It was impossible to determine the incidence of problems with snorkels. These were not at all well documented in the case reports, even though there was some indirect evidence of these as 8% died while snorkelling on the surface. It was not possible to determine whether these could be attributed to the snorkel design or misuse, or even whether this was a major contributor.

There were many other instances in which equipment was not used but could have been considered of possible value to the diver, but in which one would be hesitant to label as contributing to the death.

Discussion

The analysis of some equipment problems due to incorrect technique, was referred to in the first report.[1] Thus the problems with air supply have been previously recorded. The misuse of weight belts and many of the problems with buoyancy that were clearly errors of judgement, have also been recorded in that paper.

It is important to realise the difference between these figures and those given in the United States by the NUADC[5,6] and Australia by Project Sticky Beak.[7] In this ANZ series only when equipment fault or misuse actively contributed to the death was it recorded. Problems with diving equipment are reviewed elsewhere.[8,9] There are many other problems that are experienced in the field that are not evident in this series. An example is the diving computer, which was not commonly used during most of the period under discussion, but which has contributed to many problems since.

The reassurances given by the diving industry, regarding the reliability and sophistication of our current equipment, are possibly not correct. In many instances the misuse of equipment could be, at least partly, the responsibility of the equipment designers and at other times purely the responsibility of the diver himself.

When the equipment problems and misuse are combined with the fatalities related to equipment related techniques[1] (out of air situations, overweighting, buoyancy control, etc.), it is evident that more attention should be given to diving training and to training in the use of diving equipment.

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WHAT PRICE TASMANIAN SCALLOPS?

A report of morbidity and mortality associated with the scallop diving season in Tasmania 1990.

Margaret Walker

Introduction

The D'Entrecasteaux Channel is a narrow strip of water lying between Tasmania's southeast coastline and Bruny Island. It is a natural breeding ground for many forms of fish life, especially the famous Tasmanian scallop. Prior to 1969 the channel was heavily harvested for scallops by commercial fishermen using dredges. Divers could also collect scallops, but as it was dangerous to dive close to the dredging operations so this was only performed to a limited degree. In 1969 the area was closed because of the enormous damage to the sea bottom caused by dredging, which removes the top layer of sand and all weed and marine life. After a period of recuperation, the channel was reopened in 1982 and for three years was heavily dredged, before it was again closed to scallop fishing in 1985.

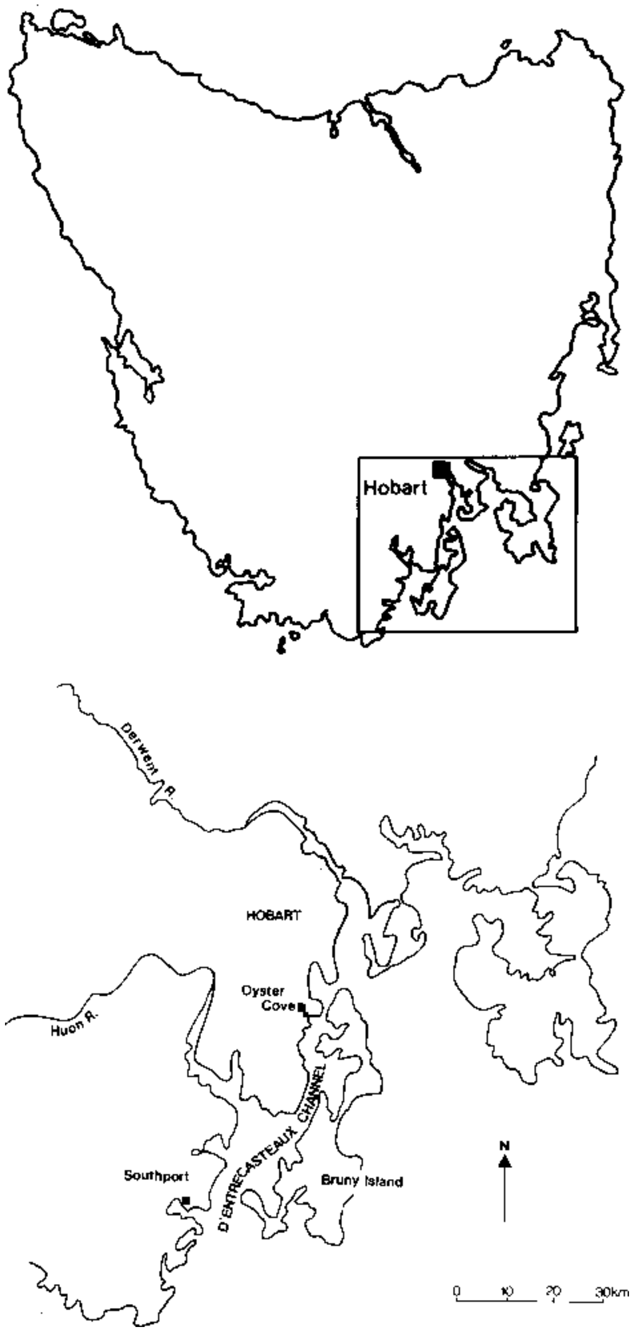

Figure 1 shows the location of the D'Entrecasteaux Channel, where all the accidents occurred.

In 1990, after many years in which it was just not legally possible for the average sport diver to obtain a meal of scallops in Tasmania, the Department of Sea Fisheries opened the channel for scallop fishing by sport divers only. For a short season of four weeks in the month of July, the average sport diver could dive unmolested, and take up to 200 scallops per day for his own use, with a maximum possession limit of 400. The area opened for diving extended from Oyster Cove in the north to Southport Bluff, and consisted of fairly uniformly shallow water no deeper than 16 m. Most scallops were found in water less than 9 m deep. (Figure 1.)

Unfortunately, the weather was unkind to the divers, with heavy rainfall washing tannin and other particulate matter from the Huon River into the channel, reducing the visibility to near zero in most areas. The water temperature was also very low, varying from 5 to 9 °C. Despite the poor conditions, divers, enticed by the lure of fresh Tasmanian scallops, turned out in their hundreds. Many were inexperienced, unqualified and/or unfit, and the local police and Fisheries authorities were kept busy helping exhausted divers, bordering on hypothermia, from the water.

There were two deaths directly related to diving and three cases of decompression sickness (DCS) treated at the Royal Hobart Hospital (RHH) Hyperbaric Medical Unit during the four week season and these are reported here.

Case Reports

Case 1

J was a 34 year old man, very fit and keen on sport. The day before his diving accident, he had been snow skiing, but due to poor snow cover had decided to go diving the following day instead. He was an experienced diver who was said to be meticulous in his preparation and planning of dives, and had completed three advanced diving courses. The dive took place in water with a maximum depth of 11 m and temperature of 9 degrees Celsius.. There was a cool surface wind. The visibility was near zero. He wore a 9 mm wetsuit and used full scuba gear, which was later tested and found to be in good working order. He and his buddy had performed 5 dives, all of approximately 15 minutes duration, but had not found many scallops. On his 6th dive for the day, J went down alone with a torch in one last attempt to fill his quota. His buddy remained in the boat, and very quickly lost sight of J's bubbles. After 30 minutes he started to search for J. J was found on the surface floating on his back, with yellow froth coming out of his mouth. His regulator was not in his mouth and his buoyancy compensator was not inflated. His mask and weight belt were on. His tank contained 60 bar of air. J was retrieved from the water and cardio-pulmonary resuscitation (CPR) was commenced and continued for 90 minutes before being abandoned. His body temperature was 32 °C, taken per rectum, on his recovery from the water, and had risen to 32.7 °C by the end of the resuscitation period.

Unfortunately, the autopsy was performed with no special precautions and no prior X-rays[1], despite there being a protocol for post-mortem examination of divers[2] approved by the RHH Administration, Radiology and Pathology Departments some four years earlier. This protocol was introduced by Dr Peter McCartney, Director of Diving and Hyperbaric Medicine. The infrequency of such post-mortems, a change of forensic staff, and the failure to involve the Hyperbaric Medical Unit in the early stages of the investigation, led to the protocol being overlooked. However, the examination performed found that the trachea and bronchial tree contained thick yellow frothy fluid and microscopically the lungs showed small areas of intra-alveolar haemorrhage. Also, there were vessels in all organs which were dilated and devoid of blood, suggesting air embolism. The official cause of death was drowning and hypothermia was suggested as a probable trigger.

Case 2

E was a 53 year old man, apparently in good health, who had no formal diving qualifications, but was said to be an experienced diver. He had not dived for over 12 months. On the first dive of the day, he and his buddy dived to 9 m maximum depth for 20 minutes on hookah (surface air supply). After depositing their scallops on the boat, they descended for more scallops. This time they were on the bottom for 10 to 15 minutes before surfacing. The water temperature that day was 5 ºC, the visibility near zero, and there was a cool surface wind. They swam to the surface together. The buddy then swam back to the boat, thinking that E was following. However, on arriving at the boat, he was told that E had gone back down, so he returned to find him. He was unable to see under the water, so followed E's air hose down to locate him floating unconscious, just above the sea bottom in 9 m of water, with his regulator out of his mouth. He ditched E's weight belt and took him to the surface, where he put his own regulator in E's mouth and swam with him to the boat. It was thought that he was breathing at this time. He was transferred to a Police Boat where CPR was commenced and continued until a doctor made the decision to stop.

This time X-rays and CT scan were performed on the refrigerated body before autopsy 24 hours after death. The CT scan showed air bubbles in the brain, heart, aorta and blood vessels of the liver and mesentery (Plates 2-4). At autopsy the diagnosis of massive arterial gas embolism was confirmed by opening the major vessels under water in the approved manner.[2] Microscopically, there were distended and ruptured alveoli in the lungs, and distended empty vessels were seen in most organs. There was no extravascular gas. A myocardial infarction 3 to 4 weeks old was found, with severe generalised coronary disease. Information later received from his General Practitioner revealed that he had been seen earlier in the year complaining of chest pains and throat pains. He was found to have an elevated cholesterol, and was asked to return if the pains recurred, but did not return for follow up.

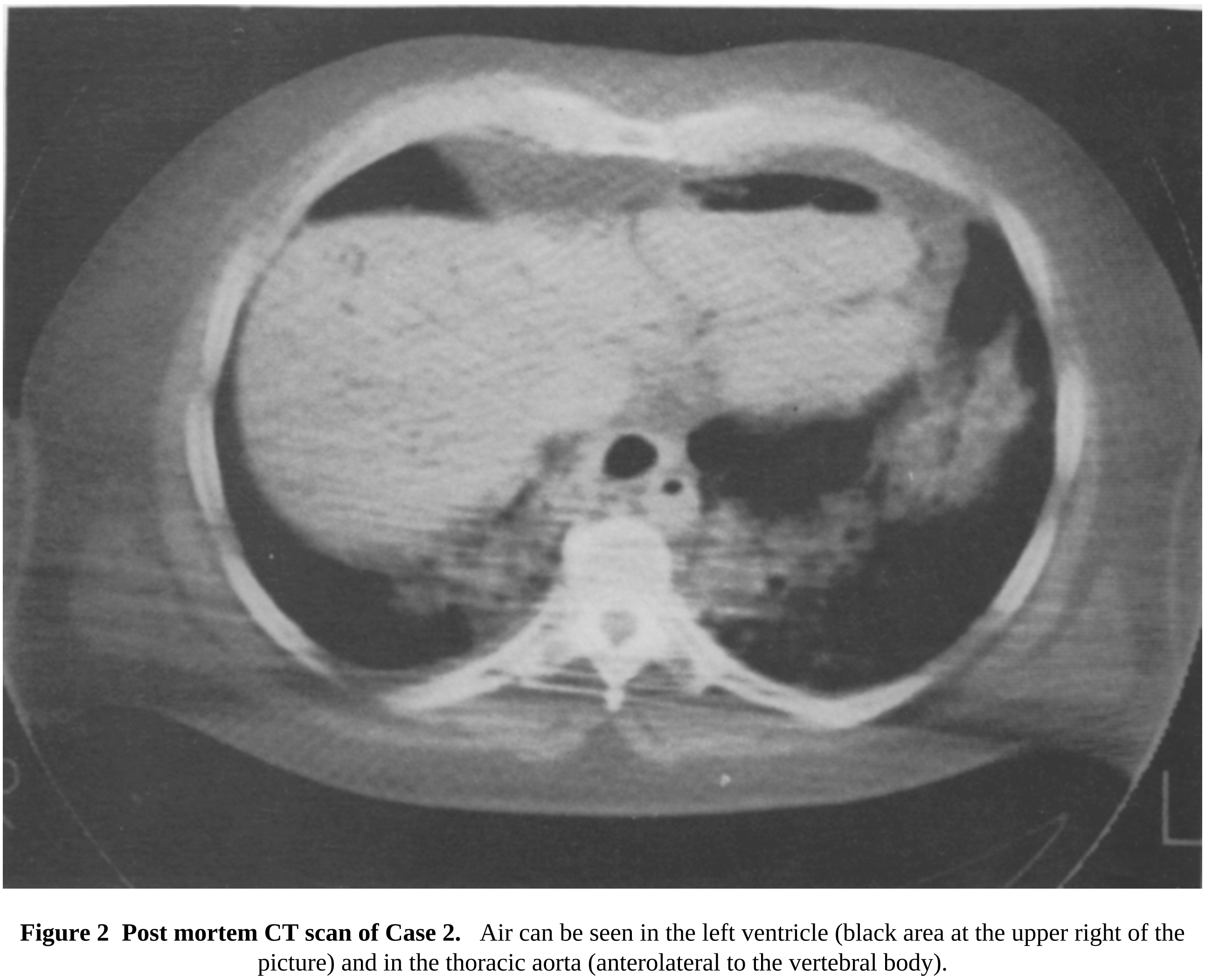

Figure 2 Post mortem CT scan of Case 2. Air can be seen in the left ventricle (black area at the upper right of the picture) and in the thoracic aorta (anterolateral to the vertebral body).

Case 3

R was a 37 year old self taught diver, who had not dived for 5 years. He was suffering from a respiratory tract infection, but decided to dive anyway. On the day of his dives the water temperature was 9 ^{o}C, and visibility was zero. He wore a 7 mm wetsuit. He dived on scuba to approximately 8 m (no depth gauge was used) for 30 minutes gathering scallops, returned to the boat, and after a 45 minute surface interval performed a second dive to 8 m for 20 minutes. Following the second dive he attempted to surface, but was pulled down by the weight of his scallops and due to the poor visibility could not see his bubbles to indicate which way was up. He panicked and swam actively to the surface finning vigorously. On surfacing, his nose bled and he felt some pain in his sinuses. This settled, and he felt reasonably well until about 3 hours later, when he developed an ache across his anterior chest, pain in both arms, tightness in his neck and vague abdominal discomfort. He had a marked feeling of dyspnoea but there was no pleuritic pain. After 3 hours of worsening discomfort, he presented to hospital for assessment.

His physical examination was normal, except for some blood in the nasal passages, and there were no neurological signs. An ECG was normal, and there was no pneumothorax on chest X-ray. Although his signs were not classical, he improved with 100% oxygen, and recompression to 18 metres of sea water (msw) produced complete relief of all his symptoms, confirming the diagnosis of decompression sickness. His chest discomfort recurred overnight, and two daily oxygen soaks to 18 msw were required before he remained symptom-free. He has decided not to dive again.

Case 4

B was a 25 year old professional sea urchin diver, who had performed his usual dives for urchins the day before he presented for treatment. These consisted of a 30 minute dive to 5 m on hookah followed 20 minutes later by a 70 minute dive to 16 m which included two bounces to the surface, with no decompression stops. Two hours later, he developed pain in his left elbow and shoulder and

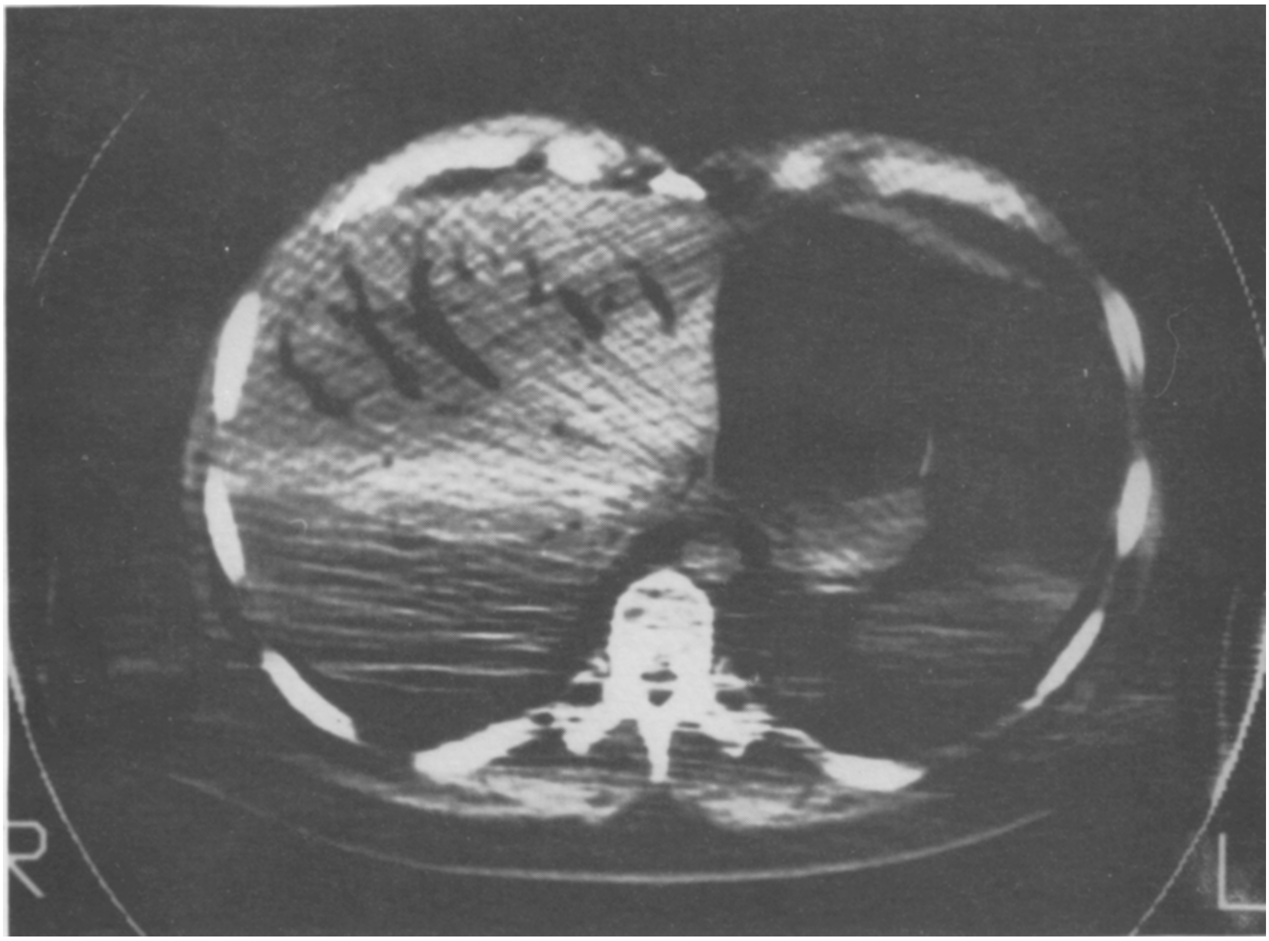

Figure 3 Postmortem CT of Case 2. Air (black lines) is shown in the blood vessels of the liver.

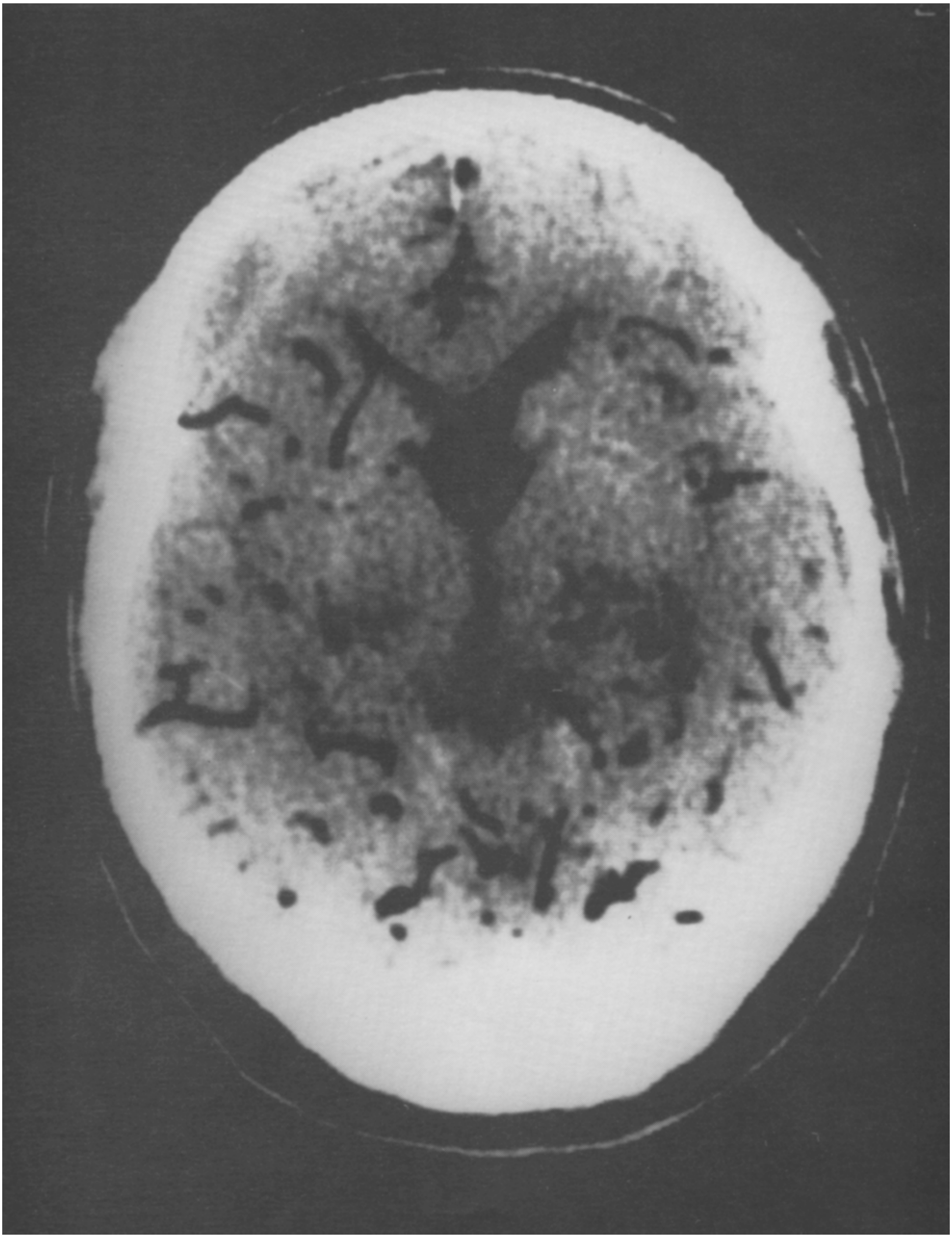

Fig ure 4 Post-mortem CT scan of Case 2.
Air is clearly shown, replacing blood in the cerebral blood vessels. Air is also present in the cerebral ventricles.

paraesthesiae in his left arm which lasted for two hours before resolving. The next day he decided to do some scallop diving, and dived to 5 m for 60 minutes. Twenty minutes later, his symptoms of the previous night recurred worse than before, and he presented to hospital for treatment.

Physical examination was normal, and no altered sensation could be detected in his left arm despite a persistent feeling of "pins and needles" in the arm. 100% oxygen produced significant relief of his symptoms. He was treated with recompression to 18 msw according to USN Table 6 with complete resolution of symptoms at depth. His left shoulder pain recurred the next day, and two further daily 18 msw oxygen soaks were required to prevent their recurrence. He remained well at his six week follow up appointment. He was advised not dive deeper than 10 m for three months and to be very conservative with decompression during his working dives in future.

Case 5

C was a 29 year old qualified sport scuba diver, who had completed several advanced diving courses. He had not used hookah apparatus before, and was diving on hookah for the first time that day. The water temperature was 9 ^{o}C and the visibility so poor he could not see his hand when he held it in front of his face. He wore a 7 mm wet suit. He had no depth gauge, but thought he had dived to 18 m for 45 minutes after a brief visit to the surface. He then had a 1 hour surface interval followed by another dive to 18 m for 60 minutes. His surface air supply then failed, and as he was unfamiliar with the equipment and had no alternative air source, he ditched his weight belt and made a rapid, uncontrolled ascent. On arrival at the surface, he had a bleeding nose, pain in his left ear, severe pain in both arms and both hips, and he developed chest pain and dyspnoea. His symptoms persisted en route to hospital, and became significantly worse on driving over the hills towards Hobart, where the road reached an altitude of between 250 and 350 m above sea level.

At hospital he was distressed and dyspnoeic but had no clinical or radiological evidence of pneumothorax. He was tender to palpation over both hips. Examination of the ears revealed a retraction pocket in the superior aspect of his left eardrum (probably a chronic problem), with erythema of the drum. His Eustachian tube function was normal, but he fell to the right after 5 seconds in the sharpened Romberg test. There were no other neurological abnormalities.

His symptoms greatly improved on recompression to 18 msw and he was treated with a USN Table 6. His hip pain was improved, although not abolished, and he required three further 18 msw oxygen soaks before his symptoms completely resolved. His sharpened Romberg test was normal at discharge. ENT review after treatment revealed no Eustachian tube or vestibular dysfunction and no treatment was required for the retraction pocket in the left eardrum.

Discussion

The cases described here represent a cluster of diving accidents associated with relatively shallow, cold water diving in both experienced and inexperienced divers. That it is possible to develop decompression sickness in water at less than 2 ATA is not well appreciated by the average diver but is documented.[3] When hypothermia is also present, the risk of DCS is increased.[4] The risks of pulmonary barotrauma are well recognised in shallow water. Recent articles reporting diving accidents in Australia[5,6] have emphasised contributions from both human and environmental factors in the aetiology of accidents, and both are relevant here.

Although the water was uniformly shallow, the extreme cold and zero visibility made diving very hazardous. Diving in cold water requires special precautions, especially when heat loss by conduction to the water is exacerbated by evaporative cooling, after the dive, by a surface wind. The neoprene of wetsuits provides good insulation while in the water, but is ideal for evaporative cooling once on the surface, making windproof jackets essential where there is a surface wind. In the water described here, where the temperature was 5 to 9 ^{o}C, a neoprene wetsuit of thickness 7 to 9 mm usually provides adequate thermal insulation when immersion times are not prolonged for much more than 60 minutes.[7] In Case 1, hypothermia probably contributed significantly as a result of prolonged immersion in 9 ^{o}C water, despite a 9 mm wet suit. Dry suits are required for colder temperatures, such as in Antarctica, where the water temperature is close to 0 ^{o}C.

It is documented, but unfortunately not well recognised, that some divers make a very poor assessment of their thermal status and may deny feeling cold and continue to dive when their core temperature is significantly reduced.[8,9] In cool climates it is likely that many divers have a significantly reduced core temperature after a 60 minute dive, and they are certainly cold peripherally. Such cold stress can then lead to decreased cognition, irrational behaviour, and poor judgement, especially in making emergency decisions. Cooling of the limbs impairs strength, coordination and the ability to perform fine movements which may be life-saving, such as ditching a weight belt, inflating a buoyancy compensator, or retrieving a dislodged regulator.[4]

For these reasons, trainee divers in cool climates should be carefully taught about the risks of hypothermia and how to prevent and treat it. Similarly, local medical officers and paramedics should be familiar with techniques for resuscitation and rewarming of hypothermic divers.[4] This does not overcome the problem of educating the large numbers of untrained divers who are currently diving in Tasmania.

Two of the divers in this report had no diving qualification, although they were said to have had some experience years before. At present in Tasmania a scuba diving qualification is not legally required to hire diving gear or have tanks filled, nor is it necessary to produce a scuba card to purchase a licence to dive for scallops or other fish. It is unknown how many unqualified divers were in the Channel during the 1990 scallop season nor how many of them suffered morbidity without seeking medical aid.

Two of the divers were qualified sport divers, who had completed advanced diving courses, but had not dived much during the cold Tasmanian winter. The fit, intelligent, qualified, but "out of practice" diver recurs frequently in diving accident statistics. It is important for qualified divers to keep refreshing their knowledge and safety skills, especially after a period of absence from the activity.

The fifth diver was a professional diver who developed DCS due to poor dive planning in his working dives the day before his scallop diving expedition. He did not seek treatment and elected to continue diving the next day. It seems surprising that a professional diver could ignore the symptoms of decompression sickness and continue to dive.

Medical conditions which should have precluded diving were found in these cases. Case 2 had coronary disease and a recent myocardial infarction. Case 3 had a current respiratory tract infection and a long lay-off time. Case 5 had a chronic middle ear problem which had not previously been addressed and although it is unlikely this contributed to his accident, he suffered barotrauma to this ear and developed marked disequilibrium with his DCS, manifested by a poor Romberg test. Prior to this accident, he had never been seen by a doctor experienced in diving medicine as his medicals had been performed by his local General Practitioner.[10]

Diving technique faults were evident in these cases. Poor dive planning and failure to make appropriate allowances for the poor conditions (e.g. limiting immersion times, avoiding repeated bounces to the surface and the use of buddy lines) were common faults. Diving alone, and in Case 5, diving with unfamiliar equipment and no alternative air supply, which lead to an out-of-air situation, panic and rapid ascent, are serious diving errors. Only Case 2 had contact with his buddy while underwater, due to the poor visibility. None used buddy lines. Cases 1,3,4 and 5 dived alone, or with a boat-boy only. It is important to remember that buddy diving is a specific, planned procedure, and is not just diving with a "mate" in the same area. Similarly, safe diving in zero visibility requires special techniques and knowledge, and the action of Case 1 in taking a torch down for his last dive was probably counter-productive as all it would produce would be glare reflected from the particulate matter in the water.

Buoyancy problems were also evident. None of the divers took into account the weight of the scallops, and the effort required to swim to the surface with a full bag of scallops and normal lead weighting. The three hookah divers in particular had no buoyancy compensators to help their ascent.

These cases serve as yet another reminder of the potential dangers of poorly planned compressed air diving. Adequate physical fitness, a sound understanding of the implications and limitations of scuba and hookah equipment, and a healthy respect for a hostile environment remain essential for safe diving. However, they continue to be hard lessons for divers to learn.

In view of the morbidity encountered amongst divers in 1990, the Department of Sea Fisheries in Tasmania is currently considering whether the D'Entrecasteaux Channel will be opened to scallop divers again in the future.

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QUEENSLAND SCUBA DIVERS AND THEIR TABLES

Jeffrey Wilks and Vincent O'Hagan

Introduction

Increasing emphasis is being placed on scuba diver safety by the world's major certifying agencies.[1,2] Though Australian statistics show recreational diving to be increasing in popularity[3], and that safety is improving relative to the number of divers in the sport[4], there are still many unnecessary accidents occurring. In particular, divers' inability to effectively plan dives using their tables[5,6] may place them at risk for out-of-air emergencies and decompression sickness.[7]

Australian divers are not alone in having problems with their dive tables. In one American study 2,576 divers were asked to complete five decompression problems similar to situations that might arise on charter trips.[8] Only 49% of the respondents successfully completed all five questions. In another study of 1,000 active certified divers only 20% could correctly answer a single repetitive dive problem.[9]

While there is growing evidence that many certified divers cannot use their tables to plan diving activities we still know very little about the type of mistakes that are being made in the use of tables. The present study examined divers' answers to two repetitive dive problems in an attempt to pin-point specific types of error.

Method

SAMPLING

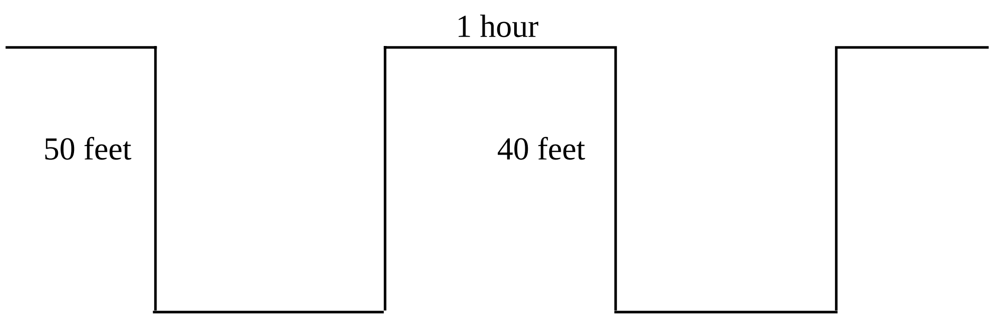
A random sample of 1500 certified divers in Queensland was drawn from the computer records of the National Association of Underwater Instructors (NAUI). After removing records where the address was incomplete, or "care of" a resort or dive shop, the first sample was reduced to 1373 divers. As the research project had a particular interest in the Great Barrier Reef, a second sample of 192 PADI (Professional Association of Diving Instructors) divers certified in Central Queensland, was also included in the study.

From a total of 1565 questionnaires mailed to divers throughout Queensland in September 1989, 291 were returned unopened as divers had left their previous address. Completed questionnaires were returned by 380 respondents.

SUBJECTS

Of the 380 completed returns, 285 (75%) were from active divers and 95 (25%) were from subjects who reported that they had not dived since gaining their open water certification. Active divers (who dive at least once a year), had an average age of 28 years, with a range from 14 to 60 years. There were 177 (62%) males and 108 (38%) females in the final sample. Based on scales of occupational status developed at the Australian National University[10] the sample represents a full range of employment categories. Sixty-six percent of the sample were single and only 25% had children. Overall, the characteristics of this sample compare well to profiles of active divers in other studies.[11,12] Most subjects (74%) had been certified for between one and four years. The majority of divers surveyed do most of their diving from commercial charter boats and are therefore subject to the requirements set out under Queensland's new Workplace Health and Safety Regulations.[13] These include logging each dive in the same format as used in the present

FIGURE 1 TWO DIVE PROFILE



Residual Nitrogen Time	=	Residual Nitrogen Time	=
<u>Actual Bottom Time</u>	= 42 minutes	<u>Actual Bottom Time</u>	= 50 minutes
Total Bottom Time	=	Total Bottom Time	=