# *Air evacuation of DCI patients.*

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## Decompression Illness (DCI):

- Development of DCI
- Symptoms and presentation
- Classification:
  - Mild symptoms
  - Serious symptoms
- The pathophysiology of DCI
- Effects and principles of treatment
- First aid treatment. On-site and during transportation of patient.
- Specific considerations during air evacuation.
- Flying after Treatment for DCI
- Management of DCI in remote locations. Air-evac or not !
- Flying after diving guidelines

DEKOMPRESSIONSSYGE
Klassifikation

*Deskriptiv protokol-UHMS/EUBS*

1. Udvikling
2. Symptomer
3. Supplerende information

DEKOMPRESSIONSSYGE
Udvikling

Progredierende
- Langsomt
- Hurtigt

Statisk (uden klar ændring over tid)

Spontan bedring (før behandlingsstart)

Tilbagefald (efter tydelig initial bedring)
- Før behandling
- Under behandling
- Efter behandling

New term and classification

– *Acute decompression illness - DCI*

Manifestation term e.g.

– Acute neurological DCI

– Acute DCI with girdle pain

– Acute skin DCI

Originally with additional development term, e.g.

– Acute neurological DCI in spontaneous improvement

## DCI Symptoms…

Skin – Iching, marbelling.

Often selflimting.

Lymphatic – swollen skin and lymphnotes

Pain/Pain-only/Muskuloskeletal (”Bends”)

Asymetric pain in large weight bearing joints (shoulder, elbow, knee, hip)

Neurological (medullar;cerebral ratio = 5:1)

– Spinal (girdle pain, reduced reflexes and muscle power, reduced bladder function, reduced sensation

– Cerebral (half side sensory- and power deficits, visual changes, extreme fattigue, personality changes)

- Cerebellum (dissiness, vertical nystagmus, Balance, coordination)

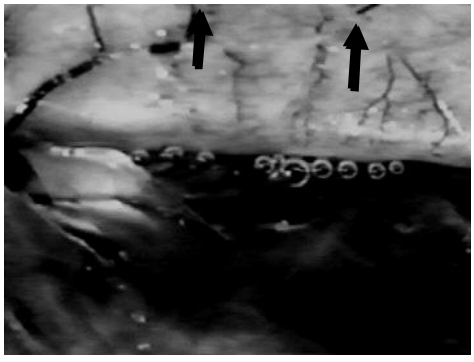
## DCI Symptoms…

Audiovestibular (”stagger”)

- Symptoms: vertigo, tinnitus, hearing loss. Nausea, vommitus
- Balance disturbance, nystagmus, affected hearing threshold
- OBS: PLF – a barotrauma

Cardiopulmonary (”chokes”)

- Extremely uncommon, hypotension, tachycardia, dyspnea, cough, pulmonary edema.



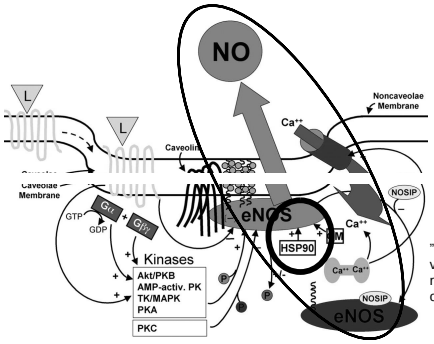
AGE = Arterial gas emblolism..
Neurologiske symptomer, cerebrale, inden for 5-10 minutter..

De novo formation of bubbles requires supersaturation exceeding those seen in the vascular system
On bubble formation with a factor 50-100

Thus – bubbles form in gas nuclei – about 1µm and gas filled

Such bubbles – in hydrofobic surfaces will be stable indefinitely

Hydrophobic areas exist on endothelial surface as CAVEOLAE – here NO production is localized



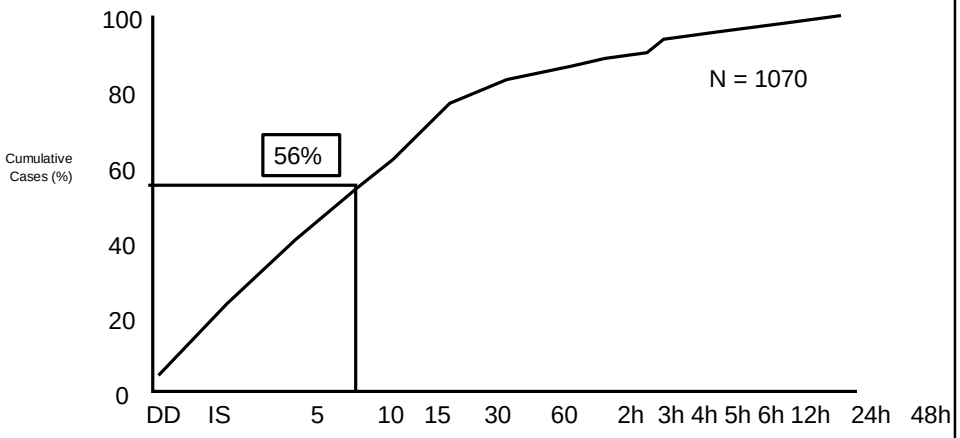

"NO is an important vasodilator and reduces the stickiness of the endothelium surface"

By Philip W. Shaul

# SYMPTOMATIC BUBBLES

1) *Primary effects - Mechanical Disruption*
   - *Tissue Distortion*
   - *Venous obstruction*
   - *Nerveous tissue, cochlear, middle ear,*
   - *blood vessels, endothelial disruption*
2) *Blood-bubble interface*
   - *Leukocyte activation with endothelial adherance,*
   - *Platelets activation,*
   - *Complement activation*
   - *Coagulation/ fibrinolysis*
3) *Tissue Damage*
   - *Infarction*
   - *Haemorrhage*

# CNS DCI Latency




Modified from: Francis et al. *UBR* 15: 403-417, 1989.

# MECHANISMS of TREATMENT

- Bubble Compression
- Redissolving Inert Gas
- Hyperoxygenation
- Counter diffusion
- Resolving Oedema
- Rx Ischemia-reperfusion

Divers Alert Network data 2003:

23% of all DCI involved exposure to air travel.

18.6% were by air ambulance

Overall data of DCI: 4.3% air-evac to recom-pression facility.

Air-evac involve specific risks. The following slides will identify these risks and quantify them where data exsist.

Ref.: Divers Alert Network. Report on decompression illness, diving fatalities and project dive exploration: 2003 eds. Durham (NC): Divers Alert Network; 2003. 132p.

The obvisous risk of mechanical failure and risk of crash. Human errors leading to crash.

Overall incidence (survey of 173 EMS air ambulance providers) of mishaps:
11.4 per 1 million patient transports.

Helicopter evac of DCI patient often considered a ”high-risk” operation.

Ref. Low RB et.al. Am J Emerg Med, 1991;9:103-6.

Specific Air Transport Risks with DCI

1. Pressure reduction and subsequent bubble expansion.
2. Evolution of new bubbles
3. Reduced $pO_2$ – tissue ischemia
4. Vibration characteristics. Most likely not a problem….
5. Risks of relaps – Flying after treatment – FAT.

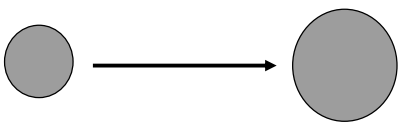
1. Pressure reduction…

## Bubble expansion !

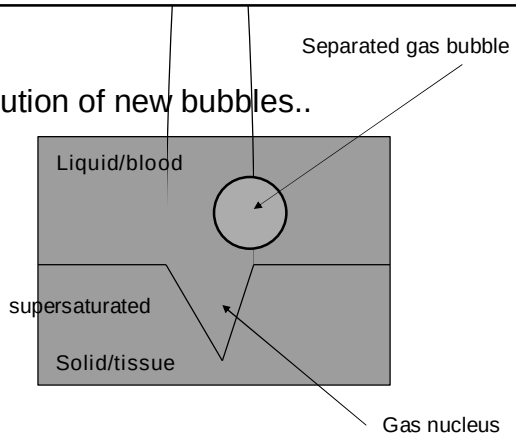
EXAMPLE:

A diver with sub-clinical symptoms of DCS.
He develops symptoms while in the aircraft:

The bubble in the tissue will grow with a factor of $0,7^{-1} = 1,43$



## 2. Evolution of new bubbles..




The nucleus is left to generate more bubbles as long as the state of supersaturation exists.

Survey of 1159 dcs-cases:

13.9% had symptoms before flying
5.6% developed symptoms of DCI during flight.

## 2. Evolution of new bubbles…cont.

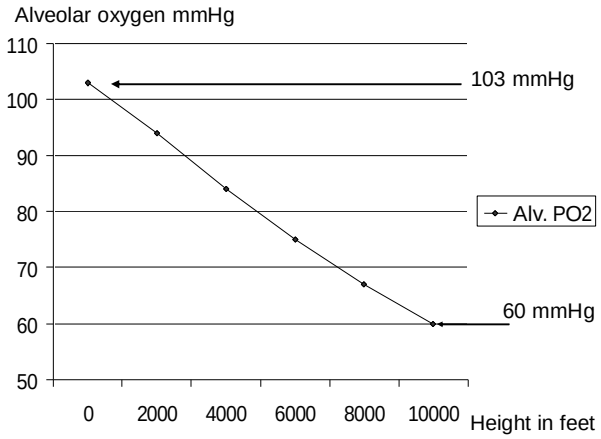
Analysis showed:

Increased risk of neurological DCI
Residual symptoms after first Tx
Residual symptoms after 3 month

By Vann, R.D. Et al. Divers Alert Network. Aviation Space Environ Med 1993;64:801-807.

## 3. Reduced $pO_2$….

### Reduced $pO_2$ – tissue ischemia




## 5. Risk of relaps – Flying after treatment..

126 out of 151 divers treated for DCI. Cut-off 72 hours.

**Table 1. Patients with complete relief after initial recompressions before flight.**

| | Flight <72 hrs | Flight ≥ 72 hrs |
|---|---|---|
| Total Patients | 54 | 41 |
| # Who Relapsed During Flight | 3 | 6 |
| % Who Relapsed During Flight | 5.6 | 14.6 |

Overall relaps rate 9%

p=0.13

**Table 2. Patients with residual symptms after initial recompressions before flight.**

| | Flight <72 hrs | Flight ≥ 72 hrs |
|---|---|---|
| Total Patients | 20 | 11 |
| # Who Worsened During Flight | 17 | 5 |
| % Who Worsened During Flight | 85.0 | 45.5 |

p=0.02

Uguccioni D. et al. Undersea Hyperb Med;25:36.1998. Freiberger J. et al. Aviat Space Environ Med;64:801-7, 1993.

## 5. Risk of relaps – Flying after treatment..

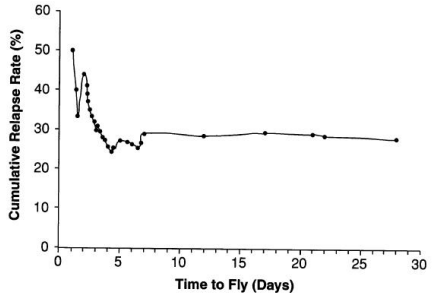



Figure 2. The relationship of time to fly to cumulative relapse rate.

The cumulative rate of relaps from FAT stabilizes after 3 to 4 days…

*FLYING HOME AFTER NEUROLOGICAL DCI*

No residual symptoms:
3 procedures in use: (need prospective study)
- 72 hr wait
- Prophylactic Rx: TT5s (or TT6) + 24-72 hr wait
- 3 to 6 week wait (Problem: insurers should pay hotel. Some do, some don't…)

Stable residual symptoms: Same but the wait begins only *after achieving plateau* from repetitive recompressions

Unstable residual symptoms:
No flying or Med-evacuation (without pressurization = 1 atm. aircraft)

Overall statement: 72 hours after last treatment. 24 hours if profylactic.

## 5. Risk of relaps – Flying after treatment..

### After treatment recommendations

Stay-off from diving

- 3-4 weeks if mild DCI with total remission of symptoms and findings
- 3 months if neurological DCI with ”moderate” symptoms and findings
- Permanent prohibition if motor or autonomous neurological sequel

*Clinical control within a year*

- Evacuation by land, sea or air is usually indicated to transport an injured diver from the dive site (usually remote) to emergency medical care and recompression. However less than 5-10% of DCI presents hyperacutely and requires such urgency.

- it is quite common to need to manage DCI more than 72 hours after the onset of symptoms in places distant to the dive site.

## MANAGEMENT OF DCI in flight..

- ABC – (Obs: assisted ventilatory support,
  pulmunary drainage if pneumothorax,
  especially if treatment in nonoplace, chest x-ray). Advanced life support a rare event…
- 100 % Oxygen ( NRM @ 15 lpm; DV; ET tube; BVM )
- Supine è Left Lateral
- IV (NaCl; Ringers; Oral)
  First Hour: 1 - 2 liters
  2ml / kg / hour Urine output (*NB* retention)
  If doubt – urinary catheterisation

- For neurological or cardiorespiratory DCI (other than minor sensory changes), choose a method of transport that is likely to get the diver to advanced life support or recompression within 4 hours.

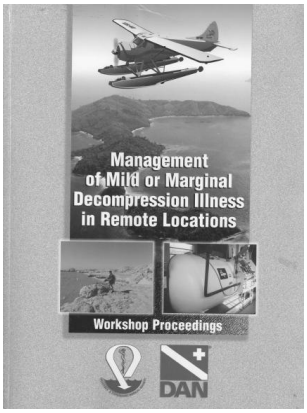
-Avoid elevations or decompression greater than 1000 ft above the altitude where the injury occurred. This may imply the need for sea level pressurization or low-level flying depending on the aircraft.

-Maintain continuous 100% oxygenation throughout the evacuation (if possible) up to 8 hours. Thereafter provide 30 minute air breathing periods for every 2 hours on oxygen for a maximum of 16 hours on 100% oxygen.

-Maintain fluid administration – Isotonic Saline (NaCl), Ringers solution. No glucose infusions.

- Transfer under pressure (i.e., in a transport chamber), while ideal, is rarely available and *usually impractical*.

## Mangement of mild or marginal DCI in remote locations….




Mitchell S.J. et al. (eds). Workshop proceedings. Durham, N.C.: Divers Alert Network, 2005. ISBN:0-9673066-6-3

## DCI on remote locations……

CONSENSUS STATEMENT 1

Marginal symptoms

– Limb pain

(severity of pain has no prognostic significance. Classical girdle pain excluded).

– Constitutional symptoms

(fattigue, malaise, headache, nausea, loss of appetite)

– Some cutaneous sensory changes

(paraesthesiae present in pathcy or non-dermatomal distributions, i.e. non-spinal)

– Rash

Where these manifistations are static or remitting and associated objektive neurological dysfunction has been excluded by medical examination (repeated over 24 hours).

## DCI on remote locations……

CONSENSUS STATEMENT 2

Untreated mild symptoms and signs due to DCI are unlikely to progress after 24 hours from the end of diving.

*Obs: no further decompression (diving or acent to altitude in the presence of mild symptoms)*

CONSENSUS STATEMENT 3
Level B epidemiological evidence indicate that a delay prior to recompression for a patient with mild DCI is not associated with worsening of long term outcome.

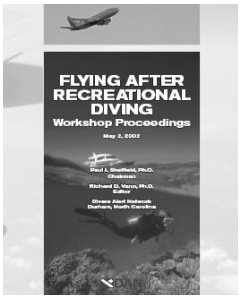
CONSENSUS STATEMENT 4

Some patients with mild symptoms and signs after diving can be treated adequately without recompression (fluids, normobaric oxygen). For those with DCI, recovery may be slower in the absence of recompression.

## DCI on remote locations……

CONSENSUS STATEMENT 5
Divers with MILD DCI 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.

- Guidelines for a single no-stop dive
  - USN: wait 2 hrs
  - DAN: wait 12 hrs
  - USAF: wait 24 hrs
  - NOAA: Wait depdt on sat. index (max 24 hours)
  - DMAC: wait 8h (<60 min past 12 h, ”short” flights, otherwise 24hrs)
  - STANDARD TABEL: Depending on saturation group.




Sheffield, Paul and Vann, Richard (ed.). DAN *Flying After Diving Workshop Proceedings*. Durham, N.C.: Divers Alert Network, 2004. ISBN 0-9673066-4-7

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Vann RD. Diving at the No-Stop Limits: Chamber trials of flying after diving. In: Flying After Diving Workshop. Vann RD, ed. 2004. Durham: Divers Alert Network. ISBN 9673066-4-7. 32-37.

Vann R, Gerth W, Denoble P, Pieper C, Thalmann E. Experimental trials to assess the risks of decompression sickness in flying after diving. Undersea & Hyperbaric Med 2004; 31(3).

Flynn ET. 1999 U.S. Navy procedures for ascent to altitude after diving. In: Flying After Diving Workshop. Vann RD, ed. 2004. Durham: Divers Alert Network. ISBN 9673066-4-7. 20-31.

Freiberger JJ, Denoble PJ, Pieper CF, Uguccioni DM, Pollock NW, Vann RD. The relative risk of decompression sickness during and after air travel following diving. Aviat Space Environ Med 2002; 73(10):980-984.

The following guidelines are the consensus of attendees at the 2002 Flying After Diving Workshop.

• They apply to air dives followed by flights at cabin altitudes of 2,000 to 8,000 feet (610 to 2,438 meters) for divers who do not have symptoms of decompression ilness (DCI).

• The recommended preflight surface intervals do not guarantee avoidance of DCI. Longer surface intervals will reduce DCI risk further.

For a single no-decompression dive, a minimum preflight surface interval of 12 hours is suggested.

For multiple dives per day or multiple days of diving, a minimum preflight surface interval of 18 hours is suggested.

For dives requiring decompression stops, there is little evidence on which to base a recommendation, and a preflight surface interval substantially longer than 18 hours appears prudent.