Consensus guideline

Pre-hospital management of decompression illness: expert review of key principles and controversies

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Abstract

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Guidelines for the pre-hospital management of decompression illness (DCI) had not been formally revised since the 2004 Divers Alert Network/Undersea and Hyperbaric Medical Society workshop held in Sydney, entitled "*Management of mild or marginal decompression illness in remote locations*". A contemporary review was initiated by the Diver's Alert Network and undertaken by a multinational committee with members from Australasia, the USA and Europe. The process began with literature reviews by designated committee members on: the diagnosis of DCI; first aid strategies for DCI; remote triage of possible DCI victims by diving medicine experts; evacuation of DCI victims; effect of delay to recompression in DCI; pitfalls in management when DCI victims present at hospitals without diving medicine expertise and in-water recompression. This was followed by presentation of those reviews at a dedicated workshop at the 2017 UHMS Annual Meeting, discussion by registrants at that workshop and finally several committee meetings to formulate statements addressing points considered of prime importance to the management of DCI in the field. The committee placed particular emphasis on resolving controversies around the definition of "*mild DCI*" arising over 12 years of practical application of the 2004 workshop's findings, and on the controversial issue of in-water recompression. The guideline statements are promulgated in this paper. The full workshop proceedings are in preparation for publication.

Introduction

Decompression illness (DCI) is a collective term which embraces decompression sickness (DCS) and arterial gas embolism (AGE);[1] two dysbaric pathologies in which bubbles are presumed to be the primary vectors of injury. In the former, bubbles form in tissues and/or venous blood from dissolved inert gas absorbed during the dive and, in the latter, bubbles are introduced into the arterial circulation by pulmonary barotrauma. These pathologies are described in detail elsewhere.[1] In practice, while DCS is more commonly seen than AGE, some manifestations are potentially common to both and management is generally the same for both. Therefore, the collective term 'DCI' is used here except where there is a need to refer to either pathology specifically.

DCI may present with a wide range of symptoms of variable specificity and severity.[1] Some presentations are mild and unlikely to result in long-term harm even without medical management, whereas some are potentially disabling or even life threatening and require therapeutic intervention. After the reported success of recompression in 1909,[2] it became a quasi-standard of care for DCI. Between 1939 and 1965, treatment tables utilizing oxygen (O_2) breathing were developed,[3–5] and recompression with hyperbaric O_2 has similarly become a standard of care. In the early 2000s, as dive travel to remote locations gathered pace, the perception that recompression was necessary for all cases of DCI irrespective of severity became troublesome. Increasing numbers of seemingly mild DCI cases were occurring in remote locations where evacuations for treatment were logistically difficult, very expensive and potentially hazardous.

These challenges motivated consideration of whether some DCI cases might not require evacuation and could be managed without recompression. A workshop entitled *Management of mild or marginal decompression illness in remote locations workshop* (henceforth referred to as the '2004 workshop') was conducted as a two-day pre-course to the 2004 Undersea and Hyperbaric Medical Society Annual Scientific Meeting in Sydney.[6] A series of presentations on various aspects of pre-hospital management of DCI were given by recognised experts. Commentary during discussion sessions was invited from all attendees, but final decisions on the consensus statements were taken among a group of 25 'discussants' who were all experienced diving physicians from a broad range of nations. The most significant outcome of the 2004 workshop was a consensus that DCI presentations conforming to a definition of 'mild' could be adequately managed without recompression. The symptoms and signs included in the mild category were musculoskeletal pain, rash, constitutional symptoms and some cutaneous sensory changes. These manifestations were further characterised by explanatory footnotes, as were other criteria required for the mild definition to be applied.

The 2004 workshop definition of mild DCI has been widely applied in making decisions not to recompress, usually in situations where recompression would be difficult to access. It is fascinating to reflect on how this paradigm considered radical in 2004 has subsequently come to be viewed as routine practice. Indeed, aspects of the definition of mild are now considered by many as being too restrictive. In particular, the 2004 workshop consensus stipulated that in order for a case to be considered mild there must be a neurological examination by a doctor to exclude non-obvious but significant neurological signs. Such an examination may not be readily available in remote locations.

Other recent attempts to review the necessity for a neurological examination in designating mild DCI were made at diving medicine conferences in 2013 and 2016. A number of commentators suggested it was already relatively common practice for diving medicine physicians remotely triaging injured divers to waive the need for a neurological examination in designating a case as mild if, based on evaluation of the available information, they were comfortable that significant neurological manifestations were very unlikely. This approach appeared popular but no process for codifying or quantifying the participants' views was achieved and no proceedings were ever published. If nothing else, the recurrence of this subject on multiple diving medical society agendas suggests that it justifies attention.

Another controversial issue of high relevance to pre-hospital management of DCI is that of in-water recompression (IWR). The primary indication for IWR is to rapidly initiate treatment for DCI when a recompression chamber is not readily available. However, during IWR it is not possible to provide other medical care, the patient is exposed to environmental stresses, and a convulsion due to central nervous system (CNS) oxygen toxicity could result in drowning. As a result, IWR schedules are typically shallower and shorter than standard treatment tables used in recompression chambers. It is difficult to evaluate the benefits of IWR versus its recognized risks.

There are compelling reasons to consider IWR when evaluating the pre-hospital management of DCI. First, IWR is happening. IWR has and continues to be actively promoted by prominent diving physicianss for use by diving fishermen operating in locations remote from recompression chamber facilities.[1,7,8] Second, recreational diving is increasingly taking place in remote locations without ready access to recompression chamber facilities. Third, with the increase in so-called technical diving there are more diving operations with the requisite equipment and skill mix that might be considered appropriate for conduct of IWR.[9] There is no documentation of how frequently technical divers are using IWR, but one technical diving training organization has begun conducting training specifically in IWR methods.[10] It is the existence of technical divers in the modern diving milieu that perhaps most strongly justifies a revision of the medical community's perspectives on IWR. Finally, divers suffering neurological DCI are often left with residual neurological problems despite evacuation for recompression.[11,12] There is a widely held belief that early recompression may be associated with better outcomes in such cases and IWR offers an obvious opportunity for this.

The present initiative was instigated by the Diver's Alert Network (DAN) who seek clarity from the medical community on the above controversies, within the framework of a broader review of guidelines for pre-hospital management of DCI. The process employed in generating these guidelines is presented below. This is followed by the consensus statements derived from that process. The discussion section provides contextualisation and justification of some potentially controversial statements.

Methods

Representatives of DAN America and DAN Europe jointly approached one of the authors (SJM) to chair a committee of experts tasked with reviewing guidelines for pre-hospital management of DCI. The following criteria were applied to committee membership:

- No committee members would be employees of DAN, have relevant conflicts of interest, or receive any

remuneration for participation;
- With one exception (see below) all committee members would be highly experienced diving medicine physicians actively involved in treating divers with DCI;
- One committee member would be a non-physician diver;
- The committee membership would be drawn from various regions to provide a global perspective.

Potential committee members were identified in joint discussions between the chair and DAN representatives and the final composition is reflected in the authorship. The diver representative (author DJD) is an active technical diver and a decompression physiologist. Members were drawn from Australasia (two), the USA (three) and Europe (three).

The approach to deriving the consensus statements was similar to the one adopted for the 2004 workshop. The committee's deliberations were based around a pre-course workshop held prior to the 2017 Undersea and Hyperbaric Medical Society Annual Scientific Meeting. Topics of relevance to pre-hospital management of DCI were identified as follows:
- Presentations of DCI and diagnostic pearls;
- First-aid strategies for DCI and the evidence underpinning them;
- Common pitfalls when divers present to hospitals or doctors without expertise in diving medicine;
- Remote triage of the possible DCI case by diving medicine experts;
- Transportation of a diver with DCI and the effect of increasing delay to recompression on outcome;
- The controversial issue of in water recompression.

Each topic was allocated to a committee member who presented it at the pre-course and produced a manuscript for the proceedings. Where appropriate, the presenter was also required to generate a series of draft consensus statements related to their topic for subsequent discussion by the committee. To be clear, it was not the intent to comprehensively embrace all facets of the topic areas (and therefore all aspects of pre-hospital management of DCI) within the consensus statements. That level of detail will be contained in the published proceedings. The consensus statements presented here are intended to address principles that were considered deserving of emphasis. Some are simply re-statements of widely accepted and non-controversial principles, whilst others address more controversial issues.

Each presentation was followed by 30 minutes for questions and commentary involving any of the 55 registrants who wished to contribute. The chair kept notes of this commentary. On each of the following two days the committee met in private for four hours to discuss, modify and finalise the draft consensus statements proposed for the relevant subject areas. We prospectively determined that any statement upon which we could not agree unanimously would be subjected to a majority-rules vote, and that the need for a vote and its result would be reported.

Consideration was given to applying a formal classification of evidence to our consensus statements. However, it was decided that any system chosen would be difficult to apply to an area of practice that is poorly informed by directly relevant human data, frequently based on indirectly evidence, such as inferences from animal data, and influenced heavily by observational studies and anecdote. It was determined that simply describing any relevant evidence would be the best option under the circumstances.

Results

The committee's consensus on important matters are presented in Table 1. All were accepted unanimously.

Discussion

These statements represent practice recommendations issued by a committee of experts after a review process comprised sequentially of a literature review, presentation and discussion at a conference event convened for the purpose followed by two half-day committee meetings. Many of the statements constitute endorsement of previously established and widely accepted practice. The statements in relation to defining mild DCI draw heavily on the findings of the 2004 workshop. However, there are several that represent important modifications. These include: the addition of subcutaneous swelling (lymphatic DCI) to the mild category; the softening of the requirement for a neurological examination by a doctor before classifying a case of DCI as mild; and the conditional recognition of in-water recompression (IWR) as a legitimate option in the management of DCI. These are modifications to previously held positions that merit further discussion.

SUBCUTANEOUS SWELLING (LYMPHATIC DCI) AS A MILD MANIFESTATION

There are several reasons why lymphatic DCI was added to the definition of mild DCI established by the 2004 workshop. First, lymphatic DCI can occur as an isolated manifestation in divers who remain otherwise well. Second, there is no clear association between lymphatic symptoms and concurrent appearance of other more serious manifestations. Third, the value of recompression for lymphatic manifestations is unknown, but certainly not obvious. Recompression often seems to make little difference to the presence of the swelling which typically resolves spontaneously over 24–48 hours. Finally, there appear to be no long-term consequences of lymphatic swelling in DCI.

REMOTE CLASSIFICATION OF DCI AS MILD WITHOUT A NEUROLOGICAL EXAMINATION

The matter of whether a neurological examination by a doctor should be mandatory prior to diagnosing mild DCI (as defined in the preceding statements) was a key issue for the present committee to resolve after several recent consensus

Table 1

Statements on key elements of pre-hospital management of decompression illness (DCI); statements appear in bold type, but in some cases are followed by italicised explanatory notes or footnotes. Where relevant, the evidential basis for the statement is recorded in the 'supporting material and comments' column.

STATEMENTS	SUPPORTING MATERIAL AND COMMENTS
1. PROCEDURAL CONSIDERATIONS	
A. Divers and dive operations should have contact details for, and a rapid and reliable means of communicating with diving emergency services and local emergency services in order to obtain advice about initial management, regional retrieval systems and treatment facilities.	
B. All divers who become unwell after diving should be discussed with a diving medicine physician as soon as possible.	
The ambiguous term "unwell" is used deliberately in recognition of the potentially non-specific manifestations of DCI. *There is no clearly defined threshold latency for symptom onset after diving beyond which DCI becomes an 'impossible' diagnosis. In part, this reflects the possibility that divers may inaccurately report symptom latency to avoid adverse judgement for inaction.*	
2. FIRST AID PROCEDURES	
A. Normobaric oxygen (surface oxygen administered as close to 100% as possible) is beneficial in the treatment of DCI. Normobaric oxygen should be administered as soon as possible after onset of symptoms.	Observational human studies[13,14] *In vivo* studies of bubble and symptom resolution[15–21]
B. Training of divers in oxygen administration is highly recommended.	
C. A system capable of administering a high percentage of inspired oxygen (close to 100%) and an oxygen supply sufficient to cover the duration of the most plausible evacuation scenario is highly recommended for all diving activities.	
In situations where oxygen supplies are limited, and where patient oxygenation may be compromised (such as when drowning and DCI coexist) consideration should be given to planning use of available oxygen to ensure that some oxygen supplementation can be maintained until further supplies can be obtained.	
D. A horizontal position is generally encouraged in early-presenting DCI, and should be maintained during evacuation if practicable. The recovery position is recommended in unconscious patients. The useful duration of attention to positioning in DCI is unknown. *The head down (Trendelenburg) position is no longer recommended in management of DCI.*	Human evidence of enhanced inert gas washout in horizontal subjects[22] *In vivo* evidence that large arterial bubbles distribute cephalad in the upright position[23] *In vivo* evidence that the head down position is harmful in DCI[24,25]
E. Oral hydration is recommended but should be avoided if the patient is not fully conscious. Fluids should be non-carbonated, non-caffeinated, non-alcoholic, and ideally isotonic (but drinking water is acceptable). **F. If suitably qualified and skilled responders are present, particularly in severe cases, intravascular rehydration (intravenous or intraosseous access) with non-glucose containing isotonic crystalloid is preferred.** *Intravenous glucose-containing solutions should not be given.*	Human evidence that diving causes dehydration[26] and that purposeful hydration reduces post-dive venous gas emboli[27] *In vivo* evidence dehydration may worsen DCI[28] Human case evidence that aggressive IV resuscitation may be lifesaving in fulminant DCI[29]

G. Treatment with a non-steroidal anti-inflammatory drug (NSAID) is appropriate if there are no contraindications.

Human RCT showing improved tempo of recovery in DCI using a NSAID as an adjuvant to hyperbaric oxygen[30]

H. Other agents such as corticosteroids, pentoxyphylline, aspirin, lidocaine and nicergoline have been utilized by suitably qualified responders in early management of DCI but there is insufficient evidence to support or refute their application.

I. Divers should be kept thermally comfortable (warm but not hyperthermic). Hyperthermia should be avoided especially in cases with severe neurological signs and symptoms. For example, avoid exposure to the sun, unnecessary activity, or excess clothing.

Human evidence that warm subjects eliminate inert gas more quickly[22,31]
Mild hyperthermia worsens neurological injury *in vivo*[32,33] and in humans[34]

3. TRIAGE BY TELEMEDICINE

A. The principle goals of triage are to:
evaluate the likelihood that reported symptoms are DCI, another diving disorder, or a non-diving disorder;

advise on patient management and the need for evacuation to a specialist diving medical service for assessment and possible recompression treatment.

Triage in this context refers to consultation via telephone or some other means of communication with a diving medicine expert who is not present at the accident site.

B. With respect to DCI, 'mild' symptoms and signs are: limb pain (footnotes 1, 2); constitutional symptoms such as fatigue; some cutaneous sensory changes (3); rash; subcutaneous swelling ('lymphatic DCI') where these manifestations are static or remitting (4, 5) and significant (6) neurological dysfunction is excluded to the satisfaction of a diving medicine physician (7).

Conclusion of the 2004 workshop[6] with two changes:

1. Subcutaneous swelling added to the definition of mild DCI by the present committee (see discussion);

2. Criteria for exclusion of significant neurological dysfunction rephrased by the present committee (see discussion).

1. Severity of pain has little prognostic significance, but severity of pain may influence management decisions independent of the classification of pain as a 'mild' symptom.

2. Classical girdle pain syndromes are suggestive of spinal involvement and do not fall under the classification of "limb pain".

3. The intent of "some cutaneous sensory changes" is to embrace subjective cutaneous sensory phenomena such as 'tingling' present in patchy or non-dermatomal distributions suggestive of non-spinal, non-specific, and benign processes. Subjective sensory changes in certain characteristic patterns such as in both feet, may predict evolution of spinal symptoms and should not be considered as 'mild'.

4. If symptoms are qualitatively mild but are progressive, then the diver must be continuously monitored to detect any appearance of symptoms not considered mild. The 'mild' status cannot be considered final until symptoms are static or remitting.

5. The possibility of the delayed development of new symptoms means the 'mild' designation must be repeatedly reviewed over at least 24 hours following diving or the most recent decompression, the latter applying if there has been an ascent to altitude. Untreated mild symptoms and signs due to DCI are unlikely to progress after 24 hours from completion of diving.

6. "Significant" in this setting is intended to imply a problem that has the potential to leave the diver with functionally important sequelae.

7. Exclusion of significant neurological signs is most reliably achieved by a neurological examination performed by a doctor. However, such examination may not be available, and there are plausible scenarios in which a global appraisal of other facts of the case renders significant neurological injury extremely unlikely. In such scenarios it can be appropriate for a diving medicine physician to manage a case as 'mild' in the absence of a neurological examination.

C. Recompression therapy is the gold standard therapy for DCI. However, some divers with symptoms or signs meeting the above definition of mild DCI may be managed without recompression therapy.

Conclusion of the 2004 workshop[6]

The phrase 'some divers' is used intentionally. Divers with mild DCI will often be offered recompression if it is readily available because this will speed recovery.

A decision to invoke this guideline can only be made by a diving medicine physician on a case-by-case basis (see Guideline 1B). It is not to be used to formulate management policy for all divers with apparently mild DCI.

D. Divers diagnosed with mild DCI who do not undergo recompression should be treated in accordance with guideline 2 A-I for a duration at the discretion of the advising diving medicine physician. These divers should be monitored regularly for 24 hours to exclude development of new symptoms falling outside the mild definition.

Conclusion of the 2004 workshop[6]

4. EFFECT OF DELAY TO RECOMPRESSION

A. The best outcomes after recompression (especially in cases with more severe symptoms) are likely to be obtained by immediate recompression. The latter will only be possible if on-site recompression is available.

Observational human evidence that good outcomes are obtained with very early recompression[35–37]

B. For cases suffering mild symptoms, a delay prior to recompression is unlikely to be associated with any worsening of long-term outcome.

Conclusion of the 2004 workshop[6]

C. In more serious presentations recompression should be obtained as soon as safely possible. There is limited evidence that delays longer than six hours result in slower or less complete recovery.

Observational human evidence for an inflection in risk of less complete recovery with recompression latencies longer than six hours[11,12,38]

5. TRANSPORTATION OF A DCI PATIENT

A. Arrangements for transport of a diver with DCI should be agreed between the first responders, the triaging diving medicine physician, the receiving physician and the retrieval team before the evacuation begins.

B. If air evacuation is used, the aircraft should either be pressurized to one atmosphere or remain at a low-altitude where possible.

Low altitude in this context is preferably less than 150 m above pick-up location. The risk of greater altitude exposures should be balanced against the risk of deterioration if not retrieved and should be made in consultation with a diving medicine physician.

C. Some divers with mild symptoms or signs (defined above) after diving may be evacuated by commercial airliner to obtain treatment after a surface interval of at least 24 hours, and this is unlikely to be associated with worsening of outcome.

Conclusion of the 2004 workshop[6]

Most favourable experience with commercial airliner evacuations comes from short haul flights of between one and two hours duration. There is much less experience with longer flights.	
Provision of oxygen in as high an inspired percentage as possible is optimal practice for such evacuations. In addition, the risk of such evacuation will be reduced by pre-flight oxygen breathing.	
6. IN-WATER RECOMPRESSION (IWR)	
A. Recompression and hyperbaric oxygen administered in a recompression chamber is acknowledged as the gold standard of care for DCI. However, in locations without ready access to a suitable hyperbaric chamber facility, and if symptoms are significant or progressing, in-water recompression using oxygen is an option. This is only appropriate where groups of divers (including the 'patient') have prior relevant training (see below) that imparts an understanding of related risks and facilitates a collective acceptance of responsibility for the decision to proceed.	Observational human evidence that very early recompression results in good outcomes,[36,39–46] or better outcomes compared to longer delays[37]
B. IWR should not be conducted if there is hearing loss, vertigo, vomiting, altered level of consciousness, shock, respiratory distress or a degree of physical incapacitation that makes return underwater unsafe.	
C. The team, which at a minimum includes the patient, a dive buddy who will accompany the patient throughout the in-water recompression, and a surface supervisor, must all be trained, certified and practiced in decompression procedures using 100% oxygen underwater.	
D. The team must be suitably equipped for IWR using oxygen including: adequate thermal protection; an adequate oxygen supply and a means of supplying 100% oxygen (or close to it) for the duration of the anticipated protocol (both in-water and surface phases); a means of maintaining stable depth; a method of communication (e.g., a slate). A full-face mask or mouthpiece retaining device is strongly recommended.	Observational human evidence for the efficacy of mouthpiece retaining devices in preventing drowning after loss of consciousness underwater[47]
E. IWR should be accomplished with the patient breathing 100% oxygen, and at a maximum depth of 9 msw (30 fsw), according to a recognized protocol. The use of breathing gases other than oxygen for IWR is not recommended.	Published regimens for IWR,[8,48–50] with some observational human evidence of efficacy[8,49]
Recognised protocols include the "Clipperton protocol", "Australian method", and the oxygen IWR method of the US Navy.	
F. IWR may not result in complete resolution of DCI, and signs or symptoms may recur. Any injured diver completing an IWR procedure should be discussed with or reviewed by a diving medicine physician at the earliest possible opportunity.	

initiatives failed to publish a conclusion. The committee considered four related options.

1. *Retain the requirement for a competent neurological examination prior to remote classification of a DCI case as mild.*
There was historical support for this option. One paper in the 2004 workshop proceedings[6] refers to datasets demonstrating the frequent co-existence of mild symptoms and more serious neurological manifestations in divers with DCI.[51] These data did not identify what proportion of such cases would have required a neurological examination to detect the serious neurological component (as opposed to detection by symptom history alone). However, the author cited anecdote from several authorities who, during comprehensive evaluation of divers, found neurological problems that were not reported in the referral history. These observations culminated in his conclusion:

"*Until a person with any decompression manifestation has been competently examined neurologically, there can be no confident prediction that they have only mild manifestations at that stage and do not need an urgent recompression*".[51]

This resonated strongly with the 2004 workshop discussants who were already grappling with the prospect of adopting a new and liberal approach to the management of DCI patients. The requirement for a neurological examination before that liberal approach could be invoked appealed as a safety net that would minimise the risk of inappropriate patient management decisions. The present committee retained an open mind on this option. However, practice recommendations that are increasingly ignored or modified in real world application (see Introduction) deserve scrutiny and possibly revision. The committee ultimately settled on a more nuanced approach (see option four below).

2. *Eliminate the requirement for a neurological examination from the definition of mild DCI.*
Based on the 12-year experience with increasingly liberal application of the 2004 workshop findings, some diving medicine physicians have suggested removing any requirement for a neurological examination in defining mild DCI. However, the committee did not agree that wholesale rejection of the exam was wise, and as alluded to above, adopted a more nuanced approach.

3. *Retain the neurological examination requirement, but widen the group who can administer it.*
It has been suggested that divers themselves could learn to administer a neurological examination thus widening the pool of available examiners in remote locations. Indeed, some diver training agencies already teach a 'five-minute neuro' screening examination to divers. However, it is unlikely that such examinations would be sufficiently sensitive in the present context, or that their findings could be defended in the face of critical scrutiny. It is difficult to teach effective neurological examination even to medical students, despite the fact they are knowledgeable and intelligent, taught by experts and have many opportunities to see patients with real neurological signs.[52,53] The notion that effective neurological examination could be taught by diving instructors (who themselves have never seen an abnormal neurological sign) to diver students with no opportunities to see real signs or practice on patients must be considered with scepticism. At the very least, it seems debateable whether a remote diving medicine expert trying to decide whether to evacuate a sick diver could rely upon neurological examination findings recorded by another diver. The committee saw no harm in divers attempting neurological examinations and offering their findings to a remote diving medicine physician. However, we considered it impractical to formally codify a role for non-medical neurological examiners in best-practice recommendations.

4. *Reword the relevant statement to allow a remote diving medicine physician more discretion over how neurological function is assessed.*
The committee resolved to deal with this issue by changing the original wording in the 2004 workshop consensus from "*…and associated objective neurological dysfunction has been excluded by medical examination*" to "*…and significant neurological dysfunction has been excluded to the satisfaction of a diving medicine physician*."

Although similar, there are some subtle but important changes in meaning. First, the emphasis has been shifted from detecting any objective neurological dysfunction to detecting "*significant*" neurological dysfunction. This reflects a view that neurological manifestations likely to result in disability can most often be detected by a blunter instrument than meticulous examination and will often be obvious to the diver (or an unskilled observer) and so reported as a symptom.

Secondly, the explicit reference to "*medical examination*" has been dropped in favour of a less-directive reference to "*the satisfaction of a diving medicine physician*". A neurological examination by a doctor will still be part of achieving "*satisfaction*" in many (perhaps most) scenarios, but the revised wording leaves open the possibility that it might not. In the latter scenario, a remote diving medicine physician may feel they have excluded significant neurological dysfunction 'to their satisfaction' based on an appraisal of all the facts of the case and their own experience. It would be extremely difficult to codify a protocol for making such decisions because the circumstances under which they might be made are so varied.

Finally, the term "*diving medicine physician*" has been employed explicitly to imply that decisions invoking the definition of mild DCI in management decisions should be made by a physician with training and experience in the management of DCI, especially if the definition is to be applied in the absence of a neurological examination. Paramedics or inexperienced diving doctors should escalate such decisions to the most senior and experienced diving medicine physician accessible. Such practitioners are best positioned to filter the case information and apply their experience to interpreting the type of diving, the nature of the symptoms, the tempo of symptom onset, the time since diving and other relevant facts in deciding whether a neurological examination is necessary.

IN-WATER RECOMPRESSION

Prominent publications providing guidelines on treatment of DCI generally avoid the topic of IWR,[54,55] or are discouraging.[11] One contemporary textbook does provide supportive commentary and suggests an approach for implementation.[1] Whatever the opinion of the wider diving medicine community, IWR has for some time been practiced by groups of sea harvesters (with support of interested medical groups), and by technical divers.[7,8,48,49,56–60]

The principle argument in support of IWR is in scenarios where there is no realistic possibility of accessing recompression in a hyperbaric chamber, or to achieve recompression much more quickly than would be possible by evacuation to a hyperbaric facility. Unfortunately, there is little evidence for an outcome advantage for very early recompression because most attempts to quantify outcomes in DCI cases stratified by both severity and latency to recompression involve latencies much longer than can be achieved with IWR. One small study in military divers suggested recompression within one hour was associated with a better outcome than longer latencies.[37] Also, there is considerable anecdote supporting good results with early recompression in military and commercial diving scenarios where hyperbaric chambers are immediately available. One member of the committee (DJD) synthesised data from multiple reports of US Navy test dive programmes where divers developing DCI were almost invariably recompressed rapidly. The data were broadly indicative of rapid and complete recovery in the vast majority of cases.[35,36,38–46,61] This contrasted with a large series of recreational divers with much longer median recompression latency who required greater numbers of recompression treatments and exhibited a substantially higher incidence of residual symptoms on completion of hyperbaric treatment.[62] This analysis will be reported in more detail in the 2017 workshop proceedings.

The principle argument against IWR is its perceived hazards. Arguably the most significant is an oxygen toxic seizure. The inspired oxygen partial pressure (PO_2) threshold below which seizures never occur irrespective of exposure duration has not been defined but it is lower than usually recommended for IWR (typically 192 kPa [1.9 atm abs]); breathing 100% oxygen at 9 msw or 30 fsw).[8,48–50] Whilst we are not aware of any reports of an oxygen toxicity event during IWR, seizures have certainly occurred in oxygen exposures of equivalent magnitude.[63–65]

In this regard, there is an obvious trade-off between increasing pressure to achieve bubble volume reduction and the safety of the inspired PO_2. The committee does not support IWR at pressures greater than 192 kPa (1.9 atm abs). Greater safety could be achieved by limiting oxygen breathing to lower pressures where convulsions are rarer, but whereas there is some evidence for the efficacy of treatment of DCI at pressures near 1.9 atm,[5] the extent to which lower pressures might compromise the efficacy of the intervention is unknown.

Mitigating the risk of adverse consequences of a seizure centres on protecting the airway. This can be achieved (though is not guaranteed) by the use of a full-face mask or a mouthpiece retaining strap.[47] Other key risk management strategies include tethering the diver to a decompression stage throughout the recompression so they cannot sink in the event of loss of consciousness, and ensuring the diver is accompanied at all times so they can be rescued immediately to the surface if a seizure occurs.

Evaluation of contemporary real-world practice trends and of the potential benefits and risks of IWR led the committee to issue a related series of essentially positive statements with conditional references to the use of oxygen, the prior training of all participants (including the victim), maximum pressure, contraindications and equipment requirements. There are other aspects of this complex topic, such as patient selection, which will be further elaborated in the 2017 pre-course proceedings.

Conclusion

These guidelines for early management of DCI represent the consensus of a committee of experts. Many of the recommendations draw heavily on the collective experience of that expert group rather than on objective evidence. In much the same way as experience in application of the 2004 workshop guidelines has provided impetus and direction for aspects of this review, future experience with the present guidelines or the emergence of new experimental evidence may determine that these recommendations be reviewed and changed.

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