Contents

Guideline "Diving Accident"

Preliminary remarks .............................................. Page 2
Definition .......................................................... Page 3
Immediate life-saving measures ................................ Page 4
  - First aid by laypersons ..................................... Page 5
  - First aid by medical personnel ....................... Page 7
Transport to hyperbaric chamber ....................... Page 8
First hyperbaric treatment .................................. Page 9
Transport to hyperbaric treatment centre .......... Page 10
Subsequent hyperbaric treatments ...................... Page 11
Fitness to dive after diving accident .................. Page 12
Relevant web references ..................................... Page 13
Relevant literature .............................................. Page 13
Abbreviations and technical terms ..................... Page 16

Appendices

1 Short version of the guideline .......................... Page 18
2 Block diagram „System of Diving Accidents“ ........ Page 23
3 Flow chart „Diving Accident Management“ (mod. after DAN Europe) Page 24
4 Table “Pathogenesis and Symptoms of Diving Accidents” Page 25
5 Table “Differential Diagnosis of Diving Accidents” Page 26
6 Check list „5 Minutes Neurocheck” (DAN Europe) Page 27
7 Flow chart „First Hyperbaric Chamber Treatment after Diving Accident” Page 29
8 Guideline Statement ........................................... Page 30
Preliminary remarks

Responsibility
The German Diving and Hyperbaric Medical Society, "Gesellschaft für Tauch- und Überdruckmedizin e.V." (GTÜM), represented by its executive committee, is responsible for this guideline. The guideline was developed in cooperation with societies affiliated with the GTÜM, the Austrian Diving and Hyperbaric Medical Society, "Österreichische Gesellschaft für Tauch- und Hyperbarmedizin" (ÖGTH), and the Swiss Underwater and Hyperbaric Medical Society, "Schweizerische Gesellschaft für Unterwasser- und Hyperbarmedizin" (SUHMS). No external funding and/or other support were received for developing the guideline.

Authors
The guideline was developed by a panel of experts chaired by Dr. med. Peter HJ Müller (Germany) as „Guideline Phase 1“ according to the methodical recommendations „Leitlinie für Leitlinien“ (Guidelines for Guidelines) published by the Association of the Scientific Medical Societies in Germany "Arbeitgemeinschaft Medizinisch-wissenschaftlicher Fachgesellschaften" (AWMF, status 02/2000). Expert panel members were: Dr. med. Wilfried Beuster (Austria), Dr. med. Volker Warninghoff (Germany), Dr. med. Wolfgang Hühn (Germany), Dr. med. Hans Joachim Roggenbach (Germany), Dr. med. Peter Knessl (Switzerland), Dr. med. Wilhelm Welslau (Germany/Austria) and Dr. med. Jürg Wendling (Switzerland).

Level of evidence
The guideline developed in phase 1 was discussed in phase 2 according to AWMF recommendations (see above) at a consensus conference in the course of a scientific meeting of GTÜM, ÖGTH and SUHMS in Heidelberg on 19/04/2008 and 20/04/2008. The panel of experts from phase 1 presented the guideline. An international jury presided by Prof. Dr. med. Alf O. Brubakk (Norway) acted as the steering committee in phase 2. Members were: Dr. med. Wolfgang Förster, (Germany), Dr. med. Peter Germonpré (Belgium), Dr. med. Ulrich van Laak (Germany), Dr. med. Clemens Mader (Austria), Dr. med. Peter Nussberger (Switzerland) and Dr. Adel Taher (Egypt), as well as Dr. med. Wilhelm Welslau as non-voting corresponding member of the panel of experts from phase 1.

The present guideline is based on the guideline "Diving Accident" first developed in 2002 and revised in 2005. For further details please refer to the Guideline Statement (see Appendix 8). Since no new randomised controlled trials have been published since 2005, the guideline was discussed again at a consensus conference according to the methodical recommendations of the AWMF.

Validity
The jury and the expert audience of the consensus conference approbated the guideline in phase 2 on 20/04/2008. It is valid until October 2011 and has to be revised at least every 3 years.
Objectives

This guideline is intended to provide assistance in medical decision making for effective patient care. In terms of quality assurance, the guideline represents high quality medical care, also with respect to economic necessities. It provides the individual physician with instructions and information based on state-of-the-art medical knowledge in an area of emergency care far from routine. The recommendations apply state-of-the-art medical knowledge regarding the treatment of diving accidents, namely

- regarding first aid by laypersons and medical assistance personnel,
- regarding the concept of the "rescue chain" and the transportation of diving accident victims,
- regarding the first definitive therapy of diving accidents,
- regarding the subsequent medical care of diving accidents.

The guideline is intended for:

- all divers, especially diving instructors and other lay persons providing first aid,
- physician first responders and emergency physicians as well as paramedics,
- all physicians at therapeutic hyperbaric chambers.

Applicability

If there is any doubt regarding the applicability of the guideline, an expert (experienced diving physician) should be consulted in individual cases. This is explicitly stated in the guideline in the sections covering first aid by lay persons, first aid my medical personnel, the first hyperbaric treatment and the issue of fitness to dive after a diving accident.

National Adaptation

In Austria and Switzerland, authorities and organizations have to be involved separately. The ÖGTH (Austria) and the SUHMS (Switzerland) are responsible for this process, which will not be described here. National adaptation also applies to translations in other national languages.

Definition

Diving accidents have various causes. A „diving accident“ in the sense of this guideline is a potentially life-threatening event that can occur while diving with or without diving equipment. It is caused by a rapid reduction of ambient pressure during the decompression phase. It is characterized by the formation of free gas bubbles in blood and tissues. From this process, a decompression illness can arise, which is also termed "decompression incident" or "decompression injury". The commonly used international abbreviation is „DCI“. Depending on the physiological mechanisms involved, diving accidents can be divided in "decompression sickness", DCS, and "arterial gas embolism", AGE (see Appendix 2 “System of Diving Accidents”).

DCS occurs after a prolonged stay at high pressure, which results in an elevated inert gas loading of tissues. It is traditionally divided in DCS type I with the cardinal symptom "musculoskeletal pain", and „DCS type II“ with the cardinal symptom „neurological symptoms“. This system is also used in this guideline (see below, box "Symptoms").
addition, a classification intended for medical laypersons (= divers) is used worldwide, which distinguishes „mild symptoms“ (unusual tiredness, itching) and „severe symptoms“, including AGE (see Appendix 3 „Diving Accident Management“). Further classifications are used, which up to now have not been generally accepted. For the sake of clarity, these are not mentioned in the guideline, although they may provide some advantages compared to the traditional classification system.

AGE is typically the result of a pulmonary barotrauma with over-distension or rupture of lung tissue. It is caused by insufficient exhalation during ascent and the resulting reduction of ambient pressure. Pneumothorax and/or mediastinal emphysema are possible additional findings. Moreover, a transition of gas into the arterial system can occur in case of massive bubble formation in venous blood vessels, through various shunt mechanisms, for example, through a persisting foramen ovale (PFO) or a pulmonary shunt. In many cases, DCS type II and AGE cannot be distinguished clinically (see Appendix 4 "Pathogenesis and Symptoms of Diving Accidents" and Appendix 5 "Differential Diagnosis of Diving Accidents").

**Immediate life-saving measures**

In most cases, first aid in diving accidents is provided by dive partners or safety divers. The effectiveness of first aid and subsequent treatment depends critically on the fast and adequate action of the persons providing first aid. This requires:

a) the appropriate training of all divers,

b) the availability of an emergency equipment that fits the needs of the planned dive, and

c) fail-safe communication devices (e.g. mobile phones and relevant phone numbers).

This ensures that the actions recommended in this guideline can be carried out effectively.

Appendix 3 (flow chart „Diving Accident Management“) is based on a diagram published by Divers Alert Network (DAN) Europe. The flow chart in Appendix 3 differs from the original DAN diagram in some details. Since the latter is widely used among divers, it should be noted that the DAN diagram is basically correct and can be used.

A "diving accident" is presumptively diagnosed, if one of the following applies:

- Patient has been breathing underwater from a diving apparatus, regardless of the breathing gas/breathing gas mixture used (maybe just one breath) or
- Patient has been breathing from an underwater air reservoir (e.g. wreck or cave) or
- Patient has been breath-hold diving (usually several deep dives) and
- one or more of the following symptoms is present:

**Mild Symptoms**

- Unusual tiredness
- Itching

which completely disappear within 30 minutes after initiation of specific first aid.
Specific first aid
- 100% oxygen breathing, irrespective of the breathing gas mixture used during the dive
- Give fluid orally, 0.5 - 1 litre (no alcoholic or caffeinated beverages!).
- Protect against hypothermia as well as hyperthermia.
- Perform basic neurological examination (see Appendix 6 „5 Minutes Neurocheck“).
- Never try in-water recompression.
- If symptoms disappear within 30 minutes: continue 100% oxygen therapy, call diving physician, observe for 24 hours.
- If symptoms persist longer than 30 minutes: treat like severe symptoms.

Severe Symptoms
Symptoms that occur while still underwater or other symptoms, like:
- Discolouration and alteration of the skin
- Pain
- Tingling
- Physical weakness
- Numbness
- Paralysis
- Breathing troubles
- Vision, hearing or speech troubles
- Vertigo
- Nausea
- Impaired consciousness
- Unconsciousness

First Aid by Laypersons

Cardiopulmonary resuscitation
Perform cardiopulmonary resuscitation according to ERC guidelines, if needed.

Specific First Aid
- Positioning:
  - Fully conscious diver: put diver in a supine position.
  - Otherwise: put diver in the recovery position.
- 100% oxygen breathing (start oxygen therapy as soon as possibly and irrespective of breathing gas during the dive):
  - If breathing sufficiently, irrespective of the diver’s state of consciousness, give 100% oxygen (O\textsubscript{2}) via a tight-fitting face mask with:
    a) demand valve or
    b) closed circuit system with carbon dioxide (CO\textsubscript{2}) absorber,
    c) if no other systems are available, with constant flow (15 - 25 litre/min, non re-breathing mask with oxygen reservoir),
  - If not breathing sufficiently, perform artificial respiration via face mask with 100% O\textsubscript{2} via
    a) Ambu/Laerdal bag with reservoir, constant flow (15 - 25 litre/min) or
    b) Ambu/Laerdal bag with demand valve or
    c) closed circuit system with CO\textsubscript{2} absorber.
Give oxygen without breaks until reaching the hyperbaric treatment chamber. Give highest possible oxygen concentration even if oxygen supply is limited, under no circumstances mix oxygen with ambient air, and do not use constant flow below 15 litre/min.

- **Administration of fluids:**
  - If diver is fully conscious: give fluids orally (0.5 - 1.0 litre/hour, no alcoholic or caffeinated beverages).
  - Divers with impaired consciousness: do not give fluids orally! (Intravenous fluid required).

- Call emergency control centre, notify centre of „suspected diving accident“.

**Additional Actions**

- Perform basic neurological examination (see Appendix 6 „5 Minutes Neurocheck“)
- Protect against hypothermia as well as hyperthermia (shelter diver). If diver is hypothermic: no active rewarming (e.g. hot shower), since this might lead to an aggravation of symptoms and other complications.
- Never attempt in-water recompression. In-water recompression is never indicated in central Europe.

**Organisation of Transport**

- Call emergency control centre to organize transport.
  
  There is no general preference for a specific mode of transport. The fastest (in terms of total transport time), and most gentle mode of transport should be used. There are no restrictions for helicopter transport (lowest safe flying altitude).
- Transport destination: nearest accident and emergency unit within reach, preferably close to a therapeutic hyperbaric chamber.
- Documentation:
  
  When the diver is transferred to emergency medical services/emergency transport team provide them with documentation of diving data, course of symptoms and treatment.
- Impound diving gear:
  
  All devices that could help in the reconstruction of the dive and the diving accident, (e.g. decompression computer, depth meter), should be impounded and handed over to emergency medical services.
- Diving partners should be observed as well.

**Diving Medical Hotlines**

Contact a diving physician as soon as possible for specific instructions. Call for example:

- National DAN hotline in Germany and Austria: 00800 326 668 783 (00800 DAN NOTRUF)
- National DAN hotline in Switzerland: +41 333 333 333 (or 1414 for calls within Switzerland)
- VDST hotline: +49-1805-660560
- Contact office of the Naval Medical Institute of the German Navy (Schiffahrtmedizinisches Institut): +49-431-54091441
- Diver hotline aqua med: +49-700-34835463
- International DAN hotline: +39-0396057858

Use the keyword „Diving Accident“.
An updated list with phone numbers of additional hotlines can be found on the GTÜM website at www.gtuem.org.
First of all, the diving medical specialist should give his opinion on whether or not a hyperbaric chamber treatment is indicated, and if so, how urgent it is. In most cases lay persons and physicians not specialised in diving medicine are not able to assess this.

**First Aid by Medical Personnel**

**Cardiopulmonary resuscitation**
Perform cardiopulmonary resuscitation according to ERC guidelines, if needed.

**Specific first aid**
- Positioning: see above
- 100% oxygen breathing or artificial respiration (aim at FiO₂ = 1.0, initiate therapy as soon as possible, irrespective of the breathing gas used during the dive):
  - If breathing sufficiently: see above.
  - If not breathing sufficiently: perform artificial respiration with 100% O₂, if necessary, secure the airway according to ERC guidelines.
Oxygen treatment should be continued without interruptions until reaching the hyperbaric treatment chamber.
Give the highest possible oxygen concentration even if oxygen supply is limited, under no circumstances mix oxygen with ambient air, and do not use constant flow below 15 litre/min.
- Intravenous fluid administration:
  Give 0.5-1.0 litre/hour i.v., do not use glucose-only solutions.

**Medication**
- In general, follow emergency medicine standard procedures,
- Up to now, no drug has been definitively proven to be specifically effective in the treatment of diving accidents.

**Additional actions**
- In general, follow emergency medicine standard procedures.
- Perform basic neurological examination (repeatedly, see, for example, Appendix 6 "5 Minutes Neurocheck").
- Urinary catheter, if indicated.
- Pleural drainage, if indicated.
- Protect against hypothermia as well as hyperthermia. If the diver is hypothermic, prevent further heat loss. Patients with severe hypothermia (no longer shivering) should be moved as little as possible. In case of severe hypothermia, active rewarming by means available on-site is often ineffective and, without the possibility of intensive care intervention, there is a risk of cardio-vascular complications, which might not be controllable. In addition, rewarming (e.g. a hot shower) might result in an aggravation of DCI symptoms.
- **Hyperbaric chamber treatment.**
On indication, treatment in a therapeutic hyperbaric chamber should be initiated as soon as possible, eventually after phone consultation with a diving physician. In most cases, a hyperbaric chamber treatment is required, even if the initiation of treatment is delayed.

Phone Consultation with a Diving Physician
Contact a diving physician to agree on the course of action, for example:

- National DAN hotline in Germany and Austria: 00800 326 668 783 (00800 DAN NOTRUF)
- National DAN hotline in Switzerland: +41 333 333 333 (or 1414 for calls within Switzerland),
- VDST hotline: +49-1805-660560
- Contact office of the Naval Medical Institute of the German Navy (Schiffahrtmedizinisches Institut): +49-431-54091441
- Diver hotline aqua med: +49-700-34835463
- International DAN hotline: +39-0396057858, key word „diving accident“

An updated list with phone numbers of additional hotlines can be found on the GTÜM web site at www.gtuem.org.

Monitoring and Documentation
- Emergency physician report,
- Documentation of dive data, the course of symptoms and treatment actions by laypersons,
- Carry-on devices (e.g. decompression computer, depth meter).

Transport to Hyperbaric Chamber

Mode of Transport
- Helicopter (lowest safe flying altitude),
- Land-based rescue vehicles,
  (preferably low-vibration, caution: drives over mountain passes),
- Boat (preferably low-vibration),
- Plane (cabin pressure close to 1 bar).

During transport of DCI patients without previous hyperbaric chamber treatment, a reduction of pressure below the pressure at the dive site (for example a drive over higher mountain passes) has to be avoided, if possible, since this could result in an aggravation of symptoms.

Medical care during transport
- Oxygen
  Oxygen breathing or artificial respiration with 100% oxygen (aim for FiO₂ = 1.0) has to be continued without interruptions until a therapeutic hyperbaric chamber is reached.
- Continue specific first aid measures (see above) that have been commenced.
  - Repeat basic neurological examination periodically (see, for example, Appendix 6 "5 Minutes Neurocheck").
First Hyperbaric Treatment

Technical minimum requirements for the hyperbaric treatment chamber

- In the EU the hyperbaric treatment chamber has to meet the requirements of EN 14931.
- General requirements are:
  - Working pressure min. 280 kPa (2.8 bar abs./18 msw),
  - O₂ breathing should be available for all persons in the hyperbaric chamber,
  - Emergency medicine equipment according to DIN 13232 (in Germany).

Actions before treatment

- Perform neurological examination, in case of emergency while initiating treatment (documentation!).
- If pulmonary barotrauma is suspected: perform thoracic X-ray (p.a./lateral), alternatively (preferred) thoracic CT scan, to rule out pneumothorax. This examination should always be performed, if feasible within a reasonable time frame.
- Pleural drainage, if indicated.
- Urinary catheter, if indicated.
- Myringotomy, if indicated.
- If patient is intubated: fill endotracheal tube cuff with fluid or check cuff pressure continuously.
- Additional actions may be required in individual cases.
- Consult diving medical phone hotline, if necessary:
  - National DAN hotline in Germany and Austria: 00800 326 668 783 (00800 DAN NOTRUF)
  - National DAN hotline in Switzerland: +41 333 333 333 (or 1414 for calls within Switzerland)
  - VDST hotline: +49-1805-660560
  - Contact office of the Naval Medical Institute of the German Navy (Schiffahrtsmedizinisches Institut): +49-431-54091441
  - Diver hotline aqua med: +49-700-34835463
  - International DAN hotline: +39-0396057858, key word „diving accident“

An updated list with phone numbers of additional hotlines can be found on the GTÜM web site at www.gtuem.org.

Treatment Tables

- Standard treatment table is US Navy Treatment Table 6 or modifications of this table. This table is recommended for all diving accidents, irrespective of the breathing gas used by the diving accident victim (e.g. oxygen, air, Nitrox, Heliox, or Trimix).
- Other treatment tables (e.g. Comex-Table „Cx 30“) should only be used by experienced treatment centres and personnel with the required knowledge and equipment, who are able to deal with potential adverse events and effects.
- For omitted decompression without symptoms, shorter tables may be used (e.g. „US Navy Treatment Table 5“ or the so-called “Problem Wound Treatment Protocol”).
Actions during first treatment

- Repeated neurological check-ups, for example during air breathing intervals, always prior to decisions on potentially required extension of the treatment table (documentation!)
- Repeated auscultation of lungs (pneumothorax, equal ventilation of both sites?), perform auscultation prior to each decompression,
- Periodical check on all gas-filled confinements in medical equipment (e.g. endotracheal tube cuff, infusion, drip chamber, blood pressure cuff), perform check prior to each decompression.

Adjunctive therapy

- In general, follow emergency medicine standard procedures.
- If the patient is awake: special psychological support for reassurance and relief of anxiety may be needed.
- Balance fluids, if indicated based on symptoms.
- Up to now, no drug has been definitively proven to be specifically effective in the treatment of diving accidents.

Documentation:

Transport to Hyperbaric Treatment Centre

If symptoms persist after the first hyperbaric treatment, one or more follow up treatments are necessary starting within 24 hours. If inpatient care cannot be provided between treatments at the hyperbaric chamber, organize transport to a hyperbaric treatment centre that has this capability. When deciding on the mode of transport, the distance to be covered, transport time and the guidelines below (see Mode of Transport) should all be taken into consideration.

Mode of Transport

- Helicopter (decision on flying altitude and time of transport on case-by-case basis),
- Plane (decision on cabin pressure and time of transport on case-by-case basis),
- Boat (preferably low-vibration),
- Land-based rescue vehicles (preferably low-vibration).

Regarding a secondary transport, there is no firm evidence to support a general requirement for transport with 1 bar cabin pressure. A flight with regular cabin pressure should be considered, not only with respect to the costs involved, but also in the patient's interest, because such flights are often faster and easier to organise.

In principle, flight transport of DCI patients with regular cabin pressure (e.g. 0.8 bar abs.) is possible after one hyperbaric treatment. As a general rule, in-flight oxygen breathing should be available.
The decision about mode of transport should be made depending on a) the course of symptoms b) severity of persisting symptoms in the specific case. There are no international standard recommendations that specify after what time and after how many hyperbaric treatments flight DCI patients should be transported and what cabin pressure should be applied. This should be decided on a case-by-case basis together with experienced diving physicians.

Actions during transport:
- In general, follow standard procedures in emergency medicine and intensive care medicine.
- Continue commenced treatment.
- Give 100% oxygen depending on symptoms.
- Balance fluids; ensure hydration especially during flights (i.v. or orally).
- Perform basic neurological follow up examinations.
- Documentation, e.g. emergency medicine/emergency medical transport protocol.
- Medication: generally follow standard procedures in emergency medicine and intensive care medicine.

Subsequent Hyperbaric Treatments

If symptoms persist after first hyperbaric treatment one or more follow up treatments are necessary starting within 24 hours.

Type and number of hyperbaric treatments following the first hyperbaric treatment
- If necessary, perform second treatment according to standard treatment table (see above) or
- start immediately with hyperbaric oxygen treatments at least once a day, e.g. according to the so-called „problem wound treatment protocol“.
- Other treatment tables (e.g. Comex-Table „Cx 30“) should only be used by experienced treatment centres and personnel with the required knowledge and equipment who are able to deal with potential adverse events and effects.

Intervals between treatments
24 hours maximum, maximal 2 treatments within 24 hours.

Additional diagnostics / check-ups depending on clinical symptoms
- Magnetic resonance imaging (MRI),
- Computed tomography (CT),
- Periodical examinations by neurologist
- Assessment of pulmonary function, depending on symptoms
- Additional examinations by specialists
Physiotherapy
- Between hyperbaric treatments:
  - depending on clinical symptom, by specialised personnel,
  - starting max. 3 days after diving accident.
- During hyperbaric treatment:
  - There is no evidence that this will have any advantage over physiotherapy between hyperbaric treatments.

Decision on termination of hyperbaric treatments
- After complete and lasting disappearance of symptoms hyperbaric treatments may be terminated. To reach a lasting disappearance of symptoms 1 or 2 hyperbaric treatments after disappearance of symptoms may be indicated.
- If in the course of treatment symptoms do not continue to reduce over 3 to 5 days after an initial reduction, hyperbaric treatment should be terminated and rehabilitation treatment recommended for neurological symptoms should be continued.

Documentation

Additional treatment
Medication and additional therapy: depending on clinical symptoms and following recommendations of consulted medical specialists.

Rehabilitation after termination of hyperbaric treatments
If neurological deficits persist after hyperbaric treatment has been terminated, rehabilitation treatment according to the clinical symptoms should follow immediately.

Fitness to Dive after Diving Accident

With recreational divers the assessment of fitness to dive after diving accidents should generally follow the recommendations of national and international diving medical associations. Special statutory provisions apply to occupational divers (in Germany: Regulations for accident prevention in diving work (UVV „Taucherarbeiten“) including the related specific occupational medical check-up procedures (G 31)).

The reassessment of fitness to dive requires that the diving accident therapy has been terminated and a stable treatment result has been achieved, also in case of residual symptoms.

The reassessment of fitness to dive should be reserved to experienced diving physicians with a minimum qualification comparable to "Diving Medicine Physician, EDTC" (see qualification guidelines at www.gtuem.org, www.oegth.at and www.edtc.org) and with practical experience in treating diving accidents. Corresponding conditions apply to occupational divers.
Relevant Web References

1. DGUV - Deutsche Gesetzliche Unfallversicherung (German Statutory Accident Insurance): [www.dguv.de](http://www.dguv.de) (English version available).
   For occupational divers: In Germany, occupational accident victims are protected by a comprehensive care system. On this website you will find information regarding the administrative proceedings (accident notification requirement etc.).

2. ERC – European Resuscitation Council: [www.erc.edu](http://www.erc.edu)
   On this site you will find the latest guidelines on cardiopulmonary resuscitation.

3. GTÜM – Gesellschaft für Tauch- und Überdruckmedizin e.V.: [www.gtuem.org](http://www.gtuem.org) (in German)

4. ÖGTH – Österreichische Gesellschaft für Tauch- und Hyperbarmedizin: [www.oegth.at](http://www.oegth.at) (in German)

5. SUHMS – Schweizerische Gesellschaft für Tauch- und Hyperbarmedizin: [www.suhms.org](http://www.suhms.org) (in English)

Relevant Literature


6. Ball R: Effect of severity, time to recompression with oxygen, and re-treatment on outcome in forty-nine cases of spinal cord decompression sickness. Undersea Hyperb Med. 1993; 20: 133-45


34. Hampson NB (Ed.): Hyperbaric Oxygen Therapy: A Committee Report. Undersea and Hyperbaric Medical Society, 10531 Metropolitan Avenue, Kensington MD 20805-2627, USA. Revised 1999

Abbreviations and Technical Terms

AGE Arterial Gas Embolism
AWMF Association of the Scientific Medical Societies in Germany
(Arbeitsgemeinschaft wissenschaftlicher medizinischer Fachgesellschaften)
ÄZQ Agency for Quality in Medicine in Germany
(Ärztlche Zentralstelle Qualitätssicherung)
bar absolute measurement unit of absolute pressure
BGI "Berufsgenossenschaftliche Information": Information published by the "Berufsgenossenschaften" (German statutory accident insurance institutions) and the German Federation of institutions for statutory accident insurance and prevention (HVBG)
BGV "Berufsgenossenschaftliche Vorschrift für Sicherheit und Gesundheit bei der Arbeit": Regulations published by the "Berufsgenossenschaften" (German statutory accident insurance institutions) and the German Federation of institutions for statutory accident insurance and prevention (HVBG)
Urinary catheter device for urinary diversion
CO₂ carbon dioxide
CT computed tomography
Cuff inflatable cuff on the distal end of an endotracheal tube
DAN Divers Alert Network
DCI decompression illness or incident or injury
DCS decompression sickness
decompression pressure reduction
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>demand valve</td>
<td>valve, which controls the supply of gas by opening to provide flow only when the user inhales (= on demand)</td>
</tr>
<tr>
<td>endotracheal tube</td>
<td>anatomically adapted relatively rigid respiration tube for insertion into mouth, nose or tracheostoma</td>
</tr>
<tr>
<td>ERC</td>
<td>European Resuscitation Council</td>
</tr>
<tr>
<td>EUBS</td>
<td>European Underwater and Baromedical Society</td>
</tr>
<tr>
<td>FiO₂</td>
<td>fraction of inspired oxygen (O₂) in a gas mixture, expressed as a number between 0 and 1</td>
</tr>
<tr>
<td>GTÜM</td>
<td>Gesellschaft für Tauch- und Überdruckmedizin e.V. (German Diving and Hyperbaric Medicine Society)</td>
</tr>
<tr>
<td>HBO</td>
<td>hyperbaric oxygen</td>
</tr>
<tr>
<td>Heliox</td>
<td>breathing gas mixture of helium and oxygen</td>
</tr>
<tr>
<td>ICHM</td>
<td>International Committee for Hyperbaric Medicine</td>
</tr>
<tr>
<td>kPa</td>
<td>kilopascal</td>
</tr>
<tr>
<td>NMRI</td>
<td>nuclear magnetic resonance imaging</td>
</tr>
<tr>
<td>Neurocheck</td>
<td>basic neurological examination</td>
</tr>
<tr>
<td>Nitrox</td>
<td>breathing gas mixture of nitrogen and oxygen</td>
</tr>
<tr>
<td>O₂</td>
<td>oxygen</td>
</tr>
<tr>
<td>ÖGTH</td>
<td>Österreichische Gesellschaft für Tauch- und Hyperarmedizin (Austrian Diving and Hyperbaric Medicine Society)</td>
</tr>
<tr>
<td>Pleural drainage</td>
<td>drainage of the pleura for diversion of air and pathological fluid accumulations</td>
</tr>
<tr>
<td>„problem wound</td>
<td>treatment table for hyperbaric chambers with 90 min. oxygen breathing at 240 kPa (2.4 bar abs./14 msw), also used for the treatment of diving accidents</td>
</tr>
<tr>
<td>SUHMS</td>
<td>Schweizerische Gesellschaft für Unterwasser- und Hyperbarmedizin (Swiss Underwater and Hyperbaric Medical Society)</td>
</tr>
<tr>
<td>h(rs.)</td>
<td>hour(s)</td>
</tr>
<tr>
<td>thoracic CT</td>
<td>computed tomography of chest organs</td>
</tr>
<tr>
<td>Treatment Table 5</td>
<td>US Navy Treatment Table for hyperbaric chambers with initial oxygen breathing at 280 kPa (2.8 bar abs./ 18 msw), used for the prevention of diving accidents in case of omitted decompression</td>
</tr>
<tr>
<td>Treatment Table 6</td>
<td>US Navy Treatment Table for hyperbaric chambers with initial oxygen breathing at 280 kPa (2.8 bar abs./ 18 msw), used for the treatment of diving accidents</td>
</tr>
<tr>
<td>Trimix</td>
<td>breathing gas mixture of helium, nitrogen and oxygen</td>
</tr>
<tr>
<td>tube</td>
<td>endotracheal tube: anatomically adapted relatively rigid respiration tube for insertion into mouth, nose or tracheostoma</td>
</tr>
<tr>
<td>UHMS</td>
<td>Undersea and Hyperbaric Medical Society</td>
</tr>
<tr>
<td>VDD</td>
<td>Verband deutscher Druckkammerzentren e.V. (Association of German Hyperbaric Treatment Centers)</td>
</tr>
<tr>
<td>VDST</td>
<td>Verband Deutscher Sporttaucher e.V. (German Recreational Divers Association)</td>
</tr>
</tbody>
</table>
Guideline "Diving Accident"
- Short version -

Definition
Diving accidents in the sense of this guideline are also referred to as "decompression accident", "decompression illness", "decompression incident" or "decompression injury" (DCI). These accidents are caused by a rapid reduction of ambient pressure and are characterized by the formation of gas bubbles in blood and tissues. Depending on the physiological mechanisms involved, a distinction is drawn between "Decompression Sickness" (DCS) and "Arterial Gas Embolism" (AGE). However, in many cases the clinical picture does not allow a decision between DCS and AGE. Important differential diagnoses may be, for example, barotrauma of the inner ear (rupture of the round window membrane), cerebral insult due to embolism or bleeding, vertebral disc herniation, myocardial infarction, hypoglycaemia or epilepsy.

First aid in suspected diving accidents

First aid by medical laypersons
In most cases, first aid is provided by the dive partners. Effectiveness of first aid and further treatment depend on an appropriate training of all divers, an emergency kit fitted to the needs of the planned dive, and failsafe communication devices (e.g. mobile phone and relevant phone numbers).

For mild symptoms (unusual tiredness, skin itching):
- Give 100% oxygen (irrespective of the breathing gas used during the dive).
- Give fluid orally (0.5-1.0 litres, no alcoholic or caffeinated beverages).
- Protect against hypothermia as well as hyperthermia.
- Perform basic neurological examination.
- Never try in-water recompression.
- If symptoms disappear within 30 minutes: continue 100% oxygen, call diving physician, and observe for 24 hours.
- If symptoms persist longer than 30 minutes: treat like severe symptoms.

If symptoms appear while still underwater or if other symptoms are present, like:
- Discolouration or alteration of the skin
- Pain
- Tingling
- Physical weakness
- Numbness
- Paralysis
- Breathing troubles
- Vision, hearing or speech troubles
- Vertigo
- Nausea
- Decreased consciousness
- Unconsciousness

follow instructions below:
Specific first aid

- Cardiopulmonary resuscitation according to ERC guidelines, if needed.
- If diver is unconscious, put in recovery position, otherwise put in a supine position.
- Give 100% oxygen (start as soon as possible, irrespective of the breathing gas used during the dive):
  a) if breathing sufficiently: via face mask (with demand valve or closed circuit system with CO₂ absorber), if not available: with constant flow (15 - 25 litre/min, non re-breathing mask with oxygen reservoir),
  b) if not breathing sufficiently perform artificial respiration with 100% O₂ (Ambu/Laerdal bag with reservoir, constant flow (15 - 25 litre/min) or demand valve or closed circuit system with CO₂ absorber.

Give oxygen without breaks until reaching treatment chamber. Give highest possible oxygen concentration even if oxygen supply is limited (no air mix, no constant flow below 15 litre/min).

- Fluids:
  a) If diver is fully conscious: give fluids orally (0.5 - 1.0 litre/hour no alcoholic or caffeinated beverages),
  b) Diver with impaired consciousness: do not give fluids orally.
- Call emergency control centre and notify them of „suspected diving accident“.

Additional actions

- Perform basic neurological examination.
- Protect against hypothermia as well as hyperthermia. If hypothermic: no active re-warming.
- Never try in-water recompression.
- Organize transport:
  a) Call emergency control centre.
  b) Mode of transport: no preference for specific mode of transport, transport fast and gentle, no restrictions for helicopter transport (lowest safe flying altitude).
  c) Transport destination: nearest emergency unit, preferably close to hyperbaric treatment chamber.
- Observe dive partner as well.
- Impound diving gear (e.g. decompression computer).
- Consult diving medical phone hotline, if necessary, key word „diving accident“:
  - National DAN hotline in Germany and Austria: 00800 326 668 783 (00800 DAN NOTRUF)
  - National DAN hotline in Switzerland: +41 333 333 333 (or 1414 for calls within Switzerland)
  - VDST hotline: +49-1805-660560
  - Contact office of the Naval Medical Institute of the German Navy (Schiffsmedizinisches Institut): +49-431-54091441
  - Diver hotline aqua med: +49-700-34835463
  - International DAN hotline: +39-0396057858

More hotlines can be found on the GTÜM web site at www.gtuem.org.
First Aid by Medical Personnel

Specific First Aid:
- Cardiopulmonary resuscitation according to ERC guidelines, if needed
- If diver is unconscious, put in recovery position, otherwise put in a supine position
- Give 100% oxygen (irrespective of the breathing gas used during the dive):
  c) if breathing sufficiently: see above,
  d) if not breathing sufficiently: perform artificial respiration with 100% O₂ (aim at FiO₂ = 1.0), if necessary via endotracheal tube, without breaks until reaching hyperbaric treatment chamber
  e) Give highest possible oxygen concentration even if oxygen supply is limited (no air mix, no constant flow below 15 litre/min).
- Intravenous fluids: give 0.5-1.0 ltr./h i.v., do not use glucose-only solutions.
- Medication: generally follow standard procedures in emergency medicine. Up to now, no drug has been definitively proven to be specifically effective in the treatment of diving accidents.

Additional actions
- Perform basic neurological follow-up examinations.
- Urinary catheter, if indicated.
- Pleural drainage, if indicated.
- Protect against hypothermia as well as hyperthermia. If hypothermic, active re-warming only with ICU-like capabilities on site.
- Hyperbaric chamber treatment as soon as possible, eventually after consultation with a diving medical hotline. Even a delayed hyperbaric chamber treatment is often effective.
- Consult diving medical hotline (see above).
- Monitoring and documentation: emergency treatment protocol, documentation of diving data by laypersons, development of symptoms and treatment, impounded instruments (e.g. decompression computer).

Transport to next Hyperbaric Treatment Chamber

Transport by helicopter (lowest safe flying altitude), land-based vehicle, boat, or plane (cabin pressure close to 1.0 bar). Transport with as little vibration as possible and without reduction of ambient pressure. Continue oxygen treatment without breaks until reaching hyperbaric chamber. Continue commenced treatment.

First Hyperbaric Treatment

Hyperbaric Chamber
Hyperbaric treatment chamber, working pressure min. 280 kPa (2.8 bar abs./18 msw), in Europe, construction and equipment according to EN 14931, emergency medicine equipment according to DIN 13232 (in Germany).
**Actions before treatment**

- Perform neurological examination (documentation!).
- If pulmonary barotrauma is suspected: perform thoracic X-ray (p.a./lateral) / thoracic CT scan if feasible within reasonable time frame.
- Pleural drainage, if indicated.
- Urinary catheter, if indicated.
- Myringotomy, if indicated.
- If patient is intubated: fill cuff with fluid or check cuff pressure continuously.
- Consult diving medical phone hotline if necessary (see above).

**Treatment tables**

- Standard treatment table is US Navy Treatment Table 6 or modifications of this table for all diving accidents irrespective of breathing gas used by the diving casualty.
- For omitted decompression without symptoms shorter tables may be used (e.g. US Navy Treatment Table 5).

**Actions during treatment**

- Repeated neurological examinations (documentation!).
- Repeated auscultation of lungs; perform auscultation prior to each decompression.
- Periodical check of all gas-filled confinements (e.g. endotracheal tube cuff, infusion, drip chamber, blood pressure cuff); perform check prior to each decompression.

**Adjuvant treatment**

- Generally follow standard procedures in emergency medicine and intensive care medicine.
- If the patient is awake: special psychological support for reassurance and relief of anxiety.
- Balance fluids, if indicated based on symptoms.
- Up to now, no drug has been definitively proven to be specifically effective in the treatment of diving accidents.
- Documentation of treatment for physicians continuing treatment.

**Transport to Hyperbaric Treatment Centre**

If symptoms persist after first hyperbaric treatment, one or more follow up treatments are necessary starting within 24 hours. If inpatient care cannot be provided between treatments at the hyperbaric chamber, organize transport to a hyperbaric treatment centre which has this capability. In principle, flight transport with regular cabin pressure (e.g. 0.8 bar abs.) is possible after one hyperbaric treatment. As a general rule, in-flight oxygen breathing should be available. Decide about transport together with experienced diving physicians, take into account earlier and persisting symptoms in the specific case.
Actions during transport:
- Generally follow standard procedures in emergency medicine and intensive care medicine.
- Continue commenced treatment.
- Give 100% oxygen depending on symptoms.
- Balance fluids, ensure hydration especially during flights (i.v./orally).
- Perform basic neurological follow-up examinations.
- Documentation, e.g. emergency medicine protocol.
- Medication: follow standard procedures in emergency medicine and intensive care medicine.

Subsequent Hyperbaric Treatments
- If necessary, perform second treatment according to standard treatment table or start immediately with hyperbaric oxygen treatments, e.g., “problem wound treatment protocol”. Max. 2 treatments within 24 hours, max. interval between treatments 24 hours.
- Diagnostics: depending on clinical symptoms, MRI, CT and periodical examinations by neurologist, reassessment of pulmonary function, additional examinations by specialists depending on clinical symptoms.
- Physiotherapy: between hyperbaric treatments depending on clinical symptoms, starting max. 3 days after diving accident. Physiotherapy during hyperbaric treatment is possible, but there is no evidence that this will have any advantage over physiotherapy between hyperbaric treatments alone.
- Medication and additional treatment: depending on clinical symptoms and following recommendations of consulted medical specialists.
- Decision on termination of hyperbaric treatments: after complete and lasting disappearance of symptoms hyperbaric treatments may be terminated. If in the course of treatment symptoms do not continue to reduce over 3 to 5 days after an initial reduction, hyperbaric treatment should be terminated and rehabilitation treatment recommended for neurological symptoms should be continued.
- Documentation
- Rehabilitation: if neurological deficits persist after hyperbaric treatment has been terminated, rehabilitation treatment according to the clinical symptoms will follow immediately.

Diving fitness after Diving accident
With recreational divers the assessment of diving fitness after diving accidents should generally follow the recommendations of national and international diving medical associations. Special statutory provisions apply to occupational divers.
The reassessment of fitness to dive requires that the treatment has been terminated and a stable treatment result has been achieved.
Assessment of fitness to dive should be reserved to experienced diving physicians with a minimum qualification comparable to "Diving Medicine Physician, EDTC" and with practical experience in treating diving accidents.
Guideline for Diving Accidents - Appendix 2

System of Diving Accidents

DCI

DCS type I

Inert gas saturation

DCS type II

Pulmonary barotrauma

AGE

Shunt mechanisms

Pneumothorax

Mediastinal emphysema

System of Diving Accidents
**Flow Chart Diving Accident Management**
modified after Divers Alert Network Europe

- **Underwater STAY?**
  - yes
    - MILD Symptoms? (Unusual tiredness, skin itching)
      - yes
        - SEVERE symptoms: pain, skin discoulouration and alterations, unusual weekness, numbness, tingling, breathing troubles, visual, hearing, speech troubles, vertigo, nausea, paralyses, decreased consciousness, unconsciousness, coma.
        - **Remember:** any symptom occurring while still at depth is always a „severe“ symptom.
      - no
        - Free of symptoms within 30 minutes?
          - no
            - Treat like SEVERE symptoms
          - yes
            - 1. Give 100% oxygen
              2. Consult diving physician
              3. Observe 24 hours

- no
  - NOT a diving accident!
    - Go to the nearest hospital

**IMMEDIATE TREATMENT**

1. Cardio Pulmonary Resuscitation (CPR), if needed
2. Keep airway open
3. Put diver in a supine position
4. Give 100% oxygen with face mask continously for as long as possible
5. Protect diver from hypothermia
6. If fully conscious, give water (0,5-1 litre/hour) orally
7. By a physician: intravenous fluid, no glucose-only solutions
8. Consult a diving medical specialist
9. Plan transportation to emergency unit, preferably near hyperbaric chamber
10. In case of air evacuation: maximum possible cabin pressurization
# Pathogenesis and Symptoms of Diving Accidents

<table>
<thead>
<tr>
<th>Pathogenetic Factors</th>
<th>Decompression Sickness (DCS)</th>
<th>Arterial Gas Embolism (AGE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• greater diving depth / high ambient pressure</td>
<td>shunting of venous gas bubbles into arterial circulation due to:</td>
</tr>
<tr>
<td></td>
<td>• long exposure time</td>
<td>• pulmonary barotrauma with overdistension of the lungs</td>
</tr>
<tr>
<td></td>
<td>• saturation of body tissue with inert gas (depending on breathing gas used, usually nitrogen (abbreviation “N\textsubscript{2}”)</td>
<td>• paradoxical embolism due to</td>
</tr>
<tr>
<td></td>
<td>• too fast ascent after long and/or deep dives with high level of tissue saturation</td>
<td>a) shunting of venous gas bubbles via lung blood vessels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) shunting of venous gas bubbles via a \textit{patent foramen ovale} (PFO)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time until symptoms appear</th>
<th>Decompression Sickness (DCS)</th>
<th>Arterial Gas Embolism (AGE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>minutes to hours, max. 24 hours after completion of dive (in special cases max. 48 Std.)</td>
<td></td>
<td>minutes after completion of dive, sometimes already during ascent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>DCS type I</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skin symptoms</strong></td>
<td>• itching</td>
<td>• apathy / unconsciousness</td>
</tr>
<tr>
<td></td>
<td>• point-shaped reddening</td>
<td>• vertigo / vomiting</td>
</tr>
<tr>
<td></td>
<td>• swelling</td>
<td>• confusion, disorientation</td>
</tr>
<tr>
<td></td>
<td>• marbled skin *</td>
<td>• speech and/or vision troubles</td>
</tr>
<tr>
<td><strong>Muscle and joint pain („bends“):</strong></td>
<td>• large and middle-sized joints (also depending on exertion level)</td>
<td>• various neurological deficits: mild sensory disturbances to complete paralysis</td>
</tr>
<tr>
<td></td>
<td>• skeletal muscles.</td>
<td>if respiratory centre is affected: rapid reduction in blood pressure</td>
</tr>
<tr>
<td></td>
<td>• rare: foot and hand joints</td>
<td>breathing troubles, cardiac arrest</td>
</tr>
<tr>
<td><strong>Lymphatic system:</strong></td>
<td>• swollen, tender lymph nodes, (rare)</td>
<td>• pupillary asymmetry possible: unilaterally widened pupil</td>
</tr>
<tr>
<td><strong>Other:</strong></td>
<td>• unusual tiredness *</td>
<td>• other neurological symptoms</td>
</tr>
</tbody>
</table>

**DCS Type II**

- apathy / unconsciousness
- vertigo / vomiting
- confusion, disorientation
- speech and/or vision troubles
- various neurological deficits: mild sensory disturbances to complete paralysis
- if respiratory centre is affected: rapid reduction in blood pressure
- breathing troubles, cardiac arrest
- pupillary asymmetry possible: unilaterally widened pupil
- other neurological symptoms

*) These symptoms can also be indicative of DCS type II or AGE!
Differential Diagnosis of Diving Accidents

Often, it is difficult to distinguish between DCS and AGE at the site of the accident. Mixed types are common. Note: Treatment is the same for both diagnoses.

<table>
<thead>
<tr>
<th>Differential Diagnosis</th>
<th>Clinical Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCS type II with inner ear symptoms</td>
<td>• barotrauma of the inner ear (rupture of the round window membrane)</td>
</tr>
<tr>
<td></td>
<td>• hearing loss</td>
</tr>
<tr>
<td></td>
<td>• tinnitus</td>
</tr>
<tr>
<td></td>
<td>• vertigo</td>
</tr>
<tr>
<td></td>
<td>Caution: many patients do not exhibit the complete classical triad of symptoms</td>
</tr>
<tr>
<td>DCS type II with neurological symptoms</td>
<td>• cerebral insult caused by embolism or bleeding</td>
</tr>
<tr>
<td></td>
<td>• vertebral disc herniation</td>
</tr>
<tr>
<td></td>
<td>• motor, sensory or cerebral neurological deficits</td>
</tr>
<tr>
<td></td>
<td>• symptoms of paraplegia</td>
</tr>
<tr>
<td>DCS type I</td>
<td>• cardiac infarction</td>
</tr>
<tr>
<td>DCI (AGE)</td>
<td>• hypoglycaemia</td>
</tr>
<tr>
<td>DCI (AGE)</td>
<td>• epilepsy</td>
</tr>
<tr>
<td>DCI suspected uncertain symptoms</td>
<td>• breathing gas contamination (CO etc.)</td>
</tr>
<tr>
<td></td>
<td>• toxic effect of breathing gas in mixed gas diving</td>
</tr>
<tr>
<td></td>
<td>• hypercapnia due to skip breathing</td>
</tr>
<tr>
<td></td>
<td>• hyperventilation due to psychological stress</td>
</tr>
<tr>
<td></td>
<td>• hypoglycaemia</td>
</tr>
<tr>
<td></td>
<td>• psychotropic drugs</td>
</tr>
<tr>
<td></td>
<td>• headache</td>
</tr>
<tr>
<td></td>
<td>• impaired consciousness</td>
</tr>
<tr>
<td></td>
<td>• vertigo</td>
</tr>
<tr>
<td>Check No. 1</td>
<td>Time: Yes</td>
</tr>
<tr>
<td>----</td>
<td>--------</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>7. Muscle strength</th>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ask the diver to lift both shoulders, while applying a gentle pressure onto them with the palm of your hands. By doing this, it should be easy to determine if the diver is able to generate the same force on both sites or if there are left-right differences.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the diver to bend both arms at the elbow in a 90° angle. Then ask him to move his hands up, down and sideways, while you provide resistance to his movements with your hands. Assess potential left-right differences in strength.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the diver to lie down flat on his back. Then ask him to lift his knees against the resistance of your hands and to move his ankle joints up and down against your resistance.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>8. Sensory perception</th>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ask the diver to close his eyes. Then touch the left and right halves of his torso in turn, then the outer and inner sites of his limbs and ask the diver, whether the sensation is the same on both sites. Assess and document the result of this test separately for each body part.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>9. Balance and motor coordination</th>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ask the diver to stand with his feet together and parallel, extend his arms in front of him, palms facing upwards and close his eyes. The diver should be able to keep his balance if he is not standing on shaky ground.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Caution: During this test the diver might loose his balance and fall, you have to be prepared to catch him!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the diver to close his eyes. Then ask him to extend his arms in front of him and try to touch the tip of his nose alternately with his left and right index fingers. Assess potential left-right differences.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask the diver to lie down flat on his back. Ask him to alternately move his left and right heels over the shin of the opposite leg. Assess potential left-right differences.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. Additional remarks and observations:
Considerations upon arrival of patients with diving accident at the hyperbaric chamber:
- Chest X-ray / thorax CT?
- Pleural drainage?
- Both lungs synchronously and equally ventilated?
- Urinary catheter?
- Myringotomy?
- Endotracheal tube cuff?
- Safe venous access?

First Hyperbaric Treatment of Diving Accidents

Symptoms present on arrival at hyperbaric chamber?
Yes
No

Does diver come to hyperbaric chamber because of previous symptoms?
Yes
No

Omitted decompression?
Yes
No

Observation

US Navy Treatment Table 6 or modified (280 kPa / O2 breathing)

Diver almost or free of symptoms after 60 min O2 breathing at 280 kPa?
Yes
No

Continue with Table 6 without extension decompress to 190 kPa
Start O2 breathing for attendant 30 min prior to decompression to 100 kPa

1st Extension (280 kPa):
5 min air and 20 min O2 breathing

Diver almost or free of symptoms after 80 min O2 breathing at 280 kPa?
Yes
No

Continue with Table 6 with decompression to 190 kPa

2nd Extension (280 kPa):
5 min air and 20 min O2 breathing continue with Table 6

Diver almost or free of symptoms after 60 min O2 breathing at 190 kPa?
Yes
No

Continue with Table 6 until 120 min total time of O2 breathing at 190 kPa
Start O2 breathing for attendant 60 min prior to decompression to 100 kPa

3rd Extension (190 kPa):
15 min air and 60 min O2 breathing

Diver almost or free of symptoms after 120 min of O2 breathing at 190 kPa? (prior to 3rd extension!)
Yes
No

Continue with Table 6 until 180 min total time of O2 breathing at 190 kPa
Start O2 breathing for attendant 60 min prior to decompression to 100 kPa

4th Extension (190 kPa):
15 min air and 60 min O2 breathing

Diver almost or free of symptoms after 180 min of O2 breathing at 190 kPa?
Yes
No

Continue with Table 6 until 240 min total time of O2 breathing at 190 kPa
Start O2 breathing for attendant 60 min prior to decompression to 100 kPa

Problem Wound Treatment Table
(240 kPa / 90 min O2 breathing)

Start O2 breathing for attendant when starting decompression
Guidelines Statement

Guideline "Diving Accident" published by the GTÜM e.V. (Germany) in cooperation with the ÖGTH (Austria) and the SUHMS (Switzerland)

1 Questions regarding the quality of the guideline development process

Responsibility for guideline development

1.1 Is the agency responsible for guideline development clearly identified?

Responsible for guideline development is the leading "Gesellschaft für Tauch- und Überdruckmedizin e.V." (GTÜM). The development of the initial release was carried out in 2002 in cooperation with the GTÜM affiliated societies in Austria (ÖGTH, Österreichische Gesellschaft für Tauch- und Hyperbarmedizin) and Switzerland (SUHMS, Schweizerische Gesellschaft für Unterwasser- und Hyperbarmedizin). The guideline was revised in 2005 in cooperation with the ÖGTH, the present revised version of 2008 was developed in cooperation with the ÖGTH and the SUHMS.

1.2 Was external funding and/or other support received for developing the guideline?

No external funding and/or other support were received. All costs incurring in the context of guideline development were covered by the GTÜM, including reimbursement of expenses for experts (see 1.4) and members of the jury (see 1.10).

1.3 If support on the part of commercial lobbies was received or if there is any evidence of potential biases or conflict of interests, were their potential influence on the guideline discussed?

Not applicable.

Authors of the guideline

1.4 Is there a description of the individuals – for example, professionals and interest groups, including patients – who were involved in developing the guideline with respect to their function and the nature of their involvement?

Panel of experts for the revision of the guideline in 2008:
Dr. med. Peter HJ Müller, specialist in anesthesiology, Bellheim (DE) (Chair)
Dr. med. Wilfried Beuster, specialist in trauma surgery, Klagenfurt (AT)
Dr. med. Wolfgang Huhn, specialist in general medicine, Wetzlar (DE)
Dr. med. Peter Knessl, specialist in anesthesiology, Kilchberg (CH)
Dr. med. Hans Joachim Roggenbach, specialist in internal medicine, Essen (DE)
Dr. med. Volker Warninghoff, specialist in anesthesiology, Kiel (DE)
Dr. med. Wilhelm Welslau, specialist in occupational medicine, Vienna (AT)
Dr. med. Jürg Wendling, specialist in surgery, Biel (CH)

Panel of experts for the revision of the guideline in 2005:
Dr. med. Wilhelm Welslau, specialist in occupational medicine, Vienna (Chair)
Dr. med. Wilfried Beuster, specialist in trauma surgery, Klagenfurt (AT)
Dr. med. Wolfgang Förster, specialist in occupational medicine, Munich (DE)
Dr. med. Wolfgang Huhn, specialist general medicine, Wetzlar (DE)
Dr. med. Armin Kemner, specialist in anesthesiology, Murnau (DE)
Dr. med. Peter Müller, specialist in anesthesiology, London (GB)
Dr. med. Claus-Martin Muth, specialist in anesthesiology, Ulm (DE)
Dr. med. Hans Joachim Roggenbach, specialist internal medicine, Essen (DE)
Panel of experts for the development of the initial release of the guideline in 2002:
- Dr. med. Wilhelm Welslau, specialist in occupational medicine, Vienna (Chair)
- Dr. med. Wilfried Beuster, specialist in trauma surgery, Klagenfurt (AT)
- Dr. med. Wolfgang Förster, specialist in occupational medicine, Munich (DE)
- Dr. med. Günter Frey, specialist in anesthesiology, Ulm (DE)
- Dr. med. Armin Kemmer, specialist in anesthesiology, Murnau (DE)
- Dr. med. Ulrich van Laak, Kronshagen (DE)
- Dr. med. Claus-Martin Muth, specialist in anesthesiology, Ulm (DE)
- Dr. med. Doreen Peusch-Dreyer, specialist in urology, Schwaneckede (DE)
- Prof. Dr. med. Peter Radermacher, specialist in anesthesiology, Ulm (DE)
- Dr. med. Adel Taher, Egypt (EG)
- Dr. med. Jürg Wendling, Biel (CH)
- Dr. rer. nat. Jürgen Wenzel, Cologne (DE)
- Norbert Zanker, Brussels (BE)

1.5 Were all groups primarily affected by the guideline (relevant specialist disciplines and patients) involved in the development of the guideline?

Yes.

Identification and interpretation of evidence

1.6 Is there a description of the sources of information and the methods used to collect (that is, identify and select) the evidence on which the guideline is based?

References search and identification:
- Literature research with MEDLINE including reference update from 1966 to 2008
- Computer-aided literature research, Assessment of grey literature and convention reports of EUBS, UHMS and ICHM (GTÜM literature database)
- Manual literature research and unpublished research reports (by each expert)

1.7 Are the sources of information and search strategies adequate and referenced?

For computer-aided literature research the panel of experts had access to the GTÜM literature database (MS Access® database with search function incl. full text search, monthly update by the GTÜM's librarian, available at „www.gtuem.org”, status: March 2008):

List of data source used:

Databases:
- MEDLINE Standard incl. SERLINE (starting 1966, Medline on Silverplatter)
- Databank of Undersea and Hyperbaric Medical Society (UHMS), U.S.A.
- National Library of Medicine (NLM), U.S.A.
- Dt. Institut f. Medizinische Dokumentation u. Information (DIMDI), Germany

Convention reports:
- 2nd International Congress on Hyperbaric Oxygenation 1964
- International Symposium on Hyperbaric Physiology and Medicine 1997
- 1st ECHM Consensus Conference, Lille, 1994
- 2nd ECHM Consensus Conference, Marseille, 1996
- 7th ECHM Consensus Conference, Lille, 2004
Other sources (books):
- Kindwall, Hyperbaric Medicine Practice (1994)
- Elliott, Medical Assessment of Fitness to Dive (1995)
- Brubakk & Neuman (Eds.): Bennett and Elliott’s Physiology and Medicine of Diving, 5th Ed., 2003
- Edmonds, Lowry, Pennefather, Walker: Diving and Subaqueous Medicine, 4th Ed., 2002

Keywords used for database search:
(Search profile for MEDLINE, profiles for other databases were very similar)
- HBO or hyperbaric oxygen or hyperbaric-oxygenation or hyperbaric oxygenation or hyperbaric oxigenation or hyperbaric-therapy or hyperbaric therapy or hyperbaric-medicine or hyperbaric medicine
- Hyperbaric hyperoxia or hyperbaric-hyperoxia or oxygen toxicity or oxygen-toxicity or oxygen-intoxication or oxygen-intoxication or nitrogen toxicity or nitrogen-toxicity or nitrogen intoxication or nitrogen-intoxication
- inert gas narcosis or inert-gas-narcosis or nitrogen narcosis or nitrogen-narcosis or HPNS or high pressure neurological syndrome or high-pressure-neurological-syndrome or high pressure nervous syndrome or high-pressure-nervous-syndrome
- caisson or barotrauma or recompression or gas-embolism or gas embolism or decompression sickness or decompression-sickness or decompression illness or decompression-illness or arterial air embolism or arterial-air-embolism
- diving or submarine-medicine or submarine medicine or submarine escape training or submarine-escape-training or escape training or escape-training or decompression chamber or decompression-chamber or hyperbaric-chamber or hyperbaric chamber or undersea-biomed-res or undersea-hyperb-med
- diver in TI
- diver in AB
- divers in MESH
- divers in TI
- divers in MESH

Descriptors used:
Medical Subject Headings (MeSH) descriptors used by the GTÜM’s literature database are the same used by MEDLINE.

A total of 29,693 references were identified. The selection of relevant literature about the individual sub topics of the guidelines was done by the experts with respect to the issue being addressed. Additionally, each of the experts involved in developing the guideline performed manual search for relevant literature without limitations or regimentation.

1.8 Is there a description of the methods used to interpret and assess the strength of the evidence?

Evidence assessment was done according to the classification issued by the US Agency for Health Care Policy and Research (AHCPR 1992):

Levels of evidence / description
- Ia Evidence obtained from meta-analyses of randomised controlled trials
- Ib Evidence obtained from at least one randomised controlled trial
- Iia Evidence obtained from at least one well-designed controlled study without randomisation
- IIb Evidence obtained from at least one other type of well-designed quasi-experimental study
- III Evidence obtained from well-designed non-experimental descriptive studies, such as comparative studies, correlation studies, and case studies
- IV Evidence obtained from consensus conference / expert committee reports or opinions and/or clinical experience of respected authorities
Formulation of recommendations

1.9 Is there a description of the methods used to formulate recommendations?

Whenever possible, randomized controlled trials (RCTs) were consulted. However, in some fundamental areas RCTs are not available as they not be carried out for ethical reasons. The same is true in other areas of medicine, for which despite internationally accepted therapy standard procedures no randomised studies are available (e.g. artificial respiration in patients with respiratory failure).

1.10 Are the techniques used to reach consensus on the recommendations explicitly described?

Phase 1: in 10/2007 the expert panel listed in 1.4 was formed for the development of the guideline according to AWMF recommendations (Methodical Recommendations „Leitlinie für Leitlinien” (guidelines for guidelines), status 02/2000). The entire communication in the context of guideline development is discussed with all expert panel members.

Phase 2: The guidelines developed in phase 1 were discussed in phase 2 according to AWMF recommendations (Methodical Recommendations „Leitlinie für Leitlinien” (guidelines for guidelines), status 02/2000) in the course of the scientific meeting of the GTÜM e.V. at a consensus conference from 19-20/04/2008 according to NIH standards. The panel of experts from phase 1 presented the guidelines. An international jury acted as steering committee in phase 2, consisting of:

Prof. Dr. med. Alf O. Brubakk (Norway, Chair)
Dr. med. Wolfgang Förster (Germany)
Dr. med. Peter Germonpré (Belgium)
Dr. med. Peter Nussberger (Switzerland)
Dr. med. Clemens Mader (Austria)
Dr. med. Ulrich van Laak (Germany)
Dr. med. Adel Taher (Egypt)
Dr. med. Wilhelm Welslau (representative of the phase 1 panel of experts, non-voting)

1.11 Is there a description of the methods used to seek views of interested parties not on the panel?

Upon completion of phase 1, groups that were not involved in the development of the guidelines in phase 1 may participate in the consensus conference and have the opportunity to introduce their views into the discussion.

1.12 Is there an exact documentation of the link between the major recommendations and the level of supporting evidence?

No.

Expert reviews and pilot studies

1.13 Were the guidelines subjected to independent review by experts or outside panels prior to their publication or release?

The 2002 guideline, in the form approbated by the jury at the consensus conference, had been published in an appropriate peer-reviewed scientific journal in 2003.

1.14 If so, is information given about methods and how comments were addressed?

Yes.

1.15 Were the guidelines piloted or pre-tested?

No.
1.16 *Is information given about the pilot or pre-test process and findings?*

Not applicable.

1.17 *Was the guideline compared to sets of guidelines that deal with the same topic?*

The guideline „Diving Accident“ is comparable to the decisions of the consensus conferences of the ECHM of 1994, 1996 and 2004, the recommendations of the UHMS Committee Reports of 2003 and the HTA Reports of the German Federal Joint Committee (G-BA) for DCS and AGE of 2003 and is consistent with their essential statements.

**Validity period / updating of the guideline**

1.18 *Is there a mention of a date for reviewing or updating the guideline?*

The guideline „Diving Accident“ will be revised at least every 3 years.

1.19 *Are the methods and the body responsible for reviewing and updating the guideline clearly identified?*

The guideline will be revised by a panel of experts, composed of representatives of the respective Scientific Medical Societies, GTÜM, ÖGTH and SUHMS. If such a committee cannot be formed, a panel of experts will be formed at least 6 months prior to the scientific meeting of the GTÜM by the GTÜM alone. The panel of experts will reassess the validity of the guideline (guideline phase 1). In the course of the scientific meeting, required modifications of the guideline will be appròbated as guideline phase 2 by a consensus conference.

**Clarity of the development process**

1.20 *Have the potential systematic errors / conflicts been adequately discussed?*

In the course of communication during the development of the guideline in phase 1, potential systemic errors and especially conflicts were discussed in detail among the panel of experts. No systemic errors could be detected. All decisions by the panel of experts were made by unanimous vote.

1.21 *Is there an accurate summary in the document that reflects the contents and recommendations of the guideline as well as the methods for its development (e.g. in form of a guideline report)*

In compliance with above requirements, the guideline document contains:

a) the present guideline statement

b) the comprehensive guideline including literature references, list of references, tables, diagrams, flow charts and check lists

c) a short version of the guideline
2 Contents and Format of the Guideline

Objectives of the Guidelines

2.1 Are the reasons for developing the guidelines clearly stated?

These guidelines are intended to provide assistance in medical decision making for effective patient care. In terms of quality assurance, the guidelines represent high quality medical care, also with respect to economic necessities. They provide the individual physician with instructions and information based on state-of-the-art medical knowledge in an area of emergency care far from routine.

2.2 Are the objectives of the guidelines clearly defined?

Presentation of state-of-the-art medical knowledge regarding the treatment of diving accidents,
- regarding first aid by laypersons, medical assistance personnel and physicians
- regarding the concept of the "rescue chain" and the transportation of diving accident victims
- regarding the first definitive treatment of diving accidents
- regarding the subsequent medical care for diving accidents

Context (Applicability / Flexibility)

2.3 Is/Are the target patient group to whom the guidelines are meant to apply clearly defined (e.g. regarding sex, age, disease state, concomitant diseases, etc.)?

The guidelines apply to all persons, who have suffered a diving accident as defined in the guidelines, without limitations regarding sex, age, state of disease or concomitant diseases.

2.4 Are the health professionals for whom the guidelines are intended, identified (e.g. target physician group)?

The guideline is intended for
- all divers, especially all diving instructors,
- first responders (lay persons), physician first responders and emergency physicians
- all rescue associations
- all physicians at hyperbaric chambers

2.5 Is there a description of the circumstances (clinical or non-clinical) in which exceptions might or should be made in using the guidelines?

Yes, if there is any doubt regarding the applicability of the guideline, an expert (experienced diving physician) should be consulted in individual cases. This is explicitly stated in the guideline in the sections covering first aid by lay persons, first aid my medical personnel, first hyperbaric treatment and the issue of diving fitness after a diving accident.

2.6 Were the patient's views, preferences and potential reactions taken into account?

No, diving accidents are medical emergencies. Since there are no equivalent treatment options available, the patient's views, preferences and potential reactions cannot be taken into account.
Clarity

2.7 Do the guidelines describe the discussed health/health care issue in unambiguous and generally understandable terms?

Yes, all sections of the guideline are composed in terms appropriate for the respective reader.

2.8 a) Are the recommendations logical, consistent, unambiguous, and easy to follow and are they clearly presented?

Yes.

2.8 b) Do the guidelines contain major (key) recommendations and can they be identified easily?

Yes, it contains tables, block diagrams and flow charts, in addition to the condensed version of the guideline.

2.9 Are the different possible options for management of the condition and the respective decision criterions clearly described in the guidelines?

Yes.

2.10 Are there specific recommendations regarding the decision for outpatient vs. inpatient medical care?

Yes.

2.11 Do the guidelines indicate which actions are necessary?

Yes.

2.12 Do the guidelines indicate which actions are inappropriate, unnecessary or obsolete?

Yes.

Costs and benefits, side effects, results

2.13 Is there a description of the health benefits that are expected to be gained from adherence to the guidelines, for example regarding morbidity, mortality, symptoms and quality of life?

No.

2.14 Is there a mention of potential risks in adherence to the guidelines (side effects and complications)?

No.

2.15 Were the incurring costs and other resources taken into account in developing the guidelines?

No. Due to the varying degree of severity of individual cases, no statement can be made regarding the total costs of treatment. For example, for mild symptoms like "skin bends", in most cases a single outpatient hyperbaric treatment is sufficient, while persisting neurological symptoms may require numerous hyperbaric treatments.
2.16 Were potential benefits, risks and costs considered and does the assessment support the recommended approach?

No.

3 Applicability of the Guidelines

Dissemination and implementation

3.1 a) Are there instruments/measures that could facilitate implementation of the guidelines?

- Publication in medical scientific literature (intended publication)
- Training courses offered by diving medical associations (GTÜM, ÖGTH, SUHMS)
- Information intended for laypersons via magazines (after publication at consensus conference)

3.1 b) Were potential problems regarding changes of attitude or behaviour of physicians and other health care providers implementing the guidelines taken into account?

Yes.

On the one hand, no problems are anticipated, since:
- divers are usually well informed about the procedure,
- the procedure after diagnosed diving accidents has remained unchanged for years,
- every hospital will attempt to keep hospital stays after diagnosed (!) diving accidents as short as possible.

On the other hand, there are still reports of undiagnosed and untreated diving accidents, because:
- diving medicine is not a standard part of medical education and
- divers as well as diving instructors/diving schools tend to dissimulate accidents for various reasons.

3.1 c) Were potential organisational obstacles in implementation of the guidelines taken into account?

Yes, an aggressive information campaign for the guideline is required, among physicians as well as other health care providers, because diving medicine is not a standard part of medical education.

3.2 National/international guidelines only:

Does the guideline suggest/specify the methods for local adaptation?

Yes, in Austria, national authorities and organizations have to be separately involved. The ÖGTH is responsible for this process, which will not be described here. Other regional adaptations are not indicated and unnecessary.

Monitoring of guidelines/clinical audit

3.3 Does the guideline document mention how measurable criteria for monitoring compliance can be inferred from the recommendations?

No.

3.4 Does the guideline document define measurable criteria/indicators that can be used to monitor the effect of guideline implementation?

No.