Telemedicine in the management of diving accidents: correlation of phone-assessed symptom severity with clinical findings

Christian Wölfel, Guido Schüpfer, Christoph Konrad, Peter Knessl and Jürg Wendling

Abstract
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Introduction: The object of this study was to evaluate to what extent the severity of decompression illness (DCI) assessed by a diving medicine specialist over the phone correlates with actual clinical findings.
Methods: The phone protocols of calls received by a diving medical hotline between January 2008 and December 2009 were analysed. Each case was followed up after completion of the treatment and categorised into one out of four severity groups according to the same standard protocol used for categorisation at the time of the initial hotline call.
Results: In 47 of 151 calls, DCI was suspected by the hotline experts. The initial estimation was consistent with the clinical findings in 37 cases, 9 were overestimated and one was underestimated. With the 95% bootstrap confidence interval 0.551 to 0.864 and computed weighted Cohen's coefficient = 0.721, the consistency between hotline assessment and clinical assessment can be considered as good. The five divers with minimal symptoms who were categorised as "*no DCI possible*" could not be followed up.
Conclusion: We conclude that, despite some limitations to the study, particularly the limited sample size, a reliable assessment of the severity of DCI can be provided by a specialist-based telephone hotline.

Key words
Diving accidents, decompression illness, clinical audit, underwater medicine

Introduction

Remote management of diving emergencies can be considered appropriate in situations where no on-site professional care by diving medicine experts is available within reasonable time. Phone hotlines offering medical assistance to divers or rescuers are not new, but there are few data published concerning the correlation of phone-assessed symptom severity with actual clinical findings.

Most hyperbaric treatment centres in Switzerland – a nation with almost eight million inhabitants and an estimated 25,000 recreational divers (Binkert H, personal communication, 2011) – have been closed down in recent years on political or economic grounds.[1] Currently the only hospital-based centre treating diving emergencies is situated at the westernmost edge of the country in Geneva. Because of this development, it became necessary to manage the limited resources in cooperation with other bodies to ensure good patient care.

The Swiss diving accident hotline (DAN Suisse), which is part of the European division of the worldwide Divers Alert Network (DAN), works in close cooperation with the dispatch centre of the Swiss airborne rescue service REGA. All divers in need may use REGA's emergency phone number as a relay to an on-call diving medicine specialist. The hotline service is not only available within the country, but can also be contacted from abroad. Incoming hotline calls are referred by the REGA dispatcher to one of six experienced diving medicine physicians (DMP). The on-call physician gathers information about the diver's data, his dive profile, the development of symptoms and signs and the medical history by interviewing the patient, his dive partner or on-site helpers according to a standard protocol. Based on this information, he estimates the severity of the reported case and recommends a course of action which, in a suspected case of DCI, includes administration of normobaric oxygen (NBO_2) and possibly transfer for hyperbaric oxygen treatment (HBOT). He also recommends an appropriate means of transport. In case of a life- or health-threatening emergency, evacuation by air will be initiated simultaneously by the REGA dispatch centre.[2]

The hotline DMP stays in close contact with the treatment centre or, if discharged, the patient to supervise the course of events and intervene if necessary. As soon as the initial treatment has been completed, all medical protocols and reports are transferred to another member of the hotline medical team for review of completeness and collection of missing documents. In case of deficiencies, this expert will contact the patient to obtain more information and offer further advice. Selected cases are subject to biannual case presentation and discussion by the hotline physicians and other DMPs. A high number of hotline calls, especially from abroad, concern injuries or indisposition unrelated to DCI. In these cases, general advice and assistance is provided by a triage centre to which the caller is referred.

The aim of the present study was to evaluate the relationship of severity of decompression illness (DCI), as determined via a telemedicine hotline, with the clinical findings on arrival at a treatment facility.

Methods

The database for this retrospective study was extracted from the original phone protocols recorded by the hotline specialist during or shortly after the emergency call, from the reports following treatment and from follow-up e-mails with the patient. Cases with initial phone calls from 01 January 2008 to 31 December 2009 were used. We excluded all calls concerning events definitely unrelated to DCI (injuries, questions about previous dive accidents or fitness-to-dive issues) but also diving-related lesions without evidence for DCI like isolated barotraumas (Figure 1).

For the comparison of the severity assessments, we had to exclude all cases where the hotline was contacted after the patient had already been evaluated in a clinical centre. However, some of the cases could be used for the analysis of the distribution of symptoms and signs of DCI, so that the number of patients differs for these two investigations.

The standard telephone protocol sheet includes the following information as a minimum:

- personal data, phone number;
- dive/accident site;
- dive profile, equipment and breathing gas used for the last dive (and the five dives before, if there was repetitive diving);
- detailed description of symptoms and signs, including the time lapse to their occurrence in relation to the dive profile or to the time of surfacing;
- measures taken on site (e.g., NBO_2, bystander resuscitation);
- the diver's medical history and evident health disorders prior to the dive;
- the present state of training.

Symptoms and signs were categorised according to a modification of the Francis and Smith classification for description and terminology of DCI (Table 1).[3] There were some modifications made in order to improve usability in a hotline setting, the main aim of these modifications being not to miss potentially severe symptoms.

The main DCI manifestation sites were recorded: cutaneous DCI was assumed in the presence of skin alterations like pruritus associated with macular eruptions, including "*cutis marmorata*"; if pain was mentioned, limb pain was categorised as musculoskeletal DCI, but girdle pain was categorised into the neurological severe group because of the high probability of spinal DCI. Paraesthesiae, with or without hypaesthesia, were categorised as a 'neurological light' manifestation. Cerebral symptoms and signs such as severe headache, dizziness, unconsciousness, convulsion, speech difficulty, impaired vision and mono- or hemiparesis were subsumed with symptoms for spinal DCI like girdle pain, paraparesis, paraplegia, urinary retention as 'neurological severe'. Suspicion of inner ear DCI with symptoms like vertigo, nausea, vomiting, hearing loss and tinnitus was also classed in this group. Soft tissue swelling, especially involving the abdomen, thighs and breasts indicated lymphatic DCI. If the patient was dyspnoeic or showed evidence of pulmonary oedema, pulmonary DCI was assumed. General malaise, anorexia or fatigue were categorised in the group of ambiguous symptoms possibly related to DCI. An actual case with multi-site symptoms/signs was classified into the group of most relevant manifestation but all the other symptoms were documented also.

If the reported symptoms and signs of DCI were improving spontaneously, the course is described accordingly, whereas a spontaneous deterioration of the patient's condition was denoted as progressive DCI. Besides these two dynamic forms, static and relapsing DCI were described as well.[4] With more than five minutes' remaining bottom time to the 'no-stop' time we assumed a low inert gas load. At least moderate gas burden was presumed if there was less than five minutes' bottom time remaining, if a decompression stop had to be respected or in case of repetitive diving. In any violation of a decompression algorithm, we classed the gas load as high. In the case of a rapid ascent with or without clinical signs of barotrauma, the patient was considered to be at high risk for pulmonary over distension and AGE. All details available concerning the breathing gas mixture, the dive profile and ascent rate, the state of physical and dive training, the dive conditions and the activity during the dive (e.g., recreational dive versus construction dive) were also taken into account.

A code for the DCI severity was used which determined the initial telephone decision about therapy:

0 – the case is most probably not related to DCI and can be treated in a regular hospital or by a GP;

+ – mild incident which might be due to DCI; NBO_2 is recommended and medical examination necessary; HBOT is not indicated;

++ – most probably DCI, therapy must be provided in a hyperbaric facility;

+++ – life-threatening DCI which will need hyperbaric and intensive care treatment.

All DCI events which showed severe neurological or pulmonary manifestations came into the '++' category, the same as if the course of DCI symptoms was progressive.

Table 1
Clinical classification of DCI used by the Swiss hotline team

Course	Clinical manifestation	Dive profile
Progressive	Skin	Pulmonary barotruama
Static	Pain	Gas burden
Improving	Neurological light	
Relapsing	Neurological severe	
	Lymphatic	
	Pulmonary	
	Ambiguous	

Patients classed into groups '0' and '+', i.e., where no HBOT was recommended, received a phone call from a hotline DMP the following day at the latest for check-up. The contact details for the non-DMP physician caring for the diver were sought in order to brief them with regard to late-onset symptoms and signs of DCI. The hotline DMP contacted the treatment centre the day after the start of the therapy and requested a preliminary report. A written follow-up consent was obtained from the patient. When the treatment was completed and only if the consent was given, the documents were submitted to the first author of the study who checked them for completeness, gathered further reports and assessed the manifestations and severity of the cases according to the description by the treatment centre. He also received follow-up information by contacting the patients individually from eight weeks to nine months after the incident. For the follow-up assessment the same categorisation as described above was used.

STATISTICS

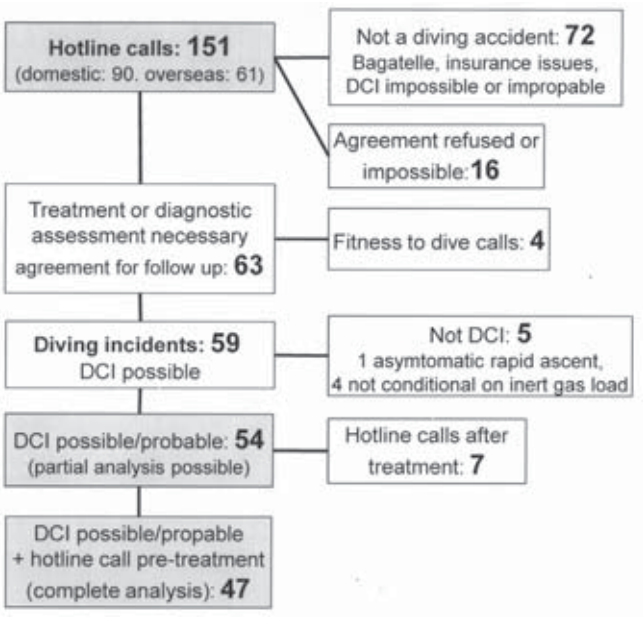
For demographic analysis, Microsoft Excel® was used. For the comparison of severity assessments, we computed the weighted Cohen's coefficient (with absolute weights).[5] The weighting ensures that differences between assessments that are "*close*" (adjacent categories) are considered to be "*better*" than those that are "*not close*". In general, confidence intervals based on large-sample theory do not perform well for Cohen's . Typically, therefore, a 'bootstrap' is used to compute confidence intervals (where M = 10,000 bootstrap samples were drawn); > 0.75 can be considered excellent agreement, values of k between 0.4 and 0.75 as fair to good agreement.[6,7]

All confidence intervals were computed using $\alpha = 0.05$. All analyses were performed using R (R Development Core Team, 2010).[8] Cohen's was computed using the package *psy* (Falissard B. 2005. *psy*: Various procedures used in psychometry. R package version 0.7), and bootstrap confidence intervals using the package *boot* (Canty A and Ripley B. 2009. *Boot*: Bootstrap R (S-Plus) Functions. R package version 1.2-35). The tables of descriptive statistics were generated using the package *report tools*.[9]

Table 2
Gender and age distribution, number of dives and depths

	Women (n = 13)	**Men** (n = 50)	**All** (n = 63)
Age (years) median (range)	35.8 (22–52)	40.5 (23–70)	39.5 (22–70)
Diving experience			
< 20 dives	-	1	1
21–100 dives	1	7	8
101–500 dives	7	29	36
> 500	5	13	18
Max. depth (msw)			
mean (SD)	30.1 (20.4)	42.9 (19.6)	40.2 (20.3)
range	6–82	10–101	6–101

Figure 1
Overview of hotline calls to DAN Suisse over a two-year period (2008–2009)



Results

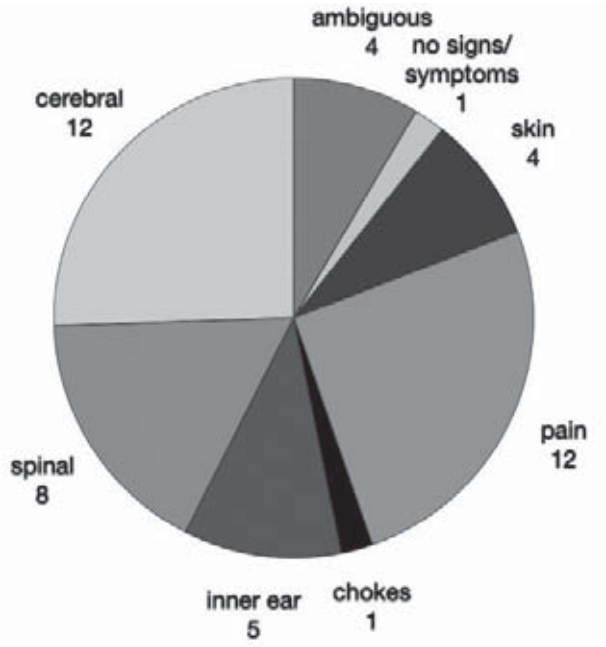
Figure 1 shows an overview of the hotline calls. 47 calls were related to diving accidents and occurred before the initiation of definitive treatment so that a complete analysis was possible in these cases. In addition, as much information as possible was extracted from the data available on the remaining calls. Therefore, the total case numbers reported may vary. None of the cases which were initially suspected as non-bubble related turned out to be DCI later.

DIVING BEHAVIOUR AND DIVE PROFILES

The gender and age distribution, the number of dives and the depths of the dives are shown in Table 2. Only 17 of the 59 included dives were shallower than 30 metres' water depth (mw).

For 55 of the 59 dives, there were sufficient data on the dive profile, circumstances of the dive, number of repetitive dives and the breathing gas, so that we were able to estimate the gas load and the probability for pulmonary barotrauma. High gas load was assumed in 20 cases, moderate or low in 35 cases. High probability for pulmonary barotrauma was expected after 14 dives, moderate or low after 41 dives. Looking for cases with moderate or low gas load as well as low or moderate probability for pulmonary barotrauma, we found 23 profiles. In most of these cases of 'undeserved' DCI

Figure 2
Main site of symptoms of DCI (hotline assessment), *n* = 47



other risk factors like patent foramen ovale (PFO, three), transpulmonary shunt (one), PFO and transpulmonary shunt (one), dehydration (one), repeated diving to minor depths (three), obesity (one) and former episodes of DCI (three) were identified.[10–12] In nine of the affected divers, no follow up was possible.

MANIFESTATIONS OF DCI

As shown in Figure 2, in about half of the 47 reported cases, DCI initially manifested with pain or with cerebral symptoms. In 26 cases, the symptoms were described as distressing (cerebral, spinal, pulmonary or inner ear). In one case, the hotline was called after an emergency ascent from 35 mw. While this diver remained symptom free, his buddy died. In seven cases, there was more than one manifestation site. Three were relatively minor (joint bends and ambiguous symptoms or skin bends), whereas in four cases cerebral symptoms were combined with pulmonary, inner-ear or spinal lesions.

ASSESSMENT OF SEVERITY

Table 3 shows the correlation of the estimated grade at the time of the call compared to clinical assessment. Clinically there were five cases categorised as, '0', 18 as, '+', 19 as, '++' and 1 as, '+++'. The initial estimation was consistent with the clinical findings in 37 of 47 cases, nine were overestimated and one was underestimated. Cohen's = 0.721 with 95% bootstrap confidence interval 0.551 to 0.864. Therefore, the agreement between the telephone and subsequent clinical assessment can be considered as 'good'.

Table 3
Comparison between DAN Suisse phone hotline DCI severity scores and subsequent clinical grading of DCI severity (see text for explanation of grading)

Telephone category	Clinical category			
	0	+	++	+++
0 (*n* = 5)	5	–	–	–
+ (*n* = 19)	4	14	1	–
++ (*n* = 20)	–	3	17	–
+++ (*n* = 3)	–	1	1	1

DELAY TO NORMOBARIC AND HYPERBARIC OXYGEN TREATMENT

NBO_2 was used in 40 divers and 29 required HBOT. The median time from surfacing to NBO_2 was 0.875 h (immediately to 48 h) and the median time to HBOT was 11 h (2–170 h). By comparison in Europe, the median time to NBO_2 was reported as 0.75 h (immediately to 48 h) and to HBOT a median of 5 h (2–170 h), while the corresponding intervals for remote areas outside Europe reached a median of 4 h (0.75–24 h) for NBO_2 and a median of 36 h (9–72 h) for HBOT.[13,14]

Discussion

Many recreational divers are aware of the existence of diving medical hotlines in various parts of the world. Information concerning the assistance and rescue networks is now included in the basic training of a majority of novice divers. According to some publications, hotlines are used frequently.[15] On the other hand, there are no publications to our knowledge relating the remote phone assessment with the clinical findings during the primary clinical assessment. Comparable studies exist only for clinical disciplines other than diving medicine.[16–18] We intended to fill this gap at least partly for a small national hotline. We used mostly handwritten notes for data analysis. Audio recording was not technically possible and might have breached privacy laws. It cannot be excluded that some information that was potentially useful for evaluation was lost. As the accident assistance is given the first priority during a hotline call, the data completeness required for a later evaluation may suffer. Nevertheless, thanks to the hotline DMPs' experience, adequate record keeping was fulfilled in most of the cases. Inter-investigator variability was not evaluated. The case numbers were sufficient for a statistical analysis.

Our decision to categorise the presumed DCI cases into four severity groups might seem arbitrary. But this approach simplified the workflow by implication of a therapeutic decision in each triage group and allowed re-evaluation based on the clinical presentation. In nine cases, the clinical findings were less severe than initially graded by the hotline specialist. We did not assess if these patients

were consequently over treated. In view of possible severe sequelae, it is common practice in diving medicine to pre-emptively treat patients in the presence of serious, or rapidly developing initial symptoms. The improvement in symptoms during transportation as a result of the administration of NBO_2 and other supportive measures may contribute to this apparent over estimation.[19]

The one case that was underestimated is worth discussing. A young woman presenting with a discontinuous course of cerebral symptoms after repetitive diving called the hotline late, after consulting a general practitioner without any diving medical training, who found her psychosomatically ill. She was referred to a local DMP who found a slight sensorimotor deficit caused possibly by a radicular irritation and denied any relation to DCI. Because of the persistence of fluctuating symptoms, an MRI of the neck and head was performed several weeks later, with a diagnosis of a vertebral artery dissection.[20,21] In view of this diagnosis, we interpreted this case as a symptom underestimation although the underlying pathology was not related to DCI.

It remains questionable whether minor DCI was missed among the divers categorised as 'no DCI possible' by the hotline DMP. We are trying to prevent misinterpretations by contacting the patients again shortly after their initial call and encouraging them to call the hotline if there are any residual or new health issues up to 48 hours after diving.

Failure to contact the hotline in the presence of symptoms might be because of non-recognition or denial by the diver or associated others.[22,23] Skin manifestations of cutaneous DCI are easily misinterpreted by divers or by physicians not trained in diving medicine as an allergic reaction, jellyfish sting or sunburn and classical 'bends' as musculoskeletal injury. Missed hotline contact in such minor cases could explain the relative over-representation of severe cases in our sample in comparison to other publications.[24]

For an experienced DMP it might be straightforward to diagnose the type and severity of a diving emergency based on medical history and clinical findings. In the telemedicine setting, the latter are missing. It is not surprising, therefore, that a hotline physician tends to attribute symptoms described by callers into a more severe category. Besides these difficulties, medicolegal aspects also have to be considered.[25] The times elapsed from the onset of possible manifestations of DCI to a hotline call and to the initiation of treatment in this investigation are also noteworthy. Various factors contribute to this, such as diver delay to make a hotline call and the availability of transport and of hyperbaric facilities

A diving medical hotline may not only actually shorten the time to recompression treatment by organising the transfer and HBOT facility information but alleviate the symptoms and signs by advising immediate initiation of NBO_2 therapy. This reflects our own observations and is worthy of further investigation. Diving medical hotlines are widely believed to be able to shorten the time to recompression. Our data showed that recompression treatment was provided more quickly inside Europe than in remote areas. Whether or not this observation correlates with the greater availability of hyperbaric treatment centres, with better transportation or with the use of a DMP hotline cannot be determined based on this small sample. By encouraging the hotline callers to use NBO_2 if there is a possibility of DCI, symptoms and signs can be alleviated. Further prospective studies with large numbers of cases are needed to investigate these factors effectively.

Diving medicine hotlines can be considered as a form of telemedicine, in spite of missing some aspects such as electronic imaging or laboratory data transfer, both primarily non-essential in the initial management of diving accidents.[26] The existing infrastructures, e.g., mobile phone networks, are sufficient for diving medical purposes even if the calls arrive from very remote areas. Future technical development might permit the submission of data about dive profiles by mobile phone. PDAs have been shown to be useable as dive computers if enclosed in an underwater housing and equipped with a compatible sensor device.[27]

Besides the comparison of the hotline diagnosis to the final clinical diagnosis, our limited study has served a quality assurance purpose and helped us to better adapt the hotline to developing international telemedicine standards.[28] We have demonstrated that accurate assessment of the severity of DCI can be achieved by a specialist-manned telephone hotline. Overestimation of severity occurred in less than one fifth of the cases, and the hotline provides divers with a specialist DMP's prompt advice, enabling them to receive specialised treatment. A standardised international reporting system similar to existing cancer registries would be helpful to evaluate indications and treatment options. Further prospective studies with larger numbers of patients are necessary to evaluate the consistency of decisions provided by diving medical hotlines. These studies should also aim at the introduction of a benchmarking system in order to enhance the quality of these commonly used services.

Conclusion

In a small group of divers contacting a diving emergency hotline manned by diving medical specialists, reliable estimates of the severity of the condition were possible in the majority of cases.

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Christian Wölfel, MD, Institute of Anaesthesiology, Spital Schwyz, Schwyz, Switzerland
Guido Schüpfer, MD, PhD, MBA, HSG Institute of Anaesthesiology, Kantonsspital Luzern, Lucerne, Switzerland
Christoph Konrad, MD, Professor, Institute of Anaesthesiology, Kantonsspital Luzern, Lucerne, Switzerland
Peter Knessl, MD, Institute of Anaesthesiology, See Spital, Kilchberg, Switzerland
Jürg Wendling, MD, National Director DAN Europe Suisse, Biel, Switzerland

Address for correspondence:
Christian Wölfel
Spital Schwyz, Anaesthesie
Waldeggstrasse 10
CH 6430 Schwyz, Switzerland
Phone: *+41-(0)41-818-4586*
Fax.: *+41-(0)41-818-4007*
E-mail: *<christian.woelfel@spital-schwyz.ch>*