Propranolol Could Delay Nitrogen Narcosis During Submarine Escapes From 600 to 1,000 fsw.

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SUBMARINE ESCAPES

- In 1970, 3 successful trial escapes performed at sea from 176 m (keel depth: 182 m, 600 fsw) from HMS *Osiris*. The 3 escapers had "no difficulty carrying out the simple escape procedures"

- In 1987, 2 submariners aboard HMS *Otus* escaped from a depth of 183 m, still the deepest submarine escape by humans ever recorded

- Deeper experimental escapes with animals breathing oxygen:

1. 300 m (984 fsw) with goats
2. 400 m (1,320 fsw) with rats

ESCAPES FROM DISABLED SUBMARINES

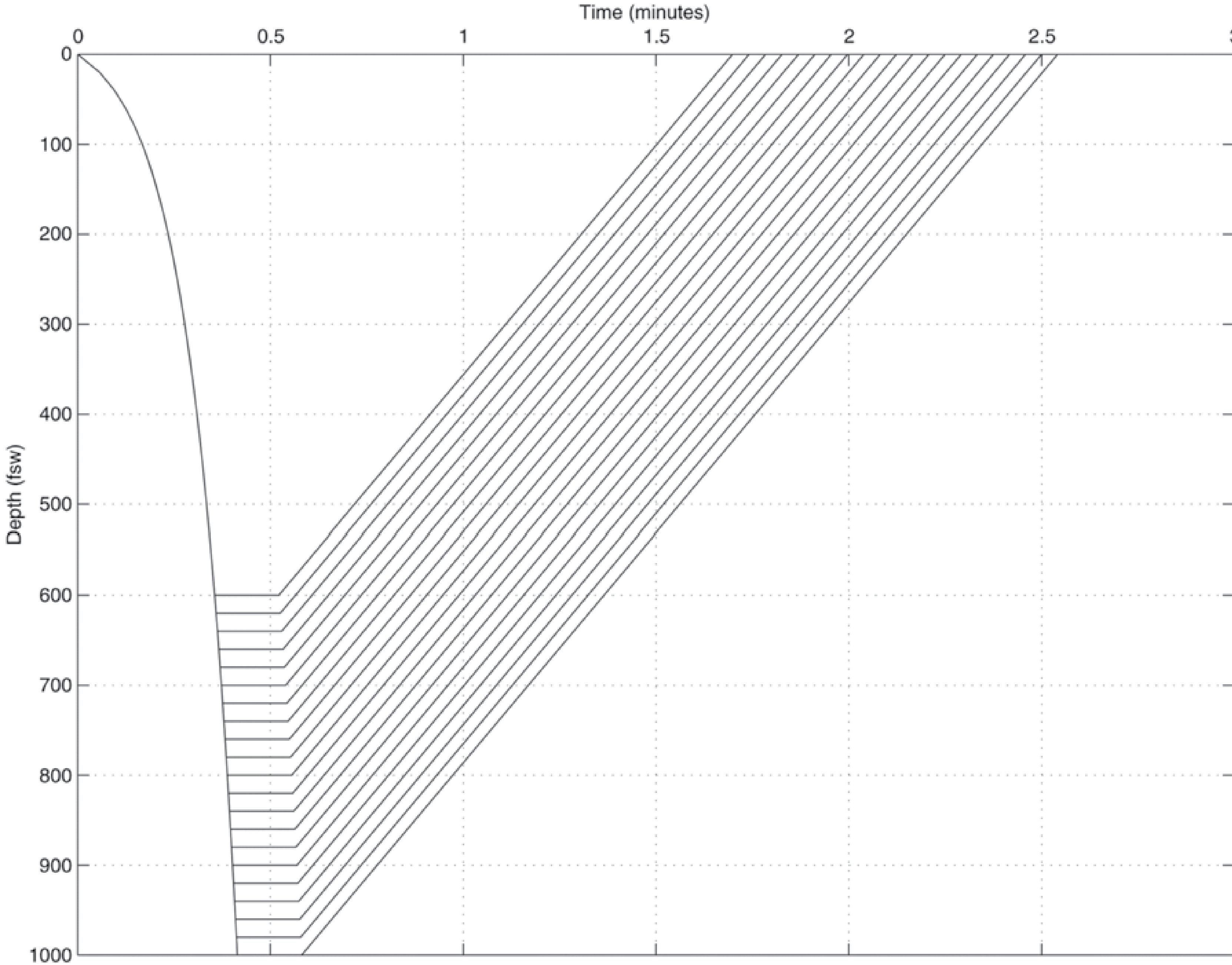
- Currently, US Navy recommends escapes for depths down to 600 fsw
- Deeper escapes discouraged due to concerns for decompression sickness, nitrogen narcosis and CNS oxygen toxicity
- Risks faced in such deep escapes may be acceptable if the rescue is not occurring before conditions in DISSUB become life-threatening

ESCAPE EQUIPMENT

Escape Trunk rated to 750 fsw

ESCAPE EQUIPMENT

Submarine Escape and Immersion Equipment (SEIE)
rated to 1,000 fsw



Depth-time profiles of escapes from depths ranging from 600 to 1,000 fsw, with a DT of 10 s.

Hypotheses

- Incapacitating nitrogen narcosis can be delayed to later stages of escapes from 600 to 1,000 fsw, after leaving the escape trunk (where a few simple yet essential tasks need to be performed)
- During ascent and at the surface, SEIE prevents drowning
- This delay can be produced by prolonging circulation time from the lungs to the brain through a reduction in cardiac output

COMPUTER SIMULATIONS

- Software developed to model gas transport from the environment to tissues during conditions of rapidly-changing pressures (typical of submarine escapes)
- This software allowed changes in parameters such as lung to brain circulation time and cardiac output
  1. Baseline lung to brain circulation time assumed = 14 s
  2. Baseline cardiac output assumed = 5 l/min

COMPUTER SIMULATIONS

- Beta-blocker Propranolol chosen because of its quantified ability to reduce cardiac output
- Prolongation of lung to brain circulation time assumed to be inversely proportional to changes in cardiac output
- Risk of nitrogen narcosis expressed as Equivalent Narcosis Depth (END) in fsw, corresponding to nitrogen pressure in Vessel-Rich-Group tissues after 5 min of air diving at that equivalent depth
- Simulations were performed with different depths and dwell times

Effects of Changes in CO and Lungs to Brain Circulation Times on END Prior to Leaving Escape Trunk

Cardiac Output (%)	Dwell Time (s)		
600 fsw	10	30	60
75	1	31	137
100	5	60	194
150	18	112	282
800 fsw	10	30	60
75	2	43	184
100	7	81	260
150	25	151	378
1000 fsw	10	30	60
75	2	52	227
100	9	98	322
150	30	185	468

Effects of Changes in CO and Lungs to Brain Circulation Times on END During the Entire Escape

Cardiac Output (%)	Dwell Time (s)		
600 fsw	10	30	60
75	167	235	319
100	208	279	364
150	255	331	421
800 fsw	10	30	60
75	279	354	449
100	325	405	506
150	384	472	578
1000 fsw	10	30	60
75	394	476	584
100	450	539	654
150	522	620	740

Conclusions

- Nitrogen narcosis during submarines escapes can be delayed by reducing cardiac output and prolonging lungs to brain circulation time
- This effect could be achieved by oral administration of the beta-blocker Propranolol prior to escape
- An even greater hemodynamic effect may be expected in submariners with hyperdynamic circulation

Questions?