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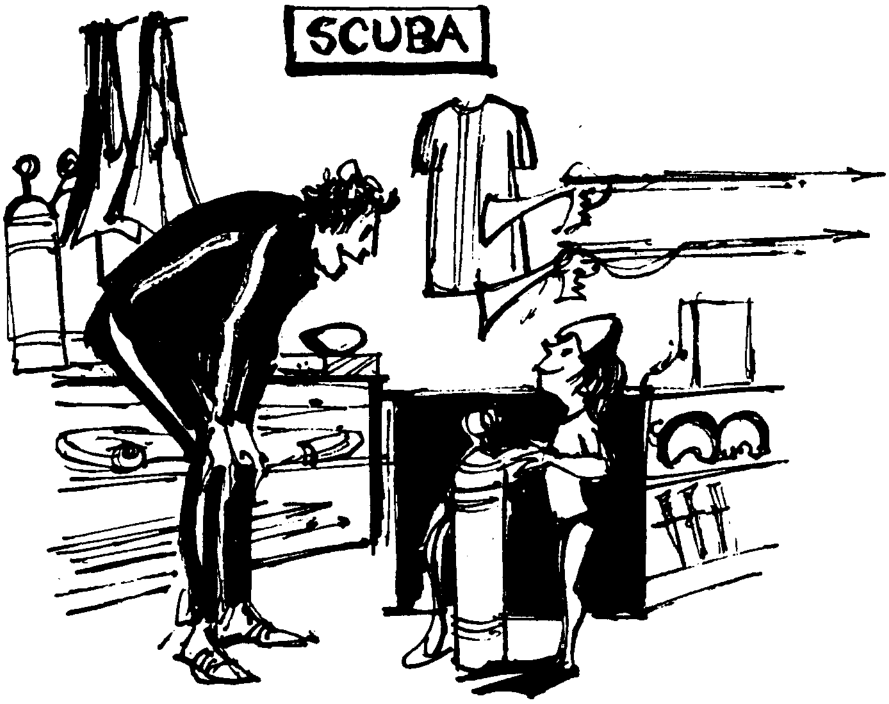

NON, TU N'EST PAS TROP JEUNE.
CA N'EST PAS POSSIBLE.

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EDITORIAL

Assessment of Fitness to Dive can be a difficult decision for both doctors and diving instructors though the factors given critical weighting in making the decision will be different in most instances. In this issue both groups are given informative articles which may assist them evaluate against a wider data background. Dr Harpur's paper is in some measure a bridge between the two groups and indicates the value of an informed and involved doctor in the assessment of diving incidents: his opinions on Emergency Ascent deserve close study and implementation. Naturally his work would be less well documented if he did not have the active and intelligent assistance of the diving community at Tobermory, Ontario, Canada. There should never be any doubt about the need for, and the value of, interaction and co-operation between the medical and the lay diving communities. The "Stickybeak" project in Australia is greatly in the debt also of the State Attorney General's/Justice/Law Department of every State. No one group can "go it alone".

There is much immediate comfort to obtained from the rigid, blind by-the-rules approach to decisions on Fitness, but people, thank God, are individual and few are everlastingly perfect. Problems arise in deciding in each case the degree of variation from the ideal one can allow. It is probable that much more information will have to be acquired before the true significance of childhood wheeze, a past heart attack, controlled diabetes or a post-trauma paraplegia can be assessed in a meaningful manner. There are growing attempts to collect such information; the UMS is starting a scheme, the University of Rhode Island has one, and the Stickybeak and RAN files exist in Australia. All readers are asked to accept the value of reports and to support these confidential data collection schemes in their efforts to improve advice to future divers (as well as present ones!).

One matter only lightly touched upon is the question of lower age limits for scuba diving. A recent course in New South Wales for school children during their holidays, for which no medical check was required and which gave them confidence to use scuba but not full instruction and testing, indicates the need to consider this matter before some tragedy occurs and press hysteria sweeps over the media about diving dangers. The interesting paper by Henri Pouliquen, which applies to the special conditions of Tahiti Lagoon, shows that infant divers may become a reality in areas with warm water. The prospect is somewhat alarming, but must be faced and discussed.

As usual the Annual Scientific conference has produced interesting papers. Dr Bruce Bassett's paper discussing the decompression sickness rates of the United States Navy decompression tables and his revised no-decompression limits for sport divers brings to light information that is not generally available in Australia. A 6% incidence of bends on dives made to the no-decompression limits in a chamber should give readers food for thought. His "belt and suspenders" approach has much to recommend it.

All readers are wished a safe, interesting and enjoyable Christmas and coming year. They are assured that the Editor longs to have their contributions but not their obituaries. Dive safely and encourage others to do likewise.

NOTES TO CORRESPONDENTS AND AUTHORS

Please type all correspondence, in double spacing and only on one side of the paper, and be certain to give your name and address even though they may not be for publication.

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

REPRINTING OF ARTICLES

L 'ENFANT ET LA PLONGEE

Henri Pouliquen

The matter of scuba diving by children is little known, until recently it having been something parents have had to decide each for their own children, empirically. The writer, who is Chairman of the Coral Club Sub Tahiti and Vice-President of the French Polynesian Committee of FFESSM, followed this method when teaching his 12 year old son and another child. On the basis of this experience a diving school for children was established in 1979 and this has very quickly expanded. There have now been more than 7,000 scuba dives by children and valuable experience has been obtained, and is here shared.

The idea to enable children to scuba dive came in 1975 when I saw the Tahiti Lagoon, square miles of water, depths of 2 to 4 metres, the water always warm, with marvellous corals and a constantly changing scene of multi-coloured fish. The first problems encountered were material ones as I needed small air tanks and small mouth-pieces for the regulators. I chose aluminium tanks from a French manufacturer. These were usually buoyant so it was necessary to "weight" the children. Small diving masks were also necessary and these were obtained from the USA. Once the equipment was obtained the school started operating every day, even twice daily.

After six months the school had more than 70 graduates from 6 to 13 years old. As months went by, parents brought me younger and younger children. Now we have 4 and 5 year olds diving easily, admired by adult divers. For the child under 7 years old it is a game: the explanations before the first dive must be short, with appropriate and simple words. It is not necessary to speak of the possible problems as they do not dive in more than 1.5m deep water. It is important to choose a very clear water with a maximum of small fishes. From the very first dive the child has to be interested by the underwater fauna. During the whole first dive the child has to be supported by the tank while being free to move. Do not discourage the children by giving them heavy tanks, so put them on when the children are in the water. My boats are provided with short ropes from the sides and the tanks are hung in the water from the boats. The children cling to the ropes while the instructors dress them with the equipment, in the water. The little divers never experience the full weight of the tanks.

After 3 or 4 dives, all children over 7 years old are able to take off the mask and put it on again, and remove and replace the mouthpiece. This very soon becomes a game and they enjoy doing it. As far as the children between 4 and 7 years old are concerned, it is necessary to proceed more slowly, to choose well fitting masks so that no water can enter. The "very little ones" look at the older children and with a little bit of patience we achieve the same result.

It is very remarkable to observe the self-confidence that the young divers acquire. I have seen shy children, who after some dives, have changed their personality. Parents are amazed by the metamorphosis of their children. Sometimes improvements are noticeable at school, the young divers working better.

The children's improvement with breathholding is spectacular. They quickly learn how to "equalise" their ears (Valsalva) and then astonish their parents by their diving ability.

TABLE 1

Criteria adopted by L'Ecole de Plongee pour Enfants de Lagon de Tahiti

AGE OF CHILD	MAXIMUM DEPTH	DURATION AT MAX. DEPTH (MINUTES)	DECOMPRESSION STOPS ON MAX. DEPTHS AT 3m	COMMENTS
2 1/2 to 4 years	1m		--	Children supported throughout the dive.
4 to 4 years	3m	20 to 25	--	As a rule the dive is ended when children show "goose flesh".
6 to 8 years	4m	5	20 to 25 min	
8 to 9 years	7m	7	20 to 25 min	It is important to know that in Tahiti the water is often over 26°C.
10 to 11 years	12m	12	20 to 25 min	
12 to 13 years	18m	15	20 to 25 min	Often children wear a diving jacket so that dives can be lengthened on depths of less than 3m.
14 to 15 years	26m	20	20 to 25 min	

For each child a medical certificate, indicating absence of contraindications for diving, is required.

Statistics, after more than 7,000 children dives over a period of 36 months, are as follows: the physical development of children who have dived frequently is often spectacular. In no case has development been disturbed. There have been no incidents during the dives. This diving school, open every day throughout the year in a natural environment, is conducted at all times in strict accordance with the criteria listed (Table 1).

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SPUMS SCIENTIFIC MEETING 1982

PHYSICAL FITNESS FOR DIVING

Greg Leslie

I have been asked to give a paper on physical fitness for diving. I feel this problem is best approached with first a discussion on physical fitness, on what it means and what effects training can produce. Following this, I feel that there should be a general discussion about the criteria for fitness for diving.

Physical fitness can be defined as the physiological adaptation to exercise demands. There are three elements involved in physical fitness:

1) strength

2) endurance

3) flexibility

With training these are developed gradually, according to the stress applied. Continued exercise increases the capacity for further exercise, however with disuse these elements diminish.

STRENGTH

Strength is the ability to exert muscular force. To understand this, we must first consider the elements present in muscle contraction. As you know, any muscle consists of a number of fibres and a motor unit consists of a motor nerve fibre and all the muscle fibres it innervates. The muscle fibre basically consists of sarcomeres. The sarcomere consists of molecules of actin which slide across myosin filaments. Muscle contraction comes about due to the sliding of actin molecules across myosin fibrils. This requires energy from the phosphagens ATP and phosphocreatine. The reaction is triggered off by the release of ACh at the nerve muscle end plate. The only action the muscle has is to contract. It cannot lengthen actively its resting length. This is obviously an energy consuming process and the energy for this is supplied by the splitting of the phosphogens ATP and creatine-phosphate. The strength of a person's muscles depends somewhat on his genetic make-up. However, physical training can modify this considerably. Changes in muscles brought about by physical training include an increase in the cross sectional size of the muscle and it does appear that the strength of the muscle is proportional to its cross sectional area.

Secondly, there is increased capillary blood supply to a muscle following physical training.

Thirdly, and perhaps very importantly, is the neurological adaptation which occurs with continued training. This is most important in sports involving skillful use of muscles, such as tennis.

The biochemical changes which occur during training, have been studied and will be discussed later in this paper.

ENDURANCE

Endurance may be defined as the ability to sustain intense activity for a period of time, to postpone fatigue and to recover rapidly. Endurance may be seen locally, in a single group of muscles, or generally where many muscle groups are involved. The latter is referred to as cardiorespiratory or aerobic endurance.

There are three sources of phosphagens. These are the suppliers of energy for contraction of muscles. Both muscle strength and endurance depend on a continued supply of these phosphagens. Each of the three sources may be predominant in different activities. The sources are:

1) The muscle stores of ATP and phosphocreatine. These have been measured and the total capacity appears to be 0.6 moles. The power developed by these muscle stores is a maximum of 3.6 moles/min.

2) Anaerobic Glycolysis.
The capacity of this system without super-added oxygen is about 1.2 moles in total. The maximum power developed is 1.6 moles/min.

3) Aerobic Metabolism
Here the capacity is infinity, but the maximum power developed is in the order of 1 mole/min.

The total store of phosphagens is small. For example - a 100 metre sprint at maximum pace requires about 0.43 moles of ATP, ie. over half the muscle store. However, resynthesis of the phosphagens occurs both from anaerobic and aerobic sources.

Anaerobic glycolysis is a method of producing ATP without the presence of oxygen. The biochemical reactions consist of the breaking down of glycogen, first to glucose then to G6P, to F16 DP, eventually to Triose Phosphates. In the absence of oxygen these are metabolised to lactate. One mole of glucose produces 2 moles of ATP in this way. (If oxygen is present the lactate is converted to pyruvate or the reactions may be reversed to reform glycogen in the liver). This reaction produces ATP available for muscle contraction in the absence of oxygen. However the total supply of muscle glycogen is small and sufficient for only 1.2 moles of ATP, ie. about 3 x 100 metre sprints. This system is used predominantly for short, sharp bursts of energy. For an example, in a 1500 metre running race, anaerobic glycolysis and muscle stores would be used at the beginning of a race, during which time an oxygen debt is created. The middle portion of the race would proceed under aerobic metabolism and the muscle stores and anaerobic glycolysis would be used for the increased power needed at the finish of the race. However, in the absence of oxygen, little endurance would be possible. At the end of the race, muscle glycogen is resynthesised, while the oxygen debt is repaid.

Various training regimes can be aimed at increasing total muscle content of ATP and phosphocreatine and improving anaerobic glycolysis. However, the greatest area of potential improvement with exercise training is the improvement of aerobic supply of ATP.

Aerobic production of ATP comes via the Krebs cycle. In this, pyruvate is fed into the cycle of chemical reactions mediated by enzymes with the production of ATP. This is by far the most productive method of formation of ATP and requires the use of oxygen. The source of pyruvate is either from glucose, or fatty acids or occasionally amino acids. The limiting factor to energy production here is the supply of oxygen to the exercising muscles. With aerobic metabolism the total yield of ATP is 38 moles for every mole of glucose metabolized (12 moles of ATP per mole of acetyl consumed). Thus our problem is to convey oxygen from the surrounding air to the mitochondria in the exercising muscles. This depends on a number of factors:

The first is respiration, the transfer of oxygen into the lungs and its transfer across the alveolar membrane into the blood. From thence it must be transferred into the muscles and this depends on the heart and the peripheral blood vessels. Oxygen is carried in the blood chemically combined to haemoglobin and the haemoglobin concentration and blood volume are important here. When the blood reaches the muscles the ability of the muscles to extract oxygen from the blood is important, creating the arteriovenous oxygen difference. Finally the intracellular enzymes at the muscle level are important in oxygen usage.

The maximum amount of oxygen that a person is capable of consuming per kilogram per minute is a guide of his aerobic fitness. At rest oxygen consumption is about 225 ml per minute. With maximal exercise oxygen consumption rises to about 3,500 ml per minute. Physical training can increase the maximal oxygen consumption and it does so in the following ways:

<u>The Lungs</u>

There is evidence of increased vital capacity following physical training, increased minute volume, and there appears to be an improvement in lung diffusion capacity.

<u>The Heart</u>

There is an increase in the heart volume, an increase in the stroke volume and in some cases an increase in attainable heart rate. Maximum cardiac output increases.

<u>The Blood</u>

Physical training causes an increase in the blood volume, an increase in the total haemoglobin and in the haemoglobin concentration.

Thus we see that training improves O_2 delivery to the muscles

<u>The Muscles</u>

There is also a change in the muscles themselves. There is an increase in the muscle mass and a decrease in the amount of fat. Various changes in the muscles have been found using muscle biopsy techniques. There is an increase of skeletal muscle myoglobin, an increased capacity of the muscles to oxidise glycogen to form carbon-dioxide, water and ATP. This seems to be due to an increase in the number, size and surface area of the mitochondria in the skeletal muscles. For example, it was noted that there was 120% increase in the mitochondria of the vastus lateralis muscle after 28 weeks of endurance training. Also, there is an increase in the activity and concentration of enzymes involved in the Krebs cycle and electron transport system. These increased by a factor of two. Training also increases the ability of skeletal muscle to oxidise fatty acids to carbon dioxide, water and ATP. A two-fold increase has been noted experimentally. A trained person uses more fat and less glycogen for a given work load than an untrained person. This results in less depletion of muscle glycogen and less production of lactic acid, which is responsible for many of the features of fatigue.

Also, following training muscle glycogen and triglycerides stores increase by a factor of two. It is also noted that ATP and phosphocreatine stores in muscle increase by a factor of 20 to 40%. There is increased oxygen extraction from the blood by the muscles in the trained individual. This increases the arterio-venous oxygen difference thus supplying more oxygen to the muscles.

By physical training a fit person can increase both the strength and endurance in his muscles. This can be measured objectively. In the laboratory it is possible to measure the maximum oxygen consumption of a person which is a measure of his aerobic capacity. However, the equipment is cumbersome and not readily applicable to day to day testing. Cooper and his co-workers have made studies linking laboratory oxygen consumption studies to performances in the field with running, swimming, cycling and other activities. He has related maximum consumption in the laboratory to a person's ability to run or swim or cycle a certain distance in a certain time. He has constructed several tables enabling one to assess fairly accurately a person's aerobic capacity by running or cycling or swimming a given distance in a certain time. His most popular test is the 12 minute test which can be applied for either running or swimming. The person, after a warm-up, runs or swims as fast as he can for 12 minutes. The distance covered is measured and by consultation with the charts his aerobic capacity can be assessed.

There are six categories of fitness: Very poor, poor, fair, good, excellent and superior. These are classified in the age groups of 13 to 20, 20 to 30, 30 to 40, 40 to 50, 50 to 60 and above 60. For example, in the age group 40 to 49, the poor group has an oxygen consumption of 30 - 33 ml/

kg/min. This sort of person was able to cover only 1.14 miles in 12 minutes. The superior group had a consumption of over 48 ml/kg/min and was able to cover 1.66 miles in 12 minutes.

Similar tables exist for swimming. Thus it is relatively easy to design a simple test to assess the aerobic fitness of a person. A good case can be made for a certain minimum fitness level for diving.

The present levels necessary for certification seem somewhat inadequate. Reasons for insisting on a certain minimal level of fitness are fairly obvious. It improves the diver's safety and also enjoyment.

Incidents can and do occur while diving, requiring a reasonable degree of fitness to overcome them satisfactorily. This is certainly most important in the inexperienced diver and this is the person who will usually be undergoing testing for certification. A more experienced diver can often weather the storm with less expenditure of energy. Obvious examples are currents, loss of way, surfacing a fair distance from shore or boat or encounters with unfriendly ocean inhabitants. Or helping a stranded buddy, etc.

A fit person can enjoy a better dive and is certainly more psychologically prepared for any misadventure which may occur.

I would not be so bold as to suggest which level of fitness one should consider for safe diving certification but I feel that with discussion from the audience that some basic ideas may be formulated.

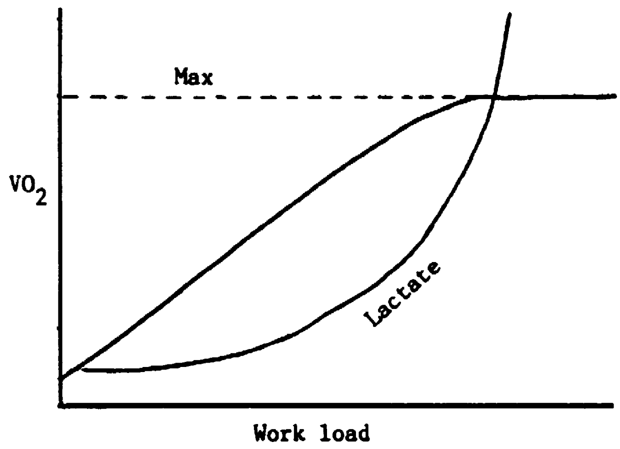
BASIC EXERCISE PHYSIOLOGY

Fred Bove

The state of exercise can best be defined by the whole body oxygen consumption (VO_2). Normal resting VO_2 is about 3.5 ml O_2/kg/min, and during exercise it can rise to 76 ml O_2/kg/min in well trained athletes. If a person is tested with a steadily increasing work load, one finds that VO_2 rises lineally with work load to a maximum (VO_2 max). At VO_2 max, although work load may be increased, no further increment in VO_2 occurs, so anaerobic metabolism in the skeletal muscles becomes dominant, and fatigue develops within minutes.

Figure one demonstrates these relationships. As a person approaches VO_2 maximum, work load becomes greater, dyspnoea is present and a state of generalized discomfort develops. Because of rapid lactate production at or near VO_2 maximum, a metabolic acidosis also develops, and causes further hyperventilation as well as muscle fatigue due to a marked lowering of the local pH in the muscles. Normally, an individual can exercise comfortably up to 50% of VO_2 maximum, and no lactate buildup in blood or

FIGURE 1



muscle will occur. Beyond 50% of maximum, blood lactate will rise to a new steady state, and as VO_2 maximum is approached, the lactate rise is continuous.

If one wished to measure a diver's capacity for exercise, measuring VO2 maximum would provide the most accurate assessment of physical capacity. However, since VO_2 maximum is somewhat difficult to measure, various methods for assessing its value indirectly have been devised. A good alternative to direct measurement is to measure heart rate in a standard protocol. Since for most people, VO_2 and work load are tightly related, VO_2 can be estimated for a standard treadmill work load, and attainment of maximum VO_2 can be assessed by heart rate criteria. For a sport diver to function well in diving, which may include some occasional heavy exercise needed for emergencies, a capability of working at ten times the resting VO2 should be possible. If we want the diver to use ten times basal oxygen for some time, then his maximum should be about fourteen times basal. We refer to these multiples of basal VO_2 as mets. Our sport diver should be able to sustain 10 mets for a brief (four to five minute periods without becoming incapacitated by acute fatigue). His or her maximum should be about fourteen mets. Note that based on body weight, the female sport diver should end up with about the same relative capacity. Male divers will have greater VO_2 values because of greater body weight. If you are concerned about a diver's physical capacity, a treadmill test should demonstrate that the diver can sustain 10 mets of work for 4-5 minutes comfortably, and the heart rate should be about 70% of maximal. If a diver cannot perform at this level, a conditioning programme should be suggested.

It is a simple matter to understand exercise capacity from the above principle. Next, we must discuss variations in VO_2 maximum since work capacity is determined by this value. VO_2 maximum varies with age, sex and state of health. It peaks between 25 and 30, then declines thereafter at a rate dependant on the amount of physical activity. Males generally have higher VO_2 maximum, but much of the difference is due to body size and proportion of adipose tissue. With the proliferation of excellent women athletes, the differences in VO_2 maximum, when normalized for body weight and lean muscle mass, are not as disparate as once thought. Illness which compromises lung, blood or heart performance limits VO_2 maximum also. Thus a diver with chronic lung or heart disease, anaemia, or abnormal haemoglobin will have a reduced exercise capacity. Finally, the state of physical activity is important. Inactivity reduces VO2 maximum (poor conditioning). The training programmes of athletes are based on this concept.

Many of the problems in divers which require judgement on ability to dive, involve questions on physical capacity. The above guidelines can be used for this purpose, while also taking into account the skills needed to be a successful diver.

Beyond physical capacity lies the problems of sudden incapacitation by illness, inability to learn the necessary diving skills, and the psychological aspects of diver selection. All these aspects must be considered when evaluating a person for diving.

Dr Bove kindly provided this precis of his lecture. Unfortunately, it is but a pale shadow of the brilliance and erudition of his oral presentation.

Question:

In working out maximum oxygen uptake is it better to measure it using a bicycle ergometer or a treadmill?

Dr Fred Bove

Both instruments have been used enough so that we can get a pretty good idea of maximum oxygen uptake from either. The individual who is being studied can affect the treadmill more than the bicycle. If you get a very large or obese person on a treadmill then you have to allow for their weight, because there is some energy consumed in lifting weight as you step on a treadmill.

The advantage of the bicycle is that the subject stays a little more stationary. If you want to do blood studies, it is easier to put an intravenous line in the subject's arm on a bicycle and sample from it, than on a treadmill.

You can get good data from either method. The treadmill is used a lot in cardiovascular clinical studies, where you are just measuring heart rate.

Question:

I was just wondering about the blood pressure reducing effects of exercise. Blood pressure goes down with weight reduction, would that explain the effect of exercise?

Dr Fred Bove

The blood pressure lowering effect is not due to weight loss. If the person loses weight during training you may see more. But you can get the blood pressure lowering factor by exercise without having significant reduction in weight.

Question: Dr Chris Lourey

Some years ago there were some telemetry studies done with athletes exercising on land and in water. On land they showed the two normal pressure responses, a rise in the systolic and a fall in the diastolic. But when they were exercised in water they showed an elevation of the diastolic. In sports divers with occult heart disease or hypertension or a high systolic, a rise in diastolic could be a cardiac stress. Would you like to comment?

Dr Fred Bove

I am not familiar with that study. I think you should tell an individual who wishes to get into a diving programme and who is grossly unfit for diving, requiring treatment for hypertension or weight reduction, or perhaps just is in poor physical condition, to forget about this year's diving course and to get in shape and come back for next year's diving course. I think if you can convince that person to get into condition, you will see an overall improvement in the cardiovascular response to exercise, including a lessened heart rate response, less dyspnoea with stress, and such like. My experience is that if you get a person fit, he can go diving better.

The premise that I would take is that if you get the individual into better shape, you will find that he will make a better diver, that he can handle the exercise load better. Fit people have a better overall cardiac response to diving as well as to exercise on land. I do not know the answer to your question as to whether they have an increased diastolic compared with on land. But generally you will find the diver improves with fitness and can handle diving better if you get him trained.

Question:

How do you train a sport diver to maximise his oxygen consumption?

Dr Fred Bove

I do not think that you need to try to make a sport diver into a world class athlete in order to make him dive well. The great majority of candidates for sport diving are average. That is, they are not well conditioned. If they have to do a long surface swim with equipment on against a current, it will be an overstress situation.

We should train the diver to be able to handle the average situation that he could come up against in sport diving. Not make him into a world class diver or champion swimmer or runner. So we do not have to try and train the sport diver to run twelve miles a day, or to swim three miles a day.

We would like to generate a moderate programme of exercise which can train that sport diver to be able to handle the stresses that he will experience in diving. We are aiming to make a person fit enough to dive. He does not have to become an expert athlete.

A study was done by NASA. They put trained and sedentary people to bed, which degraded their performance, then gave them all a training programme. The trained persons went back to their previous performance while the sedentary improved on theirs but not up to the level of the trained group. The trained persons had more or less achieved what they could achieve from training. So if you de-train them and then re-train them they will go back to where they were. The maximum oxygen consumption can not be improved ad infinitum in the fully trained person. In other words there is a limit to what you can gain from training. The trained individuals when de-trained and re-trained got back to what they could achieve before. The untrained or average individuals improved beyond their previous condition but not to the same level. This was interpreted as saying that the individuals who were in average condition were not able to improve to the point that the other individuals had reached. In other words there was an inherent difference or inborn difference between the different individuals. It is also possible that the sedentary individuals, if they had had a longer training programme, could have achieved more.

If you give everyone the same training programme, you are going to have individuals who come out with a much higher maximum oxygen consumption because they have got soma inbuilt advantage, which we do not clearly understand. There will be some people who train and end up with a higher maximum oxygen consumption and better aerobics than other persons who are given the same training programme.

What I am saying is that there are inherited differences among individuals, and if you give everyone the same training programme, you are going to have a spectrum of responses.

Question: Bob Halstead

I want to comment from the instructor's point of view. I find that the very fittest people on diving courses tend to be the worst divers at the end of the course. The reason is that they tend to have inappropriate behaviour in the water, deliberately swimming against the current and so on. This would appear to be a psychological attitude that they are fit and can do anything. Whereas the lees fit person behaves in a different fashion.

Dr Fred Bove

Fitness means different things. I see people who say that they are fit. A twenty-five year old who has been working at weight lifting is all solid muscle, and he says that he is fit. That person is really not fit for diving. He needs endurance rather than strong musculature. If somebody says they are fit, and they have arms the size of your thighs, that person is not really fit for diving, that person is trained the wrong way for diving. It is not going to help him at all, in fact it is going to give him trouble. The other extreme is the long distance runner who says "I can do anything because I run fifty miles a day". You are then going to run into the same problem. That person may only weigh 110 lbs and when you put the tank on his back he falls down and can not get up again. His arms are about the size of your little finger. They are the two extremes. I think that the two extremes are not fit for diving. What we are trying to do is to get the average person, who is not trained at all, not physically conditioned at all, to get into some degree of physical condition so that he can handle the normal exercise that is needed for diving. At the same time you have got to get his mind into the right shape too. Physical condition is one thing, train him for that, but also train him to not overestimate his capacities, because they are different. We should train both the body and the mind at the same time, as they are two different things.

TWO CASES OF NECROTISING FASCITIS

Peter McCartney

Mr TW was a 58 year old plant operator at a paper mill who had had no previous ill health other than five years of occasional arthritis.

History

Rigors and 'flu for eight days. Constipation for seven days. Jaundice and dark urine with pain and swelling in both buttocks for five days.
Three days previously admitted to New Norfolk Hospital as ? hepatitis and treated with IM penicillin 1.5 mega units BD.

Admission Findings

Septicaemic (38^5) dehydrated, jaundiced, tender hepatomegly, massive induration of both buttocks.

Investigations

WCC 33,000	)
Bilirubin	)
Urea and creatinine	) raised x 3
Al Phos 305	)

Ultra Sound = gall stones, ducts not dilated, therefore cholangitis unlikely to be cause of septicaemea.

Management

IV fluids, central venous pressure line catheterised, antibiotics - Gentamycin and metronidozole.

Day One

First Operation -
A wide excision and debridement of both ischiorectal fossae. Little pus and no true abscess.

Day Two

Much improved, afebrile. Deterioration of renal function, creatinine levels rising to seven times normal. Moderate acidosis.

Cultures showed heavy mixed bacteroides fragilis, anaerobic strep. clostridium species and E Coli.

Day Three

Continued to improve. Small darkened area 0.5 cm noted on the scrotum.

Day Four

Area of obvious gangrene now 6 cm diameter. General deterioration.

Second Operation -
Extensive necrotic oedematous stringy tissue excised. Considerable blood loss associated with very radical excision. Dopamine infusion needed to maintain BP 100/6O. WCC 83,000 - Not leukaemia.

Two hyperbaric (HBO) treatments given (BD for four or five days planned)

Third Operation -
Required to control bleeding by repacking wounds.

Day Five

Fourth Operation -
Further re-exploration and debridement.

Third hyperbaric treatment.

Day Six

Much improved. WCC 40,000. Creatinine now nine times normal but no longer climbing.

Fourth HBO treatment.

Fifth Operation -
In view of his improving prognosis a right transverse colostomy and minor debridement was carried out. Cardiorespiratory arrest occurred after this procedure. He was found to have a right upper lobe collapse.

The patient's condition precluded further HBO.

Colostomy bleeding, requiring transfusion, was probably secondary to minor diffuse intravascular coagulation. The diuretic phase of renal failure was starting.

Day Eight

Sixth Operation -
Minor debridement, but followed by heavy blood loss requiring transfusion

Day Ten

Haematemesis which was treated conservatively with twelve units of whole blood. Endoscopy was not helpful. He had had a total of 46 units at this time.

Day Twelve

Seventh Operation -
A rebleed forced this surgery. At gastroscopy multiple superficial ulcers mainly in the gastric fundus were seen. A truncal vagotomy and pyloroplasty was performed. He was ventilated post-op and commenced on total parenteral nutrition.

Day Nineteen

A rebleed which was managed conservatively with the transfusion of sixteen units fresh frozen plasma and platelets. Cimetidine was added to his treatment. A dramatic result followed bicarbonate infusion. The gastric pH rose to ten measured via a nasogastric tube.

Day Twenty-One

He developed a progressive metabolic acidosis related to his renal failure and TPN.

Day Thirty

He appeared terminal. TPN was stopped. pH was corrected with massive transfusion of bicarbonate.

Day Thirty-One

Started improving in spite of everything.

Day Fifty

The problems persisting at convalescence were;

(a) weight loss from 107 kg to 70 kg

(b) malnutrition

(c) poor appetite and vomiting

(d) apathy and withdrawal

(e) muscle weakness

Day Fifty-Two

By now there had been a remarkable healing of the perineum and scrotum. Thin split skin grafts were laid over the area. He was discharged to continue convalescence at New

Norfolk eleven weeks after his admission. His colostomy closed at a later date with completely satisfactory anal function.

Mr MT was a 58 year old gardener.

History

A fourteen day illness with abdominal pain, diarrhoea. For three days an E Coli urinary tract infection. He had been treated with erythromycin and tetracyclines.

Admission Findings

Septicaemic, distended tender abdomen, creptins over right iliac fossa. Scrotum and perineum oedematous and indurated.

Investigations

WCC 23,0OO
Normal Glucose and renal function
X-ray of the abdomen showed gas in the tissues of the right flank

Management

IV fluids, antibiotics

Day One

Operation

An extensive right ischiorectal lesion was found and widely excised. The abdomen was explored and showed necrotic muscle and fascia, from the perineum, over the abdomen to the lower right ribs. Relieving incisions only were performed.

Cultures from the wounds grew heavy mixed growth of E Coli. Bacteroides fragilis and anaerobic strep. Postoperatively he was continued on antibiotics, penicillin, Gentamycin and metronidazole. IV fluids and Cimetidine were given.

Day One to Four

Twice daily HBO treatments given to a total of six treatments.

Day Four

He was greatly improved being afebrile with a normal WCC. His treatment was continued.

Second Operation

Closure of the defect with Teflon mesh. Postoperatively HBO was resumed and a TPN commenced as well as oral feeding through a nasogastric tube.

Days Six to Ten

Seven further HBO treatments

Day Twenty-Eight

Split skin grafts applied to the teflon mesh which had become filled with granulation tissue. The perineal wound left to granulate with success.

Colostomy closed at a later date with completely satisfactory anal function.

CASE REPORTS

John McKee

I am a general surgeon in Bega on the far south coast of New South Wales and while the amateur divers do not bother me very often, quite a few times over the years I have been asked to give assistance in the treatment of abalone divers who have run into problems. There are forty abalone divers in my area and from time to time they get into real or imagined problems. This year I have dealt with two cases of possible decompression sickness.

The first was a 28 year old abalone diver. He had the usual story of severe pain in one shoulder and arm. He had been diving for seven years. He used decompression stops very rarely. He hardly ever used a depth gauge. He said that he spent the last half hour or so in shallower water than earlier in the day. That can mean anything.

On the day in question he had done three dives. The first to 90 feet for 45 minutes. He then came up and emptied his abalone shells into the boat. After a surface interval of five minutes he dived to 90 feet for 90 minutes. He then came up to the surface again and unloaded his bag. This time he extended his surface interval to 10 minutes before he went down to 60 feet for 30 minutes. When coming up, before he reached the surface, he experienced severe pain in his left arm and shoulder. When he arrived at the hospital I estimated that he had a limb bend of moderate severity. We gave him oxygen to breathe all night. At this stage I was contemplating whether or not to try to send him by helicopter to Sydney. His general condition was quite satisfactory. He had no other evidence of decompression sickness. By the next morning his pain was a lot better, so he was kept on oxygen for another 24 hours and the pain completely resolved. The X-rays of both shoulders showed no abnormality.

The second case was 10 years older and perhaps a little wiser. He had dived for quite a few years as an abalone diver. He also was brought to the hospital at night with suspected decompression sickness. He gave a history of repeated dives to no more than 70 feet that day. The first dive was to 70 feet for at least 90 minutes and the subsequent six to eight dives were at shallower depths but for similar lengths of time. When coming back to shore he felt discomfort in both legs, a feeling of numbness. By the time he reached hospital he had developed rigors and a high temperature. We kept him under observation while giving him oxygen. Overnight he completely recovered from his symptoms and walked out of hospital the following day.

Then I felt that the correct diagnosis was a virus infection with a high temperature and discomfort with paraesthesia in both limbs.

The third case is one which I think could be included with Fred Bove's discussion on diving fitness. He was a school teacher, a diver, a diving instructor, who died last year at the age of 30. When aged 22 he had a subarachnoid haemorrhage from a congenital berry aneurism involving the anterior communicating artery. He survived this episode. The aneurism was clipped off in Melbourne. Eventually he resumed diving. I think this particular case was brought up either at a SPUMS meeting or one of Carl Edmond's courses some years ago, when we discussed whether or not this fit young man should be allowed to dive again. Here was a young man who had actually had an angiogram which had revealed an aneurism which had ruptured and been clipped. The rest of us were still diving and none of us had had an angiogram. (Remember that the most common age for ruptured berry aneurism is in the forties). It was felt that as he was symptomless and well he should be allowed to return to diving. He passed very adequately a medical examination undertaken by a SPUMS member. Unfortunately some months later, which was exactly four years from when the aneurism was clipped, he had his first grand mal seizure. Prior to this, he had been completely symptomless. After the grand mal episode he was started on Dilantin 100 mg three times daily, and was free of fits. He continued to dive for a further twelve months, then he had a further episode of grand mal. So the serum Dilantin was measured and it was found to be 22 millimoles per litre, the normal range being between 40 and 80. His Dilantin was then increased to 180 mg daily.

Over the next twelve months, until about twelve months ago, he had three or four further fits. During this time he did dive intermittently, but he did not instruct. Until about twelve months ago it seemed as if the grand mal seizures were under control. Early last year, he started to have what was thought to be petit mal. The episodes came on without warning and he would partly lose awareness of his surroundings and was often unable to retain the thread of a conversation. The attacks usually concluded within seconds but often they would come on so quickly, that he himself was aware that he looked vague.

Late last year he was seen by the neurologist in Melbourne, who had been involved with his management from the time of the sub-arachnoid haemorrhage onwards, and he was given prominal in an increasing dose in addition to the Dilantin. Unfortunately within a few weeks of this he was brought to the hospital one afternoon, unconscious. He had been by himself in his dive shop. He was thought to have been eating his lunch as he was found unconscious, with food in his mouth. It was uncertain whether he had asphyxiated through food inhalation or through some other factor. He was immediately placed on a respirator. A lumbar puncture was done and blood-stained fluid obtained. He was then transferred the same day to Canberra for further management, as we felt the outlook was rather poor. He died the following day.

At post mortem he was found to have had a further subarachnoid haemorrhage. It was impossible to determine the site of the leakage. I have spoken to numerous neurosurgeons and I understand that the anterior communicating artery aneurism has the worst prognosis of all, because it is the most difficult to reach, and technically the most difficult to get adequate occlusion of the aneurism.

Initially it was felt that for some years he was doing well, that he was fit to dive on most base lines that we would draw. But as time went by, presumably through the effects of the original ischaemic episode he developed grand mal seizures. As we all know, a seizure of any sort in the water is very likely to lead to drowning. In this case fortunately the final episode was on land and no-one else was involved. It is an unusual case that I would draw to your attention, for all of us to remember in the future.

Dr Victor Brand: Chairman

How did you administer oxygen to the first two cases?

Dr John McKee

For giving oxygen at sea, or immediately they have landed, I have an adaptor that takes a regulator that fits an oxygen cylinder. Others have been given oxygen by mask by the ambulance man while coming to hospital, and the flow rate there could be almost anything. At hospital we have usually given them something between six and ten litres a minute.

Dr David Brownbill

A couple of comments about your case of subarachnoid haemorrhage. He was not likely to re-bleed from the clipped aneurism. The most likely thing is that he developed another haemorrhage from a different site. It is well recorded and I think it is the most likely cause of death.

I would like to remind you that following surgery he had a 10% chance, right from the start, of developing epilepsy. The fact that he did not have anything for four years, one quarter of the people do not have epilepsy for four years, did not alter his chances.

There is no such thing as a well controlled epileptic. They are always liable, under the right (or perhaps wrong) set of circumstances, to develop a further fit. In someone who has bad intracranial surgery, if one admits to a 10% risk of him having a fit, diving is a matter requiring consideration by all concerned. But once he has shown that he has a predilection to fitting by having had one, diving is absolutely contraindicated.

Dr Fred Bove

I do not think that you would expect to find any changes in the X-rays of the shoulders of a person with decompression sickness. We think that somehow there is a vascular involvement of the long bones, although that is not an explanation of the pain. A bone scan would be a much more useful piece of information because it would tell you whether there was any alteration of the blood flow in the region of the pain. The X-ray obviously would not change for many months. So if you are concerned you might do a bone scan to see whether there are ischaemic areas.

Dr John McKee

The X-rays were taken 300 miles from a centre with scan equipment, but more to reassure the diver than me and partly to help decide whether to spend about $100,000 transferring him to Sydney for treatment. Very frequently one gets these divers with various symptoms, and the transfer cost, by helicopter or by Hercules, is now pretty tremendous.

Dr Fred Bove

Just one more comment. When I was at Philadelphia, we treated a case of limb bends in a commercial diver working in the Atlantic Ocean who, by the time he got to the chamber had lost all his symptoms. We still treated him in the chamber. I would suggest that where there is a chamber available you should still treat the symptom free patient with perhaps a table 5. There is a remote chance that you are preventing long term changes in the bone.

HOW COMMON IS DYSBARIC OSTEONECROSIS?

John Knight

Every diver has heard of dysbaric osteonecrosis. Very few are aware that the risk of developing dysbaric osteonecrosis is low if one follows normal air diving procedures.

Surveys of naval divers in the UK (1) and the USA (2) have shown a very low incidence of dysbaric osteonecrosis. This contrasts with earlier surveys of compressed air workers. The major difference between the two groups was that compressed air workers spent a working shift under pressure while the divers had much shorter periods under water. Many of the naval divers with bone changes had been involved in experimental diving such as testing new decompression tables and deep diving.

JAPANESE EXPERIENCES

In 1976 there were two papers from Japan published in English. Ohta and Matsunage (3) reported a three year survey (1966-1968) of the men of a village (Ohura) on the shore of the Ariake Sea off Northern Kyushu where there were about 400 divers (active or retired). The men dived to collect the expensive shell fish Atruria Japonica from November to March (winter). Except during bad weather they dived in 10m to 30m, while there was light, with a lunch break of an hour. This gave two four-hour dives each day. During the rest of the year they collected other shell fish from 30m to 60m, worked on salvage jobs from 20m to 70m or more, and did construction jobs in 10m to 30m. To quote Ohta and Matsumaga they "had used no modern technique of decompression". This probably explains the fact that three to five men died each year from accidents or decompression sickness. Decompression sickness was very common, so common as to be considered unavoidable. Their treatment was baths and booze.

TABLE 1

CLASSIFICATION OF DYSBARIC OSTEONECROSIS

JUXTA-ARTICULAR LESIONS

A1	Dense areas with intact articular cortex
A2	Spherical segmental opacities
A3	Linear opacity
A4	Structural failures
a)	Translucent subcortical band
b)	Collapse of articular cortex
c)	Sequestration of cortex
A5	Secondary degenerative arthritis (osteo-arthritis)

Of the 301 divers who were X-rayed, 152 (50.51) had bone lesions. Of these, 44 men (29%) had juxta-articular lesions. Between them they had 54 juxta-articular lesions. The group had a high incidence of previous decompression sickness, but there was no significant relationship between the site of the bends pain and the lesions. The incidence of bone changes was higher in those who had been diving longer and in those who had gone deeper. The results of the first year's X-rays had been published in Japan in 1966.

The figures were quite horrifying. In the group with up to 4 years diving experience, 22% had bone changes, none of which were juxta-articular. The 5 to 9 year group had an incidence of 46%. The 10 to 14 year group had an incidence of 71%. After 15 years of diving the incidence was 74% and after 20 years it settled at 82%. The deepest depth figures were just as depressing. No lesions in those who had not exceeded 9m, but there were only 8 of them. The 10m to 19m group had a 20% incidence, luckily for them without juxta-articular lesions. Those who dived between 20m and 29m had a 46% incidence, while 30m to 39m was associated with an incidence of 53%. The 40m to 49m range had an incidence of 64%, while over 50m it was 74%.

The survey had some failings. Only 43 divers were X-rayed on all three possible occasions. Only 144 were X-rayed twice or more. So the figures are probably an underestimate of the incidence.

The same year Amako, Kawashima, Torisu and Hayashi (4) published a paper which carried the same survey on till 1972. Since the survey started the divers had obtained a small chamber which was used for deck decompression. They had also abandoned the lunch break. This report covered 450 divers X-rayed of whom 123 had been observed for more than seven years.

Of the 450 divers, 268 had bone lesions (59.5%). 81 had juxta-articular lesions (18% of the total). 30% of those with lesions had the potentially disabling juxta-articular lesions.

An interesting finding was that the divers developed bone islands between X-rays. This led the authors to add a third category (C. Bone Islands) to the usually accepted classification of dysbaric osteonecrosis.

The incidence of dysbaric osteonecrosis increased from 46% in the 16-19 year olds, to 49% for the next decade, to 70% for divers in their 30’s and to 75% in the forties group. Those over 50 only had a 60% incidence, presumably because of death and retirement. The associations between experience and depth and increased osteonecrosis were confirmed.

The most interesting findings were those about the 123 divers who were studied for seven years. In 1965, 36 had multiple lesions, 18 had solitary lesions, while 69 had no lesions. By 1972 there were 69 with multiple lesions and 27 with solitary lesions. Only 27 divers had no evidence of dysbaric osteonecrosis. During the six years of the survey, 79 divers had developed new lesions. 27 of them had new juxta-articular lesions, 25 had new head, neck and shaft lesions, while 13 had developed bone islands, which are not normally considered to be due to dysbaric osteonecrosis. To confuse matters, some of those who had lesions on the first survey did not develop new ones. In all, 44 divers came through the survey without developing lesions.

THE AUSTRALIAN SCENE

In 1976 Williams and Unsworth (5) reported on the X-rays of 110 divers, 31 from the RAN, 15 from the NSW Police, 8 marine biologists or scientific workers, 37 commercial divers and 19 sports divers. Three divers were said to have used other than compressed air. This suggests the use of helium, but helium is not specifically mentioned in the paper. Naval clearance divers use oxygen-nitrogen mixtures which differ in composition from compressed air. Abalone divers are commercial divers as they make their living from diving. But abalone divers are known to treat decompression tables rather casually, while employee divers are usually more careful. Abalone divers are not mentioned in the paper. Progression of any lesions discovered could not be followed as only 30% of the participants had two sets of X-rays taken.

84 divers (72%) had no bone changes, 8 (7%) had juxta-articular lesions. Again this is a high proportion (30%) of those with lesions. 18 (17%) had head, neck and shaft lesions. Presumably two divers had both sorts of lesions as their table gives 20 with B type lesions while simple mathematics gives 18.

They also found 18 other X-ray lesions involving joints. Such things as osteochondritis dissecans, myositis ossificans, deltoid bursitis, shoulder dislocation, arthritis after fracture, traumatic arthritis, tendon calcifications, capsular calcification and periosteal avulsion do not appear in other reports. This group appears to have had more than its fair share of serious trauma as 22 lesions were attributed to trauma among 110 men (20%).

When one considers the various groups of divers included in the survey, the RAN had 13 of 31 with lesions (42%), the NSW Police 5 out of 15 (33%), the commercial divers 6 out of 37 (16%), other full time divers 1 out of 8 (12.5%) [there were no head, neck and shaft lesions in this group] and the sports divers had 3 with lesions from 19 subjects (15.4%).

The incidence of juxta-articular lesions was RAN 1 in 31 (3.2%), Police 2 in 15 (13%), commercial divers 3 in 37 (8%), other fulltime divers 1 in 8 (12.5%) and sports divers 1 in 19 (5.2%).

The figures for the RAN divers are high because only those RAN divers who had suspicious X-rays were referred to Prince Henry Hospital. When the total RAN diver population is considered the incidence was much the same as in other navies. Harrison (1) found 18 definite lesions in 383 divers (4.7%) while a survey of 834 USN divers (2) produced 16 with lesions (1.7%).

This paper by William and Unsworth (5) was the first report of dysbaric osteonecrosis lesions in sports divers, and one of the three cases was a juxta-articular lesion

OPTIMISM IN THE 1970’s

In 1977 Dr John D Davidson of the MRC Radiological panel visited Melbourne. He gave a lecture on dysbaric osteonecrosis. He quoted, from MRC sources, the findings from five tunnelling contracts between 1955 and 1966.

There had been a decompression sickness rate of 1.3% Type I and 0.12% Type II, but the incidence of dysbaric osteonecrosis had been 19.2% of the 1,694 tunnel workers. 334 men had definite lesions while another 229 (13.31%) had suspected lesions. 7 of these lesions (3.5%) were re-classified as definite lesions during follow up.

The lesions were distributed as in Table 2. 40% were juxta-articular. This was a much higher percentage of potentially disabling lesions than in the Japanese fishermen. However, the Japanese had nearly three times the incidence of bone changes so were more at risk.

TABLE 2

DISTRIBUTION OF 820 DYSBARIC OSTEONECROSIS LESIONS IN 334 TUNNEL WORKERS

JUXTA-ARTICULAR	
Dense areas	21%
Increased calcification	9%
Dense lines	5%
Structural failure	5%
Osteoarthritis	5%
HEAD, NECK AND SHAFT	
Dense areas	20%
Increased calcification	40%

At that time the MRC had X-rays of 2,300 compressed air workers and of 2,516 divers. 383 tunnellers (17%) had bone changes, while only 60 divers (2.4%) were affected. Dividing the men into air divers and helium divers, on the basis of a maximum depth of more than 50m, the incidence was 0.4% in 804 air divers and 2.7% in 1,158 helium divers. Modern commercial diving seemed to have beaten the bogey.

THE NORTH SEA IN 1979

Last year David Elliott told us about the latest figures from the North Sea. In August 1981 The Lancet published a paper on the subject (6). It was a survey of 4,980 divers of whom 4,670 (93.8%) had no lesion. 106 had suspected lesions (2.1%) and 207 (4.21) had definite lesions. 700 men have been X-rayed 5 or more times and over 2,000 have had three or more sets of X-rays. Interestingly, 82 men were excluded from the survey because of the poor quality of the X-rays. Included in the normal group were those whose "only radiological abnormality was a bone island, a cyst or some other unimportant change".

62 men (1.2%) had a definite juxta-articular lesion. 142 men (2.8%) had a definite head, neck or shaft lesion. Again, those with juxta-articular lesions formed a large proportion (43%) of those with lesions.

The anatomical distribution is shown in Figure 1. As some men had multiple lesions, there were 72 juxta-articular and 274 head, neck and shaft lesions to record. The numbers in brackets are those with damaged joints.

When discussing the factors associated with dysbaric osteonecrosis, the authors, by controlling the experience factor, were able to show that age, per se, is not associated with the lesions. However, diving experience (and therefore in general, age) is. Prevalence rose from 0.7% for those

TABLE 3

DYSBARIC OSTEONECROSIS IN 4980 COMMERCIAL DIVERS

LESION	DIVERS	%
None	4670	93.8
Suspected Head, Neck, Shaft	71	1.4
Definite Head, Neck, Shaft	142	2.8
Suspected Juxta-Articular	35	0.7
Definite Juxta-Articular		
Intact	53	1.1
With Damage to Joint	6	0.2
With Secondary Osteoarthritis	2	0.2
Surgically treated	1	0.2

with less than 4 years experience, to 2.2% between 4 and 8 years, 5.5% between 8 and 12 years and to 10.7% after 12 years of diving.

Fatter and heavier men were statistically more likely to develop lesions. So were men who had had decompression sickness. Of those who claimed never to have been bent (60%), 1.7% had developed lesions. But 10.7% of those who admitted having decompression sickness developed lesions. 8 of the 9 men who had damaged joints said that they had been bent.

FIGURE 1
SITES OF DYSBARIC OSTEONECROSIS IN 207 COMMERCIAL DIVERS

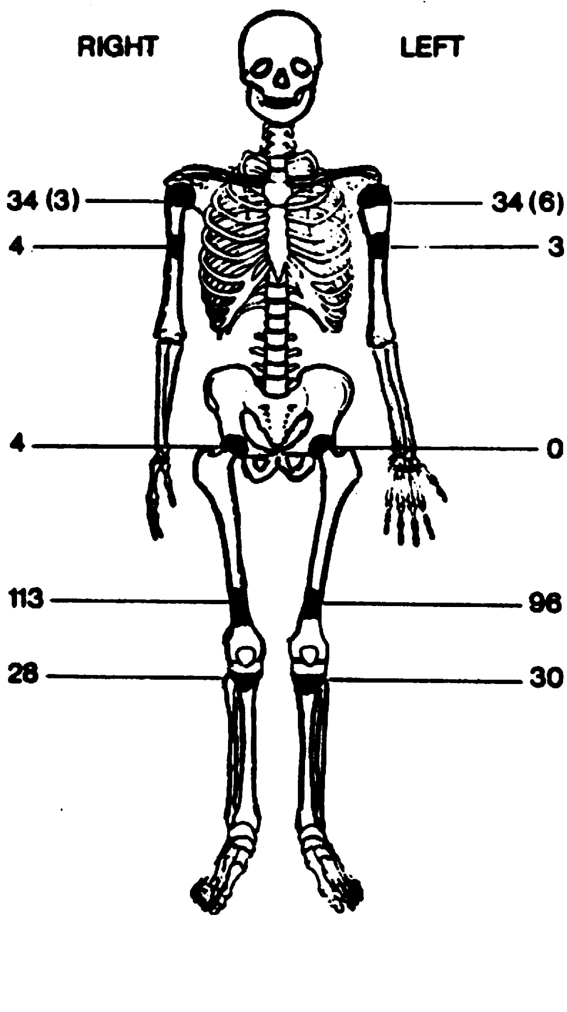


TABLE 4

DIVING EXPERIENCE AND DYSBARIC OSTEONECROSIS

YEARS DIVING	NORMAL	LESIONS	PREVALENCE
Less than 4	1262	9	0.7%
4 to 8	1300	29	2.2%
8 to 12	885	52	5.5%
12 or more	869	104	10.7%

TABLE 5

DECOMPRESSION SICKNESS AND DYSBARIC OSTEONECROSIS

DECOMPRESSION SICKNESS	DYSBARIC OSTEONECROSIS		
	NO	YES	TOTAL
NO	2978	52	3030
YES	1228	147	1375
TOTAL	4206	199	4405

Quite definitely, dysbaric osteonecrosis is related to the type of diving. Compressed air to 30m was lesion free. 31-50m gave 8 men lesions (0.8% of those exposed to this as a maximum depth). 51-100m gave 19 men lesions (1.6%), 101-2OOm gave 139 men lesions (8.1%) while 201m or more resulted in 30 men with lesions (15.8%). Saturation diving, with adequate records had been done by 1,725 men, of whom 143 had lesions. Again the incidence increased with depth.

The MRC report points out that femoral juxta-articular lesions are rare in divers and that only nine divers had damaged humeral heads making it impossible to be certain about the proportion of juxta-articular lesions that will progress to change. However, in 93 compressed air workers with juxta-articular lesions, nine went on to joint damage (9.7%). But one should include the 48 who had joint damage at the first survey which pushes the incidence up to 40%. For the divers reported on, the figure cannot be less than 9 in 72 (12.5%).

TABLE 6

DYSBARIC OSTEONECROSIS AND MAXIMUM DEPTH

MAXIMUM DEPTH IN METRES	DIVERS	DEFINITE LESIONS	%
Less than 30	317	0	0.0
31 to 50	1025	8	0.8
51 to 100	1171	19	1.6
101 to 200	1718	139	8.1
200 and deeper	190	30	15.8

The prevalence of bone lesions in the North Sea diving population has risen from 0.94% in 1975 to almost 5% in 1979. The incidence, proportion of new cases per year, has varied but remained below 1.27% of those at risk per year. There is a sharp rise in the incidence of dysbaric osteonecrosis after the sixth year of experience which is about the time most divers start helium and saturation diving.

1,725 saturation divers had 143 lesions (8.3%). Of these 27 were juxta-articular or damaged joints (1.5%) and 116 had head, neck and shaft lesions (6.7%). 3,255 men had never done saturation diving or were without sufficient data. Simple arithmetic gives us 38 men with juxta-articular lesions (1.2%) and 26 with shaft, head and neck lesions (0.8%) in the non-saturation group. This ignores multiple lesions in both groups. According to the number of lesions recorded up to 10 men had more than one juxta-articular lesion while 275 head, neck and shaft lesions were shared by 204 men.

DAMAGED JOINT

David Elliott told us last year that minor bends were very common in commercial diving and that the saturation depth is often 150 feet above working depth. These facts

TABLE 7

DYSBARIC OSTEONECROSIS AND SATURATION

MAXIMUM DEPTH SATURATION (m)	DIVERS	MOST RECENT X-RAY RESULT			
		NORMAL	DEFINITE HNS (%)	DEFINITE JA (%)	DAMAGED JOINT
1 to 100	215	212	1 (0.5)	1	1
101 to 150	664	621	32 (4.8)	10 (1.5)	1
151 to 200	656	589	57 (8.7)	9 (1.4)	1
201 to 300	136	118	16 (11.8)	2 (1.5)	0
301 or deeper	54	42	10 (18.5)	2 (3.7)	0

could explain why the incidence of dysbaric osteonecrosis is higher now than it was in the middle of the 1970's.

ADVICE TO THE SPORTS DIVER

What can we make of this? Sports divers who do not go below 30m, and observe the tables properly are most unlikely to develop lesions.

Those who dive below 30m, to 50m, have approximately a 1% chance of developing lesions. On the basis of the MRC figures, which do not give the lesions associated with each depth, 36% of lesions will be juxta-articular, probably in the humerus. Recorded attacks of decompression sickness increase the incidence of bone lesions nearly five times. In Australia, many cases of decompression sickness are associated with rapid ascents.

Various surveys of both new and in use depth gauges have shown that a large proportion are inaccurate. Luckily many overestimate the depth. But many underestimate the depth and can lead the diver astray in his depth-time profile.

Careful diving, using a recently calibrated depth gauge, a waterproof watch, staying within the no-decompression limits and avoiding sudden unscheduled ascents and running out of air should allow the sports diver to enjoy his or her fun without risking any joints.

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THE SAFETY OF THE UNITED STATES NAVY DECOMPRESSION TABLES AND RECOMMENDATIONS FOR SPORTS DIVERS

Bruce Bassett

I will quickly review what Haldane found and what the United States Navy (USN) modifications to the original Haldane model were, as a result of several years of development of decompression tables. Then I will analyse the safety of the USN standard air decompression tables, leading on to recommendations for sport divers based on safety analysis.

Haldane basically had two observations. Testing his animals by exposing them to increasing depth, keeping them there long enough to attain equilibrium with the inert gas pressure, saturating them, and then decompressing them, he developed the concept that there was a critical supersaturation ratio. This is often expressed as a pressure ratio. One can always reduce the pressure by one half within the realm that he worked in, to pressures of 6 atmospheres absolute. However the important aspect is the driving force for inert gas to form bubbles. Therefore it is expressed as a ratio of the nitrogen pressure, trying to force gas out of solution, versus the barometric pressure trying to keep the gas in solution. That was the empirical observation. There was some critical supersaturation ratio and if he observed it, he did not get the animals in trouble with decompression sickness (DCS).

After looking at what factors were involved in inert gas uptake and elimination, he decided that handling all the variables was difficult. So he developed a mathematical model based on the half time equation. Haldane knew that there was an infinite number of curves that described the uptake and elimination of nitrogen in various regions of the body, depending on the combinations of fat and perfusion. Of course these rates may change with other variables such as cold and exercise. By choosing a number of time constants to put into the equation one can approximate to what is really happening in the body. That was his second concept.

The first decompression tables were built using the half times 5, 10, 20, 40 and 75 minutes, applied to the half time equation. As an example, if a diver went to a depth where the nitrogen pressure in compressed air was 4 atmospheres absolute for 40 minutes one can use this equation to calculate the amount of nitrogen that is taken up. A 5 minute half time after 40 minutes will have been exposed for 8 units of half time, so that tissue would be 100% saturated. It would have a nitrogen pressure of 4 atmospheres. A 10 minute tissue after 40 minutes would have been exposed to 4 units of half time so would be about 93.75% of 4 'atmospheres. The 20 minute tissue would be 75% saturated, it would hold 3 atmospheres of nitrogen pressure and so on. Using the empirical observation that a nitrogen pressure to barometric pressure ratio of 1.58 is safe, one can calculate the barometric pressure that the diver can safely ascend to. One multiplies the calculated nitrogen pressure by 1.58 which gives you the barometric.

pressure that you can ascend to.

Haldane built decompression tables based on this empirical observation of the critical ratio and a mathematical model. Compared to what was happening at the turn of the century in terms of divers getting bent like pretzels, his tables worked because diving became much more successful and the incidence of bends went down. Sometime after 1900 when the USN was doing its diving using the Haldane tables, which were fairly limited in scope, both in depth and bottom times, it became necessary to go beyond the Haldane tables. So, using the Haldane calculation method and the Haldane observations, they went to greater depths and greater bottom times and produced a set of tables, the older pre-1955 tables. They can be recognised because they had an ascent rate of 25 feet per minute. Also within each depth range there is an asterix for the optimum bottom time at a given depth time. I am not sure what was meant by an optimum bottom time. They had times longer and shorter, but one was labelled optimum. They were used by the USN for diving for a number of years. The old tables did not have a repetitive dive system. One simply added the bottom times together and came up with the decompression requirement after the second or third dive. They did not give any credit to the off gassing that occurred on the surface.

USN Standard Air Tables

When scuba came into military use, its short duration demanded repetitive diving for useful work to be achieved. The decompression penalties of the old system were unacceptable. Perhaps there was some incidence of decompression sickness with the old tables. So in the early to mid-50's, the USN went through the whole process again, using basically the Haldane equations for half times. Then they tested them at the experimental diving unit on real live divers in water, in a wet pot, in their equipment, doing work. With all this testing, if a diver bent, that was not an acceptable schedule. They had to go back, look at the half times and the calculated nitrogen pressures, and see which one was the likely culprit for having caused that bend. Then they would reduce that calculated value. That is, reduce the bottom time. Nowadays, with statisticians breathing down our necks in research, to test a given schedule to an end point of a half percent bends with 95% confidence limits requires about 150 individual man tests. That is very expensive. Obviously they did not do that. The best that they could do was to produce a set of tables with an end point of zero bends. The result was that the tables that were produced in 1955 have not changed one iota since.

The USN had to extend the half times beyond Haldane's slowest tissue, which was 75 minutes. That was a whole body saturation time of 7 1/2 hours, six times 75 minutes. The USN tables, the standard air tables and the repetitive dive tables, have half times of 5, 10, 20, 40 and 80 and the slowest half time is 120 minutes. If one multiples that 120 minutes, the slowest tissue, by 6, 6 units of half time, it takes 12 hours to reach total saturation. Assuming that excretion is the mirror image of uptake any excess nitrogen that is put into that slowest tissue takes six times 120 minutes to be got rid of. So 12 hours is the magic number in the repetitive dive scheme of the USN tables. Once the diver has gone beyond 12 hours he is considered to be "clean". Theoretically there is no excess nitrogen in the slowest tissue.

So that was number one finding. They found they needed a 120 minute tissue basically by running dives longer than Haldane did. Maybe they discovered it as a result of repetitive dives. I am not sure.

The other change from Haldane's observations was the critical ratio. The USN found that there was a different supersaturation ratio, apparently a different critical ratio for each of the half times. At first one says, well why? Why can one tissue hold more nitrogen than another tissue? It probably has nothing to do with a physical force. It may be simply time and risk. Nitrogen molecules have to move within the body, to get together and perhaps overcome forces like surface tension and so on to form a bubble. There may be a time element for this to occur and for a bubble to come into being. If one reaches the surface with a 5 minute tissue which has 1.35 atmospheres of nitrogen in it, 5 minutes later half of the excess gas has gone because it is eliminated at the same fast rate as it is taken up. If one surfaces with a 120 minute half time tissue with 1.35 atmospheres in it, it takes a long time for that to decay down. The differing critical ratios represent time at risk, rather than a physical ability for that tissue to hold more nitrogen.

Why are these ratios different from Haldane's? Haldane based his observations on saturation divers. So he was only dealing with the slowest compartment. Under those conditions no other tissue can have any more nitrogen than that. The USN 80 minute critical ratio is essentially the same as Haldane had with his 75 minute tissue. The critical ratio is 1.58 to one and a little bit less with the 120 minute tissue. But consider a bounce dive down to 165 feet for ten minutes. For ten minutes there is a large pressure gradient. But the 120 minute tissue has not taken up very much nitrogen, nowhere near its limit. So if one tests the safety of a bounce dive and the diver is not bent it becomes apparent that the faster tissues can withstand a higher ratio.

Very simply half times and critical ratios are the essentials when describing the USN standard air decompression tables. If one can add, subtract and fiddle around a little bit with the half time equation, one can calculate these schedules. It is a very simple set of calculations. There is no deep magic in it.

M Values

Some people are confused by M values. It is simply the calculated partial pressure of nitrogen in a half time tissue allowed when you reach a given decompression stop. What I have been talking about is strictly the surfacing value. For decompression diving, the M values change, as the amount of nitrogen you can add for each 10 feet is greater than what you can have when you reach the surface.

But it also works out that the critical ratios are different. The ratios actually decrease with depth. The allowable supersaturation level is less with increased depth and it reaches its maximum on surfacing. M values are expressed in feet of sea water (fsw) absolute, which is a rather funny pressure measurement. It assumes that one is always under 33 feet of sea water. Of course feet of sea water is a pressure measurement and so one can use it in absolute terms. One uses it because then the equation gives the answer in feet of sea water which is what one needs in terms of decompression stops. It is more convenient than using M values in millimetres of mercury or pounds per square inch or atmospheres. M values can be divided by the surfacing barometric pressure to give the critical ratio. Dividing M values by the barometric pressure at sea level, 33 feet of sea water absolute, will give the critical ratio.

SAFETY OF USN STANDARD AIR TABLES

The USN standard air tables were produced in 1955. The next question is how good are these tables? They have been used by many, many people around the world for all these years. For a long time the USN did not have any idea of how good the tables were. Individual diving doctors would probably back me up on that. One would say that they had 5% bends on that particular project, or another would say that they had 10%, or another would say that he did not have any. There was a paper published in the mid 60's by Rivers, who analysed 935 cases of decompression sickness treated in the USN over a fifteen year span. But one has no idea of the incidence, because there was no denominator. The USN had no recording system for the number of dives made.

In 1970, the USN adopted a recording system, so all dives made by USN divers or other divers under the auspices of the USN were logged. I have used the first years statistics an awful lot. It was a very brief report which showed that the total number of dives made was 30,039. Of the 30 accidents in USN divers, 25 were decompression sickness. The figures were broken down by the kind of equipment that was used. Extracting just the air dives because I am considering sport diving, there are two ways of looking at the results. There were 26,035 air dives. The other 4,004 dives led to over half the accidents, so one would not want to be a heliox diver, a saturation diver, an experimental diver or a nitrox diver, the categories that made up those 4,004 dives. In the air category there was deep sea air, the use of USN standard dress, fairly deep diving, hard working diving, probably a good percent, if not all, decompression dives. Three decompression accidents gave 0.081% bends, a very respectable incidence record.

Then there was lightweight air, using full face mask, a band mask, moderate work, moderate depths, probably a mixture of decompression and no-decompression dives, with a slightly lower incidence. Finally, open circuit scuba, the biggest category of all in that year's reporting, had an incidence of 0.035%. All in all, one accident out of every 2,173 dives is a pretty good safety record. It is also a good reason for you to log your dives, so you can quit at 2,172.

I have used that information for years to promote the use of the USN tables amongst sport divers. You can not beat those statistics. However, there are some fallacies there. One big question is "How does the USN use open circuit scuba?" There were 17,266 dives on scuba. If none of those dives were made anywhere near the no-decompression limits, then one is just inflating the denominator when calculating an incidence of accidents or incidents of decompression sickness. If scuba is used primarily to scrub the sides of ships the diver is never deeper than 30 feet, probably a lot shallower than that and never anywhere near the no-decompression limits. So this inflated denominator will influence the statistics. These figures are probably the least incidence when all dives are considered. It may well equate to what sports divers do - I think that sport divers dive conservatively, so maybe over all this is what the sport diver may expect too. But the question that really comes up for sports divers is "If I dive to the limits of no-decompression, what happens"?

There is a more recent report from the USN. It is a couple of years old now, but it confirms my impressions about that inflated denominator. This analysis looked at the standard air tables and from the reporting system took only dives made to schedules, that is times and depths actually printed in the USN standard air tables. For example, at 60 feet the first entry is 60 minutes. There is no entry for less than 60 minutes. So the first entry is the no-decompression limit. Then it goes to 70 minutes, 80 minutes and so on. So for a 60 foot dive anything less than a dive of 60 minutes was not included in this analysis. As a result there was a difference in the overall numbers. This report covered a seven year span and the total number of dives reported to be on a Schedule to be found in the USN tables was only 16,167, compared to that one year's report of 17,266 open circuit scuba dives, which right away confirms that 17,000 of those dives were probably nowhere near the no-decompression limits. If one eliminates those dives the incidence goes up. Get rid of the inflated denominator and one sees a more realistic incidence of decompression sickness - 202 cases, 1.25% over all (Table 1). 6,712, 41.5% of all dives reported, were between 40 to 140 feet, the depth range of interest to sport divers. 86% of those were decompression dives. 14% were no-decompression dives. There were 98 cases of decompression sickness (48.5% of the cases) an incidence of 1.5%. That was a little higher than the overall incidence which included dives down to 300 feet. In the deeper dives the incidence actually dropped a little bit. The thing that is interesting from the point of view of sport divers, is table 1. Remember that 86% of the dives were decompression dives, and 13.9% were no-decompression dives. 86% of the cases of decompression sickness were from decompression dives and 13% were from no-decompression dives. That says that the risk of decompression sickness in USN diving is no different in no-decompression or decompression diving.

Many sport divers, when they learn to dive and learn about decompression tables, are told not to do decompression dives as they are not safe. I will agree with that for sport diving. But not with the inference that decompression dives give a higher chance of getting bent. That appears

TABLE 1

USN DIVES MADE TO DIVING MANUAL SCHEDULES 1971-1978

DEPTH IN FEET	DECOMPRESSION DIVES (%)	DCS (%)	INCIDENCE	NO-STOP DIVES (%)	DCS (%)	INCIDENCE	TOTAL (%)	DCS (%)	INCIDENCE
40-140	5,782 (86.1)	85 (86.7)	1.5%	930(13.9%)	13(13.3%)	1.4%	6,712(41.5)	98(48.5%)	1.5%
150-190	5,512 (99.4)	49 (100)	0.9%	35 (0.6%)			5,547(34.3)	49(24.3%)	0.9%
200-300	3,908(24.2)	55(27.2%)	1.4%				3,908 (100)	55 (100)	1.4%
ALL DEPTHS	15,202	189		965	13		16,167	202	1.25%

not to be true. One does not stand a higher chance of getting bent, unless one does not do it right. Sport divers cannot do it right if they do not plan enough and do not have the same standard of surface control as the USN. So when you tell sport divers not to do decompression dives, do not imply that they are going to get bent if they do decompression dives. If one does it right it is no worse and no better than no-decompression diving.

I do not promote deep diving amongst sport divers in any way. However, 5,547 dives (34.3% of the total) were between 150 feet and 190 feet. There were 49 cases of DCS (24.3% of the total) giving an incidence of 0.9%, a slightly less chance of getting bent than with the shallower dives! 99% of those dives were decompression dives. One does not dive to those depths as a sport diver, because sport divers do not do decompression dives. They are not easily handled. It gets beyond sport to do decompression dives. Between 200 feet and 300 feet the incidence went back up to about 1.4%. Obviously all of those were decompression dives.

DO THESE FIGURES APPLY TO SPORTS DIVERS?

We have to consider the question “Can one expect that kind of incidence as a sport diver?” The answer is “yes”, “maybe”, and “no”.

The answer is “yes” if one dives the same way the USN dives and one is in that segment of the population curve that describes the divers from whom these statistics were derived. Then one might expect the same statistics.

Fitness

A lot has been made in the United States about the USN tables being made for USN divers. They are supermen. They are in top physical condition and all that. Actually the usual bell shaped curve describes the USN diver population. Some are superfit and some are not so fit. Extremes are what makes the difference between the sport diver and a USN diver.

Age

There are extremes in age. There are no USN divers younger than about 18. By the time they get into the military and go into training, they are over 18. There are sport divers younger than that. So in terms of whether they match the USN divers if they are younger than 18 they do not. So we are not sure. That puts the answer in the “maybe” category. Maybe the statistics apply. At the other end of the scale, there are not very many active USN divers beyond the age of 35. By then they move up to the supervisor class and they are not the active divers. They go into the USN at 18 and they start to retire out at about 38, after 20 years service. So the USN does not have many active divers over 40. Obviously there are many of us in this room who can say “maybe” the statistics apply because I am not in that population, I am over 38.

Sex

None of those statistics apply to women divers. The USN only started taking in woman as divers very recently. They would be insignificant in that set of statistics. So if you are a woman, you can say that you are not described in that population.

General Health

Obviously, if you are not healthy enough, to pass the physical for the USN, then you would not be in that population.

Obesity

Chronic obesity is frowned upon in the military and they will take them off diving service if they are frankly obese. But I have measured body fat in military subjects. There is a range of fatness in the USN. I think that everyone at this meeting would pass a measurement of acceptable lean to fat ratio for military diving. Other things may hold us back. It is hard to find differences between military divers and sport divers, except for those I have mentioned.

Diving Patterns

When one talks about sport divers in general, many are in their 20s so they are like the USN divers. The real problem is whether sport divers dive the same way as the USN divers. That is an unknown. The USN tables say one can go to 60 feet for 60 minutes and come straight to the surface. But if for some reason the USN never dives to 60 feet for 60 minutes, and they do not tell us about it, then they are diving differently from sport divers.

If a USN diver makes a dive to 100 feet for 25 minutes and records it as having been made to schedule, it gets logged as 100 feet for 25 minutes. What he may have done was anything from a 90, 92, 93, and so on up to 100 foot dive from anything from 21 to 25 minutes. A 10 by 5 matrix of possible combinations of depth and bottom time which has been recorded as a 100 feet for 25 minutes dive. Only one out of 50 possibilities has actually been made to the limit. If one does a 60 feet dive for 60 minutes it is a 10 by 10 matrix. 100 possible combinations of depth and time which would be recorded as a 60 feet for 60 minutes dive. Then there are other little things that come out, like the USN 2 foot and 2 minute rule which is not in the diving manual. It is not mentioned on any of the tables or sport diver tables that if one is within two minutes or two feet of a schedule one goes to the next one. But the USN does this. So it is not a 60 feet for 60 minute schedule. At 58 feet you go to the 70 feet schedule and at 58 minutes you go to a 70 minute bottom time. That makes one wonder if sport divers do dive the same way as the USN does. I wonder, because it does not show up in this report, just how much repetitive diving the USN does. Sport diving is a sport of repetitive diving. It may be only once a year that one does this kind of diving. But when we do it we dive a lot on a sport diving vacation. So there are some differences to worry about.

recompression chamber after the dive. So any one of the 100 possible dives which can be logged as 60 feet for 60 minutes would be decompressed for 70 feet for 70 minutes which is 14 minutes at 10 feet.

I should not bring up reporting accuracy, but apparently in that first year there were some paper dives in those 30,000 dives. That is people who had to make proficiency dives did not get them in but nevertheless a paper was submitted indicating the dive had been made. How many there were or how significant that was, I do not know. Again, I do not know the repetitive dive frequency in the USN.

Let us take some individual schedules from the USN and also look at some laboratory studies. (Table 2). For a 60 foot for 60 minute schedule, the USN reported a 1.1% incidence of bends. If a sport diver slips past 60 minutes and does a 60 feet for 70 minute dive with its proper decompression, is that a better dive form? In the Navy's experience, no, although the numbers are pretty small, three out of 62. It looks as if he does increase his risk of bends.

Really more important are dives made in a laboratory to no-decompression limits. Spencer in Seattle has done a lot of work with no-decompression limits, using the Doppler ultrasonic, precordial bubble detector. He recorded one bend from 13 exposures to 60 feet for 60 minutes, 7.6% bends. 31% of the subjects had venous gas emboli detected.

COMPARISON OF USN, SPENCER AND BASSETT
SCHEDULES, DECOMPRESSION SICKNESS (DCS) AND VENOUS GAS EMBOLI (VGE)

SOURCE	DEPTH/TIME	DCS/DIVES	DCS	VGE
USN	60/60	2/183	1.1%	No record
USN	60/70	3/62	4.8%	No record
SPENCER	60/60	1/13	7.6%	31%
BASSETT	60/60 (E)	1/18	5.6%	27.8%
USN	80/40	0/40	0	No record
USN	80/50	2/34	5.9%	No record
BASSET	80/40 (E)	1/16	6.3I	37.5%

(E) Equivalent Flying After Diving Schedule

So what happens when one really makes dives to no-decompression limits? There is laboratory evidence. Some of the USN statistics may make us wonder a little bit about the no-decompression limits. Firstly, how close do the USN divers go to the limits? I suspect not very often, both by probability and by Navy diving supervisor unwritten laws in addition to the two foot and two minute rule. When I went through the USN diving school medical programme back in 1964, the Master USN divers were saying "Always cheat the government, never cheat the diver. Time and air are cheaper than bone and brains". They put them on the next schedule as they did not want them coming up bent. They did not want to spend a lot of time working a

My own contribution is an equivalent flying after diving schedule. My project in the last three years before I retired from the US Air Force was to validate some schedules for flying after diving. The first round of this was to test 20 odd man exposures to 6 different schedules. We made a dive in a hyperbaric chamber to a bottom time calculated so that when we ascended to the surface and continued on up to 10,000 feet altitude, it produced the same surfacing ratio as the USN no-decompression limits surfacing at sea level. In my schedule, I did not do a 60 feet for 60 minutes dive. I did a 60 feet for 20 minutes dive. But when the "diver" surfaced and continued on up to 10,000 feet, the ratio that he attained on reaching 10,000 feet was the same as coming to the surface after a 60 feet for 60 minutes dive. I called it equivalent. That was by design. The statistics back up that it was equivalent, because I had about 5.6% bends on that schedule and about 30% or less intravascular bubbles, much the same as Spencer's 60 feet for 60 minute dives.

At 80 feet for 40 minutes the USN had no bends. But at 80 feet for 50 minutes they had 6% which is the same as the dive to 80 feet in my equivalent dives, 6.3%. 100 feet for 25 minutes was the worst for the USN. It gave 4 cases in only 43 exposures, but that is a 9.3% incidence. Remember that probably only one out of 50 dives is actually made to that limit. My 100 feet for 25 minutes equivalent dive, as with all my equivalent dives, had a 6% incidence of bends. It is interesting and this will come to light when I finally give you my recommendations for sport divers, that when you go deeper the bends rate decreases. There is a reason for this in the design of the tables. I was totally clean on the 130 foot for 10 minute equivalent dive and the USN was almost clean at 130 feet for 10 minutes.

When we actually dive to the no-decompression limits in the laboratory you can see 5 to 8% bends. Depth is controlled. Bottom times are controlled. Rates of ascent are controlled. All was according to the USN tables both in Spencer's and in my laboratories.

PREVENTION OF DECOMPRESSION SICKNESS

What can you do to prevent that 6% bends incidence? One study by Pilmanis at the University of Southern California used a few divers for open water no-decompression dives made in a controlled way, to a measured depth of 100 feet, with a measured bottom time of 25 minutes and a measured ascent rate of 60 feet per minute. Some subjects produced intravascular bubbling to a great degree on that exposure. They found that if they put in a 3 minute stop at 10 feet, it drastically reduced the degree of bubbling in those subjects. If they put a 2 minute stop at 20 feet and another 3 minute stop at 10 feet they could eliminate the bubbles. This indicates that perhaps the no-decompression limits are on a knife's edge in terms of bubble production and the risk of bends. The tables were developed and tested to an end point of bends not bubbles. After a bend they cut back slightly to produce the final bottom time and tested it a few times. If there were no bends it was fine. Perhaps 30% of those people were bubbling at that time. When you put those tables into the big world, you must expect a few cases of bends to pop up. However if you cut back a bit more you can drastically reduce the bubbles so you should be able also to decrease the incidence of bends.

Sport divers represent the world's largest population of divers. More than all military divers, commercial divers, scientific divers, abalone divers, put together. There are no accurate statistics and never will be. So we do not know what the incidence is, and probably never will know.

Generally speaking the sport diving instructors tell us not to push the tables. Sport divers are instructed to avoid decompression dives, maybe for the wrong reason, but nevertheless I think it is valid. Various instructors that I have come across in my years of talking to diving groups have come up with their own safety factors. Some take 5 minutes off all the no-decompression limits across the board. Others reduce them by 2%, which actually has a little more logic to it because you end up reducing the shallower depths more than you do the deeper depths, and that in fact is what probably is needed. The other thing that is common among sport divers is that, unlike a navy diver who goes down to the bottom and stays a certain period of time and then comes up, they are up and down and all over. What influence this multilevel diving has on the risk has yet to be determined.

Revised No-Stops Limits

It seems to me the nice way to go about putting some safety factors into sport diving and to give a definition to not pushing the tables, is to re-design the tables. That is what I have done with my sport diver table (Table 4). It is not in its final form yet. I have already modified part of it. In Table 3 the half times used for the USN tables on the left, the next two columns are the H values and ratios used for the no-decompression limits of the USN tables. The H values and ratios that I am proposing for sport diver tables are presented on the right. Where did I come up with those? Did I just pull them out of my ear lobes? I told you that when I flew my man to 10,000 feet after exposures to

TABLE 3

LIMITING VALUES OF USN AND SPORT DIVER TABLES

	US NAVY		SPORT DIVER TABLE	
HALF TIME	M VALUE	RATIO	M VALUE	RATIO
5	104	3.15	95	2.88
10	88	2.67	83.2	2.52
20	72	2.18	67	2.03
40	58	1.76	53.8	1.63
80	52	1.58	46.5	1.41
120	51	1.51	44	1.33

depth I had 5 or 6% bends. That was unacceptable. We still had the problem of giving our military divers a schedule that would allow them to fly immediately after diving. We then reduced the altitude from 10,000 feet to 8,500 feet. Money and manpower was short so we could only test three schedules. Taking a group of man to 8,500 feet after their dive did not produce any bends at all. That cut back from 10,000 feet to 8,500 feet is presented in Table 3 in terms of surface and surface ratios for my sport diver table compared with the USN no-decompression limit values. It certainly makes sense to me and I have a few man tests behind it. We reduced the USN no-decompression limits to those in Table 4. These were tested. Of course sport diver tables and sport diver problems never get tested Because there is no money. So I was happy to use a little military money and have a spin-off for sport diving. These ratios worked in flying after diving. I am convinced that my dives were equivalent to no-decompression dives. Taking these numbers and plugging them back in to calculate allowable bottom times gives Table 4. The reduction is about a five minute reduction at the greater depths, a 10 minute reduction in the intermediate depths, and very significant reductions shallower than 60 feet. A 30 minute reduction at 50 feet, an 80 minute reduction at 40 feet and actually putting a limit on the 30 foot dive.

Spencer was able to bend people at 25 feet by exposing them for over 12 hours. I was able to bend 5% if I kept them at 10.75 feet for 24 hours and then took them to 10,000 feet. In this situation the ΔP was equivalent to being saturated at 22 feet of sea water. The shallowest bend so far.

Table 4 shows the no-decompression limits that I recommend. I have put them in some publications. I hope the National Certifying Agencies in the United States will start to push them.

I would like to see, along with this, some revision of the repetitive dive system.

The repetitive dive system in the USN is based on only a single half time, the 120 minute half time tissue. Each repetitive group letter was initially set up to represent an increase in nitrogen pressure of 2 feet of sea water absolute. 79% of 33 feet is 26 feet. If you had not been diving today, if you were clean on the slate, you would have 26 feet of sea water nitrogen pressure. Repetitive group A represents a nitrogen pressure in the 120 minute half time tissue of 26.1 to 28 fsw. Group B would represent by design 28.1 to 30 fsw and so on. At the end of the dive one can calculate how much nitrogen pressure is in the 120 minute tissue. Something goes wrong when one analyses the tables. The range of partial pressures of nitrogen represented in a given repetitive group ranges from 1.5 fsw to as high as 8 fsw. This is from unpublished data. I have gone through every single entry in the USN tables and calculated the nitrogen tension after any given exposure at the end of bottom time, on reaching a stop and leaving a stop and so on, and then the surfacing values. When you correlate the surfacing values with the repetitive groups assigned by the tables there is a range of about 6 to 8 feet of sea water in some groups. The dive which gives the diver a repetitive group M may have as much as 6 or 8 fsw nitrogen pressure more in the 120 minute tissue than another which also puts the diver in repetitive group M. There is an anomaly and I do not know whether it is calculation, testing or what. I have never been able to find the answer.

But it may lead to some of the anomalies that you run into. Take a 60 foot dive for 30 minutes with a surface interval of 30 minutes and then another 60 foot dive for 30 minutes. The USN dive tables tell you that one has to do an 8 minute stop at 10 feet on the second dive. The USN table also says that one could have gone to 60 feet for 60 minutes and gone directly to the surface. The reason that happens is that each repetitive group designation assumes that the diver reached the surface at the high end of that 2 foot of sea water. Likewise in the surface interval table, it assumes that one has the highest nitrogen pressure for the next repetitive group. When one goes on to the residual nitrogen table it assumes that you have the highest residual nitrogen. The table calculates the time that it would take at that depth to reach that amount of nitrogen. If in fact one was at the lower end of the nitrogen pressure one gets credited with more residual nitrogen than one had which explains the minus for that 60 foot 30 minute dive. There are some anomalies and I think it would be a nice thing for sport diving if we could eliminate them. That is going to be the most difficult one, because it will be impossible.

TABLE 4

REVISED "NO-DECOMPRESSION" LIMITS FOR SPORT DIVERS

DEPTH IN FEET	TIME IN MINUTES USN	REVISED
30	UNLIMITED	220
35	310	180
40	200	120
50	100	70
60	60	50
70	50	40
80	40	30
90	30	25
100	25	20
110	20	15
120	15	12
130	10	10
140	10	5

RECOMMENDATIONS FOR SPORT DIVERS

Until such time as I am able to satisfy myself that there is a better repetitive dive system my recommendations are to use the revised no-decompression limits (Table 4). In addition to that I recommend that all dives to greater than

30 feet end with 3 to 5 minutes at 10 to 15 feet. Do I really recommend belt and suspenders (braces) to be used together? Lower the no-decompression limits and add a safety stop? Yes, I do. And I do it myself, because sport diving is supposed to be fun and anyone who has treated a case of bends knows that bends is not fun. Anything you can do to prevent decompression sickness makes a sport of diving rather than it being the pain of diving. The question comes up "If you throw in these safety stops, how do you get your repetitive group?" The answer is easy. You count the total dive time for selecting a repetitive group. No-decompression limits are based on bottom time. You come up. You make an additional stop. If you use my schedule 50 feet for 70 minutes, you actually use that 70 minutes. Then you come up and hang on for 3 to 5 minutes at 10 feet. You then take the total underwater time of 75 minutes to enter the repetitive group selection process.

Question:

How do the BSAC/RNPL tables compare with the USN tables for safety?

Dr Bruce Bassett

I have not done that. Over the years I have played around with these tables, I have been working mainly with military divers and sport divers. I have concentrated all my efforts on the USN tables. I have not studied the British tables enough to know, I understand they are much more conservative.

They are based on a different model. The Canadian tables are based on a different model. The Swiss tables are also based on a different model. It is a half time, M value model, but more conservative M values. They all say that they have got good results with their tables. I have not analysed their tables nor their results. I am only commenting on the USN tables.

Question:

It is said that all dives greater than 100 feet, when at the no-decompression limits or longer, produce bubbles.

Dr Bruce Bassett

I have not seen evidence, as yet, that all such dives produce bubbles. I am not one of those who believes that. Or maybe I have got my head in the sand. You cannot detect bubbles in all dives. My dives were made to the no-decompression limits and I got 30% bubbles. That includes all grades of bubbles, from the occasional one to the constant stream. If people claim bubbles on every dive, they are visualising bubbles. They cannot detect them. They are assuming that they are there. I think a lot of this comes from Brian Hills' theory that bubbles form on every dive because supersaturation is thermodynamically unfeasible. It is said that the body does not tolerate that metastable state and therefore phase separation occurs on every dive. I think there are some things that are missed on that analysis. Humans become supersaturated at an altitude of 7,500 feet. Commercial airliners fly with cabin altitudes of 8,500 feet. One is beyond just being supersaturated, one is supersaturated by 1,000 feet of altitude. Many, many military aircraft fly with cabin altitudes above 8,000 feet, up to the bends threshold of 18,000 feet with literally millions and millions of manned exposures with no problems. If in fact one forms bubbles whenever one is exposed to a barometric pressure less than what the tissue nitrogen pressure is at sea level, one should be bubbling at these heights. Yet with all those millions and millions of exposures there is zero incidence of problems. So I think something is being missed in the concept that you bubble whenever you have excess gas pressure. One thing that seems to be overlooked is surface tension. The forces opposing bubble formation, de novo, are enormous. This is ignoring bubble nuclei. Once the microbubble forms, the likelihood of it existing is very, very small because a very small bubble has almost an infinite surface tension which is of course trying to collapse it. I have not seen laboratory evidence that humans do bubble whenever they exceed supersaturation. If we do so, be careful getting out of the shower.

Dr Ian Unsworth

I entirely agree with you. We were trying Doppler detection of VGE a few years ago at Prince Henry Hospital. We decided to use the US Navy Exceptional Exposure table, which I think you would agree, offers a reasonable expectation of venous gas emboli. As the director of the study and older than the others, I made the run. We did 25 or 20 minutes at 190 feet. The Doppler, as we ascended, produced an extraordinary amount of noise which the outside staff said was interference. They were tearing their hair at this. They could not get rid of it. They thought they were going to be in trouble when I came out of the chamber. At about 30 feet I was furious that my staff were not getting a decent recording. At about 20 feet I got a sledgehammer in my hip. I do not know if any of you have been bent, but it is very painful indeed. I was put back to 60 feet and successfully treated. Then I selected a female volunteer from the other members of the unit. We repeated with some trepidation and some expectation, exactly the same dive. She did not get bent. We did not even get venous gas emboli from the same exposure. That backs up what you were saying that not everyone will bubble after the same exposure to 100 feet.

Dr Bruce Bassett

I took the USN statistics and looked at the depths I wanted. Actually, when all the USN dives are considered, all depths and all bottom times, there is no correlation between bends and depth. Depths greater than 100 feet were no worse then those less then 100 feet. Gas loading seems to be more important than depth. There was a time correlation. Dives over 60 minutes did start to see an increased incidence. Other statistics seem to show that short deep dives are safer then long shallow dives. On one 130 foot dive I had 98% with skin bends - itches. There is a very positive correlation between skin itches and depth. But there is no correlation whatever between bends or detectable gas emboli and depth.

Females have about a 3 to 4 fold greater incidence of decompression sickness on altitude exposure. This has also been reported in diving.

My final recommendation is to use belt and suspenders, reduce your bottom time and do decompression stops as well.

Dr Fred Bove

As you know I have been associated with USN diving for many years. I will describe how USN diving operations are done. It will alter your thinking about the USN decompression tables.

The USN diving tables are pinned up at all dive stations, often in very large print. There are big red “X’s” on some tables because the divemasters have found some tables at certain depth and time combinations, have a high incidence of bends. One of the notorious ones is 150 feet for 30 minutes. The USN has experienced about 15% bend incidence with this table in the field, so they do not use it any more. There is nothing in the diving manuals that tells you that.

The divemasters seldom use the prescribed depth and time to decompress the diver. The usual practice in the USN is that, if they are anywhere near the depth or time limits, they move to the next schedule. Some dive masters will use two minutes, some will use three, some will even use five. That is, if the diver is within five minutes or five feet, or two minutes or two feet, of a limit for decompression, he is decompressed on the next schedule. The divemasters also will make the table more conservative if the diver is overworked, underworked, in cold water, in warm water, in current, has a tough job to do, was up late the night before, or for anything at all. They will use the decompression one or two steps beyond that of the actual depth and time, to decompress the diver.

So in the USN statistics, the actual depth and time of the dive are often lies. The statistics show an incidence of bends from these wrong dives. The recording system also has in it the decompression that was used. When one studies the depth and time log, one finds that the decompression that was prescribed by the tables was not used, but a more conservative one was chosen. One of the reasons why there is reasonably low incidence of decompression sickness in the USN is because the divemasters on the dive stations are extremely conservative. They factor in almost anything they can find in the environment to make the tables mere conservative.

The USN has certain physical requirements which are fairly stringent. Reserve divers, and sailors from the fleet coming into diving, are often not fit enough to meet the basic entry requirements for the USN Diving School. Those entry requirements are higher than the average population of, say, 25 year old sailors. At the diving school, the day begins at 0630 with a four mile run for everybody, then PT exercises - that is, vigorous callisthenics - timed by one of the divemasters for another half hour before the classroom and the diving begin. This continues throughout the course, eight weeks for the medical officers, sixteen weeks for the second class diver and twenty-four weeks for the diving officer. Everybody, including the medical officers, goes through that. When one graduates from the diving school, and joins a diving team, that same routine is followed. Navy divers are generally fit. The master divers somehow manage to extricate themselves from the exercise, but at the same time they do not dive very much, they are up on the platform supervising.

The USN assigns two people with watches to time the dive, and one or two people to watch the depth gauge. So the time is accurate to the second and the depth is accurate to the foot.

Not much of the scuba diving is done close to the no-decompression limits. Most of the scuba diving is done shallower then 30 feet. The USN does not use scuba for deep diving. Most scuba diving is shallow, less than 100 feet, often for short, inspection operations.

All in all, the USN tables are quite successful for the military operation where the diver goes over the side, goes down to a depth, does a job comes back up and rarely does a repetitive dive. There is a dive team on site, so diver number one does one part of the job and diver number two another part, diver number three, and so on. It is rare that the USN does a repetitive dive. A repetitive dive stresses the dive station, and it is not routinely used.

With all that, to take the Navy tables and the statistics related to them, with some knowledge of what operational diving in the USN is like and apply them to sport divers, who dive so very differently, is difficult. I generally tell sport divers to knock five minutes off all their bottom times for no-decompression dives. Bruce Bassett has said to take off more than five minutes at the shallow end, I think that is right. I think sport divers should be instructed not to dive right to the second of the no-decompression limits, because they will get a higher incidence of decompression sickness.

Decompression diving seems to be riskier in sport diving, probably because of the operational aspects. The divers do not do the timing right, they do not quite get their stops right, they are not prepared to have the excess gas supply and all the rest of that stuff. Remember also that a lot of military and commercial diving is done with surface decompression. When the diver gets to the 30 feet stop, they pull him out of the water and put him in a chamber. So he finishes the dive in a nice warm environment with a cup of tea in his hand. It is not quite the same as a sport diver sitting at 30 feet, 20 feet and 10 feet stops waiting to decompress in cold water with surface action of the waves and everything else. It is interesting to look at your depth gauge when there is wave action and you are at 10 feet. Half the time you are at 5 feet and the other half at 12 or 13 feet. So you are never quite sure where your 10 feet stops are.

FUTURE SPUMS MEETINGS

NUMBS

The Newcastle Underwater Medicine and Barotrauma Society will hold a meeting on Saturday 30th April and Sunday 1st May 1983.

The guest speaker will be Neville Coleman.

A comprehensive educational programme will be complemented by two diving excursions and an interesting social programme. Arrangements have been made for diving gear to be available for hire at reasonable rates. Both dives will have dive masters (qualified instructors) and safety divers.

For further details contact:-

Dr Brian McLaughlin
37 Marshall Street
New Lambton Heights NSW 2305

SPUMS 1983 ANNUAL SCIENTIFIC MEETING

PLACE: THE REGENT OF FIJI HOTEL
DATES: June 20th to 27th 1983
GUEST SPEAKER: PROFESSOR BRIAN HILLS

DIVING BEFORE, DURING AND AFTER

A BROCHURE WAS POSTED IN NOVEMBER

CONFERENCE ORGANISER:

DR JOHN KNIGHT,
80 WELLINGTON PARADE
EAST MELBOURNE VIC 3002
AUSTRALIA

GREAT KEPPEL ISLAND
29th and 30th OCTOBER 1983

"DIVING, ITU AND ENVENOMATION"

ORGANISER: Dr Chris Acott
Director of Intensive Care Unit
Rockhampton Base Hospital
ROCKHAMPTON QLD 4700

To be held in conjunction with the Intensive Care Society (Queensland Branch).

Speakers include Dr Straun Sutherland, Dr John Williamson, Dr Chris Acott and Dr John Knight.

Case histories and papers for presentation are invited.

This meeting will be the weekend following the Australian Society of Anaesthetists Meeting in Brisbane in October 1983.

COSTS: Accommodation and meals - $60.00 per person per night.
Airfare Rockhampton to Great Keppel Island and return - $65.60.

DIVING WILL BE AVAILABLE

COME AND MEET THE SEA SNAKES

MARINE BIOLOGY COURSES FOR DIVERS

With Reg Lipson

Sea Studies Services will run marine biology courses in 1983. Planned dates are:-

A level (A FIRST COURSE)

February 2, 9, 16, 23, March 2, 9, 7-9.30 pm
(excursion during this period)
April 23 and 24 10am to 5pm
(excursion April 25th)

November 9, 16, 23, 30, December 7 and 14
7-9.30 pm
(excursion during this period)

D level (THE MOLLUSCA - A DIVER'S LOOK)

June 22, 29, July 9 7-9.30 pm
(two shore dive excursions)

All classes will be at the Hawthorn Institute of Education.

For further details contact:-

SEA STUDIES SERVICES
70 Railway Parade South
Chadstone VIC 3148
Telephone: 03 277 0773

PROJECT STICKYBEAK: PROVISIONAL REPORT ON AUSTRALIAN DIVING-RELATED DEATHS IN 1981

Douglas Walker

Two persons using snorkels, seven with scuba, and two hookah divers were identified as having died during 1981. One of the snorkel users was only 8 years old and died quietly while in close proximity to adults on the beach, the other was fatally injured when hit by a power boat close to shore. The boat was proceeding into the direction of the sun at moderate speed and had been steered carefully to avoid surf skiriders. The water was a little choppy and though the victim was towing a plastic bottle float it had no flag so he was not readily visible to anyone in a boat.

Three of the scuba divers were totally inexperienced and untrained, while a fourth's experience was probably not great. One experienced diver died as a consequence of a series of events initiated by an asthma attack, another from the combined effects of fatigue, cold, entering the water while on reserve, no line in a poor visibility situation, and running out of air. The seventh scuba diver was experienced and one of a group of underwater photographers at a wreck in 40m deep water. He was seen to start his ascent alone but he never reached the surface and his body was never recovered, though his camera was found attached to the anchor line. It is possible that nitrogen narcosis and cold could have effected his actions for he was equipped with a buoyancy vest and failed either to drop his weights or indicate any problem to other divers nearby.

Both of the hookah divers who died were said to be very experienced. One died when he was dragged underwater when his hose fouled kelp as he was being pulled back to his boat on the surface, regulator out of his mouth. It is not known whether his descent was deliberate and he suffered anoxia due to a kinked hose or whether he "dry drowned" when unexpectedly submerged; neither of those pulling him back was watching at the critical moment. The other died in association with the low air situation when the compressor's reservoir started to lose its air pressure. He was thought to be starting to ascend and attention was concentrated on his buddy, who seemed to be in distress after his emergency ascent. When the victim's absence was realised his hose was used to pull him up, but parted at the junction with the regulator portion of hose when the pull strain became direct on this joint.

Information is also presented concerning an additional 1980 fatality. The diver, making his third scuba dive, was using hired equipment. He lost his dentures while on the surface and was unable therefore to retain his regulator. His buddy, though equally inexperienced, tried valiantly to save him but rough water claimed the victim.

CASE REPORTS

These reports are based in most instances on inquest documentation, though in one case no inquest was thought necessary and in another the absence of a body has led to delay in holding any inquest. Basic case details are shown in Table 1.

Case Sn 81/1

This 8 year old child was swimming in a channel between the beach and a sandbank, water depth about 6 feet. His mother and other adults were nearby keeping a general watch over his activities. He was seen to expel water from his snorkel and was not seen again until found by a searcher on the sea bed. Nobody noticed anything to indicate a swimmer in trouble. The case is included to illustrate the potential for disaster in the untrained use of even so simple a piece of equipment as a snorkel. It is not possible to say whether this tragedy was due to inhalation of water down the snorkel, build-up of carbon dioxide from use of too large a snorkel, post hyperventilation blackout, or some other reason.

CHILD. SNORKEL. SURFACE.

Case Sn 81/2

The power of Press Publicity is much less than is generally claimed, for none of the persons skin diving off the rocky point were aware that a powerboat was to make a speed trip up this area of coast that day. The boat driver saw the surf skiers and avoided their vicinity but had no hope of seeing anyone swimming on the surface as there was a small chop and he had the sun in his eyes. The wet suited victim was towing a plastic bottle float but this had no flag to make it conspicuous. There were two other divers in the area but they were near to the rocks while he was about 10m further out. The powerboat had a well tuned engine and was only proceeding at part power and this was thought to explain how none of the divers was aware of its approach. The boat's contact with the victim was heard and the other divers swam out to the area of blood which quickly disappeared. The battered body was soon recovered and brought ashore. The boat was seen to stop after a short delay and the driver was seen to examine the propeller before he continued up the coast. He was apparently unaware that he had hit anyone till informed by police at his next landfall.

This accident would not have occurred had the diver used a flag on a float, and might have been avoided if the boat's approach were noticed. However, he was making a surface snorkel recreational swim before starting a journey and not spearfishing or sport diving and this tragedy was the type of misadventure which can easily occur when surface craft mix with swimmers of any type. It is necessary to be positively visible to surface craft as even non-fatal contacts can have serious effects on the victim.

POWERBOAT. SURFACE TRAUMA. NO FLAG.

Case SC 81/1

Personality factors can be critical in either positive or negative ways. The laudable desire to overcome a physical limitation can spur the performer to the heights, or death.

TABLE 1

PROJECT STICKYBEAK 1982 BASIC INFORMATION ON FATALITIES

CASE	AGE	EXPERIENCE VICTIM	EXPERIENCE BUDDY	WATER DEPTH DIVE	EQUIPMENT INCIDENCE	OWNER	VEST	COMMENT
Sn 81/1	8	Not Signif.	-	6 ft	Not Signif.	Own	No	Unnoticed death
Sn 81/2	33	Not Signif.	-	20 ft	Surface	Own	No	Trauma (powerboat)
Sc 81/1	22	Experienced	Experienced	15 ft	Surface	Own	Yes	ASTHMA. Night dive. Panic. Separation. Ditched vest and tank instead of weight belt.
Sc 81/2	40	2nd use	Experienced	Not Signif.	Not Signif.	HIRED	Yes	Poor supervision. Imperfect regulator and vest. Separation.
Sc 81/3	30	Experienced	Experienced	120 ft	Ascent	Own	Yes	Separation. Possible effects of cold and narcosis. Body never recovered.
Sc 81/4	25	First use	C Card	5 ft	Surface	HIRED	Yes	Separation. Fatigue. Loss of face mask and fins. Excess weights. Vest not used.
Sc 81/5	26	First use	Experienced	10 ft	10 ft	HIRED	No	Water in mask, then loss of fins and mask. Valiant attempt to rescue by buddy.
Sc 81/6	20	Experienced	Experienced	25 ft	Surface	Own	No	Out of air. Surface. Choppy water. Separation. No snorkel. Unable to ditch weights (belt turned).
Sc 81/7	47	Experienced	Experienced	Not Signif.	Not Signif.	Own	No	Fatigue. Cold. Poor visibility. No line. Under ship. Entered water on reserve. Out of air. Lost way.
Sc 81/1	45	Experienced	Experienced	35 ft	Surface to 15 ft	Own	Yes	Entangled in kelp. Pulled under by hose. Failed to drop weight belt. Separation.
Sc 81/2	36	Experienced	Experienced	30 ft	Ascent	Own	No	Compressor gasket blew; Reservoir slowly emptied. Buddy needed help while victim died unnoticed. Failed to drop weight belt.

This highly experienced young diver suffered from episodes of severe asthma and one dive nearly ended fatally for this reason. He refused to follow advice from diving instructors and diving doctors to stop diving, possibly regarding his personal survival as proof that they were wrong. This dive, which ended fatally, was a night dive with a buddy from a small protected beach. Their first dive was without incident. After a break of half an hour ashore the victim used his Ventolin inhaler and they made a second dive. When he indicated a low-air situation they both surfaced. He was seen to inflate his backpack type buoyancy vest and start to swim towards the nearest land, a rocky shore area, ignoring his buddy's call to swim to the sandy beach from which they started the dive. He called out that he needed his inhaler before he was lost to sight by his buddy in the dark. After reaching the beach the buddy ditched his equipment and started to search along the rocky shoreline. The victim's backpack was seen floating away and then the body was found wedged among the rocks, held down by the weight belt, in a few feet depth of water.

It is apparent that the victim would almost certainly have survived if he had not left his buddy, under the stress of his asthma symptoms, and swum to a nearby but suitable exit area. The mistake of pulling the backpack release rather than that of his weight belt was the final factor, the sudden loss of buoyancy causing his immediate and fatal submergence. Later testing showed that the backpack on release would have entangled his arms for a time and prevented him from reaching the weight belt release even if he had retained the presence of mind to make the attempt.

ASTHMA. SEPARATION. SURFACE LOSS BUOYANCY FROM ERROR DITCHING BACKPACK FLOTATION. RETAINED WEIGHT BELT. NIGHT DIVE. PANIC RESPONSE.

<u>Case SC 81/2</u>

The day-trip advertisement included an offer of the opportunity to dive with scuba while visiting an offshore reef resort, an offer taken up by the victim and his wife when the boat reached the island. Their only experience was a half hour of instruction in shallow water ten days before. The equipment available for hire was criticised by some apparently experienced divers, criticism not appreciated by the person in charge of the equipment. There were three inexperienced persons wishing to dive, the victim and his wife being joined by another day tripper. This person soon decided not to make a dive after all, having no wish to don strange apparatus and immediately descend to the sea bed alongside the moored boat, a depth of 50 feet. They were handed the necessary equipment, the "instructor" explaining that he had an extra weight on his belt because he had a wetsuit and that they could blow up their vests if they needed a rest. After their introductory dip, apparently a special feature so that people could boast of a 50 feet dive, the "instructor" led the two remaining neophytes on an underwater swim towards the seemingly distant reef. He led the way, though he returned to them on one or more occasions, to urge them to greater speed. The victim's wife then saw him swim past her and turned around to see that her husband was floating quietly just above the sea bed. The victim was brought to the surface and towed ashore, where several persons assisted with resuscitation measures. Though the victim reached the hospital alive, he died three days later from the cerebral and pulmonary effects of the incident.

Examination of the equipment showed that the regulator was faulty, requiring four times the correct breathing effort, and the buoyancy vest contained an empty CO_2 cylinder. Neither the boat's captain nor the "instructor" gave any evidence at the inquest on the grounds that it could incriminate them.

GROSS INEXPERIENCE. HIRED SCUBA. DEFECTIVE EQUIPMENT. SEPARATION. TOTALLY INADEQUATE SUPERVISION.

<u>Case SC 81/3</u>

Adverse weather conditions forced a group of underwater photographers to change their intended dive location and they agreed on a boat dive on a wreck in about 40m depth water. There were several boats and 12 people diving, the non-divers remaining in the boats. Buddy pairs were organised but as underwater visibility was 20 feet and as photography is an individual pursuit, separation of buddies occurred. The victim was seen at one time sitting on the wreck making some adjustments of his weight belt, and later seen starting his ascent. It was only when another diver surfaced with the victim's camera, which he had found tied to the anchor line, that his absence was noticed. Search failed to reveal any trace of him. He was wearing a buoyancy vest which would have resulted in the ultimate surfacing of the body had it been inflated. No adverse local factors were known and he is said to have had some experience of this depth of dive. The facts of this fatal incident can never be known but nitrogen narcosis, and possibly cold, could explain the seeming failure to seek aid from others if in trouble, or to drop his weight belt or to inflate his vest. Pulmonary barotrauma with air embolism was not necessarily the cause, but is a possibility.

SEPARATION. 40M DIVE. DEATH DURING ASCENT. UNKNOWN FACTORS.

<u>Case SC 81/4</u>

Two sets of diving equipment were hired by the victim's friend, a newly certificated diver with a short experience of diving, as he intended to show his two friends how to dive while they were on holiday at a caravan park near the mouth of a river. He gave them verbal instruction one evening and the next day offered them a chance to try a scuba dive. They had a boat and he first gave the victim's friend a chance. He entered the water first and then she followed. Her mask immediately flooded and she sank to the river bed, 6 feet below, because she was excessively weighted. She was unable to rise until he assisted her. He later stated that they had a quiet swim around, while her version was that she returned immediately to the boat and refused to have anything more to do with diving.

Later in the day they landed on a beach near the mouth of the river and the victim decided that he would try to scuba dive. The buddy gave him a couple of practice immersions in 1m deep water, with oral inflation of the vest experience, before making a short underwater swim in slightly deeper water near the beach. After a short time the victim indicated that he was tired and wished to return to the beach. It is not known whether his earlier difficulty in getting a comfortable fit with his fins had been satisfactorily resolved, but he had no wet-suit and was overweighted. The weight belts, being hired, had weights which could not be removed and the buddy, who had a wet suit, chose the weight most appropriate for his own needs, the lighter belt. He claimed that he had been taught that one always wore a weight belt even if without a wet suit, compensating by vest inflation. The organisation concerned deny that he was ever told anything of the sort. Possibly he had never given any thought to the matter before questioning at the inquest. During the return to the shore the victim swam on the surface using his scuba regulator while the buddy swam behind and below him. Foreseeing no problems, the buddy swam below the victim and reached the shore first. He noted that his friend was only a few yards away then turned and removed his tank. When he looked next he could not see any sign of the victim, not even bubbles. Initially he thought that a trick was being played on him or that the other had decided to continue and dived again, then he became alarmed and started a search both from the shore and in the water. The police were informed and called in an experienced local diver, who quickly located the body.

The sea bed slopes rapidly in this area so though the victim was last seen where water was about 5 feet deep, he was found where the depth was 18 feet. Both fins and mask were off but the weight belt was still in position and the vest uninflated. Possibly this totally inexperienced and untrained men, fatigued and over-weighted, lost mask and fins while out of his depth and inhaled water, dying rapidly before solving his survival problems.

The buddy had intended to let his friend try a pool dive first, a safer proposition than open water, but the pool had been closed.

FIRST SCUBA DIVE. HIRED EQUIPMENT. OVERWEIGHTED AS BELT WEIGHTS FIXED. SEPARATION. SURFACE PROBLEM. LOSS OF FINS AND MASK.

Case SC 81/5

While their friends were preparing a BBQ, two of the party had a beer each and prepared to dive. The buddy, who had been diving for 10 years, had hired two scuba units so he could take his friend for his first dive. One of those remaining on shore offered to time them and let them know when their air would be getting low (sic). It was realised that something was wrong when the buddy surfaced about 10 minutes later, about 5m off the shore, and called for help. He later described how they had been swimming over the sea bed in 10 feet deep water when the victim tapped him on the shoulder and pointed to show that he had some water in his mask, then pointed to the surface. He had seemed to start towards the surface then to be kicking his way along the sea bed with one flipper missing, soon losing the second fin also. The buddy was close behind and picked up both fins. He tapped the victim on the shoulder to offer them back, then noticed that he had now lost his mask and no longer had the regulator in his mouth. The buddy put his own regulator in the victim's mouth and tried to ditch his weight belt, but the victim was kicking wildly and dislodged the buddy's mask. This forced him to surface as he could hold his breath no longer, dropping both his weights and tank to assist his escape from a risk of himself drowning. Without a weight belt he was unable to descend again, having excessive buoyancy. Recovery of the victim was affected by others of the party after they first dived and rescued the tank and weights. All equipment was later recovered and confirmed to be functioning correctly.

FIRST SCUBA DIVE. HIRED TANKS. SHALLOW DIVE. LOSS OF FINS AND MASK. RETAINED WEIGHT BELT. BUDDY MADE VALIANT ATTEMPTS TO SAVE. SEPARATION DURING INCIDENT.

Case SC 81/6

From the information available, it seems that the two divers had 2 to 3 year's scuba diving experience each, but neither had received formal instruction. They were fishing for crabs and crayfish around a reef they reached by swimming from the shore. The water was choppy though calm underwater. After a while they surfaced and sat on the reef to talk. They were low on air so the buddy said that he would dive to collect the catch bag while the victim started the return to shore. When he surfaced he observed his friend on the surface proceeding as arranged, so he himself swam underwater (to avoid the chop) until he was forced to surface through running out of air. He completed his swim using his snorkel. After arriving he discovered that his friend had been seen waving his arm and heard to shout for help before disappearing from sight. He attempted a search but was unsuccessful, though later searchers recovered the body 3 hours later from 20 to 25 feet deep water.

Examination showed that the tank was empty and that the weight belt was still on, the quick release jammed under the tank at the victim's back and out of his reach. This had resulted from its excessive looseness. The victim had no buoyancy vest and distained to carry a snorkel "because it gets in the way". He had been unable to survive the surface swim fully weighted in choppy water without a snorkel, drowning as he had no buddy to assist him.

SEPARATION. SURFACE CHOPPY WATER. NO VEST. NO SNORKEL. LOOSE BELT TURNED SO UNABLE TO

REACH QUICK RELEASE. FAILED TO DITCH EQUIPMENT AS SITUATION REQUIRED.

Case SC 81/7

The victim was a professional diver of many years' experience. With a companion he was using a heavy scrubber to clean the hull of a vessel in a harbour. The job lasted all day as time was important, the divers standing in the open cool of the wharf between dives in the cold dirty water. Before entering the water for the last time the diver pulled his reserve lever. After a short time he indicated to his buddy that he was low on air and they both started to ascend. When he failed to surface a search was organised and he was discovered, unconscious, on the harbour floor. It is not certain whether life was then extinct or whether he died after he had been brought out of the water.

FATIGUE. COLD. OUT OF AIR. DIVED WITH RESERVE ON. NO LINE IN POOR VISIBILITY WATER CONDITIONS.

Case H 81/1

Two very experienced hookah divers were in a kelp area where there were many fish to watch and crayfish to catch. After about 45 minutes at 45 feet the buddy found that his hose was entangled in the kelp and had to ditch his weight belt (with the attachment hose) at 14 feet and surface. This equipment was retrieved by his friend.

After a rest and a light meal they dived again, this time for 15 minutes. The buddy then indicated to the other his intention to return to the boat and that the other should follow him. The signal was acknowledged. The buddy again found himself fouled on the kelp and had to ditch his equipment, making a successful ascent despite the failure of his buoyancy vest to function. After surfacing he orally inflated his vest and swam to the boat.

About 5 minutes later the other diver surfaced 30m away, gave the “OK” signal and took the regulator out of his mouth. He had a catch bag containing crayfish in one hand and called to be pulled back to the boat. When last seen he was vertical in the water, at which time his hose had become taut and the people in the boat were concentrating on winding the hose back with a reel. When they next looked, he was no longer at the surface and they presumed initially that he had dived to free his hose from kelp. However, they noted that there were no bubbles apparent and became worried. The buddy put on mask, snorkel and fins and dived to find out what had happened. The victim was found thoroughly entangled in kelp, apparently dead. With some difficulty the body was pulled to the surface.

The hookah equipment was tested and found fault-free, the hose kink resistant. However; the victim's vest was found to contain no carbon dioxide cylinder, though this is unlikely to have affected the outcome of this incident. The pathologist reported the cause of death as asphyxia due to failure of the air supply and did not accept the possibility of “dry drowning” as a cause. It is possible that the victim was dragged underwater unexpectedly when the hose became hitched around kelp 15 feet below the surface, suffering laryngospasm and cardiac death before he could replace his regulator or drop his weight belt. Hose kinking, though possible, could only affect him if he had been using his regulator at the critical time. This tragedy, involving careful, safety conscious divers with good equipment, occurred when the victim was unobserved and alone at a critical time while on the surface.

SURFACE. HOSE FOULED ON KELP UNDERWATER. VICTIM PULLED UNDERWATER AND TANGLED IN KELP.

Case H 81/2

Hookah users are prime examples of the Sword of Damocles situation, for they can pass from complete ease to an emergency (out-of-air) situation with extreme rapidity. The two divers in this incident were at 30 feet catching crayfish when their friends in the boat noticed that the pressure gauge on the reserve air tank showed falling pressure. Both hose lines were therefore given three hard pulls and then a start was made to pulling the hoses into the boat. A short time later there was a small explosion as the leaking gasket on the compressor completed its failure.

It was apparent that the victim had started to ascend so attention was concentrated on the other diver, who had surfaced but seemed to be in a distressed condition. It was only after he had been pulled into the boat that it was realised that the victim had failed to surface. He was seen to be hanging motionless about 15 feet below the boat, a “dead weight” and no bubbles seemed to be ascending. The hose parted at the connection with the regulator hose unit when it was pulled to raise the body. The condition of the survivor gave them so much worry that they abandoned further attempts to recover the body and ran the boat straight back to the beach to obtain an ambulance. It is believed that the survivor's distress was the result of swallowing, and possibly also inhaling, some water. The body was recovered later with the weight belt still worn. It is not known why the victim failed to drop his belt while ascending when the air supply petered out. Pulmonary barotrauma with air embolism may have occurred but the autopsy report is inadequate to decide this point.

HOOKAH FAILURE. DEATH ON ASCENT.

Case SC 80/6

This case is reported as a late addition to the Provisional Report on the 1980 fatalities. A group of six friends hired four scuba units with the intention of diving for crayfish. One of the group had some experience of diving with an experienced local diver whose name they used in the dive shop. Because of their inexperience (sic) the victim was paired with another of the group. This was to be the victim's third dive, both previous dives had been in sheltered water (that and the previous day). No fear was felt before undertaking this dive “as he had already dived to 85 feet”. They intended to keep close together as a true buddy pair but came across some crayfish about 100 to 150 yards off the rocky shoreline in 20 to 25 feet deep water. The buddy asked the victim to return to the shore to obtain a catch bag, which he started to do, swimming on the surface using his regulator air supply.

A short time later the buddy followed underwater and saw the victim above him treading water. He surfaced and found that the victim had lost his mask and dentures and was unable to retain the mouthpiece. After a short struggle the buddy dragged the victim to a rock and started to pull him out of the water, but a large wave washed them off and contact was lost. There was a surge building up, especially over the rocks, making conditions unsafe for inexperienced divers. The victim was recovered a couple of hours later by an experienced diver. The weight belt was missing, presumed dropped by the victim.

THIRD SCUBA DIVE. HIRED EQUIPMENT. SURFACE DIFFICULTY. INEXPERIENCED BUDDY MADE VALIANT EFFORTS TO SAVE VICTIM. NO VEST. WATER POWER EXITING PROBLEM. LOST DENTURES CRITICAL.

DISCUSSION

Snorkel Deaths

There continues to be a welcome absence of deaths of spearfishermen resulting from the practice of hyperventilation. The two snorkel users reported indicate areas of danger marginal to "diving" but of potential significance, the use of snorkels by those who are insufficiently good swimmers to manage the problems which may arise, and the possibly increasing danger to all types of swimmers from the near-to-shore use of powered boats. It is unrealistic to suggest that every swimmer show a flag while near to the shoreline, though not when diving or swimming in sea lanes. A number of reports of serious but non-fatal incidents involving power craft suggest that the problem is requiring active attention by maritime organisations.

Scuba Deaths

The scuba fatalities, seven in 1981 and one from 1980, reinforce the generally accepted safety guidelines, beginning with the basic one that untrained divers are at risk if let loose in the sea. In all four fatalities involving totally inexperienced divers hired equipment was being used. Separation was a factor, as was the need for efficient buoyancy aid. The value of a snorkel and the helplessness of the scuba diver bereft of his fins is also apparent. The value of a buddy should be again apparent, despite the failure of the two buddies to save their companions under unusually difficult circumstances.

The divers who were experienced who died had all broken the accepted rules for safe diving, all being considerably separated from their buddies at critical time. The asthmatic whose death is reported died through a combination of factors, the death card being the mistake of ditching his back pack. Had he worn a conventional vest he would have survived, as also he would have done had he remained calmly on the surface and allowed his buddy to tow him to the beach. Panic, which can affect ANYONE under stress conditions, denied him this option. The professional diver's death illustrates that even the experienced cannot afford to take chances; one day comes the reckoning. Here the unadvised practice of diving without a line with scuba in a low visibility situation without possibility of direct ascent to the surface (he was under the ship's hull) was compounded by fatigue and cold impairing alertness when the out-of-air situation arose.

Hookah Deaths

Hookah divers should be constantly aware of the possibility that their air supply can be suddenly unavailable. The two victims here reported were experienced and could have been expected to survive such incidents. In the first case the kelp was a scenic and fruitful but entangling environment. The buddy had two unpleasant emergency ascents because of hose entanglement, having to ditch his belt (and regulator) on each occasion. It seems probable that the victim was surprised by his submergence and thereby was too late to ditch his belt before becoming totally entangled in the kelp and losing his air supply. Strangely, for they were careful divers, both had inoperative buoyancy vests. The second hookah fatality cannot be readily explained, though air embolism could have occurred, those in the boat being too occupied to notice the victim's momentary surfacing (if it occurred). As the air loss was not instantaneous, an experienced hookah diver would have been expected to survive.

Advice

Had all these scuba and hookah divers dived "by the book" they would have most probably survived. The fewer the chances taken, the greater the favourable factors in the dive plan, the better the expectation that misadventures are survived comfortably. Think and act to keep the odds in your own favour.

ACKNOWLEDGEMENTS

This report, like its predecessors, could not have been made without the ready support and assistance of the Attorney-General's and Justice (or Law) Department in each State, the co-operation of the Police in elucidating extra details in certain cases, and the active interest and assistance of several organisations and individual divers. The active interest of the Water Safety Council in NSW, South Australia and Western Australia in this investigation is noted with appreciation, and in particular the support over the years of the AUF and FAUI. Many others, unnamed, have greatly assisted with information, news cuttings and encouragement. It is hoped that such support will continue and additional persons and groups will become involved.

PROJECT STICKYBEAK

This project is an on-going investigation seeking to document all types and severities of diving-related incidents. Information, all of which is treated as being CONFIDENTIAL in regard to identifying details, is utilised in reports (such as this) and case reports on non-fatal incidents. Such reports can be freely used by any interested person or organisation to increase diving safety through better awareness of critical factors. Information may be sent, in confidence, to:-

Dr DG Walker
PO Box 120
NARRABEEN NSW 2101

FIRST AID PRIORITIES FOR DIVERS THE TOBERMORY VIEWPOINT

G Harpur

Due to the large number of divers attracted to the Tobermory area by the clear waters and abundant marine artifacts, we are provided with many opportunities to examine those events surrounding diving accidents which influence their outcome. In the past year approximately 30,000 dives were committed, principally between the 24th May and the Thanksgiving weekend in October, by some 7500 divers of whom 30% were student divers on their initial open water experience. Since 1974, there have been 36 accidents resulting in major injury to divers as well as countless minor incidents with less serious sequelae. In this paper I intend to present a review of the more serious incidents and accidents with particular attention to those factors which contributed to the serious or fatal outcome.

Our figures indicate that on any given dive in the last two years, the diver's chance of being injured was 0.04% and of being killed was 0.003%. These figures do show a higher incidence than is reported elsewhere, eg. the Rhode Island surveys, and may reflect the effects of cold water and the high proportion of novice divers. Training accidents have been rare, with only 1 fatality and 2 serious incidents occurring in the past 7 years.

There have been 16 deaths in the period 1974 to 1981, out of a total of 36 serious accidents. Of these deaths, 11 died before reaching the surface, 3 died after reaching the surface but before reaching the recompression facility and 2 died after completing an initial treatment table. The remaining 20 divers all survived and were entirely intact, so far as could be clinically determined, after one or more treatment runs. There were no survivors who sustained any long term injuries as a result of their accidents. This type of sharp division is probably unusual and can be most likely explained by the unique character of our situation in Tobermory. Most of the diving takes place within the confines of Fathom Five Provincial Park and this area is controlled by both OPP (Ontario Provincial Police) and Park staff routinely, so a very rapid response to any accident is possible. The average time from the victim arriving at the surface until being placed back under pressure, when indicated, is between 30 and 40 minutes. This organization also permits a very detailed investigation of each incident and accident to be carried out at the same time as the victim is being treated. Park staff and OPP dive team members conduct interviews with other members of the diving group. In more serious cases, exhaustive studies are conducted on the equipment and air supply, with the assistance and such technical support as DCIEM (Defence and Civilian Institute of Environmental Medicine) and the Centre for Forensic Science in Toronto.

TABLE 1

FACTORS RESPONSIBLE FOR INCIDENTS WHERE A DIVER FAILED TO SURFACE OR SURFACED WITH ASSISTANCE

DIVER FITNESS

Training

- None or taught by a friend
- Diving alone
- Improper response to:
  - freeze-up
  - emergency ascent
  - buoyancy control
  - shallow water blackout

Psychological State

- Unfit
- Temporary conditions
- Pre-existing long term conditions

Medical Conditions

- Temporary
- Pre-existing long term

EQUIPMENT

- Inadequate
- Malfunction

RESCUE

- Poorly organised or no plan
- Improper technique

If we consider first the group of divers who failed to make the surface on their own, we can divide them into subgroups according to the various factors which accounted for this failure in each case. In some of the accidents, more than one of the factors listed in Table 1 may have been present. The following brief case histories serve to illustrate these points.

DIVER FITNESS

TRAINING

Fortunately we have not encountered many cases of diving without formal instruction which have resulted in problems in Tobermory, although these are common elsewhere. The one example we have illustrates a combination of informal instruction, diving alone and inadequate equipment.

<u>Diving Alone</u>

PH, a 26 year old male, who had just completed his PhD in Maths and Physics, and who was a self taught skin diver, was free diving to 50-60 feet depth in an area off the shore of Georgian Bay which had a flat bottom, sloping gradually to depth in excess of 100 feet. He had no buddy, but there were several groups of scuba divers in the same general area. His friends on shore wandered away for a period, as they were accustomed to his being out for periods up to 90 - 120 minutes. He was not on the shore or visible in the water when they returned. After a period of confusion and trips to his car 1 mile away, the alarm was raised. It was now dusk. His body was located the next morning by OPP divers in 70 feet of water. It was on the bottom with 16 lb of lead in place, a full wet suit, mask and flippers and no buoyancy device. Another weight belt, visible from the surface, with 18 lb of lead on it, lay nearby. Autopsy determined the cause of death to be drowning. His lack of adequate training undoubtedly left this diver unaware of how rapidly shallow water blackout occurs, and his lack of a vest reduced his options.

We have not been able to document a single case in which equipment malfunction directly caused a diver's death or injury. It has always been the diver's response to the problem which results in the pathology. Recognition of the malfunction and effective management of it are part of good diver training. The following cases illustrate areas where the job is still being inadequately done.

Inappropriate Responses: Freeze-Up

Regulator freeze-up is a common event in cold water, which is to say in all water deeper than the thermocline in Canadian lakes at any time of the year. Proper training should reduce unnecessary use of the purge button, anxious panting and heart exertion which encourage this problem. All students should be aware of the problem, exposed to it and taught how to recognize it and how to respond appropriately. That is by breathing off the free flowing regulator to the surface. Failure to do this has been the initiating event in several incidents, two of which resulted in fatality.

In the first of these, the individual who died was an innocent bystander.

JM was an 18 year old male diver who, after qualifying the day before, was persuaded to participate in a badly conceived dive to 70 feet off Flower Pot Island. Four divers took part. Two had previous experience to 70 feet in warm water, and formed one buddy pair. JM's buddy had one previous dive to 100 feet in cold water. None of the divers were familiar with the site. No shot line was dropped to confirm depth, despite the fact that depths in excess of 300 feet are encountered in this area.

Difficulty with buoyancy control was encountered by all the divers during the descent as they had all weighted to neutral trim at the surface and failed to anticipate the effects of wet suit compression. This resulted in a rapid descent and the divers found themselves very unexpectedly at 90 feet, just 20 feet off the bottom in clear 4°C water.

At this point, one of the pair of warm water divers encountered a free flow probably secondary to anxiety and overbreathing. He abandoned his regulator and attempted buddy breathing, but was unsuccessful due to numb lips. His buddy now abandoned him, ascending rapidly. JM's partner, the most experienced diver, took over. The three remaining divers were on the bottom at 110 feet at this point. The CO2 cartridge, a 25 g size on the victim's vest had been pulled with no apparent effect. (See the later section on vests). The attempts to force buddy breathe the victim were moderately successful. This pair of divers swam up after dropping the victim's belt. JM was following in no apparent difficulty. At 50 feet the rescuer ran out of air, pulled his reserve and continued up with the victim. JM was still in attendance. At 30 feet the rescuer completely ran out of air, dropped his weight belt, blew his vest and released the victim who was now positively buoyant. Both divers arrived on the surface where the other diver was waiting. The victim was in fair shape although he underwent prophylactic recompression for possible cerebral embolism at Toronto General Hospital later.

JM never arrived at the surface. Lack of planning led to confusion and delay in the rescue attempts. The body was recovered 4 hours later by OPP divers on the bottom, in full gear with his vest and CO2 cartridge intact (ie. not activated). Autopsy showed death was due to massive air embolism. The degree of mask squeeze present suggested that JM made a breath hold lunge for the surface when the other divers took off from 30 feet. His tank contained air and there was no evidence of equipment malfunction.

Although JM did not encounter free flow, the failure of the initial victim to deal properly with this event initiated the sequence which led to his death.

The second example illustrates a much more direct effect.

SG, also an 18 year old male, was making a dive on the Arabia, which lies in 110 feet of water. He too was a low time diver, but did have several hours of post certification diving at depths of up to 40 feet in cold water. The temperature at 110 feet was 4°C as usual and the visibility 40-50 feet in low light. He encountered a free flow at 100 feet early in the dive, and abandoned his regulator. His buddy commenced buddy breathing with him, but SG refused to return the regulator. The buddy dropped his belt, activated his $C0_2$ vest and swam up, dragging the victim, he thought, by the regulator. When he arrived on the surface, SG was not with him. The body was recovered several hours later in full gear and with an intact $C0_2$ cartridge. Autopsy showed death had been due to massive air embolism to all major vessels, with damage to both lungs. Panic induced by an inappropriate response and the surprise of an unfamiliar problem had claimed another victim.

There were also many minor incidents which avoided a similar conclusion only by chance. One, which was somewhat amusing, involved a fellow and his girl in 30 feet of water. The girl encountered a free flow and abandoned her regulator. He being chivalrous, gave her his. She refused to relinquish it. As in the last case, he bounced to the surface, dragging her with him, but in this case she was unharmed. The abrupt development of a romance-shattering insight was the only damage done.

The major problem in all these cases arose because of an inappropriate response ie. abandoning the regulator. This indicates a flaw in basic training. Good free flow simulation is possible. OUC have recently published a modification to a standard scuba set, devised at Tobermory, which will permit any student to be exposed to this problem and its management, in the safety of the pool.

Inappropriate Responses: Emergency Ascent

Even with the best of training and planning and equipment, if one dives long enough one will encounter an out of air situation, more frequently if one neglects any of the foregoing.

The inadequacy of the responses currently being taught for use in this situation, are illustrated by the next series of cases.

JK was another 26 year old male diver. The frequency of this age and sex combination begins to look like an ill omen. He was performing an emergency ascent from 30 feet in open water as part of his graduation exercises. The drill to be followed was:

1. remove the mouthpiece

2. undo the weight belt and pass it to your buddy

3. swim up, humming constantly, with the instructor and flare at about 5-10 feet.

JK commenced his drill but fouled up at 2, when he undid his tank strap. He replaced his regulator, refastened his strap and after a brief rest, started again. He completed the exercise correctly and was observed to be exhaling, presumably by humming, throughout the ascent, by his instructor. At the surface he was immediately asked how he felt. He replied, “I feel fine”, just before passing out and convulsing. CPR was effectively applied and he was evacuated to the beach and subsequently to the hyperbaric chamber, in approximately 25 minutes, where an immediate table 6A with extensions was commenced. He recovered spontaneous respiration and circulation after drainage of bilateral pneumothoraces, and remained stable without any recovery of cerebral function despite repeated recompression. He died 4 days later of brain infarction. Examination of his equipment and gas analysis revealed no problems.

JK had approximately 10 litre lungs. If we assumed that he near filled his chest before his attempted ascent, the outcome is easy to explain. Humming does not permit a lot of air to escape. The amount necessary to produce a good hum can be as little as 50 ml/second. A hard hummer can get rid of 500 ml to 1 litre/second, but averages are probably around 250 ml/second. From 30 feet to the surface, JK had to clear 9 to 10 litres if he was to avoid disaster and his ascent time was 6 to 7 seconds. Humming obviously could not do the job. Unfortunately the lungs provide little warning of the impending disaster as evidenced by his “fine”. The tragic part is that his unimpeded airway had the capacity to handle flows in excess of 10 litre/second, more than 6 to 7 times his requirement. The obvious solution is to teach an ascent technique which keeps the airway open. (See continuous breathing cycle ascent below).

Probably the commonest emergency ascent technique taught is the continuously exhaling pattern. This mode of ascent was definitely used in 8 of our embolism cases who survived, in one of the fatal cases for certain, and it is highly probable it was the technique used in 4 others. This constitutes about 60% of the fatalities and about 75% of the casualties due to ascent technique.

The case of diver TR, a 42 year old male, assistant diving instructor illustrates this very well.

TR had completed a well organized dive with his club on the Arabia and was making the ascent from 110 feet when he decided that since he was ascending a little faster than the normal 60 feet a minute, he should probably do what he taught his students to do during fast or emergency ascents, ie. exhale continuously.

This was the last thing he could recall until he came to in the hyperbaric chamber some hours later. He had arrived at the surface unconscious and not breathing, brought up by his own vest due solely to vest expansion. He had some frothy red sputum coming from his nose. His group followed their emergency training and commenced artificial respiration (AR) with the victim on a 20° head low slant and transported him to the chamber. On arrival there he was breathing spontaneously, coughing up some bloody sputum. He was still very obtunded, responding only to deep pain. Rapid recompression on a table 6A resulted in dramatic recovery within 15 minutes. He was confused for the first 90 minutes after full recovery of consciousness. He kept asking how he could possibly have embolised, as he was so positive about his decision to exhale. We reassured him that although many would doubt him, we did not and explained the mechanism of small airway closure to him and the hazards of exhaling ascents. The sad part is that this diver had adequate air supply and stopped breathing only because he was misinformed.

The degree of embolism sustained in this case was obviously slight and this is typical of the injury which results from low volume air embolism. The embolism does not usually kill directly, but does alter consciousness and lead to drowning. These cases are often missed at post mortem as not many pathologists are well versed in the mechanics of diving injuries. This problem, like that created by the humming ascent, is avoided by the continuous breathing cycle ascent protocol.

Inappropriate Responses: Buoyancy Control

In many of the cases where the diver died, the cause of death was drowning and the embolism or hypoxia or fatigue which led to this outcome were not in themselves serious. In these instances a failure to get to the surface or a failure to remain there, was the critical factor in determining the outcome. Many critically injured divers survived because they reached the surface. All of those who remained on the bottom or returned to it, died.

This underscores the importance of the diver making certain that he will continue to ascend even if he loses consciousness. None of the divers recovered from the bottom had dropped their weight belt, and none had deployed the $C0_2$ cartridge or otherwise fully inflated their vest.

The case of PH cited earlier, illustrated the effects of hypoxia in free diving. Many scuba divers fail to appreciate that once they are out of air they too can become critically hypoxic during ascent for the same reasons. Calculations show that a diver who runs out of air and then attempts to swim up with no assistance from vest or from dropping a weight belt runs a significant risk of abrupt loss of consciousness during the ascent if he starts deeper than 50 feet. In trial runs from 60 feet in the chamber at Tobermory while exercising at a level equivalent to such a swimming ascent, two subjects were unable to complete a simple secondary task all the way up, both becoming confused at depths greater than 6 to 7 feet. A repeat run from 90 feet resulted in one subject getting into difficulty with confusion at 21 feet, the other at 13 feet. Such confusion under water could result in loss of control and breath holding, with subsequent embolism or aspiration of water and drowning.

A good example of this is the case of LC, a 27 year old diver on her first night dive in the company of an older more experienced diver. The dive was planned to 30 feet, but the area of the dive included depths to 90 feet. Both divers were weighted for a neutral trim at 18-20 feet with 12 lb and 14 lb lead respectively. Some incident led to both women embolizing and neither shed her weight belt or inflated her vest, but one surfaced, the other, LC, was recovered the following day, having drowned following a minimal embolism. I wish I could say the other survived, but she did not for a series of reasons I shall deal with later, but she had a chance, LC had none.

PSYCHOLOGICAL FITNESS

Many of the incidents, especially those which commence with free flow, indicate that the diver involved was under excessive pressure at the time of the incident. Most frequently this stress appears to originate in peer pressure. The low time diver attempts a dive which takes him out of his depth and experience in order to be one of the group and prove that he can hack it thus setting the stage for tragedy. As this factor is apparent in many of the cases cited, I will give no specific example.

This same problem, diving while under excessive duress, has led to two cases of spurious decompression sickness. Both of these cases presented as type two decompression sickness but the findings were inconsistent and the complaints variable. Resolution of one case required a sham chamber treatment with descent to 3 feet on compressed air resulting in an abrupt and total resolution of all symptoms and signs.

MEDICAL CONDITIONS

Temporary

Medical fitness or rather the lack thereof has been a significant factor in both incidents and fatalities. Temporary disability of minor degree has served as the trigger factor in several cases and the commonest example is difficulty with ear clearing. It would appear that we are not doing a very good job of training people in this area. We conducted a survey of novice divers during the summer of 1978 with the results shown in table 2.

TABLE 2

DAMAGE TO THE EARS OF 186 NOVICE DIVERS

No Barotrauma	79
Minimal	29
Moderate	70
Severe	8
(Bilateral)	(11)

The interesting point about this is that despite the fact the two-thirds had significant trauma to their ears, only one or two recognized this fact.

Most of the problems created by this sort of trouble have been minor. We see a steady stream each summer that we refer to as investors. The people leave home 200 or 300 kilometres away without checking that their ears can clear. They arrive in Tobermory, pay for their charter, rent equipment and get teamed up with a buddy, and still have not checked that their ears clear. Finally at 10-15 feet on the first dive, with all their money and time invested, they discover that their ears are going to be difficult. They proceed to try everything known to God and Man to get those ears to work, frequently winding up in our hands with various types of squeeze or worse.

The effects are not always trivial. There has been one case of a diver, GP, in whom air embolism resulted from panic at 10 to 12 feet over ear pain. He made a breath hold ascent and became confused with bloody cough and voice changes. Response to therapy was excellent and a modified table 6A resulted in his total recovery.

Most serious problems arising as a result of temporary disability are a result of diving while under the influence of drugs, the commonest being alcohol. The partner in the case of LC cited earlier, was a 42 year old female, KC. What event led her to embolize during that night dive was unknown. She came to the surface where she added fresh water drowning to her problems because her face was not supported free of the surface with her weight belt on and the vest was not inflated. She vomited and aspirated during resuscitation attempts. Despite effective CPR and surviving her initial chamber treatment, she eventually died with the following injuries: massive air embolism of the cerebral vessels, aspiration pneumonitis and fresh water drowning. Her blood alcohol was reported as twice the legal limit.

Fatigue, alcohol and decongestants figured in the temporary disability which led to the death of. TR, a 26 year old male diver. TR drove up to Tobermory during the night, arriving at 0600 hours having imbibed liberally en route. During his first dive of the day at 1000 hours he experienced difficulty with his ears. So he took a couple of Sudafed tablets. This was his first experience with this particular medication, and for good measure he washed them down with a couple of ounces of rye. Two hours later he made a dive to 40 feet for 45 minutes. He made an abrupt swimming ascent for reasons which were never elucidated. At the surface, he was confused and could not stay up, succeeding neither in releasing his weight belt nor in inflating his vest. He subsequently lost contact with his buddy and sank. He was recovered by other divers in a few minutes at a depth of 4 feet. He was unconscious and failed to respond to attempts at resuscitation. The cause of death was drowning secondary to minimal air embolism.

Street drugs probably played a significant role in the death of LS. This 23 year old diver approached two other divers at 100 feet with his regulator out. He took the regulator offered him and took one breath, returned it, then refused to take it back. The rescuer had located his octopus and offered the regulator to keep, but it was refused. The victim was now in total panic and holding tightly onto part of the wreck Arabia. The rescuers pried his fingers loose and took him up, squeezing his chest, pounding his gut and doing all the things they had been taught to make him exhale.

Unfortunately an air breathing mammal underwater in severe panic will give you almost anything, his lunch, his blood, but not his air so long as he remains conscious. Thus the diver predictably held his breath and sustained a massive degree of embolism resulting in instant irreversible death. Subsequent investigation showed that hallucinogens and cannabis had both been in use.

A more effective job of educating sport divers to the hazards of diving while impaired physically, emotionally or pharmacologically is the only thing that will reduce the frequency of these occurrences.

<u>Long Term Pre-existing Conditions</u>

The presence of a long term pre-existing medical condition which should contraindicate diving is becoming alarmingly common. What is most disturbing about this is that many of these divers with a history of epilepsy, or asthma, have reported their illness to the physician who did their screening physicals, required to enter Scuba training by most agencies, and were cleared as completely fit to participate in the sport. The consequences of this are well demonstrated by several incidents. I will cite two.

GB was a 42 year old diver with a long history of epilepsy which had been under control for more than 20 years, but which still required that he take Diazepam (Valium) on a regular basis. During a dive to 50 feet, off Lighthouse Point in the Tobermory harbour area, he lost consciousness during ascent while separated from his buddy. Fortunately he was positively buoyant and continued to the surface. His luck at the surface was good as he popped up under the nose of some well trained people who cleared his airway of vomitus and administered effective CPR, which was required. When he arrived at the Hyperbaric facility 20 minutes later he was still comatose and requiring AR, but now had spontaneous heart action present. After 15 minutes at 165 feet he showed no signs of recovery. When placed on a breathing mixture of 50% N_2 and 50% O_2 he responded rapidly. Within 5 minutes he was awake but struggling and confused. He remained confused for 4 hours while an extended table 6A was carried out. He then abruptly recovered totally except for a short period of amnesia surrounding the dive. The difficulty with short term memory persisted for several days. His subsequent course was one of total recovery with no sequelae. He no longer dives.

The second case is that of a 59 year old male, VK, who had pre-existing arteriosclerotic heart disease with a rhythm disturbance, requiring medication, and chronic obstructive lung disease of moderate degree, also requiring medication. At 110 feet on the Arabia this diver became stuporous and confused, but was brought up under control by his smaller female buddy in a truly remarkable display of good diving skills effectively and calmly applied. He was coughing bloody sputum and unconscious at the surface requiring AR. Recovery was rapid but complicated by aggressive behaviour and confusion adding to the problem of his management. At our unit he presented as a case of definite pulmonary barotrauma with bloody, frothy sputum and of fresh water near-drowning of significant degree superimposed on the original maladies. Hew as hypoxic and confused to begin with. This had been clearing during evacuation and with O_2 and a head low position continued to do so. He had no pneumothorax. However X-rays confirmed the presence of near-drowning and the pre-existing emphysema. As he was improving he elected not to use the chamber in the face of the serious pre-existing disease. Had he been worse or deteriorating our hand would have been forced. He subsequently made a full recovery. I am sure the possibility of a fatal outcome was not missed by much.

To reduce this sort of problem we have just drafted a short article outlining the hazards of scuba diving and listing the factors to be looked for during medical examination to determine fitness for the sport. This is to be reproduced in the journal of Family Medicine and the Medifacts tapes system, which should bring it to the attention of a majority of primary care physicians in Canada.

EQUIPMENT

Regulators

Many of the cases already cited illustrate equipment shortcomings. Regulator freeze-up can be managed. While it cannot be completely prevented by current single hose designs, many companies have produced products which are more resistant than others. To achieve low breathing resistance, high peak flows are required. Many designs have pursued this goal, neglecting the fact that these higher flow rates imply greater cooling and therefore greater risk of freeze-up. Divers should be made aware of those designs which best meet both criteria such as the excellent line by Sherwood which we have found very freeze-up resistant.

CO_2 Vest

In cold water the performance of these vests at depth is pitiful (Table 3). Below 60 feet CO_2 vests are wholly inadequate in our 4°C waters, even with the largest of cartridges. A vest can be used as a last resort air supply if fitted with the right mouthpiece and if the skill is practiced, but if it is full of CO_2 breathing would of course only hasten your demise. A CO_2 cartridge with a power inflator does not ease the problem as the one time you really need that vest is when your air supply has gone.

TABLE 3

CO_2 VEST BUOYANCY

Cartridge size	Lift at 90 feet in 5°C water
38g	5 lb
25 g	2-3 lb
12 g	1.5 lb

(Average Canadian diver-buoyancy at the end of expiration is 4 lb negative. This becomes 6 to 8 lb negative if water is inhaled).

Two young divers, MZ and JS died while diving the wreck of the Forest City. These divers were wearing CO_2 vests which at 150 feet would provide 1.25 pound lift when deployed against net negative buoyancies of approximately 10 to 12 pounds. Neither reached the surface nor survived, so the exact role played by this deficiency remains speculative.

The diver TR referred to earlier droned because he failed to inflate his vest on the surface. He was unable to do so because it had a power inflator but he was out of air. It had an oral inflator but he was fighting so hard for breath he could not spare any. It had no CO_2 or alternative last ditch fill system.

The solutions are fairly obvious and simple. An independent fill system for the vest. This should be breathable one is diving in cold water deeper than 50 feet. The training required for safe use of the system should be part of all diver courses. There is a new inadequacy in equipment which, as far as I am aware, has yet to produce a casualty that I would like to mention in passing.

Stabilizing jacket

The stabilizer jacket is being widely promoted as the ideal buoyancy device. While it is compact and comfortable in most circumstances, fully inflated many models cause significant restrictions to respiration and a sensation rather like what I have always imagined the grip of an octopus might feel like. These effects could be devastating if experienced for the first time in an emergency situation. Divers should be cautioned in this regard. Details of the restriction to respiration will be included in a study to be published shortly.

Malfunction

Equipment malfunction was an initiating factor in many cases, including JM, SG and LS and a complicating factor in others, including TR and JG. *I would like to emphasize that the malfunction per se killed none of these divers. It was their reaction to the malfunction that did.*

RESCUE

This brings me to the last area of difficulty, the response to the accident by other divers. The most frequent cause of difficulty in relation to technique was with CPR. In three of four cases where divers reached the surface but died before reaching the recompression units, faulty or no CPR was involved. In the case of TR loose bridge-work lodged in his throat. The rescuers abandoned CPR on RR because the victim vomited. As Resusci-Anne never did that they were totally unprepared. In one case, no CPR was attempted because the victim was cold, blue and had dilated pupils.

Most divers could get 2 out of 3 on that test after any dive at Tobermory. In the case of KC the initial problems were compounded by faulty CPR, which fractured ribs and may have lacerated the lungs.

CPR training for divers needs to emphasize that unconscious divers in a head low position almost inevitably vomit, in a passive way and that to save these people you must be prepared to clear the airway, spit out the chunks and keep going. Divers must also be taught that the pupillary signs are totally unreliable when dealing with a potential cerebral air embolism.

Organisation and Planning

The following case illustrates almost every factor I have discussed and many more besides.

JG was a 30 year old diver, with low time diving with a group who did not know him or his experience beyond the fact that he possessed a C card. His girl-friend was along as part of the group so the pressure was on as the group decided to dive the Arabia. Dive organisation had been fairly good throughout the weekend, but for some reason which was never clear, it was now let slip. The divers were not in standard buddy teams. On the descent one female diver aborted after crossing the thermocline at 80 feet and was left alone on the descending line. JG continued down. After completing a part of the distance around the wreck one of the more experienced divers noticed that JG was already down to 750 psi and directed him back toward the ascending line. He then turned to signal the rest of the group to follow. The girl left behind was at 70 feet and came to the surface with the rest of the group, having encountered no other diver. At the surface, the captain of the charter boat, an interested bystander, pointed out that the group was a diver short and the search for JG began. There was no-one who had not already dived. So four of those in the water made immediate repetitive dives, one of them twice, using fresh tanks. Finally 20 minutes later JG was brought to the surface, dead. Death was due to massive air embolism of the brain and heart. Subsequent investigation revealed that the diver had encountered a free flow, ascended, embolized and sunk to the bottom where he was found. As a result of the repetitive dives committed, we wound up treating 1 case of type 1 decompression sickness and 4 cases of missed decompression. I do not believe an additional comment is required

The dual fatality of JS and MZ on a dive conducted without a safety diver, reserve air or communication 8 miles off shore, illustrated the same deficiencies. The old maxim, plan your dive and dive your plan really says it all.

LESSONS FOR FIRST AID PRIORITIES

In this review of the accidents at Tobermory I have attempted to review those factors which could be altered to improve the situation and prevent the accidents or improve the outcome.

First aid has obviously got to start with training if the figures are to change much. Of 15 deaths, 11 failed to surface which certainly limits one's options in dealing with these accidents. Universal adoption of the continuous breathing cycle ascent protocol below would eliminate most of the air embolism cases. Details of this protocol are available on request.

1. Do not remove the regulator from your mouth unless you have another to replace it with, or in cases of entanglement. The regulator provides a safety valve, and a possible source of air.

2. Continue to attempt to breathe in and out at all times even if out of air or without your regulator. This ensures an open glottis and larynx, and minimises the chance of small airway closure.

3. Make certain you become positively buoyant by inflating your buoyancy compensator or dropping the weight belt or both. This guarantees that you will reach the surface despite hypoxia.

CPR training is the most critical factor to date in determining the outcome if the diver surfaces.

Good dive organization ensures rapid response and prevents incidents from becoming complicated.

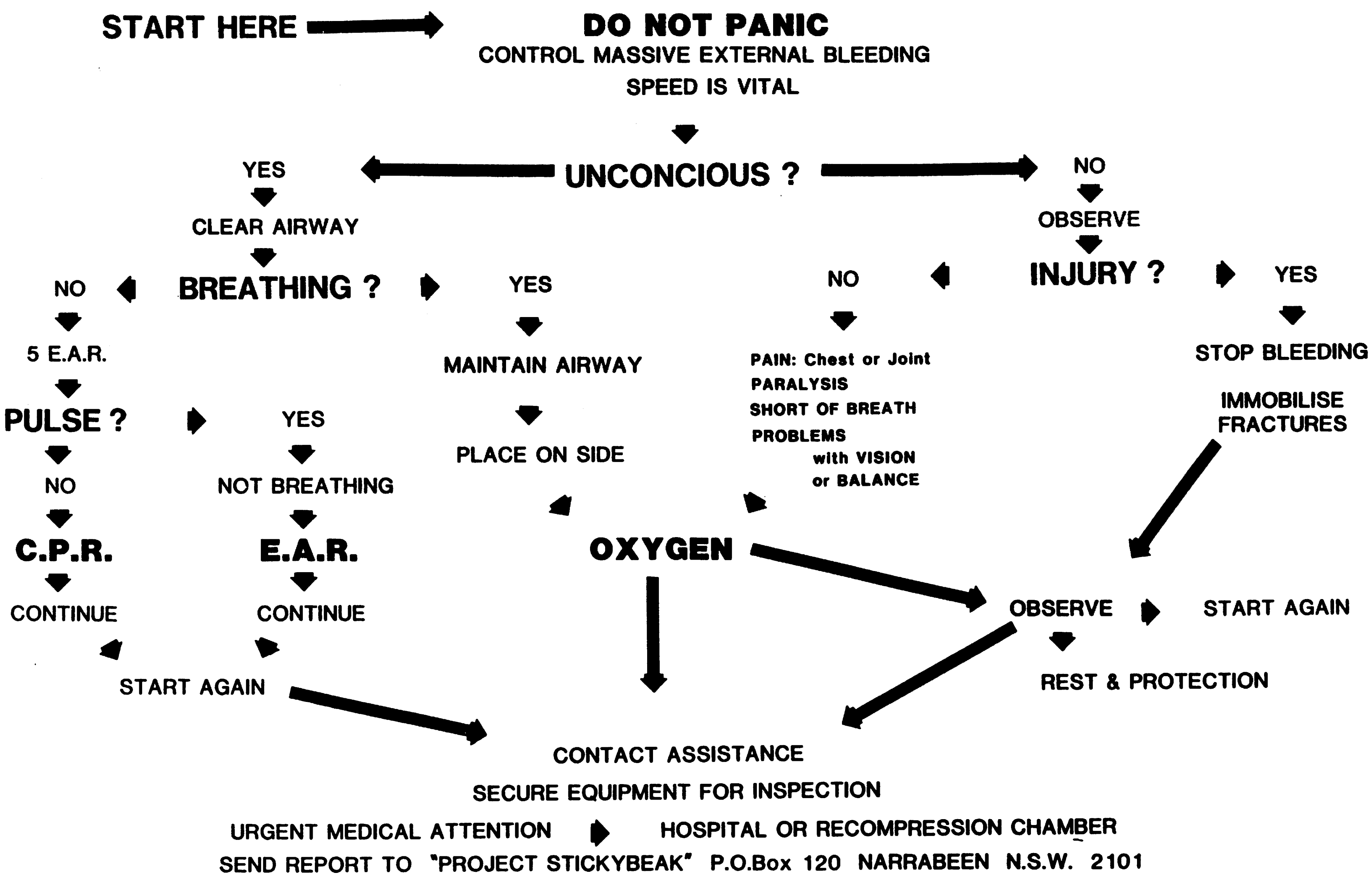
There is no conclusion to this paper, it is in fact merely a beginning in what we hope will become a broader, ongoing review of Canadian diving accidents and incidents leading to improved First Aid for Divers.

SPUMS MELBOURNE MEETING

A very interesting programme was available to members on November 20th. Unfortunately few members took the opportunity to hear Dr Peter Laverick present two cases of spinal decompression sickness and Dr Geoff Macfarlane discuss the pitfalls of histories as given by divers and the newly available recompression chamber stationed at Morwell. They were followed by Dr Harry Oxer discussing decompression accidents in Western Australia and Dr Charles Hackman who presented two cases treated recently at Prince Henry's Hospital. The final speaker was Dr John Knight who outlined "First Steps in First Aid for Diving Accidents" using a chart developed from that presented to the joint SPUMS Singapore Navy meeting in June 1980 by Dr Mike Davis and published in the SPUMS Journal Supplement 1981. The new chart appears opposite.

Those who missed the meeting will not need to miss the information as the papers will be published in the Journal during 1982.

FIRST STEPS IN FIRST AID FOR DIVING ACCIDENTS



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A REMEMBRANCE FROM TIMES PAST

A correspondent has reported an occasion, a fair few years ago, in the childhood of scuba diving, when a friend and himself filled their Porpoise tanks from an ordinary compressor rather then a CIG 3500 psi cylinder. They noticed some lung discomfort but continued to dive. Later in the day the correspondent surfaced first and noticed that his buddy's bubbles left a surface oil film when they burst. They realised that they had used air polluted by oil vapour from the compressor. They seemingly suffered no ill effects from such an exposure nor from their general ignorance of scuba diving. Till recently divers were remarkably tolerant of "dirty air", though our correspondent used CIG air wherever possible. A wise man.

Book Received

A copy of Subsea Manned Engineering by Gerhard Haux (Publishers, Best Publishing Company, USA) has been received and a review will appear in the next issue of the Journal. This book can be obtained by contacting Mr Rick Poole, Pro Diving Services, 27 Alfred Street, Coogee, Sydney NSW 2034.