THE TREATMENT OFFSHORE

OF

DECOMPRESSION SICKNESS

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EUROPEAN UNDERSEA BIOMEDICAL SOCIETY

Les Tables Rondes Sur La Biomedecine Sous-mer

WORKSHOP

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Les Tables Rondes sur la Biomedecine Sous-Mer

THE TREATMENT OFFSHORE OF DECOMPRESSION ILLNESSES*

On 17 February, 1976, some 30 physicians from the United Kingdom, United States, France, Switzerland, Norway, Canada, and Italy gathered in the Marcus Beck Library of the Royal Society of Medicine in London on a cold, grey day. They sat around a horseshoe-shaped table to deliberate how to improve the treatment of divers who contract decompression illness while working offshore on oil rigs in the North Sea. The lucky horseshoe was perhaps an omen for the good fortune which enabled not only a number of physicians, but physicians from many countries, to agree to common treatment practices. If this sounds pessimistic, this pessimism was reflected in the attendees' attitude at the end of the first day. By the end of the second day, however, there was agreement that the Workshop was a considerable success both as a venue for exchange of ideas and methods of treatment, and for the common accord reached on many techniques and tables. The difficulties of the first day were covered when it became apparent that many different types of tables were used for treatment. However, there was little dissent from the proposed treatment principles prepared by Surgeon Commander D. H. Elliott, OBE, RN, the Chairman of the meeting. These are presented in detail later.

It will not be possible to document all the material of the two days but an attempt will be made here to identify some of the more important aspects of this EUBS meeting, which was supported by the U.K. Offshore Operators Association.

In introduction, Dr. R. Houston, Medical Director, Shell(UK), noted that the biggest hazards in offshore diving have occurred in the North Sea, in diving which started at 100 m, is now at 200 m, and will soon be at 300 m and beyond. Many divers have been killed. With the industry expanding and completely dependent on diving, the problems of the health and safety of the diver are of immediate concern. Automated systems are not yet possible in North Sea conditions, and submersibles are not sufficiently sophisticated for this working environment, although diver lock-out submersibles are the choice of the future.

Dr. Houston noted that treatment procedures vary considerably among different countries; there is need to clarify these, and if necessary to agree to differ because,in emergency, doctors from the countries represented have to work together in the treatment of a particular patient. The first day was devoted to the airing of that knowledge and the second to how it is applied.

In the interest of clarification, a number of terms were defined carefully for clinical use in this field and these are given below:

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* Report prepared covering the European Undersea Biomedical Society Workshop, held in London, 17 February 1976

Dysbarism. Any pathological condition arising from a change of pressure (compression/decompression) including but not synonymous with decompression sickness.

Barotrauma. Mechanical damage to the tissues as a direct result of a change in environmental pressure. This includes both compression and decompression injury.

Decompression Barotrauma. This occurs when the gases within a cavity expand during a reduction of ambient pressure, whilst some obstruction prevents their unrestricted venting into the atmosphere. (The anatomical site of the damage needs to be specified).

Pulmonary Barotrauma. By definition this includes the chest "squeeze" of the traditional helmeted diver, but it is commonly used as an abbreviation for 'Pulmonary Decompression Barotrauma'.

Arterial Gas Embolism. A complication of Pulmonary Decompression Barotrauma.

Decompression Sickness. The overt illness which follows a reduction of environmental pressure, sufficient to cause the formation of bubbles from the gases which are dissolved in the tissues.

Compressed-Air Illness or Caisson Disease. These are terms to be reserved for the decompression sickness associated with compressed-air workers.

Silent Bubbles. These are not overt and neither are the problems that they cause (ranging from platelet disturbances to, possibly, bone necrosis); even if heard ultrasonically, they do not constitute decompression sickness.

Bends. This is a common term which has been used for almost any manifestation of decompression sickness. It should be used with caution if ambiguity is to be avoided. 'Limb-bends' for instance, is acceptable for the musculo-skeletal form of acute decompression sickness.

Type 1 and Type 2 Bends. This classifies sickness into minor and serious, and is best used only in retrospective evaluation of the efficacy of decompression tables. (It has led some inexperienced persons dealing with acute limb bends to forget that some 30% of those presenting with limb-bends have, or soon will have, some other manifestation. This could lead to inadequate treatment, if case management is linked to minor or serious types).

Decompression Disorders and Decompression Illness. These terms cover both pulmonary decompression barotrauma and its complications, such as arterial air embolism and acute decompression sickness. These terms are particularly useful as they also include those not uncommon cases that seem to fall between the two major diagnostic categories.

Among terms discouraged were:

Niggle, for limb discomfort or a pain which may either be resolved in 10 to 30 minutes or may proceed to a bend.

Aeroembolism, which is ambiguous and has been applied to aviators, decompression sickness, and arterial air embolism.

Staggers, regarded as an inadequate term for clinical usage.

Recompression. It is better to use terms such as compression or therapeutic compression.

Hit. It is too nonspecific for a decompression incident.

It was recognized, however, that in discussion with non-clinicians in the field, latitude is required.

Proceeding to a discussion of the treatment protocols in current use, Surgeon Rear Admiral John Rawlins, OBE, QHP, RN pointed out in summary at the end of the workshop that there is considerable variation in treatment procedures. Admiral Rawlins considered that at this time no conclusions could be reached. The wide range of opinions on treatment led to the conclusion that we still know too little of the pathophysiology of decompression sickness and, perversely, we appear to be trying to deduce this from the treatments used when the reality should be the other way around. Further, the physical models presently in use do not fit the facts. Admiral Rawlins remarked too on the lack of international pathologists and biochemists working in this area.

Nevertheless no great exception was made to the discussion paper by Surgeon Commander David Elliott, which reviewed treatment procedures. It is reproduced here in the version subsequently agreed upon by representatives of the EUBS and the AODC for general guidance.

EUBS TABLES RONDES SUR LA BIOMEDECINE SOUS-MER

THE CHOICE OF A THERAPEUTIC COMPRESSION TABLE IN RELATION TO THE CAUSATIVE DIVE - (AS RECOMMENDED BY REPRESENTATIVES OF THE EUROPEAN UNDERSEA BIOMEDICAL SOCIETY AND THE ASSOCIATION OF DIVING CONTRACTORS, LONDON, FEBRUARY 1976)

1. AIR DIVING

Decompression illness arising at the surface following air or oxy-nitrogen dives (of a duration less than saturation) should be treated in accordance with one of the following procedures:

1.1 IMMEDIATE TREATMENT (IF NOT LIFE-THREATENING)

i. Compress chamber with air, breathing oxygen from the surface to 60 ft (18 m)

ii. At 10 mins review:

- if limb-bends cured - USN 5 or RN 61
- if serious symptoms cured - USN 6 or RN 62
- if improving - remain at 60 ft (18 m) and at 45 mins review:
  - if cured - USN 6 or RN 62
  - if not cured - USN 6 with extra oxygen sessions
- if symptoms worsening - off oxygen and compress to 165 ft (50 m) AIR
  - if on arrival at 165 ft (50 m) limb-bend is cured, use USN 2A (RN 52) but for all serious manifestations use USN 4 (oxygen at shallow stops compulsory for patient AND ATTENDANTS) or RN 54.
  - French-trained divers would tend to use 30 m oxygen-rich rather than 50 m air tables.

1.2 IMMEDIATE TREATMENT IF LIFE-THREATENING OR IF CEREBRAL AIR EMBOLISM IS SUSPECTED

Proceed direct to 165 ft (50 m) AIR. Do not spend time on oxygen at 60 ft (18 m).

For air embolism the US Navy now use table 6A, but Royal Navy experience favours a version of USN 4 (RN 54) using a continuous rate of ascent (18 to 10 m at 1m/hr, and 10 m to surface at 0.5 m/hr) in place of stoppages from completion of 6 hrs. at 18 m.

1.3 TREATMENT AFTER SOME FIVE OR MORE HOURS DELAY BETWEEN ONSET AND COMPRESSION

Use USN 6 (RN 62) with extra oxygen sessions as needed. French-trained divers also would use 18 m oxygen tables but with a 30 m oxygen-rich option if there is no relief after 15 mins.

2. SATURATION DIVING

2.1 TREATMENT DURING SATURATION DECOMPRESSION

For the onset of decompression sickness during a slow saturation decompression breathing oxy-helium or other mixtures, compress at 5 ft/min (or 2m/min) to depth of significant relief, but by not more than 2 bar (60 ft; 20 m) for pain-only limb bends and by not more than 3 bar (100 ft; 30 m) for serious decompression sickness, inner-ear manifestations in particular.

It is worth noting that the onset of inner-ear decompression sickness may be associated with a recent switch from helium to air during the decompression. If compression is required in these circumstances the patient should be returned to an oxy-helium atmosphere. For this reason alone, when the change to air is made, it is advisable to keep one of the chamber compartments not being used by the divers at that time filled with oxy-helium. Thus it is immediately available for any necessary treatment during the period following the change of air.

Remain at that depth for a minimum of 2 hours and possibly 6 hours. Oxygen-rich mixtures (1.5 to 2.5 bar O_2) may be breathed for up to six 20-min periods with 5-min intervals on chamber atmosphere.

Resume saturation decompression from treatment depth, but with no initial upward excursion.

2.2 EXCURSION DIVING FROM SATURATION

Following an excursion, immediate compression is necessary to the depth of relief. This depth may be less than the depth of excursion, but for serious symptoms it should be not less than 3 bar.

Remain at the treatment depth for a minimum of 2 hours, for as long as improvement occurs and possibly for as long as 24 hours. Oxygen-enriched mixtures may be used (as in 2.1). Initiate saturation decompression from treatment depth, but with no initial upward excursion.

3. OXY-HELIUM "BOUNCE" DIVING

Deep oxy-helium dives from the surface, with a bottom time of relatively short duration, which lead to decompression sickness during the course of, or soon after, a decompression more rapid than used for saturation diving.

3.1 ONSET OF DECOMPRESSION SICKNESS AT THE SURFACE

Breathe oxygen by mask from the surface and compress chamber with air to 50 ft (18 m). If cured or improving after 10 minutes, continue oxygen treatment as detailed in paragraph 1.1.

If condition not improving at 10 minutes, discontinue oxygen and compress chamber to depth of relief, using pure helium. (This incoming gas must be well-mixed, perhaps by venturi, with the chamber atmosphere of air and the divers should breathe an oxy-helium mixture by mask during the compression until mixing is complete).

If the condition is serious at the surface, compress to 60 ft (18 m) with air but do not stop at 18 m. Continue on helium to depth of significant relief.

Ideally, the chamber should have a partial oxygen pressure of about 0.4 bar at all times, the diver breathing a higher-oxygen mixture by mask (as in 2.1), as needed. (The upper limit of oxygen in the chamber atmosphere should be 0.6 bar). Since the chamber contained 2.8 bar air and was further compressed using 100% helium, the chamber atmosphere will have a partial pressure of oxygen of about 0.6 bar, whatever the depth of relief.

Other methods of achieving an acceptable atmosphere are possible, but need to be carefully planned in advance.

Remain at least 2 hours (as in 2.2), after which decompression should be initiated on a saturation table, but with no initial upward excursion. For guidance the following rates may be used:

deeper than 100 m	1.5 m/hr
100 to 10 m	1.0 m/hr
10 m to surface	0.5 m/hr

3.2 ONSET OF DECOMPRESSION SICKNESS DURING THE ORIGINAL DECOMPRESSION

- Immediate compression to the depth of relief and, if relief is not achieved, to at least the full depth of the dive.

- Remain at least 2 hours, optional oxygen-enriched breathing mixtures (as in 2.1 and 2.2).

- Begin saturation decompression from treatment depth, but with no initial upward excursion.

4. UNCONTROLLED ASCENT (BLOW-UP) TO THE SURFACE

The unscheduled surfacing of a diver is hazardous at all times but especially so if he has not completed all the necessary stoppages.

ONE MUST ALWAYS BE PREPARED TO COMPRESS THE DIVER, IMMEDIATELY UPON SURFACING, IN A CHAMBER TO THE FULL DEPTH OF

HIS DIVE, AND, IF NECESSARY, TO DECOMPRESS ON A SATURATION SCHEDULE.

5. NOTES FOR ALL CASES

5.1 Attention must be paid at all times to preventing pulmonary oxygen toxicity. A UPTD (unit pulmonary toxicity dose) of 615 (equivalent to a reversible 2% decrement of vital capacity) should not be exceeded, thus allowing latitude for any further treatment.

5.2 The rate of decompression should be determined by the condition of the patient, symptoms usually being a more sensitive guide than outward signs.

5.3 Any deterioration of the patient during the decompression following a therapeutic compression should be treated by further compression to the depth of significant relief.

5.4 This outline is for guidance only since it cannot predict every situation and some differences of opinion may still exist on details of treatment between medical practitioners experienced in this field.

Commenting on treatment procedures, Dr. David Youngblood, Medical Director, Oceaneering International, also noted the lack of a uniform approach to treatment at present, commenting that the U.S. Navy procedures commonly used in the past have been replaced by "cook book" inventive methods. Classification of Type I and II bends is inadequate, as supervisors often will classify in this manner prior to diagnosis. He felt that the greatest need was to make a proper diagnosis including a rudimentary neurological examination, and to initiate a simple treatment procedure as rapidly as possible, since speed of treatment shows a direct correlation with degree of success.

Since all the material presented cannot be given here, some of the more important points about which there was general agreement will now be discussed, particularly in regard to the use of drugs and i.v. fluids or plasma expanders.

Dextran - In an excellent presentation, Mr. A. Ah-See, a surgeon from the University of Aberdeen, indicated that the wide use of

Dextran 40 was unwise. It is primarily used for loss of plasma volume rather than its antithrombic action. Although one bottle of Dextran 40, being 10%, will increase plasma volume by 1000 ml whereas one of Dextran 70, being 6%, will only increase it by 600 ml, the higher molecular weight dextran is superior because of its longer lasting effect. In 5-10 mins, the D40 will indeed replace more fluid but in the next 60 mins there will be more lost by the kidney than with D70. Further, for coagulation factors D70 is superior. However, it was generally agreed that considerable care is needed in administering i.v. fluids and much more research is needed as to how agents, such as dextran, act -- it may only be aiding the microcirculation and having no effect on agglutination. Some viewed it for use only in an acute situation where other methods are failing to help; since its validity is unproven, it was considered unnecessary at this time and in need of further verification. It was emphasized by Dr. J. Farmer, Associate Professor Otolaryngology, Duke Medical Center, that the use of i.v. dextran is contraindicated where there is inner-ear bleeding.

Corticosteroids for edema of the central nervous system were recommended for use only by experienced medical staff in a hospital. Their use is governed by the same problems for hyperbaric oxygen and dextran - we do not know when or how to use them, and more research work is required before they can be recommended except as a later resort.

Heparin also should be used only by a physician and as a last resort, but not for any otologic or vestibular cases.

Aspirin was the subject of considerable debate, but in general was not favored since it could well make any hemorrhage worse. Le Medecin Principal R. Hyacinthe, French Navy, remarked that controlled studies showed that it had no effect on the treatment of decompression sickness.

Valium was considered of value for symptomatic relief and for those treated with hyperbaric oxygen, but should not be used in vestibular cases because it will eliminate diagnostic nystagmus.

Vasoactive drugs were used by the Comex group, but as a result of wide-ranging discussion it was concluded that many of these had no effect on cerebral or auditory blood flow and were of dubious value. Nicotinic acid in particular was not recommended.

In the United Kingdom many of the ambulances carry a 50/50 mixture of nitrous oxide and oxygen (NITROX) as an analgesic. This should not be used for cases of decompression sickness because any causative bubbles will expand and make matters worse.

All operational staff, it was considered, should be told to make sure that any case sent ashore for treatment is accompanied by a responsible person who will confirm that the patient has decompression

sickness and see that pressure-chamber treatment is established.

In the case of otologic or vestibular decompression illness, compression as soon as possible to 100 ft. (30 m) beyond the incidnt was recommended, in addition to utilizing oxygen cycles and resuming decompression on a saturation mode.

The use of so-called 'Yo Yo' treatments of repeated exposures to 165 ft (50 m) air in the case of a treatment failure was unanimously refuted.

Blow-up - Cases should be compressed to the depth from which they came or deeper, and remain for 6-8 hours. Then, saturation decompression should be used, even if there are no symptoms. Captain Jim Vorosmarti, MC, USN, described 7 out of 13 cases where blow-up occurred deeper than 200 ft during decompression. Those that were recompressed only to 165 ft (50 m) did not survive. Deaths were delayed, and occurred during treatment.

Recompression in the water. It was agreed that this practice has no place in commercial or sports diving. The necessary chamber equipment for treatment should be at any site where decompression sickness may be expected. This leads to important problems on the rigs and in rig design, sometimes requiring divers to climb stairs or negotiate over a long distance climbing over equipment to get to the pressure chamber. Some form of mechanical elevator system is required instead of steps.

So far as the chamber itself is concerned, it was recommended that the inner lock be kept pressurized on stand-by at a pressure equivalent to 165 ft (50 m), with the outer lock ready.

In general, monoplace chambers (one-man, one-compartment) were not favored, although it was conceded that they may have some value for transportation of cases. However, this should only apply to stable conscious cases and not to acutely ill patients.

If a medical practitioner is not available, competence will depend on the degree of training of those present. In this regard, the Undersea Medical Society National Plan Report 5T "Selection and Training of Physicians and Paramedics for Offshore Diving" and Report II "Use of Drugs and Other Medical Treatment under Hyperbaric Conditions" were considered important guidelines for requirements, as was the content of a recent UMS workshop on the subject of "Emergency Medical Technician - Diver".

It was considered that the procedures of endotracheal intubation and defibrillation should not be carried out by offshore paramedics.

The setting up of an i.v. could be difficult in a shocked patient, and there was some doubt as to whether a paramedic would be able to find a suitable site to insert the i.v., even on the back of the hand which was considered the best site under the circumstances. In this case, a cut-down to the saphenous vein was recommended,

Communications between shore and rig have proved difficult in the past. It was recommended that some alternative to voice communication should be available and that the non coded Telex system should be on all rigs. A standard form check-list of dive and clinical data should be used by all, with copies on the rigs and at shore-treatment centers. Any information relating to communications problems should be sent to either Dr. Colin Jones, BP, Aberdeen, or Admiral Rawlins at Alverstoke.

Neurological sequelae can be prolonged after treatment. Hyperbaric oxygen and the repeated use of Table 5 were recommended for as long as improvement continues; they may well resolve the problem and reduce residual injury. This too was an area that required further research.

Perhaps one of the most important recommendations was for standardized diving accident reports with a repository for this data from all over the world. It was suggested that the U.S. Navy Safety System might be involved in this data collection.

In concluding, Tom Earls of Oceaneering International, a representative of the Association of Offshore Diving Contractors, pleaded for everybody to use the same terms and to separate the long-term and ideal solutions from the immediate and practical problems. He stressed the need to eliminate the multiplicity of treatment tables and to give clear guidelines with simple instructions and to identify possible hazards clearly. He reminded participants that it is necessary to clarify these problems if legislation is to be avoided. The legal problem of liability is heavily involved and it is necessary to know where there are differences of opinion so that the liabilities can be determined. Mr. Earls pleaded for the clinicians not to put the industry into the position -- damned if it does and damned if it does not.

In his pertinent and entertaining summary, Admiral Rawlins again stressed the need for agreement on common procedures since in reality there is little real variation, but he expressed opposition to mandatory standardization of tables since we do not know who can choose the most suitable table or who is able to supply them. Frank information from the industry is required if the best medical support is to be given and more medical, physiological, and biological specialists

are required for research into the difficult problems discussed over the two days of the meeting, together with more workshops of the present type. Constant self-criticism was advised, with as much input from other medical disciplines as possible.

The delegates dispersed back to their respective countries with a firmer grasp of the do's and don't's of treatment for decompression sickness and barotrauma, and a better awareness of the problems. A further workshop on the pathophysiological aspects of decompression sickness and its treatment will be held by the Undersea Medical Society later in 1976.