ORIGINAL PAPERS

AUSTRALIAN DIVING MEDICINE A RETROSPECTIVE 1965-95

Carl Edmonds.

Introduction

It was brought to my notice, rather cruelly I thought, that this year marks my thirtieth year of diving medicine. Although I started scuba diving in Hawaii in 1962, when the surf went down, I did not join the Underwater Research Group until 1965.

It seems a reasonable time to do a retrospective, to reminisce about the scene of thirty years ago. Although I reluctantly accept that some current diving medicos were not even born at that time, the fact is that they are still seeing clients who have been exposed to the diving hazards and medical naivety that were prevalent then.

I have selected a number of diving medical topics, which have changed over that time. Unfortunately, many others have not.

Shallow water blackout

One of the main reasons that I joined the Royal Australian Navy (RAN) was to determine the causes of unconsciousness and death in clearance divers, those professional and elite divers who used closed circuit re-breathing equipment. There was a very high incidence of "shallow water blackout" (SWB), a disorder first described by Barlow and McIntosh,[1] in the Royal Navy, during World War II. It was common in divers using oxygen (or mixed gas) re-breathing equipment at depths of less than 9 m (30 feet). There was little warning of the unconsciousness, and it was initially thought to be due to carbon dioxide (CO_2) toxicity.

With increasing improvements in CO_2 absorbent systems, together with the advanced technology being employed with closed circuit equipment, it was decided that CO_2 could no longer be the cause of this. Also, the CO_2 measurements, taken from the breathing bag, were mostly less than 1%.

SWB kept occurring so often that it was considered an inevitable occupational consequence of using re-breathing equipment. It was often not even reported officially. Sir Stanley Miles, who was a brilliant participator in diving medicine, and who therefore made the occasional mistake or two, decided that the cause must have been multifactorial, i.e., no one single cause could explain the plethora of cases.

In 1957 he introduced the concept of oxygen syncope,[2] as most of the cases occurred while breathing higher than normal oxygen, but not at a level great enough to induce convulsions. It was believed that the diver just lost consciousness, a syncope, from an unknown mechanism.

This was the situation in 1965, when two young RAN divers, using closed circuit equipment, disappeared near Jervis Bay.[3] There were fanciful conjectures surrounding their disappearance, including being eaten by sharks, capture by a Russian submarine, desertion during active service, and even extra-terrestrial fantasies that were popular at the time. The subsequent retrieval of the bodies, underwater, introduced some realism.

We were left with the one explanation, which was really a non-explanation, of SWB. There were reservations held about the capability of the divers involved, the equipment used and the techniques employed. Divers were becoming demoralised and fatalistic about the increased hazards. The authorities blamed the divers (individual idiosyncrasy), not the equipment or the dive protocols. We had to find the explanation, and fast.

The experiments were the basis of a technique which has subsequently been used throughout Australia and internationally. We decided to re-enact the incident, replicating the presumed sequence of events, preferably terminating the experiment prior to a tragic consequence.

To do this we employed three different types of equipment.

a A normal scuba system, with compressed air. This, according to popular belief, rarely if ever caused SWB.

b Similar scuba equipment, but with compressed oxygen. If Miles was correct, then this should cause oxygen syncope or SWB first.

c The same equipment (recharged) as was used by the deceased divers. We knew that this could cause SWB.

Closed circuit equipment had less oxygen in the counterlung (about 80%) than open circuit oxygen scuba (100%). We therefore hypothesised that the person on the 100% oxygen with scuba would be the first one to go, the diver with the closed circuit should be the second, and the scuba air diver should survive without problems.

A diver paramedic would use the scuba-air, I took the open circuit scuba oxygen and one of our best clearance divers would use the closed circuit equipment.

The result was not quite as expected. About half an hour into the dive, the clearance diver, on the re-breathing set, lost consciousness. We all came to the surface and that set was then transferred to another clearance diver, and we

all continued with the dive. The new diver lasted about 10 minutes. This was again repeated and the third clearance diver lasted about 5 minutes. There were no problems with either the scuba air or the scuba oxygen.

One explanation was that clearance divers were wimps, but no one was courageous enough to voice this possibility. Indeed, it was obvious from our experiments that it was the equipment itself, not the oxygen being breathed, nor the people using it, that caused the problems.

After that a whole series of experiments under different diving conditions were performed, with divers being dragged up out of the water as they lost consciousness and gas samples being taken from various parts of the equipment, pari passu with resuscitation. After a few months it was obvious that the main problem was still, as Barlow and McIntosh had said in the 1940s, the failure of the CO_2 absorption system to remove adequate CO_2, in a heavily exercising diver. This was as likely at 1 m depth as at 10 m.

The technique used to demonstrate this became known as an "accident (or incident) re-enactment" trial. As we became more proficient it was not necessary to proceed as far as unconsciousness, before the divers were surfaced and assisted.

The information that we obtained then allowed us to develop CO_2 absorption canisters which were more efficient, to such a degree that the clearance divers ended up having more faith in the School of Underwater Medicine (SUM) canisters, than in the commercial equipment. There were some quite spectacular break-throughs in understanding canister performance. In 1969, despite its theoretical unacceptability, we designed a large pendulum canister which allowed us to double our time under water in safety. The last and most significant design development was produced by the SUM scientific officer, John Pennefather, during the early 1980s.

We also devised techniques to test equipment at its extreme ranges, i.e. very close to the surface and at maximum depth, at no exercise and at maximal exertion, at extreme temperatures, etc. These many tests were excellent in highlighting the failures and the limitations of equipment. The one way you cannot test equipment is to just put it on your back and "see how it goes". That will only test the mid range and result in an inappropriately positive report.

In the earlier 1970s the School of Underwater Medicine became quite famous for its ability to deduce the limitations in various pieces of equipment, including re-breathing sets, resuscitation equipment and dive computers. All the tests were based on the same principle, i.e. to "test the limits".

Why bring up this past? Well, a casual glance at many of the re-breathing sets now emerging suggests that the inadequacies of the equipment of yesteryear have been faithfully replicated in the 1995 advanced technology. Having a sophisticated oxygen sensor with an automatic computerised gas stabilising feedback system, does nothing to stop you dying from CO_2 toxicity.

Decompression sickness treatment

Treatment of decompression sickness involved the application of compressed air, at a minimum depth of 30 m (100 feet) and more frequently at 50 m (165 feet). The first case on which I was consulted, was another diving physician who had, that day, been in the chamber and treated a diver. The fact that the diver patient got moderately better and the medical attendant got seriously bent, did not inspire confidence in the treatment tables. Nor did a review of other cases. I presumed the air table failures were because we were getting divers many hours after the initial symptoms developed. This was not so in the US Navy, who were able to treat their divers immediately. We were dealing with civilians who often got bent long distances from the chamber. Often days would pass between injury and treatment.

MEDEVAC

The RAN and RAAF accepted responsibility for treatment of civilians in 1965, in lieu of any alternative. From 1967, to reduce the delay if the diver was significantly injured, we were as likely to take all the equipment (chambers, oxygen, appliances, etc.) to him, as we were to take him to the chamber. It all depended on which was the quickest way to treat the patient. We preferred RAAF Hercules aircraft, pressurised to 1 atmosphere, to transport us.

The development of the retrieval system, and a later extension of the Navy emergency telephone system for imparting advice and treatment to the diving community, was superseded in the 1980s by the Diver Emergency Service (DES) at the Royal Adelaide Hospital Hyperbaric Medicine Unit, with finance provided by the National Safety Council of Victoria (one of its more commendable achievements). When the NSC failed, financing became a problem and was for some years hand to mouth. DES has co-operated with the Divers Alert Network, which developed concurrently in the USA and which is spreading internationally.

Thus from the sick bay at RAN SUM, a very valuable diving medical cover has evolved. There is little resemblance between the 1965 and 1995 treatment facilities, certainly as regards hardware.

OXYGEN

In 1967 we started using oxygen before the actual

recompression, because of inevitable delays. Thus the diver would get oxygen in transit to the chamber, or he would be placed on oxygen while we brought the chamber to him. It is a moot point as to whether the French or the Australians initiated this oxygen regime as a first-aid measure before recompression. It also does not matter, as we were both very much impressed with its success.

OXYGEN TABLES

Fortunately, in 1965, Workman and Goodman[4] produced their oxygen tables, allowing us to start treatment of almost all DCS at 60 foot. These tables really only became used, with any frequency, in about 1967. At that stage we were still treating very ill divers, very delayed and with variable success. Even the oxygen treatments did not seem to work in many cases, because of the excessive delays.

That was when we decided to experiment, using the criteria of success and failure. If a patient got worse during treatment, then it needed modifying. An obvious principle. We capitalised on the beneficial effects of pressure and oxygen without preconceived limitations. We took the (usually severely ill) diver to whatever depth produced a satisfactory response, and then decompressed with the maximum oxygen that would not produce convulsions.[5] Dramatic treatment for a dramatic illness.

Those were called the "Australian Tables" and I would still revert to them for serious cases (not the woozy "I may not feel 110%" cases now cluttering up our chambers). We even employed heliox to replace the air breaks, with a prescience that was based on luck and irrelevant premises.

Independently, the French developed their Comex tables, which were a middle ground between the formal and very limited US Navy tables and the very flexible and so complex Australian ones.

UNDERWATER OXYGEN TREATMENTS

The history of underwater oxygen is in no doubt. This was developed in the late 1960's at the RAN, and by 1970 was employed through many parts of the Pacific, especially where chambers were not available. The rest of the world was horrified. The underwater oxygen regime is still employed by many of the divers in remote areas, such as in the Pacific islands, the abalone fields of southern Australia, and the pearl fields of the north. More recently the deep air dip, followed by the underwater oxygen regime, was developed in Hawaii.

This underwater oxygen treatment is now a part of most national diving manuals. It took 15 years to find its way into US Navy Diving Manual.

As always, the real origins of both the surface and underwater oxygen regimes were really based on work done by others. The use of oxygen on the surface, to prevent decompression sickness deteriorating, was well described by Paul Bert[6] last century. Thus, although the current French and Australians can argue about who should be credited, the real pioneers of this treatment pre-dated both, as with the underwater oxygen. Although they may not have used the techniques that we subsequently applied, the principles of oxygen treatment at shallow depths was well described by Behnke, Yarborough and Shaw,[7,8] pre-World War II.

Hyperventilation, breath-hold diving, and drowning

In the early 1960s Craig[9] produced his brilliant observations showing that hyperventilation produced a reduction of CO_2 levels, sufficient to extend breath-holding underwater, and resulting in hypoxia and unconsciousness, drowning and death. By 1965 the message and the magnitude of the problem was starting to seep through.

Unfortunately this was not well appreciated by our macho spear fishermen at the time, and there were many.

My predecessor at RAN SUM spent some time arguing with the then Australian breath-hold champion, in 1966, and I continued the arguments in favour of ditching this technique, in the early days of television. It was difficult to confront these brilliant extroverts, but fortunately for me, the champion managed to demonstrate his human fragility by hyperventilating before a breath-hold dive, off one of the oil rigs in the Bass Straight. The inevitable happened, and a very brain damaged ex-diver was sufficiently lacking in insight to front the national television audience. The arguments that had been placed by both Dr Geoff Bayliss in 1966, and me in 1967, were there for all to witness.

A tragic case, but one which was exploited shamelessly by yours truly, attempting to have hyperventilation blackballed in Australia, and gradually weaned out of the various spearfishing club techniques.

Salt water aspiration syndrome

In 1965 salt water aspiration syndrome just did not exist. The divers inhaled salt water because of the various provocative techniques (such as buddy breathing with an increasing number of divers, until one finally "breaks the circle" and tears off to the surface). Because the regulators were not terribly efficient (those used on compressors with a low-pressure air supply produced a fine sea water mist with each inspiration) and they produced a great deal of resistance. The practice of buddy breathing and towed searches, resulted in a great number of divers who presented some hours after the dive, with apparent

evidence of respiratory tract infections and fever. This was especially noted in the winter months. It was not until a group of stalwarts from the SUM decided to "doctor" the regulators in such a way as to guarantee aspiration, that the entity became well documented.

These cases were produced by having a diver immerse his head in a bucket of sea water, trying to breath from a regulator that had holes punctured in the diaphragm, against a progressively diminished air pressure. They demonstrated their discomfort by showing a drop in the arterial oxygen level on the ear oximeter. Only then was the soggy but stalwart diver allowed to lift his head out of the bucket, in order to perform repeated lung function tests that were needed to completely describe the disorder.

Until that time it was assumed that the post-dive illness was somehow precipitated by infections sustained during the dive, although it was hard to envisage how this could develop within a couple of hours of the dive. Nevertheless, there were many names given to the disorder, inferring a very rapid and significant infection and in North America it was often referred to as the "Key West Scuba Diver's Disease".

The excellent treatment (breathing 100% O_2) was discovered purely by accident, when the human "volunteers" were given this in order to more clearly elucidate the respiratory pathology, to differentiate diffusion from perfusion anomalies. Who said that we did not have the interests of the diver at heart. No reference need be made to the 10% oxygen inhalation.[10]

Marine animal injuries

It may come as a surprise to realise that the simple and common treatments of fish stings, in 1965, was the application of cold water or ice. Those who are now proposing this treatment for jellyfish stings, probably have no idea that it was used widely, 30 years ago, with as inadequate results as it has nowadays.

In the late 60s, the RAN dispatched me to do a survey of the current treatments of marine animal injuries through the various occupational fishing groups of Australia, with a tape recorder in one hand and a bottle of whisky in the other. I was amazed at how hospitable these pirates were. It resulted in the first really valuable clinical text[11] on treatment of these injuries. It sold well and is now printed in the USA.

The concept of hot water for fish stings evolved amongst the vulnerable prawners of Tea Gardens. It was described in the medical literature by the local general medical practitioner, Dr Hans Pacey.[12] They told me that when they got their cat fish stings they would use their remedy first, prior to his (local anaesthetic injection). Both treatments worked fairly well. Hot water is the most effective, rapid and ubiquitous treatment that can be applied. Into the book it went.

In those days the jellyfish stings were treated with alcohol (methylated spirits externally, and a variety of others internally). Cleland and Southcott[13] and Barnes[14] were brilliant in their initial compilations of the clinical features of jelly fish stings, and they were followed by the very worthy work from Queensland. This included the observations of Hartwick,[15] Williamson,[16] and Fenner.[17] They have certainly expanded our knowledge on the jellyfish stings and the treatment of the box jellyfish injuries with vinegar. Acott described many vertebrate envenomations.

Frankly, we are still not well equipped to treat jellyfish stings, but at least the box jellyfish antivenom is of value, and over the last 30 years this has been added to the stonefish and sea snake antivenoms, produced by Wiener[18] and Sutherland[19] at the CSL.

In fact, Australia has every reason to be proud of all our marine envenomation pioneers, but none deserves recognition as much as Straun Sutherland. In the last 30 years he has been a venomous treasure for Australia. The enthusiastic wielding of a Bowie knife, to tear the flesh below the ligature around the wounded limb, has now been appropriately supplanted by the much more civilised pressure bandage and immobilisation techniques for first aid treatment of blue ringed octopus, cone shell and sea snake bites.[19] We have every reason to be thankful to Straun Sutherland for these innovations. Into the book it goes!

Research

In 1965 there was some valuable work performed at the RAN by Dr Geoff Bayliss, in consultation with Dr John Miller (the latter now runs a prestigious hyperbaric facility in Mobile, Alabama). Geoff had already commenced documenting diving deaths, observations on middle ear barotrauma and had planned animal experiments on air emboli.

Geoff's original work on documentation of diving deaths in 1966 was resurrected by Douglas Walker in 1970. He expanded it to the most valuable and detailed compilations of this field, under the eponym of "Project Stickybeak". Without Douglas working on this subject, now for some decades, the experts in this field would be nowhere near so well equipped with meticulous data.

The work on otology was well advanced by a group of us (naval and civilian) and led to the first ever text book on diving otology[20] (Otological Aspects of Diving, 1973). In that book the first major classification of hearing loss

and vertigo in diving was presented. Before that there was only two diving causes known for vertigo and one for hearing loss. In one fell swoop, Australia lead the diving world into otology, and it remained in the lead for many years.

Geoff's animal experimentation into air emboli went into limbo, but was brilliantly exhumed by Dr Des Gorman, who is now the leader in research activities in the Australasian region. With his meticulous approach, administrative skills and entrepreneurial personality, Des has erupted onto the international diving medicine forum. Look out world! I would consider that Des is the best thing to have happened in my years of diving medicine (not that I would ever admit this to his face, and even now proclaim it as a typographical error).

Thus Geoff has a lot to be proud of. His projects bore more fruit than he could ever have imagined.

Australia has always had the clinical material necessary for applied research. This is because of the large numbers of divers and the extensive diving that is performed all along our coastline. We have always had a health system which, although it might not have been of the Medicare type format, has required that all patients be adequately treated, irrespective of their means. This was how the RAN and RAAF came to treat so many civilians, simply because civilian facilities were not available at the time.

We needed the enthusiasm and support of the hierarchy. Initially, back in 1965, this was the RAN, its Medical Director-General, and the SUM. Now it involves a whole range of academic and hospital departments, led by the Royal Adelaide Hospital and aptly directed by Dr John Williamson, but chaperoned by Dr Des Gorman. The involvement of the National Safety Council was redeemed by the development of the Diver Emergency Service (DES) and now there is an Australian DAN, part of the international Divers Alert Network, working with DES.

Diving physicians (and diving medicine)

TRAINING

In 1965 there was one diving doctor in Australia. He was the guy who ran the SUM. He also dealt with: all diving accident treatments in and around Australia; all hyperbaric medicine treatments in Australia; most research and development; the acquisition and dissemination of all current knowledge on this subject (plus submarines).

All this was achieved by virtue of a posting order from the RAN. The officer also had to be reasonably competent at general medicine, resuscitation, treating venereal disease and as a back up clearance diver. All this without holidays.

By 1967 there were a few others, but these were essentially specialists and mainly Navy personnel. By 1970 the South Pacific Underwater Medicine Society (SPUMS) had formed, mainly as a vehicle for allowing the Navy diving physicians (Bob Thomas and me) a tax-free holiday in a prestigious tropical diving setting. It rapidly spread, as is the want of bureaucracy, to include many other groups that jumped on the bandwagon, but with a good result.

In 1971 I despatched the first Diving Medicine Newsletter to members of SPUMS, and this gradually flowered into the SPUMS Newsletter and, later, the SPUMS Journal, with full acknowledgment to Douglas Walker for most of its formative years and more recently to Dr John Knight.

The Navy then combined with SPUMS to produce the Diploma in Hyperbaric Medicine, strongly against my advice (proving yet again, that I am fallible). That was in 1974.

The overall skill of physicians advising on diving fitness and treating diving accidents, before 1965, was less than adequate. This has changed, initially at the instigation of Dr Rex Gray and with the development of the RAN SUM diving medicine courses in 1966, then the Diving Medical Centre (mainly Dr Bob Thomas) and other SPUMS approved courses. These now reach all parts of Australia, resulting in very highly qualified designated diving medical examiners. We have now have diving medical consultants, diving medical physicians, hyperbaric physicians, and diving medical examiners.

LITERATURE

Knowledge and training is always dependent on a good library. In 1965 there was only one clinical text on diving medicine.[21] That was written by Sir Stanley Miles. It was a great little book, but with a mistake on every page. Nevertheless, without it we would have been lost. It contained valuable observations of a very good clinician.

On marine animal injuries there was a very small text by Bruce Halstead,[22] and a very large three volume work by the same author,[23] both focusing heavily on identification and taxonomy, but scrimping considerably on treatment, with good reason.

A high powered text on compressed air diving and caisson work, by Bennett and Elliott, was first published in 1969.[24] It was a compilation of research papers of little value to the clinician, but fascinating to researchers

Australia has changed all that. We now have the best and most popular diving medical texts in the world.[11,25-27] Most achieved international fame, and they have spawned a large number of clones (we do not refer to this as plagiarism, but as "flattering imitation") and

promoted the dispersal of knowledge. Some of these have been mentioned elsewhere in this article, but in the 1965-75 decade they included:-

1 **Dangerous Marine Animal Injuries of the Indo-Pacific** (A RAN publication). This later evolved into **Marine Animal Injuries to Man**, and now into **Dangerous Marine Creatures** (independently published in Australia and the USA). Although I was the scribe, the contributors were legion.

2 **Otological Aspects of Diving** (A combined Naval/ Civilian publication).

3 **Diving and Subaquatic Medicine**. By far the most successful of the texts with which I have been associated. It was written by: An anaesthetist diver, Chris Lowry; A Naval scientist, John Pennefather; and me. It has been by far the most popular diving medical textbook, both in Australia and Internationally, since 1976. It has now gone into 3 editions and has, horrifyingly, emerged recently as a paperback.

Over the next two decades there was an avalanche of Australian diving medical texts. They include:

1 The **Divers Medical Companion**, a best selling (over 40,000 copies) simplified text for divers, written in 1978 by Dr Bob Thomas and Dr Bart McKenzie.

2 **Diving Medicine for Scuba Divers**, the text now most commonly used by recreational divers, for diagnosis and treatment of their ailments, written in 1992 by Dr Bob Thomas, Dr Bart McKenzie and myself. This has superseded their very successful "Divers Medical Companion" as the divers medical bible.

3 **The Sports Diving Medical**. A superb recent publication, used for the medical examination of recreational divers, written by Dr John Parker. This text has taken over the original "Sports Diving Medical", a landmark USA publication by the late Dr Jeff Davis.

4 **Australian Animal Toxins**, by Dr Straun Sutherland, 1983. A masterpiece.

5 **Oxygen First-aid for Divers,** by John Lippmann.

6 **Scuba Safety in Australia,** by Jeff Wilks, Dr John Knight and John Lippmann.

7 **The Divers Emergency Handbook**, by John Lippmann, now available internationally as the **DAN Emergency Handbook**.

8 Other books of a technical/medical nature with excellent physiological inputs, such as **Deeper into Diving**, and **The Essentials of Diving**, both by John Lippmann.

With this degree of educational material pouring out from Australia, there is no wonder that we have been accepted as leaders in the clinical diving medicine scene. We can not compete with the expensive, sophisticated technology of North America. We can and do compete successfully when it comes to assessing clinical cases and the treatment of patients.

FACILITIES.

The hyperbaric treatment chambers available in Australia have also expanded from one in 1967 to two in 1970, to about a dozen in 1995. And some of them are very good with enthusiastic clinicians, paramedics and technicians, with very sophisticated technology. The hyperbaric chambers now encircle Australia and are used frequently and judiciously. In each state there is a sophisticated and well-manned recompression facility that humbles our 6 man (sitting room only) chamber at HMAS RUSHCUTTER, circa 1965.

Finale

No, that was not all that happened in 30 years. There were many other experiments, a lot more teaching, many treatments, a few other publications and the occasional trip away diving. And there is a lot more to do. Over to you.

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NOVICE RECREATIONAL SCUBA DIVERS AND ASTHMA : TWO SMALL SURVEYS REPORTED

Rhys Cullen

Abstract

In two separate pilot studies, consecutive candidate open water divers were surveyed to estimate the incidence of asthma.

In the first of these, the diving medicals of 32 novices were examined. All had been passed as fit to dive. Two had current asthma, while two more had a history of asthma.

In the second survey, which was supported by a different Auckland dive club, fifty-two open water trainees completed a short questionnaire. Six of them answered yes to a question which asked if they had ever had, or now had, asthma or wheezing, or to use a puffer or inhaler. Eight were current smokers. One was both a smoker and asthmatic. All were medically certified as fit to dive.

The consistent finding of these surveys is that 12% of Auckland open water candidates have asthma or a history of asthma that they are willing to declare.

Two conclusions can be drawn from these results. Asthmatics are sufficiently common to make possible a prospective controlled cohort study of their outcomes as recreational divers, compared to both "normals" and smokers. Such a study is now underway in Auckland. Second, some scepticism needs to be attached to claims that asthma is an absolute contraindication to recreational diving, or that asthmatics are over-represented in diver deaths. The data just are not there to support definitive statements.

Introduction

There is, internationally, no consensus of medical opinion as to what criteria determine respiratory fitness for recreational diving.

The British Sub-Aqua Club recommends that asthmatics should not dive within 48 hours of wheezing. This is supported by a BMJ article[1] which attracted some contrary correspondence.[2, 3] The article is of limited merit. Its methodology consisted of collating completed questionnaires received from 104 divers with asthma. The questionnaire was included in the magazine *Diver*. This highly selected group of asthmatic divers provides anecdotal evidence that some divers who report themselves as having asthma also report a large number of trouble free dives. To conclude from this study, as the