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An investigation of ear trauma in divers including ear barotrauma and ear infection (Abstract only)

S E Mawle and C A Jackson

Abstract

A sample of 142 divers including technical, recreational and instructors were examined via postal questionnaire to determine prevalence of ear barotrauma, related barotrauma symptoms and middle ear infection. Sixty four percent of divers reported symptoms of barotrauma, which included pain (47.9%), temporary deafness with tinnitus (27.5%) and vertigo (9.9%). The prevalence of middle ear infection was present in over a third of the total sample (37.3%), and were significantly more prevalent in the left ear than the right ear ($p = 0.016$). Consistently wearing a hood when diving was associated with greater barotrauma symptoms than wearing a hood only in cold conditions ($p < 0.01$). A significant relationship was found between barotrauma symptoms and diver separation ($p < 0.01$), and the implications are discussed with relevance to the finding that nearly 27% of divers reported incidents involving separation from buddies when diving.

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Editor's Commentary:

Only 142 of 300 questionnaires were returned completed. Of these, over 70% of divers reported ear clearing difficulties at some time in their diving career. Using a weighting system, based on the number of years diving and the frequency with which they dived, 30 divers reported clearing problems more than 10% of the time, and in 10 this was on almost all dives. Some divers may have confused symptoms of ascent barotrauma with alternobaric vertigo, which is often not associated with barotrauma. No clear distinction is made between external and middle ear infections, all are reported as middle ear in origin. The infection rates seem surprisingly high for middle ear infections, adding to the suspicion that some of these may have been external infections. The association with wearing a hood is interesting, and the authors speculate on the possible causes for this association, most particularly tight fitting hoods. A similar investigation in Australasia would make a good SPUMS Diploma project for someone.

Key words
Ear barotrauma, ear infection, diving

The early days of hyperbaric research in Adelaide

Brian Hills

Key words
Diving, history, decompression illness, aviation, pearl divers

In 1963, as a young Senior Lecturer in the Department of Chemical Engineering at Adelaide University, I went over to the staff club one day for my usual lunch when it was my good fortune to sit next to the late Dr. Hugh LeMessurier. It was not long before we were enthralled in a discussion of how to prevent the formation of bubbles in divers and aviators which had much in common with my thesis topic of how unwanted bubbles formed in nylon melts during the spinning process. Hugh - or Lem, as we all called him - was a member of the Physiology Department funded by the Department of Civil Aviation (D.C.A.) and R.A.A.F. who had supplied a large hypobaric chamber located behind the Medical School. This was seldom used because the vacuum pump was very large and noisy, but well do I remember entering it to have my minimum bends altitude determined as 23,000 feet.

When we first met, Lem had just returned from an expedition to Thursday Island where he had recorded depth *vs* time profiles for the decompression of pearl divers, some of which had led to the bends while others had not. It was clear that the then standard Haldane calculation method underlying the Royal Naval and U.S. Naval diving tables could not explain the different outcomes. This was clearly a fascinating intellectual challenge, and I soon switched the 'bubble' topic of my Ph.D. thesis from nylon melts to deep-sea divers.

About that time the once-massive pearl shell industry centred around Broome had collapsed as plastics took over the button industry, and the only ray of hope for keeping profitable industry in the far North of Australia was culture pearls. The first 'farm' had just been set up at Kuri Bay. This was also a time of confrontation with Indonesia in which the uninhabited North looked very vulnerable - at least to the government of the day.

The Kuri Bay venture was a three-way deal in which a New York company marketed the culture pearls, a Japanese company contributed their surgical expertise derived from the cold water and small oysters native to Japan, while an Australian company supplied the oysters. In the warm tropical waters of WA where tides of 45 feet or more bring abundant nutrients, these oysters grow very rapidly and to a large size. However, the project hit a snag when there were two deaths amongst the divers and the Department of Primary Industry (D.P.I.) in Canberra requested the R.A.N. to investigate, which they did. Predictably, perhaps, the report went back to Canberra that the pearl divers were not following the navy manual and, in particular, were not following standard (Haldanian) decompression procedures. The Australian company retorted that, if they used naval tables - even the fastest U.S.N. tables - they would go bankrupt, and so the D.P.I. was left with a real problem.

They then considered that maybe two boffins could go up to Broome and, under the guise of a research project, find out what the pearl divers were really doing, so they approached Lem and myself. To do this we bought all the old W. W.II torpedo depth-and-roll recorders from an Army and Navy surplus store in Rundle Street and modified them to record a whole day's diving up to 300 feet.

When Lem and I arrived in Broome, we realised that we were just in time to put on record a most remarkable distillate of human experience and suffering arising from decompression. At one time (1890-1950) there had been as many as 800 luggers with two divers per lugger operating out of Broome alone, amounting to at least 300 million dives. By the time we arrived in Broome in 1963, there were only eight luggers operating, while many of the others rotted on the shores of Roebuck Bay. However, the remaining divers still followed the decompression procedures evolved by trial and error over the previous century.

Unlike naval divers who are paid a fixed salary, pearl divers and their ancestors were paid according to the quantity of pearl shell which they harvested. Thus, they had a great incentive to minimize decompression time during which they were suspended in the ocean out of reach of the oyster beds. There was no evidence of any medical, mathematical or scientific input to their decompression schedules but, purely by trial and error, they had devised a most remarkable means of decompressing. The price paid by their predecessors, however, was about 3,000-4,000 deaths, many more cases of residual neurologic injury and countless cases of limb bends. To this day, the major sites of interest at Broome and Thursday Island are the divers' graveyards. The decompression was administered to each Japanese diver by his Malay tender who wore a wrist watch but estimated depth simply by the length of lifeline unwound from a coil on the deck. Fortunately, I had lived in Malaya and could converse with the tenders whose divers only developed the bends when their account differed from what our instruments had recorded. They only seemed to get into trouble when they were shallower than intended - the discrepancy usually explained by strong tides. Otherwise, it was remarkable how they could decompress safely in two thirds of the time prescribed by the U.S.N. tables or about half the time once the U.S.N. divers pursue their normal practice of moving over two columns. The whole secret to their success lay in much deeper initial stops.

By this time I had switched my Ph.D. topic to decompression sickness and had realised that the wording accompanying Haldane's calculation method did not say the same thing as the equations he used to formulate diving tables. Haldane and subsequent naval tables were based upon the axiom that the bends-free diver must be bubble-free. Even in the 1960s there was the occasional mention of "silent bubbles" but, if my work is remembered at all, let it be that I was the first to appreciate the very different mathematics needed to calculate decompression tables if the gas phase is present. This is demonstrated qualitatively by the diver who develops a case of the bends during ascent. Now knowing that he has bubbles, you would move him deeper as a treatment. On the other hand, if those bubbles had not become manifest as the bends, you would continue to take him shallower, assuming that he was bubble-free.

This led to my "Thermodynamic" or "Zero-supersaturation" approach to formulating decompression schedules which, although derived applying complex mathematics to a system at phase equilibrium, provides a scientific basis on which to produce profiles closely resembling those of the pearl divers.

We needed to test these tables, so the D.C.A. funded a chamber and compressor located at the back of the Chemical Engineering Department in which we subjected goats to our new profiles and those of the pearl divers. Needless to say, these animals often escaped and could usually be found devouring the best flower beds on campus.

In the meantime, we had sent a report to Canberra confirming that the pearl divers had empirically devised better decompression methods than the Navies, and all they needed was better instrumentation in measuring depth. This pleased the D.P.I., who allowed the Australian company to carry on with its economically viable diving schedules and enabled the culture pearl industry to survive its embryo status at Kuri Bay and progress to the large flourishing industry it is today. These days diving no longer plays the vital role it did in the 1960s when we performed our studies since the technology has now been developed for culturing oysters.

My thesis, including the distillate of human experience acquired from the pearl divers, was refereed by Sir William Paton, Chairman of the Pharmacology Department at Oxford, who recommended award of a Ph.D. with distinction. However, Adelaide University does not differentiate higher degrees in this way, but the Libraries Board of South Australia published the thesis and copies were soon sold out. This encouragement led me to switch from Engineering to the Biomedical Sciences, although it meant leaving Adelaide - a move for which my wife has never forgiven me, and I can understand why.

While at Adelaide, I was invited by the Royal Navy to spend a short sabbatical at Gosport using their animal facility to convince them of the value of introducing much deeper stops to their decompression schedules than advocated by ‘Haldanian’ calculation methods or U.S. Navy variations thereof. They were impressed by the results and, as a first step towards introducing the new concept into operational diving, added the time spent at 10 feet to the 20-foot stop for air dives and surfaced directly from 20 feet. This first change alone reduced the R.N. bends rate by 75%.

However, as Associate Professor of Surgery at Duke University assigned to the Hyperbaric Unit, there was much scope to test and develop tables for much deeper dives on heliox as needed in the recovery of offshore oil which was rapidly evolving at that time. At Duke I was able to make several discoveries including the ability of dissolved gases to induce osmosis and the finding that bubbles formed by decompression in many tissues were coated by the same surface-active phospholipid (SAPL) known as surfactant in the lung.

Later moving to the North Sea as Professor of Occupational Medicine at both Dundee and Aberdeen Universities, it was interesting to find numerous copies of my thesis turning up in Scotland and Norway. As a consultant to several diving companies, it was surprising how often a troublesome diving table could be fixed not by the popular practice of adding even more time to a long 10 foot stop, but by introducing one or two short deeper stops at the start of decompression. This is exactly consistent with pearl diving practice.

In those early days in Adelaide analysing the decompression profiles of the pearl divers, many workers in the field regarded air as one gas and so, theoretically, they soon ran out of driving force for eliminating nitrogen from tissues during ascent. It was then that I realised that metabolic consumption of O_2 produced what we termed an “inherent unsaturation” in tissue and deduced that this provided the driving force for nitrogen elimination. We demonstrated this in animals and published it a year before Behnke deduced it independently as the much publicised “oxygen window” for decompression.

In recent years my research has been focussed upon SAPL which we discovered as the lubricant in the joint, the corrosion inhibitor in the stomach and, maybe, the substance masking irritant receptors in the bronchi whose erosion causes asthma, and at other sites where we had found bubbles forming in divers. However, in searching for SAPL as lamellar bodies we also found them in the spinal cord where such nuclei - so conducive to bubble formation - would be most unwelcome in a deep-sea diver. Spinal decompression sickness remains the great fear in air diving.

One worrying aspect of our discovery of the inherent unsaturation/oxygen window in Adelaide has always been the implication that, if you substitute O_2 for N_2 at the alveolar level, you do not make the same substitution at the tissue level. Hence, in HBOT, does the additional O_2 really reach the tissues or does some other mechanism - such as oxygen-induced osmosis - break the vicious cycle by relieving oedema? Once enthralled by hyperbarics, you can never leave behind the fascinating questions which it continues to pose.

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