The world as it is

Triage and management of diving accidents: the Phuket Workshop, November 2003

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Key words
Accidents, diving, first aid, decompression illness, decompression sickness

Abstract

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A five-day medical workshop was held in Phuket in November 2003, sponsored by the international Subaquatic Safety Services Recompression Network. Intentionally, it was an agenda-based workshop providing a wide review with a particular focus on triage, the indications for aero-medical evacuation, action to follow an incomplete response to initial recompression, the role of subsequent repetitive recompressions and flying home after neurological decompression illness. This summary represents the views of an international group of diving doctors experienced in recompression management, and may be a useful and thought-provoking starting point on a number of important issues. Many of these will be revisited at the Undersea and Hyperbaric Medical Society Workshop in Sydney in May 2004.

Introduction

A five-day medical workshop was held in Phuket, Thailand, in November 2003, sponsored by the international Subaquatic Safety Services (SSS) Recompression Network. The first session was well attended by the diving professionals of the island, and Mauricio Moreno, President of SSS, introduced three invited lecturers. Dr Chris Acott offered a 'doctored' scuba set for inspection and reviewed the Adelaide DIMS project; Dr Frans Cronje presented the unique, South African view of marine animal injuries. Professor Alf Brubakk, Norway, reviewed the decompression procedures of the native fishermen of the Galapagos Islands.

The next four sessions, chaired by David Elliott, had some prepared contributions by the delegates present and much discussion, but no formal papers. Intentionally, it was an agenda-based workshop and had contributions on each of several well-recognised problems. It was a wide review with a particular focus on:

- triage and the indications for aero-medical evacuation;
- action to follow an incomplete response to initial recompression;
- the role of subsequent repetitive recompressions;
- flying home after neurological decompression illness.

The issues raised and any conclusions drawn are summarised below, mainly as a series of bullet points for consideration. Many of these will be revisited at the Undersea and Hyperbaric Medical Society (UHMS) Workshop in Sydney in May 2004. The Phuket Workshop summary, which represents the views of a number of diving doctors experienced in recompression management, may be a useful and thought-provoking starting point on a number of important issues for this upcoming meeting.

1. Omitted decompression

What is recommended for asymptomatic omitted decompression in recreational divers with or without a chamber on site?

A. CHAMBER AVAILABLE

- Omitted decompression time < 30 min: USNavy Treatment Table 5 (USN5)
- Omitted decompression time > 30 min: USNavy Treatment Table 6 (USN6)
- If surface interval < 3-5 min: consider surface decompression table (SurD) if no potential complications that might be associated with the cause of premature surfacing, and if all other circumstances are appropriate
- If there are additional risks then SurD with a 6-hour 'bend watch'
- If more than 1 hour post-dive with no symptoms or signs, USN5 with bend watch
- Diver's computer failure: assess the hazard individually

B. CHAMBER REMOTE

- Surface O_2; oral fluids; 6-hour bend watch
- If no O_2 available: rest; oral fluids; no diving; expect trouble and plan accordingly
- Some working and military divers may use their formal procedure for immediate in-water stops, but this is not recommended for use by inexperienced divers

2. Early reporting of possible decompression illness

Encourage early reporting and reduce denial of decompression illness (DCI). This will probably improve outcomes.

Is there a need for better instruction for entry-level divers and instructors on what to do when unexpected manifestations are discovered? Concensus view - Yes

Is present first aid training for diving accidents adequate for dive leaders? Concensus view - No

IMPROVING AWARENESS

It was noted by SSS Thailand that their programme of informal education given by hyperbaric medicine staff for local dive leaders appears to be effective in reducing delays before reporting.

OVERCOMING DENIAL (if it is not organic)

Prevention

Education of entry-level divers and instructors that DCI is often 'no-fault'. Consider the effects of:
- social stigma or inappropriate reproach;
- potential cost of treatment if no insurance and in terms of delay;
- a diver's fear of losing their job.

Management

Education is needed regarding the hazards of non-treatment. Education of employers is also needed, and avoidance of 'black marks' from clients accruing to diving contractors for 'no-fault' recompressions. Early treatment should be considered as an acceptable safety procedure that prevents serious residua.

Table 1.
Closed- vs open-circuit oxygen equipment for conscious divers

Advantages	Disadvantages
OPEN CIRCUIT	
- Simplicity	- Short duration
- Conscious and unconscious divers	- Fire hazard
- No CO_2 retention	
- Versatile	
CLOSED CIRCUIT	
- Duration	- Breathing resistance
- Gas warming	- No flush-through possible
	- Additional training

3. First aid and local evacuation

NB Surface oxygen dosage is usually unknown.
- How common is relapse after discontinuing oxygen?
- How does this concern influence the need to recompress a now symptom-free diver?

CLOSED- VS OPEN-CIRCUIT OXYGEN EQUIPMENT

The advantages and disadvantages of closed- and open-circuit oxygen resuscitation equipment are summarised in Table 1.

DETERIORATION DURING OR RELAPSE AFTER SURFACE O_2

- How common is continued deterioration? 12% of divers were still deteriorating on arrival at chamber in spite of surface O_2.[1-3]
- How important is relapse? If symptoms and signs have resolved, consider the index of severity of the original manifestations and, unless it was trivial, give preventive recompression.

So, by unanimous consensus, unless symptoms were very mild, the diver must be recompressed. There are potentially serious medicolegal implications if this is not done.

4. Diagnosis and prognosis

In the prognosis of neurological DCI outcome, risk factors are currently non-quantifiable. However, a few indicators of severity are:
- physical signs are more important (>) than symptoms alone;
- progression / relapse > static / resolving symptoms and signs;
- working divers (e.g., inshore, Scotland) > amateurs;
- depth and decompression non-compliance;
- spinal cord injury > cerebral

5. Triage of mild and severe cases - key issues

WHO DECIDES ON TRIAGE?

- Buddy or instructor
- Dive guide or shop
- Chamber doctor
- A central hotline operator with 24-hour competent medical advice

URGENCY VS ACCEPTABLE DELAY

This is determined by:
- risk factors for deterioration;
- severity of the illness (chamber outcome is dependent on the diver's condition when first recompressed, and this in turn may be affected by delay).

REMOTE ASSESSMENT

There is a need to define the essential components of on-site assessment for any level of medical expertise. It is difficult to standardise neurological and psychological assessment when language skills may jeopardise history taking. Training is required to provide effective and valid assessment.

Difficulties with remote neurology include:
- minimum requirements;
- standardisation of examination;
- need for recumbent patient to stand for certain examinations e.g., gait or Romberg test, that during the early phases may cause adverse bubble redistribution.

So adapt:
- USN neurological examination form; or
- DAN Neurocheck.

DAN Neurocheck summary:
- Standardised and relevant
- Report generation
- Data collection and research tool
- DAN considering as global project (Cronje, South Africa)

Neurocheck challenges:
- Standardised clinical assessment perceived as research orientated and more than needed for management
- DCI dilemma:
  - inadequate classification system (but not necessary for triage?)
  - non-standardised clinical data
- May be too difficult for some locations where accidents happen
- Training required
- Computer (PC / PDA) support required

DCI EVALUATION ALGORITHM

What it is:
- Guide for hotline operators trained and expected to manage DCI cases remotely
- Guide to resource allocation:
  - type and speed of evacuation
  - destination
- System intended to optimise medical evacuation and minimise residua

What it is not:
- Replacement for clinical judgment or experience
- Guide to the DCI treatment per se
- Intended to eliminate necessary indications for recompression or evacuation

Value of a triage algorithm:
- Consistent (standardised) response
- Minimises variability related to experience
- Requires valid medical information
- Clarifies key issues
- Requires diving medical competency for its application
- Cost effective
- Reviews resource allocation
- Caveat: need for regional individualisation

6. Planning indications for aeromedical evacuation

- Severity (needs competent assessment)
- Stability
- Prognostic factors related to risk of a range of possible untreated outcomes
- Appropriate care
- Critical care / pressure requirements

7. In-water recompression and monoplace chamber on site

IN-WATER O_2 RECOMPRESSION

The theoretical basis for very shallow air compression in early cases is currently being reviewed (Brubakk, Norway). This consideration is confined to O_2 recompression:
- Are the equipment, training and other resources needed for an in-water O_2 recompression well defined?
- What is the ideal pO_2 (circa 1.6 bar)?
- Consider the pearl-diver experience from Western Australia.

WHEN TO USE PRE-PLANNED IN-WATER O_2 RECOMPRESSION?

- > 16 hrs prior to evacuation
- Sufficient O_2 supply
- Cooperative and fully conscious diver
- Harness or seat
- Diver tender
- Thermal protection provisions
- Full-face mask; communications
- No flush-through potential
- Controlled ascent

AVAILABLE CATEGORIES OF MONOPLACE CHAMBERS

- Clinical, fixed monoplace (for hyperbaric oxygen and diver treatments); hospital based
- Naval monoplace for SurD; not primarily for treatment
- Transportable monoplace chamber:
  1. Planned to be at dive site for USN6, e.g., remote scientific expeditions. For risk assessment and residual risk acceptance before departure
  2. Brought to site after incident for evacuation and possible lock-in to multiplace

- Transportable two-person chamber (brought to site after incident for evacuation)

8. Audit of recompression chamber (RCC) physical resources

RISK ASSESSMENT GUIDE AND MANAGEMENT EVALUATION

These are in relation to the operational environment.

LOCAL RESOURCES FOR RCC

Staff:
- Adequacy and needed scope of training

Equipment:
- Mixed gas treatment capability
- Life support capability
- Saturation treatment capability

9. Recompression options

Recompression and the importance of complete recovery before a return to work were discussed. Considerations include:
- If no immediate response on USN6, what options are currently being used?
- Some of these options need special resources. How available are these?
- If there is incomplete recovery on surfacing, what is the role of repetitive recompressions?

DIFFICULT TREATMENTS

Many different algorithms are in use around the world, all with apparent success. Tables, other than USN6, used by Phuket participants include:
- USN5; repeated
- USN Table 7
- USN Table 4 (e.g., if no O_2 available)
- USN Table 6A1M
- Comex30, Comex50 and other Comex tables
- Royal New Zealand Navy Table 1A (ex USN Table 1A with 50/50 HeO_2, then O_2)
- Saturation tables (various)
- Royal Navy Table 71 (ex-SETT schedule)

Other tables discussed but not used by any of the participants included the 'Hawaii Spike' (220 ft air excursion before USN6).

Evidence to support table selection is needed. There is also a need for standardisation. USN6, Comex30 and repetitive recompressions are commonly used, but there are many local differences in the depth/time and gas profiles. Any comparative analysis of results should note the various versions: e.g., USA; Cayman tables; several versions of Comex30, etc. Changes are mostly small but need to be specified.

NEED FOR EXPERIENCE AND SPECIAL RESOURCES

- Do not recompress beyond 18 m without being able to manage the complications and having full life support capabilities.
- First, discuss with others experienced in this field. If you have not done it before, do not jump in but rather review the protocol with care.
- Remember to consider the chamber attendant(s).

TREATMENT OF SURFACE-ORIENTED DEEP MIXED GAS DIVER

- Initially, follow algorithms for air and Nitrox divers.
- If unresponsive: Was the diver still on helium on, or just before, arrival at the surface?
  NB Beware of deterioration due to counter-diffusion during recompression if this is on air and consider need to switch gases.
- There is no evidence of effectiveness of any particular treatment compared with others (especially if surfaced from > 150 msw depth).

POST-RECOMPRESSION DYSEXECUTIVE SYNDROME

Although a medicolegal reality, its existence is unproven.
- Seems to follow some degree of cerebral DCI by several days; often not diagnosed at time of recompression; possible analogy to post-concussion effects.
- Delayed neuropsychological sequelae: cognitive dysfunction (memory, mood, decision making).
- Best defence: give full appropriate recompression with associated treatments using accepted procedures every time.

10. Management after surfacing: repetitive recompressions

HOW DO WE MANAGE RESIDUA?

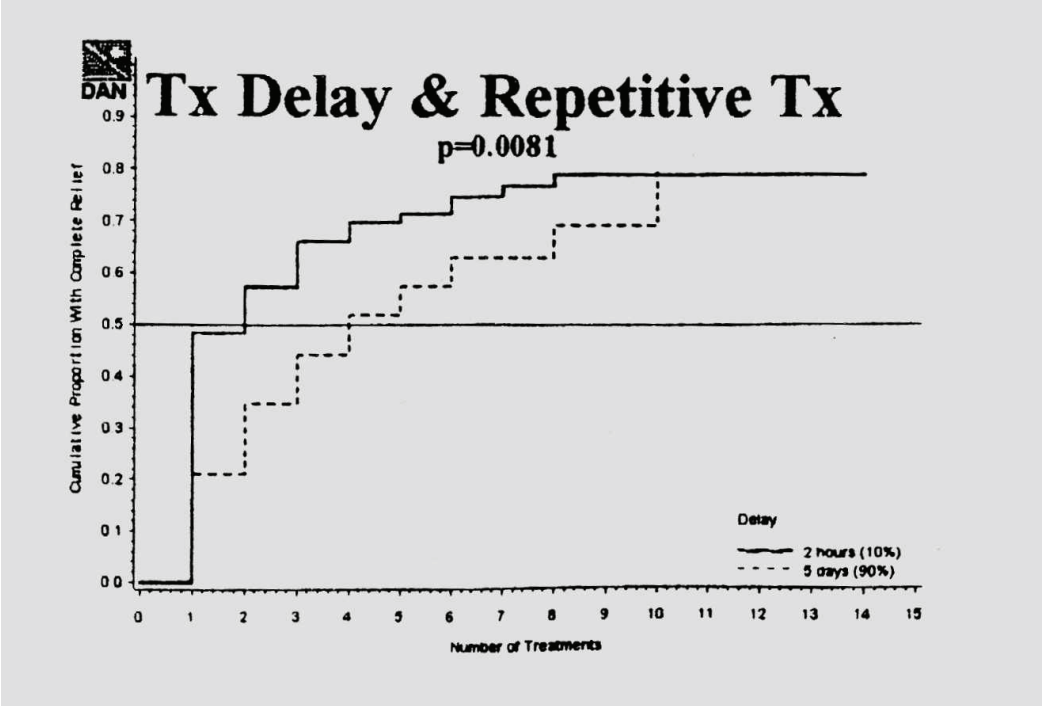
Review of 10 recompression centres in Europe and Australasia:
- No treatment
- Repetitive Comex12
- Repetitive 15 m x 90 min (USN Table9)
- Repetitive 18.60.30
- Repetitive 18 m USN5
- Repetitive 18 m USN6

All until a plateau is achieved.

REPETITIVE RECOMPRESSIONS

The tables used need to be standardised if not in compliance with already published or navy treatment tables. Repetitive recompressions can compensate for delay and may achieve full recovery in 80% of divers after both 2-hour and 5-day delays (Figure 1).[1]

Figure 1. The relationship between treatment delay and the number of repeat treatments needed to reach a clinical plateau[1]



11. Flying home after neurological DCI

PLANNING AND MANAGEMENT

No residua: three procedures are in common use (prospective study needed):

- 72-hour wait
- Prophylactic treatment; USN5s (or USN6; 18.60.30) plus 24- to 72-hour wait
- Three- to six-week wait (problem: insurers should pay hotel and some do, others do not)

Stable residua: Same approach is used, but the wait begins only after achieving a plateau symptomatically from repetitive recompressions.
Unstable residua: No flying or medical evacuation (without pressurisation).

MANAGEMENT ON DISCHARGE FROM RECOMPRESSION CENTRE

Following symptomatic relief of neurological DCI, what is the role of pre-flight

- treatment tables;
- repetitive recompressions;
- surface O_2

in the prevention of relapse?

CAUSES OF IN-FLIGHT / POST-FLIGHT RELAPSE

- Residual bubble growth (with further endothelial, platelet and leucocyte activation)
- Ischaemic penumbra
- Hypovolaemia

IN-FLIGHT OXYGEN

The goal is to maintain ground-level pO_2. There is a need to consider closed- vs open-O_2 delivery systems on aircraft? (see also para 3.) , and the acceptability of closed circuit to the various aviation agencies (FAA, CAA, airlines, etc).

12. Prospective data and follow up for analysis

HOW DO WE LEARN FROM OUR EXPERIENCE?

- Collect data, analyse and publish results
- Prospective, not retrospective studies
- Must define specific questions that the data should answer

Assessment of outcome immediately after treatment is available but how important is longer-term follow up after discharge? Problems of longer-term follow up include:

- questionnaires (by post, e-mail or telephone call) lead to low response rates and unvalidated data?
- appointments for an examination: who pays?

Conclusions from Workshop

These preliminary conclusions, above and below, are subject to examination of the records of the meeting and many will be reviewed at the UHMS Workshop to be held in Sydney, May 2004.

Urgent attention needs to be given to those items in italics:

- Omitted decompression and early reporting
- First aid (surface O_2) and local evacuation
- *Diagnosis and prognosis based on remote communication*
- *Triage of mild and severe cases*
- Aero-medical evacuation planning and criteria
- The role of in-water recompression and of a monoplace already on site
- Chamber and resources audit
- *Options if no immediate response to 18 m recompression*
- *Effectiveness of repetitive recompressions*
- *Protocol for flying home after neurological DCI*
- Collection of prospective data and follow up relating to specific questions

References

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