would be able to fit at least four trolleys. One of the reasons we have to knock back people because of the difficulty of having to lift them in and out of that small chamber.

A four bed multiplace chamber would be quite adequate for us. I mean four people lying down. I am fairly paranoid about patients being able to recline or lie flat in a chamber. I think posture in the chamber is extremely important and a lot of damage can be done if people are not properly postured during their treatment and the attendant can end up having trouble, as happened in one situation in America.

In addition to a multiplace chamber with TUP facilities and a monoplace chamber, we need a transportable chamber with TUP facilities. The entire state of Tasmania in respect of diving is now aware that transfer under pressure facilities are needed. If by some good fortune we acquired a Duocom or Paracel chamber tomorrow, it would be quite useless to us because we cannot lock it on to our chamber. So if we did receive a patient in a portable chamber we would be in the incredible situation of having to return that patient to one atmosphere pressure, that is run the risk of seriously damaging that patient, before being able to place the patient in our chamber.

Australian Standard 2299, up until perhaps a year ago, could be regarded as guidelines and recommendations. The duty of care on the part of the employer is hardening up quite considerably. The Police Department has been very quick to recognize this and have taken very energetic steps to alert our government to this. Other departments also are aware of it. Tasmanian Sea Fisheries, who employ divers, are aware of this and I am quite sure are keen to see a hyperbaric facility becoming available.

A facility which has both monoplace and multiplace facilities has a potential for very large cost saving. The important aspect of having a monoplace chamber is that as the unit gets up and running it is a facility that can easily be added to. One is not looking at doubling the cost to buy another unit because a sizable proportion of the cost of the first unit is the oxygen control unit which can serve more than one chamber. Two chambers, multiplace and monoplace, running in parallel would be a great saving of people having to go into the chamber on a daily basis and the cost effectiveness of that is quite considerable.

If we install a hyperbaric facility with intensive care capabilities, I believe that in the end it will be very cost effective. I can point to some studies from America which have looked at cost effectiveness. There are some absolutely untouched areas such as the compartment syndrome where we should be looking at treating acute cases far more seriously. This is again a backing up argument for our claim for further finance.

We have situations here where patients occupy hospital beds for ages, when they could be out of hospital much quicker after hyperbaric therapy. Even our primitive "guess the time to healing" index shows this quite clearly. Nearly all of our clinicians who deal with these patients have become aware of the benefits of hyperbaric therapy over the last few years.

I emphasise again we will need to have proper staffing. If we have proper hyperbaric facilities we will then just have to have a more generous staffing arrangement so that we can supply a better service.

The above has been adapted, by the SPUMS Journal Editorial Staff, from the transcript of a lecture presented at a meeting on Hyperbaric and Diving Medicine, sponsored by SPUMS and the Royal Hobart Hospital, 4th - 6th November, 1988, at the Royal Hobart Hospital, Tasmania.

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CRITICAL CARE IN THE HYPERBARIC CHAMBER

Ian P. Unsworth

Introduction

Some of the indications for hyperbaric management include slightly over 50% of cases that require intensive care nursing, either before or after hyperbaric oxygen (HBO) treatment. It seems illogical to have a patient in intensive care or critical care very well monitored, well ventilated, well looked after and then, for a period of two hours, take the patient off all those monitors, off the ventilator and pushed through a fairly small orifice into a small chamber for hyperbaric oxygen. What then do we need? The management of critically ill patients in a recompression chamber

Table 1

CRITICALLY ILL PATIENTS SUITABLE FOR HYPERBARIC OXYGEN.

Gas Embolism
Severe Infections
Trauma
Poisonings

must be exactly the same as in an Intensive Care or Critical Care Unit, except that it is under pressure. The chamber should be an extension of the critical care ward, both in equipment and, equally important, in staff. I believe it is absolutely vital to have adequate and appropriate staff for a chamber. No matter how good the equipment, if one has not got people who are accustomed to using it, then it is useless.

Chamber requirements

What are the chamber requirements? Obviously, apart from pressure and it is always nice to have a very high head of pressure available, one needs facilities for resuscitation and continuing resuscitation, for ventilation and the intravenous administration of agents. Medicinal drugs must be available. Some carbon monoxide patients can be very agitated, in fact manic. If one shuts these sorts of patients up in a chamber, they can do severe damage to property and personnel, so one needs restraints and restraints often can be in the form of pharmacologic material. Thirdly, one needs adequate and sufficient monitoring facilities in the chamber.

I like the idea of using a monoplace chamber for elective, non-serious, patients who can look after themselves in the monoplace situation. I do not espouse the concept of putting critically ill patients into a chamber of this nature, even though there are units around the world that do. One is separated from the patient, who may be unconscious and who may be on a ventilator, by 9 mm of plexiglass. There is nothing worse than standing by, unable to interfere, to watch one's patient fit, vomit and inhale. One knows that the only way is up and that indeed could be down for the patient. The monoplace is fine but for fit patients only.

The chamber that one needs for critical care patients is a chamber with plenty of space, certainly enough for the patients to be lying down on trolleys. A family of carbon monoxide poisoned patients was brought to Prince Henry Hospital. There were six patients and we were rather fortunate because we could put all six into the chamber simultaneously. So I suggest to anyone that one have a big chamber and then one can deal with big families.

Patients

The tableabove shows the types of critically ill patients who might benefit from HBO. There is a very wide range. I have just selected a few of these in this table. All divers are familiar with gas embolism from diving. In many people's minds, this is the only cause of gas embolism. It is not and it is by far and away the rarest of all forms of gas embolism. Severe infections, both anaerobic and mixed anaerobic-aerobic infections certainly can produce critically ill patients who, if they are treated with hyperbaric oxgyen, need exactly the same monitoring and management in the chamber that they have in the intensive care ward. Terrible trauma occurs from motor vehicle accidents, from climbing accidents or from falling accidents and crushing injuries. If the patient has something of the nature of an acute compartmental syndrome, then the patient must be monitored and looked after accurately in the chamber. To turn to the poisoning. In this symposium there have been two very eloquent presentations on carbon monoxide poisoning. These indeed are the most common of the poisonings, but one must not forget the other two needing HBO therapy, hydrogen sulphide poisoning and cyanide poisoning. In both cases they certainly need intensive care monitoring and ventilation during their chamber sojourn.

Gas embolism

I have divided gas embolism into two, normobaric and hyperbaric. Gas embolism can occur from investigations in hospitals, operative procedures in hospitals and not an insignificant number occur from cardiopulmonary bypass surgery. If the Royal Hobart Hospital is intent on going into cardiopulmonary bypass surgery, then it is mandatory to provide a well recognised means of managing the gas embolism occurring from the pump. Trauma certainly can produce normobaric gas embolism, and in my experience a number of cases of chest trauma from penetrating instruments have resulted in gas embolism.

The other type of gas embolism with which one is more familiar, is the diving or decompression accident which can occur out in open water, in other chambers, or perhaps (one hopes not) even in ones own chamber. If one causes an injury to a patient or staff member, then of course one immediately turns around and treats the injured person in that chamber.

The non-diving aetiology can be quite immense. In fact there are about 43 ways of getting arterial gas into the circulation. The problem is that hospitals around the country are very reluctant to recognise that gas embolism has occurred in their patients. Doctors, both medical and surgical, know very little about air embolism, and certainly in Sydney the only hospital that ever seems to produce air embolism is Prince Henry! I believe it is because we recognise the cases when they occur whereas the other hospitals in Sydney do not. Gas embolism is certainly an important case load.

Severe infections

What about severe infections? . Myonecrosis, both clostridial and non-clostridial, is life threatening and certainly can be helped markedly with hyperbaric oxygen. In the mixed infections, necrotising fasciitis and the progressive postoperative gangrene, if one has hyperbaric facilities then they should be used. If the facility is not immediately available then it is, as it were, optional. One does not transfer patients long distances to get the benefit of hyperbaric oxygen in necrotising fasciitis, for example. The manage-

ment is radical surgery and antibiotics. This is the type of patient which I imagine one would be using the chamber for here.

Other conditions

Crush injury, compartmental syndrome, and acute spinal trauma are experimental at the present time). However, we have been using hyperbaric oxygen for these for five or six years at Prince Henry Hospital. I am told by spinal colleagues that there is certainly evidence hyperbaric oxygen used adjunctively has long term benefit. So I am continuing to treat their patients as requested but there are certain criteria we apply.

What is the rationale, very briefly, for HBO in spinal injury? In the centre of the cord one can conceive that there is a segment of dead cord, that is irretrievably damaged. On either side of this proposed dead section there is a zone of hypoxia that is reversible. There may be small vessel thrombosis, oedema and vasospasm that renders this area nonfunctional. If one can reoxygenate this area rapidly after injury, one may well push through oedema and vessels that are still patent sufficient oxygen to restore function in these areas. The patient is left with much smaller zones of residual neurological damage. I think that this does have value and we are continuing to use hyperbaric oxygen for these injuries. If in the future this comes to be accepted as an adjunct for acute spinal trauma, then one may well be asked at the Royal Hobart Hospital to manage cases of cervical or thoracic spinal trauma in the chamber. There will have to be plenty of room with some of these patients because they are, or may well be, on neck traction or skull traction, and one will need that little extra space to hang the weights off the end of the bed. Another reason for plenty of room in any proposed chamber.

In crush injuries and ischaemic limbs hyperbaric oxygen is of adjunctive value. Once restoration of blood flow has occurred surgically or by whatever means these cases can and should be treated with hyperbaric oxgyen. These sick patients may have other injuries besides just crushed limbs.

The other speakers have said sufficient on carbon monoxide this morning. Remember that it is the combination with haemoglobin and myoglobin that reduces oxygen carriage and with the cytochrome oxidase A3 in the brain and other tissues that reduces energy production. It is the cytochrome involvement that gives the clinical manifestations of nerve damage, not the haemoglobin involvement.

Management in the chamber

Very briefly about the management of some cases in the chamber, getting down to the nuts and bolts of chamber management with acute critical care patients. One has several systems to take care of. First the respiratory system. One has to make a decision, does the patient need intermittent positive pressure ventilation, or can the patient breathe spontaneously. Along with that of course, the patient should be intubated. One can have intubated patients breathing spontaneously in the chamber, and know that they are getting very high concentrations of oxygen.

Many years ago when I had more time, money and sense I was doing animal experiments in the chamber. We were looking at full scan EEGs in the pigs breathing hyperbaric oxygen, intubated but breathing spontaneously with the CO_2 absorber on, to see what happened when they were at high oxygen pressures. In fact they did exactly the same as humans do, they fitted.

The tightest masks are certainly known to leak. One may only be in fact giving the patient about 97% oxygen because of leaks around the mask. Intubate the patient and one knows there will be no leak and that they are getting 100% oxygen. Carbon dioxide absorption is very important because a rise in arterial carbon dioxide leaves the patient open to the central nervous system problems of oxygen toxicity by causing cerebral vasodilatation and increased cerebral blood flow. It is very important to keep the PCO2 down. The use of oxygen in chambers requires a good scavenging system. If one allows the oxygen percentage in the chamber to rise, one is creating a totally unnecessary fire hazard. So the patient's oxygen must be vented overboard. When being ventilated, some critical care patients may be on positive end expired pressure (PEEP). At a constant pressure, or constant depth, there is no problem, but while during ascent, the PEEP must be reduced. In fact it must be removed because cases of burst lungs from the maintenance of PEEP during ascent have been recorded. PEEP during ascent is dangerous and should never be used.

Cardiac Arrest

Another system that certainly needs care is the cardiovascular system, the monitoring of which we will look at shortly. I have often been asked what happens if the patient has a cardiac arrest under pressure while breathing hyperbaric oxygen. One manages the arrest just as one would in intensive care or critical care ward. If the patient requires it one uses the defibrillator. People have asked whether there is an unacceptable risk of ignition in the chamber. It is not particularly high, certainly there are no problems. The humidity is usually very high in chambers. If the patient has gone into ventricular fibrillation then certainly one must defibrillate.

Oxygen toxicity

Central nervous system (CNS) toxicity manifested

by fits is a possibility, so obviously the patient will have to be closely watched to observe the onset of oxygen toxicity signs such as lip twitching, small muscle twitching and so on. Anaesthetics can be given in chambers using a Boyle's machine with a carbon dioxide absorber.

Equipment

A number of ventilators at the Prince Henry Hospital can be used under pressure. The Bird, Mark VII works well, but there are other ventilators which work satisfactorily under pressure. I have used a Campbell to ventilate a goat at 200 feet with the goat surviving. Some of these ventilators are satisfactory for work at quite high pressures such as the Monaghan and the Manly.

If one does not have a ventilator in the chamber, one can ventilate a patient with by hand. In my experience of the three self inflating bags, the Air Viva, the old Ambu bag and the Laerdahl, only the Laerdahl is any good in a chamber. It is always wise, with a ventilator in the chamber to have a bag as well as a backup system because ventilators have a habit of suddenly malfunctioning at the worst possible time.

One can use a closed circuit absorber system. The absorber is to extract carbon dioxide from the circuit. However this circuit should never be used on patients poisoned with carbon monoxide because carbon monoxide comes out the same way that it goes in, which is through the lungs. If the patient who is poisoned with carbon monoxide is on a recirculating circuit he is excreting carbon monoxide which is then rather carefully put back into the inspired gas.

Monitoring patients is done in exactly the same way in the chamber as in the intensive care ward. One must not use mercury manometers as mercury vapour is toxic and mercury if spilt is almost impossible to remove from the chamber. One can use aneroid manometers. One can insert an intra-arterial cannulae and read the blood pressure in exactly the same way, through a transducer, as in intensive care. There is no problem whatever. Monitor the patient's electrocardiogram by whatever means one likes. This is important because arrhythmias can sometimes occur in hyperbaric oxygen. One can monitor the patient from outside, or have a monitor inside with the attendant. In this case the monitor must be battery powered as no 240 volts mains electricity is permitted in a chamber.

Although I was doing EEGs for a large number of carbon monoxide patients in the early days, I now do not routinely monitor EEGs. The trace is always very good because the patient is in a shielded environment. If there is the appropriate plug through the chamber wall, then EEGs on patients are technically good quality.

The Datascope works very well under pressure for a simple ECG and pulse rate. It can go in with the patient or one can have bigger monitors outside. We have tried other monitors in the chamber. The Datex Cardiocap is not very good under pressure, whereas the Kontron works much better. The Minimon works quite well and one can use that for pressures as well if one so desires. The Life-Pak 6 defibrillator can be used in a chamber if the hot wire ECG component on top can be removed. The hot wire component is a potential for fire under increased oxygen tensions. However it can be removed and the defibrillator component alone taken in. Then it is not a synchronised defibrillator because there is no ECG, but that does not matter if from the monitor one sees that the patient is in asystole. One has the paddles and one charges up the defibrillator and just hits the patient as one would anywhere else. The thought of fire is least in one's mind, one wishes to save a patient's life.

In the chamber there is really no problem or reason why ordinary intravenous infusion sets should not work well. There are closed air spaces, but one can adjust these with changing pressures. The ordinary drip set works perfectly well provided it is looked after. Power driven intravenous lines can be used. Even little syringe pumps can work well down to 12 m (45 feet) or so. The IMED is perfectly acceptable for giving inotropes to a very sick patient.

There are some very, very good bubble filters available and these should be put on all intravenous lines because the introduction of bubbles into the circulation at pressure will cause problems on ascent. Closed systems of fluid administration are much better than open. Plastic packs of blood and other fluids are readily available which do not have to be vented, they just collapse.

Urine measurement is usually done in intensive care and there is no reason why it should not be done in the chamber as well.

Chest drains occasionally crop up with prior pneumothoraces or if the patient has had thoracotomies or pneumonectomies. The management of these is no particular problem. Always make sure however that the chest drains are open to atmosphere during changes in pressure, either ascent or descent.

Staff

Very occasionally one might have problems with staff. Sometimes the medical staff are very reluctant to get into the chamber, but I think that once the chamber is organised within ones hospital, one will find a lot of doctors creeping around and having a look at this thing in a very quiet way. They have heard about it. That is the opportunity to really stimulate a desire in these young people to go into the chamber and be an attendant, with a member of the trained nursing staff, and look after patients. The nursing staff are the vital component of any hyperbaric unit. They are

literally worth their weight in gold. They must be intensive care trained. I have no doubts about that whatsoever. There are no worries about putting any critical care patient in the chamber when the staff are able to manage all the equipment without any problems whatsoever. Trained staff, critical care trained and perhaps scuba divers as well are what makes a unit.

Recommendations

I must reiterate several items. If a hospital accepts that hyperbaric medicine has a use in the hospital, then it is vital, if not mandatory, that satisfactory equipment is provided, that the chamber or chambers are big enough and are adequately equipped and are adequately staffed.

The above is an edited transcript of a lecture on Critical Care in the Hyperbaric Chamber given by Dr. Unsworth at a meeting on Hyperbaric and Diving Medicine, sponsored by SPUMS and the Royal Hobart Hospital, 4th - 6th November, 1988, at the Royal Hobart Hospital, Tasmania.

Dr Ian P. Unsworth's address is the Hyperbaric Unit, The Prince Henry Hospital, Anzac Parade, Little Bay, New South Wales 2036, Australia.

MINUTES OF THE EXECUTIVE COMMITTEE MEETING
Held on 5th November 1988 at Hobart

Present

Drs A Slark (President), D Davies (Secretary), G Barry (Treasure), D Walker (Editor), C Lourey, P McCartney, C Acott (Past President) D Gorman, P Chapman-Smith (Chairman NZ chapter) and J Knight.

Meeting commenced at 1415.

1 **Minutes of the last meeting**

The minutes were read by the Secretary.Acceptance moved Dr J.Knight. Seconded Dr C.Acott. Carried.

2 **Matters arising**

2.1 The President was to write to various registration bodies informing them of the SPUMS Diploma of Diving and Hyperbaric Medicine. This has yet to be done.

2.2 Travel insurance for SPUMS conferences was discussed. It was noted that the GRE Company will not cover retrieval for diving accidents but QBE will. The Committee recommends that insurance be purchased by all attending the conferences but it must remain the responsibility of the individual member.

2.3 The article in "Chest" of December 1987 was further discussed. There has been a big response in the Letters to the Editor and a letter has been accepted from the Hyperbaric Unit at Royal Adelaide Hospital. Members are recommended to seek out the article and follow its progress through the letters column.

2.4 The results of the Incorporation plebiscite were accepted by the Committee. Motion was put by the President, seconded by Dr Knight that "the Committee undertake appropriate measures to proceed with Incorporation of the Society". Passed unanimously. Dr Lourey will contact the Solicitors on our behalf.

3 **Correspondence**

3.1 Journal

3.1.1 Dr J Williamson proposed formation of Editorial sub-committee and made other meritorious suggestions about the Journal. Dr Williamson will be asked to join the enlarged sub-committee with the possibility that it be enlarged further as required.

Moved by the President. Seconded Dr P.McCartney. Carried.

3.1.2 Advertising policy for the Journal has not yet been discussed. This has been postponed sine die.

3.2 Dr J McKee transmitted a request from the Mana Island Resort Rugby Team for sponsorship in the way of Rugby Jumpers. These would cost $50.00 each and they require at least 17. The committee felt that it was not our policy to support a single tourist organisation.

3.3 Mediclinic International Conventions are holding conferences at several venues along the Great Barrier Reef. They request videos on medical aspects of diving and a list of doctors who would give talks about diving medicine. The Secretary wrote requesting further details but has received no reply.

3.4 Dr Yehuda Melamed has requested publicity for the XVth Annual Scientific Meeting of the EUBS which is being held in Eilat from the 17th to 23rd September 1989. The Editorial sub-committee agreed to advertise the meeting in the Journal.

3.5 The Executive Director of UHMS has invited members of SPUMS to the UHMS Annual Scientific Meeting to be held in Honolulu from the 7th to 11th June, 1989. This follows on the week after the SPUMS Conference in Vila. Connecting flights can be arranged either via Sydney or