

SCIENTIFIC GUIDELINES FOR OCCUPATIONAL MEDICINE

Guideline for diving accidents

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by the German Society for Diving and Hyperbaric Medicine (GTÜM) and the Swiss Underwater and Hyperbaric Medicine Society (SUHMS)
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Abstract

In April 2015 the German Society for Diving and Hyperbaric Medicine (GTÜM) and the Swiss Underwater and Hyperbaric Medical Society (SUHMS) published the updated guideline for diving accidents 2014-2017. These multidisciplinary guideline were developed within a structured consensus process by members of the German Interdisciplinary Association for Intensive Care and Emergency Medicine (DIVI), Hyperbaric Medicine Section, the German Sports Divers Association (VDST), the Naval Medical Institute (SchiffMedInst), the Occupational Accident Insurance Body for the Building Trade (BG BAU), the Association of German Hyperbaric Treatment Centres (VDD) and the German Society of Occupational and Environmental Medicine (DGAUM).

This consensus-based guidelines project (development grade S2k) with a representative group of developers was conducted by the Association of Scientific Medical Societies in Germany (AWMF). It provides information and instructions based on up-to-date evidence to all divers and other lay persons for providing first aid, along with recommendations to medical first responders and emergency medics, paramedics and all physicians working in therapeutic hyperbaric chambers regarding the diagnosis and treatment of diving accidents.

On-site 100% oxygen first aid treatment, still patient positioning and fluid administration are recommended. Hyperbaric oxygen therapy (HBOT) remains unchanged as the established treatment in severe cases, as there are no therapeutic alternatives. The basic treatment scheme recommended for diving accidents is hyperbaric oxygenation at 280 kPa. For quality

management purposes there is a need in the future for a nationwide register of hyperbaric therapy.

Keywords: *decompression sickness – oxygen – hyperbaric oxygen therapy – patient positioning – fluid therapy*

1. Definition and epidemiology

Incidents when diving may have various causes which need not necessarily be linked to hyperbaric exposure. Fundamentally, the initial presumption should be of a diving accident. A “diving accident” in the sense of this guideline is an event which is potentially life-threatening or harmful to health, brought on by a drop in the ambient pressure when diving or from other hyperbaric atmospheres with and without diving equipment in the decompression phase.

These processes are variously referred to in English as “decompression illness”, a “decompression incident” or a “decompression injury”, and the standard abbreviation adopted internationally for this is “DCI”. In German and in the Guideline, the term used is “Dekompressionsunfall”.

Depending on the mechanism by which they were brought on, DCIs can be differentiated as follows (see also Figure 1):

“Decompression Sickness” (“DCS” – in German: “Dekompressionskrankheit”):

The indicator is the formation of gas bubbles in the blood and tissue following extended exposure to atmospheric overpressure and corresponding saturation with inert gas.

“Arterial Gas Embolism” (“AGE” – in German: “Arterielle Gasembolie”):

Gas bubbles in the arterial circuit following pulmonary barotrauma or following right-to-left shunting of venous bubbles.

The risk of a decompression injuries in divers or compressed air workers is significantly dependent on the diving conditions and tasks performed. Frequency is indicated at between 1 (sports diver) and 9.5 (professional diver) per 10,000 dives (Vann et al. 2011).

There are only limited statistics available on the frequency of DCIs in Germany. In the concluding report of the Hospitals Committee, the number of the most serious diving accidents in Germany was estimated at over 200 per year. Several hundred cases of less serious injuries requiring treatment can be added (Hospital Committee, 2003). Concerning vocationally-induced decompression illness, the documentation from the statutory accident insurance bodies is available. It indicates that over the period 1993-2012 there were a total of 267 notifications of the existence of an occupational illness due to “Illness through work

involving compressed air" (BK No. 2201). Over the same period, a total of 126 cases were recognised as an occupational illness.

There is no evidence-based data. The diving accident statistics gathered exhibit statistical differences and defects. There is a lack of comparability.

The suspected high number of unrecorded diving accidents is justified as follows:

Divers suffer a DCI and are not treated as an in-patient.

Out-patient treatment is not recorded.

Divers treat their symptoms themselves.

Misdiagnoses.

2. Symptoms and diagnosis

The range of symptoms of DCI makes diagnosis more difficult.

The diagnosis "diving accident" should be made following a physical examination, taking the dive and previously-existing problems or illnesses into consideration. All symptoms which have arisen following a dive should be viewed as a possible DCI.

These guidelines classify the degree of severity of the diving accident using the following classification:

Mild symptoms

Fatigue

Some cutaneous sensory changes/itching/pruritus

with complete or near-complete regression within 30 minutes following application of the specific first-aid measures.

Severe symptoms

Rash

Tingling sensations (formication)

Numbness

Pain

Paralysis

Bladder dysfunction

Muscular weakness

Difficulty breathing/dyspnea

Visual disturbance/reduced hearing/altered speech

Dizziness

Nausea/vomiting

Consciousness disturbance

Loss of consciousness

Persistence of unchanged mild symptoms after 30 minutes despite the specific first-aid measures, or reoccurrence

Due to the frequent neurological symptoms, a neurological examination is to be conducted on all divers with a suspected diving accident, if this does not impair other treatment. An initial orienting examination should also be carried out by the person giving first aid.

3 Treatment

For diving accidents, as a rule it is the diving partner, safety diver, diving group leader and diving instructor who are called on to administer first aid on the spot.

The success of these first-aid measures and the later treatment is critically depending on these first aid measures being applied rapidly and correctly.

Requirements:

Suitable training for all divers

The availability of emergency equipment adapted to the planned dive

A diving accident plan (diving emergency plan, telephone numbers)

Reliable means of communication

3.1 On-site first aid

The suspected diagnosis of a “diving accident” is probable in the event of the following conditions pertaining:

The person was breathing using diving equipment under water, regardless of the breathing gas/breathing gas mix used (potentially even with just a single breath)

or

Air which had collected under water (e.g. in a wreck or cave) was inhaled

or

freediving has been performed (generally several deep dives)

and

The person has mild and/or severe symptoms (see Section on “Symptoms and diagnosis”).

Measures for mild symptoms

Check consciousness, ability to move and perception (e.g. "5 minute on-site neurological examination", see Appendix).

Immediate breathing of 100% oxygen or breathing gas with the highest oxygen content, regardless of the gas mix breathed during the dive.

Divers able to drink independently should be encouraged to drink 0.5-1 litre of fluids per hour (preferably isotonic, non-carbonated beverages, no alcoholic drinks)

Protect against both cooling down and overheating.

No wet recompression.

Continue 100% oxygen breathing until a diving medicine physician can be consulted, even if symptom-free within 30 minutes.

Telephone consultation with a diving medicine physician.

Record the course of the diving accident and the measures administered.

If symptoms persist unchanged after 30 minutes or reoccur, treat as severe symptoms.

Monitor divers for 24 hours following regression of mild symptoms.

Diving partners may subsequently similarly start to exhibit symptoms over time They should be monitored for mild or severe symptoms and, if necessary, included in further diagnostic and/or therapeutic measures.

Telephone consultation with a diving medicine physician

A physician trained in diving medicine¹² should advise whether hyperbaric chamber treatment is required and its urgency. Lay persons and even physicians without diving medicine training are generally insufficiently trained to give such advice.

National DAN hotline for Germany and Austria: 00800 326 668 783 (00800 DAN NOTRUF)

National DAN hotline for Switzerland (via REGA): +41 333 333 333 (or 1414 for calls within Switzerland)

VDST hotline: +49 69 800 88 616

Naval Medical Institute (Schiffahrtmedizinisches Institut der Marine) contact: +49 431 5409 1441

Aqua med divers' hotline: +49 700 34835463

International DAN hotline: +39 06 4211 8685 or 5685

On all these numbers, state the keyword "Diving accident".

A current list including telephone numbers can be found on the GTÜM's internet site (<http://www.gtuem.org>).

Measures for severe symptoms

CPR (basic life support):

For unconscious divers with no identifiable independent breathing, the recommendations for resuscitation measures in accordance with the current international guidelines apply in full¹³.

Diving accident-specific first aid:

Check consciousness, ability to move and perception (e.g. "5 minute on-site neurological examination", see Appendix).

Position:

Lateral recumbent position if consciousness is impaired

Still patient positioning

Do not have the head lowered

Immediate breathing of 100% O₂, regardless of the gas mix breathed during the dive:

If the patient is breathing adequately independently, then regardless of the state of consciousness arrange breathing of 100% O₂ using a close-fitting mask/breathing regulator (ensure that the mask is tightly sealed) with:

- Demand valve or
- Circulation system with carbon dioxide absorber
- Possibly via constant dosing (at least 15 litres/minute) with a reservoir bag, if no better systems are available.

In the event of inadequate independent breathing, ventilate using a mask with 100% O₂ feed via:

- Ventilation bag with 100% O₂ demand valve or
- Ventilation bag with O₂ reservoir and O₂ constant dosing (at least 15 litres/minute) or
- Circulation system with CO₂ absorber.

The breathing of 100% oxygen must also be continued without any break by the emergency service until reaching the hyperbaric chamber for treatment.

Even where the reserve of O₂ is very limited, O₂ should always be given in the highest possible concentration, and in no instances mixed with ambient air or, if constant dosing, at less than 15 litres/minute.

Administering fluids

Divers able to drink independently should be encouraged to drink 0.5-1 litre of fluids per hour (preferably isotonic, non-carbonated beverages/no alcoholic drinks)

Protect against both cooling down and overheating. In the event of hypothermia, do not actively raise the body temperature, as this can lead to a worsening of the diving accident symptoms.

Alert the rescue services call centre – “Suspected diving accident”

No wet recompression

Telephone consultation with a diving medicine physician

Record the course of the diving accident and the measures administered

Organising transportation:

Organise the means of transport via the rescue services control centre

Transport destination: Nearest suitable reachable emergency department, if possible close to a hyperbaric therapy chamber

Check whether the diving partners are symptom-free and that there are no breaches of decompression requirements, if necessary seeking advice from a diving medicine physician over the phone

Documentation: When transferring the diver to the emergency services/accompanying the diver during transportation, pass on the documentation with the diving data, the pattern of symptoms and the treatment measures administered to date.

Securing equipment: All devices which might contribute to a reconstruction of the diving accident must remain untouched. The diving computer is to be given to the diver or the emergency services staff.

3.2 Primary treatment by specialist medical personnel

CPR (basic + advanced life support):

Resuscitation measures are to be carried out in accordance with the latest international guidelines¹⁴.

Drowning can be the consequence of a diving accident and must be treated specifically in such an instance.

Diving accident-specific measures for severe symptoms

Position:

Position the diver in accordance with the standards for medical emergencies

Still patient positioning

Breathing of 100% O₂ (starting as soon as possible, regardless of the gas mix breathed during the dive) with:

Regulator or

Demand valve or

CPAP mask (note risk in the event of suspected pneumothorax) or

Circulation system with absorber for CO₂,

alternatively via constant dosing (at least 15 litres/minute) via a tightly-sealing mask with a reservoir bag, if no better systems are available

Continue to administer oxygen until reaching a hyperbaric therapy chamber,

Even when the reserve of O₂ is limited, 100% O₂ should be breathed for as long as possible, taking into account that transportation will need to be effected with air breathing throughout.

Airwaymanagement:

With insufficiency of oxygenisation but adequate vigilance, a CPAP/NIV mask is preferable to intubation for continuous neurological evaluation.

Fluid replacement:

0.5-1 litre of fluid per hour intravenous (full electrolyte solutions preferred)

Drugs:

Except for oxygen, to date no drug has clearly proven any benefit in the treatment of diving accidents.

Further measures

Fundamentally, adopt procedures in line with the standard for medical emergencies

Repeated examinations over the course of treatment, including neurological aspects

Monitoring of vital signs

Urinary catheter in the event of bladder dysfunction

A pleural drain if necessary

Protect against both cooling down and overheating. In the event of hypothermia, do not actively raise the body temperature, as this can lead to a worsening of diving accident symptoms,

Telephone consultation of a diving medicine physician,

If indicated the fastest possible treatment in a hyperbaric therapy chamber

Hyperbaric chamber therapy is necessary in most cases, even if the start of treatment is delayed

Documentation of diving data, the pattern of symptoms and the treatment measures administered

Evaluation whether the diving partner also needs to be examined and if necessary needs to be treated by a medic trained in diving medicine physician¹⁵

3.3 Transportation (primary transportation)

Means of transport

In principle there is no preference for a particular means of transport. The fastest and most protective means of transport should be used, having regard to the overall transport time.

Helicopter (lowest possible viable altitude)

Land-based rescue vehicles (risk if journey involves mountain passes, due to additional reduction in pressure)

Boat (lowest possible vibrations)

Treatment during transportation

Breathing or ventilation using 100% O₂ should be continued without any break until a hyperbaric therapy chamber is reached.

Even when the reserve of O₂ is limited, 100% O₂ should be breathed for as long as possible, taking into account that transportation will need to be effected with air breathing throughout.

Frequent repetition of examination of the patient, including neurological aspects.

3.4 Hyperbaric chamber therapy

In principle, the first hyperbaric chamber therapy should occur as fast as possible. Even when the start of treatment is delayed (even by several days), it can still cause an improvement in the set of symptoms.

Measures prior to the first hyperbaric chamber therapy

Diagnostic imaging is not necessary as a matter of routine. If pneumothorax is suspected, imaging should be performed (thoracic x-ray, thoracic ultrasound, thoracic CT scan), if possible without significant loss of time delay.

Pleural drain if necessary,

Paracentesis if the patient is unable to perform pressure equalisation in the middle ear,

Urinary catheter if necessary.

Additional measures as medically required in the respective individual instance.

Treatment tables

The standard treatment table is "US Navy Treatment Table 6" or modifications of this table, with an initial treatment pressure of 280 kPa, see Figure "US Navy Treatment Table 6". This table is recommended for all diving accidents, regardless of the breathing gas used by the diver suffering the accident (e.g. air, nitrox, triox, trimix or heliox).

The hyperbaric chamber therapy can be shortened in the event of full regression of the symptoms listed below within the first 10 minutes of hyperbaric oxygenation at 280 kPa.

Constitutional or non-specific symptoms – pronounced fatigue

Cutaneous symptoms – changes of the skin

Lymphatic symptoms – localised swelling

Musculoskeletal symptoms – Pain in the joints and limbs

Mild peripheral-neurological subjective sensory disturbances *without* objectively-ascertainable pathological findings

In these cases the treatment can be shortened and ended in accordance with “US Navy Treatment Table 5” or similar tables. However, no additional severe symptoms must be present or have been present.

In the event of incomplete regression or a lack of regression in complaints or symptoms under hyperbaric oxygenation, the initial hyperbaric chamber therapy is extended. A maximum of two extensions, each of 25 minutes’ duration (20 minutes of oxygen breathing and 5 minutes of air breathing), are carried out at a treatment pressure of 280 kPa, and likewise a maximum of two extensions, each of 75 minutes’ duration (3 x 20 minutes of oxygen breathing and 3 x 5 minutes of air breathing), are carried out at a treatment pressure of 190 kPa.

If the treated diver is *not* nearly complaint-free after 60 minutes (3x 20 minutes) oxygen breathing at the initial treatment pressure of 280 kPa, then an initial extension of 20 minutes oxygen breathing and 5 minutes air breathing using the same pressure is carried out.

If the treated diver is *not* nearly complaint-free after 80 minutes (4x 20 minutes) of oxygen breathing at the initial treatment pressure of 280 kPa, then a second extension of 20 minutes oxygen breathing and 5 minutes air breathing using the same pressure is carried out. After this decompression to 190 kPa is performed in accordance with Table 6.

If the treated diver is *not* nearly complaint-free after 60 minutes (3x 20 minutes) of oxygen breathing at a treatment pressure of 190 kPa, then after a total of 120 minutes (6x 20 minutes) of oxygen breathing at this pressure a third extension, of a further 60 minutes (3x 20 minutes) of oxygen breathing and 15 minutes (3x 5 minutes) of air breathing is carried out.

If the treated diver is *not* nearly complaint-free after a total of 120 minutes (6x 20 minutes) of oxygen breathing at 190 kPa, then after a total of 180 minutes (9x 20 minutes) of oxygen breathing at this pressure a fourth extension, of a further 60 minutes (3x 20 minutes) of oxygen breathing and 15 minutes (3x 5 minutes) of air breathing is completed. After this, following a total of 240 minutes of oxygen breathing at 190kPa, decompression to ambient temperature is performed in accordance with Table 6.

Other treatment tables, particularly tables with longer treatment times and higher treatment pressures, together with mixed gas and saturation treatment tables should remain for use by facilities and personnel with special experience, knowledge and appropriate equipment

which enable them to deal with situations in the event of undesirable events and results. Oxygen-enriched breathing gas mixtures are to be applied with all treatment tables.

If hyperbaric chamber therapy is indicated in the event of inadequate decompression without any symptoms, shorter treatment tables are possible, for example "US Navy Treatment Table 5" or alternative tables (e.g. 240 kPa / 90 minutes oxygen breathing).

Having had initial hyperbaric chamber therapy without any improvement, the diagnosis of DCI should be verified.

Measures during the initial hyperbaric chamber treatment

Repeated neurological control examinations, e.g. during air breathing phases, prior to decision regarding possible extensions of the treatment table (documentation!)

Repeated clinical examination and auscultation of the lungs (pneumothorax? Possibly checking for even-sided breathing? Obstruction of the jugular vein?), especially following pressure reductions in the treatment table.

Regular check on all enclosed air-filled hollows in the medical treatment equipment (e.g. cuff of the ventilation tube, drip, droplet chamber, blood pressure sleeve), every time before and during pressure reductions in the treatment table.

Further measures

Fundamentally, adopt procedures in line with the standard for medical emergencies/intensive care medicine.

Balancing of fluids.

Except for oxygen, to date no drug has clearly proven any benefit in the treatment of diving accidents.

Documentation

Document measures carried out, to pass this information on to the person(s) continuing the treatment of the patient.

3.5 Transfer (secondary transportation)

If symptoms are still present following the first hyperbaric chamber treatment, further treatments must possibly follow within 24 hours in the event of an assured diagnosis. If it is not possible to offer in-patient medical care on site between the hyperbaric chamber treatments a transfer to a suitably-equipped treatment centre must be arranged. The mode of transfer is chosen taking into account the patient's condition, the transportation route and time and the possible "means of transport".

Means of transport

Helicopter

Air ambulance

Passenger aircraft

Boat

Land-based emergency services vehicles

There is no assured data giving rise to a general requirement of transportation under 1-bar conditions for secondary transfer. Flights at regular cabin pressure (e.g. 0.8 bar absolute) can be organised very much more quickly and more easily.

There are signs that relapses of DCI past hyperbaric chamber treatment occur more frequently during or after flying than if the patient does not fly. Equally, there are signs that during the flight one need not anticipate the onset of symptoms with a greater degree of severity and that the prospects for treatment are not made worse.

Thus, transporting patients following hyperbaric chamber treatment, a flight at regular cabin pressure (e.g. 0.8 bar absolute) does not represent a fundamental barrier to transportation.

The decision regarding such transportation is to be taken depending on a) the course of the illness to date and b) the severity of the persisting symptoms. Internationally, there are no standard recommendations as to after what time and after how many hyperbaric chamber treatment DCI patients should fly, or at what cabin pressure. The decision should be agreed with experienced diving medicine physicians in the individual instance.

Medical treatment during transportation

The need for and scope of medical care during transportation is influenced by severity of the illness.

Adopt procedures in line with the standard for medical emergencies/intensive care medicine

It must be possible to breathe oxygen

Balancing of fluids

Clinical and neurological progress monitoring

Documentation, e.g. emergency physician log/intensive care transport log

Patients without or with minimal residual symptoms following primary treatment may be carried by a regular charter airline

3.6 Follow-up treatments

If symptoms are still present following the first hyperbaric chamber treatment, a follow-up treatment should be added within 24 hours.

Treatment tables following initial hyperbaric chamber treatment

A second hyperbaric chamber treatment in accordance with the standard treatment table "US Navy Treatment Table 6" or

Treatment at least once a day with hyperbaric oxygen (HBO), e.g. 240 kPa / 90 min. O₂ breathing.

Other treatment tables should remain for use by facilities and personnel with experience, knowledge and appropriate equipment which enable them to deal with undesirable results.

Intervals between hyperbaric chamber treatments

Maximum 24 hours, but a maximum of 2 treatments within 24 hours.

Further diagnostics / control examinations following clinical symptoms

Magnetic resonance imaging (MRI)

Computer tomography (CT scan)

Specialist neurological consultations on a regular basis

Further specialist medical consultations, depending on the set of symptoms and the organ systems affected.

Decision on ending of hyperbaric chamber treatment

After complete and persistent recovery, the hyperbaric chamber therapy can be ended.

The hyperbaric chamber therapy is to be terminated if, after an initial improvement there is no further improvement in the set of symptoms after several treatments carried out over the course of 3-5 days.

Further treatment measures and rehabilitation

Intensive specific therapeutic and rehabilitation measures are to be started as early as possible if possible accompanying the hyperbaric chamber therapy.

Any advantages of physiotherapy during as opposed to only between hyperbaric chamber therapies are not proven.

Pharmacological and other specific treatment should reflect the clinical pattern of illness in accordance with the medical specialties involved.

If neurological deficits persist, the rehabilitation measure recommended for the neurological condition is added directly to the hyperbaric chamber therapy and continued.

4 Fitness to dive following a diving accident

The assessment of fitness for diving for sports divers following a diving accident is to be conducted in accordance with the recommendations of the national and international expert associations for diving medicine.

The precondition for the examination of renewed fitness for diving for sports divers is complete ending of the diving accident therapy and stability of the treatment outcome even in the event of residuals.

The assessment of renewed fitness for diving for sports divers should only be carried out by an experienced physician training in diving medicine¹⁶. In addition, he should have practical experience in the treatment of diving accidents.

For professional divers, special national regulations are to be applied including the associated occupational medical care and assessment of fitness to dive.

5 Quality management

There is no nationwide evaluation of diving accident data in Germany.

With a view for measurement of quality for diving accident care and scientific contributions to health service research, there is a need for central data recording by the national expert associations.

Financing

The consensus meetings and the methodological support by the AWMF when issuing up the guideline were founded by the GTÜM. Travel costs were met by the members of the guidelines group.

Independence and presentation of conflicts of interest

Given the increasing importance of guidelines for the diagnosis and treatment of illnesses, potential conflicts of interest between the people collaborating on the guidelines are becoming even more important. Conflicts of interest are defined as situations carrying a risk that the capacity for professional judgement relating to a primary interest is inappropriately influenced by secondary interests. Secondary interests which might come into conflict with the primary interests of evidence-based preparation of guidelines are, for example, material interests such as the interest in maintaining a relationship with a pharmaceutical company. The non-material interests include, potentially, the mandating organisation (e.g. expert association), the employer and the scientific focus of the person concerned. Likewise, social or intellectual interests may lead to a conflict of interest as secondary interests. The presentation of possible conflicts of interest was set out for the members of the guidelines group using the form suggested by the AWMF.

The conflicts of interest indicated by the authors of this guideline were evaluated by the guideline coordinator. The conflicts of interest of the guideline coordinator, as presented, were assessed by the AWMF staff member providing the methodological support.

The members of the guidelines group who had disclosed a conflict of interest through the possession of shares in the business of a hyperbaric chamber centre did not participate

during decision-taking on key questions concerning indication and frequency of hyperbaric chamber treatment.

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