meaning of certain descriptive phrases relating to the post-mortem appearance of the divers' internal organs, particularly the lungs.

REPORTS OF CASES

Deaths from Equipment Failure and Poor Diving Techniques

Case 1. A man, aged 24 years, entered a river to test a "frogman" outfit he had made. The apparatus was strapped to his back and he tested it by submerging himself to a depth of two feet. The test lasted for only a few minutes and then he swam straight into 12 feet of water. After two or three minutes he surfaced, removed his face mask and was observed to sink. No cry for help was heard. Two onlookers swam promptly to his assistance, but experienced great difficulty raising the diver to the surface due to the weight and encumbrance of the apparatus. It was noted that a Mae West life jacket the diver was wearing was not inflated. There was also no quick-release gear on the harness of the apparatus. After four attempts the diver was eventually recovered from the water. Artificial respiration was started promptly, but he failed to respond. The results of a post-mortem examination showed that death was due to drowning.
Case 2. An experienced spearfisherman, aged 27 years, equipped with a twin-cylinder aqualung was diving in 35 feet of water with a companion. The companion gave chase to a fish which he successfully speared; however, when he looked around for the diver, he was missing. A search was promptly instituted and the diver's body was found wedged in a crevice about 10 feet below the surface. The diver had attempted to "ditch" his equipment, but in the confined space in which he was trapped his weight belt became tangled in the aqualung harness. The searchers had to cut his harness and remove the aqualung before he could be released. Post-mortem examination findings showed that death was due to drowning.

Case 3. A spearfisherman, aged 37 years, who was in good health and considered an experienced swimmer, was spearfishing about 20 feet from a rocky shoreline. An onlooker noticed he was in difficulties and promptly informed two other spearfishermen in the group, who immediately went to the assistance of the diver in distress. The diver was found lying on his back with the aqualung harness tangled about his legs. The cylinders of the aqualung were caught in the rocks and difficulty was experienced in extricating the diver. On reaching the shore, mouth-to-mouth resuscitation was instituted, but the diver failed to respond. Death was due to drowning.

Terrell (1965), when discussing diving safety, stated that "no diver should be allowed beyond the reach of immediate effective assistance". Obviously the nature of the diving operation and the type of equipment in use are going to be important factors in deciding the stringency of safety precautions. Shallow depth of water is no excuse for neglecting safety precautions, as is illustrated in the above three cases.

In Case 1, the diver, who was using new and untried equipment, should have been secured to the shore by a life-line and been under the direct supervision of a person who was responsible for seeing that the diver was recovered if he gave any indication of being in distress. The provision of quick-release buckles on the harness would also have enabled the diver or his rescuers to remove the equipment rapidly when its failure occurred.

Cases 2 and 3 illustrate the great need for caution when diving near rocky underwater ledges and crevices. It is sound practice to dive with a companion in these situations, but both divers must remain in communication with each other. When two divers are linked by a "buddy-line" the safety of the pair is greatly enhanced. Usually a buddy-line is 6 to 10 feet long and is securely attached to the wrist or arm of the diver. A little skill is needed in underwater swimming in this manner, but the advantages in increased safety are certainly worth the effort.
Coincidental Illness

Case 4. A man, aged 38 years, who had been spearfishing alone was found dead on a beach clad in a wet suit but without any aqualung equipment. He had had a history of mental depression, and was known to consume excessive amounts of alcohol periodically. Death was due to drowning, but the findings at post-mortem examination also revealed the existence of a previous state of prolonged respiratory and circulatory embarrassment within the lungs.

Case 5. A man, aged 29 years, was spearfishing a quarter of a mile off-shore. He brought up his catch to his diving boat, changed his air cylinder and then dived back into the water. About a quarter of a minute later he surfaced and called out "help me". He was recovered from the water unconscious and in respiratory distress. Resuscitative efforts included a thoracotomy and cardiac massage performed on the beach. Death was due to drowning, but at post-mortem examination there was evidence of respiratory tract infection and study of histological sections revealed evidence of a pre-existing allergic condition.

Diving is an activity which demands a considerable degree of physical fitness and mental alertness. Handbooks on diving (Terrell, 1965; Poulet, 1964; Brookes and Broadhurst, 1962) normally include a chapter on medical standards required for diving, together with descriptions of illnesses and conditions that give rise to temporary or permanent unfitness for diving. Unfortunately, many recreational divers, particularly those that have received no formal instruction in diving, regard minor respiratory tract infections as merely an irksome inconvenience and of no potential serious consequence.

Miles (1962) describes two cases, one fatal, in which respiratory tract infections rapidly spread and developed after diving. He put forward the explanation that if the breathing gas was trapped in small groups of alveoli by infected secretions in bronchioles, then going undar pressure would cause the infected matter to be drawn into the alveoli. Decrease in pressure on the ascent would have the reverse effect.
Pulmonary Barotrauma

Case 6. A man, aged 24 years, was undergoing a "free ascent" exercise in which his equipment was removed at a depth of 30 feet and he was to swim to the surface unaided. On surfacing, the diver groaned and was seen to sink back into the water. Prompt resuscitation with 100% oxygen failed to revive him. At post-mortem examination, supraclavicular subcutaneous and mediastinal emphysema were noted. There were also numerous air blebs on the lung surface and in the pulmonary interstitial tissues. Air emboli were noted in the left ventricle and in the cerebral, coronary and mesenteric vessels.

Pulmonary barotrauma in diving is usually caused by the diver holding his breath on the way to the surface after abandoning his equipment. Denney and Glas (1964) have described how, in accordance with Boyle's law, a diver who receives air from his set at a depth of 33 feet (two atmospheres absolute) will approximately double the volume of air in his lungs as he ascends to the surface (one atmosphere absolute). This intrapulmonary expansion of air has been shown to result in alveolar wall damage, mediastinal emphysema, pneumothorax and arterial air embolism (Collins, 1962; Duffner, 1961; Liebow et alii, 1959).

Immediate recompression to six atmospheres absolute in a therapeutic recompression chamber may save the victim of severe pulmonary barotrauma by rapidly reducing the volume of air trapped in the circulation and mediastinal tissues. Recompression must then be followed by an adequate therapeutic decompression regime (Weeth, 1965; Denney and Read, 1965). In the absence of adequate recompression facilities the prognosis is grim. Harveyson et alii (1956), in Queensland, described a case of air embolism following a free ascent from a depth of 20 feet. Over a period of 16 hours acute pulmonary oedema developed and despite energetic conventional measures, death occurred 28 hours after the accident.

Deaths After Attempted Recompression Therapy in Open Water

Case 7. A native pearl diver, aged 31 years, completed three uneventful dives in the forenoon and was down for the fourth time when he was seen to surface unconscious and without his diving helmet. He was brought on board the diving boat, redressed in another diving helmet and returned to the water for therapeutic recompression. Details are not available, but two attempts were made to treat the diver by recompression. The diver failed to recover consciousness and died. At post-mortem examination the features of drowning were noted, together with evidence of pneumonia in the lower lobe of the left lung.
Case 8. A native pearl diver, aged 35 years, entered the water at 7 a.m. and was working in 7 to 8 fathoms (42 to 48 feet), when at 7.30 a.m. he floated to the surface without his helmet and in distress. He was brought to the side of the lugger where he answered a question from his attendant. A helmet was secured on the diver and he was recompressed in the water for about half an hour. He was then surfaced, but his attendant was uncertain if the diver was alive or not. The diver was recompressed for a second time in the water, and on surfacing was found to be pulseless and not breathing. Blood-stained froth was seen coming from his mouth. Death was due to drowning.

Case 9. A native pearl diver, aged 26 years, over a period of six hours made three dives to a depth of 18 to 19 fathoms (108 to 114 feet), spending between 30 and 40 minutes at depth on each occasion. Shortly after surfacing on completion of the third dive the diver "lost his mind" and could not control the valve on his helmet. He was returned to depth for recompression in company with another diver, who stayed with him for about five minutes, when it appeared the victim was rational once more. When finally brought to the surface, the diver was dead. The post-mortem report stated that decompression sickness (caisson disease) was the major contributing factor to the cause of death.

Diving in the pearling industry of northern Australia is usually undertaken with the use of a half-suit or helmet and corselet technique. This latter consists of a standard diving helmet permanently attached to a metal corselet, with canvas extensions which form a type of cape over the shoulders of the diver. Air is supplied to the helmet from a surface engine-driven compressor. A life-line is made fast to the front of the corselet. This equipment can be very easily lifted over the diver’s head either on the surface or in the water. The air pressure in the helmet is maintained at a level sufficient to prevent the entry of water.

Official inquiries into the deaths of pearl divers reveal that many have dangerous misconceptions about the physiology of diving. Decompression from depth is governed by rule of thumb based on the master diver’s experience and judgement rather than on adherence to the figures in calculated decompression tables. When repetitive diving is carried out in depths greater than 30 feet, the decompression schedule has to be modified by taking into account the depth of the deepest dive and the interval between dives (Workman, 1965; Miles, 1962).

Cases 7, 8 and 9 show how the procedure of therapeutic recompression in open waters can have a fatal outcome when applied to divers suffering severe decompression sickness or possible pulmonary barotrauma. Apart from the impossibility of applying basic medical care to the unconscious
diver, there is the added risk that with certain types of equipment the diver may lose his air supply or suffer hypothermia from prolonged immersion (Behnke, 1965).

DISCUSSION

A study of the cases presented emphasizes that in diving ignorance is not bliss. The safe enjoyment of recreational diving and the successful completion of a commercial diving operation begins with the medical selection of the diver.

In general, divers should be physically fit volunteers who are free from a history of conditions that predispose to loss of consciousness under water (such as epilepsy and diabetes). They should have no acute or chronic conditions that may be aggravated by the underwater environment, such as ear infections and respiratory tract disease, which could predispose to air trapping. Jarrett (1965) and Miles (1962) have described useful outlines of the medical standards required by civilian divers. The medical standards applicable to commercial divers in New South Wales are laid down by law (Regulations under the Scaffolding and Lifts Act, 1912-1960), but unfortunately there is no legislation covering recreational diving. In many States there is no legislation covering diving activities whether commercial or otherwise. Weeth (1965) has stressed that medical practitioners and laymen who have responsibility for divers should be in possession of the U.S. Navy Diving Manual. Certainly, naval diving manuals and publications (Royal Naval Diving Manual; United States Navy Diving Manual; Submarine Medicine Practice) contain a wealth of information on the management of diving accidents and illnesses, but the regulations relating to the conduct of diving operations may be restrictive for certain types of recreational diving. They are particularly valuable for advice on the problems of deep and hazardous diving.

To adhere to established diving practices is a major factor in diving accident prevention. A diver should have a thorough knowledge of the capabilities and limitations of the type of equipment he is using. Unfortunately, at present in Australia, provided a person can afford to buy an aqualung, there is no legal requirement for him to undertake a course of instruction in diving in any of the established underwater clubs. Unfamiliarity with new equipment and ignorance of elementary diving physiology can combine very easily to result in a fatal accident. A diving training course should include lectures given by a medical practitioner on the physiology of organs with air containing spaces (particularly the middle ear, paranasal sinuses and lungs) explaining
how changes in pressure affect them. In discussing the special hazards of diving, for example, decompression sickness, pulmonary barotrauma, nitrogen narcosis and oxygen poisoning, emphasis should be placed on preventive measures such as the following of decompression tables, exhalation on free ascents and the necessity of keeping within the depth limitations of the breathing gas mixture used. Laophier (1957), in a very interesting paper on diving medicine, does not recommend the use of oxygen and "high oxygen mixtures" for sports divers. The possibility of a grand mal type convulsion occurring, due to the toxic effect of high pressure oxygen on the central nervous system, at depths as shallow as 25 feet makes this an unduly hazardous form of diving for the amateur.

The provision of adequate recompression facilities for treating cases of pulmonary barotrauma and decompression sickness presents many problems. The cost of even small recompression chambers is such that they are beyond the means of most recreational diving clubs and many commercial divers. At present there are only about seven recompression chambers on the Australian mainland and not all of these are operational, as they are only used from time to time on major tunnelling and bridge building works involving the use of compressed air operations. The only chamber that provides a 24-hour service for the treatment of civilian divers is the Naval Recompression Chamber, at H.M.A.S. RUSHCUTTER in Sydney (Miller and Bayliss, 1966). A further problem is that the recompression chambers are concentrated in the capital cities, quite often in areas remote from diving activities. When one considers the length of Australia's coastline and the number of localities in which diving is carried out, the chances of adequate therapeutic recompression facilities being available near the scene of a diving accident are slender.

In the absence of adequate therapeutic recompression facilities the object of the diving exercise or operation must justify the risks involved. In free ascent training, thorough instructions and the presence of a trained diver accompanying the novice on his ascent can greatly enhance the safety of this activity. In 50,000 free ascents carried out in submarine escape training by the Royal Navy, there were only 25 accidents, 19 of which resulted in cerebral air embolism. Immediate recompression (within a minute of leaving the water in the training tank) resulted in a complete recovery in all cases (Miles, 1962).
SUMMARY

Nine diving deaths out of 25 known fatal diving accidents that have occurred in Australia in the last decade are described. Comments are made on the measures that the divers concerned could have taken, which would probably have averted a fatal outcome to a diving accident.

The importance of divers being medically fit and conversant with the special hazards of the underwater environment is stressed. The problems in availability of recompression chambers in Australia are described.
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