BRIEF NOTES ON 16 CASES TREATED AT THE UNIVERSITY OF MICHIGAN HYPERBARIC UNIT

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In Michigan we average 3 to 5 Scuba diving deaths a year and many non-fatal accidents are reported, often by hearsay rather than by written reports. The following cases presented at our chamber for treatment over a two year period. I will briefly outline the circumstances and my own interpretations, based on available information. There were 7 cases of Air Embolism and 7 of decompression sickness among these non-fatal diving incidents.

A. Air Embolism and Pulmonary Barotrauma

CASE 1 46 year old male making a controlled free-ascent in a quarry at the correct speed, with an instructor in attendance. He was a 3 pack-a-day smoker and had bronchitis. He suffered pulmonary barotrauma with subcutaneous emphysema. No treatment was required beyond a period of observation.

CASE 2 46 year old male, surfacing correctly from 80 feet in a large lake, became suddenly paralysed and had loss of vision. He was treated 6 hours later with complete recovery. He had a repeat experience one year later, with the same symptoms. This suggests either a small ischaemic area in the brain or a repeat air embolism. Second treatment also was successful.

CASE 3 27 year old man suffered chest pain and obtundation after making a struggling ascent from 15 feet in a swamp. He did not exhale while being hauled to the surface, it was stated. Chamber treatment was successful.

CASE 4 31 year old male performing ditch-and-don manoeuvre in a pool. He suddenly surfaced with subsequent pupil dilatation and taxia. Treatment in the hyperbaric chamber was successful.

CASE 5 32 year old male was doing a “NAUI-bailout”. This involves jumping into a pool with all equipment in one’s arms and donning it underwater. He developed extreme headache and decreased visual acuity. The provisional diagnosis was of air embolism but subsequently I felt that he had suffered a sphenoidal sinus squeeze. Symptoms resolved when he was pressurised.

CASE 6 This 15 year old scuba student reported substernal chest pain and dyspnoea following a pool scuba lesson. Chest X-Ray revealed pneumo mediastinum. This resolved without necessity for treatment. The diagnosis was made not by the primary physician but by the later X-ray.

CASE 7 This 27 year old advanced scuba student, practicing buoyant emergency ascents while buddy breathing, had an episode of panic and separated from his buddy. He ascended rapidly without exhaling. Subsequently, severe headache, substernal chest pain and shortness of breath occurred. He presented 5 days later, improved. No treatment was then required. The impression was gained that this quarry diving incident had caused a cerebral air embolism in association with pneumo mediastinum and a minimal pneumothorax.

CASE 8 This 27 year old male was an advanced diver practicing free ascents in a lake. On the first attempt from 60 feet he surfaced exhaling but on the surface he convulsed and became comatose. He had fixed dilated pupils on admission and suffered cardiac and respiratory arrest on arrival. He had been betting beers on who could surface with least speed and least “popping out of the water”. He lost! He was pressurised 1.5 hours later and had an excellent recovery. He had suffered cerebral air embolism, pneumo-mediastinum, bilateral pneumothoraces and subcutaneous emphysema. Incidentally,

he was a 1-1.5 pack per day smoker with a chronic 2 year productive cough.

CASE 9 This boy of 18 took “PCP” (a horse tranquilliser), put on a scuba tank and made a solo dive in a 110 feet deep lake. He exited the water on the opposite side, fell off the dock backwards and plunged into the water. On recovery he had unequal pupils, nystagmus, and reflex asymmetry in knee-jerk testing. Recovery was complete after recompression (which was very eventful). Diagnosis was not clear since “PCP” causes many of the same symptoms and signs as observed here.

B. Decompression Sickness Cases

CASE 10 This 31 year old wreck diver did not follow decompression tables on two successive dives to 150 feet for 20 minutes. He thought that breathing oxygen on the surface was enough protection. Spinal cord decompression illness resulted: recovery was complete after recompression and three months of physical therapy.

CASE 11 This 26 year old female diver made successive decompression dives on a wreck. Although she followed the tables religiously she was maximally exerting herself and the US Navy Tables are designed for males at intermediate levels of exercise. She suffered wrist pains (in a previously injured joint) and progressed to shoulder pains. Recurrence of symptoms during “ascent” in the chamber necessitated an extension of treatment.

CASES 12 AND 13 were two wreck divers with joint pains on surfacing from 110 feet. The first diver had spent 20 minutes at this depth on each of two dives.

CASE 14 Caisson worker, aged 35, presented with pain after working a double shift and then decanting out without decompression.

CASE 15 This 31 year old wreck diver ran out of air and did a buddy breathing ascent to 60 feet, then a free ascent to the surface. This followed a 20 minutes bottom time. He developed paresthesias and numbness of both arms which cleared on recompression therapy.

CASE 16 A “hard-hat” diver developed severe pulmonary symptoms and elbow pain after surfacing from 110 feet following a bottom time of 70 minutes. He had severe skin, joint and cardiovascular symptoms which required recompression and extreme supportive measures.

In summary, these cases are of diverse aetiology and probably represent only about one quarter of the cases that occur. The following comments are offered:

a. Inexperience or lack of training, including poor judgement, is a factor despite all these divers being certified.

b. Poor physical health may be present, eg. heavy smoking and chronic bronchitis was noted in two cases.

c. In one case a female followed a dive profile not suitable for females.

d. Drug intoxication with “PCP”. Many had alcohol within the preceding 24 hours.

e. Open water “free ascents” are inherently dangerous.

Our divers dive in deep, poorly illuminated, cold waters. Excessive cigarette smoking alcohol and drug intoxication are serious problems and further reduce the safety margin.

CLINICAL EXPERIENCE WITH A SINGLE PATIENT HYPERBARIC CHAMBER

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This paper summarizes practical experiences with the first 100 cases treated in a single patient Hyperbaric Chamber at Prince Henry's Hospital, Melbourne.

The Unit, generously donated by the William Duchland Foundation in 1960, is a Vickers RHS/3 Radiotherapy System which utilizes a high flow oxygen supply with no recirculation.

The chamber is 7 feet in length with an internal diameter of two feet. The walls are double layered methylmethacrylate with an interface of air. Oxygen flow rates vary between 250 and 400 litres per minute.

Advantages of this single Unit are:

1. Relatively Cheap Installation. The Unit is located in a small room at the far end of a general surgical ward.

2. Low running costs. Oxygen is taken from the Hospital's Liquid Oxygen supply. At the current rate of $12.30 for 100 cubic metres, 2 hours of therapy costs no more than $4.30.

3. The whole body is visible and immersed with oxygen. The patient does not have to endure the discomfort of a mask and it is ensured that the highest concentration of oxygen is inhaled at all times.

4. Minimal risks to attendants. There are no problems with medical attendants enduring the effects of pressure or nitrogen within the Unit.

Patient Comfort

Practical problems of patient therapy involve - apprehension, boredom and sheer claustrophobia. Light sedation is often administered for the first treatment but simply psychology of explanation and reassurance is more effective. Boredom is relieved by a radio transmitted through the chamber intercom circuit and claustrophobia is a more difficult problem involving tact and strong persuasive powers.

COMPLICATIONS

1. Effects on the Ears

Ear discomfort is reduced by slow pressurisation and Valsalva manouvers performed by the patient. No myringotomies are undertaken and severe aural dysbarism is relieved by suddenly dropping the chamber pressure 1 p.s.i. followed by slow re-pressurisation.

2. Convulsions

Two convulsions due to oxygen toxicity are reported in our series. Both occurred at the unnessicarily pressure of 3 Atmospheres Absolute. It is now our practice to treat at 2.5 A.T.A. and no problems have occurred at this pressure.

3. Lung complications

Pulmonary effects from high oxygen tensions have not been evident but is has recently been decided to use 5 minute air breaks every 25 minutes on oxygen, particularly duirng prolonged therapy.

Deep breathing is encouraged, following removal of the patient to the normal air environment. This practice tends to prevent the onset of atelectasis.

4. Risk of Fire

Of all the possible problems, fire in an oxygen environment is the single item that would have tragic consequences. The late 1960's were beset by fires in space-craft, fires in research units and fires in clinical Hyperbaric Units. We were obsessional in following these precautions in eliminating all possible sources of ignition:-

1. No electrical circuits

2. No heating

3. No static

We therefore increased humidity and did not allow the patient to wear any synthetic clothing whatsoever. Pure cotton theatre garments were the usual apparel.

PATIENTS TREATED

1.	Ischaemic Limb Disease	44
2.	Specific Wound Infection	22
3.	Gas Gangrene	14
4.	Joint Bends	6
5.	Carbon Monoxide Poisoning	4
6.	Air Embolism	1
7.	Miscellaneous	9
		100

In our first one hundred cases we treated 44 ischaemic conditions, 22 specific wound infections, 14 cases of true gas gangrene, and 6 cases of joint bends, 4 cases of carbon monoxide poisoning with 1 of air embolism concluding the main series.

VASCULAR CONDITIONS

1.	Athero-sclerosis	15
2.	Vasospastic	12
3.	Post Operative Ischaemia	12
4.	Occlusive	5
		44

The high number of ischaemic limbs treated resulted from the activities and interests of the vascular surgeons at our hospital. The therapy was of dubious value in chronic ischaemic limb disease but often of diagnostic help in delineating an ischaemic boundary. Improved results were seen when combining the oxygen with oral $\propto$ blocking agents.

Surprisingly several patients with vasospastic disease involving the fingers did particularly well. Sudden dramatic relief of the spasm occurred either during or several hours after therapy.

A patient with Raynauds disease showed considerable improvement following one treatment session.

Wound Infections - Gas Gangrene

The 22 specific wound infection were mainly post operative; where clostridial welchii had been isolated or gas gangrene suspected. These progressed well and none went on to develop a toxic gas gangrene picture. It is of course impossible to ascertain whether oxygen any help since broad spectrum anti-biotic cover was administered in each patient.

Of all conditions treated none has been so satisfying, curative and life saving as the application of hyperbaric oxygen in gas gangrene. We totally agree with this statement obtained from a surgical colleague at the Royal Melbourne Hospital - "The treatment of clostridial gas gangrene with Hyperbaric Oxygen therapy has been a giant a step forward in the treatment of this disease as was penicillin in the treatment of pneumonia".

All 14 patients in our series were toxic and exhibited clinical evidence of gas, crepitus, and wound discolouration. Seven had gangrene of a below knee amputation stump following surgery for peripheral vascular disease; 2 of these were diabetics. Self contamination of the stump from the rectum was the likely source of infection.

Six patients developed gas gangrene of the limbs following trauma; compound fractures of the leg after motor cycle accidents were a common cause. Gas gangrene of the abdominal wall occurred in two patients with colostomies.

All cases were treated at the following regime:-

1. Oxygen - at 2.5 ATA - 2 sessions daily, therapy continuing for up to 5 days.

2. Penicillin - approximately 24 Mega Units per day.

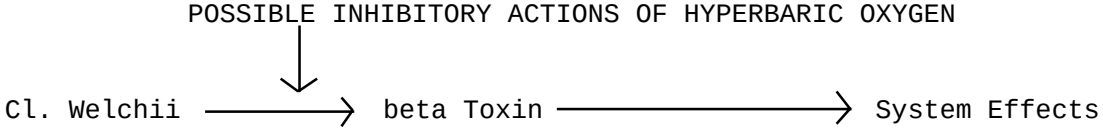
3. Surgical Debridement and Suture Removal - when necessary.

There were three deaths in the series, one followed severe abdominal trauma, another died with extensive secondary carcinoma and an 84 year old died five hours after surgical debridement.

It was interesting to observe that patients who were confused and apathetic before treatment became alert and co-operative in the high pressure oxygen environment.

Improvement in the system condition was often apparent following the first treatment.

There is no question that we totally agree with other workers in the field that Hyperbaric Oxygen in life and limb saving - an essential tool in the treatment of gas gangrene. Furthermore it may reduce the need for extensive mutilating surgery. In theory it converts a favourable environment for the anaerobes into an unfavourable one. Ischaemic tissues become oxygenated, toxin production is inhibited and penicillin activity is aided.



COMPLICATIONS OF DIVING

An interesting group of patients treated were divers with joint pains. Four of the six were professional Abalone Divers. This group presented with severe shoulder pain associated with some restriction of movement. No other clinical signs were present.

Recompression therapy following Table 6A or 6B resulted in a full cure in all cases. We now feel it is desirable to intersperse 5 minute air breaks every 20 minutes, particularly when using the longer recompression table, ie. Table 6B.

Following treatment the patients are returned to the ward on oxygen. This practice tends to decrease the incidence of "niggles" in the next few days which is due to the nitrogen re-expanding the original bubble. We allow them home the following day, and they are told not to dive for at least one week - preferably two.

CARBON MONOXIDE POISONING

Only 4 cases of carbon monoxide poisoning have been treated. Our low figures compared with those from Sydney are likely to be due to the natural gas supply in Melbourne. Carbon monoxide however, is not a fashionable form of poisoning today.

All our cases were suicidal rather than accidental and all used a pipe from the car exhaust as a source of inhalation. Furthermore they had consumed prior to the attempt either sedatives, tranquillisers or alcohol. This common practice tends to confuse the overall picture. The experience gained was that Hyperbaric Oxygen was useful particularly in the later stages. It is useful for practical purpose to be aware of the half life of carbon monoxide in air and oxygen (Reference 1)

1. Breathing air - half life is 4 hours
2. Breathing 100% O2 at 1 ATA - 49 minutes
3. Breathing 100% O2 at 2.5 ATA - 9 minutes

Associated therapy involves the administration of steroids and diuretics for cerebral oedema and strict airway maintenance at all times. Psychiatric referral is invariably necessary.

In conclusion it appears that the indications for Hyperbaric Oxygen are clearly outlined:-

1. Gas Gangrene
2. Carbon monoxide poisoning
3. Radiotherapy of specific tumours
4. Air embolism
5. Decompression sickness
6. Surface infection, burns, ulcers
7. Selective ischaemic conditions

The Unit is available for use 24 hours per day and priority emergencies include air embolism, carbon monoxide poisoning, gas gangrene and joint Bends.

Experience has shown *Whom to Treat, How to Treat* and *When to Treat*.

The Unit is regarded as an important therapeutic facility which although not fully stressed on a day to day basis, is available when required. Since the completion of this paper one further case of gas gangrene has been treated. This patient received

a gun shot wound of the abdomen and subsequently died following surgery of the bowel and abdominal wall. He remained intubated while in the chamber and was ventilated with a simple fluid logic ventilator. The ECG was monitored with praecordial leads connected to an external cardiac monitor through the special sockets present in the chamber door.

It is important to inflate the cuff of the endotracheal tube with water and not air, since pressurisation compresses the cuff and prevents a proper seal.

A further patient with gas gangrene of the abdominal wall following abdomino-perineal resection of the rectum has just completed five days of oxygen, antibiotics and surgical debridement, including the removal of left rectus muscle.

He appears to have made a satisfactory recovery and will not require further hyperbaric oxygen therapy.

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References

1. Unsworth IP (1974) Acute Carbon Monoxide Poisoning, Anaesth. and Intensive Care, 4:329.

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Some people are abnormally sensitive to decompression sickness. One New Zealand diver is so liable that he must limit himself to 20 feet depth maximum.

Chest pain after a dive may indicate mediastinal emphysema or myocardial ischaemia.

Many divers are too buoyant to maintain a 10 foot or 20 foot decompression stop depth. Sport divers should avoid dives requiring decompression stops.

Cold gives little warning of the onset of Hypothermia. Abnormal behaviour (forgetfulness) may occur. 70% of the human body is within 2.5 cms of the surface. Activity increases heat loss. Danger period continues after the victim has been removed from the water. Heat loss occurs even in "warm" water. Severe but reversible hypothermia may produce a deathlike appearance and therapy be wrongly though useless.

In-water Oxygen therapy can be limited to 10 metres by so limiting the length of the gas supply hose.

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