SPUMS JOURNAL

South Pacific Underwater Medicine Society

APRIL TO JUNE 1981

I'M LOOKING FOR SOME TABLES WITHOUT DECO STOPS!

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EDITORIAL

The dramatic story of the diving bell incident is reported in detail for a number of reasons. First, it is a good story of suspense, of man against Murphy's Law, with ultimate victory to the good guys. But even more than this, it is a glimpse of the responsibilities and problems faced by oil industry diving supervisors and divers. This story gives some indication of their high level of awareness of, and response to, problems we can discuss in comfort. To them hypothermia is a real danger, to us a chapter heading. The fact that the details have been made so freely available so rapidly is highly significant, an indication of an awareness of the need for the sharing of information for the good of all. It is instructive to note the efficient co-operation of the two organisations: doctors are certainly not the only 'professionals' in the diving business.

In the evolution of diving, first came the tough, accepting, working men without awareness of the possibility that there was anything complicated in diving, it was just another job. Then came the ENT specialists, who became the experts who called the shots, but they were soon elbowed out by the physiologists, not all of whom were experienced in actual diving. Now it is the age of the anaesthetists, who have so integrated their specialty with physiology that Diving Medicine seems within their sphere of interest. That they deserve to hold a position of pre-eminence in diving matters is witnessed by the paper given by Dr Chris Acott at the 1980 SPUMS Scientific Meeting, here printed. It is of great interest to know that such expertise is available to victims, once the person of first contact becomes aware of the need for such care. Dr Jimmy How's paper on what may be described as "the third world" of diving, which is too easily dismissed as a minor problem affecting few people, is a most useful reminder of the vast amount of 'basic diving" which exists simultaneously with the well publicised "pinnacles" of 1,000 feet and saturation diving. It is humbling to consider the work tasks of large numbers of simple divers, who include many sponge and pearl divers around the world, and until recently included our own abalone divers.

The paper by Dr Bassett is most welcome, though he brings no comfort to those hopeful souls who await Tables which are twice as generous in depth/time allowance than even the most obscure present Tables. The day is not yet in sight when men can really join the sea mammals and forget their adaptation to land, but dolphins and whales cannot hope to come ashore, so both parties have had to sacrifice something for what they have gained. To forget this is to end up in dead trouble.

This is the year of the Disabled and we welcome the BS-AC paper on training. to disabled people. Readers will remember Dr Nic Fleming's classic paper on the training of a few Israeli war-caused paraplegics. Difficulty has been experienced in attempting to follow-up this group of divers, so the true value of the effort involved cannot be fairly assessed. Devoted instructors and intelligent, highly motivated pupils are absolute essentials before attempting any such training and diving thereafter will require the provision of strict safety backup measures. Information from readers concerning any type of disabled divers will be welcomed.

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Authors are requested to be considerate of the limited facilities for the re-drawing of tables, graphs or illustrations and should provide these in a presentation suitable for photo-reduction direct. Books, journals, notices of symposia etc., will be given consideration for notice in this journal.

"LOST BELL" INCIDENT: SURVIVING HYPOTHERMIA

Based on information provided by Wharton Williams Taylor Diving Contractors

ABSTRACT

The umbilical of a bell (SDC) operating from a well equipped vessel began to leak gas while the bell was at 515 fsw, and ruptured during raising procedures. The bell wire remained intact. During the raising of the bell it lost pressure dramatically at 165 fsw, relief being obtained by urgent lowering to 400 fsw. The two divers trapped in the bell reported that they were cold and shivering but the true severity of their hypothermia was not appreciated until after the rescue. Ship/bell communication difficulties were experienced. Survival was the result of the high state of training of all concerned and the availability of two Survival Kits in the bell for each diver. An improved (Mark II) 2 W Survival Kit is reported. Rescue was affected by Comex divers operating from a bell lowered from another 'diving' ship, transfer in a strong current being made possible by a swim line between the two bells. Post-decompression helicopter flight to shore was followed by a simple knee bend in one diver.

THE INCIDENT

At approximately 10.05 hours on 21.1.81 the 2W Superintendent visited the dive shack to check the progress of a routine bell dive to inspect a mooring over 500 feet deep. Dive platform was the well equipped MV Stena Seaspread. He noted that the umbilical winch had 2 bars "up" pressure set to counteract the tendency of the umbilical to pay out as a result of the very strong surface current (2 knots on the port bow). While this was being discussed it was noticed that gas was escaping downstream from the panel and bubbles were seen to be escaping through the moonpool, though these were difficult to observe because of the wave action.

A message was sent to the two divers, both of whom were in the bell at this time, to inform them of this leak of surface supply gas. They replied that their onboard gas had just cut in. As the bell was connected to the job and the tool basket was adjacent to them, one diver was instructed to lock-out on onboard gas to stow the TV camera/cable and black light/cable clear of the bell, in the basket, while the other took the bell out of motion compensation into constant tension and pulled the clamp weight off the seabed in preparation for aborting the dive.

As the crane began to recover the basket clear of the bell a loud noise together with a sharp shudder was felt in the dive shack. The crane driver immediately stopped hauling up when he felt the shudder. At this precise moment the colour TV monitor went dead. It was connected to the camera in the basket. The diver was urged back into the bell and a seal was obtained. As the swim line was still attached he was allowed to lock-out again and remove it. He was able to report that the bell-umbilical-basket were all clear. A seal was again obtained, one of the divers being seen to indicate this to the bell monitor at the precise moment that this TV monitor and the communications went dead, the internal and external gauges dropped off to zero, and the umbilical started to move up as the tail pressure of 2 bars took effect.

The Superintendent ran to the moonpool and felt the main umbilical. It was very slack. The remainder of the umbilical was recovered in order to clear the moonpool for the communications transducer. After several attempts contact was established with the bell and the divers were informed of the plan to lift them, stage by stage, to 165 fsw so that the standby surface diver could make a visual check of the situation. The bell depth was checked by interrogation of the X beacon on the bell. When the bell reached 165 fsw communications were very good but the surface diver was unable to see the bell and was swept off his intended route from his basket to the bell wire. Having regard to this difficulty and the fact that the vessel was on dynamic positioning with thrusters running, this diver was recovered onto the ship and given therapeutic Table 5. Two more standby divers were made ready should they be required. By this time the bell had been at 41 metres for about 20 minutes. There had been some loss of pressure ascribed to cooling of the bell gas but now there occurred a sudden loss of bell pressure, which the divers thought was a loss of seal and so demanded an urgent lowering of the bell. This descent was stopped at 400 fsw, where the divers signified they were happy to remain. Communications were difficult and careful choice of all questions was required to enable short clear replies to be made.

In view of the changed situation, for initially the situation seemed merely to require the winching up of the bell, it was decided to request assistance from the MV Uncle John, which had a diving system and was relatively nearby. An emergency control centre was set up on shore also. The divers were now dressed in their survival suits with emergency onboard battery packs supplying power for the bell scrubber and lighting. Two hoses were made ready, one for gas (4%) and the other for hot water, it being intended to lower these attached to the bell wire for an emergency hook-up temporarily, the transducer was recovered and a sodasorb drum put around it to act as a shield from thruster and surface noise interference. A slight improvement in communications was obtained. The bell was slowly brought up 10 feet but the divers called and urged "all stop!". Shortly after this a black and white TV camera was lowered down the bell wire to ascertain bell attitude (vertical) and provide additional light to the divers. A strong current was observed, made visible by the rapid plankton flow across the screen.

It was arranged with the Uncle John that a swim line would be run down the bell wire and the other end passed to the Uncle John and thereby to the rescue bell to enable it to locate and the divers cross despite the current. The emergency bell evacuation cross haul wire is run to starboard and would not serve, so a surface diver was used to under run the intended swim line to the ship's port side.

In order to view the swim line when it arrived at the bell the TV camera was recovered and run down the port guide wire. When the Uncle John's remote controlled vehicle arrived near the crippled bell this swim line greatly assisted the Comex divers cross over to it. The gas and hot water hoses were lowered down the main bell wire to the bell. The Comex diver, after a delay caused by the strength of the current, took a spare gas rig (AGA mask) and hot water with DUI fittings on it to the bell. A message board was used for communications before entering the bell. The Comex diver reported the two bell divers to be "in high spirits". He sprayed hot water around them to slowly warm them through. A second rescue diver came over and after observing one diver for 20 minutes judged him fit to be escorted over to the safety of the rescue bell. Due to the current and the fact that the Uncle John's bellman now had 3 rigs to tend, some delay occurred while the rig was untangled and taken back for the second diver.

The divers were transferred under pressure aboard the Uncle John and examined by a doctor. The bell itself was recovered and the probable course of events established. It is surmised that the strong current had drawn off an excessive amount of bell umbilical and that this had snagged in at least one place on a number of possible snag points. The tool basket had been lowered through a loop of snagged umbilical, effectively putting a complete turn round its wire. Chaffing of the outer fibre covering of the umbilical occurred due to the friction of this wire as the ship heaved. The initial loss of pressure was due to a hole wearing in the gas hose. The "bang" heard by both divers and the surface crew was probably the TV cable snagging and then parting when the tool basket was raised, and the actual severing of the umbilical was almost certainly caused when the basket was raised the second time: the SWL of the crane is rated at 15 tons. This snagging explains why neither the bell nor the surface experienced undue tension on the umbilical, as the only excessive load would have been between the tool basket and the point where the umbilical was trapped on the SALM. The bell's internal depth gauge valves are connected to the surface gauge via the umbilical and it was through this line that the bell depressurisation took place, the loss being limited because the severed umbilical trailed below the bell during the ascent and only became apparent when bell pressure exceeded ambient at the open end. It was not realised that the gauge valve was open. From loss of services to transfer under pressure was 11 hours.

MEDICAL COMMENT

The divers reported at debriefing that they had experienced fairly severe and uncontrollable convulsions in their arms and legs. These spasms occurred with no regularity and lasted between 1 to 3 seconds, the affected limb suddenly jerked violently, uncontrollably and without warning. This appears to have been a hypothermia effect. The growing ability of both divers to ignore the cold as time wore on, such that towards the time of their rescue they were rather unconcerned about it, is an indication that they had suffered severe heat loss and were much worse off than they realised at the time of their rescue. It is suspected that had rescue been delayed another hour they would have both become unconscious, which would have greatly increased the problems of rescue. In line with the North Sea practice, they were airlifted by helicopter after the completion of decompression, the usual prohibition of flying for 24 hours not being applied to helicopter flights. This may be a factor in the development of a simple knee bend in one of the divers. The diver who had to work the communications suffered more from heat loss than his companion, because he had to change from the foetal position they adopted to conserve heat and get his hands free from the survival pack. This matter has been noted and the Mark II Survival Kits have sleeves (insulated and retractable).

DISCUSSION

These divers survived because the positive safety factors which had been deliberately built into the diving procedures outweighed the negative environmental factors, the chief of which was heat loss. Those involved prepared for possible emergency situations through the provision of survival kits and practice drills, they were alert and rapid in their recognition of and response to trouble, of good morale, and willingness to call for additional assistance at the appropriate early stage. It cannot have been altogether easy to request the assistance of another diving organisation. The response of the Comex diving organisation similarly demonstrated that their personnel could undertake a difficult and unfamiliar rescue task under adverse conditions, one which required the co-operation of two diving platforms. The availability (and use) of two survival packs for each diver was critical to their survival, though this was not appreciated till later. Had the trapped divers not acted so correctly to reduce their heat loss in this helium atmosphere, or acted in a panic fashion, the outcome of this incident would have been a double fatality. The incident revealed the need for improved communication backup facility efficiency, surface/bell contact assisting both situation assessment and maintenance of morale by all parties, a new avenue for the operation of Murphy's Law (an open gauge) and the value of survival suits. The new 2W Diver Survival Pack, the Mark II, will meet the problem experienced here of increased loss when operating essential equipment (retractable insulated arms with mitts) and unit to reduce respiratory heat loss (thermal regenerator). The practice of allowing helicopter flights soon after leaving decompression may require closer evaluation. That this full description of what occurred was made freely available for publication is an excellent sign of awareness that diving safety requires publication and discussion of problems.

APPENDIX

2W Diver Survival Kit Mark II

Presentation: The kit is vacuum packed in two strong PVC canvas satchels which incorporate a window showing the representation of the contents and dressing procedure. The compressible items have been selected for their recovery properties after such packing. Tie cords are fitted to assist in installation. Closure is by sealed zips.

Contents

Thermal Undersuit plus towel: dryness increases comfort.

Survival Bag. The Holofil™ bag has a full harness fitted to hold the diver back onto the seat in a slouched forward position, away from the risk of fouling the bottom hatch. There is an inflatable seat cushion and waterproof back and bottom section. External (retractable) insulated arms allow the diver to work yet remain insulated. Bag and harness are sized for divers 5’4" to 6’6".

Breathing System integrates thermal regenerator and CO_2 scrubber. Dead space is only 0.05 litre. Testing at Robert Gordon Institute of Technology is reported to show 95% heat recovery in heliox at 300 m. The oral nasal has been selected for maximum comfort.

Consumables. A high energy pack ensures energy balance and 1.5 pints of water is supplied to offset dehydration. Also, four sanitary bags are included.

Training

It is vital that emergency equipment be used properly. A video cassette recording is available on request.

SPUMS SCIENTIFIC MEETING 1980

THURSDAY JUNE 26th

DECOMPRESSION SICKNESS SESSION ONE

Dr John Miller

My first case history is about a young lady of 22 who was on a package deal holiday from Switzerland to the Caribbean who was diving at about 100 feet. She saw a big fish which surprised her. She shot towards the surface. She was held by her companions a short while at about 70 feet and then she went to the surface. She arrived on the surface unconscious and needing artificial respiration, she was also paralysed. She was taken to the nearest recompression chamber and recompressed. She regained consciousness, but she was difficult to deal with. She was very slow in mentation and she was still paralysed. They did as much for her there as they could by treating her with one of the short oxygen tables. Then they telephoned us and we made arrangements for her to be shipped to our facility. She was recompressed at Duke and subsequently made a fairly good recovery. But she still had some residual paralyses of her hip, which has taken about 4 to 5 months to regress. It is fairly typical of what we are doing.

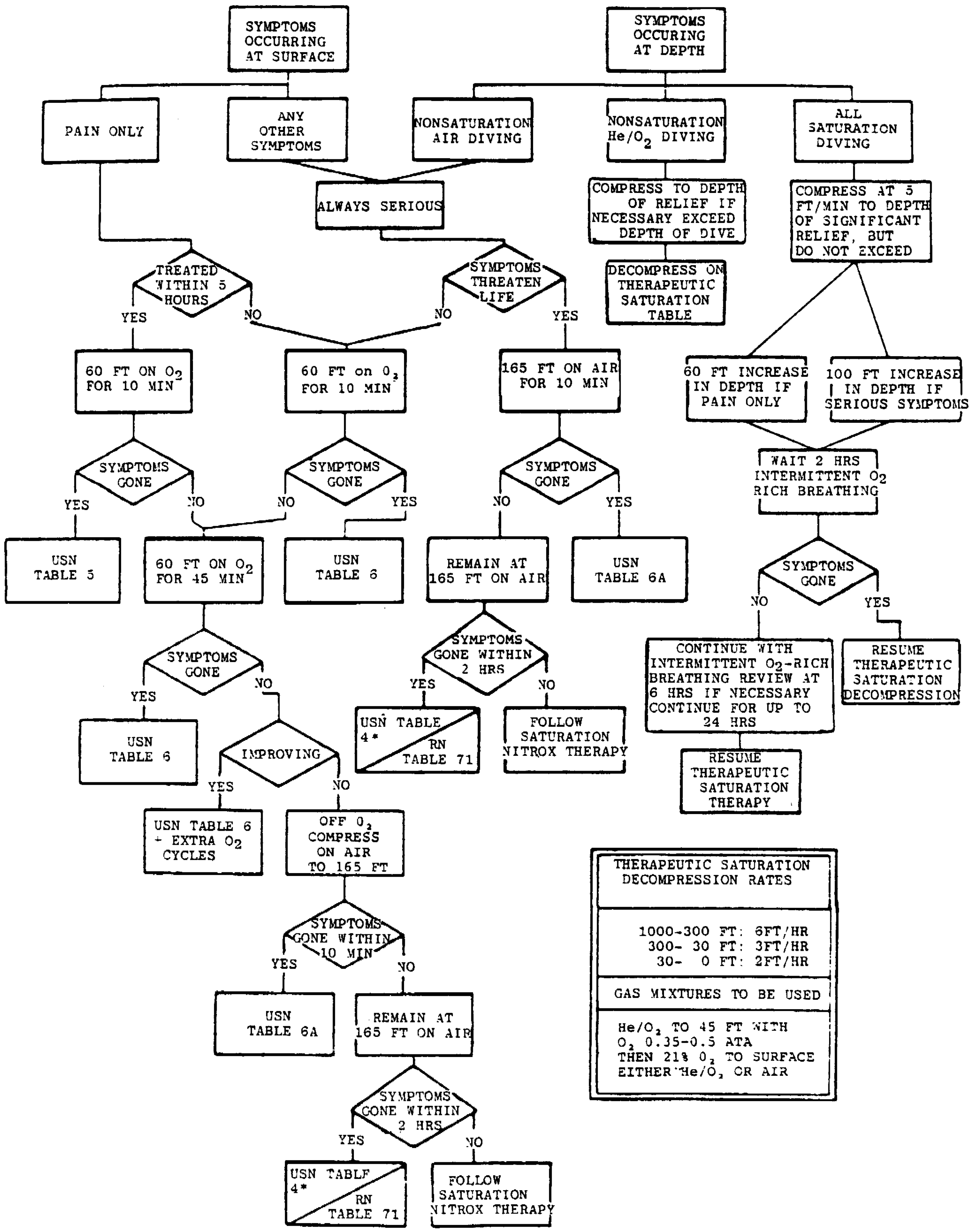
This girl had both a cerebral air embolism and probably decompression sickness. The majority of the cases that we get from the Caribbean and the Bahamas are a mixed type of lesion. Another one that we had was a young woman taking an instructor’s course. She was supposed to be doing a simulated rescue where she was the victim unconscious on the bottom of a twenty foot tank. Another student was to go down and give her a breath from his regulator, then support her airway and take her to the surface. He hyperinflated her lungs with an almighty push on his purge button and then managed to support her airway by placing his whole hand around her larynx. He forcefully dragged her to the surface despite her protests. She was recompressed in the chamber there for her cerebral air embolism. She was a little slow to regain consciousness so they stayed longer than 30 minutes at 165 feet. In these circumstances they should have used US Navy Table 4, but they used an “exceptional exposure” decompression. This gave her decompression sickness which they then treated inadequately. She developed a recurrence. They did that five times, with each recurrence getting worse and worse. Eventually they shipped her to us. She required a very prolonged treatment indeed.

I want to talk about the elements in the treatment of decompression sickness. Recompression is the standard thing to do, and the other things that are important are oxygen and fluid therapy, adequate time an depth and then the use of specific pharmacological agents.

Figure I is a simple man’s approach to treating a diving accident, particularly decompression sickness when you have recompression facilities available. It has proved to be very effective. I included the possibility of having unlimited recompression facilities available, but most chambers do not have unlimited capability. So there are cut off points along the way to go into. Either you have symptoms occurring on the surface after a dive or at depth during decompression. We generally regard symptoms that occur at depth as being potentially more serious than similar symptoms which started at the surface. This is because a patient who develops symptoms at depth is not nearly as far into his decompression as a patient who develops symptoms at the surface. That is why you go through a complicated system of calculating the time between dives and the various sort of categories that you can get into for a second dive during the day.

The symptoms can be pain only, limited only to the joints, or involving other organs as well. The other organs are generally the central nervous system and/or the lungs. Usually if one has severe decompression sickness involving the lungs, otherwise known as “the chokes”, unless that is treated very rapidly the patient will die. I do not know of any patients who have spontaneously recovered from the chokes. This is not true in most other cases of central nervous system decompression sickness. It is true in a number of cases of cerebral air embolism. Regardless of what you do they do not survive.

THE DUKE UNIVERSITY FLOW-CHART FOR THE TREATMENT OF DECOMPRESSION SICKNESS



* Always use the oxygen version of USN Table 4, for both patient and attendant (s)

The idea is to establish a number of points, based on the pathophysiology of decompression sickness, in order to make decisions. The first is whether the interval between development of symptoms and the start of treatment exceeds 4 to 6 hours. It takes that time for all the intravascular phenomena to stabilize around the gas phase. Many patients who are treated after the 4 to 6 hour period are more difficult to treat than if you have them immediately after they develop symptoms. Then there are a number of decision points whether or not the patient has got better after a given time period or treatment.

The first thing is to recompress the patient to 60 feet, breathing oxygen. It is usual to deliver oxygen with air breaks, either as 25 minutes of oxygen with a 5 minute air break or 20 minutes of oxygen with a 5 minute air break, the idea being to avoid the onset of pulmonary oxygen toxicity. We evaluate at the end of the first oxygen period. The decision tree gives you the choice “symptoms better” or “not better”. If they are better and it is the pain-only bend, you can use a short oxygen treatment like USN Table 5. If not better, you have to stay longer.

The philosophy is one of doing something that is rational in relation to the pathophysiology. We are trying to treat the symptoms and the underlying condition. We recompress, then assess the patient by symptoms without any attempt to nominate beforehand what sort of table we are going to use. At the same time we continue with whatever adjuvant therapy was instituted. We use this flow chart primarily to be able to know where we have been during the treatment. With this series of steps you can eventually get yourself either out of your own chain of capabilities or ultimately into the bottom of the chart which says “followed saturation nitrox therapy”, which I will be dealing with in Singapore.

The right hand side of the flow chart is primarily designed for oxy-helium diving, either bounce or saturation. You recompress to 60 feet on oxygen, if the patient is not better with a standard table 5 or table 6, you immediately go to saturation oxy-helium treatment. We do not need to deal with that any further.

There are occasions such as cerebral air embolism or somebody who has the chokes or somebody who has a very high cord or lower brain stem decompression sickness, when you would be prepared to jump straight to 165 feet simply because the symptoms are threatening the patient’s life. Again if you follow that through you eventually get to the saturation point. Most people are put on USN Table 5 partly as an inducement for people to report their symptoms on a Friday afternoon. Most of us now use Table 6 most of the time. 85% of cases get completely better with one or the other of these two Tables. When they do not then you have a problem. Our solution is on the flow chart. We go to 165 feet and stay for an indeterminate period of time, as long as 8 hours. Then we follow a proven safe pathway back from 165 feet to either 100 feet or 60 feet. At 100 feet we change to a safe oxygen environment so that we can stay there as long as we like. Then we follow an appropriate way out when the rate of improvement of the patient has obviously slowed down.

You can see the rationale that we have for using this type of flow chart. Although it may not be ideal, it is rational. It saves a lot of time in making decisions simply because a lot of the thinking is done for you beforehand. It also restricts the number of Tables that are used to a relatively small number. Also, if we have a record of what we have done we can then compare responses between patients.

The adjuvant therapy we use is mainly balanced salt solution, or in the Australian situation Hartmann’s solution. We have slowly stopped using dextran over the last three years. In many instances of central nervous system oedema steroids have been demonstrated to be effective. Whether or not they are effective in cerebral air embolism or central nervous decompression sickness, we do not know. We still use steroids and we tend to use it in neurosurgical dosages. But we really do not know whether we are treating the patient or treating ourselves. We stopped using heparin. It sounds good, reversing coagulopathy with low dose heparin, but 5,000 units subcutaneously, if you give it to enough patients, will occasionally produce total heparinization of the patient, although it is theoretically not possible. 1,000 units every 6 hours does nothing but keep the intravenous open. I prefer to avoid those sorts of complications. We use appropriate antibiotics and other therapy as required according to the patient’s condition.

Many recompression facilities that people consider to be pretty basic can in fact be used for saturation treatment at a pinch. It is not that difficult to set up a scrubbing system for CO_2. In fact quite a nice scrubbing system consists of a pair of pantihose. You take a couple of handfuls of soda lime and pack it down into the toe and you knot the pantihose above that lump. Then you put another couple of handfuls in and knot above that. You keep on doing that until the whole pair of pantihose is filled. You hang that up in the chamber. That acts as a very good CO_2 absorber. As the CO_2 starts to rise a bit, and you can tell that as you get a little bit headachy, you massage the legs of the pantihose and by doing so you change the active surface that is available. Oxygen addition is no great problem. Venturis are used for all sorts of purposes and they are relatively inexpensive. A venturi to add oxygen provides a good mixer for the gas in the chamber. At a pinch you can get by with a sheet of masonite and do a Rolf Harris wobble-board routine to stir the gas.

During saturation treatment at 100 feet you have to get the oxygen down from 0.8 atmospheres to 0.5 of an atmosphere. You can do that in two ways. If you have not spent a lot of time at 165 feet, you can have the patient and the attendants in the chamber breathe the oxygen down. Then you just add little bits of oxygen as you need it. Or you can add additional nitrogen, which is not much of a problem if you have access to nitrogen.

All you need in terms of gas supply and gas analysis, is a simple oxygen analyser, which is pretty cheap, a supply of sodalime, a sheet of masonite, a few pairs of pantihose and of course, oxygen. You also need some sort of cover over the chamber because if it is out in the hot sun the people inside will get very hot and become dehydrated very, very quickly. Once you have a cover over the chamber you do not need a sophisticated cooling system to cool it. If you have adequate evaporation then wet blankets on the chamber will remove heat from the chamber. If you are in a humid, hot climate then cooling is somewhat more difficult, but it can be done if you play a spray of water on the chamber. Saturation treatment can be done in most small chambers, but it is uncomfortable and messy. It is not something to be embarked upon lightly. Because of these problems and the staffing and logistical problem of handling this sort of operation for the necessary length of time the patients are likely to be sent to a major centre rather than treated with nitrox saturation in the chambers around the Caribbean. Generally speaking, the major centres they go to are ourselves or the chamber at Brooks Air Force Base at San Antonio, Texas.

Chairman (Dr Tony Slark)
I would like to tell you a story about a patient of mine which was similar to the story you opened with. She was diving under a ledge when she saw jaws looking at her, so she said. She darted straight to the surface. When she reached us she was, as you said, “a bit slow in mentation”. Her only comment was “Aw shit”. After being on the long oxygen Table for about half an hour she brightened up a great deal. Her symptoms all disappeared and she would not stop talking.

Dr John Miller
Our Swiss girl had a remarkable increase in her level of mentation during her treatment. She went from speaking only German to becoming multi-lingual during the course of 24 hours. We also have had one of these strange birds that people did not like. That was the lady who was on the instructor’s course. She arrived in a gold lame bikini. She was young but very well used. She was on her third husband at the age of 24. She had scars from various riding and motor cycle accidents. She and her husband ran a travel business among other things. They were both learning to fly with the idea that they would get groups of people together, fly them, in their own tax deductable aeroplane, to the Caribbean and then teach them how to dive. She was a fine young lady whose libido was to say the least, extraordinary.

Dr Jimmy How
In the treatment of decompression sickness you really have to deal with each individual patient. It is not just the application of a table or the application of a particular flow chart. I think we have to determine the response. I fully agree with John Miller that one should hang on at 60 feet and then wait and determine the type of table according to these patient’s response. I am frightened to have tables and flow charts in case we begin not to think at all and just flow into it in one way or the other. Most of us here, I think, are not doing treatment at all. But you may see patients who turn up at your clinic or at your hospital. I would like to tell you about a case to emphasize how important it is that doctors do not fall into the trap of applying tables in our minds and forgetting that the patient has to be examined clinically to determine what really is wrong with him.

This happened last week while I was anxiously waiting for you all to turn up. We had a case that was three weeks delayed. This chap had a dive to 100 feet for 90 minutes. When he surfaced he had swelling on his face and swelling around his neck. That was all he had. He was not dyspnoeic. He went to a general practitioner. He was examined and treated for nephritis for about a week. He was not getting any better. Then he went down to the Government outpatients. He was again examined and asked to go home. Finally a registrar saw him and when they took the history they found that he had got a diving history so they thought it could be bends. They quickly sent him over to us to think about maybe pulmonary barotrauma or some form of decompression sickness. Now all of these doctors probably did not do enough clinical examination of the patient. My doctor saw him, examined him and gave me the history. I said “Have you examined him?” and he said “Yes. The chest was clear, everything was clear”. But I was not happy. With the swelling of the face many things could have happened. There could be lymphoedema from decompression sickness or there could be a ruptured lung with air tracking up both sides of the neck. So I said “You cannot put him the chamber until we have a chest X-ray and have a look at it”. We took a chest X-ray and the right apical lobe was completely opaque. We examined the case again and we found dullness and diminished air entry on the right side. Watching carefully while he breathed we could see that the chest was not moving equally. Now I stress all this because we really look at our cases. Sometimes the moment you think of the bends you refer the patient to a chamber just because he has been diving. People forget that he is a patient any more and people forget about clinical examination. This patient had a complete opacity of the right upper lobe. Had we put him into the chamber, we would have been in a bit of a problem.

At the moment he is still in hospital being bronchoscoped. Your guess is as good as mine as to what the diagnosis is. It could be a carcinoma, it could be something from the mediastinum, or it could be an effusion into that part of the lung. Clinical examination is really important before putting the patient in the chamber. I say this because we sometimes get misdiagnoses sent to our hospital. It is common in Singapore where decompression sickness is really not well known at all. We have no lectures in the University on such illnesses. It is important that knowledge of decompression sickness be propagated. I find that proper clinical examination will usually reveal the correct diagnosis. Many cases have been misdiagnosed as transverse myelitis and things like that. Once we have the proper diagnosis and have examined the case, we can go into the chamber. Then we can go into our flow chart and determine specifically which table we are going to apply.

Chairman (Dr Tony Slark)
I think that was a most valuable comment. I have been trying to impress this sort of knowledge to all medical groups for a long time. The diving accident patient deserves the very best of medical management whether there is a recompression chamber immediately available or not. I have also noticed that doctors tend to switch off if they think it may be a diving accident and tend to not treat the case as a patient who really requires the full gamut of their normal medical skills including those of full investigation. We certainly try to make sure that everybody is given the benefit of X-rays, ECG’s and blood screening tests, at least initiated, before they actually go into the chamber.

I think that is very important and something that is often forgotten by our colleagues. When they know that somebody is in fact a diving accident, they tend to feel that their ignorance of diving means that they cannot deal with the patient in a proper medical fashion at all. This is not true and we should try to educate our colleagues. Thank you very much for making that point, Jimmy.

Dr Jimmy How
I would just like to add a word of caution here. When one is dealing with delayed cases we can play around a little with time. The caution is that acute cases come in. Then one should not try to run through a battery of tests and delay another 4 to 6 hours. Time becomes precious. One should determine by a clear clinical examination where you think tests are indicated. You should proceed with them. But be very careful not to waste time as time is as important as compression in the treatment of acute cases. Do not delay to a point that jeopardizes the prognosis of the patient. The misdiagnosed cases that I have been talking about I see at least 4 days after the incident. Then you really have to have a good clinical examination. You need a good clinical examination in either case, but we need a bit of speed in acute cases.

Question
Why did the young lady in the instructor’s course, who obviously had an air embolism, need treatment for decompression sickness?

Dr John Miller
She was at first not a case of decompression sickness, she was clearly a cerebral air embolism. They treated her by recompression to 165 feet. Then they stayed longer than 30 minutes at 165 feet. If you stay less than 30 minutes at 165 feet you are allowed to follow a very shortened course of recompression therapy whereby you come back to 60 feet at 25 feet a minute and then plug into the longer of the two short oxygen decompression sickness tables, which is called table 6A. If you stay longer than 30 minutes then you are automatically committed to a significantly longer decompression. The standard treatment formats in that situation are the US Navy Table 4 and the RN Table 71. That gets you into something like a 36 or 38 hour decompression. They felt it was going to be too long, so they switched the whole treatment then into an experimental type of decompression by using the exceptional exposure tables of the US Navy Diving Manual. They calculated the “appropriate” decompression from these and that was what caused her decompression sickness. By the time she developed decompression sickness she was in fact long since over the cerebral air embolism episode.

I might also echo what Jimmy has said of the need to quickly and thoroughly perform a physical examination. For over 2 years we have been looking very closely at people who reputedly had a pain only bend. On a detailed neurological examination we kept on finding relatively minor, but nevertheless present, neurological dysfunction. So a high proportion of the people who claim they feel the pain in a joint also have a patchy numbness or a little weakness and not infrequently it is around the sacral distribution so you have to look at the sacral outflow.

Dr Chris Lourey
It is a total body disorder that you are dealing with. We had a case, an abalone diver, who presented at one of the major teaching hospitals in Melbourne with a pain in his knee. The senior resident on duty was mildly aware of decompression sickness. He knew it was due to bubbles so he applied an above the knee tourniquet. The pain did not resolve. Some twelve hours later he presented at Prince Henry’s Hospital, which has a chamber, not with a Type 1 bend, but with a severe Type II vestibular lesion.

One of the problems is that there is not only a level of ignorance in the community but that there is a fair level of ignorance in the profession. Not all of us have the experience or the skills of treating decompression sickness but we should be able to make the medical community aware of the salient features of decompression sickness.

Dr Jimmy How
Also a point about air embolism and decompression sickness. We should not separate air embolism and look at it simply as air embolism nor decompression sickness as decompression sickness requiring two different sets of Tables to treat. A clear history, a good history is very, very necessary as in all medicine. How long has he been underwater? If you have been underwater long enough, whether you are going to get symptoms or not, you are going to bubble. It is just if you do not get decompression sickness nobody will ever know that they bubbled.

If the diver shoots up there are lots and lots of intravascular bubbles. He is going to bubble a great deal in addition to his air embolism. Sometimes air embolism is not cleared because we are looking at two things. Usually one takes him to 165 feet and then comes back to 60 feet after a short while. Some treatments fail because that ascent from 165 feet to 60 feet was too rapid. In many cases it would be a better idea to move on the US Navy Table 4 or RN Table 71. I would certainly keep him at 165 feet and bring him up slowly with intermittent oxygen at a partial pressure close to or over 2 atmospheres at that depth. We can now bring him up, taking care of both the intravascular bubbles all over the body and the ruptured lung which gave rise to the air embolism. You must look at the history, if he has been diving long enough, deep enough and then he ruptured his lung.

Dr John Miller
Table 6A was designed exclusively for submarine escape training accidents where there is absolutely no tissue nitrogen loading. There the situation is relatively clear cut. Cerebral air embolism associated with diving is not at all clear cut. In a number of the cases that we have had, if you go very carefully into the history, you can find something that may or may not be related to a cerebral air embolism occurring or certainly one can put a pointer to a mixed type of lesion.

Dr Mike Davis
I would like to add another case to the two that we have heard already to reinforce how important an adequate history and examination is. This was a man of 32 who presented with a pain only bend in the right shoulder. When he was examined he had nystagmus and one would immediately assume that he had a cerebral problem as well. His nystagmus was due no severe vital meningitis that had occurred 15 years earlier and had always been with him ever since and had not got any worse on this occasion. We do not believe he had a bend at all, but that this was purely a physical strain to the shoulder doing some heavy lifting work that was related to the dive. It is a good example of how vital it is to take a good history.

Dr John Miller
A further example is a problem that I had about 12 years ago in Turkey. This was a man in his thirties who was grossly overweight. I subsequently discovered that he had a history of chronic duodenal ulcer. He and some friends went spear fishing on a Sunday afternoon after a Saturday night wedding. He had been 90 minutes at 115 feet when the elastic broke as he was loading his speargun. The butt of the gun drove into his belly. He came straight to the surface and was comatose when he reached the surface.

You can imagine the effect of all that gas that was in his stomach, expanding and blasting out through the hole in the duodenum. The other people with him did not know any of this. He arrived at the little chamber we had on the expedition in a comatose state, having apparently been seen to be loading his speargun, the elastic broke, and go straight to the surface. You will appreciate that my Turkish was pretty rudimentary. We got him into the chamber. There was improvement at 60 feet. So then we went to 165 feet and he improved tremendously. He woke up and was able to talk to me. I then discovered that his abdomen was board-like and elicited the history of the ulcer. Unfortunately, the wretched man died in the chamber before anything could be done for him. Again it is an example of the fact that you may be dealing with decompression sickness but the decompression sickness may be masking something else. It may be a duodenal ulcer or it could be a bleed or it could be a myocardial infarction.

Dr Jimmy How
I would like to make two other points. One is, do not look at the tables and then decide that he does not need any recompression because his dive was within the limits, so it cannot be decompression sickness. Divers do get decompression sickness, even though their dive was within the tables. I do not know why, but they do. I have seen such cases. Two chaps doing exactly the same dive, one chap got sick, the other did not.

The second point is that it is easy to malinger in decompression sickness. I have a special way of watching them. They have to walk a great distance to my office. I get my medics to take a look at him, how he comes in. When he walks in he smiles and then he changes into a very sad man. You have got to know that he is really not very sick. But when he reaches my door he has here a pain, there a pain. They are great guys because they know that the moment you diagnose them as something residual they get about 2 weeks off the rig. They do not need to get back to the rig. They get time off. Some of them would try to malinger over here to get off the rig to see their wives for a fortnight. So that is the second point.

I had a very unusual case where the diagnosis was made on a full history. He was flown from Diego Garcia to Singapore for treatment. A Taiwanese diver was employed to build the harbour at Diego Garcia for the Americans. He came up from a 45 feet dive and the history was that he became totally blind and he collapsed. He was diagnosed as a case of decompression sickness. They radioed to the Philippines as the nearest place with an American chamber. The people in the Philippines said that it would take too long to reach the Philippines and that he had better go to Singapore. While the arrangements were being made, the patient regained his sight.

Being a Taiwanese diver we could speak Mandarin with him, which his employers could not do, and get a clear history. What had happened was that he came up from a dive to 45 feet for about 45 minutes. The water was cold. After surfacing he grabbed hold of the rail on the side of the boat and he could not feel anything. He had a friend who had been totally paralysed who had told him that in paralysis you first lose all your feeling and then you become paralysed. And this poor chap was so cold, that he could not feel the rail. When he caught hold of the railing the thing that came to mind was his friend who was paralysed, and he thought he was going to be paralysed. He was so hysterical that he went totally blind. He just could not see any more and he just fell on the deck. This sort of blindness is unusual in decompression sickness. Most commonly it is a patchy fog, they see a black fog all over and rarely do you get a complete blindness of this nature. After talking to him we asked him to stand up and walk. The chap just stood up and he was walking around and he was quite happy. We really could not call him a case of decompression sickness so we discharged him. That night we went out to dinner together and that was all the treatment he got. The next day we telephoned the American Embassy and said that the patient was quite well and that we had discharged him. So you can see that all this takes us back again to basics. Watch out for the symptomatology again the clinical examination and the symptomatology. You have to match them up.

Question

Should a patient with air embolism be put in the Trendelenberg position?

Dr John Miller

I do not think it is a tremendously rationalor useful thing to do. Even if there were a lot of gas trapped around the valves it would be the mitral valve that would have bubbles of gas trapped under it and not the tricuspid valve. Elevating the legs might be useful if you are dealing with a venous air embolism. Also it is often very inconvenient to do when you are transporting a patient. However, it is taught fervently to most paramedical personnel and it certainly does no harm. It certainly allows a little bit of extra venous return for somebody who for various reasons has had some impairment of cardiac output. If the people transporting the patient really fervently desire to do this why not let them do it?

But the Trendelenberg position increases the central venous pressure and therefore increases the intracranial pressure. That is going to tend to increase the back pressure which would tend to develop into cerebral oedema. So it may even be a bad thing to do.

Dr Jimmy How

I see it in another way. The moment you have bubbles reaching the brain you can get into a shock situation. If you compare decompression sickness in aviators with decompression sickness in divers you find cerebral effects are commoner in aviators, while strangely enough in divers it is the spinal cord that is more commonly affected with decompression sickness. You can get a shock syndrome when the blood pressure falls rapidly. I suppose that it is due to the micro-damage in the vessels and the effects of anoxia. By and large when you record the blood pressure it is low. I think it would help if we use that position. It would push the blood back to the vital organs. When you have bubble formation it is mainly venous. Venous return is increased when one is in the Trendelenberg position. I think it should be the left lateral as well. This would tend to allow the blood to rush through and the lungs to filter out the bubbles. Someone has said that there is always a small intra-auricular defect even in the adult. This would allow bubbles to reach the arterial blood. So if you allow the bubbles to go freely through the heart the chance of this is reduced. I still teach the medics to put the patient into that position, because it will help in at least these two situations.

Dr Chris Acott

If bubbles reach the right side of the heart the blood flow to the right ventricle will be decreased. So the amount of blood that is going into the left side of the heart will drop. Therefore the cardiac output will drop. That is why you get a drop in blood pressure. Because of the air bubbles trapped in the lung you get an increase in pulmonary vascular resistance. The pulmonary artery pressure is increased. So you get pressure rise in the right ventricle. As 33% of adults have got a patent intraventricular septum you can get air going into the left side of the heart. And it may reach your brain. I think the decrease in blood pressure is due to the decrease in cardiac output. Secondly it may be due to the decreased blood flow to the vasomotor centre of the brain.

Dr John Knight

As a change from the people who have got good chambers I am going to talk about treating decompression sickness without a chamber.

TABLE I

PRESENTING SYMPTOMS OF DECOMPRESSION SICKNESS. US NAVY

From Rivera (1963). US Navy. 900 cases

Cerebral (including inner ear)	6.4%
Spinal	0.2%
Cardiorespiratory	0.4%
Pain only	82.7%
Other	10.3%

If you follow the tables closely, serious decompression sickness has a pretty low incidence, adding up to somewhere about 7% (Table 1). However, if you treat sports divers, who have deep water to dive in, you get a different picture. Edmonds worked in Sydney and Erde in Hawaii. They treated 100 people and somewhere above 50% had serious decompression sickness (Table 2). Depending on where you are situated you are going to get a very different group of people to treat. We are lucky here, we are not likely to get serious decompression sickness because we have not been in any water deeper than about 60 feet so far. So even if we are going to have trouble, we would be very unlikely to get anyone seriously ill with decompression sickness.

TABLE 2

PRESENTING SYMPTOMS OF DECOMPRESSION SICKNESS. SPORTS DIVERS

From Erde & Edmonds (1975). Sports divers. 100 cases.

Cerebral (including inner ear)	33%
Spinal	13%
Both spinal and cerebral	5%
Cardiorespiratory	1%
Pain only	33%
Other	15%

How to avoid decompression sickness ought to be emphasized to divers. Table 3 is a simple collection of information. Most diving boats in Australia do not have a shot rope that will dangle directly beneath the boat. They have a rope and they may tie a tank on it, and it dangles at an angle depending on the currents going under the boat. Some years ago the Royal Australian Navy rescued a helicopter when they should not, as it was in 200 feet of water. They would have done much better to have employed a commercial firm using helium to get it for them. But they felt they had to prove that they could do it. It was in a very current prone place. Their decompressions were done on shot ropes. But the shot ropes were not vertical owing to the current. It is said that every diver got bent during the recovery.

TABLE 3

HOW TO AVOID DECOMPRESSION SICKNESS

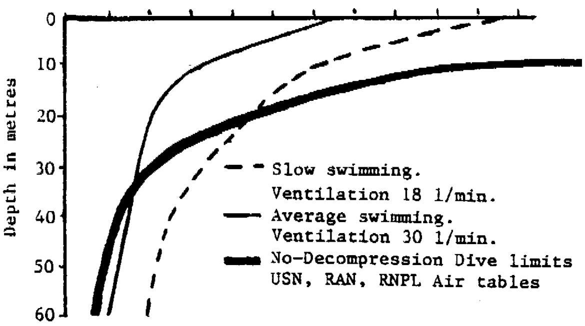
Always do “no decompression” dives
Know the depth of water
Watch the time
Ascent at 60 feet per minute or slower
Do not fly within 12 hours of diving

If you must decompress:
Follow tables
Use a shot rope
Have spare air on the shot rope

FIGURE I

NO-DECOMPRESSION LIMITS AND 72 CU FT CYLINDER ENDURANCE

Time in 10 minute intervals



There is still a myth taught in Australia that you cannot get bent on one tank. In Figure 1 the black line is the no decompression limits of the USN, RAN and RNPL air Tables. They are all within the thickness of that line. If you swim very slowly and do not work too hard you can make your air last to take you outside that envelope from 30 metres downwards (the dotted line). Even if you are working reasonably hard and ventilating at nearly double the rate (the thin line) you can persuade your tank to last you outside the safety envelope at about 35 metres, which explains why I will not go deeper than about 80 feet. Remembering that the safety envelope is not safe for everybody.

This is a story that was published in the British Medical Journal in 1973. A 34 year old diver who dived quite deep on air was a little short on decompression time. He used the usual treatment that divers use for their pain, beer or whisky or some other alcoholic beverage. He turned up at the hospital on an island in the English Channel that did not have a recompression chamber, a little bit outside John Miller’s envelope of 4-6 hours. Actually 15 hours after surfacing. He complained of a pain in his right shoulder, that he was giddy, that he could not walk very well, and that he could not move his right arm. The doctors discovered other things wrong with him. Treatment was rather difficult as he was drunk. They could not get the patient over to England until the next day. They thought that they really ought to try something in the interval. They used Dextran 40 to decrease the sludging and correct the haemoconcentration and stop lipid emboli. They used some heparin to try and slow down the clotting process. They used Mannitol to reduce the cerebral oedema, and they used fructose to sober him up. They gave him aminophylline for the broncho-constriction. Probably the most important thing that they did was to give him oxygen. The point is that he improved with that treatment.

TABLE 4

PROBLEM AND TREATMENT

Problem	Treatment
Bubbles	Reduce size by compression oxygen breathing
Haemoconcentration	Infuse liquids
Circulatory stagnation	Dextran 40 and fluids
Tissue anoxia	Oxygen

When you are away from home and nice chambers you still have got the same problems with decompression sickness (Table 4). You have got bubbles that have got to be squashed. You want to get the gas out of the bubbles and you use oxygen for that. You can rehydrate them by putting liquids in. You can improve the stagnation of the shut down circulation with Dextran 40 and fluids. Ordinary electrolyte fluids are probably just as good. The Dextran 40 does work miraculously in people who have got shutdown areas and it seems to unclump and free the red cells. But you must give them plenty of fluids with it otherwise you get a jelly in the terminal renal tubules. And you cannot do much about that in the wilds.

TABLE 5

FACTORS AFFECTING SUSCEPTIBILITY

Previous Dives	
Acclimatisation	Age
Obesity	Physical Condition
Alcohol	Exertion
Fatigue	Hydration
Chilling	Intercurrent Illness
Anxiety	Drugs

Table 5 lists the factors affecting susceptibility to decompression sickness. Age and physical condition and hydration all affect us. The morning after the night before is not a good time to go diving but we all do it. Those of us who have not dived for a year, are a little anxious when we fall into the water. Those of us who are diving without adequate protective clothing are prone to get chilled. Those of us who have a headache may have taken aspirin and be improving. Those of us who have got anxieties and are taking Valium do not know what will happen underwater. Alcohol and fatigue and obesity are pretty regular components of a SPUMS meeting. As for acclimatization, those of us who do not dive very often are more at risk than the bloke who is working under pressure every day.

TABLE 6

ADVANTAGES OF OXYGEN THERAPY IN 9 METRES OF WATER

No nitrogen added to tissues during treatment.
Bubbles approximately halved in volume.
Diameter reduced approximately 20%.
Increased tissue oxygenation.
Large nitrogen pressure gradient.
No risk of CNS oxygen toxicity.
No risk of DCS for attendants.
Wet suits still effective insulation.

Now to turn to Carl Edmond's underwater oxygen treatment which is considered to be controversial but is in fact only taking the 60 feet oxygen Tables out of the chamber and popping them in the water at 9 metres (30 feet) (Table 6). It has some advantages, you are not adding nitrogen to the tissues, which you do if you recompress somebody on air. The bubble diameter goes down and there is a large nitrogen pressure gradient while you are breathing oxygen at 9 metres (30 feet). You improve tissue oxygenation. You should have no risk of CNS toxicity. You are certainly not going to bend the attendant. And the wet suit still keeps you reasonably warm. I am not going to say that this treatment is ideal. In fact I do not think it is ideal, but when you are faced with a 12-24 hour delay before getting the patient to a chamber, and he has got to pay for the aircraft, I think it is probably worthwhile considering, if you have got this equipment with you, treating him, because you may cure him and save him that journey.

TABLE 7

REQUIREMENTS FOR EMERGENCY RECOMPRESSION IN WATER USING OXYGEN

Full face mask
Depth limit 9m
Wet suit
Shot rope
Support
Attendant in the water
Communication system

Table 7 shows what you need. The patient needs to have a full face mask so that he can vomit or go unconscious without drowning. The patient must wear protective clothing and insulation, a wet suit. You have got to have a shot rope, so you know where the patient is. You need to have ropes tied to the patient so that he cannot drop deeper than 9 metres. They have got to be supported because trying to stay at one depth in the water is extremely difficult.

The patient must be overweighted. Sitting him in the bight of a rope is a perfectly adequate way of supporting him. But the patient will not thank you. In a trial of the equipment at Truk, Janene got very fed up after about 20 minutes sitting in the bight of the rope. We had weighted her around the waist, so her feet were light and floated up tipping her backwards. Also the bight of the rope cut into her bottom. It will cut in even more uncomfortably if it is tied round the waist. These people are going to be in the water for nearly three hours. You have got to have an attendant down there to make sure that the patient is getting better. It is best to have two attendants. This allows an efficient communication system. The patient can speak into the full face mask and the attendant can hear. A yank on the line to get the second attendant down to take over and the first attendant to take a message back to the surface.

TABLE 8

TREATMENT PLAN

Patient to 9 metres on oxygen (hose length 12m)
Attendant breathing air.
30-90 minutes at 9 metres then ascend at one metre event 12 minutes (or 1 foot every 4 minutes).
If symptoms recur, halt ascent for 30 minutes. If oxygen runs out during the patient to the surface.
Do <u>not</u> give the patient air underwater.
After surfacing give 100% oxygen alternate hours for 12 hours.

All you need on the jetty is a large oxygen cylinder and the yellow box. SPUMS has a back pack that you bolt the oxygen hose to so that the mask will not pull off the patient's face. It is a good idea to have a non-return valve at the bottom of the oxygen line so that if anything goes wrong the face mask does not suddenly fill up with water. The hose is marked off in feet, because the treatment is extremely simple (Table 8). You take him down to 9 metres. You leave him there for 30 minutes, and then if he is better, you pull him up at the rate of a metre every 12 minutes or a foot every four minutes. Marks which is probably a better method of reducing pressure than coming up in metre steps every 12 to 15 minutes. Marks on the hose are a great help in controlling the ascent.

If he has a neurological bend he gets at least 60 minutes at 9 metres before being brought up. The stay at 9 metres can be safely extended to 90 minutes. The E size cylinder will allow 90 minutes at 9 metres and the 120 minutes of decompression as well as having some left for oxygen at the surface.

FIGURE 2

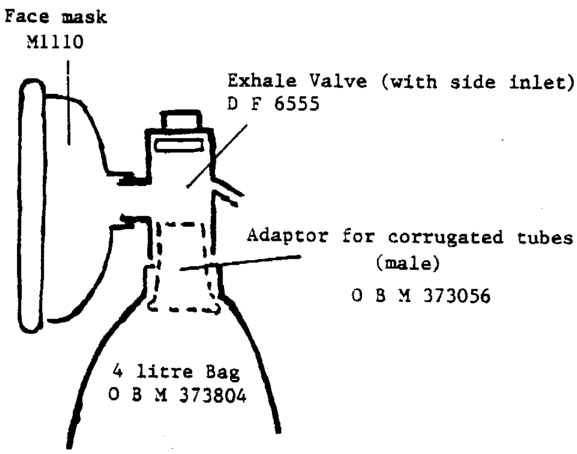
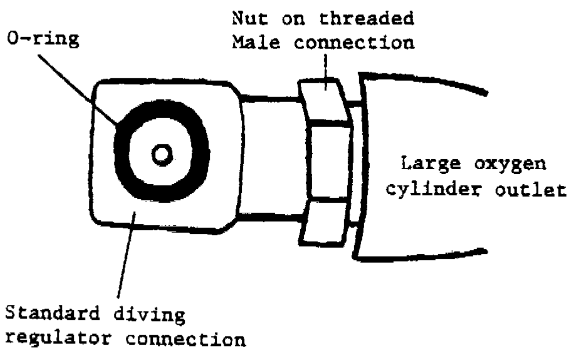


FIGURE 3

ADAPTOR TO FIT A DIVING REGULATOR TO A LARGE OXYGEN CYLINDER



One must continue to give him oxygen once he has been decompressed. For oxygen at the surface one can either use a simple bag and mask set up (Figure 2) made from readily accessible anaesthetic equipment or the diver’s regulator as recommended by Mike Davis. To use a regulator with a D or E cylinder one needs an adaptor (Figure 3) to screw into the cylinder outlet in place of the reducing valve used for the underwater treatment. The bag and mask have the advantage that you can watch the bag moving with each breath and see that the chap is breathing properly.

Chairman (Dr Tony Slark)

In New Zealand we recommend that divers besides staying within the no-decompression (no-stops) limits use up the spare air that should remain at the end of a no-stop dive doing a decompression stop. There is often a great deal of interest to be found during the 20 foot level on the cliff face. This stop enables you to use up your gas and will add to your safety margins.

Question

You say that the person can vomit into the mask. How do you get rid of the vomit?

Dr John Knight

It is a full face mask and there is plenty of space to vomit into. After vomiting, you just pull the chin away and the vomit drains out. Because it is a full face mask, if the patient goes unconscious, he will not drown, but I would not use the equipment for an unconscious patient.

Dr John Miller

In spite of the use of a wet suit the water temperature is terribly important. This system should not be used if the water temperature is less than 32-33°C. 2.5 to 3.5 hours in a wet suit in cooler water makes hypothermia during treatment a very real issue. It is probably useful in the equatorial belt. It is not useful in places like the Caribbean. It is not useful in Southern Australia nor in New Zealand waters. It is useful only in this warm water part of the world.

Dr Nick Cooper

Recently a treatment at Heron Island, using the Edmonds Underwater Oxygen Apparatus had to be abandoned after 30 minutes because the patient got too cold to tolerate staying down any longer. So hypothermia is a real risk with this treatment. Water temperature there is about 24°C.

Dr Jimmy How

This problem is very real. You will be hearing a lot about fishermen divers at the conference who are three to four days away out in the South China sea diving to get their fish. When they get bent they take about three to four days to reach Singapore. That is a very real problem and this underwater oxygen treatment could help them tremendously.

Our fishermen divers do almost exactly what is recommended here. With one important difference, they use air. Also they go much deeper. They do wet decompression therapy, and do it very badly. The victim is unconscious, and is lowered in a basket back to 110 feet or to 130 feet. Somebody comes down to accompany him. The saddest part of the whole story is that after he wakes up from his unconsciousness and his paralysis has improved they winch him right back into paralysis again because they pull him up without any decompression stops. In fact they repeat another dive. We keep on trying to teach about the need for extra decompression on the second dive.

Dr John Miller
To emphasize that some more. The standard way of producing an animal model of serious decompression sickness is to give an animal a dive that is either bends producing or almost so. Then, after a surface interval, recompress to a predetermined depth, stay there for a short while and decompress straight to the surface. That produces a very good spinal cord decompression sickness. An analogue of that sometimes happens in humans. This is one of the things that bothers me about this underwater oxygen therapy. If the treatment has not been completely effective, then it carries with it the potential of turning the pain only bend inadequately treated into a very severe spinal cord injury. That would be another caveat.

Dr John Knight
The instructions that come with the kit say that you take him to 9 metres, 30 feet, and keep him there for half an hour. If he is completely better then you start decompressing him. If be is not completely better, you give him another 30 minutes, and if he has got a spinal problem in the first place, you give him at least an hour, and you can extend that by another 30 minutes if you are worried. One E size cylinder will do all that treatment and still have oxygen left for him to breathe at the surface. I do not know how many times it has been used. I know it has been used in New Guinea, Rabaul and Bougainville. It has been used on patients with neurological bends. Carl Edmonds claims that everyone has been considerably improved and most of them have been rendered symptom free. When you consider that the alternative is a long delay, and then a delayed treatment, I do think that it may well have a part to play.

Dr John Miller
I agree than underwater oxygen therapy can have a place, but within the caveats of the need for a high water temperature and the possibility that if the treatment is not adequate that you could be in a worsening situation.

Chairman (Dr Tony Slark)
This only treats with pressure and oxygen and is not in any way going to help the long term biochemical results of bubble formation. It is possible that relying upon this system at a delayed stage in the patient’s management could result in further delays at a time when one should be treating, not bubbles, but what the bubbles have subsequently produced in the blood, the preliminary stage of coagulation coagulopathy.

Dr Jimmy How
I have my reservations about this treatment. I would subscribe to 30 minutes at 9 metres. But I am worried about convulsions if you extend it for another 30 minutes. We train our Navy divers in oxygen sets and I have seen convulsions at 25 feet. The only difference here is that the treatment is free flow, whereas we have a circle system, a closed circuit, for our divers when breathing oxygen. To my mind, if you try to push it for another 30 minutes, the chances are quite high that you will get a convulsion even if you give them free flow.

Dr John Miller

I treat people for 6 hours or more at 2 atmospheres absolute breathing 100% oxygen and they do not convulse. Admittedly they are in a chamber. The important thing is that they are at rest. You are talking about one situation and transposing to another. The working diver is breathing on a closed circuit rig which requires a certain amount of CO_2 to activate the soda lime. It is equipment that has got a fairly high breathing resistance. The effort of working and of breathing against this resistance is quite enough to raise the $PaC0_2$ which lowers the threshold for oxygen convulsions. With the underwater oxygen treatment you have virtually no breathing resistance and the patient is at rest, not working. if the patient were to start shivering, that might be a whole different thing.

Question

Do you regard oxygen therapy as essential in the treatment of decompression sickness?

Dr John Miller

Yes, but not necessarily in the water. Even without recompression you can give fluids and simple things like aspirin. That was the point in my talk about reports from the South of France. I would give the patient a good fluid load and maybe some aspirin. I would do that even when I was going to use this underwater oxygen equipment.

Question

What would you do if you were in the middle of the Coral Sea with a diver with a pain only bend 12 to 14 hours from a chamber?

Dr John Miller

It is quite simple. You give him a good fluid load. I would also give him a couple of aspirin and while I was doing that, I would be having him breathe oxygen as much as possible. By then something like 30 minutes would have gone by. If he was getting better by himself, I would continue fluid and oxygen. If he was not I would put him over the side to soak. There are some advantages in giving him oxygen at the surface. You will need time to examine him, because I want to find out whether or not he has in fact got decompression sickness. And if he has, whether or not he has any neurological complications associated with it. If you have the oxygen treatment equipment on hand, it is awfully easy and awfully tempting to use it when a guy says he has got a pain in his knee. I think that what you should do is to proceed with due caution, knowing that you have got that as a back up. You can then afford to be thorough.

Chairman (Dr Tony Stark)
I view the pathology of decompression sickness as going through various phases in which different aspects of treatment are most important.

In the first phase it is recompression pressure itself, that is the most important factor. Then hyperbaric oxygen becomes more significant than pressure. Later, the pathology changes further and it may be that hyperbaric oxygen is the only part of the treatment that is necessary at all. Going on further, neither is going to make any difference and the lesions are absolutely permanent.

Other questions were asked and statements made by the audience. Unfortunately, the quality of the recording was not good enough to allow transcription.

SPUMS SCIENTIFIC MEETING 1980

FRIDAY JUNE 27th
DECOMPRESSION SICKNESS SESSION TWO

Dr Chris Acott

Cerebral oedema and the use of barbiturates in the treatment of head injury is one of my interests. I have made the assumption that bubbles in the cerebral circulation causes the same patho-physiological responses as an acute head injury or an acute stroke. If so, the ischaemia, which is the primary neurological damage, is followed by secondary neurological damage. We all know that the most important thing in treating head injuries is not the actual primary insult, but the problem that secondary damage is caused through hypoxia and retention of CO_2 and an unclear airway. The mainstay in the treatment of cerebral decompression sickness or cerebral air embolism is recompressional pressure, but before this can be instituted we have to make the diagnosis. A recompression chamber has to be made ready and available. The diver has to be transported to the recompression chamber. And delay has to be minimized between the diagnosis being made and the diver actually reaching the chamber. In South Australia we have a recompression chamber at the Royal Adelaide Hospital. It is a Vickers monoplace oxygen chamber which I regard as a one man coffin.

In South Australia the majority of diving is done either on the Eyre Peninsula or down the coast from Adelaide or at Mt Gambler. Now Mt Gambier presents a very special problem and this is what stimulated me to think about this. People dive in sink-holes, caves in the limestone where the roof has fallen in to allow access. These are almost all on farms, and so transport and getting facilities to the diver is difficult. If somebody gets bent at Mt Gambler, it is 250 miles to Adelaide and about 250 miles to Melbourne, so there will be delays of up to probably three or four hours.

After Tuesday night’s talk, I think we have a very, very good retrieval system in South Australia. An Anaesthetic Registrar, or an ICU Registrar, in his final year, or a Staff Anaesthetist or Staff ICU person goes out. We always go out to the patient and bring the patient back. This is in preference to bringing the patient to us. We have a St Johns Ambulance aircraft on ten minute standby. The pilot has to be within ten minutes of the Adelaide airport. We have a helicopter and a very efficient road system. We take everything with us, including resuscitation equipment and monitoring equipment. We can intubate in the field, we can monitor ECG’s, we can put in a CVP, and we can ventilate the patient with a Bird respirator. Here is an example of how efficient our system is. The pupils of a girl, aged 13, who had an extradural haematoma, dilated up while the doctor, 150 miles from Adelaide, was talking to me. We had that girl on the table with her head open within 2 hours.

Because of the physical impracticalities of Mt Gambier, I considered what we should do if some diver came up convulsing and was unconscious. Is there any first aid we can give the diver at the site? And if recompression treatment fails, is there any other treatment that we can give the diver after his treatment? So I began to think about the use of barbiturates in cerebral oedema, which after a delay of about three of four hours is probably the thing that we are treating. You have the primary cerebral insult which is followed by cerebral hypoxia. This can either be global or focal. We know that if we examine divers with bends very closely, you find subtle neurological changes, which means they probably have got focal lesions. The cerebral hypoxia sets up a chain of events which then follows a never-ending circle and ultimately leads to neuronal death and death of the patient.

Catecholamine-mediated hypermetabolism is increased. There is an increase in anaerobic glycolysis which leads to an increase in lactic acidosis. This acidosis can lead to two things. First an inter-cerebral hyperosmolarity and oedema which causes neuronal damage. Also, it leads to reactive hyperaemia and disturbed autoregulation of the cerebral blood flow. Both of these lead to vasogenic oedema. So you get a raised intercranial pressure which itself will decrease cerebral perfusion pressure, and so reduce cerebral perfusion and so you have got secondary damage to the neurones which then completes the vicious circle leading to cerebral hypoxia, and so you get the whole circle starting all over again.

Why do I advocate the use of barbiturates? Experimental evidence, mainly from the United States, in baboons, monkeys and dogs, has shown that experimental animals, subjected to ischaemia, either global or focal, have a 100% survival rate if they are treated with barbiturates, either post or pre-ischaemic episode. The response to post-ischaemia treatment is quite important. Reye's syndrome, which occurs mainly in children following a viral illness, and consists of cerebral oedema, hepatic coma, liver failure and hypoglycaemia had a mortality rate of 75% until people began to use barbiturates in the treatment. Now the mortality rate is zero. In a trial in Pittsburg, in the United States, 14 out of 22 patients who had a cardiac arrest survived when treated with thiopentone after the arrest. The arrest time was between 5 minutes and 22 minutes of cardiac standstill. There is also good evidence coming from the United States about the use of barbiturates in head injury patients. Anaesthetists here know that cerebral air embolism occurs in patients on bypass, and they seem to survive and not have any neuronal damage at all even though they have been shown by Doppler monitoring to have bubbles being lodged in the cerebral circulation. I think that probably the reason is that they were all induced with thiopentone beforehand.

How do the barbiturates work? They supposedly depress the lactic acidosis induced by catecholamine release intracellularly. They also, since 1950, have been known to decrease the cerebral metabolic rate. They decrease the neuronal metabolism. They decrease blood pressure and so decrease cerebral blood flow which becomes quite important in treating cerebral oedema. It is said that they have a membrane stabilizing effect.

If you are going to use barbiturates in head injuries or the sort of situation I have postulated, one has to consider when you have to give them and in what dosage. Experimental evidence suggests that you have to give barbiturates within 3 hours of the primary insult for it to have any effect. So when you read about the inefficiency of barbiturates in the journals, consider when the barbiturates were actually given. They can be given either pre- or post- ischaemia, but they have to be given within 3 hours of the insult and this is quite important. It is also no use deciding 24 hours after all treatment has failed to give the fellow barbiturates. Clinically, the dose varies, however one has to give enough barbiturate to make the EEG on the patient isoelectric. After that you can continue giving barbiturate and it will have no effect-on survival at all. Our regime for head injuries at the Flinders Medical Centre, in Adelaide, is to start with an initial dose of 3 to 15 mg per kg of thiopentone. This dose is tolerated haemodynamically. This is followed up by 1.54 mgs per hour for the next 24 hours. Then we switch over to saline and amylobarbitone 1.54 mg per kg three times a day and this is titrated against the patient's intracranial pressure, as we have a Richmond screw intraventricular drain in place and are monitoring his intracranial pressure.

There are obviously several problems associated with this giving of barbiturates:

1. You need to have haemodynamic monitoring blood pressure, pulse rate etc., even CVP.
2. You have got to have a person who is skilled in resuscitation, so obviously you need an anaesthetist.
3. You need full resuscitation equipment.

The other major thing is that the barbiturates will alter all neurological signs and so you need a careful clinical assessment beforehand, using the Glasgow coma scale and various clinical evaluations of what is going on.

That sort of thing does not really present much of a problem to us in South Australia, because all our retrievals are done by anaesthetists, and we actually do these things in the field without any problems.

Advantages that may be seen for this treatment are:

1. If a diver is convulsing then obviously these convulsions are repressed.
2. If you consider the cerebral compliance curve the stimuli response in intracranial pressure is reduced to a minimum because you had him barbiturized and still and transport him like that.
3. It is thought that using hyperbaric oxygen with the patient barbiturized you will increase his threshold to having cerebral oxygen toxicity.

Question: Dr Bill Hurst
What advantage does barbiturate have over Decadron?

Dr Chris Acott
A lot of people believe that steroids have got no place in the treatment of acute head injuries. They have only got a place in the treatment of cerebral rumours. Patients coming to an operation for removal of a cerebral rumour are often only kept alive by their dose of steroids. It is a debatable point. If I had a head injury I would like everything given to me including steroids if there was any chance that they might do me some good. There are cerebral compliance curve studies where steroids have shown a great decrease in intracranial pressure. It has been similar to that with hyperventilation, barbiturates and mannitol. So if you did not want to use barbiturates in a patient who is convulsing, I feel that you could begin with a dose of steroids. I do not think that you are going to do him any harm at all.

Question: Dr Janene Mannerheim
When you are measuring his neurological signs by examining him, how are you going to do that when he is unconscious and you are transporting him?

Dr Chris Acott

You would use thiopentone initially and then transport him. Theoretically, if you use up to 4 or 5 mg of thiopentone per kg and the transportation getting him to a chamber takes two hours, the patient can be aroused and examined at the end of the journey. It takes a while for the barbiturates, especially this barbiturate, to be redistributed however I think you could examine him. 4 mg per kg is the standard dose for induction of anaesthesia.

Question: Dr Janene Mannerheim
You do not think you might overdose the patient trying to get a flat EEG?

Dr Chris Acott

That is when you have got them on an EEG in theatre and an EEG in the ICU. What I meant by the isoelectric EEG is the fact that once you have got the EEG isoelectric you do not have to go to any greater dose of thiopentone. I think any dose of thiopentone is worthwhile because it will reduce the cerebral metabolic rate and so reduce the oxygen requirements. If you have got a diver from Mt Gambier who is also cold, you are also adding the advantage of a guy who is hypothermic as well as having barbiturates on board. In South Australia we are the only place in the world at the moment that still uses hypothermia to remove intracerebral rumours.

Question: Dr Tony Slark

You gave us your starting dose, if I have got you right, as 3 to 15 mg per kg. That is an extraordinarily wide range of dosage to start. How do you choose when you are going to give 3 mg or 15 mg ?

Dr Chris Acott

Just on the haemodynamic responses if you give 3 mg per kg and you do not get much of a response you can increase it if you want to. People advocate using up to 15 mg in some cases. Obviously if you hit them with 5 mg or 6 mg and then, as you often do, you get a great decrease in blood pressure and a bit of tachycardia, you will be worried about cerebral perfusion pressure. If you want to get the EEG isoelectric you have to watch the blood pressure as well.

Question: Dr Darrell Wallner
I am just a little bit concerned; how would you ensure that you were also not depressing respiration?

Dr Chris Acott

In South Australia, those who go out to collect patients are all anaesthetists. If necessary we can put down an endotracheal tube and ventilate them which we would do if the respiration was depressed.

Question: Dr Chris Lourey

I can see the rationale of using barbiturates for controlling fitting and the rationale of having the expertise on site. However, I cannot see the rationale of large doses of barbiturates. If you can have an anaesthetist on site who has the skill to place the endotracheal tube, why not completely paralyse the patient, ventilate him with at least 60% oxygen, possibly give steroids, and then when he reaches a hospital with recompression facilities, de-curarise?

Dr Chris Acott

I discussed what we use in head injuries at Flinders Medical Centre and what they are trying to do. I would not like to use relaxants to stop him fitting, as just because somebody is paralysed and cannot move, does not mean that the EEG stops having fits. I agree with you paralyse and ventilate him and take him away. I think that is the way to do it. If you are going to use barbiturates, you are going to have to ventilate the patient. We know that we can reverse all the muscle relaxants once we get him into the chamber. At least you have a secure airway and you are reducing the secondary damage that is going to happen.

Dr John Miller

Oxygen toxicity in this situation with oxygen enrichment during transport, particularly with a barbiturate load on board is unlikely to be a problem. There are situations where repeated oxygen treatments may be given in the chamber where oxygen toxicity will probably ensue. I am pretty simple minded about some of these things. For the most part, pulmonary oxygen toxicity is a reversible lesion, at least functionally, if not pathologically. Pathologically there are significant changes in the lung. The gas exchange returns to normal, particularly at rest. What does it matter, if you impair his exercise capabilities to some extent in order to save somebody’s life?

A couple of comments about the use of barbiturates in these cases and a little bit about the differences between cerebral air embolism and central nervous system decompression sickness. Central nervous system decompression sickness is due primarily to obstruction of the venous outflow from the spinal cord. Cerebral decompression sickness is very uncommon by itself. Central nervous system decompression sickness is a global cord lesion. It may be quite high in the cord. In cerebral air embolism you may have one or a series of focal lesions that are arterially mediated throughout the brain and the brain stem. The nature of both is to produce an endothelial injury and that results in oedema either of the cord or of the brain.

For some time now we have also thought about giving patients barbiturates, particularly the ones that have obviously very severe injuries. We have not done so on the following grounds. Recovery and rousability following a single induction dose of thiopentone is rapid. However, although thiopentone is said to be short-acting, it is only short-acting by virtue of the fact that the drug redistributes in the body tissues, and comes therefore to a lower level. So when you give another dose of thiopentone that will also produce a peak with unconsciousness and subsequently redistribution. In order to have a maintenance level at a nice elementary point, the patient may not be rousable. We have avoided using thiopentone because of the fact that we cannot predict beforehand just how rousable a patient will be after a particular series of doses of thiopentone when we are faced with the situation where the co-operation of the patient may be vital. Theoretically, I am very much in favour of doing it in serious cases of cerebral air embolism, where we have documented a major injury and have made a full clinical evaluation beforehand. Essentially, you are cooling the brain down, reducing cerebral oxygen requirements, reducing the perfusion pressure and at the same time going on with oxygen, steroids and all the other things.

Dr Jimmy How

If you have a diver with a cerebral air embolism, there is obviously going to be tissue damage within the lungs, with air being carried to the brain. He may also have a pneumothorax. I share Janene's worry. I think such a high dosage of thiopentone to a patient could mask useful signs.

We have used very small doses of Valium such as 5 mg and our patients go off to sleep. This introduces two problems when you reduce pressure. With a very drowsy patient who is breathing slowly during the ascent from 165' to 60', you have to keep on rousing the patient, as there is the chance of lung damage from over-expansion if he is breathing very slowly. How serious this is, I am not sure, but we always keep our patients awake. Secondly, if he is drowsy the signs and symptoms of a small pneumothorax getting bigger may be masked. The patient may not be awake enough to complain of pain or difficulty in breathing.

Question: Dr Chris Lourey

Could we have some comments in regard to transport delays such as getting the patient to the RAN chamber in Sydney?

Dr Chris Acott

The time lag is one thing that I am worried about. That is why I was advocating the use of barbiturates, etc. In the extreme case of a person convulsing, to give him a haemodynamically stable dose of thiopentone and put in an endotracheal tube. In South Australia we have intercostal drainage tubes and we know how to put them in. If we put them in, on both sides is necessary, if we have clinical indications.

Once you have given the initial dose of thiopentone you will decrease the cerebral metabolic rate. Then you can paralyse him and take him to Sydney. Those of us who have worked in ICU caring for patients with a Richmond screw intraventricular drainage will have seen the changes in intracranial pressure when somebody is moved and what thiopentone does to it. As an anaesthetic aside, bypass patients all obviously get the same air bubbles but very few have any clinical problems.

You have got everything going for you, you are moving him, he is still, he is paralysed, you are reducing his stimuli and you can get him to the chamber and there is no need for another dose of thiopentone within 2 or 3 hours. To get him moving again you give him atropine and some neostigmine. It all followed from my reading about cerebral oedema.

Dr John Miller

We have treated a number of patients with severe cerebral air embolism following some sort of medical catastrophe rather than diving. They have had significant delays of up to 54 hours between the incident and treatment in the chamber. In most patients where there has been a significant delay, we have found despite very aggressive compression therapy and very aggressive oxygenation, that there is consistently a latent period of about 18 to 30 hours between the onset of treatment and the beginning of an improvement. If one is going to use a barbiturate and recognising that there is a latent period, then why not take the advantage of the cerebral barbiturate right through into that period? Instead of turning off when you get to the chamber, use the chamber as the extra part of the treatment as well as the barbiturate. Then turn the barbiturate off some time just before you would expect to see some improvement, and the patient may well wake up.

Dr Mike Davis

You are in a unique position in Adelaide. You have a group of people who are extremely competent in the basic precepts of resuscitation and maintenance of patients during transfer. That is unique and there are very many areas of the Pacific Basin and America and Europe and a lot of other places where such skills are not available. I think there is a great risk of putting the cart before the horse. Whilst theoretically barbiturates in this situation sound attractive, there are certain riders that I would put on that. Firstly, that there is a great deal more basic education required in the management of airways, fluids, etc. during any form of evacuation. The second thing is the role of thiopentone, as far as I understand it, in the management of severe intracranial conditions, is in the reduction of intracranial pressure. There is no evidence as yet that the use of barbiturates in situations where intracranial pressure is not elevated improves survival. This includes Reye's syndrome, when the primary problem is a raised intracranial pressure which you are treating with thiopentone.

We do not know to what degree the intracranial pressure rises in air embolism. I would be somewhat dubious about the use of barbiturates in a situation where you are not monitoring intracranial pressure. I think that there would be potential risks to advocating that sort of treatment, particularly in the field, when not everybody may have your competence to manage the patient.

Dr Chris Acott

According to a paper in Critical Care Medicine thiopentone will reduce cerebral oedema. They treated cardiac arrest patients who had 5 minutes to 22 minutes of cardiac standstill. How much cerebral oedema we get with cardiac arrest we do not know, but they used barbiturates. It is a debate that is going on on both sides of the North of the Atlantic. I am one who ardently believes.

Dr Jimmy How

Patients should be transported with a clear airway and adequate oxygenation.

Dr John Miller

Yes, and hyperoxygenation of the patient. Hyperoxygenation is a cerebral vasoconstrictor and a reducer of intracranial pressure.

Question: (unidentified voice)

Do you give the barbiturate all at once?

Dr Chris Acott

No, the slug dose is titrated. You do not draw up a gram and just give it. If you do not get the response you want with 3 mg per kg give more and see what happens.

Chairman (Dr John Knight)

Any more questions on barbiturates, cerebral oedema and so on? If not, I think we will ask Jimmy How to tell us about the diving habits of the people he treats, and why they get bent 4 days out from Singapore.

Dr Jimmy How

I will not talk too much about the fishermen divers because you can hear a great deal of this at the conference in Singapore. Professor Ong is looking after them in terms of the preventive side and Professor Bose of the orthopaedic department after we have finished with them and have sent the patient to the rehabilitation unit.

We see four categories of patients. Firstly, we have professional divers. They come to us because we have good communications in Singapore and we have the chamber here. The cases that come have already been treated and failed.

By and large these cases are due to failure to follow the tables. They are rushing. In an emergency they have to surface, and when they surface their problems start. They also like surface oxygen decompression. They come up to about 40 feet and then from 40 feet they shoot up to the surface. They rush into the chamber and try to be under pressure again within 5 minutes. Then they breathe oxygen just to cut short the decompression time. Many of them have problems at the stage when they leave the water, getting caught up with things as they rush into the chamber. When they reach the chamber some of them start to get the symptoms and signs coming on. They come to us from Brunei, from the Indonesian side and even from the east coast of Malaysia. All these come to Singapore for treatment.

In the second group are the fishermen divers. They are the people you will hear about in Singapore. Their equipment is primitive. They just do not know anything about diving. They do about three or four dives a day. Basically, they are of the older age group. One would think that because they do so many dives a day they would have a tolerance, but this is not really so. When they get a hit, it is just purely because of the type of diving that they are doing. The best way to get their fish is just to throw some dynamite in, “boom” it goes, and then they can take any hookah and go down and choose the size of fish they want. That is exactly what they do at 120 feet out in the South China Sea, about three days away from Singapore.

By and large those who come back to us have gone down to fish as soon as they anchor. They remain underwater for two or three hours and they come up. They have their lunch and down they go again. They repeat the same thing over again. They go on about three dives a day. The amazing thing is that they have been doing this for 10 years and no bends. But lo and behold in the tenth or eleventh year they become completely paralysed.

The sports divers are mostly visitors. They come up here and they get very engrossed in their diving. They put on a second tank and they go in, they put on a third tank and they go in. Some of them do not use the tables properly and decompress less than they should. They too come back to Singapore and give us some problems.

The fourth group we see are divers in the Navy and it is a very small group. They do not get decompression sickness. We have some experimental diving. We have to push them deep. We get some problems. So these are the sorts of cases we have seen in Singapore.

We will hear more in Singapore regarding the fishermen divers, when we will be showing you some slides about these people. The equipment they have is very primitive. They wear a World War II gas mask. Air comes in through the hose and bubbles out at the side of the mask. There is one chap on top controlling the compressor. As they lower the hookah they increase the pressure. Sometimes the compressor stops and no more air reaches the man. They ditch the mask and charge all the way up. Very, very primitive indeed. We are trying to educate these fishermen divers, they are beginning to understand decompression and lately we are receiving fewer cases.

Chairman (Dr John Knight)

Thank you Jimmy, that is a most illuminating description of what I would have called an almost suicidal method of diving. But it is not very different from what the abalone divers were doing in Victoria 10 to 12 years ago. The abalone divers had problems with decompression sickness. I am sure Jimmy can remember very clearly the two men who went out from Eden and did what turned out to be a suicidal series of dives. They involved other people in a lot of inconvenience because they did not die before the boat was picked up and towed in. They died in the chamber later, which was partly due to chamber problems. But they had gone out and done a series of dives which, if you looked at the tables, the amount of missed decompression was so much that you could only have thought that they did not really want to survive. Anybody got any questions to ask Jimmy?

Question (unidentified voice)

I visited Nauru early last year. They disregard their decompression stops and sometimes they get bent and sometimes they seem to be alright.

Chairman (Dr John Knight)

If I could just elaborate on that. In Nauru there is a delicacy known as a red fish which many years ago used to be found plentifully at 50 feet. People could breathhold dive and spear them. Then the island got its first scuba tanks and quite quickly the red fish was fished out to about 190-210 feet. Now you do not see them of any size much above that. Surprisingly, few of them get bent. Those that do mostly have either run out of air, and have had to make a rapid ascent, or have seen a shark and made a rapid ascent.

Two years ago Nauru was achieving up to 12 cases of decompression sickness a year with a diving population of about 50. About then, the Nauru Government bought their own chamber, because the nearest chamber was in Sydney. The first bloke they treated in the new chamber died, but considering what he was like before he was treated, that was not really surprising. I went up there to try to inform the local doctors about decompression sickness and also talked to the volunteer chamber attendants. These were all people who give up their free time. They do not like using long treatments because that means they cannot go to work. The Phosphate Commission will not pay them if they do not turn up. The Nauru Government will, but the Phosphate Commission is the major employer, so they had an economic incentive to give the shortest possible treatment. In spite of this, they have had some quite good successes using a primitive chamber that is so hot that everybody inside it is sweating buckets. Which, if you remember John Miller talking about fluid load, is fluid unloading to make everything as difficult as possible.

Dr John Miller

This sort of diving practice is of course not unknown in many other parts of the world. There is a delightful paper in one of the sociology journals written by an American sociologist called H Russell Bernard. In the mid-sixties he wrote this superb paper about a year that he spent with the sponge divers of the Greek island of Kalimnos. He was able to describe a whole set of social circumstances, all the things to do with the macho image, where these people stand in their community and what happens to them. When we are dealing with what we consider to be an odd diving practice, we need to look at the total picture of how that fits in with the local society instead of rushing in and pointing out how wrong they are.

I am not, on the other hand, saying that we should simply withdraw and allow the noble fellows to go on doing their thing. I think we have to be fairly circumspect about how we educate people.

Dr Mike Davis

It is worth remembering that observation of one group of divers produced a fundamental new concept of decompression sickness. That was the paper by Le Mesurier and Hills on the Torres Strait divers. So as well as throwing up our hands in horror, we ought to look at their diving habits because there might be something we can learn from them.

Question (unidentified voice)

How do you explain how whales can go down thousands of feet? How far can whales go down?

Dr John Miller

Whales have been caught in nets as deep as 3,000 feet. Now that does not mean that whales do repetitive breathhold dives to 3,000 feet. Repetitive breathhold dives in man can indeed cause decompression sickness. All of the diving mammals have specialised parts of their circulation. They have an overgrowth of the epidural venous plexus that enables them to shunt blood away from the lung. It enables them to shunt blood into the thorax in such a way that they can selectively, as the pressure increases, compress the tissues of the lung. They have a very highly compliant thoracic wall and very highly compliant lungs. Then they splint the rest of the lung with the blood from the epidural venous plexus. They certainly seem to have an enormous capacity for dissolving nitrogen. I think it is very uncommon for most of the diving mammals to repetitively dive to exceptional depths. I think they spend a great deal of time close to the surface and only occasionally sound to great depths.

A young Danish submarine medical officer was intrigued by the way his instructors were able to breathhold dive down to 100 feet to the bottom of the submarine training tank. Eventually one of them developed decompression sickness, which led him to think about the possibility of developing decompression sickness following repetitive breathhold dives. He and others were able to demonstrate that decompression sickness following repetitive breathhold dives is indeed a possibility. Mythology is probably behind Taravana, which is severe decompression sickness that some Pacific Islanders get. They have to brave the wrath of the Princess who guards the black coral which is found at extreme depth. They then dive repetitively to get this and the more dives they do per day the greater the standing they have in the community until eventually the wrath of the Princess gets them.

You can imagine that on each of these dives some of the nitrogen in the lungs goes, with a great driving pressure, into the tissues and does not all come back out. This progressively builds up. These people go down to quite extreme depths on their breathhold dives and then pedal like hell for the surface. This is very much equivalent to a blow-up. It is not surprising that when they get decompression sickness it is either the chokes or very severe neurological decompression sickness. That is what the Princess does to them.

Chairman (Dr John Knight)

Taravana is known to the English speaking world through a chapter written by ER Cross in a book on breathhold diving. He wrote that one group of islanders went pearl fishing and got this strange disease, but the men of the next island never got it. The only difference between the two group's techniques was the time spent at the surface between dives. Both groups did the same number of dives in a day, but the second group spent longer hanging on to the canoe before they went down again. Presumably, being able in that time, to breathe off some of the nitrogen that they had absorbed.

CANADIAN HIGH ARCTIC NURSES TRAIN AT LOS ANGELES HARBOUR COMMERCIAL DIVING CENTER FOR BEAUFORT SEA OFFSHORE JOBS

A pilot group of registered nurses and paramedics completed a diving medical course on February 13, at the Commercial Diving Center in Wilmington, California.

The medical personnel are employees of the Arctic Exploration Services Ltd., which is headquartered in Calgary, Canada. The firm specializes in furnishing professional and technical specialists for Canada's oilpatch operations in the Beaufort Sea in the high Arctic.

The exclusive training contract was engineered by Terry Hodgins, Superintendent of CAN-DIVE OCEANEERING in Vancouver, British Columbia, and Jim Rippon, Operations Manager for Arctic Operations Services. CAN-DIVE is an affiliate diving contractor of OCEANEERING INTERNATIONAL INC., of Houston, Texas, which also owns the Commercial Diving Center. Both Rippon and Hodgins attended the training.

The initial group of medical people are based in Tuktoyaktuk on the Beaufort Sea, some 100 miles north of the Arctic Circle. The five female nurses and nine male paramedics rotate from the home base out to the offshore oil drilling platforms off the coast of Canada's Northwest Territory.

While stationed aboard the drill ships, the medical personnel are on call 24 hours a day, seven days a week. They perform medical support for the non-diving, as well as the diving people on the rigs.

Arctic Exploration Services foresaw the need for increased diving medical training but none was available in Canada. Terry Hodgins, himself a graduate of the Commercial Diving Center's Emergency Medical Technician/Diver Course, solved the problem by setting up the contract for Arctic Exploration's people to come to Southern California for the specialized medical training.

As its title suggests, Arctic Exploration Services provides highly skilled individuals and technical equipment to frontier regions of the world. In addition to medical services, Arctic Exploration also furnishes Marine Radio Officers, Radio Operator/Weather Observers and technical equipment rentals.

CAN-DIVE provides both conventional and bell/ saturation diving services and some 60% of its divers are graduates of the Commercial Diving Center.

The training at CDC provided a basic foundation in emergency diving procedures for nurses and paramedics working in cooperation with diving personnel who must function in the remote and unique environment associated with offshore petroleum exploration and production in high Arctic regions.

The objectives of the course were to instil within each participant the necessary knowledge to work in close co-operation with diving crews to provide emergency medical care management for divers who are ill or become injured while working offshore.

The training emphasized the hazards of the underwater environment, causes, symptoms, treatment and prevention of diving injuries and related diving diseases.

The medical personnel were given an understanding of basic definitions and terminology associated with commercial diving operations, and to know safe diving practices.

All made dives in CDC's operational diving ball to acquaint them with the diver's perception of his working area. One of the factors taken into consideration in awarding the exclusive training contract to CDC is that the school is the only school in the US with an operation bell/saturation diving system, which is similar to saturation systems being used in the Arctic.

Tuktoyaktuk, site of Arctic Exploration's base, is the Eskimo name meaning "place where the reindeers cross", and 90% of the village's population are native Eskimos.

CALL-DIVE and Arctic Exploration, in conjunction with the Commercial Diving Center are planning to continue to update the information and experience the nurses and paramedics have gained from this pilot course.

PRACTICAL ASPECTS OF DIVING TABLES FOR SPORT DIVERS

Bruce E Bassett

Over the years that divers in the United States have used SCUBA for recreational diving, the US Navy Standard Air Decompression Tables have been the accepted reference for avoiding decompression, calculating repetitive dives, or for making correct decompression stops. Decompression tables were designed to prevent decompression sickness (DCS). How successful are these tables in preventing DCS? In the US Navy, DCS occurs in only 0.03 to 0.04% of all dives made per year (1). Is this record also attained in sport diving? No one can answer that question with certainty because the incidence of DCS in sport diving is, and will likely remain, unknown.

As the sport of SCUBA diving has grown and developed most instructors and certifying agencies have tended to agree on certain basic safety principles which should be followed by sport divers. Thus most agree that: 130 feet should be the maximum depth; all dives should be made within the no-decompression limits of the US Navy Tables; and divers should not "push" these no-decompression limits. It is in the third recommendation that there is a wide variety of "factors" expoused by different divers/instructors. Some reduce the limits by a fixed amount of time (ie. 5 minutes), some use a percentage of the time (2 to 10%) to reduce the limits, some add "safety" decompression stops, and most merely say, "don't push the tables".

It is proposed here that SPORT DIVER tables be designed to provide a standardized approach for sport divers to avoid "pushing" the limits of the US Navy Tables. The rationale for altering the basis of the US Navy Tables will be explained as will the design of such Tables. The proposed SPORT DIVER tables are not to be extrapolations of the US Navy or any other tables per se, but they will be compared with others. Finally, the Tables are strictly designed with the sport diver in mind. They are totally devoted to avoiding "pushing the limits".

RATIONALE FOR ALTERING THE TABLES

US Navy Experience

If one looks at the US Navy statistics regarding the incidence of DCS, ie. 0.03 to 0.04%, the logical questions formed are "why alter the Tables?" The logic of this question is reinforced by a lack of DCS incidence statistics for sport divers in general. However, in examining the US Navy statistics the question must be asked "How does the US Navy dive with open-circuit scuba?" The US Navy Diving Manual does not set absolute depth/time limits for the use of SCUBA but states that "whenever possible SCUBA operations must be conducted so that no decompression will be required" (chapter 5 pages 5-40 5.3.6). It also states (Chapter 4 figure 4-17) that 60 feet is the normal working limit for open-circuit scuba and 130 feet is the maximum working limit. As far as these recommendations go we can assume that all, or nearly all, US Navy scuba dives are conducted within the no-decompression limits. But what fraction of Navy scuba dives are nowhere near these limits? If a high percentage of their scuba dives are shallower than 40 feet, or much shorter than the deeper time limits, which is probably the case by the nature of their use of scuba, then the DCS incidence figures are misleading by a deflated denominator ie. incidence = number DCS cases divided by number dives. The incidence figure of concern to sport divers would be number DCS cases divided by number dives made to the exact no-decompression limits. That statistic is not readily available for US Navy dives.

Laboratory Findings

Merrill Spencer conducted a large number of dives to the US Navy no-decompression limits (and some beyond the limits) in a recompression chamber, and a smaller number in the open ocean, using the Doppler Ultrasonic bubble detector to monitor post-dive intravascular bubble formation (2). In chamber dives his results were as presented in Table 1. His experience, as others have noted, with open water dives, was that a higher percentage had bubbles and bends than on equivalent "dry" dives in the chambers.

TABLE 1

BUBBLES AND BENDS AFTER DIVING

DEPTH/TIME	EXPOSURES	BUBBLES (%)	BENT (%)
70/50 (c)	12	33.3	8.3
60/60 (c)	13	31	7.6
125/20 (c)	9	56	11
165/10 (c)	6	33	0
165/10 (w)	6	83	33

c = in chamber; w = in water
(From Spencer - 1976)

Andrew Pilmanis at the USC Catalina Marine Science Center found, also using the "bubble detector", that open water dives to 100 feet for 25 minutes produced intravascular bubbles in all subjects and that the degree of "bubbling" was influenced by the level of work performed while at depth (3). No bends occurred in his subjects, but one other significant finding was noted. In a subject who had repeated significant "bubbling" upon surfacing directly from an exposure of 100 feet for 25 minutes, the degree of bubbling could be drastically reduced by a short stop at 10 feet and eliminated by short stops at 20 and 10 feet. This may indicate that only minor alterations in the no-decompression limits may drastically alter the results and that perhaps the present limits are on the "knife's edge" with regard to bubble formation and bends.

Ulf Balldin from Sweden has made interesting observations regarding flying following dives made to the limits of the US Navy no decompression limits, specifically 50 feet for 100 minutes and 130 feet for 10 minutes (4). These were also "dry" chamber dives and the subjects were monitored with the bubble detector while exposed to altitude. The altitude exposures were made to either 3,000 meters (9,840 ft), 2,000 meters (6,560 ft) or 1,000 meters (3,280 ft) after a three hour surface interval. The incidence of intravascular bubbling was as shown in Table 2.

TABLE 2
BUBBLES AFTER DIVING AND ASCENT TO ALTITUDE

POST-DIVE ALTITUDE	BUBBLES (%)
3,000 m (9,840 ft)	60
2,000 m (6,560 ft)	30
1,000 m (3,280 ft)	10

(From Balldin - 1980)

It is interpreted that silent bubbles were formed upon surfacing from the dives, which then became detectable upon further pressure reduction to altitude. There were no bends among his subjects but again, these were "dry" chamber exposures.

TABLE 3
PROFILES OF USN NO-DECOMPRESSION DIVES AND EXPERIMENTAL DIVES FOLLOWED IMMEDIATELY BY ASCENT TO 10,000 FEET CALCULATED TO PRODUCE THE SAME DECOMPRESSION STRESS

DECOMPRESSION DEPTH/TIME	EXPERIMENTAL DEPTH/TIME
130/10	130.0/7
100/25	100.0/10
80/40	80.0/14
60/60	60.0/20
40/200	40.0/30
22/24 hours	10.75/24 hours

(From Bassett - 1979)

In a tri-service project conducted at the USAF School of Aerospace Medicine concerning flying immediately after diving, further evidence was gained that the present no-decompression limits may not be sufficiently conservative (5). Exposure times at depths to 130 fsw were calculated to give the same decompression stress with an ascent directly to 10,000 feet as diving to the no-decompression limits and ascending directly to sea level, ie. the comparative profiles shown in Table 3. The results were as shown in Table 4.

TABLE 4
BUBBLES AND BENDS AFTER DIVING AND ASCENT TO ALTITUDE

DEPTH	EXPOSURES	BUBBLES(%)	BENDS (%)
130	20	0	0
100	18	38.9	5.5
80	16	37.5	6.3
60	18	27.8	5.5
40	18	22.2	5.5
10.75(=22)	20	20.0	5.0

The dives were calculated to give the same decompression stress as a no-decompression dive. (From Bassett - 1979)

In summary, the laboratory evidence is that the "true" incidence of intravascular bubbling and bends on dives made to the US Navy no-compression limits:

1. ranges from 10-56% bubbles in dry chamber exposures;
2. ranges from 83-100% bubbles in open water exposures;
3. ranges from 0 -11% bends in dry chamber exposures;
4. ranges from 0-33% bends in open water exposures;
5. long shallow dives produce higher bubbles/ bends incidence than short deeper dives.

This then is the rationale for proposing reduced no-decompression limits for the sports diver. If Sport Diver Tables are to be designed to make diving safer, then additional consideration must be given to their design. One area of investigation that has been performed has been an analysis of the Repetitive Dive Tables of the US Navy.

The repetitive group letters of the Navy system are based on a theoretical calculated difference in nitrogen pressure, equivalent to 2 fsw per group letter, in the slowest theoretical compartment for tissue (ie. the 120 minute half-time). When all dives within the US Navy Standard Decompression Tables are calculated, there are many anomalies found. The range of mean differences in PN_2 between subsequent repetitive group is from 1.2 fsw (A to B) to 1.8 fsw (G to H and M to N). Also the range of PN_2 found within a given repetitive group letter is from 2 fsw (A) to 6 fsw (M) (6).

Because of these anomalies, such conditions as the 60/30, 30 minute surface interval, 60/30 repetitive dive sequence that produces a decompression dive on the second 60/30 dive arise. While this example is obviously a safe, conservative approach, a more precise system of repetitive groups would reduce such anomalies and make the system produce more "realistic" results.

DESIGN CRITERIA FOR SPORT DIVER TABLES

Limits of Navy Tables

The limiting factors in the US Navy Tables are the calculated nitrogen tensions in six theoretical "tissues". These nitrogen tension limits were determined empirically (ie. by trial and error) during the development and testing of the Standard Air Decompression Tables and are referred to as "M-values" for maximum nitrogen tensions allowed upon surfacing. These M-values, which are expressed in feet of sea water absolute (fswa) can also be expressed as ratios of nitrogen tension to total pressure, ie. by dividing the M-value by 33 fswa (the absolute pressure at sea level). These are presented in Table 5.

Reducing the Limits

Since these limits represent the driving force for gas phase separation (ie. bubble formation), they are the limits which must be reduced to

TABLE 5
LIMITING FACTORS FOR US NAVY AIR DECOMPRESSION TABLES

Half-time tissue (min.)	5	10	20	40	80	120
M-value (fswa)	104	88	72	58	52	51
Ratio	3.15	2.67	2.18	1.76	1.58	1.55
No-decompression limits for various half-time tissues	110/20 120/15 130/10 120/15	90/30 100/25 110/20 100/25	70/50 80/40 90/30 80/10	50/100 60/60 70/50	40/200	

TABLE 6
LIMITING FACTORS FOR PROPOSED SPORT DIVER TABLES

Half-time tissue (min.)	5	10	20	40	80	120
M-value (fswa)	95	83.2	67	53.8	46.5	44
Ratio	2.88	2.52	2.03	1.63	1.41	1.33
M-value reduction (fswa)	-9.0	-4.8	-5.0	-4.2	-5.5	-7.0

design a set of tables for sport divers. Considering the laboratory evidence presented earlier the recommended revised M-values and ratios for proposed SPORT DIVER Tables are presented in Table 6.

Limits of SPORT DIVER TABLES

Using the reduced M-values, the calculated "no-decompression" limits of the proposed SPORT DIVER Tables are given in Table 7.

TABLE 7
SPORT DIVER TABLE NO-DECOMPRESSION LIMITS

Depth/Time	Limiting 1/2 time tissues
140/5	5
130/5	5
120/10	5
110/15	5
100/20	10
90/25	20
80/30	20
70/40	20,40
60/50	40
50/70	40
40/120	40,80
35/180 & 30/220	120

Repetitive Diving Revisions

In order to produce repetitive groups for strictly "no-decompression" SPORT DIVER tables, to provide for more flexibility in repetitive dive planning, and to eliminate most of the anomalies encountered in using the US Navy repetitive dive tables, 18 repetitive groups are proposed (instead of the 15 involved in the Navy no-decompression tables) with a precise range of 1 fswa per repetitive group designation. In the proposed Surface Interval Credit Table there is no minimum time of ten minutes, but with short surface intervals the residual Nitrogen times will always be equal to or greater than the Bottom Time of the first dive.

Finally, an additional part of the proposed SPORT DIVER Tables will be to include a three minute minimum stop at 10 to 20 feet on ALL dives made. This is again an attempt to standardize safety factors and put in an extra margin to make the tables as safe as possible.

RECOMMENDATIONS

SPORT DIVER Tables

In summary the proposed Sport Diver tables:

1. are more conservative in their design limits than the US Navy Tables;
2. provide standardized safety factors;
3. appear slightly more complex than the present tables because of a larger number of repetitive groups;
4. are designed to be presented like the PADI tables - simple to use with practice;
5. reduce some of the anomalies present in the US Navy repetitive dive system;
6. should be validated by manned testing, but can be used without because they are more conservative in all respects than the presently accepted standard.
7. can be used for multi-level/step diving.

Flying After Diving

Because of the results of Balldin and of Bassett, previously discussed, most if not all of the current recommendations regarding flying after diving are suspect.

Edel's (7) two-hour surface interval rule does not appear to be sufficiently conservative since 3 to 4 hours in the two studies cited was insufficient time to clear bubbles apparently formed as a result of dives made to the no-decompression limits. Additional evidence indicates that bubbles, once formed, may persist for as long as 18 hours.

The "D group rule" may not be any better for the same reasons, namely if bubbles are formed they may persist during the surface interval involved in allowing the decay of the repetitive group from some higher letter down to a "D" group. Surfacing from a dive with a "D" group and immediately flying to a maximum of 8,000 feet above sea level (unpressurized flight altitude or cabin altitude of pressurized aircraft) may be safe. However, CL Smith's (8) recommendations that it is safe to fly to 10,000 feet with a "D" group is unsafe, as shown by the Air Force tests, ie. Table 8.

TABLE 8

BUBBLES AND BENDS AFTER CHAMBER DIVES ASCENT TO ALTITUDE WHILE IN REPETITIVE GROUPS D AND E

DEPTH/ TIME	REPETITIVE GROUP	BUBBLES(%)	BENDS(%)
130/7	D	0	0
100/10	D	38.9	5.5
80/14	D	37.5	6.3
60/20	D	27.8	5.5
40/34	E	22.2	5.0

Use of the "Cross Corrections" (9) for flying immediately after diving would also not be sufficiently conservative, particularly at the shallower depths as indicated in Table 9.

TABLE 9

CROSS NO-DECOMPRESSION LIMITS FOR 10,000 FEET COMPARED WITH BASSETT (1979) TESTED DIVES

CROSS DEPTH/TIME	TESTED DEPTH/TIME	BUBBLES (%)
130/5	130/7	0
100/5	100/10	38.9
80/15	80/14	37.5
60/30	60/20	27.8
40/60	45/34	22.2

In view of these findings it is recommended that a minimum surface interval of 12 hours be allowed between any diving and flying to any altitude in excess of 3,000 feet.

Diving at Altitude

Related in most respects to flying after diving, the situation with diving at altitude is also unsettled. The "Cross Corrections" if used in conjunction with the SPORT DIVER Limits should be sufficiently conservative. Decompression dives using the Cross Corrections should NOT be performed. An additional safety precaution is not to dive at altitude until 12 hours after arrival there.

As an alternative, there are some tables developed by the Swiss that appear to be very conservative and which have the added benefit of having been validated by manned testing (10).

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A SCUBA DIVING ACQUAINTANCE COURSE FOR THE SEVERELY DISABLED

Abridged from a report by
CEN Sturgess and MC Clatworthy

In this paper "disabled" means having bilateral lower-limb dysfunction. Such disabilities are of less importance in diving than the absence of, or dysfunction of, a hand or arm. It is hoped that this report with that of Flemming and Melamed (1) will be regarded as components of a continuing programme and used accordingly.

It has long been accepted that sporting activities provide unrivalled opportunities for disabled persons to obtain enjoyment, satisfaction and social integration. To date the majority of sporting activities for disabled have centred on non-risk team competitive games. In contrast the risk sports such as sailing, canoeing and sub aqua have received little attention.

A number of severely disabled persons have learned to dive by contacting diving groups on an individual basis. The United States Army has run courses for war-disabled in Hawaii. Flemming and Melamed ran a course of scuba training for six Israeli war-disabled in 1974 (1). Since 1974 the BSAC has operated an advisory service for diving for the disabled, but no amateur part-time courses have been organised.

The authors conducted such a course in 1980. The objectives of the course were:

(a) to acquaint disabled trainees fully with both the theoretical and practical aspects of diving and diving training in order to develop interest and confidence;
(b) to assist the disabled trainees in becoming members of able-bodied diving groups on a fully integrated basis. (It was not the intention to establish disabled diving groups, this would be both impractical and undesirable).

According to Flemming and Melamed (1) disabled trainees should be passed medically fit to dive and capable of independent travel to the dive site. They may require assistance getting into and out of the boat and water but once in the water they can dive unaided. If separated from the boat the subject can inflate his (or her) life jacket and survive on the surface. This level of independence ensures a high degree of safety and permits the disabled person to join able-bodied diving groups on a fully integrated basis.

Flemming and Melamed (1) considered that the medical and physiological requirements for disabled candidates were:

1. Medical requirements were the same as demanded for any person who is to join a diving course. (A full medical examination, according to the standard BSAC medical test sheet, was conducted on each candidate).
2. The respiratory system should be completely normal and all the respiratory muscles under control. For paraplegics the spinal lesion should not be above T5 and preferably not above T8.
3. The candidate's skin should be without injury or pressure sores.
4. There should be no urinary tract infection and full control of urine and bowel movements, with or without artificial aids.
5. For paraplegics tie disability should not have been caused by a spinal bend.
6. Paraplegic candidates with partial spinal lesions should be made aware that diving may make possibly the lesion complete although there is no record of this actually happening.
7. The disabled person should be participating regularly in intensive swimming.
8. The disabled person should have a stable personality with a full knowledge of his abilities and disabilities, be self-disciplined and able to accept orders without resentment.

The authors, through their routine contact with a number of Midlands BSAC branches, found interest in the topic of diving for the disabled. Although BSAC branches were aware of the possibilities of diving for the disabled through the efforts of Flemming (2), they were unsure how to proceed. Although the Sports Council publicises diving for the disabled (3) most disabled persons seem unaware of this activity. Disabled persons were reluctant to approach exclusively able-bodied diving groups without assessing their suitability beforehand. The authors found considerable interest in the possibility of diving among the members of a swimming club for the disabled. They considered that an acquaintance course of one evening per week, where the disabled candidates would be exposed to all of the lecture and pool training requirements up to BSAC third class standard, would enable the disabled trainees to acquire a substantial foreknowledge of diving, and of the requirements of BSAC branches, to practice the practical techniques and solve problems on a group basis. The instructors for the course were to be drawn from interested BSAC branches adjacent to the disabled persons' home addresses. They would acquire experience, develop confidence in working with the disabled and feed information back to their branches. If the disabled candidates desired to continue diving, the instructors would form a bridge between the acquaintance course and the BSAC branch environment.

Three male disabled swimmers were interested in the course. All had bilateral lower limb dysfunction. They could drive and all were capable of changing, showering and entering the water without assistance.

TP: aged 34, has been paraplegic partial T8/9 since a motor car accident in 1962. Height 178cm, weight 81kg. He is in full-time employment on the staff of a regional newspaper. He is normally mobile in a wheelchair. He swims 3 times a week and has represented his disabled swimming club in regional, national and international competitions. He represented the UK in the 1974 Disabled Olympics. He has held the disabled world record for the 50m backstroke. He is active in administering sports for the disabled at a regional level.

PO: age 29, has had bilateral lower limb dysfunction since he contracted polio in 1959 at the age of 8. Height 170cm, weight 69kg. He is in full-time employment on the managerial staff of a national company. He is normally mobile on crutches. He swims 3 or 4 times a week and represents his disabled swimming club in regional, national and international competitions.

SB: age 28, has congenital bilateral lower limb dysfunction. Height 155cm, weight: 69kg. He swims twice per week and represents his disabled swimming club in regional, national and international competitions.

The course was conducted at the University of Birmingham Sports Centre in a pool 25m long by 10m wide with a maximum depth of 3m extending for one third of the pool length, the rest of the pool was shelving with depths of 1m to 2m. The pool has plastic edging, is used by a disabled swimming club and has easy access for wheelchairs. A lecture theatre was available on the same level with immediate access from the pool.

The course organiser was assisted by the BSAC Regional Coach, an Advanced instructor, as chief instructor. Of the four other instructors three were Club Instructors and the fourth instructor was a Branch Instructor (not nationally qualified) but with previous experience of working with the disabled. A general practitioner who was an experienced diver, and a physiologist gave support in their specialties.

The course, based on the BSAC lecture and pool schedule for third class diver, was run for 10 consecutive weeks beginning mid January 1980. Once a week the candidates had a 3/4 hour lecture followed by one hour in the pool, after which there was half an hour devoted to debriefing. The lectures given were abridged with concentration on the essential items. They were not full lectures as associated with normal branch training programmes. The level of competence expected was below that which would be normally required in branch training. The practical exercises were simply to show that no major problems remained. These departures from normal practice were necessary to cover all the pool training exercises and relevant theoretical material up to BSAC third class standard within 10 sessions. It was made abundantly clear to the candidates that the course was only an acquaintance course and should they wish to proceed further they would be required to go through a full training scheme under normal branch conditions. The philosophy adopted was to pursue an accelerated BSAC recommended training scheme and only to consider changes as and when the disabled trainees encountered difficulties with the standard scheme.

The candidates were all extremely highly motivated. The trainees, all being accomplished swimmers, did not experience any difficulties with the standard BSAC swimming test, except that it was obviously impossible for any candidate to tread water with both arms out of the water. All the candidates could continuously maintain one arm out of the water. One candidate (PO) was very positively buoyant. The disabled candidates had no control over their legs and as contact with the pool sides and bottom is best avoided wherever possible due to abrasive damage to the limbs (1), they always entered the pool at the deep end. When training able-bodied divers it is usual to retire to the shallow end of the pool for discussions in the water. This is not desirable for disabled trainees and in-water discussions are best conducted treading water or holding onto the pool side in the deep end of the pool. Swimming with a 5kg weight belt resulted in the candidates' legs dragging on the bottom of the pool in the shallow end. It would be preferable to conduct this exercise for the equivalent distance (50m) across the deep end of the pool. Fitting a mask and snorkel as the act of raising the arms tends to sink the body, and the disabled trainee cannot tread water. There were some slight problems with mask clearing but these were soon resolved. After a few trials the scheme adopted was as follows:

(1) dive, recover the mask, swim to the surface

(2) take a deep breath, fit the mask body sinks

(3) clear mask underwater, swim to the surface

(4) dive, recover the snorkel, swim to the surface

(5) fit snorkel - body sinks

(6) swim to the surface, clear snorkel.

The exercise of swimming using a snorkel, but without a mask again poses a problem for the disabled trainee. Able-bodied trainees simply support the snorkel at the side of the head with one hand and fin. The disabled trainee requires both arms to propel himself effectively through the water. The modification adopted for the pool exercise was to wear the mask with the face plate on the back of the head and use the strap to restrain the snorkel, so releasing both arms for swimming. However, this raises an interesting point for open water snorkelling for the disabled, should the disabled snorkeller have separate retaining straps for the mask and snorkel in the event that the mask is lost?

Life saving is obviously the area where the disabled trainees were expected to have the most difficulty. Flemming and Melamed (1) recommend that for open water activities the disabled diver should always be accompanied by two experienced companions. Nevertheless the risk of separation is always present and the extent to which the disabled trainees could perform life saving exercises was explored.

The procedure eventually adopted for snorkel lifesaving was as follows:.

1. The disabled trainee approached the victim who was equipped with an ABLJ and lying face down in the water.

2. He righted the body and partially inflated the victim's life jacket.

3. The trainee removed the victim's mask and snorkel and, supported by the victim's inflated lifejacket administered EAR and signalled distress. The exercise could have been terminated at this point but the candidates were keen no continue the normal procedure.

4. The disabled trainee slowly towed the body one length of the pool (from deep water to halfway and back) using an extended tow from the lifejacket straps and swimming with one arm.

5. On arrival at the poolside, an the deep end, the trainee supported the body with his arms under the armpits of the body. If bystanders were present the trainee requested help and instructed the helper in removing the body from the water. Again the rescue could be terminated at this stage, however, the candidates were anxious to explore the possibilities of removing the body from the water.

6. The rescuer then positioned the victim's arms as far over the pool side as possible and supported this position with his body, holding on to the edges of the splash-channel.

7. The rescuer then reached down and placed his arm between the legs of the victim from the rear and back lap into the splash channel between the body and the pool side.

8. Once in position the disabled rescuer could, by manoeuvring his upper arm and shoulder under the victim's crutch, deposit the body on the pool side to the level of the body's waist.

9. The rescuer then pushed the body's legs onto the pool side while holding onto the splash channel.

10. The rescuer climbed from the pool, administered EAR (from a sitting position) and finally manoeuvred the body into the coma position.

Obviously, while removing the body from the water the risk of abrasive skin damage was present, but no abrasions occurred.

Their first excursion underwater without the need to return to the surface was undoubtedly the highlight of the course for the trainees. The aqualungs were fitted to the candidates in the water. A significant proportion of the time was spent allowing the trainees to become generally acquainted with the possibilities of underwater movement, with the instructors keeping the trainees under constant surveillance but not interfering. This activity caused much excitement. PO who had displayed considerable buoyancy during the swim test required a 2kg weight belt to enable him to stay underwater. Also this candidate demonstrated slight apprehension initially during surfacing, but this quickly disappeared. After the free-swimming period all the candidates performed the required exercises without problems. The disabled diver has considerably more problems than the able-bodied in maintaining a balanced sitting position on the bottom of the pool (1). Each trainee required the use of a heavy weight belt to maintain balance during the ditch and retrieve exercise. Some difficulty with balance was apparent during the removal of the aqualung over the head. All the candidates found that removal of the aqualung around the side of the body easier.

The best entry method appeared to be, fit the aqualung on the pool side and roll forwards into the water holding the mask and valve with one hand and securing the cylinder with the other hand.

During the lecture on open water diving the recommendations for the disabled from Flemming and Melamed were dealt with in depth. The instructors reinforced the recommendation of Flemming and Melamed that disabled divers do not conduct decompression dives.

The aqualung rescue techniques used followed directly from the experiences obtained with snorkel rescues.

1. Both rescuer and victim were equipped with ABLJ's.

2. The rescuer approached the victim (lying face down in the bottom of the pool) on the surface duck dived, released the victim's weight belt, and lifted the body to the surface by swimming with one arm. This presented problems but all the candidates were successful.

3. The rescuer partially inflated the victim's lifejacket.

4. Supported by the victim's lifejacket the rescuer administered EAR. The rescue could be ended at this stage. The rescuer was instructed depending on prevailing conditions, to administer EAR and signal for help.

5. The rescuer towed the victim one length of the pool (half length towards shallow end and return) using the extended tow method. This exercise took a considerable time but all the candidates were successful.

6. On reaching the pool side the rescuer supported the victim and was instructed in the use of bystanders for help.

7. The rescuer removed his aqualung and passed it out of the water.

8. The rescuer removed the victim's aqualung and passed it out of the water.

9. The rescuer removed the body from the water and gave EAR using the procedures outlined for the snorkel rescue (steps 6 to i0).

All the candidates were successful in both rescues.

All the candidates for this course easily passed the medical and physiological requirements for entry to the course. The candidates had all experienced their disability for long periods of time and were extremely well adjusted both physically and psychologically. Furthermore, for PO and SB their level of swimming ability was far above average and was exceptional for TP. Other disabled candidates may not be able to cope so well.

The course amply fulfilled its objective of acquainting disabled persons with diving and diving training. The course gave the disabled trainees sufficient confidence to join able-bodied diving groups. The use of instructors gathered from BSAC branches, geographically convenient for the disabled trainees, to form a bridge no assist the integration of the disabled trainees into branches was an outstanding success. After the course the candidates joined the contributing BSAC branches.

The objective of this and earlier courses was to acquaint disabled persons with aqualung diving. All the candidates found use of mask and snorkel easy and this considerably added to their enjoyment of swimming. Snorkelling is a pursuit that possesses considerable potential for development in the sphere of water sports for the disabled, and specifically orientated snorkel courses should be investigated.

Although the course was successful it was felt that for the future courses the course syllabus would probably need modification. As this course was a pilot experiment it was thought reasonable to fully explore all the pool requirements up to BSAC third class standard, if not for the trainees benefit, then certainly for the organisers' and instructors' benefit. However, it was felt that in future courses only the major items of the pool requirements need be covered. This would allow shortening of the course and less duplication during follow-up branch training programmes. Although the trainees were told that the level of competence expected would be below normal branch levels in fact they achieved acceptable levels of performance for the majority of the pool exercises. This was partly due to the quality of the trainees, but is also an indication that the course was too long for an acquaintance course.

As current acquaintance courses for able-bodied trainees only require two to four hours in the pool, the authors felt that an acquaintance course for disabled trainees need only have four to five hours in the pool. Qualified support staff was available for this course and is obviously required for the selection of candidates. However, the support staff were not required during the actual pool periods. It is felt that, providing the selection process is sufficiently rigorous, BSAC qualified instructors can effectively man such courses.

In this course, as detailed earlier, the disabled trainees were exposed to the full rescue procedure and this activity requires comment. During an aqualung rescue exercise (similar comments apply to snorkel rescue) there are three obvious end-points in view of training disabled divers. In the opinion of the authors all disabled trainees should be capable of raising the body to the surface from the bottom of the pool unaided (weighting is important), inflate lifejacket(s), effectively administer EAR, signal distress and know how to utilise assistance in a useful manner. As a pool exercise it is also felt that all disabled trainees should be capable of towing the body for 25m (in deep water), albeit slowly, supporting the body at the pool side, engaging assistance, and utilising that assistance meaningfully. Furthermore, it is thought that acquainting the disabled trainees with possible techniques for, and difficulties of, removing a prone body from the water under ideal conditions is desirable, but success or failure at this part of the rescue procedure should not be used as part of an assessment. Finally the authors consider that as a disabled diver faced with lifting a fully kitted diver from depth must use a buoyancy assisted rescue procedure, attendance on a modified Open Water Rescue Course should be considered mandatory for disabled divers.

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University of Birmingham Diving Club, for the use of the pool and lecture theatre; to Mike Arnot, Diane Salomonson, and Derek Webb the other instructors on the course; to Dr S King and Dr P Wilshaw for medical and physiological advice and facilities; to Burntwood, BSAC Branch No. 539, Leamington & Warwick, BSAC Branch No. 217, United Birmingham Hospitals, BSAC Special Branch No. 675 for support during the course and follow-up training.

Flemming and Melamed (1) considered that the medical and physiological requirements for disabled candidates were:

1. Medical requirements were the same as demanded for any person who is to join a diving course. (A full medical examination, according to the standard BSAC medical test sheet, was conducted on each candidate).

2. The respiratory system should be completely normal and all the respiratory muscles under control. For paraplegics the spinal lesion should not be above T5 and preferably not above T8.

3. The candidate's skin should be without injury or pressure sores.

4. There should be no urinary tract infection and full control of urine and bowel movements, with or without artificial aids.

5. For paraplegics the disability should not have been caused by a spinal bend.

6. Paraplegic candidates with partial spinal lesions should be made aware that diving may make possibly the lesion complete although there is no record of this actually happening.

7. The disabled person should be participating regularly in intensive swimming.

8. The disabled person should have a stable personality with a full knowledge of his abilities and disabilities, be self-disciplined and able to accept orders without resentment.

The course described took place over the period January to April 1980; in August 1980 the position of the various candidates was as follows:.

TP has joined a BSAC branch. He passed A and B tests. Some delays in training occurred due to holiday arrangements. He is newsletter editor for the branch.

PO has joined a BSAC branch. He has passed A and B tests and was about to take C test.

SB has joined a BSAC branch. He has passed A, B and C tests, and was currently undergoing pool aqualung training.

REFERENCES

(1) Flemming NC & Melamed Y. Report of a Scuba Diving Training Course for Paraplegics and Double Leg Amputees with an Assessment of Physiological and Rehabilitation Factors. Proc. BSAC Diving Officers Conference. 1974. Reproduced Newsletter South Pacific Underwater Medicine Society (SPUMS) Jan-March 1977.

(2) Flemming NC. "Guidance for Branch Diving Officers on the Possibility of Diving Training for Disabled People". Proc. BSAC Diving Officers Conference. 1974.

(3) Water Sports for the Disabled. Handbook published by the RYA Seamanship Foundation. Available from the Sports Council, 70 Brompton Road, London, SW3 1EX.

A copy of the full text will be available to any member of SPUMS who sends $3 (to cover photostat and postage costs) to SPUMS, 80 Wellington Parade, East Melbourne, 3002.

A PLAICE IN THE SUN

There's a new fish restaurant in the Armadale suburb of Melbourne called Fish's. Robin Brampton, my old lunch mate, went there and liked it. He always liked a rather fishy story they tell, and included it.

"There was once a brilliant sturgeon on the staff of the community-health fishility. He was in fact one of its flounders. Wiser than Salmon, a fin fellow who would never shrimp from his responsibilities, he was successful and happy, he always whistled a happy tuna.

"One day, one of his patients, a mere whipper snapper, told the sturgeon that his medical theories were full of abalone and started trouting him around telling everybody that the sturgeon's treatments had made him more eel than he had been, and then actually conched him with a malpractice suit.

"Well, the sturgeon was in a real pickerel. The board demanded his oyster, and chased him off the staff. But the case smelt to high heaven, so the judge denied the plaintiff's clam. The board tried to hire the sturgeon back, but by then he had hit the bottlenose pretty hard, and the end of our shad tail is that the sturgeon wound up in squid roe.

"Buoy, isn't that a fine kettle of you know what?"

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PUBLICATIONS OF INTEREST

DIVING AND SUBAQUATIC MEDICINE (2nd Edition)
Edmonds, Lowry and Pennefather.

This book has been virtually rewritten and is more up-to-the-minute on the subject of diving related problems than is usually thought possible for books dealing with actively growing areas of knowledge. The 1st Edition was a good book, this is excellent. The layout follows the pattern of the 1st Edition, with bold accentuation of vital basic information. There is a generous sprinkling of brief case notes which illustrate the practical import of the information provided and add to the reader's awareness of the clinical experience which backs up the statements in the next. The presentation has the authority of earned knowledge without didactic overtones, there being an apparent acceptance of possible incompleteness of our present understanding of some diving problems. There are tables, figures and photos, as one would expect, but also several colour prints. These are no mere indulgence, for the conditions they show would be poorly demonstrated by black and white reproductions. For those who like to find a touch of the unusual while browsing through a book, there are tales of a couple of unusual suicides, a visit from a "Baroness Von Munchausen" type of patient and a couple of speared divers (thankfully not in glorious colour!). It deserves to be THE book for serious divers and doctors interested in Diving Medicine and is likely to remain such for a long time. It is thoroughly recommended for both lay and medical, professional and amateur divers. It is both readable and informative. Buy it now before printing costs increase!

Diving and Subaquatic Medicine is available from: Biomedical Medicine Services Pty Ltd., 25 Battle Boulevarde, Seaforth, New South Wales, Australia, 2092. Enclose cheque or money order for just $28.00, add postage Aust. $4.50 for surface mail or Aust. $6.50 for SAL (air).

NOAA DIVING MANUAL (2nd Edition)
US Department of Commerce - National Oceanic and Atmospheric Administration.

The NOAA manual deserves a place in any library of diving books and it can be expected to replace the USN and RN manuals as a practical work reference book for non-naval divers. It is comprehensive, including both theory and practice, first aid and definitive management. The information is well presented and critical points are signified by bold type. The tables and illustrations are good and coloured representation of therapeutic tables helpful though it would be an improvement if the air and oxygen phases retained their colour code of printing for all tables rather than being table specific, an opening for Murphy's Law to operate sometime. It is a useful publication.

US UNDERWATER DIVING FATALITY STATISTICS 1970-78 John McAniff NUADC

This University of Rhode Island Report reads more easily than do the usual reports and contains some information deserving wide currency. Of particular interest to this reviewer is the information that the US scheme had staff and is funded, which contrasts sharply with the UK and Australian situations. There is a comment on the range of medical information available, which ranges from world class to that of some political appointee who notes that the victim is indeed dead! There is nothing to indicate that the depth of the incident is being ascertained, the tables provided merely giving the depth of body recovery/incident depth without differentiating the two. The statement that about 10% of deaths occur during training needs heavy type apparently, before the US Diving Organisations take heed: training for out-of-air and emergency situations continues to be the leading factor for such deaths. Readers may recollect that this fact has been reported in our pages previously, without producing any noticeable reaction, it must be admitted. There appears to be a higher incidence of equipment failure and air embolism than in Australian cases, though the great difference in numbers at risk makes direct comparisons unwise. This report, like its predecessors, should be read and discussed by those with an interest in the problems of improving diving safety.

PRELIMINARY DIVER FATALITY DATA ON THE NORWEGIAN SHELF.
Norwegian Underwater Institute Report 3-80

This short resume of fatality information has been prepared by the Norwegian Underwater Institute. Like the reports made by Commander Warner, UK Department of Energy, there are noteworthy omissions. In a world where the youthful peccadillos of political opinions of multitudes of people are believed to be recorded 'in case', it is a truly remarkable fact that the deaths of divers can occur to the knowledge of many and yet the facts be unascertainable by authorised persons. There are cases noted in this NYJI report where the records apparently do not adequately define the place of death, or the depth. This indicates the unsatisfactory nature of recent schemes to investigate and record even fatal incidents. The fatalities which are recorded include chamber fires and explosions and unspecified medical disabilities: it is not satisfactory nowadays, if it ever was, to say baldly "cardiomyopathy", "medically unfit", or "polluted air, malaria crisis 2 days previously". Such thumbnail reporting leaves little to guide those who seek to avoid the repetition of such events, we need to know whether they were preventable. Such reports as this are of great value as "trailers" to increase receptivity to the following fuller reports. It is hoped such reports will be repeated.

SPUMS JOURNAL
This interesting and informative quarterly publication is available to members of the South Pacific Underwater Medicine Society. For subscription details see page 5.