



**ENT & diving pathology:  
IE Decompression Sickness  
vs IE Barotrauma**

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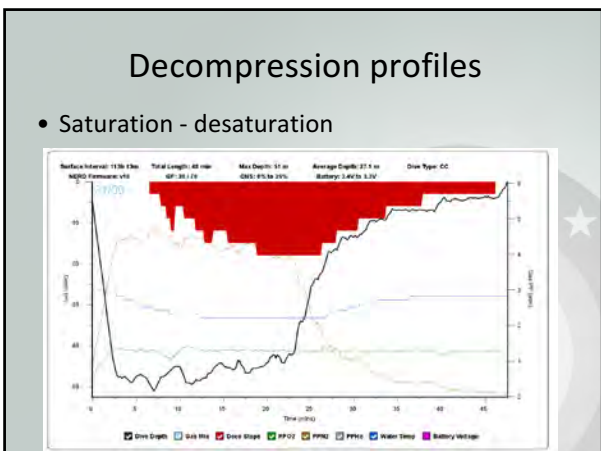
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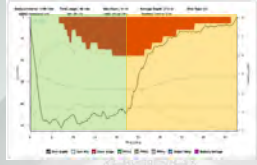
**Emergency inner ear injury in divers**

- **Inner ear decompression sickness**
  - Recompression is the only effective treatment
  - Only if applied early and aggressively
- **Inner Ear Barotrauma**
  - Hyperbaric oxygen may improve symptoms
    - Bubble size reduction
    - Oxygenation of ischemic tissue
  - Recompression may aggravate symptoms



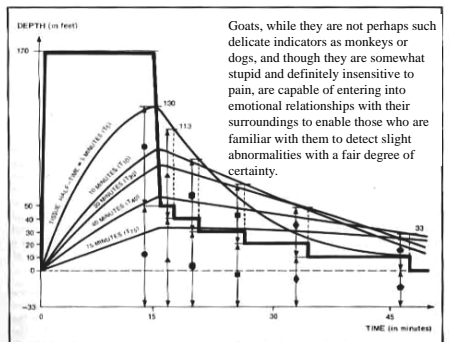
### Decompression factors

- **Saturation**
  - Depth
  - Gas mix
  - Bottom Time
  - (Physical Effort)
- **Desaturation**
  - Speed of ascent
  - Gas mix
  - Decompression stop depth
  - Decompression stop duration
  - Physical effort
  - (De)hydration
  - Position in water
  - Cardio-pulmonary "fitness"
  - ...
  - ...



Dive computers only calculate – do not measure (much) !

### Principles of decompression



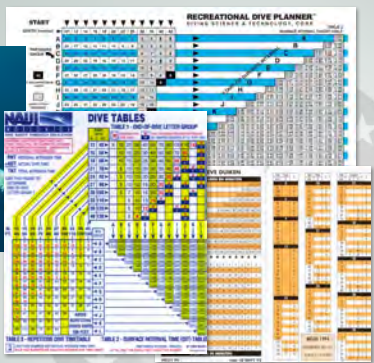
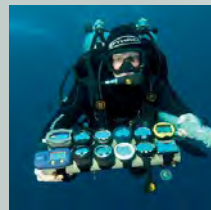
### Principles of decompression



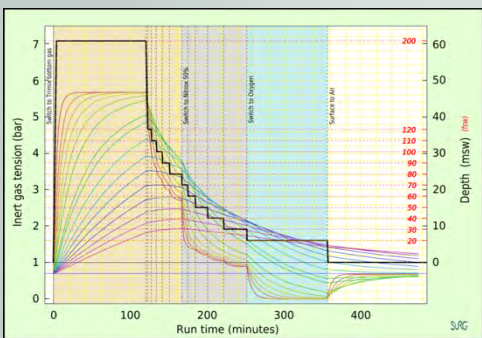
TABLE I.  
Stoppages during the ascent of a diver after ordinary limits of time from surface.

Depth Feet	Pressure Fathoms per square foot		Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths*					Total time for ascent in min.
	0-6	0-16			60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	
0-35	0-6	0-16	No limit	1	---	---	---	---	---	0-1
35-42	6-7	16-18 1/2	Over 2 hours	---	---	---	---	---	---	5
			Up to 1 hour	---	---	---	---	---	---	1 1/2
42-48	7-8	18 1/2-21	1-2 hours	1 1/2	---	---	---	---	---	6 1/2
			Over 2 hours	---	---	---	---	---	---	10
			Up to 1 hour	---	---	---	---	---	---	2
48-54	8-9	21-24	1-1 1/2 hours	2	---	---	---	---	---	7
			Over 1 1/2 hours	---	---	---	---	---	---	12
			Up to 1 hour	---	---	---	---	---	---	2
54-60	9-10	24-26 1/2	Up to 30 mins.	2	---	---	---	---	---	2
			30-45 mins.	---	---	---	---	---	---	5
			1-1 1/2 hours	---	---	---	---	---	---	10
			1 1/2-2 hours	---	---	---	---	---	---	15
			Over 2 hours	---	---	---	---	---	---	22
60-66	10-11	26 1/2-29 1/2	Up to 1 hour	2	---	---	---	---	---	2
			1-1 1/2 hours	---	---	---	---	---	---	7
			1 1/2-2 hours	---	---	---	---	---	---	10
			2-3 hours	---	---	---	---	---	---	15
			Over 3 hours	---	---	---	---	---	---	22
66-72	11-12	29 1/2-32	Up to 1 hour	2	---	---	---	---	---	2
			1-1 1/2 hours	---	---	---	---	---	---	7
			1 1/2-2 hours	---	---	---	---	---	---	10
			2-3 hours	---	---	---	---	---	---	15
			Over 3 hours	---	---	---	---	---	---	22

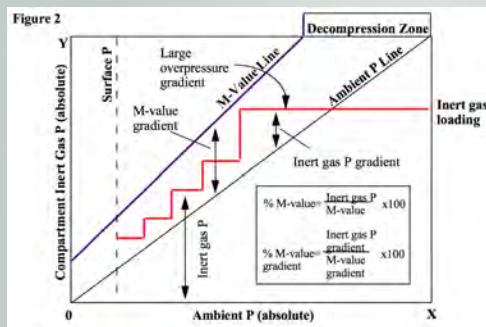
### Principles of decompression

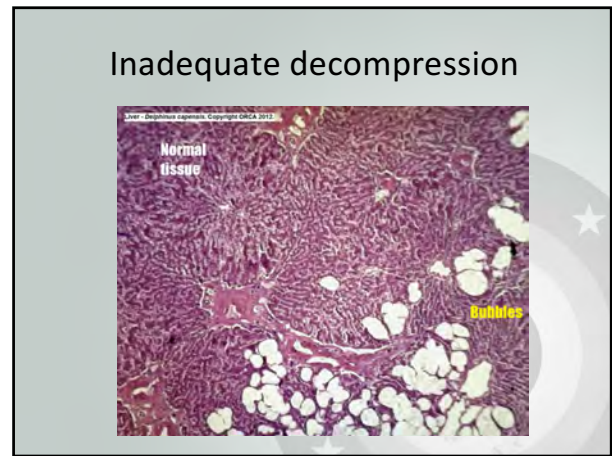
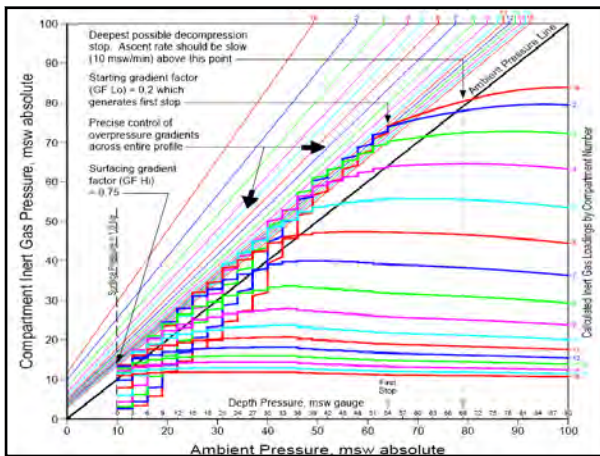


### Principles of decompression



### Principles of decompression





### Bubbles in the inner ear

- In-Situ bubble formation**
  - Endolymph
  - Perilymph

Unlikely in "normal diving", although theoretically possible

  - Three compartment tissue
  - Indirect gas exchange

*Doolette D.J., Mitchell S.J. Biophysical basis for inner ear decompression sickness. J Appl Physiol 2003; 94 (6): 2145-2150*

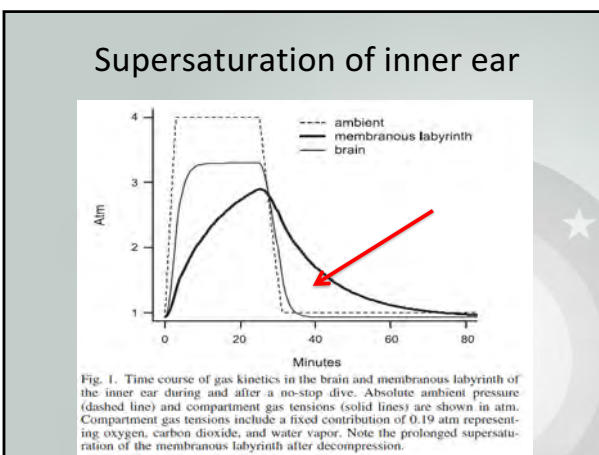
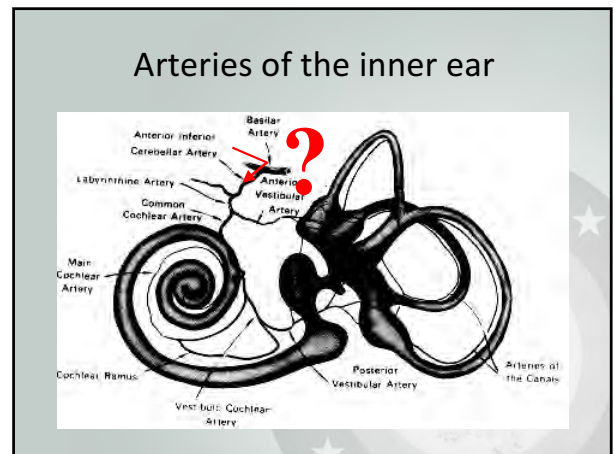
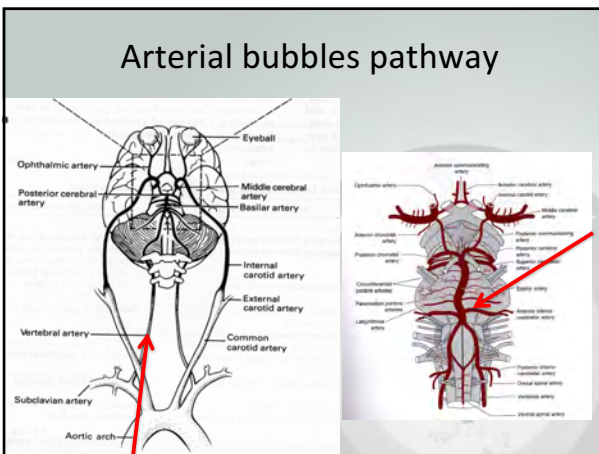
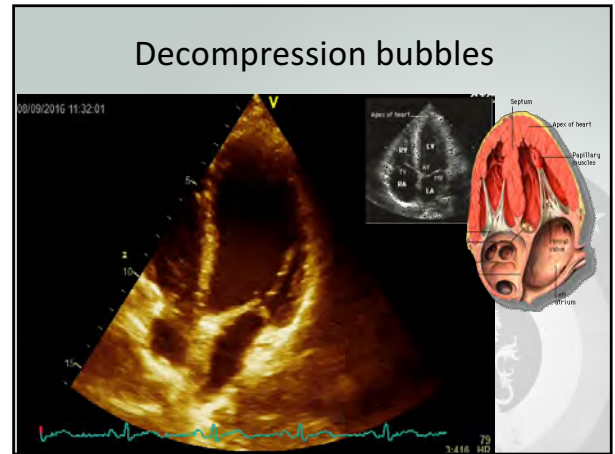
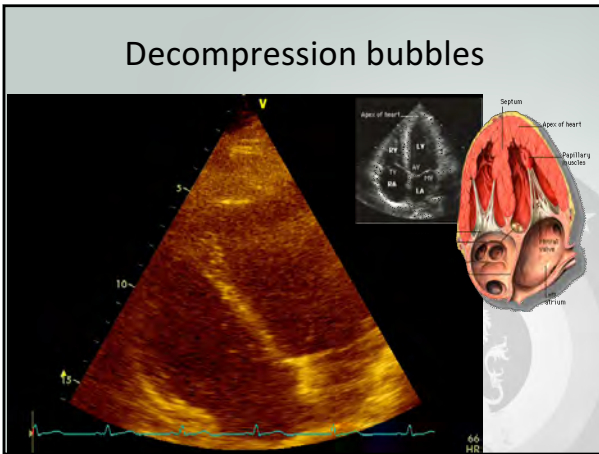
### Three-compartment tissue

A diagram of a three-compartment tissue model. It shows three stacked boxes: 'Endolymph compartment' at the top, 'Vascular compartment' in the middle, and 'Perilymph compartment' at the bottom. Arrows indicate bidirectional gas exchange between these compartments. External pressures  $P_a$  and  $P_{atm}$  are indicated. To the right is a graph of partial pressure (atm) vs. time (minutes) from 0 to 30. The graph shows three curves: 'vascular tissue' (highest), 'endolymph' (middle), and 'perilymph' (lowest). A red arrow points to the peak of the vascular tissue curve.

*Doolette D.J., Mitchell S.J. Biophysical basis for inner ear decompression sickness. J Appl Physiol 2003;94(6): 2145-2150*

### Bubbles in the inner ear

- Vascular bubbles**
  - After many (deeper) dives, even with respect of decompression schedule, **circulating bubbles** can be detected in the central venous circulation
  - 30% of all divers have a Patent Foramen Ovale of the heart
  - **Paradoxical embolisation** of venous nitrogen bubbles to the arterial circulation is not uncommon



- ### Proposed mechanism of DCS
- Circulating bubbles passing through a Patent Foramen Ovale or Pulmonary Shunts
  - Embolise the brain (ACI, AVert) and the AICA
  - Disappear in undersaturated tissues (brain)
  - Stabilise and grow in **supersaturated** tissues (inner ear)
- More likely than "in situ" bubbles**

### Symptoms of IEDCS & IEBT

- Cochlear and/or vestibular symptoms
- Appearing rapidly after surfacing from a dive
- Without other rational cause
- Excluding BPPV

#### How to differentiate between IEDCS and IEBT ?

### IEDCS

### IEBT

- > Vestibular symptoms
  - Nausea, vomiting
  - Nystagmus, rotational vertigo
- < Deafness
- Timing: 5-30 minutes after surfacing
- Dive profile: saturation or desaturation factors
- Other symptoms of DCS (cutaneous, visual, neurological)

*Klingmann C, et al. Barotrauma and decompression illness of the inner ear: 46 cases during treatment and follow-up. Otol Neurotol. 2007;28(4):447-54.*

### IEDCS

### IEBT

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• &gt; Vestibular symptoms                     <ul style="list-style-type: none"> <li>– Nausea, vomiting</li> <li>– Nystagmus, rotational vertigo</li> </ul> </li> <li>• &lt; Deafness</li> <li>• Timing: 5-30 minutes after surfacing</li> <li>• Dive profile: saturation or desaturation factors</li> <li>• Other symptoms of DCS (cutaneous, visual, neurological)</li> </ul> | <ul style="list-style-type: none"> <li>• &gt; Cochlear symptoms                     <ul style="list-style-type: none"> <li>– Deafness, hearing loss</li> <li>– Tinnitus, fullness</li> </ul> </li> <li>• Instability</li> <li>• During descent, or during ascent or &lt;5 min after surfacing</li> <li>• Dive profile: difficulties of ear equalisation (±)</li> <li>• No other symptoms of DCS</li> </ul> |
|---|--|

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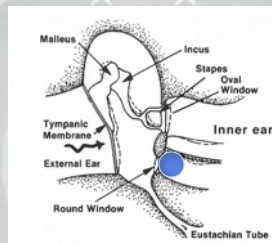
#### QUICK-QUESTIONNAIRE INNER EAR BAROTRAUMIA / DCS

	I.E.B.T.	I.E. DCS	CM/DCS
<b>1. Dive History</b>			
- Upper respiratory tract infection	+1	0	0
- Difficulty equalization ear upon descent	+2	0	0
- Forced Valsalva manoeuvre	+2	0	0
- Rapid descent	+2	0	0
- Cold / Musc.Exertion / Fatigue / Stress during dive	0	+2	+2
- No-Decompression dive	+1	+1	0
- Error in decompression procedure / ascent speed	0	+5	+5
- Important muscular exercise or Valsalva manoeuvre at D-stop or < 30 minutes after dive	+1	+2	+2
- First symptoms during descent	+10	+5	+5
- First symptoms at D-stop or < 1 hr after dive	+1	+2	+2
<b>2. Physical Exam</b>			
- Rotational vertigo	+1	+1	+1
- Spontaneous horizontal nystagmus	+1	+1	+1
- Perceptive hearing loss	+2	0	+1
- Positive Römberg-sign	+1	+1	0
- Negative deviation while arms extended	+1	+1	0
- Otoscopy: NO signs of middle ear barotraumatism	-1	-1	+1
- Cerebellar symptoms	0	0	+5
- Impaired consciousness	0	0	+5
- Other symptoms of neurological (or other) DCS	0	+2	+2
<b>TOTAL</b>			

*A difference of > 3 points indicates a high diagnostic probability, and an emergency treatment must be initiated accordingly.*

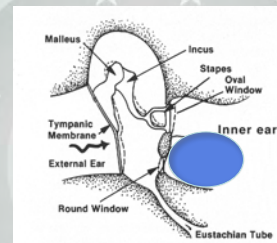
### IEBT paradox

- Caused by barotrauma on DESCENT
- Symptoms often only on ASCENT
- Boyle & Mariotte's Law !
  - Air introduced into perilymph at depth
  - Expands during ascent to cause symptoms



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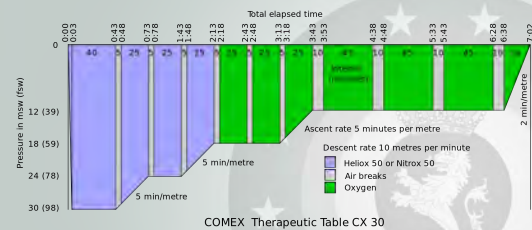


### Diving-induced endolymphatic hydrops

- Poorly described (**exception: P Van Der Eecken !**)
- Diving with “insufficiently equalised ears”
- Symptoms:
  - Typical delay of a few hours (even overnight)
  - Fullness of ear, possible vertigo (balance)
  - Hearing loss low frequencies (“Menière-like” syndrome)
- Cause: irritation of endolymphatic / perilymphatic structures by repeated/prolonged stapes pressure ?
- Treatment: beta-histine / acetazolamide / HBO ?

### Treatment of IEDCS

- Recompression treatment table (Cx30, USN6)



### Treatment of IEBT

- Bed rest, head 30° elevation
- Corticotherapy (IV – PO)
- In case of persistent vertigo / aggravation: surgical intervention (round window coverage; oval window blood patch)
  - Recent report: surgical intervention <10 days in case of suspected perilymphatic fistula: 100% improvement of hearing within 2 days of surgery (90% complete recovery)

Morvan JB et al. Perilymphatic fistula after underwater diving – a series of 11 cases. *Diving Hyperb Med* 2016; 46(2):72-75

### Treatment of IEBT

- In case of doubt (DD IEDCS) – hyperbaric recompression strongly recommended !
  - Placement of transtympanic grommets
  - Compression without active Valsalva manoeuvres
  - In case of aggravation of symptoms
    - Diagnosis of IEBT likely
    - Surgical intervention high rate of success

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### Post-treatment


- **IEDCS**
  - Analysis of dive profile and risk factors
    - PFO ?
  - Return to diving discouraged unless full recovery
  - Adapted diving (low-bubble profiles) and risk acceptance by diver ?
- **IEBT**
  - Recurrence likely unless operated (RW scarring ?)
  - Return to diving only if diver understands and accepts risk
  - Case reports of successful return to diving

Elliott EJ et al. The assessment and management of inner ear barotrauma in divers and recommendations for returning to diving. *Diving Hyperb Med* 2014; 44:208-222

### IEDCS – IEBT

- **Recognise & treat as an emergency !**
- Contact hyperbaric / diving medicine specialist
  - 24/24 Hotline for diving emergencies
  - Toll-free number (Belgium)
  - Telephone advice only
  - Referral to HBO centre in case of need





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