$N_2$ narcosis

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Runtime: 25 min
Slides: 22
Nitrogen narcosis

Air dive @ 47 meter

https://youtu.be/0fD1gsLlqMY
N₂ narcosis - symptoms

- slowing of mentation
- loss of memory
- overconfidence
- excitement
- euphoria
- hallucinations
- stupefaction
- coma
Neuro cognitive effects

• Noticeable from 30 msw (average)
• 10–20 msw: impairment of unrehearsed mental and physical tasks, such as sorting cards
• 30-50 msw: central processing affected > amnesia
• decreased pain perception!
• decreased manual dexterity, reaction times
• linear to depth
• automated motor skills are relatively preserved

Neurocognitive effects

<table>
<thead>
<tr>
<th>Depth</th>
<th>Mood and behaviour</th>
<th>Intellectual function</th>
<th>Response to stimuli</th>
<th>Coordination and balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10m</td>
<td>Mild Euphoria</td>
<td>Mild reasoning</td>
<td>Delayed</td>
<td>Little</td>
</tr>
<tr>
<td>20m</td>
<td></td>
<td>Impediment</td>
<td>Response to</td>
<td>Impediment</td>
</tr>
<tr>
<td>30m</td>
<td></td>
<td>Fixed Ideas</td>
<td>Audio/Visual</td>
<td></td>
</tr>
<tr>
<td>40m</td>
<td></td>
<td></td>
<td>Stimuli</td>
<td></td>
</tr>
<tr>
<td>50m</td>
<td>Over confidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60m</td>
<td>Laughter</td>
<td>Confusion</td>
<td>Dizziness</td>
<td></td>
</tr>
<tr>
<td>70m</td>
<td>Hysteria/Terror</td>
<td>Drowsiness</td>
<td>Severe delayed</td>
<td></td>
</tr>
<tr>
<td>80m</td>
<td></td>
<td>Severe judgment loss</td>
<td>Impaired dexterity</td>
<td></td>
</tr>
<tr>
<td>90m</td>
<td>Hallucination</td>
<td>Stupor</td>
<td>Unconsciousness</td>
<td></td>
</tr>
<tr>
<td>90+</td>
<td></td>
<td></td>
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</tbody>
</table>

*Death*
• Early report by Colladon 1826: “a state of excitement as if I had drunk some alcoholic liquor”
• Green 1861: sleepiness, hallucinations
• Damant 1930: loss of memory
• Hill 1933: semi loss of consciousness attributed to:
  – impure air from faulty compressors
  – carbon dioxide
• Behnke 1935 recognized N₂ as the culprit
Inert gas narcosis

• Traditional view:
  – expansion of the phospholipid bilayer by uptake of inert gas
  – fluidization of the gel like bilayer
  – pressure reversal of anaesthetic effect

• Modern view:
  – interaction with membrane proteins
  – ligand-gated ion channels

Molecular and basic mechanisms of anaesthesia (postgraduate issue), Br J Anaesth 2002; 89: 1–183.
Ligand-gated ion channels sensitive to anaesthetic gases and vapours

- Nicotinic acetylcholine
- GABA\textsubscript{A} (\(\gamma\)-aminobutyric acid receptor A)
- Glycine
- Glutamate receptors
  - NMDA (N-methyl-D-aspartate)
  - AMPA (\(\alpha\)-amino-3-hydroxy-5-methyl-4-isoazolepropionate)
  - Kainate
- 5-HT\textsubscript{3} (5-hydroxytryptamine 3 receptor)
• $N_2$ has $0.03 - 0.05 \times$ narcotic potency of $N_2O$
• also analgesic effect: 50 msw on air.
Nigrostriatal pathway

- regulation of motor, locomotor and cognitive functions
- dopamine level in striatum (rats)
- 3 bar N\textsubscript{2}:
  - decrease glutamate
  - increase serotonin
  - decreased striatal dopamine level

DOPAMINE

Maximal variations under inert and anesthetic gases at pressure

- Helium
- Nitrogen
- Argon
- Nitrous oxide (40%)

P < 0.001***
P < 0.05 *

Entonox vs nitrogen narcosis
Predisposing/risk factors

- cold
- reduced sensory input
- hypercapnia
- exertion
- anxiety
- alcohol
• Australian database:
  – $N_2$ narcosis contributed to 9% of diving deaths
• DAN data base 2010 annual report:
  – 3.6% of diving fatalities caused by $N_2$ narcosis
• Depths > 30 msw associated with a 3.5-fold increase in $N_2$ narcosis related incidents

Figure 2 Number of reported diving incidents involving narcosis (1999–2013). Analysis of incidents known, or thought, to have involved narcosis, as reported by those involved at depths of less than or greater than 30 msw. Total number of reported incidents = 6,135. (Source: British Sub-Aqua Club incident database.

Duration of effect

20 divers
20 min @ 33 msw
critical flicker fusion frequency
Post dive persistence of effect!
However this could also be due to post dive fatigue.

Adaptation?

- often asked by divers
- animals studies: no physiological adaptation
- repetitive dives to depth: no adaptation
- there is however:
  - habituation
  - anticipation

Chamber awareness course

- Dry dive:
  - PADI specialty
  - 40 msw
  - experience nitrogen narcosis
  - experience the increased density of air and other effects
Depth limits

- **open water certification**: Max 18 meter
- **advanced open water**: Max 30 meter
- **deep diver specialty**: Max 40 meter
- **technical diving**: 40 MSW
- **trimix**: > 30-40 msw
- **commercial divers**: Air up to 50 msw

- recognizing narcotic effects
- practising mental tasks at depth
- memory test
Equivalent $N_2$ Depth

• dive plan: air dive 55 msw depth
  – max nitrogen depth of 30 msw
  – 30 msw = 4 bar ambient pressure
  – $PN_2 = 0.78 \times 4 = 3.15$ bar (on air)

• replace part of $N_2$ by He
  – ambient pressure @ 55msw = 6.5 bar
  – max $PO_2 = 1.4$ bar

• $6.5 = 3.15 + 1.4 + 1.95$
  – $PO_2 1.4$ bar = 21%
  – $PN_2 3.15$ bar = 49%
  – $PHe 1.95$ bar = 30%
## ‘inert’ gas narcosis

<table>
<thead>
<tr>
<th></th>
<th>Molecular weight</th>
<th>Relative narcotic potency</th>
<th>Lipid solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>He</td>
<td>4</td>
<td><strong>0.2</strong></td>
<td>0.015</td>
</tr>
<tr>
<td>Ne</td>
<td>20</td>
<td>0.3</td>
<td>0.019</td>
</tr>
<tr>
<td>H₂</td>
<td>2</td>
<td>0.6</td>
<td>0.036</td>
</tr>
<tr>
<td>N₂</td>
<td>28</td>
<td>1</td>
<td>0.067</td>
</tr>
<tr>
<td>Ar</td>
<td>40</td>
<td>2.3</td>
<td>0.14</td>
</tr>
<tr>
<td>Kr</td>
<td>83</td>
<td>2.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Xe</td>
<td>131</td>
<td>25</td>
<td>1.7</td>
</tr>
</tbody>
</table>

*Note: He = Helium, Ne = Neon, H₂ = Hydrogen, N₂ = Nitrogen, Ar = Argon, Kr = Krypton, Xe = Xenon*
Helium

advantage
• no narcotic effect
• low density
• reduced Reynolds number
• reduction of turbulent flow
• less breathing resistance at depth

disadvantage
• high thermal conductivity
• heat loss!
• very expensive
• increased deco time
• Donald Duck voice
• HPNS!
Thistlegorm
launched April 1940
bombed 6-10-1941
Red Sea 25-40 msw

Thank you for listening