Prehospital Care of Patients with Diving Accidents and Emergencies

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1

Guadalupe Island, Mexico
October 2021

2

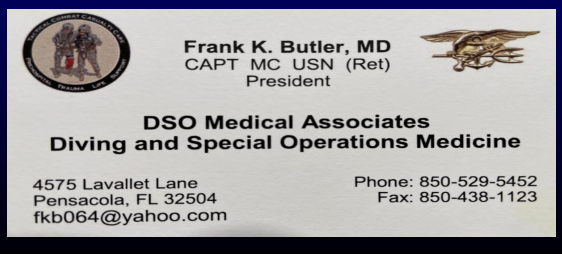
Thanks to:

- WTS: Dr. Dorlac and Dr. Morgan
- Dr. Jim Chimiak – Divers Alert Network
- Dr. Bob Mabry – Emergency Medicine
- Mr. Scotty Bsolleter – Paramedic

3

Disclosure

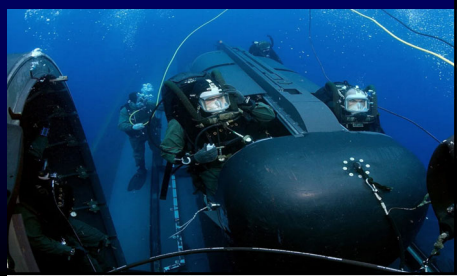
- DSO Medical Associates
- Consult on medicolegal cases involving serious injury or death that result from scuba diving



4

Let's Define "Diving"

- Shallow-water diving with possible neck injury
- Breath-hold Diving
- Technical (rebreather diving)
- Saturation diving
- Recreational SCUBA diving



5

EMS Entry – Life Flight or Ground Ambulance

- Air medical crew: Nurse + Paramedic
- Ground Crew: 2 Paramedics (or 1 PM + 1 EMT)
- Level of dive medicine training?

6

Scuba Diving-Related Injuries

- Water in the Lung Disease
  - Drowning
  - Swimming-Induced Pulmonary Edema
- Bubble Disease
  - Arterial Gas Embolism
  - Decompression Sickness
- Trauma
  - Boat prop injuries
  - Shark bites

7

Scuba Diving Fatalities

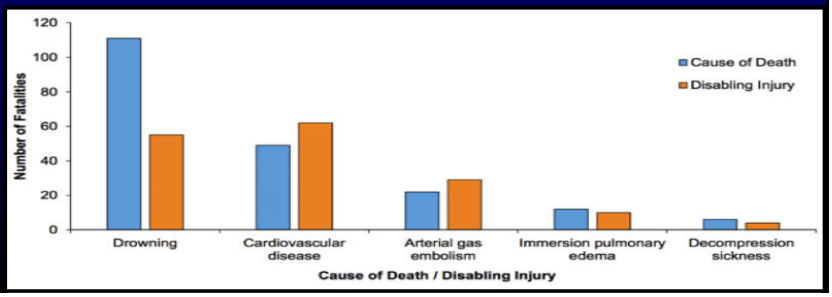
What is the #1 cause of scuba diving fatalities ?

8

Drowning

- Overweighted
- Cardiac event
- Entanglement
- Diving injury
- Trauma
- Panic

Divers Alert Network
Annual Dive Report
2015



9

DAN Case Report 5593

- 51 y/o male
- Surfaced after second dive of the day
- Immediately developed difficulty with buoyancy and sank
- Body recovered on bottom
- 28 pound weight belt not removed
- Buoyancy compensator vest inflator hose not connected

10

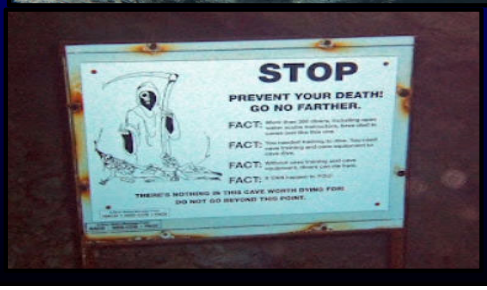
DAN Case Report 1293

- 50 y/o male
- 30 FSW for 24 minute dive
- Rough seas with 2 knot (mph) current
- Surfaced 100 yards downcurrent
- Became unconscious trying to swim to boat
- Drowned
- Lessons learned:
  - Don't swim against a strong current
  - If in trouble on the surface: Inflate your bouyancy compensator, drop your weights, relax, and signal the boat

11

Case Report 1978

- Cave dive - Morrison Springs, FL
- Sign: "Warning – 22 divers have lost their lives diving this cave. Will you be the next?"
- "22" changed to "23" by hand….
- Woman had dove there yesterday
- Remembered to use a caving line
- Forgot to bring a knife or shears
- Became entangled – drowned
- Also – fishing line



12

Entanglement: Trauma Shears

Don't leave the surface without them!

13

Management of Near-Drowning: Szpilman – Chest - 2021

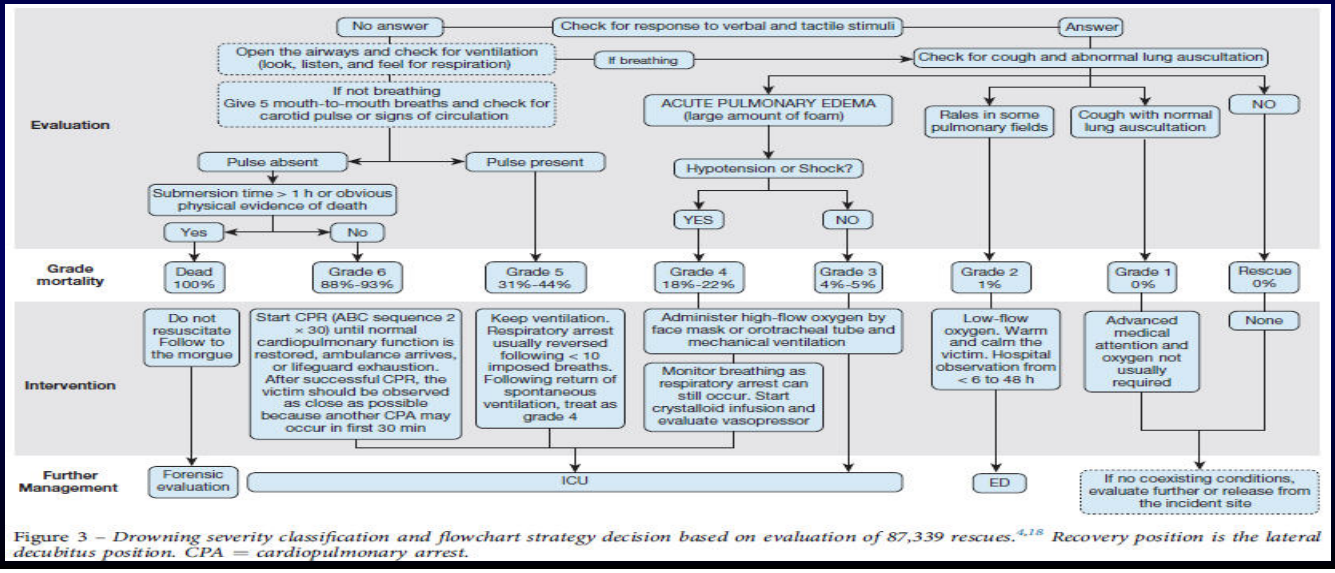


Figure 3 – *Drowning severity classification and flowchart strategy decision based on evaluation of 87,339 rescues.*[4,18] *Recovery position is the lateral decubitus position. CPA = cardiopulmonary arrest.*

14

Management of Near-Drowning Patients – The Short Version

- Pulse ox; cardiac monitor; be alert for emesis
- Secure the airway if unconscious
- Supplemental oxygen
  - Target O2 saturation 90% or higher
  - Prevent hypoxic cardiac arrest
- No Heimlich maneuver
- Rescue position if unconscious
- Aggressive resuscitation of cold-water drowning patients, especially children

15

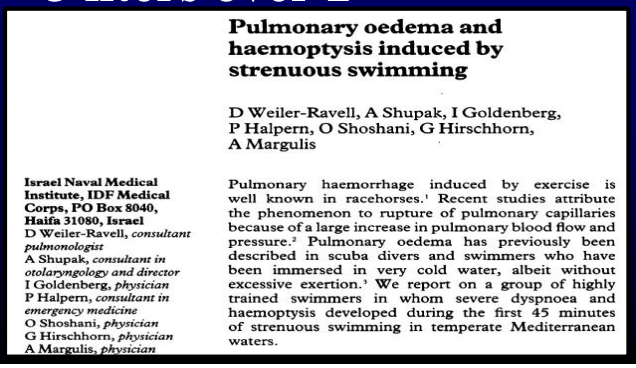
Swimming-Induced Pulmonary Edema (SIPE)

- Immersion causes redistribution of blood to the central circulation; endogenous fluid challenge
- Overhydration may predispose to SIPE
- Cold-induced peripheral vasoconstriction may accentuate
- S/S: 1) Respiratory distress – coughing + dyspnea
  2) Frothy sputum
  3) Hypoxemia
  4) S/S occur while immersed

16

Israeli SEALs
Weiler-Ravel – BMJ - 1995

- 30 very fit combat swimmers
- 2.4 km surface swim - 23 degree C water
- Forced hydration pre-swim – 5 liters over 2 hours
- 8 of the swimmers developed SIPE within 45 minutes



Pulmonary oedema and haemoptysis induced by strenuous swimming

D Weiler-Ravell, A Shupak, I Goldenberg, P Halpern, O Shoshani, G Hirschhorn, A Margulis

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G Hirschhorn, *physician*
A Margulis, *physician*

Pulmonary haemorrhage induced by exercise is well known in racehorses.[1] Recent studies attribute the phenomenon to rupture of pulmonary capillaries because of a large increase in pulmonary blood flow and pressure.[2] Pulmonary oedema has previously been described in scuba divers and swimmers who have been immersed in very cold water, albeit without excessive exertion.[3] We report on a group of highly trained swimmers in whom severe dyspnoea and haemoptysis developed during the first 45 minutes of strenuous swimming in temperate Mediterranean waters.

17

Management of Swimming-Induced Pulmonary Edema

- Treatment
  - Get them out of the water!
  - No recompression therapy
  - Supplemental oxygen – target O2 sat 90% or higher
  - Don't be in a hurry to start fluids
  - Transport to ED

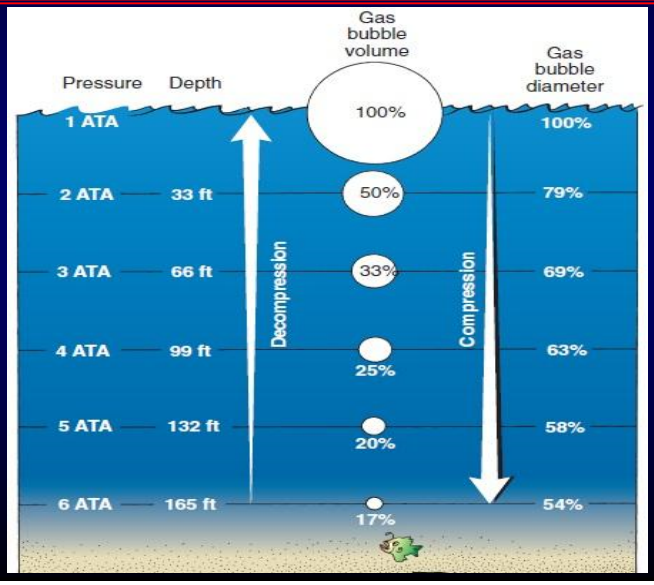
18

Bubble Disease:

Arterial Gas Embolism (AGE)
and
Decompression Sickness (DCS)

19

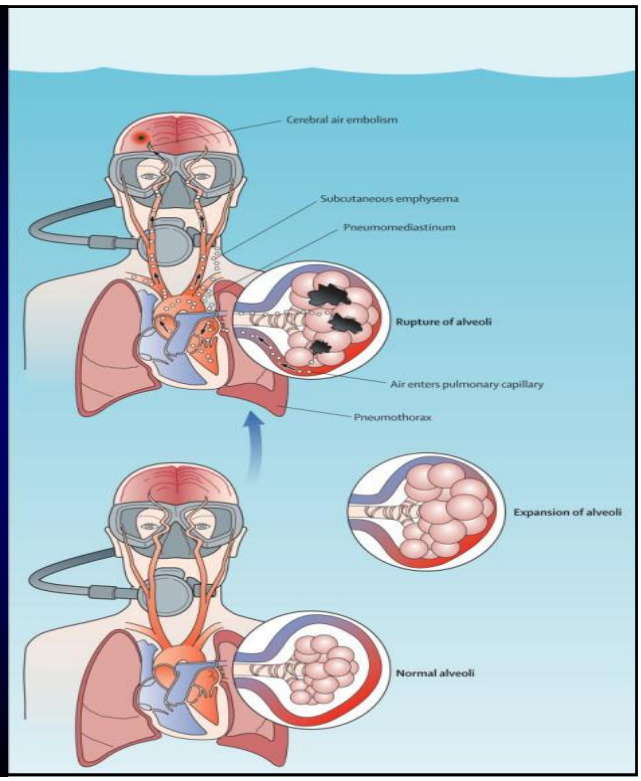
Boyle's Law
P1V1 = P2V2



20

Pulmonary Barotrauma

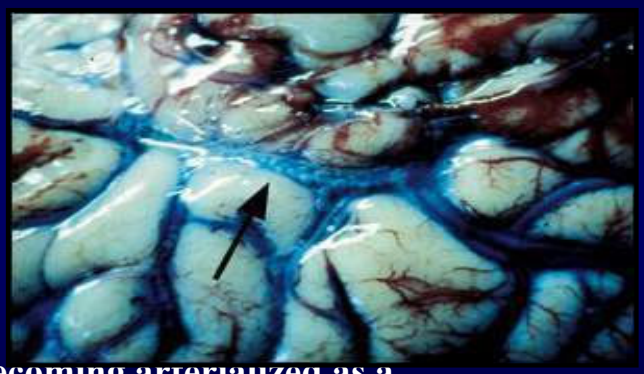
- Air unable to leave lungs as pressure decreases on ascent
- Expands as pressure drops
- Ruptures the alveoli
- Air enters pulmonary venous circulation
- To left heart
- Then systemic circulation



21

Arterial Gas Embolism (AGE)

- Breath-holding on ascent
  - Panic ascent
    - Out of air
    - Trauma
    - Shark encounter
  - Lung pathologies

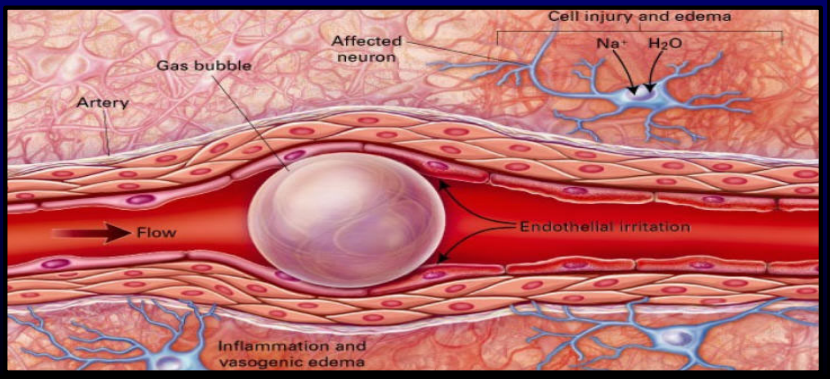


- May also result from venous bubbles becoming arterialized as a result of a Patent Foramen Ovale
- May also be iatrogenic

22

Arterial Gas Embolism (AGE)

- Similar to stroke
- Sudden loss of consciousness after surfacing
- Confusion, altered state of consciousness
- Hemiparesis
- Vision loss



23

Arterial Gas Embolism (AGE)

- 41 y/o male physician
- H/O childhood asthma
- Uses inhaler with URIs only (about twice a year)
- 87 feet for 15 minutes dive
- Using Suunto Guardian dive computer
- Unhurried, normal ascent
- Took a 3-minute safety stop at 15 feet

24

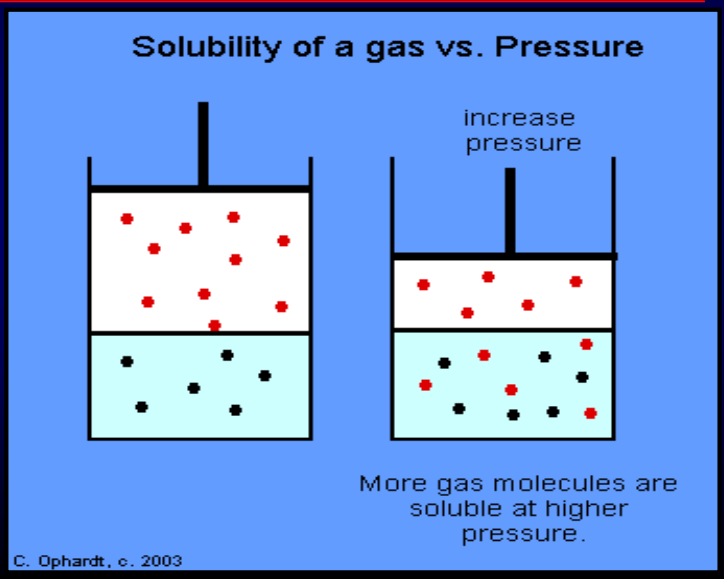
Arterial Gas Embolism (AGE)

- Onset of S/S 1 minute after surfacing
- Trying to take regulator off tank – could not raise either arm
- Progressed to inability to stand or speak
- No chest pain, dyspnea, bloody sputum
- No LOC
- Dx? Rx?

25

Decompression Sickness Henry's Law (1)

The quantity of gas which will dissolve in a liquid at a given temperature is proportional to the partial pressure of gas in contact with the liquid.



26

Decompression Sickness
Henry's Law (2)

How much nitrogen is dissolved in the tissues of the body at 1 atmosphere?

27

Henry's Law (3)

How much gas is dissolved in a diver who is "saturated" at 33 FSW? 66 FSW?

28

Decompression Sickness (DCS)

- 66 foot dive = 3 ATA
- Gas in solution triples – if you stay for 12 hours
- Supersaturation = more gas present than can stay dissolved at that pressure
- At some level, this can create bubbles – in venous system and body tissues
- Have to stay for a limited period (60 minutes) – or do decompression stops on the way up

29

Excess Gas in Tissues

- Come up slowly - gas removed by lungs
- Come up quickly - bubbles form in tissues and venous circulation

30

Gas Bubbles in Venous Blood

31

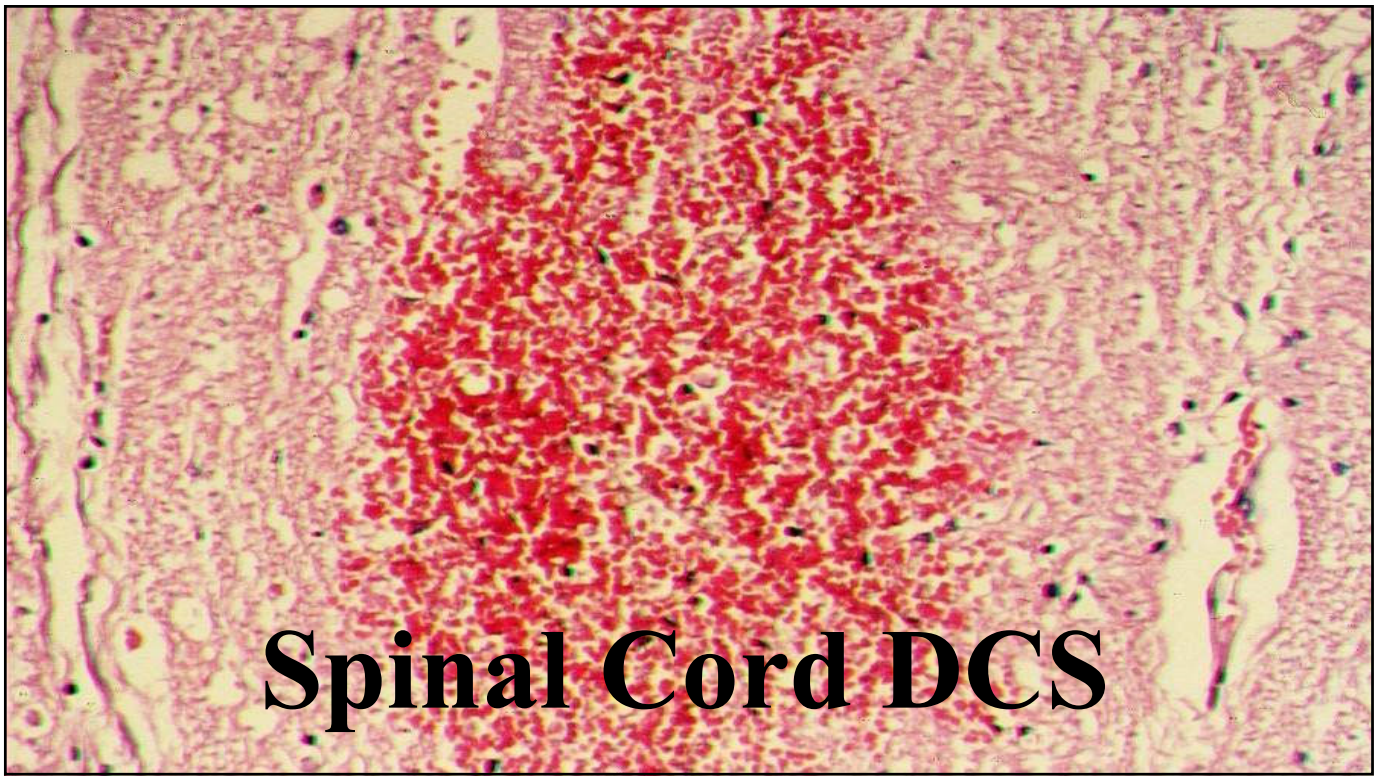
Signs/Symptoms of Decompression Sickness (DCS)

- Very variable presentations
- The two classic symptom patterns:
  - Severe joint pain
  - Paraparesis/paraplegia
- LOC; altered mental status; other neuro symptoms
- Non-painful, non-pruritic skin rash
- Cardiopulmonary symptoms
- Inner ear symptoms: Vertigo, nausea, hearing loss
- Serious symptoms often progress

32

Decompression Sickness Affecting the Joints

33



34

Navy Experimental Diving Unit Case Report: 1984

- 30 y/o NEDU diver
- Experimental 130 FSW No-D ft HeO2 profile
- Brought into sick bay by his buddy because he couldn't remember where the bathroom was (he worked in the building)
- No pain; no motor or sensory deficits
- Oriented to place and person

35

NEDU Case Report (cont)

- Remembered wife's name but not his dog's
- Didn't know state, year or president
- Didn't know the name of the friend who brought him in
- Dx?
- Rx?

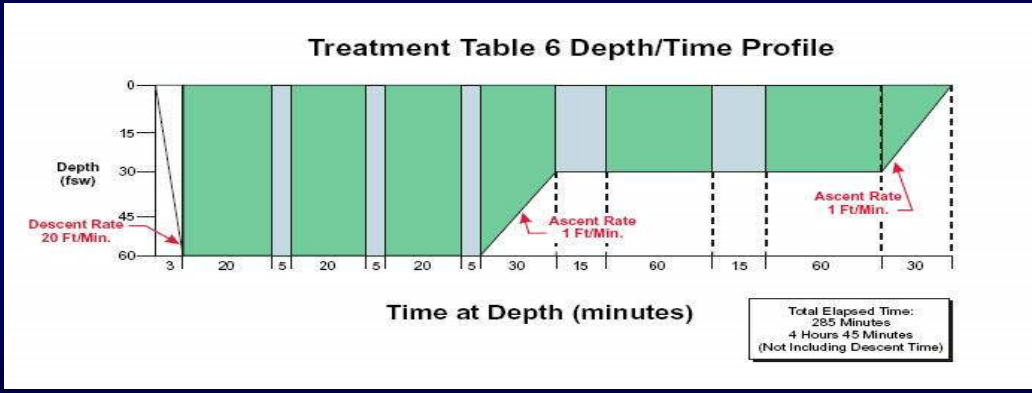
36

Prehospital Treatment of DCS + AGE

- Administer oxygen at highest possible FIO2
  - Goal is to maximize the "Oxygen Window"
  - Accelerate resolution of bubbles
- Position: Supine or rescue
- Initiate procedure for emergent recompression with HBO2
- Lidocaine for AGE?
- Fluids?
- NSAIDs?

37

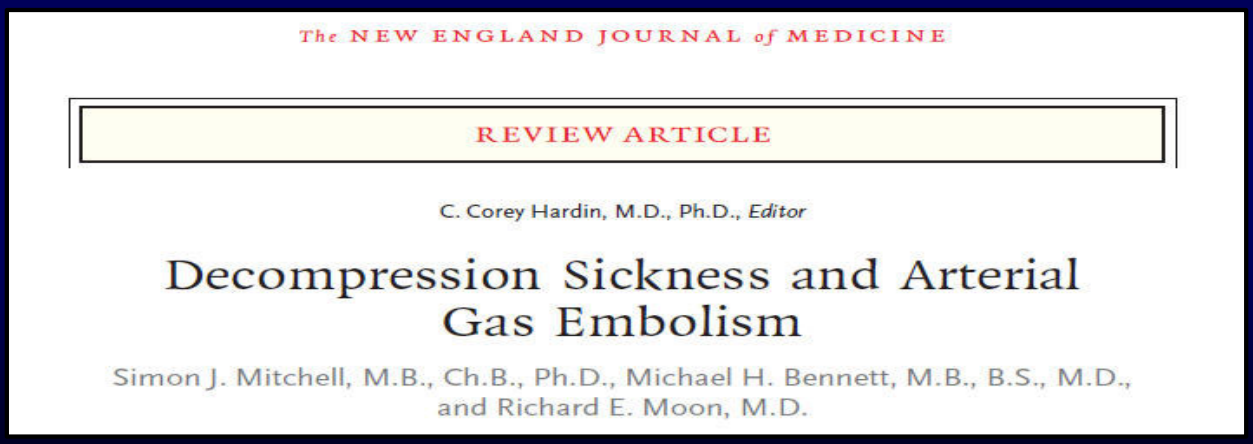
Treatment of DCS : Hyperbaric Oxygen



- Start at 60 FSW on 100% O2 - DMO has option to go to 165 FSW early if patient not doing well

38

Treatment of DCS + AGE NEJM 2022



The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

C. Corey Hardin, M.D., Ph.D., *Editor*

Decompression Sickness and Arterial Gas Embolism

Simon J. Mitchell, M.B., Ch.B., Ph.D., Michael H. Bennett, M.B., B.S., M.D., and Richard E. Moon, M.D.

39

DCS/ AGE Pearls

- When in doubt, recompress
- Not all hospitals have recompression chambers
- Not all hospitals with chambers will accept diving emergency patients
- Delays to recompression worsen outcomes
- Divers Alert Network: **919-684-9111**

40

Trauma: Boat Prop Injuries

Prop awareness while diving!

41

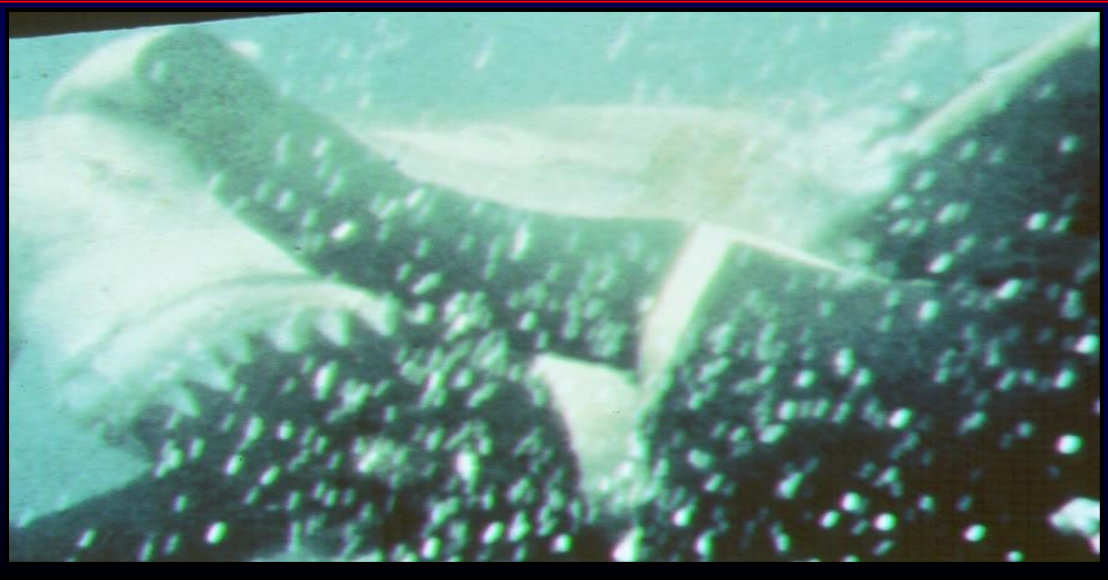
Prehospital Trauma Management: Boat Prop Injuries

- Sacramento, CA - 2003
- 38 y/o mother of three
- Severe thigh bleeding from prop injury
- Bystander - Army medic – applied a tourniquet
- Bleeding controlled – patient alert
- EMS arrived – and removed the tourniquet
- Patient bled to death in transit to hospital

Butler + Holcomb
Wall St Journal OpEd 2020

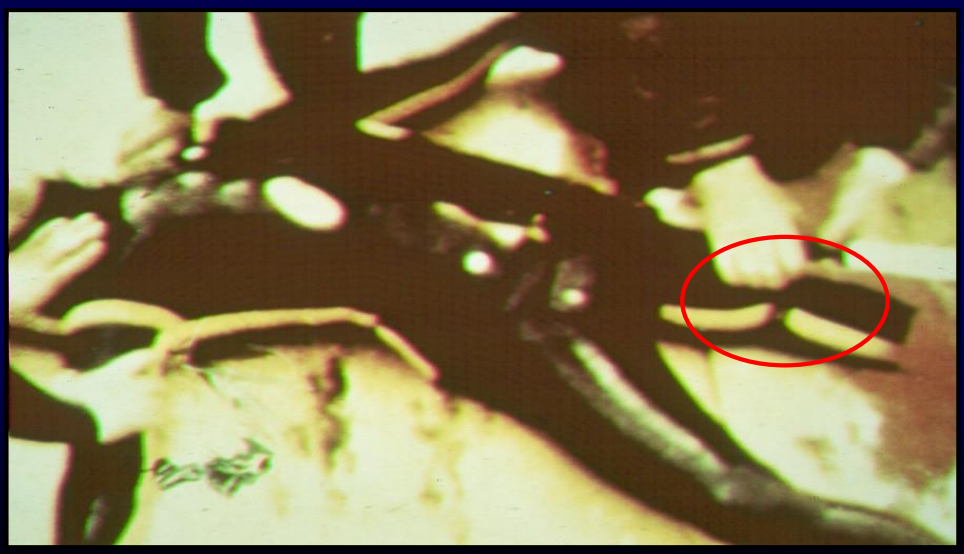
42

Shark Bites: Uncommon - But Do Happen



43

Management of Diving-Related Trauma



44

Final Thought on Tourniquets

When the U.S went to war in Afghanistan in 2001, almost no one in the U.S. military carried a tourniquet.

By 2015, no American service man or woman stepped onto a battlefield without one.

45

Tourniquets and Hemostatic Dressings

American College of Surgeons and White House *Stop the Bleed* program

46

Questions?

47