

# The world as it is

## Diving Accident Guidelines of the German Society for Diving and Hyperbaric Medicine: summary version

Peter HJ Müller (Chairperson), Wilfried Beuster, Wolfgang Hühn, Peter Knessl, Hans Joachim Roggenbach, Volker Warninghoff, Wilhelm Welslau and Jürg Wendling

### Editorial statement:

These guidelines are published here with the approval of the Executive Committees of EUBS and SPUMS, but do not necessarily reflect the policies of either Society. It was felt that their promulgation would be of use to members, and we thank the German Society for making their work more widely available. Minor editing has been necessary to fit.

### Introduction

The following is a synopsis of the German Diving Accident Guidelines, which may be found on <www.gtuem.org> in German and English. It is the second revision of a guideline initially published in 2002. The first version was reviewed in 2005 and then revised and updated in 2008. It is valid until October 2011, when the next revision is scheduled. Each version was developed by a group of experts and then presented to a consensus conference organised by the GTÜM. An independent international steering committee (jury) at the conference created the final document. The current guideline, therefore, reaches level two evidence for guidelines. This is the first version published in both English and German. The extensive reference list used in preparing this document is available on the GTÜM website.

### Definitions

Diving accidents, in the sense of these guidelines, are also referred to as ‘decompression accident’, ‘decompression illness’, ‘decompression incident’ or ‘decompression injury’ (DCI). Such accidents, caused by a rapid reduction of ambient pressure, 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 distinction between DCS and AGE. Differential diagnoses may be barotrauma of the inner ear (round window membrane rupture), cerebral embolism or bleeding, vertebral disc herniation, myocardial infarction, hypoglycaemia or epilepsy (Figure 1 and Tables 1 and 2).

### First aid in suspected diving accidents (Figure 2)

#### FIRST AID BY 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 fluids 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 min, continue 100% oxygen, call diving physician, and observe for 24 h
- if symptoms persist longer than 30 minutes: treat like severe symptoms.

If symptoms appear while still underwater or if other symptoms are present, such as:

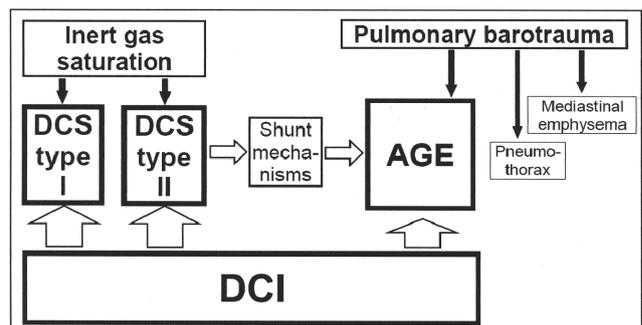
- skin rash or discolouration
- pain
- tingling and/or numbness
- physical weakness/paralysis
- breathing difficulties
- vision, hearing or speech problems
- nausea and/or vertigo
- impaired consciousness,

follow the instructions below.

#### Specific first aid

- Cardiopulmonary resuscitation according to ERC guidelines, as indicated
- If diver is unconscious, put in recovery position; otherwise put in a supine position

**Figure 1**  
System of dive accidents



**Table 1**  
**Pathogenesis and symptoms of diving accidents**  
 \* These symptoms can also be indicative of DCS type II or AGE

	<b>Decompression Sickness (DCS)</b>	<b>Arterial Gas Embolism (AGE)</b>
<b>Pathogenesis</b>	<ul style="list-style-type: none"> <li>• greater diving depth / high ambient pressure</li> <li>• long exposure time</li> <li>• saturation of body tissue with inert gas (depending on breathing gas used, usually nitrogen (N<sub>2</sub>))</li> <li>• too fast ascent after long and/or deep dives with high level of tissue saturation</li> </ul>	shunting of venous gas bubbles into arterial circulation due to: <ul style="list-style-type: none"> <li>• pulmonary barotrauma with over-distension of the lungs</li> <li>• paradoxical embolism due to                             <ol style="list-style-type: none"> <li>a) shunting of venous gas bubbles via lung blood vessels</li> <li>b) shunting of venous gas bubbles via a patent <i>foramen ovale</i> (PFO)</li> </ol> </li> </ul>
<b>Time until symptoms appear</b>	minutes to hours max. 24 hrs after completion of dive (in rare cases max. 48 hrs)	minutes after completion of dive sometimes already during ascent
<b>Symptoms</b>	<p><b><u>DCS type I</u></b></p> <p><b>Skin symptoms</b></p> <ul style="list-style-type: none"> <li>• itching</li> <li>• punctate reddening</li> <li>• swelling</li> <li>• marbled skin *</li> </ul> <p><b>Muscle and joint pain ('bends'):</b></p> <ul style="list-style-type: none"> <li>• large and middle-sized joints (also depending on exertion level)</li> <li>• skeletal muscles.</li> <li>• rare: foot and hand joints</li> </ul> <p><b>Lymphatic system:</b></p> <ul style="list-style-type: none"> <li>• swollen, tender lymph nodes, (rare)</li> </ul> <p><b>Other:</b></p> <ul style="list-style-type: none"> <li>• unusual tiredness *</li> </ul> <p><b><u>DCS Type II</u></b></p> <ul style="list-style-type: none"> <li>• apathy / unconsciousness</li> <li>• vertigo / vomiting</li> <li>• sensory disturbances, paresis, paraplegia</li> <li>• urinary and faecal incontinence or retention</li> <li>• disturbed motor coordination</li> <li>• hearing / vision / speech troubles</li> <li>• acute dyspnoea ('chokes') accompanied by chest pain, coughing, feeling of suffocation</li> <li>• additionally sometimes muscle and joint pain developing during ascent (distribution same as with type I)</li> <li>• other neurological symptoms</li> </ul>	<p><b><u>AGE</u></b></p> <ul style="list-style-type: none"> <li>• apathy / unconsciousness</li> <li>• vertigo / vomiting</li> <li>• confusion / disorientation</li> <li>• speech and/or vision difficulties</li> <li>• various neurological deficits: mild sensory disturbances to complete paralysis</li> <li>• if respiratory centre is affected: rapid reduction in blood pressure, breathing difficulties, cardiac arrest</li> <li>• unilaterally dilated pupil</li> <li>• other neurological symptoms</li> </ul>

- 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 CO<sub>2</sub> absorber); if not available: with constant flow (15–25 L.min<sup>-1</sup>, non-rebreather mask with O<sub>2</sub> reservoir)
  - b) If not breathing sufficiently perform artificial respiration with 100% O<sub>2</sub> (Ambu/Laerdal bag with reservoir, constant flow (15–25 L.min<sup>-1</sup>) or demand valve or closed circuit system with CO<sub>2</sub> absorber)
- Give O<sub>2</sub> without breaks until reaching chamber; give highest possible O<sub>2</sub> concentration even if O<sub>2</sub> supply is limited (no air mix, no constant flow below 15 L.min<sup>-1</sup>).
- Fluids:
  - a) Diver fully conscious: give fluids orally (0.5–1.0 L.h<sup>-1</sup>); no alcoholic or caffeinated beverages

Table 2

Differential diagnosis of diving accidents. It is often 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

	Differential Diagnosis	Clinical Symptoms
<b>DCS type II with inner ear symptoms</b>	<ul style="list-style-type: none"> <li>barotrauma of the inner ear (rupture of the round window membrane)</li> </ul>	<ul style="list-style-type: none"> <li>hearing loss</li> <li>tinnitus</li> <li>vertigo</li> </ul> <p>Caution: many patients do not exhibit the complete classical triad of symptoms</p>
<b>DCS type II with neurological symptoms</b>	<ul style="list-style-type: none"> <li>cerebral insult caused by embolism or bleeding</li> <li>vertebral disc herniation</li> </ul>	<ul style="list-style-type: none"> <li>motor, sensory or cerebral neurological deficits</li> <li>symptoms of paraplegia</li> </ul>
<b>DCS type I</b>	<ul style="list-style-type: none"> <li>cardiac infarction</li> </ul>	<ul style="list-style-type: none"> <li>e.g., pain in the left shoulder</li> </ul>
<b>DCI (AGE)</b>	<ul style="list-style-type: none"> <li>hypoglycaemia</li> </ul>	<ul style="list-style-type: none"> <li>e.g., unconsciousness</li> </ul>
<b>DCI (AGE)</b>	<ul style="list-style-type: none"> <li>epilepsy</li> </ul>	<ul style="list-style-type: none"> <li>e.g., seizures</li> </ul>
<b>DCI suspected uncertain symptoms</b>	<ul style="list-style-type: none"> <li>breathing gas contamination (CO etc.)</li> <li>toxic effect of breathing gas in mixed gas diving</li> <li>hypercapnia due to skip breathing</li> <li>hyperventilation due to psychological stress</li> <li>hypoglycaemia</li> <li>psychotropic drugs</li> </ul>	<ul style="list-style-type: none"> <li>headache</li> <li>impaired consciousness</li> <li>vertigo</li> </ul>

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 and hyperthermia; if hypothermic: no active re-warming
  - Never try in-water recompression
  - Organize transport
  - Call emergency control centre.
    - Mode of transport: no preference for specific mode of transport, transport fast and gentle, no restrictions for helicopter transport (lowest safe flying altitude)
    - Transport destination: nearest emergency unit, preferably close to hyperbaric treatment chamber
  - Document diving data, development of symptoms and treatment
  - Observe dive partner as well
  - Impound diving gear (e.g., decompression computer)
  - Consult diving medical phone hotline, if necessary; key words "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 within Switzerland)

3 VDST hotline: +49-1805-660560

4 Office of the Naval Medical Institute, German Navy: +49-431-54091441

5 Diver hotline aqua med: +49-700-34835463

6 International DAN hotline: +39-0396057858

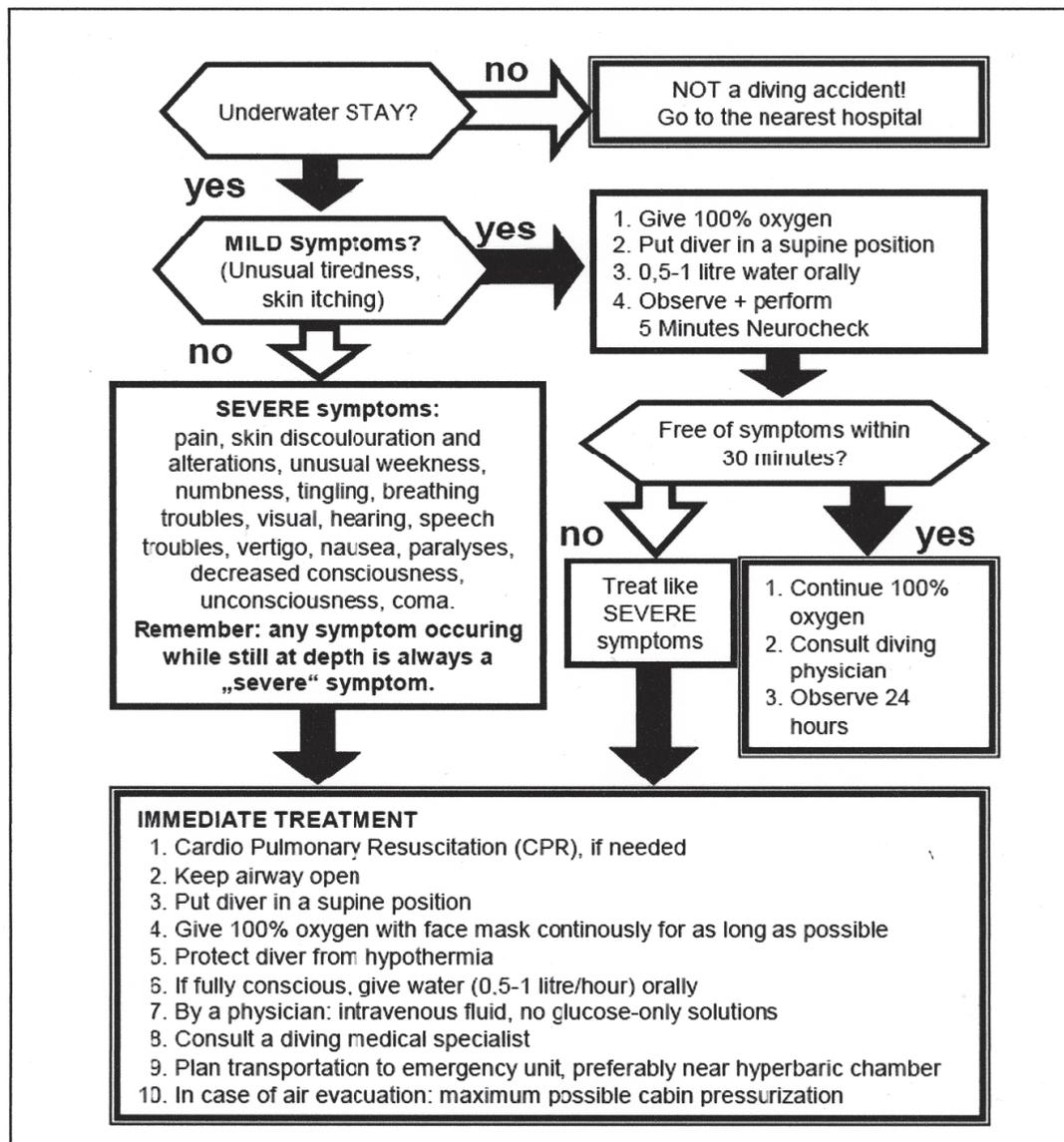
**More hotlines can be found at <[www.gtuem.org](http://www.gtuem.org)>**

#### FIRST AID BY MEDICAL PERSONNEL

##### Specific first aid

- Cardiopulmonary resuscitation according to ERC guidelines, as indicated
- 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):
  - if breathing sufficiently: see above
  - if not breathing sufficiently: perform artificial respiration with 100% O<sub>2</sub> (aim at FiO<sub>2</sub> = 1.0), if necessary via endotracheal tube, without breaks until reaching hyperbaric treatment chamber
  - Give highest possible oxygen concentration even if oxygen supply is limited (no air mix, no constant flow below 15 L.min<sup>-1</sup>)
- Intravenous fluids: give 0.5–1.0 L.h<sup>-1</sup> i.v.; do not use glucose-containing solutions
- Medication: generally follow standard procedures in emergency medicine; up to now, no drug has been

**Figure 2**  
**Flow chart: diving accident management (modified after Divers Alert Network Europe)**



definitively proven to be specifically effective in the treatment of diving accidents.

#### *Additional actions*

- Perform basic neurological follow-up examinations
- Urinary catheter, as indicated
- Pleural drainage, as indicated
- Protect against hypothermia as well as hyperthermia. If hypothermic, active re-warming only with ICU-like capabilities on site
- Hyperbaric treatment as soon as possible, after consultation with a diving medical hotline; even delayed hyperbaric 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**

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 O<sub>2</sub> treatment without breaks until reaching hyperbaric chamber; continue commenced treatment.

#### **First hyperbaric treatment (Figure 3)**

Hyperbaric treatment chamber, working pressure min. 280 kPa (2.8 bar; 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 chest X-ray (p.a./lateral) / thoracic CT scan if feasible within reasonable time frame
- Pleural drainage, as indicated
- Urinary catheter, as indicated
- Myringotomies, as indicated
- If patient is intubated: fill cuff with fluid or check cuff pressure continuously
- Consult diving medical hotline as needed (see above).

#### *Treatment tables*

- Standard treatment table is US Navy Treatment Table 6 (or modifications of this) for all diving accidents irrespective of breathing gas used by the 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
- Periodic check of all gas-filled confinements (e.g., endotracheal tube cuff, infusion, drip chamber, blood pressure cuff) including before each decompression.

#### *Adjuvant treatment*

- Generally follow standard procedures in emergency and intensive care medicine
- If the patient is awake, special psychological support for reassurance and relief of anxiety
- Check bladder; ensure adequate hydration and fluid balance
- Up to now, no drug has been proven definitively to be effective in the treatment of diving accidents
- Documentation 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 initial hyperbaric chamber, organize transport to a hyperbaric centre which has this capability. In principle, flight transport with regular cabin pressure (e.g., 81 kPa; 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, taking into account previous 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
- Ensure adequate hydration and fluid balance, 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 needed, perform second treatment according to standard DCI treatment table or hyperbaric oxygen treatments, e.g., 'problem wound treatment protocol'; maximum two treatments within 24 hours, maximum interval between treatments 24 hours.
- Diagnostics: depending on clinical symptoms, MRI, CT and periodic examination by neurologist, reassessment of pulmonary function, additional examinations by specialists depending on clinical symptoms
- Physiotherapy: between hyperbaric treatments depending on clinical symptoms, starting max. three days after diving accident. Physiotherapy during hyperbaric treatment is possible, but there is no evidence that this will have any additional advantage.
- Medication and additional treatment: depending on clinical symptoms and following recommendations of consulted medical specialists
- Decision on stopping hyperbaric treatments: after complete and lasting disappearance of symptoms, hyperbaric treatments may be terminated. If symptoms do not continue to improve over three to five days after an initial reduction, hyperbaric treatment should be stopped and rehabilitation treatment recommended for neurological symptoms should be continued.
- Documentation
- Rehabilitation: if neurological deficits persist after hyperbaric treatment has ended, rehabilitation 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.

#### **For further information contact:**

*Dr. med. Peter HJ Müller*

*Secretary General of the GTÜM e.V.*

**Email:** <p.mueller@gtuem.org>

#### **Key words**

Diving accidents, decompression illness, decompression sickness, cerebral arterial gas embolism (CAGE), first aid, hyperbaric oxygen therapy, transport, medical society

