sensation. With the latter there is usually loss of bladder function and bowel action. But this chap was patchy. He also said that when he came up he coughed up blood which made me very suspicious. You normally get this sort of patchy loss of sensation as a residual effect. I said to him "Have you been here before?" and he refused to say very much. Finally, after about half an hour my secretary managed to discover that he was admitted to our place in 1977 on the 27th May and when he left after physiotherapy he did have these areas of patchy numbness. We had managed to convert him from complete paralysis back to grade 4 or 5. He went back to work as a fisherman diver because the money was good. Each time they come back with a boatload of fish it is worth $60,000 which is good money. Obviously there was something happening to his lungs, so we sent him for an X-ray which showed tuberculosis with haemorrhage. Yet another case where by slowing down we find great returns. I have learnt to slow down and apply a mental discipline to every case because of the time factor, the delay in reaching us.

THE PRINCIPLES OF TREATMENT

Dr David Elliott

It was kind of the Chairman to introduce me as the Medical Advisor for Shell, but one of the things that I am really quite proud of is that I was employed as diving adviser to Shell, not as the medical adviser, advising on their commercial contracts all around the world. Not that I think that makes any difference to this lecture.

The principles of the treatment of decompression sickness, pulmonary barotrauma and arterial gas embolism you all know inside out. You have got three things to play with, pressure, oxygen and drugs.

Pressure

Pressure is obviously good at squashing down bubbles. But to be a bit iconoclastic, an awful lot of bubbles are cylindrical in shape and all you do is shorten them. Nevertheless experience has shown that pressure is good news for somebody who has got bends. In fact some limb bends are extremely pressure sensitive, so much so that it is very, very difficult to believe that they can be so sensitive. I am talking of bends at as deep as 1,000 feet or more, where 3 to 5 feet of difference in pressure can actually make all the difference between pain and relief. Pressure is definitely the important treatment.

I will say a little more on the type of pressure. Do you go to the depth of relief, or do you go to some arbitrary depth? The depth of relief is obviously the best thing to do. If you can cure the pain with pressure, you have no more problems. The problem is getting them back from that particular depth. However, the depth of relief is not an easy end point and there are some conditions where there is residual bruising. If you are running an ENG (electronystagmogram) on somebody with vertigo the ENG will not necessarily revert to normal for 48 hours after you have in fact cured his lesion. So depth of relief even in skilled hands is not a good depth necessarily to go to. Certainly in unskilled hands it is asking for problems. The depth of the dive is a very useful treatment depth and indeed for blowup we find that the depth of the dive is the depth of relief. A blowup can be from a depth deeper than your chamber goes to and this can be embarrassing.

With 150 foot diving, a 165 feet chamber will be adequate. But people who go down to 250 feet on air, could be in real trouble, because 165 feet would not necessarily be enough pressure to cure them.

Oxygen

50 m or 165 feet of air has a surface equivalent of 120% oxygen. The French Navy uses a 40% oxygen, 60% nitrogen table. At 30 m, which is 100 feet the PO2 of that is 1.6 atmospheres, which is equivalent to 160% oxygen at the surface. You can see that by pushing the oxygen partial pressure up while applying the pressure you can deliver a very good dose of oxygen to the patient. Comex, the French Diving Company, use a 50/50 mixture. They can even use that at 50 metres, which will give a partial pressure of 3 atmospheres or 300% oxygen at the surface. The 18 m oxygen Goodman and Workman tables give you very nearly 3 ATA of oxygen. Oxygen is easy to deliver. Before we leave pressure and oxygen, let us not forget that the balance is an inert gas, usually nitrogen. You may well hear in coming months some discussions as to whether or not nitrogen is the best treatment gas for air bends. As far as I am concerned, the hypothesis that helium may be a good inert gas for treatment of air bends remains an hypothesis until it has been further investigated. There is one particular centre that is pushing helium treatment for treatment of air bends. As yet the case is unproven.

Recompression is the treatment of choice. It should be given to any person who suffers virtually any condition within 36 hours of a dive. There are people who have had coronaries, acute appendicitis, cerebral vascular accidents, all of whom have been slung in the chamber because they might he slightly bent. Surprisingly, it did not do that correct diagnosis too much damage. They got through OK. The alternative, diagnosing bends incorrectly as a stroke or a heart attack or appendicitis, could leave the diver with permanent damage. So, when in doubt recompress.

To re-emphasize the point which I made yesterday about immediate recompression and no examination until you get to depth.

That is what one does if the patient reports immediately he has a symptom and it can be treated then and there. In cases where there is a more than 5 to 6 hour delay, I agree that one would want to examine the patient and to put up a drip and do all the other things that will be necessary, or in Tony Slark's words, to consider him as a hospital patient.

TREATMENT WITHOUT A CHAMBER

First Aid

Perhaps the most important thing is knowing what you do if you have a patient and you have no chamber. I will run through the list in case there are one or two which may be new to you or may trigger a distant bell in your heads.

The first thing is to put the patient in the head down position and on one side if conscious.

The second thing to do is to arrange for transport to the nearest chamber, preferably a helicopter flying below 1,000 feet or an aeroplane pressurised to 1,000 feet. Bear in mind that commercial aircraft are normally pressurised to 8,000 feet and also bear in mind that going over mountains can quite definitely make a patient worse. Altitude does not help at all. Nevertheless arrange for transport by the most rapid means possible.

Provide oxygen by a tight fitting mask. It is important to give as much oxygen as you can.

Avoid analgesics at this stage, even if the patient has got pain. Pain is a useful management guide. In particular avoid the mixture called Entonox. It is used in ambulances and by midwives as an analgesic agent in the UK. It is a 50/50 mixture of oxygen and nitrous oxide. It has been very well shown that nitrous oxide can be used as a bubble amplifier. So Entonox is contraindicated. I managed to get the British Oxygen Company to put a note about this danger in their detailed warning list for the analgesic agent. The same warning has been distributed to all UK ambulance services.

The next important thing is fluids. Oral fluids if the man will take it. The person is going to be dehydrated due to plasma shift. Lots of oral fluids are needed to keep the red cells flowing round smartly. At least a litre an hour. Setting up a drip even for somebody with a limb bend will not do him any harm. If you want to use dextran take blood for haematocrit first. For academic reasons dextran 70 if preferred to dextran 40 because it has a slightly better tapered effect. It does not last quite so long but it is not such a strong solution. 500 ml hourly appears to be the consensus view at the moment, what the majority of people in Europe would do for such cases. The other problem is hydration.

So if he is not having oral fluids, push them in as lactates, 5% dextrose, normal saline, plasma or whatever you have got. Try to maintain a colloid osmotic pressure of greater than 20 mm Hg to prevent oedema.

Drugs

There is tremendous scope for discussion about steroids which I shall avoid. The function of the steroids is to stabilize the vascular endothelium and to reduce the CNS oedema. I would personally give it in cord decompression sickness. I give a large star dose of hydrocortisone or dexamethasone and then a heavy maintenance dose, but not for more than two or three days, so that you can cut it off without tapering. I would give it to anybody who has got CNS problems following gas embolism even if it proved in retrospect to be unnecessary, because of the fatalities that I have seen.

Other drugs to consider are the osmotic agents. Glycerol tastes absolutely foul and is best given by nasogastric tube. 0.8 mi per kg in 50% flavoured water is the recommendation. The maximum effect is in one hour and lasts up to six hours. Mannitol has also been given successfully but there is a rebound after about 20 minutes or so, so it is a pretty desperate measure. There was one case written up by a guy from Guernsey, who managed to get apparently a complete relief, which did not relapse, using just mannitol.

Valium is very useful if you have got a problem with staggers, a labyrinthine hit. But bear in mind that it will suppress the manifestations. So it is going to make subsequent management rather difficult. I would withhold it unless I found it absolutely necessary, so that when we get to the recompression chamber we can see whether or not the recompression is working. If you do give it the chamber receiving the case must be informed. They should then give the patient the maximum recompression they can possibly manage on the grounds that the symptoms have been masked. Having no symptoms to guide them they had better assume that the patient is not responding to recompression and give him the maximum treatment.

Heparin is still mentioned. I regret to say that I recommended it in the first edition of the book. That was based on the lipaemia clearing activity of heparin. However Joe Farmer of Duke University has persuaded us that even in sub-anticoagulant doses of 2000 units there could nevertheless be a haemorrhagic effect. If there is any sort of problem in the labyrinth, heparin is contraindicated. The trouble is that even if you get a lot of cases you really cannot ever conduct a decent trial. So heparin is a bit of a myth.

Aspirin, which has a very useful platelet effect, is also contraindicated for the same reason, in that it may exacerbate labyrinthine haemorrhage.

Then do not forget some of the other practical procedures. Catheterisation should be considered and is a useful monitor, as you want to keep the fluid intake such that the output is about 1 to 2 ml per Kg per hour. Pleurocentesis, using the Heimlich valve may be required. Do not forget, and I am sure you will not, but the people accompanying the patient might forget, passive movement and pressure points for anybody who is quadriplegic.

I will not say anything about in-water re-compression, except to say that we do not recommend it in Europe, for the simple reason that the water is too cold. I think that in water as warm as we have here in the Philippines it would be quite reasonable to give in-water treatment decompression a try. I have no personal experience of it. Somewhere between these waters and European waters there is that water temperature at which I think it becomes inadvisable.

Those are the things that you can do in the absence of a chamber.

If the patient has got only chest problems, evidence of pneumothorax or mediastinal air but no neurological problems, there is no need to recompress the individual. But you have to keep him by the chamber just in case he does get neurological symptoms. The treatment needed is either pleurocentesis for pneumothorax or if it is mediastinal emphysema, oxygen by mask to help get the inert gas out.

TREATMENT IN A CHAMBER

I have got a few more slides and I have got all the gen here on treatment on bends in the chamber, treatment, the conventional treatment, the new treatments that are coming up, the problems that exist for those of us who are responsible for recompression chambers, selecting the right kind of treatment for the particular casualty. I have got the treatment of helium bends from bounce diving, the helium bends that occur from saturation diving, excursion from saturation diving, a copy of the world's deepest bend, which was deeper than 1,600 feet in onset which is quite an interesting story, and some further thoughts on the treatment of blowup, but in the interests of time I am going to scrub that tonight. I prefer to leave it until later in the programme.

DIVING ACCIDENTS

David Elliott

It is no coincidence that in the North Sea, although we resented the advent of rules and regulations for diving, they have in fact done a lot of good. Here are the fatality figures for commercial diving on the North-west European Continental shelf. In 1971 there were three deaths in an estimated total diver population of 200. The diver population is estimated from the number of annual diving medicals, which are required by everyone diving in the North Sea. It is only an estimate because some people have a medical and then go and work in other parts of the world. Then regulations were introduced, first in the UK and then virtually identical ones by Norway. Even so in 1974 there were ten deaths in an estimated diver population of 800. In 1975 there were nine deaths in an estimated diver population of 1,000. In 1978 and in 1979 the fatalities came down to three and the population went up to 2,500. In 1980 there was a record which we will be unable to beat, thank heavens, there was a fatality rate in the North-west European shelf of zero in 2,500 divers.

The philosophy of government regulations in Europe is not the American style of writing rigid regulations that you will do this or that. It is a philosophy of allocating responsibility and making sure if something goes wrong, that the person who should have been responsible is punished, if necessary in Court. The responsibility goes all the way up from the diver himself, who after all is responsible for saying whether or not on any given day he is fit to dive. If he conceals the fact that he has a hangover, or is on drugs, or any other condition which should have stopped him diving it is firmly his responsibility. It goes on up through the chain of command, supervisors, superintendents, the diving company as a whole and last but not least, to the oil company whose responsibility it is to make sure that its contractors are behaving in accordance with the principles of Health and Safety at Work.

So my job includes reviewing all our diving contractors around the world. For instance in North-west Borneo on one diving contract we had three bids. One bid was for a dive of up to 300 feet using a closed bell system. Another European company bid for bounce diving from a barge. They of course were very much cheaper. The company which actually won the contract had an intermediate technique. That was sufficiently dramatic to make me insist when we call tenders for diving contracts, that they all bid to the same standards of safety. Throughout the world Shell uses the North Sea Rules and Regulations which have produced some useful effect, judging from the crude fatality figures.

CAUSES OF DIVING ACCIDENTS

There are accidents specific to diving, those that occur in the water and the accidents associated with decompression. We can subdivide these into those caused by compression, the things that happen at maximum depth, and the decompression illnesses (which we have already dealt with). Also we have the coincidental illness or injury. Commercial divers go into a dive and they live at pressure for as long as a month. So their pressurised environment is dry as well as wet. For your purposes, coincidental illness or injury is such things as blowing a hole in yourself using a water jet gun, or swimming around at 250 feet when some idiot drops a spanner off the rig and it hits you on the back of the head. Those have both happened. Incidental illness includes myocardial infarction and cerebrovascular accidents, both of which have happened to divers in the water in the North Sea.

The causes of these accidents are very difficult to classify. We can use the usual epidemiological approach of host factors, environmental factors and the actual cause of