too rapid an ascent so separated. The victim reached the surface and appeared well initially, then lost consciousness. This was clinically a cerebral gas embolism scenario, though not confirmed at autopsy. Dive discipline does not appeal to all but may nevertheless have survival benefits, as in case SC 98/8. Here the dive organiser was safety conscious and checked the recent dive experience of those on the live aboard dive boat. However no "warning bells" rang when the victim's first buddy refused to dive again with her because she ignored her buddy, did not check her contents gauge and used excessive air. On the fatal dive she failed to wait for her allotted buddy, whose later descent was aborted through sinus squeeze. Remarkably she rejoined her buddy and they surfaced together to find themselves in a current. Their "safety sausages" were faulty and dive boat slow to recognise and respond to their signals. She apparently became impatient and dived again, leaving her buddy. Her body was later fond floating, tank empty and some air in her BCD. There was evidence of a past myocardial infarction but no evidence of either an gas embolism or further cardiac event.

The experience of the diver in SC 98/3 is unknown. He and his two buddies ascended when he was low on air during their return swim. The dive leader, an instructor, suggested they snorkel back the remaining distance, but he aspirated some water and resumed using his scuba regulator. The instructor had begun to tow him but before reaching the dive boat he said "no air" and lost consciousness. In the absence of apparent cardiac disease, the pathologist suggested the cause of death was cardiac arrhythmia.

It is clear that running out of air remains a potentially fatal event, as also is overconfidence in ones diving ability, and that being solo is arguably unwise. The responsibility to perform a correct head count remains a responsibility dive masters neglect at risk to their divers' safety. The old basic rules for safer diving still remain valid.

Acknowledgements

This investigation would not be possible without the understanding and support of the Law, Justice or Attorney General's Department in each State, the Coroners and police when they are approached for assistance.

PROJECT STICKYBEAK

Readers are asked to assist this safety project by contacting the author with information, however tenuous, of serious or fatal incidents involving persons using a snorkel, scuba, hose supply or any form of rebreather apparatus. All communications are treated as being medically confidential. The information is essential if such incidents are to be identified and the causes brought to the attention of those involved in diving safety and diving training. **See back cover for address to write to**.

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. His address is P.O. Box 120, Narrabeen, New South Wales 2101, Australia. Fax + 61-(0)2-9970-6004. E-mail <dougwalker@ausdoctors.net>.

ABALONE DIVING IN WESTERN AUSTRALIA DIVING PRACTICES IN 1999

Robert M Wong

Key Words

Abalone, occupational diving.

Introduction

Abalone divers are only one group of Australian diving fishermen. They work in New South Wales, South Australia, Tasmania, Victoria and Western Australia, diving mostly in shallow water. This is not always possible because of overfishing in past years and the activities of poachers who do not have abalone licences. Other groups of diving fishermen include pearl divers, who have been working in Western Australia, the Northern Territory and Queensland for over 100 years; divers on Tasmanian salmon farms, where the salmon are fattened in moored nets, since the 1980s; divers doing the same sort of work and more for the tuna farms in South Australia since the 1990s: and other divers who collect tropical fish, periwinkles, and other shellfish.

Abalone diving

In the early years of Australian abalone diving (1960s-1970s) there was no regulation of abalone fishing and as a result divers went deeper and deeper as enthusiastic collecting stripped the shallower waters. In this era there were many diving accidents (decompression sickness and cerebral arterial gas embolism after emergency ascents when the compressor stopped) and a number of deaths from the bends. The most horrific were in 1972 in Mallacoota, Victoria, where two poachers from New South Wales, where divers were not licensed, died in the chamber after days under pressure. Shortly afterwards the Victorian Government refused to renew single abalone diver licences, requiring the applicant to purchase an extra licence from another diver who would then have to leave the industry. This and the introduction of quotas reduced the need for divers to take as many risks as they had done and, with an

TABLE 1

ESTIMATED NUMBERS OF AUSTRALIAN ABALONE DIVERS

	1980s	1999
Tasmania	125	125
NSW	57	35
Victoria	90	70
South Australia	35	45
Western Australia	14	26

education drive about the need for decompression, led to safer diving practices. Table 1 gives estimates of the number of abalone divers in the 1980s and in 1999.

The diving pattern on the East Coast in 1980s was said to be 60 feet (18 m) for about 60 minutes then ascend at 60 ft/minute (18 m/minute) with a decompression stop at 10 ft (3 m) for 5 minutes. Surface intervals were short with the second dive to 40 ft (13 msw) for 1.5 hours and the third to 20 feet (6 msw) for up to some hours.

However the diving practices of that time have also been described as the first dive starting soon after arrival at the dive site. It lasted until lunch time or the site was fished out, with an ascent to the surface every time a bag was full of abalone or the compressor motor ran out of fuel. After lunch the diver might move into shallower water and repeat the process until it was time to go to shore.

Divers in southern waters worked between 4 to 12 hours a day, weather permitting, in water temperatures of 9°C in winter and 16°C in summer.

Once quotas were introduced abalone could be sold only to licensed processors and direct sale to restaurants or fish shops was made illegal. This of course did not stop poaching, but the amount of overfishing was reduced.

Western Australia

Fishing for abalone in Western Australia on a commercial scale began in 1968. Divers, who were mainly self-taught, used surface supplied “hookah” systems. This simple system consists of a petrol driven compressor, usually but not always, supplying a reservoir holding compressed air, with a hose to a second stage regulator in the diver’s mouth. Usually there was one diver with one tender in each boat. The divers followed no scientific decompression profiles. Decompression sickness (DCS), often unrecognised, was common and minor symptoms were usually ignored. In-water recompression was occasionally used. Only serious cases impossible to ignore, such as paralysis, were treated in a recompression facility.

TABLE 2

DEMOGRAPHICS OF WESTERN AUSTRALIAN ABALONE DIVERS (1980S)

	Average	Range
Age	38.1	(23-63)
Years of diving	16.1	(0.4-35)
Years of abalone diving	12.1	(0.1-31)
Hours diving/day	5.2	(1.5-9)
Days/year	105.8	(28-200)
Max depth average day	15 m	(4.5-30 m)
Treated DCS incidence	4.1 a year	

Before a quota system was introduced in 1987, divers dived as much as possible to maximise their income. Before the quota system divers were in the water for 5-8 hours a day, with surface intervals of only 10 minutes and a total surface time of 60 minutes per day. Diving was restricted only by the weather and was encouraged by rising prices. Once quotas were introduced incomes were limited and the intensity of diving was reduced. It now averages 45 days per year, when two dives are done per day and diving lasts up to 4 to 5 consecutive days.

Table 2 gives the demographics of Western Australian abalone divers in the 1980s

In Western Australia the quota system was introduced in 1987. Regulation was introduced by the Department of Fisheries to control the “catch rate”. However, no information was collected on DCS incidence or dysbaric osteonecrosis (DON) by the Eepartment.

The divers’ incomes depend on the size of their quotas and whether they can reach the quota limit, which may be impossible owing to bad weather. In Western Australia a licence which was worth $Aust 250,000 in 1984 was worth $Aust 3,000,000 in 1999. The price paid to the divers by licenced abalone processors varied between $35 and $50 a kilo, fresh in the shell, in Melbourne during June and July 2001. In 1964 the Melbourne price was 2 shillings and 5 pence a pound (55 cents per kilo) for cleaned, shelled, salted and drained abalone.

The West Australian quota system also introduced zones for licences and quotas. Zone 1 runs from the South Australian border to Esperance, Zone 2 from Esperance to Busselton and Zone 3 covers the area north of Busselton. In early 2000 there were 26 licence holders, 6 in Zone 1, 8 in Zone 2 and 12 in Zone 3.

Three species of abalone (*Haliotis*) are harvested. In 1999 Greenlip (*H laevigata*), minimum legal size 140 mm across the shell, provided 5 tonnes of meat, Blacklip

(*H conicopora*) minimum size 140 mm gave 1.2 tonnes of meat and Roe's abalone (*H roei*) 70 mm across the shell were harvested for 1.7 tonnes unshelled weight.

Western Australia abalone divers co-operated with a survey conducted by the author in 1999 to obtain information about their current dive practices and the changes that have occurred over the years.

The survey showed that the depth of dives ranged from 6 m to over 30 m, with an average of 20 m. As in the past, most divers were not trained, although some had undergone recreational diving training. Some experimented with enriched air nitrox, with one case of oxygen toxicity reported. Some use oxygen empirically. The majority of the divers relied on dive computers. Some divers stated that they adopted the pearling industry's dive techniques using a very slow rate of ascent and oxygen decompression. Alternative air supplies or communications were not used, which resulted in one death from entanglement in 1998.

1999 Overview Zone 1

Before the introduction of the quota system, the divers in Zone 1 dived a minimum of 6 to 7 hours a day. It took an average of 20 minute to fill the neck bag, then the diver would ascend and descend again with or without any surface interval. If there was one it would last about 15 minutes. They made use of the "SOS" meter, an early decompression gauge containing a gas filled bladder. Underwater the increased pressure forced gas through a ceramic filter so simulating gas uptake. Green was safe to ascend and red required decompression time. No oxygen was used.

In 1999 there were six divers, three in their 20s, two in their 30s and one over 50, working in Zone 1. Their training was self-taught, recreational and on-the-job training. They dived mostly using hookah, but about 7% of dives were done using oxygen enriched air nitrox (EAN) on scuba. This is more expensive than using hookah, but is less likely to cause DCS if used using air tables. Alternatively it can allow longer underwater times when using a nitrox computer and equivalent air depths (EAD). Some divers used a "scooter", either battery or hydraulically powered. Some used a shark cage while others wore a shark pod (a South African shark repelling device).

To keep warm they used hot water heated 8 mm wet suits. The simplest and least efficient system is to pour hot water into the wet suit before diving. More efficient is to run water from the boat engine's cooling system through a hose into the wet suit. Heat control was provided by having a copper tube covered by insulation, which can be moved to adjust the temperature of water entering the diver's wet suit, near the diver's end of the hose. Water temperatures vary between 15 and 21°C.

About 10% of the dives were shallower than 10 m, 40% between 10 and 20 m, 50% between 20 and 30 m and only 1% between 30 and 40 m.

They averaged 80 days diving per year with average in-water times of 4.5-5.5 hours and 4-5 dives with an average bottom time of 40 minutes. Surface intervals were usually 30-45 minutes. Reverse dive profiles occurred in approximately 25% of the dives, depending on the availability of abalone and dive site depths.

Divers commonly used a dive computer, often the "Aladin Pro". Decompression stops were seldom used. Some divers ascended at "no faster than the smallest bubbles" while some computer records showed 5-6 m/minute. Figures 1 to 3 show computer printouts of typical dives.

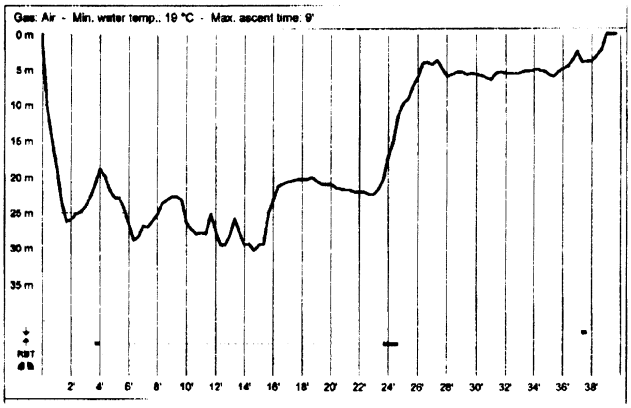

Figure 1. The printout from the dive computer used for a decompression air dive, for 38 minutes, that reached a maximum depth of 30.4 m. There was a 12 minute decompression period at around 5 m.

The black bars across the bottom of the graph at the level of the upward pointing arrow are records of the time that the rapid ascent alarm was activated. The black bar on the right, at the level of the down pointing arrow, shows when the alarm that decompression time still remained was activated.

DIVING INCIDENTS ZONE 1

There was one case of oxygen toxicity using nitrox. A diver using nitrox 38% O_2 (PO_2 0.38 bar at surface) was swimming at 22 m (PO_2 1.21 bar), then dived down to 27 m (PO_2 1.4 bar) against the current. Suddenly he experienced tunnel vision and became disorientated. He inflated the parachute used to raise the catch and rode up with it. Tunnel vision persisted for a while on board the boat. He now sets the computer alarm at 1.3 bar.

No DCS patients have reported recently for treatment. Musculoskeletal DCS in divers with more than 10 years experience is often self-treated with in-water recompression to the depth of relief then decompression empirically.

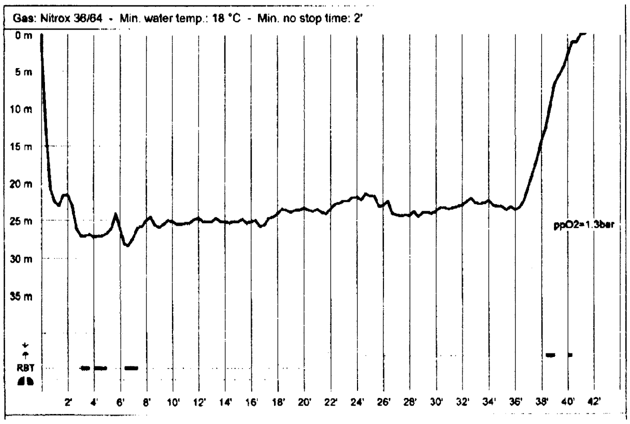

Figure 2. The printout from the dive computer used for a dive using nitrox (36% O_2) to a maximum of 28.2 m (PO_2 1.37 bar) which lasted for 39 minutes. The intended PO_2 for the dive was 1.3 bar.

The black bars on the left at the level of the letters RBT is when the exceeding planned depth alarm was activated. The black bars on the right, at the level of the upward pointing arrow, are records of the time that the rapid ascent alarm was activated.

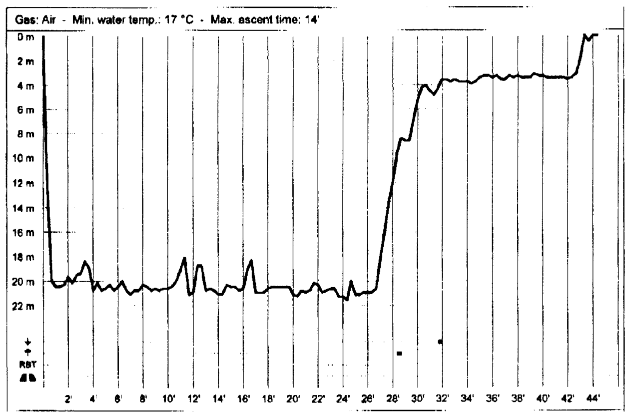

Figure 3. The printout from the dive computer used for a decompression air dive lasting 42 minutes that reached a maximum depth of 21.6 m. There was a 10 minute decompression period at around 3 m.

The black bar at the bottom of the graph, at the level of the upward pointing arrow, records the time that the rapid ascent alarm was activated. The black bar on the right, at the level of the down pointing arrow, shows when the alarm that decompression time still remained was activated.

There were no reports of DON, however there are a number of retired divers in the area who have shoulder pain.

1999 Overview Zone 2

Of the eight divers working in Zone 2 four were between 25-32 years old and four were over 40. Most had recreational diver training, the others were self-taught and had on-the-job training. They used the same equipment as the Zone 1 divers. They used 7 or 9 mm wet suits with hot water from the engines. Summer water temperatures are 17°-23° C, going down to 15-20° C in winter.

Dives were usually in the 16-22 m range, however, some shells were collected at between 30-35 m. 20% of dives were deeper than 25 m.

They averaged about 60 diving days per year. Eight years ago they dived 125 days a year. The average dive time was between 3-4.5 hours a day. Bottom time varied depending on depth, but usually between 20-50 minutes (on average 35-40 minutes). Surface intervals average between 35-40 minutes. They commonly used dive computers, based on Bühlmann's tables. The average ascent rate was about 6 m/minute.Oxygen was used for decompression at 6 and 3 m, also at the surface, particularly on a rough day.

DIVING INCIDENTS ZONE 2

There were two deaths. One followed a shark attack in 1998 and one diver died in 1999 from entrapment and running out of air.

No DCS has been reported in the past 5 years, but it was as high as 20% in the past, mainly "niggles", rashes or itches. Neurological DCS was uncommon.

There was one known case of DON in the past. No accurate information about other cases was available.

1999 Overview Zone 3

This Zone is shallow, intertidal water. Diving is in depths up to 6 m with major problems with swells and surge. One third of the quota comes from around the Perth metropolitan area.

The 12 divers were aged between 20 and 50. They wore 13.6 kg (30 lb) weight belts and a 11.4 kg (25 lb) chest weight and walked on the bottom wearing rubber mining boots. They used neck bags which can hold 50 kg of abalone shells.

They dived for about 80-90 days a year, diving for 6-8 hours with bottom times of 2-3 hours and surface intervals of approximately 10-15 minutes.

No incidents of DCS were reported in 1999.

Conclusions

It is claimed that over the past 5 years, there have been no cases of DCS despite the abalone divers' repetitive dives. Reverse dive profiles occurred in about 25% of the dives. The true incidence of DCS and DON is not known, as currently there is no requirement for abalone divers to undergo commercial diving medical examinations.

There were 2 fatalities, one from entrapment (1999) and the other from shark attack (1998).

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THE WORLD AS IT IS

ASEPTIC BONE NECROSIS AS A DIAGNOSTIC PUZZLE

Robert M Wong and David Wright

Key Words

Legal and insurance, medical conditions and problems, osteonecrosis.

Introduction

Aseptic Bone Necrosis (ABN) is also known as Avascular Necrosis (AVN) and, when it occurs in divers and compressed air (caisson and tunnel) workers, as Dysbaric Osteonecrosis (DON).

Apart from hyperbaric exposure, there are many non-dysbaric causes. A number of non-dysbaric causative factors have been listed in text-books, some of these are, in alphabetical order:

Alcaptonuria
Alcoholism
Arteriosclerosis
Cirrhosis of the liver
Diabetes mellitus
Gaucher's disease
Gout
Haemoglobinopathies
Hepatitis,
Hyperlipidaemia
Idiopathic
Inflammatory bowel disease
Organ transplant recipients
Pancreatitis
Rheumatoid arthritis
Radiation
Systemic Lupus Erythematous

Radiological and pathological features of both dysbaric and non-dysbaric osteonecrosis are indistinguishable and both are characterised by intramedullary venous stasis, ischaemia and bone necrosis.

Occurrence in divers

The prevalence of DON has been reported to be as high as 79% in Greek professional divers,[1] 85.7% in Turkish sponge divers,[2] 65% in the Hawaiian diving fishermen,[3] while other diving fishermen in Japan also recorded in excess of 50%.[4] Australian abalone divers had a prevalence of 32%.[5]

Of course, these reports were about divers who often ignored normal decompression procedures, overstayed their bottom time and had inadequate decompression.

For divers who adhere to decompression tables, however, the incidence is much lower. Royal Navy Clearance divers had an incidence of about 5-7%.[6] Commercial divers had a 4.2% incidence.[7] Although it is very rare in recreational divers, nonetheless, DON has been described.[8,9]

Non-dysbaric ABN

Excluding hyperbaric exposure, trauma is a common cause of ABN. It has been stated that up to 30% of patients with certain medical conditions such as Systemic Lupus Erythematous, Sickle Cell Anaemia, etc. may develop avascular necrosis.[10] In non-traumatic osteonecrosis, about two thirds of the cases are related to hypercortisonism and/or increased alcohol intake.[10]

ABN is the underlying diagnosis in 5% to 18% of the more than 500,000 total hip arthroplasties performed for advanced stages of osteoarthritis in the US and Western Europe.

A diagnostic problem

A man with osteoarthritis of his left hip was diagnosed as having AVN. A number of aetiological factors had to be entertained. Whatever the cause of his condition, it presented a dilemma to his Workers Compensation as he could no longer continue to work in his job.