SECOND EUROPEAN CONSENSUS CONFERENCE ON HYPERBARIC MEDICINE

THE TREATMENT OF DECOMPRESSION ACCIDENTS IN RECREATIONAL DIVING

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RECOMMENDATIONS OF THE JURY*

QUESTION 1 : Is there a difference between recreational and commercial diving decompression accidents?

Whatever the reasons and the methods for diving, they all share similar risk (the same decompression profile after the same dive will bring about the same decompression risk), similar physiopathology (a decompression accident will generate similar disorders in both circumstances) and similar results (if the delay to treatment is similar).

The observed differences between decompression accidents in the two types of diving essentially regard the degree of risk (fitness to dive, training, work load, depth, environment, safety standards) and the delay before treatment (symptom recognition, hyperbaric chamber availability).

The recommendations of the jury (Type 1 recommendation) are the following :

- implementing fitness to dive standards, both for recreational and commercial diving.
- implementing an adequate classification of Decompression Accidents
- implementing a coordinated network for the collection and the retrospective analysis of data concerning decompression accidents
- improving the recreational diving safety standards to approach the current standards applied in commercial diving, with special regard to :
    - availability of oxygen on every dive site
    - availability of a recompression chamber within a delay of 4 hours
    - preparation of an emergency plan before any dive
- recreational divers should be trained, like commercial divers are, to recognize signs and symptoms of decompression accidents.

QUESTION 2 : How to classify decompression accidents?

Depending on the intended utilization objective, there are three possible ways to classify decompression accidents:

- immediate clinical use, need for rapid and efficient communication between divers and Emergency Services, on site first aid and medical evacuation of injured divers, data selection and availability for clinical studies.
- epidemiological use for the retrospective analysis of data and of treatment results.
- description of lesions based on anatomical-pathological observations.

The recommendations of the Jury (Type 1 recommendation) are the following:

- immediate use classification should be simple and objective. The jury recommends that it is based on that adopted by the UHMS (Smith and Francis).
- epidemiological use classification for retrospective analysis should allow for the institution of a data bank collecting the observations from a great numbers of countries. To this purpose, harmonization between national classifications should be established in order to allow transcodification. This classification should:
    - be multithematic in its conception
    - include the type of diving, chronological data, clinical manifestations and a two-year follow-up.

QUESTION 3 : Which experimental model for decompression studies?

Considering the complexity of the question and the difficulty in conducting rigorous clinical studies with sufficient numbers of experimental subjects, the Jury agreed that animal studies are still needed.

The recommendations of the jury (Type 1 recommendation) are the following:

- experimental studies are necessary for more information on decompression accidents
- the variables to study are many and include:
    - the bubble phenomenon
    - central neurological manifestations
    - bone and skin manifestations
    - pulmonary disorders
    - cardio-vascular disorders.
- as a general principle in vitro studies should precede in vivo studies, and in vitro studies should be done before in vivo ones.
- among the animal models so far used, small animals (rodents) do not seem to adequately reproduce the human observations. Among the larger animals, the dog is less and less used, sheep and ewes are mainly used for pulmonary studies, while the pig seems to be the animal that better reflects human reactions to decompression.

Concerning methodology, the Jury recommends that studies:

- consider clinically significant parameters,
- consider experimental conditions, particularly when anesthesia modalities may interfere with the observations,
- include a detailed description of the animal model in each published paper.

QUESTION 4 : Which initial recompression modality?

Decompression accidents are true medical emergencies that must benefit from treatment in specialized centers as soon as possible. A specialized center is considered as a hospital based facility, having not only a hyperbaric chamber but also a permanent and adequately trained medical and paramedical staff.

The victims of a decompression accident should be immediately directed from the site of the diving accident to the closest specialized center (Type 1 recommendation).

Minor decompression accidents (pain only) should be treated with oxygen recompression tables at 18 meters depth maximum (Type 1 recommendation).

Regarding more serious decompression accidents (neurological and vestibular accidents), the jury observed that there are presently two acceptable protocols, as neither one has been proved better by any scientifically valid study to date:

- oxygen recompression tables at 2.8 ATA (with possible extensions)
- hyperoxygenated breathing mixtures at 4.0 ATA.

The choice between the two may depend on personal experience and on local logistics. However, under no circumstance the un-availability of one of the two accepted modalities should delay the treatment (type 1 recommendation).

The jury also considered the following optional treatment modalities (type 3 recommendation):

- compression to 6 ATA in case of cerebral arterial gas embolism, with the condition that this compression is performed using hyperoxygenated mixtures and not compressed air and that the delay to treatment is not more than a few hours.
- saturation treatment tables in case of persistent symptoms.

Finally the jury recommends that :

- in water recompression should never be undertaken as the initial recompression modality for a decompression accident (Type 1 recommendation).
- all decompression accidents should be the object of a standardized recording method aimed at the creation of database for epidemiological studies (type 1 recommendation).

QUESTION 5 : Which fluid replacement protocol and which role for drugs in the treatment of decompression accidents ?

1 - Fluid treatment

Victims of decompression accidents generally suffer from a certain degree of dehydration, depending on decreased fluid input, increased urinary output, capillary fluid leakage and disorder-related relative hypovolemia.

The degree of dehydration should be evaluated:

1. on site: history, dive conditions, thirst, clinical evaluation of neurological conditions, hemodynamics, temperature, vasoconstriction, dryness of mucosae, urinary output.
2. at hospital: urinary output, hemodynamics to include CVP, hematocrit, plasma proteins and electrolytes.
3. Recommended hydration protocols:

a) Pre-hospital:

1. **oral hydration** is recommended only if the patient is conscious (Type 1 recommendation)

Contra-indications to oral re-hydration are stringent and include :

- any consciousness abnormality
- nausea and vomiting
- suspected lesions of the gastro-intestinal tract.

Oral re-hydration should be done with plain water, possibly with the addition of electrolytes but with no gas. The administered fluid should be cold if the patient is hyperthermic. Sugar is not recommended. The amount of fluids administered should be adapted to the patient's thirst and acceptance.

2. **intravenous re-hydration** should be preferred if a physician is present. Recommended procedures are as follows:

- use a peripheral venous catheter (18 gauge) and preferably Ringer Lactate as the infusion fluid. Glucose containing solutions are not recommended.
- the addition of colloids can be considered if large quantities of fluids are needed. Recommended colloids, in order of preference, are starch-containing solutions, gelatines, haptene

added dextranes (Type 3 recommendation).

b) At the hospital:

3. **intravenous re-hydration** is recommended while controlling the routine physiological parameters: urinary output, hemodynamics, CVP, standard laboratory tests.

2 - Drug treatment

a) Strongly recommended (type 1 recommendation) :

- normobaric oxygen

  The administration of normobaric oxygen allows for the treatment of hypoxemia and favours the elimination of inert gas bubbles. Oxygen should be administered with an oro-nasal mask with reservoir bag, at a minimal flow rate of 15 l/min, or with CPAP mask circuit, using either a free flow regulator or a demand valve, in such a way to obtain a FiO2 close to 1.

  In case of respiratory distress, shock or coma, the patient should be intubated and ventilated with a FiO2 = 1 and setting the ventilator to avoid pressure and volume trauma. Normobaric oxygen should be continued until hyperbaric recompression is started (with a maximum of 6 hours when the FiO2 is 1).

b) Recommended (Type 2 recommendation):

- any necessary drug for the support treatment of an intensive care patient (adequate first aid kit)

c) Optional (Type 3 recommendation):

- on site
  - any way to prevent hyperthermia
  - aspirin: 500 mg orally in the adult patient (contra-indications similar to oral re-hydration)
- at the hospital : use drugs having no significant collateral effects, such as:
  - aspirin : 500 mg if not already administered or contraindicated
  - lignocaine
  - low dose heparin (avoid complete decoagulation)
  - steroids, calcium channel blockers, antioxydants

QUESTION 6: Which treatment protocol for persistent symptoms after the initial recompression ?

The Jury concluded that there are no scientifically valid data to allow for a recommended approach to this issue.

More studies are necessary as well as the adoption of standardized evaluation methods. Concerning spinal cord injuries, a specific scoring system (such as the ASIA scale) is recommended for pre and post treatment evaluation and during the two-year follow up.

Randomized prospective studies are needed to better evaluate the efficacy of hyperbaric oxygen therapy and of rehabilitation before any protocol can be proposed or recommended. However, in analogy with any other neurological injury, rehabilitation should be started as soon as possible (Type 1 recommendation).

Hyperbaric oxygen treatment is recommended to a maximum of 10 treatment sessions after the initial recompression, in combination and during rehabilitation therapy. The continuation of HBO therapy can be accepted if objective improvement is observed under pressure during the hyperbaric treatment sessions (Type 3 recommendation).