

The world as it is

Problems of a preclinical treatment algorithm for diving accidents: analysis of the Swiss hyperbaric situation

Jürg Wendling, Peter Nussberger and Christian Wölfel

Key words

Diving accidents, decompression illness, first aid, hyperbaric facilities, policy

Abstract

(Wendling J, Nussberger P, Wölfel C. Problems of a preclinical treatment algorithm for diving accidents: analysis of the Swiss hyperbaric situation. *Diving and Hyperbaric Medicine*. 2009;39(2):100-3.)

Following recent changes in the medical infrastructure in Switzerland, the number of hyperbaric facilities fell from ten to two, and the existing algorithms for telemedical assistance of divers required review. A retrospective study of decompression illness (DCI) from 2004 to 2008 showed that many divers were asymptomatic at the start of hyperbaric treatment. Because of this and recent publications, we may need to modify in the future the decision to recompress a diver. The descriptive nomenclature for DCI was used to determine the probability that symptoms represent DCI. Secondly we evaluated the probability that symptoms may be due to other pathologies or of psychosomatic origin, and thirdly the potential of symptoms for sequelae and their degree of invalidism was estimated. This process will result in one of three therapeutic decisions:

- An absolute indication for hospital-based hyperbaric treatment
- Immediate recompression if available or normobaric oxygen (NBO) with telemedical supervision and adequate monitoring; in exceptional situations, on-site chamber recompression or in-water recompression may be considered.
- NBO as a preventive measure for two hours and 'bends watch' for 24 h.

A prospective study should confirm evidence of good treatment practice. The key for further improvements will be to better understand ambiguous symptoms and to differentiate so-called 'mild' neurological symptoms. As a consequence of the reduction in hyperbaric facilities, longer transfer and treatment delays have resulted. Therefore, there is a need for careful evaluation of the indications for hyperbaric treatment of injured divers and also of the need to install on-site chambers for professional diving operations.

Introduction

Switzerland is a small country in the middle of Europe, full of mountains but isolated from the seashores. There are numerous natural fresh-water lakes mostly originating from the glacial period. Some of them are very deep. Most have a sediment bottom; however, many have rocky drop offs, caves or colourful underwater springs. While the 'big lakes' are at about 400 m altitude, many smaller ones in the Alps are higher, up to 2,500 m. Local diving, therefore, is generally drysuit diving with water temperatures around 4°C, and depths up to 50 metres' fresh water (mfw) are very common. Extreme deep diving (down to 180 mfw) is popular in a small but active technical diver community.

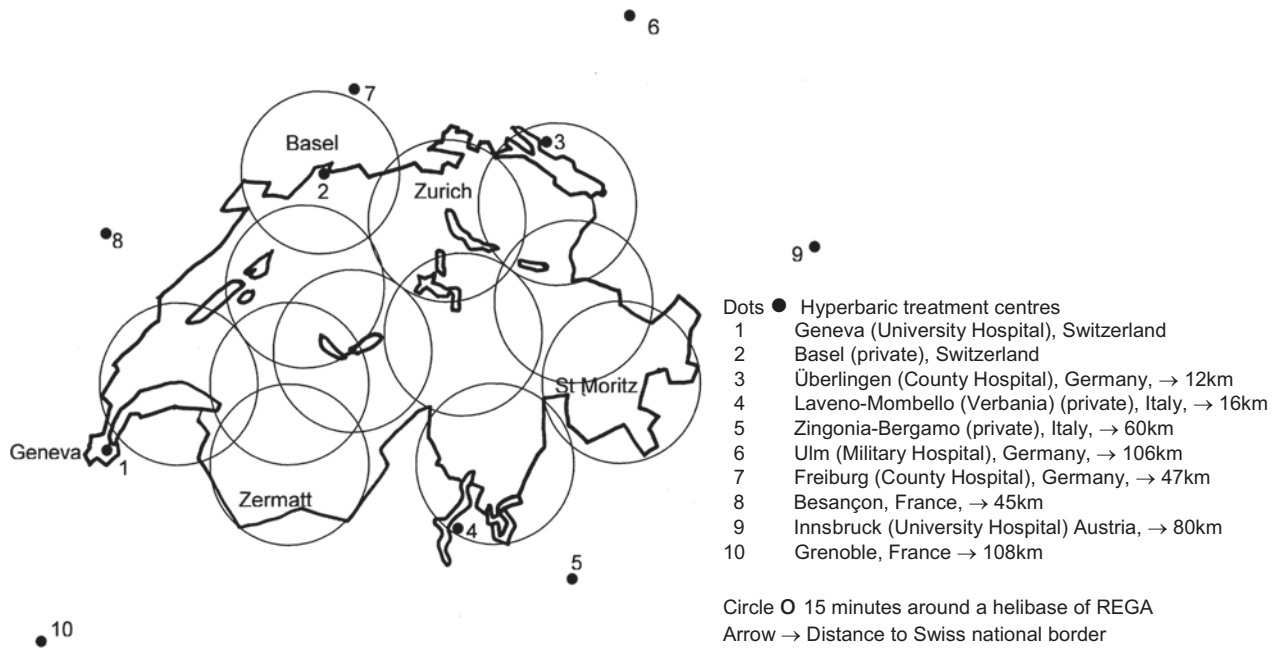
The commonest problem in emergency situations, therefore, is difficulty of access in spite of helicopter availability, particularly in bad weather conditions. The second problem is that the technical and cave divers tend to assume that they have access to a full recompression service when they call the hotline, not understanding that treatment in quasi saturation conditions needs preparations and presents logistical challenges.

Historical perspective

Switzerland, though a land-locked country, was a leader in the development of deep diving physiology and practice over many years.¹ By the 1980s a network of hyperbaric chambers had been established, reflecting an appropriate acceptance of hyperbaric medicine by the community and amongst medical specialties. Eighteen years ago, together with the establishment of the DAN Hotline for Europe in Zurich, a medical team of diving physicians started to advise divers in need and to organise and coordinate appropriate treatment: first-aid normobaric oxygen (NBO), recompression if indicated and medical follow up for up to two years after a diving incident.

The Swiss Air Ambulance, REGA, provided the telephone hotline whereby doctors were called by pager and divers were transferred rapidly by helicopter to the closest chamber. Eleven REGA helicopter bases and a few from cooperating local groups were able to get to anywhere in Switzerland within 15 minutes and to bring the patient to a recompression chamber within less than 20 minutes (Figure 1). All divers with symptoms compatible with decompression illness

Figure 1
Availability of HBOT chambers and helicopter-based medevacuation in Switzerland



(DCI) were brought to one of the ten hyperbaric chambers for assessment and recompression treatment (HBOT) if indicated.

Changes in Swiss health services since 2004

Treatment for DCI was paid for by a fixed daily ‘hospital fee’ by private health insurance (mandatory in Switzerland, controlled by Government audit) and the considerable extra costs of recompression were covered by the ‘deficit guarantee’ of the Canton (State of Switzerland). In 2004, new public health insurance regulations came into force; hospitals now had to be managed like a private commercial company. Due to budget restrictions, many specialist services were shut down, including hyperbaric facilities; four of five university hospital-based chambers (in Berne, Basel, Zurich and Lausanne) and four of five private chambers. The remaining two chambers still available for outpatient treatments are in Geneva and Basel. This has resulted in an increase in treatment delays of between 30 and 90 minutes and helicopters may not always be available for long-distance transfer. Also, patients have now to contribute to their costs, as the 2004 public health insurance regulations only provide a much reduced coverage for HBOT, and indications for recompression must be clearly justified. Switzerland suddenly became a ‘remote’ country from a diving perspective. As a result, Swiss policies for the telemedical management of diving accidents became necessary. A three-pronged approach was adopted for this.

Retrospective review of DCI cases from 2004 to 2008

Using the Divers Alert Network (DAN) Europe Suisse case reports databank, 198 possible cases of presumed DCI were identified from January 2004 to December 2008. The cases (142 men, 56 women) show a typical age distribution: nine were aged 8–14, 106 were 25–39, 77 were 40–69 and six were more than 60 years old. Severity categories and treatment are shown in Table 1. Only seven had residua (more than minor sensory impairment), all but one survived;

Table 1
Annual incidence and severity of DCI cases in Switzerland; HBOT – hyperbaric oxygen; NBO – normobaric oxygen
* mostly not DCI after assessment

Year	Symptoms				Fatalities
	Nil	Mild	Moderate	Severe	
2004	5	7	16	5	5
2005	4	13	11	4	4
2006	8	12	14	5	2
2007	4	23	22	4	5
2008	6	11	17	7	3
Total	27	66	80	25	19
%	14	33	40	13	10
HBOT	1	23	42	14	
NBO	20	31	33	11*	
Bends watch	6	12	5	-	

that death being from an intracerebral haemorrhage while diving, not DCI). Diving fatalities are added to the table from another source (National Statistics Board). From these cases we note some interesting findings:

- Twenty divers (10%) were asymptomatic at the start of HBOT (the main indication being omitted decompression).
- Six divers (3%) reported having experienced similar symptoms after previous dives, which resolved spontaneously.
- Twenty-nine divers (15%) had patterns of paraesthesia and sensory impairment not typical for specific spinal or cerebral lesions.

Review of international recommendations

A review of recommendations in the world literature was undertaken. Since there are no evidence-based criteria for the need for therapeutic recompression in divers with suspected DCI,² only 'expert opinion' could be obtained:

- US Navy diving manual: always recompress to 2.4 MPa (in-water recompression if no chamber available)³
- Société de Médecine et de Physiologie Subaquatiques et Hyperbares de langue française: all types of neurological symptoms may be spinal, so recompress⁴
- *Bennett and Elliott's physiology and medicine of diving*: always recompress⁵
- Comex medical book: immediate recompression in all cases⁶
- Australian recommendations: Type I DCS is self-healing; many neurological symptoms are 'peripheral'; many symptoms are of psychosomatic origin⁷
- DAN: Distinguish between mild versus severe neurological symptoms; paraesthesia and pain are the most frequent symptoms, spinal or cerebral symptoms rarer; mild symptoms (sensory, pain, rash) appear generally after one hour, while severe neurological symptoms appear within minutes (however, may appear later in some cases)⁸
- Undersea and Hyperbaric Medical Society/DAN Workshop, Sydney, 2004: in simplified summary, a clearly defined set of 'mild' symptoms behaves differently from severe symptoms, therefore allowing a flexible decision upon HBOT according to their natural prognosis, versus probability of complications due to transport and other remote conditions.⁹

Survey of hyperbaric physicians' opinions

A short questionnaire was sent to diving accident hotline experts in Barcelona, Marseille, Aberdeen, Plymouth, UK Royal Navy, Bergen, Sharm-el-Sheik and Bados inviting their opinions on a series of scenarios and their actual practice on their diver hotline:

Scenario 1: Omitted decompression, no symptoms, delay to call 30 min – HBO versus NBO versus 'wait and see'?

- 6:1 for NBO, but 'neurocheck' necessary; duration 1–6 h, consider use of rebreather; management to be based

on DOLA score.¹⁰

Scenario 2: Pain-only DCI; delay more than 24 h post dive – HBO versus NBO?

- 3:3 HBO, if possible, and if not more than 4 h away from a chamber

Scenario 3: mild neurological symptoms (sensory), acute – HBO versus NBO?

- 5:2 HBO (one proposal: if lower limb, give HBO – suspect spinal lesion; if upper limb, give NBO – suspect peripheral lesion or other pathology)
- when rapidly improving: 5:2 NBO
- when lasting more than 24 h: 4:3 NBO
- Atypical symptoms (unlikely DCI): 4:3 HBO if possible.

Scenario 4: Use of on-site chamber with tender and technician versus referral to clinical chamber?

- 5:2 for on-site treatment, but first call hotline; recompression on medical advice only; O₂ only (generally US Navy treatment table 6).

Scenario 5: Is an algorithm used by 'hotline' doctors?

- 6:1 No; case-by-case assessment preferred; Royal Navy uses algorithm from their diving manual.

Similar opinions were expressed by Australian, New Zealand and South African hotline doctors. It seems that transport times of up to four h for recreational diving accidents are typical worldwide and accepted as appropriate, be it only to obtain a competent, medically qualified assessment.

Discussion and conclusions

The loss of therapeutic resources in Switzerland has been considerable in recent years, but, using neighbouring countries' recompression facilities, transport times can be kept to an acceptable level (Figure 1). Greater flexibility when faced with mild symptoms compatible with DCI has been adopted. However, this needs an intensive information campaign for diving providers, training organisations and emergency department physicians in order to understand the need for external consultation and shared decision making. If the change to discretionary decisions is not fully understood at all levels, divers will be placed at risk.

The Swiss medical hotline team now uses a revised guideline (Table 2) based on the above reviews and a prospective study is being conducted to ensure that the new protocols improve the overall outcome for DCI and that the reduction of indications for HBO is associated with patient satisfaction and good cost effectiveness.

The Swiss Underwater Hyperbaric Medicine Society needs to be active in providing family and hospital doctors with information about the medical indications for HBOT, not only for diving incidents. For the time-being, the approximately 40 DCI cases in recreational divers per year in Switzerland can be managed successfully with currently available resources. However, professional diving operators and tunnelling projects will need an on-site chamber and

Table 2
Guideline for Swiss diving accidents hotline 2009

1) Make working diagnosis using descriptive nomenclature for DCI

- a) Classify symptoms according to severity (neurocheck via phone, differentiate light and severe neurological symptoms)
- b) Type of onset (time after surfacing)
- c) Type of symptom evolution (progression? Additional symptoms?)
- d) Note probability and severity of barostress
- e) Note gasload and probable decompression stress

2) Check probability of non-DCI origin

- a) Concomitant diseases known?
- b) Other immersion- or pressure-related pathologies possible?
- c) Possibility of psychosomatic symptoms (stress, social)

3) Estimate potential for progression and/or invalidating sequelae

- a) Severe neurological symptoms (type II DCS), particularly medullary pathologies, progressive evolution

4) Triage decision (what treatment procedure)

- a) If instability of vital functions (cardio-respiratory, unconscious) – immediate transport to next emergency medical centre (with ICU)
- b) If severe type II symptoms (high potential for sequelae) medevac and recompression in hospital-based centre
- c) Type I DCS with light neurological symptoms ('peripheral' type), some ambiguous signs, omitted decompression >20 min – immediate recompression in local chamber if available, otherwise transport to regional chamber. In exceptional remote situations, NBO and monitoring 24 h (telemedical supervision) may be considered.
- d) Omitted decompression (no symptoms, <20 min), rapid ascent (no symptoms), pain only or skin symptoms >24 h: NBO + bends watch 24 h, repeat neurocheck.

medical support through a hotline to support commercial diving operations in Switzerland.

Acknowledgements

We thank DAN EUROPE and REGA, the Swiss air ambulance service, for their excellent cooperation and support over many years.

References

- 1 J Wendling, P Nussberger, B Schenk. Milestones of the deep diving research laboratory Zurich. *SPUMS Journal*. 1999;29(2):91-8.
- 2 Bennett MH, Lehm JP, Mitchell SJ, Wasiak J. Recompression and adjunctive therapy for decompression illness (Cochrane Review). In: *The Cochrane Library* (Issue 2, 2006). CD005007.

- Chichester, UK: John Wiley & Sons, Ltd; 2006.
- 3 *US Navy Diving Manual*, Revision 6, SS521-AG-PRO-010, Published by Direction of Commander, Naval Sea Systems Command, Flagstaff, AZ: Best Publishing Company; 2008.
- 4 B Broussolle, J Méliet, M Coulange. *Physiologie et médecine de la plongée*. 2nd edition. Paris: Ellipses Edition Marketing SA; 2006.
- 5 Moon RE, Gorman DF. Treatment of decompression disorders. In: Brubakk AO, Neumann TS, editors. *Bennett and Elliott's physiology and medicine of diving*, 5th edition. Edinburgh: Saunders; 2003. p. 600-50.
- 6 *Comex Medical Book*, revised edition 1986. Aubagne (France): Comex SA, Imprimerie Louis Lartigot; 1986.
- 7 Walker R. Decompression sickness. In: Edmonds C, Lowry C, Pennefather J, Walker R, editors. *Diving and subaquatic medicine*, 4th edition. London: Hodder Arnold; 2002. p. 111-66; 414; 418-32.
- 8 *DAN annual diving report, 2006 edition*. Durham, NC: Divers Alert Network DAN; 2006.
- 9 Mitchell S, Doolette D, Wachholz C, Vann R. *Management of mild or marginal decompression illness in remote locations*. Workshop Proceedings. Durham, NC: Undersea and Hyperbaric Medical Society/DAN; 2005.
- 10 Desola J, Sala-Sanjaume J, Garcia A. A score index for assessment of decompression sickness risk after omitted decompression (DOLA or ADOL index). *Proceedings International Joint Meeting on Hyperbaric and Underwater Medicine*. Milan: European Underwater and Baromedical Society/International College of Hyperbaric Medicine; 1996.

Received: 31 March 2009

Accepted: 04 May 2009

Jürg Wendling, MD, is a consultant general and hand surgeon at Hospital Center Biel-Bienne, is a diving and hyperbaric medicine specialist, Director of DAN Europe Suisse, member of the European Committee for Hyperbaric Medicine, Swiss Delegate to European Diving Technology Committee (EDTC) and Chairman, Medical Subcommittee, EDTC.

Peter Nussberger, MD, is a general surgeon and Head of Department of Surgery, Riehen Hospital, Basel, member of DAN Europe Suisse Medical Team, President of Swiss Underwater and Hyperbaric Medical Society, and a past assistant to Professor A Bühlmann, Zurich.

Christian Wölfel, MD, is an anesthesiologist at Kantonsspital Luzern, Diving Medicine Physician, member of DAN Europe Suisse Medical Team, and the Training Committee of Swiss Underwater and Hyperbaric Medical Society.

Address for correspondence:

Jürg Wendling, MD
Faubourg du Lac 67, CH-2502 Bienne
Switzerland

Phone: +41-(0)32-322-3876

Fax: +41-(0)32-322-3839

E-mail: <mail@wendling.ch>

This paper is based on a presentation by Dr Wendling at the SPUMS ASM, Kimbe, PNG, 2008.