Altitude Decompression Illness: an Historical Perspective
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Decompression Illness

It All Starts Under the Sea

Ancient landmarks

- 4500 BC – breath holding dives for pearls
- 400 BC – Scyllis uses hollow reed to escape Xerxses fleet, and cut the ships moorings on the way!
- 320 BC – Alexander the Great used 1st diving bell
- 300 BC – Aristotle describes rupture of the eardrum in divers

Ancient landmarks

Alexander the and the diving bell

Early History

- 1620 – Cornelius Drebbel develops 1 ATA diving bell
- 1662 – Henshaw uses compressed air to treat disease
- 1670 – Boyle demonstrates increased bubble volume with decreased pressure and vise versa
- 1691 – Edmund Halley adds replenished air to diving bell
- 1715 – John Lethbridge develops diving suit
- 1774 – Freminet used air compressed helmet to dive 50 ft. for 1 hour
- 1774 – Oxygen discovered by Carl Scheele; Joseph Priestley 1775 (“oxygen” coined by Antoine Lavoisier 1778)

Antoine Lavoisier

Theory that oxygen is required for combustion

In nature nothing is created, nothing is lost, everything changes.

Treatise upon the Elements of Chemistry

1789 - Discovers toxic effects of oxygen

Clinical beginnings

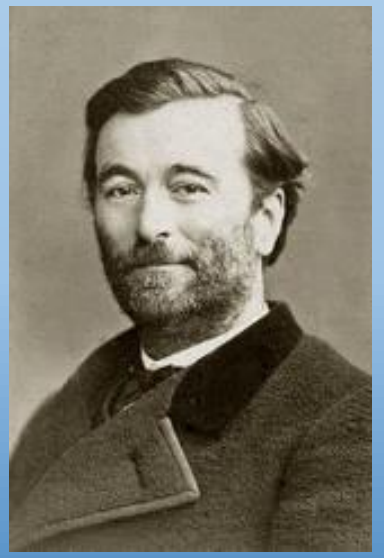
1670: Boyle - 1st description of the decompression phenomenon; eye bubble of the snake

1834: Junod constructs a chamber using pressures from 2-4 ATA to treat pulmonary disease

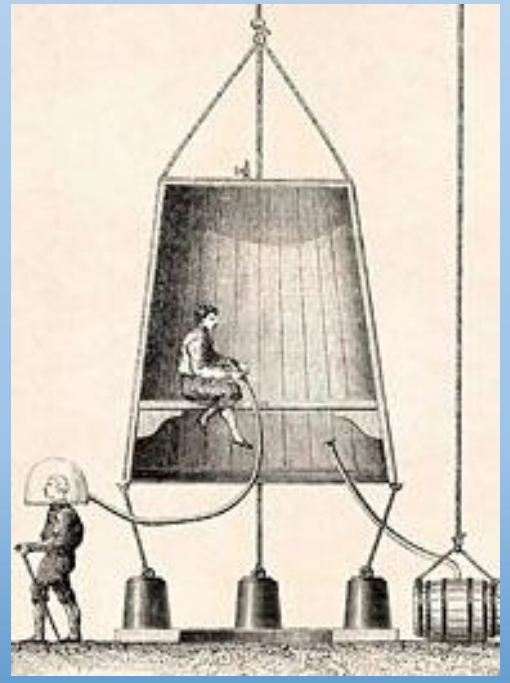
1841: Watele observed that recompression relieved the symptoms of decompression sickness

1871: Paul Bert showed that decompression bubbles consistent mainly of nitrogen

1891 Corning uses the 1st hyperbaric chamber US to treat nervous conditions



Diving devices

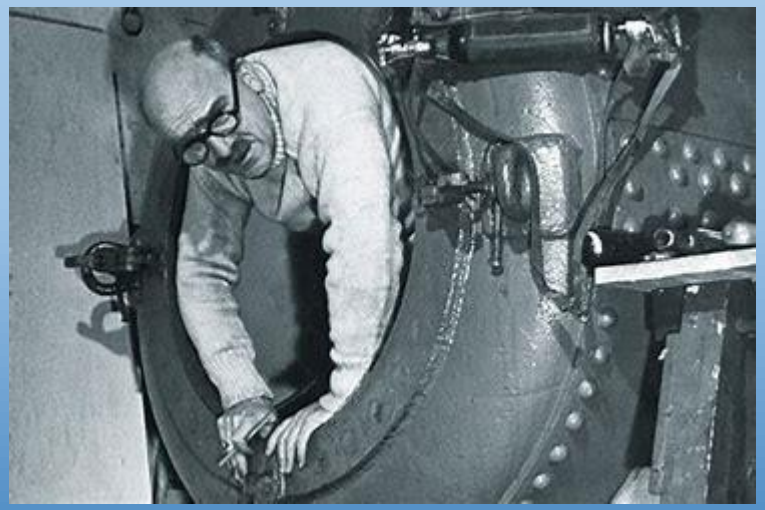


Modern History

1907 – Royal Navy tasks John Haldane to increase diving safety

1908 – Haldane publishes first decompression tables

"Decompression is not safe if the pressure of nitrogen inside the body becomes much more than twice that of the atmospheric nitrogen".



TABLES DE HALDANE, 1908

TABLE 1.

Paliers à la remontée après un temps de plongée d'une durée « normale ».

Profondeur			Pression Livres par pouce carré (psi)	Temps, depuis le départ de la surface jusqu'au début de la remontée	Temps approximatif jusqu'au premier palier	Paliers en minutes à différentes profondeurs*						Temps total de remontée
Pieds	Brasses	Mètres				60 pieds [~18 m]	50 pieds [~15 m]	40 pieds [~12 m]	30 pieds [~9 m]	20 pieds [~6 m]	10 pieds [~3 m]	
0-36	0-6	~0-11	0-16	Sans limite	—	—	—	—	—	—	—	0-1
36-42	6-7	~11-13	16-18½	Plus de 3 heures	1	—	—	—	—	—	5	6
42-48	7-8	~13-15	18½-21	Jusqu'à 1 heure	—	—	—	—	—	—	—	1½
				1 à 3 heures	1½	—	—	—	—	—	5	6½
				Plus de 3 heures	1½	—	—	—	—	—	10	11½
48-54	8-9	~15-16	21-24	Jusqu'à ½ heure	—	—	—	—	—	—	—	2
				½ à 1½ heure	2	—	—	—	—	—	5	7
				1½ à 3 heures	2	—	—	—	—	—	10	12
				Plus de 3 heures	2	—	—	—	—	—	20	22
54-60	9-10	~16-18	24-26½	Jusqu'à 20 min	—	—	—	—	—	—	—	2
				20 à 45 min	2	—	—	—	—	—	5	7
				¾ à 1½ heure	2	—	—	—	—	—	10	12
				1½ à 3 heures	2	—	—	—	—	5	15	22
				Plus de 3 heures	2	—	—	—	—	10	20	32
60-66	10-11	~18-20	26½-29½	Jusqu'à ¼ heure	2	—	—	—	—	—	—	2
				¼ à ½ heure	2	—	—	—	—	—	5	7
				½ à 1 heure	2	—	—	—	—	3	10	15
				1 à 2 heures	2	—	—	—	—	5	15	22
				2 à 3 heures	2	—	—	—	—	10	20	32

1918-1937: the Orval Cunningham era

1918: Cunningham treat symptoms of the Spanish influenza epidemic

1928: Cunningham constructs largest chamber located in Cleveland Ohio

1937: Cunningham chamber was dismantled for scrap metal

Can Altitude Cause Decompression Illness?

- In theory, 18000 ft is one half the pressure at sea level and can induce decompression illness if flying at that level or higher.
- However, early thoughts was it could not induce decompression illness as pressure returns therefore treating any bubbles.

The rise of altitude DCS

1937: Behnke and Shah 1st used hyperbaric oxygen for treatment of altitude symptoms

1941: Germans coin the term “Drukfall Krankheit” (later called decompression sickness)

Late 1940’s: Engineering advances facilitate aircraft ascents to 30000 feet or more

1943-1958: ten altitude chamber deaths and seven aircraft fatalities

Vast majority of symptoms resolve upon landing

The rise of altitude DCS

1955: Behnke publishes “Decompression Sickness” review article

Risk of decompression sickness in exposures without preoxygenation is greater than 50%, but symptoms are mostly alleviated upon return to ground level

Bubble formation, chiefly intravascular gas emboli, are responsible for symptoms

Recompression of gas emboli restore individuals to the state of well being

The rise of altitude DCS

1959: Pfrommer's "Decompression Sickness: The State of the Art"

Decompression causes gas bubbles, fat emboli or vasospasm

Risk associations include obesity, age, fatty foods, alcohol, and hypoxia

Treatment: oxygen, vasopressor drugs, IV fluids and lumbar puncture

Recompression pressures of 3-5 atmospheres absolute has not been properly evaluated yet

- Dr. John R. Pfrommer Jr.
- June 9, 1922 - September 12, 2018

The rise of altitude DCS

1960: Donnell and Norton report 1942 case of neurocirculartory collapse DCS after recompression, but not published until 1958.

Precipitates hyperbaric chamber to support altitude/space research at Brooks AFB

1963: President Kennedy commissions the USAF School of Aerospace Medicine at Brooks AFB
https://www.youtube.com/watch?v=6DTX9OiKi9U

Altitude Decompression Symptoms

- Joint Pain – does not change due to palpation or movement
  - May change with pressure

Pathophysiology of DCS

- Mechanical effects of bubbles
  - Compress / distort surrounding structures
  - Block blood flow
  - Endothelial damage
- “Bio-chemical” effects of bubbles
  - PMN activation
  - Platelet aggregation
  - Complement activation
  - Coagulation induction
  - Release of vasoactive substances

Manifestations of DCS

- Skin Symptoms
  - Tingling
  - Rash
- Lymphedema
- Musculo-skeletal pain (Bends)

- Neurologic dysfunction
  - CNS
  - Peripheral nervous system
- Cardio-respiratory symptoms (Chokes)
- Cutis Marmorata

Onset of Symptoms

- Symptom onset
  - 50% report symptoms within 1 hour of decompression stress
  - 90% report symptoms within 6 hour of decompression stress
  - 99% report symptoms within 24 hour of decompression stress

  Symptom onset beyond 36 hours after decompression stress makes DCS an unlikely diagnosis

Manifestations of DCS

- Severe symptoms tend to present early in the course
- Cutaneous and lymphatic symptoms such as pruritis and edema are mild and do not require treatment *if found alone*
  - Exception is cutis marmorata
- Thorough physical exam – emphasis on neurological exam

Cutis Marmorata

Musculo-Skeletal Manifestations
Pain

- Most common symptom
- Present in about 90% of DCS cases
- Mainly involves large joints
- Mild to severe in intensity
- Thorough neurological exam important

Neurological Manifestations

- Numbness
  - Patchy
  - Peripheral nerve distribution
  - Dermatomal
- Weakness / paralysis
- Nystagmus
- Vertigo
- Dizziness
- Gait abnormality
- Romberg

- Headache
- Cranial nerve dysfunction
- Personality changes
- Delirium
- Altered consciousness
- Fatigue***
- General weakness / malaise***

Neurologic Exam is Key!

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 1 of 2)

(See text of Appendix 5A for examination procedures and definitions of terms.)

Patient's Name: _____ Date/Time: _____

Describe pain/numbness: _____

HISTORY

Type of dive last performed: _____ Depth: _____ How long: _____

Number of dives in last 24 hours: _____

Was symptom noticed before, during, or after the dive? _____

If during, was it while descending, on the bottom, or ascending? _____

Has symptom increased or decreased since it was first noticed? _____

Have any other symptoms occurred since the first one was noticed? _____

Describe: _____

Has patient ever had a similar symptom before? _____ When: _____

Has patient ever had decompression sickness or an air embolism before? _____ When: _____

MENTAL STATUS/STATE OF CONSCIOUSNESS

COORDINATION

Walk: _____
Heel-to-Toe: _____
Romberg: _____
Finger-to-Nose: _____
Heel-Shin Slide: _____
Rapid Movement: _____

CRANIAL NERVES

Sense of Smell: (I): _____
Vision/Visual Fld (II): _____
Eye Movements, Pupils (III, IV, VI): _____
Facial Sensation, Chewing (V): _____
Facial Expression Muscles (VII): _____
Hearing (VIII): _____
Upper Mouth, Throat Sensation (IX): _____
Gag & Voice (X): _____
Shoulder Shrug (XI): _____
Tongue (XII): _____

STRENGTH (Grade 0 to 5)

Upper Body

Deltoids	L _____	R _____
Latissimus	L _____	R _____
Biceps	L _____	R _____
Triceps	L _____	R _____
Forearms	L _____	R _____
Hands	L _____	R _____

Lower Body

Hips

Flexion	L _____	R _____
Extension	L _____	R _____
Abduction	L _____	R _____
Adduction	L _____	R _____

Knees

Flexion	L _____	R _____
Extension	L _____	R _____

Figure 5A-1a. Neurological Examination Checklist (sheet 1 of 2).

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 2 of 2)

REFLEXES

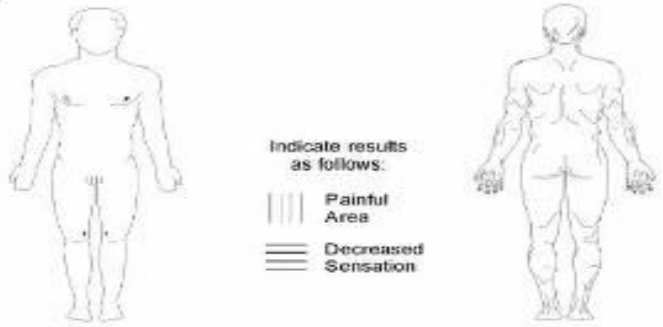
(Grade: Normal, Hypoactive, Hyperactive, Absent

Biceps	L _____ R _____	**Ankles**	
Triceps	L _____ R _____	Dorsiflexion	L _____ R _____
Knees	L _____ R _____	Plantarflexion	L _____ R _____
Ankles	L _____ R _____	**Toes**	L _____ R _____

Sensory Examination for Skin Sensation

(Use diagram to record location of sensory abnormalities – numbness, tingling, etc.)

LOCATION



COMMENTS

_____

_____

_____

_____

_____

_____

_____

_____

Examination Performed by: _____

Figure 5A-1b. Neurological Examination Checklist (sheet 2 of 2).

Diagnosis of DCS
“The Bottom Line”

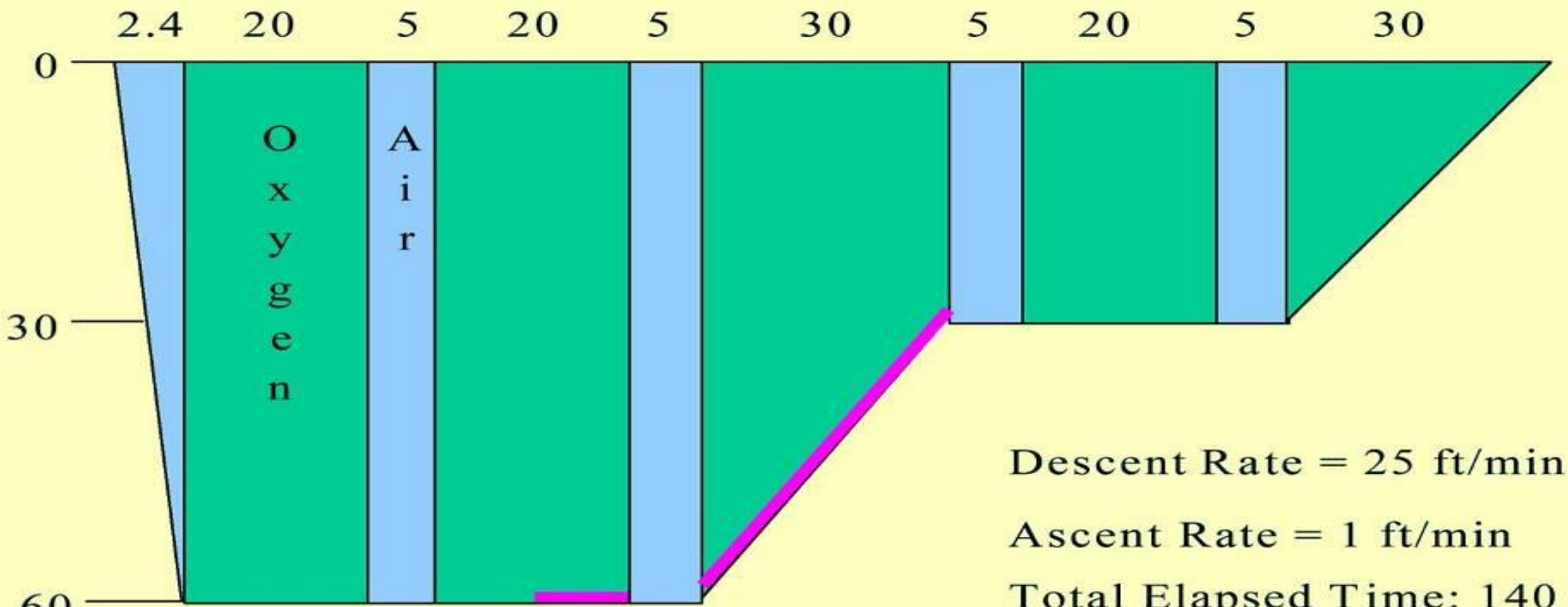
- **Requires** a decompression stress
  - From diving or altitude exposure
- Signs and symptoms consistent with DCS
  - Can be almost any unexplained sign/symptom
  - Generally appears within 24 hours

Err on the conservative side. DCS is a “fuzzy” diagnosis at times and we tend to over-diagnose and treat.

Treatment Table 5

- Only used for Type 1 DCS (mild DCS)
- Continue with TT 5 ONLY if 100% symptom resolution within 10 minutes of achieving treatment depth (60 fsw)
  - Switch to TT 6 if failure to achieve 100% resolution within 10 minutes
  - May utilize up to two additional 20 minute oxygen breathing periods at 30 feet

USAF Table 5



IO breathes O_2

Descent Rate = 25 ft/min

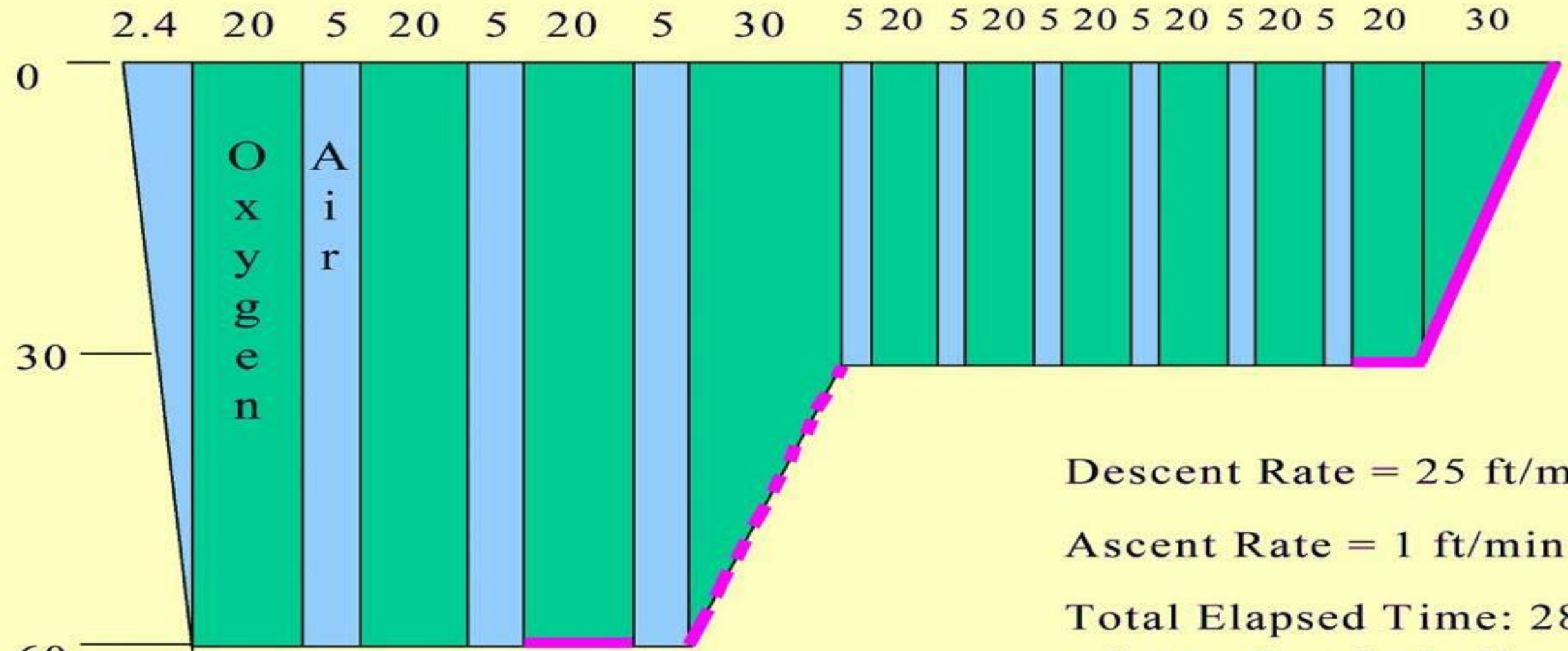
Ascent Rate = 1 ft/min

Total Elapsed Time: 140 minutes (not including descent time)

Treatment Table 6

- May be used for Type 1 or Type 2 DCS
- Mandatory if:
  - TT 5 fails in the treatment of Type 1 DCS
  - Type 2 DCS – neurological and chokes
  - AGE
- May extend with 2 additional oxygen breathing periods at 60 fsw and 2 additional hours at 30 fsw

USAF Table 6



Descent Rate = 25 ft/min

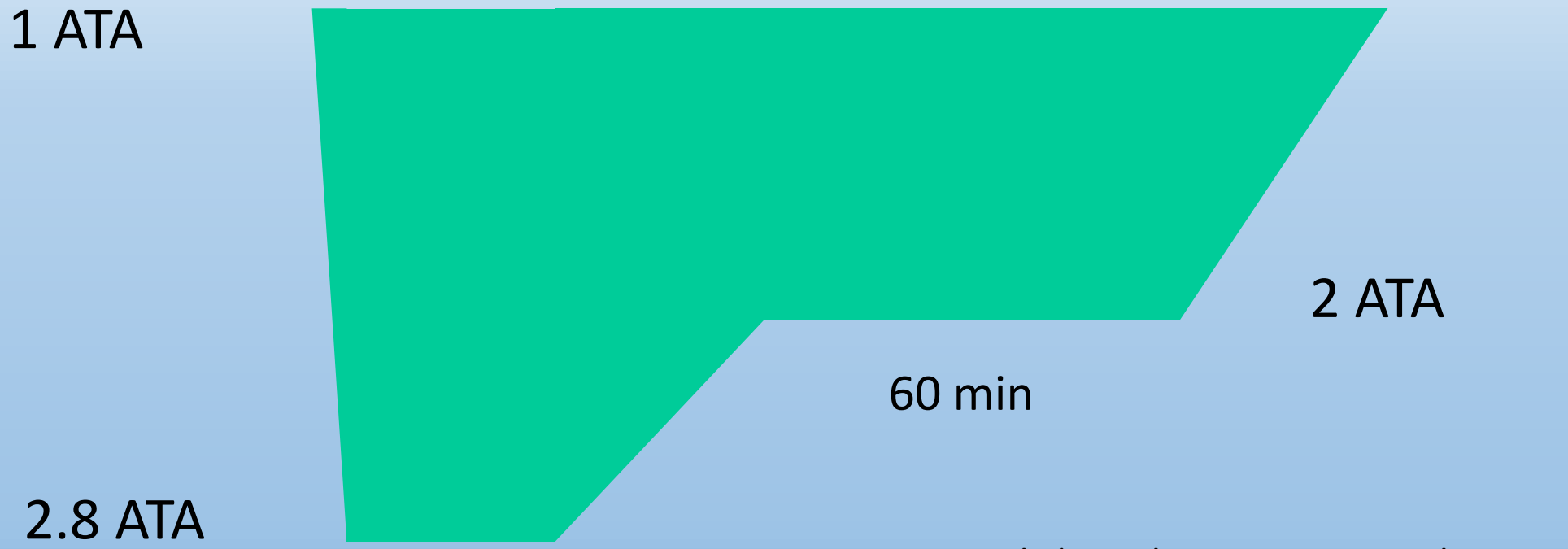
Ascent Rate = 1 ft/min

Total Elapsed Time: 285 minutes (not including descent time)

USN TT Alternatives

- Hart / Kindwall Monoplace Treatment Tables
  - No air breaks
  - Shorter in duration
  - Retrospective evidence suggests efficacy similar to USN TT for mild to moderate DCS
    - Cianci P, Slade JB. Delayed Treatment of Decompression Sickness with, No-Air-Break Tables: Review of 140 Cases. Aviat Space Environ Med 2006; 1003 - 1008

Hart – Kindwall Table



Total elapsed time: 150 min + descent
All ascents at 1 ft / min
UDPT = 402

Treatment Endpoints

- Complete resolution of symptoms or plateau of resolution
- Follow-on or “tailing” dives may be either TT 5, TT 6, or standard wound care dives depending on severity of symptoms
  - Frequency of dives *may* be limited by pulmonary oxygen toxicity
- Most resolve with the initial treatment dive. Typically 1-3 treatment dives for DCS or AGE
- Utilization review per UHMS guidelines at 10 treatment dives

Is it ever too late to treat?

- No

Questions?