UHMS Plenary Session: Undersea and Diving Medicine Updates

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Disclaimer...

- “The literature is immense and my time is short... so, in choosing a few articles to review here does not do this ocean of published literature justice... but, hopefully, I’ll show you the whales in this ocean... and maybe even their planned course...”

  ~Davut Savaser, MD MPH

Anyone Know What Nationality My Name Originates From...?

“Davut Savaser”

Undersea Hyperb Med. 2013 Jan-Feb;40(1):63-7.

Development of underwater and hyperbaric medicine as a medical specialty in Turkey.

Aktaş S, Toklu AS, Yildiz S, Uzun G.

Department of Underwater and Hyperbaric Medicine, Istanbul University, Istanbul Faculty of Medicine, Capa, Istanbul, Turkey. saktas@istanbul.edu.tr

Abstract

Underwater and hyperbaric medicine focuses on diving physiology, prevention and treatment of health problems related to the exposure to high ambient pressure and therapeutic use of hyperbaric oxygen for several medical conditions. Adequate educational standards should be developed for physicians working in the field of underwater and hyperbaric medicine. In Turkey, underwater and hyperbaric medicine is one of the medical specialties. The history of underwater and hyperbaric medicine as a medical specialty is dated back to the 1960s. In this paper, we review standards and the development of underwater and hyperbaric medicine as a medical specialty in Turkey.

PMID: 23397869 [PubMed - indexed for MEDLINE]

Table 1. Indications of hyperbaric oxygen therapy covered by the Social Security Institution of Turkey

Indication	Initial treatment	Maximum treatment
1. Decompression illness	20	40
2. Air or gas embolism	20	40
3. Carbon monoxide, cyanide poisoning, acute smoke inhalation	5	30
4. Gas gangrene	10	50
5. Necrotizing soft tissue infections	20	50
6. Crush injuries, compartment syndrome, other acute traumatic ischemia	20	50
7. Chronic wounds	30	60
8. Chronic refractory osteomyelitis	40	80
9. Radiation necrosis	30	60
10. Compromised skin flaps and grafts	20	30
11. Thermal burns	20	30
12. Brain abscess	20	40
13. Anoxic encephalopathy	20	50
14. Sudden hearing loss	20	40
15. Retinal artery occlusion	20	40
16. Acute osteomyelitis of skull, sternum and vertebrae	40	80
17. Idiopathic avascular necrosis of the bone	30	60

FIGURE 1. Distribution of hyperbaric centers in Turkey

(■) hyperbaric center in a state/military hospital, (★) private hyperbaric center, (▲) hyperbaric center in a university hosptial, (□) hyperbaric centers planned to be established in near future. Turkey map was downloaded from www.d-maps.com [8]

Potential Logo...

UNDERSEA & HYPERBARIC MEDICAL SOCIETY

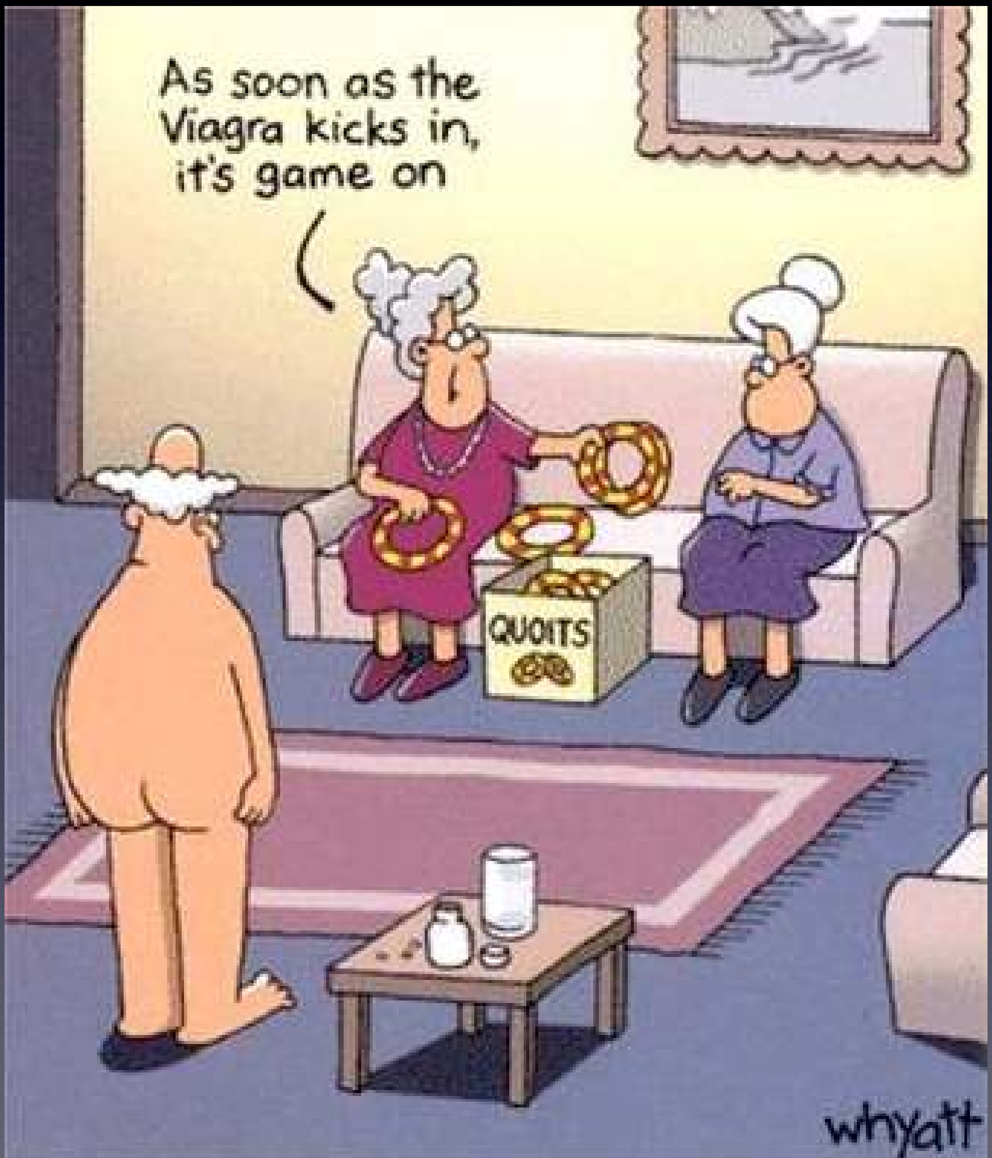
UNDERSEA & HYPERBARIC MEDICAL SOCIETY

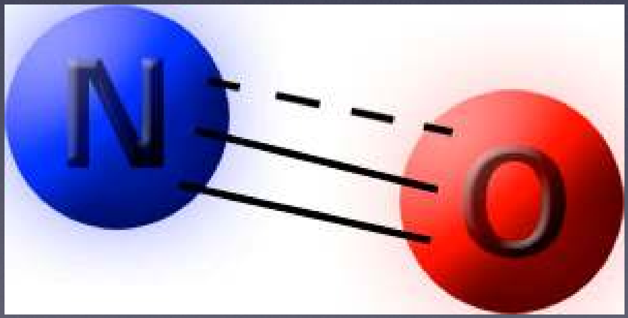
CANADIAN CHAPTER - CHAPITRE CANADIEN

UNDERSEA & HYPERBARIC MEDICAL SOCIETY

What do micro-particles, Viagra, breath-hold diving and SCUBA diving all have in common?

Nitric Oxide (NO)!





Looking at NO...

UHM 2013, VOL. 40, NO. 2 – ENDOTHELIAL FUNCTION IN SCUBA AND BREATH-HOLD DIVING

Nitric oxide-related endothelial changes in breath-hold and scuba divers

S. Theunissen [1,2], *F. Guerrero* [2], *N. Sponsiello* [1,3,4], *D. Cialoni* [1,3,4], *M. Pieri* [3], *P. Germonpré* [1,5], *G. Obeid* [5], *F. Tillmans* [1], *V. Papadopoulou* [1,6], *W. Hemelryck* [1], *A. Marroni* [3], *D. De Bels* [1,7], *C. Balestra* [1,3,4]

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[2] Université de Bretagne Occidentale, UFR Sciences et Techniques, Brest, France;

[3] DAN Europe Research, Brussels, Belgium;

[4] DAN Europe, Apnea Task Force, Roseto, Italy;

[5] Center for Hyperbaric Oxygen Therapy, Military Hospital Queen Astrid, Brussels, Belgium;

[6] Department of Bioengineering, Imperial College London, London, UK;

[7] Intensive Care Department, Brugmann University Hospital, Brussels, Belgium

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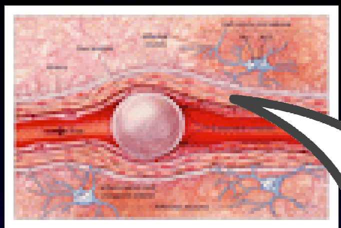
Background

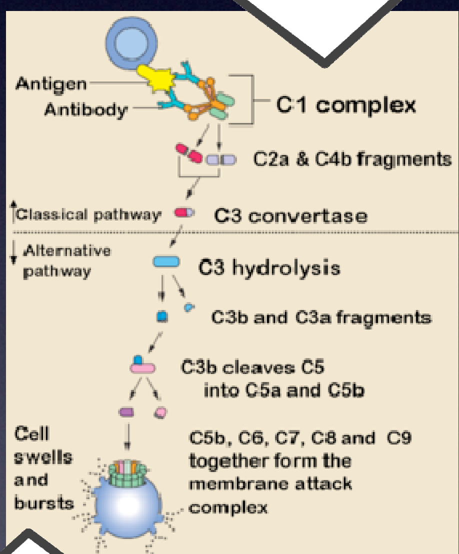
- Prior studies have shown that SCUBA diving is associated with:
    - increased pulmonary artery pressure (PAP)
    - reduced cardiac output (CO)
    - right ventricular overload and impaired left ventricular (LV) diastolic performance
    - **impaired arterial endothelial function and enhanced oxidative stress*****
- Most above changes are still present after dive completion

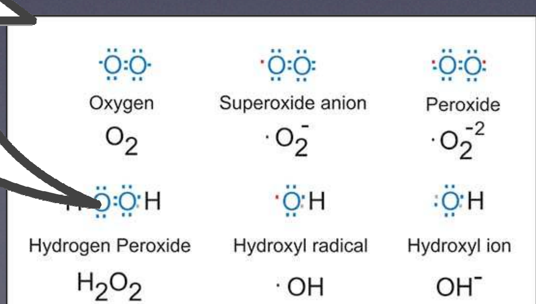
Background

- On the contrary, BH-diving:
  - O_2 partial pressure increases during deep portion of dive (limited time)
  - Associated with transient hyperoxia followed by build-up of CO_2, and then hypoxia as they surface
  - Also associated with chest wall compression and significant hemodynamic changes

Hypotheses to Suggest Endothelial Dysfunction







- Hypothesis #1: Venous gas emboli (VGE) formation acting on endothelial cells, and act as foreign bodies, in turn, activating the complement pathway which leads to endothelial damage
- Hypothesis #2: Presence of reactive oxygen species (ROS) affects endothelium related to increased O2 partial pressure
- ***Common denominator***: Each hypothesis/theory has an effect on endothelial function

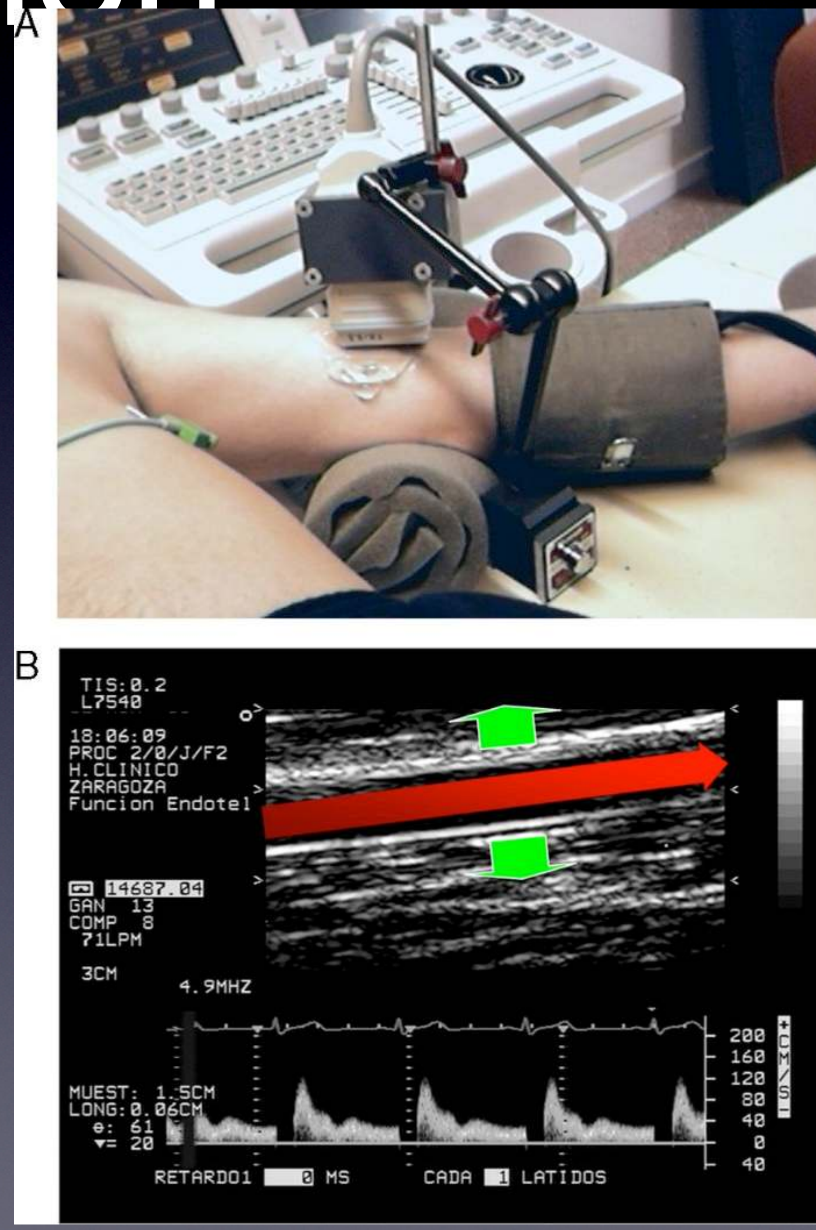
Purpose of the Study

- Scuba and Breath-hold divers are compared to investigate whether endothelial response changes are similar despite different exposures

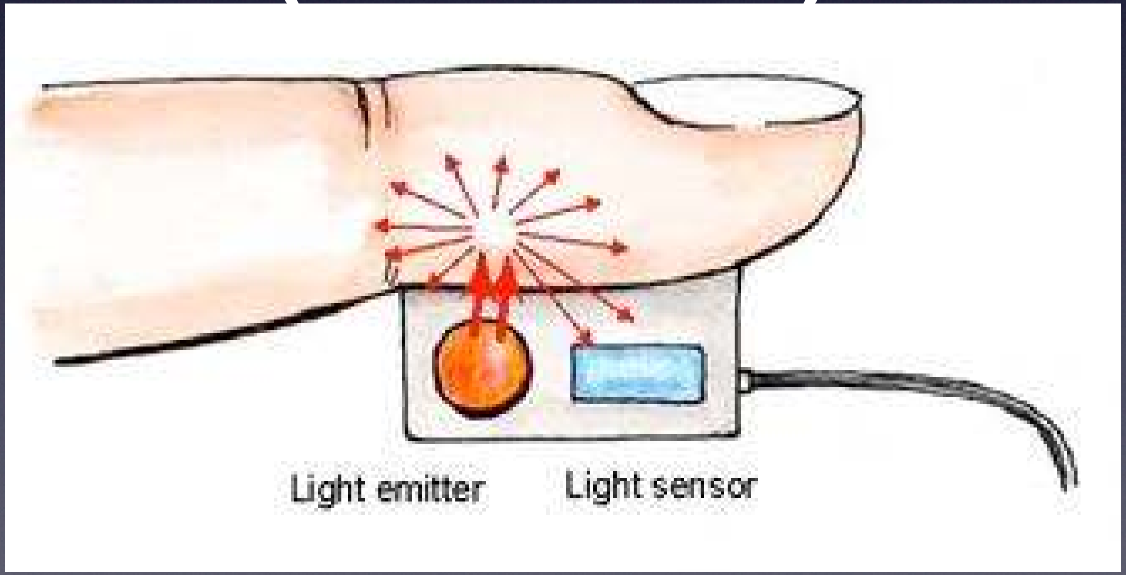
Methods

- 14 divers [9 SCUBA, 5 breath-hold (BH)]
- SCUBA - 25 meters (~82 fsw) for 00:25
- BH dive - 20 meters (~65 fsw) for total immersion time of 25 minutes in dive pool (on avg ~10 dives)
- Flow-mediated dilation (FMD) measured via echography of the brachial artery
- Peripheral post-occlusion reactive hyperemia (PORH) via digital plethysmography
- Plasma nitric oxide (NO) concentration

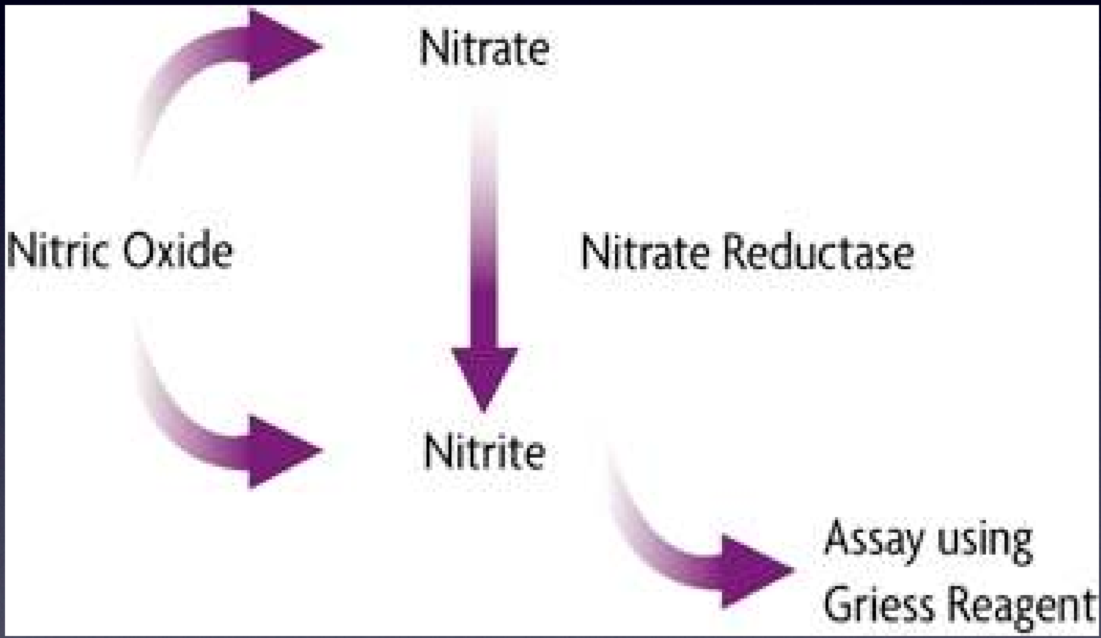
Flow-Mediated Dilation



Digital Plethysmography Post-Occlusive Reactive Hyperemia (PORH)

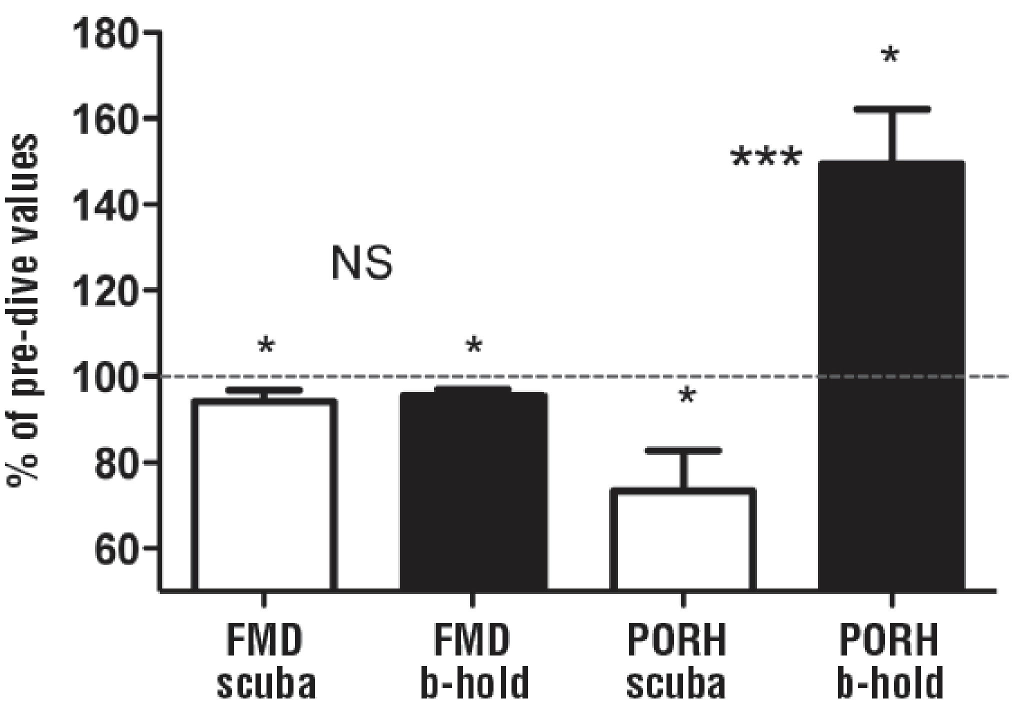


Nitric Oxide Assay Kit



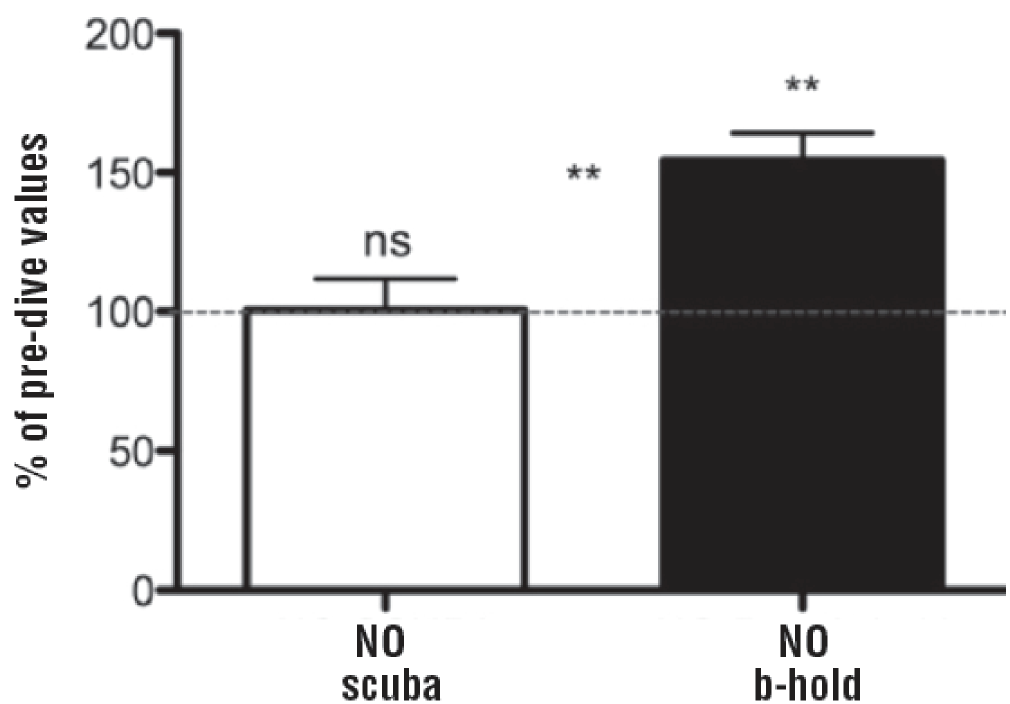
Figures 1 & 2

FIGURE 1 – FMD and PORH before and after diving



Flow-mediated dilation (FMD) and post-occlusion reactive hyperemia (PORH) before and after diving.
Results are shown in percentages of pre-dive values
(* $p<0.05$; ** $p<0.01$; *** $p<0.001$).

FIGURE 2 – NO after BH or scuba



Evolution of circulating nitric oxide (NO) after breath-hold ($n = 5$) or scuba ($n = 9$) diving.
Results are shown in percentages of NO pre dive values
(* $p<0.05$; ** $p<0.01$; *** $p<0.001$).

Results

- No significant difference in Table 1 statistics (i.e. anthropometric data between groups)

	Scuba	Breath-hold
Flow-Mediated Dilation	↓	↓
PORH	↓	↑
[NO]	---	↑

Conclusions

- FMD decreased in both groups secondary to induction of oxidative stress and reduction of available NO at the level of smooth vascular muscle
- Increase in NO in BH group was secondary to ***increased physical exertion*** in BH diver vs SCUBA group
- The reduction of bioavailable NO seems to be due to the transient hyperoxia on descent and hypoxia on ascent for BH diving

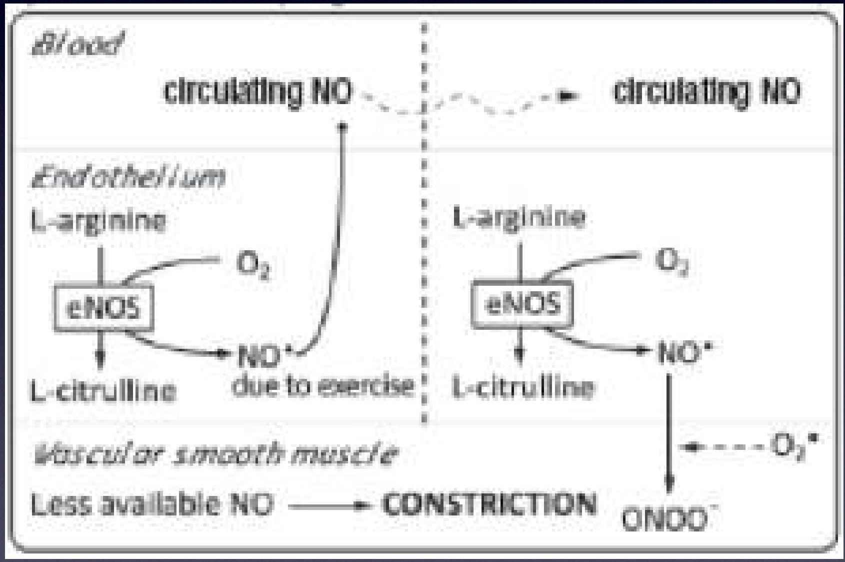
Theories Behind Findings

- Hyperoxia induces vasoconstriction because oxidative stress has been evoked; increase in ppO2 induces oxidative stress

- Hyperoxia also enhances production rate of anion superoxide, a powerful reactive oxygen species, which interacts with NO, leading to its destruction and production of peroxinitrite (OONO-)

- ROS scavenge NO but also decrease NO bioavailability and also oxidize tetrabiopterin (BH4), a co-factor of eNOS, to dihydrobiopterin (BH2); also downregulate eNOS itself

- This will lead to decreased NO-mediated vasodilation and, therefore, decreased FMD, and increased endohelial dysfunction




NOAA
Physicians Training in
Diving Medicine
AUG 6-17, 2012

Teleconference Case

It All Started With A Dive
Case presenting with Abdominal Pain

Case Report

CT finding of VGE in the portal veins and IVC in a diver with abdominal pain: A Case Report.

Submitted 2/22/07; Accepted 6/26/07

N. BIRD

Hyperbaric Medicine Fellow; University of California at San Diego, Department of Hyperbaric Medicine

Additional Case Series

The Journal of Emergency Medicine, Vol. ■, No. ■, pp. 1–5, 2013

0736-4679/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.jemermed.2012.11.039

Clinical Communications: Adults

PORTAL VENOUS GAS ON COMPUTED TOMOGRAPHY IMAGING IN PATIENTS WITH DECOMPRESSION SICKNESS

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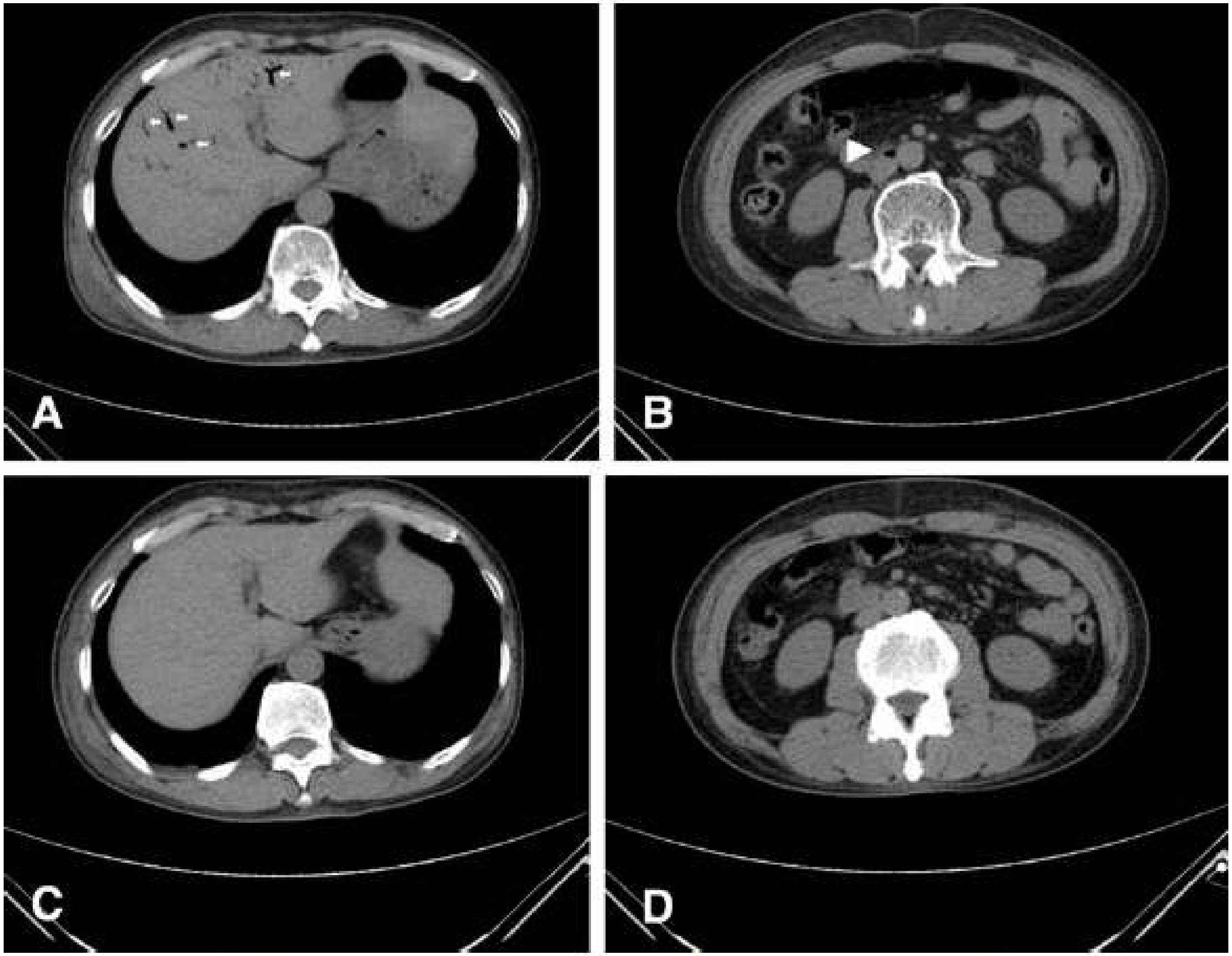
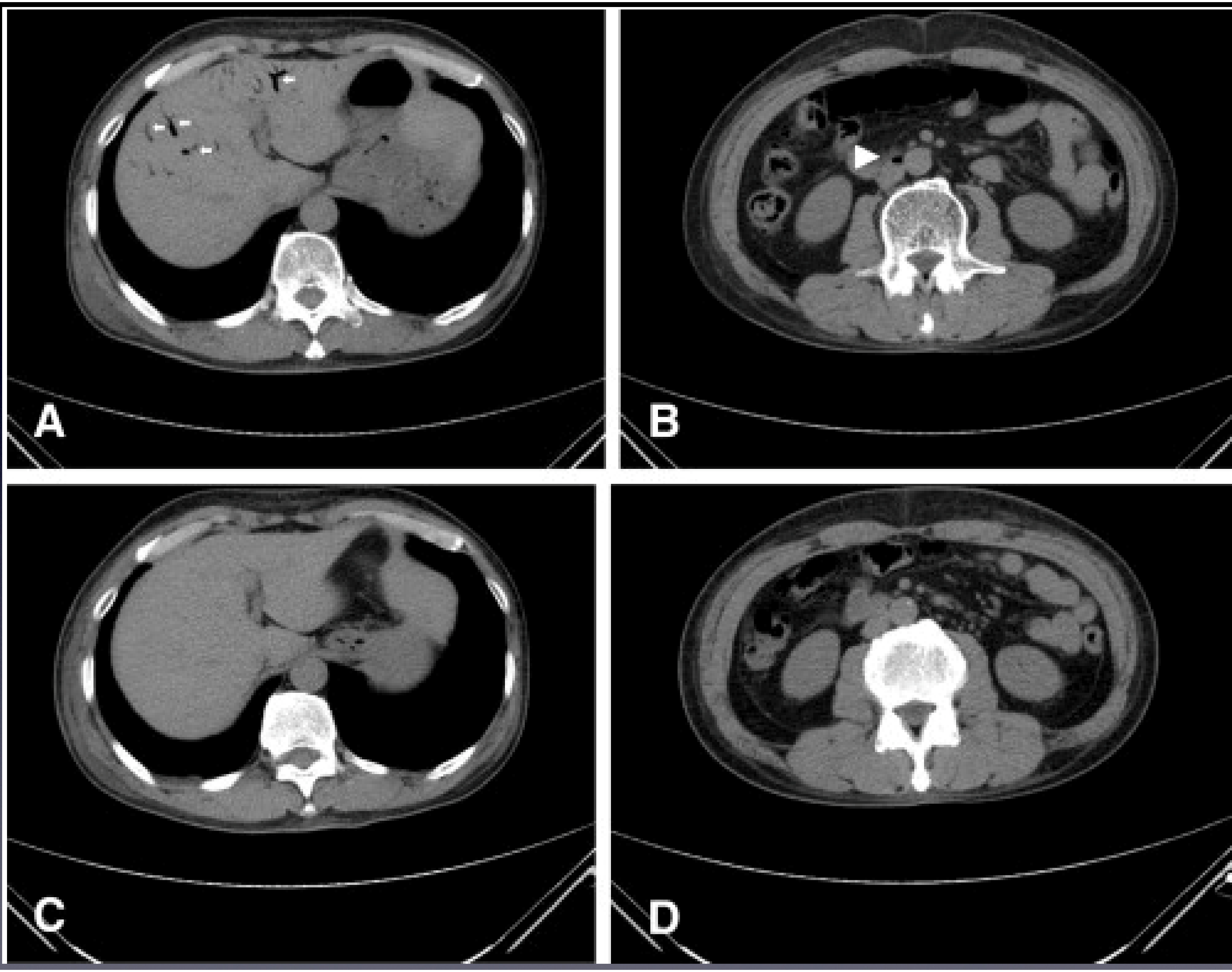


Figure 1. (A, B) Abdominal computed tomography (CT) before hyperbaric oxygen therapy. The images show gases in the portal vein (arrows) and inferior vena cava (arrow head). (C, D) Abdominal CT after hyperbaric oxygen therapy. The images show that the gases in the portal vein and inferior vena cava had disappeared completely.


A
B
C
D

Patient Characteristics

Table 1. Patient Summary

Patient No.	Age (Years)	Sex	Maximum Depth/Stay Time	Method of Dive	Trouble During Dive	Symptoms	Location of Venous Gases	HBOT	Venous Gases after HBOT	Outcomes
1	49	Male	27 m/18 min	SCUBA	No	Vertigo, mild dyspnea	Portal vein	Table 6	Disappeared	Survival
2	51	Male	20 m/25 min	SCUBA	No	Vertigo, dyspnea	Portal vein Mesenteric vein	Table 6	Disappeared	Survival
3	61	Male	51 m/30 min	SCUBA	Yes	Conscious disturbance	Portal vein Mesenteric vein	Table 6	—	Death
4	64	Male	25 m/3 h	Surface-supplied	No	Syncope, general fatigue, mild dyspnea	Portal vein IVC	Table 6	Disappeared	Survival

HBOT = hyperbaric oxygen therapy; IVC = inferior vena cava; SCUBA = self-contained underwater breathing apparatus; Table 6 = United States Navy Treatment Table 6.

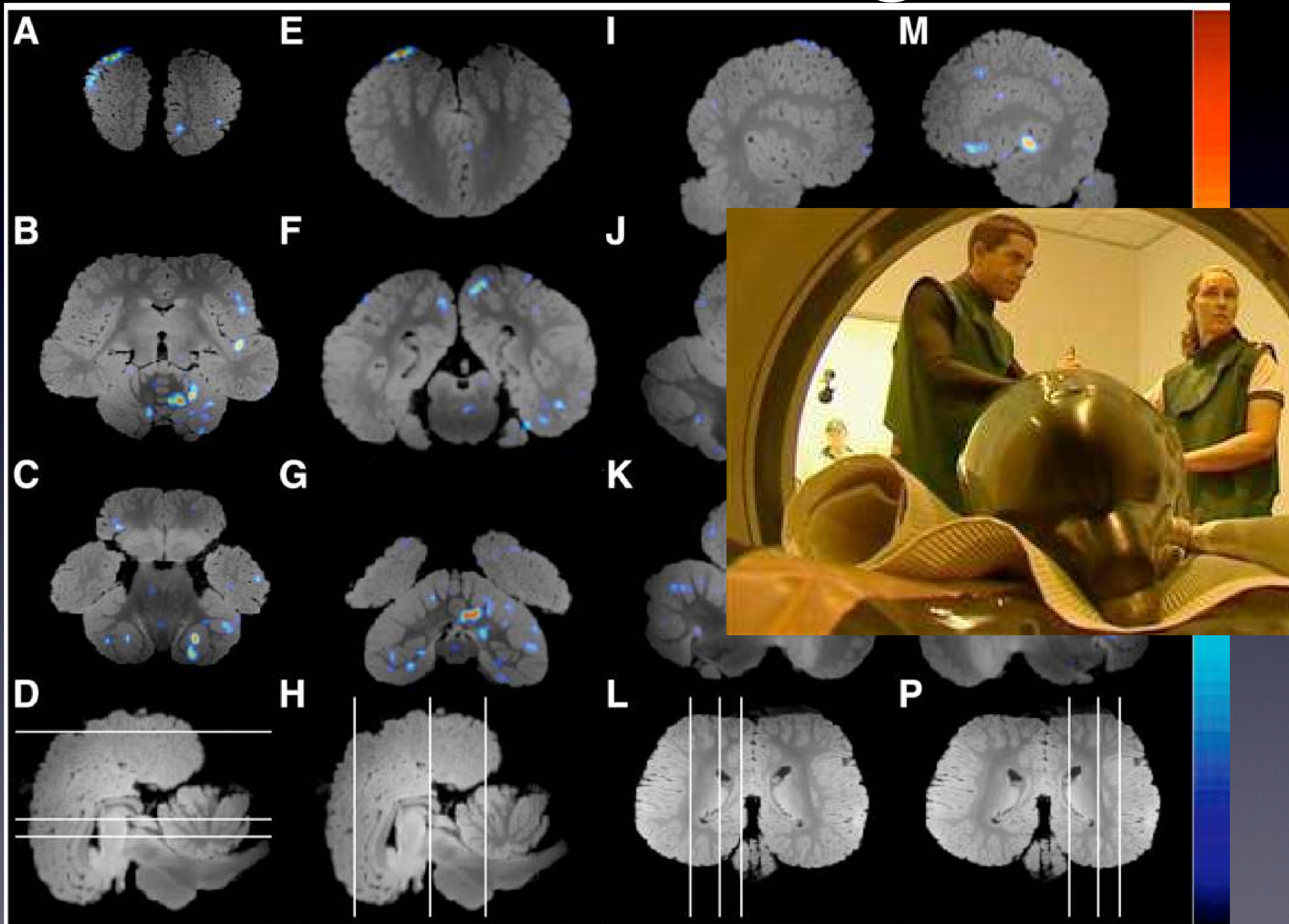
Summary

- Report that portal venous gas on CT, despite lack of abdominal pain may NOT be a rare finding (4/9, 44.5% of patients)
- Divers with abdominal pain; differential should includes PVG as the cause of their symptoms
- End-organ effects are unknown; still recommend HBOT for patients presenting with history/symptoms consistent with DCS +/- PVG
- Relationship between DCS severity and presence of PVG is unknown as well, although it is hypothesized to correlate

Speaking of imaging, radiology has also been a hot topic and also has implications with DCS diagnostics...

What about MRI for DCS?

MRI of what organ?



Diffusion Tensor MRI for DCS

Published in final edited form as:
Undersea Hyperb Med. 2013 ; 40(1): 23–31.

Diffusion tensor MRI of spinal decompression sickness

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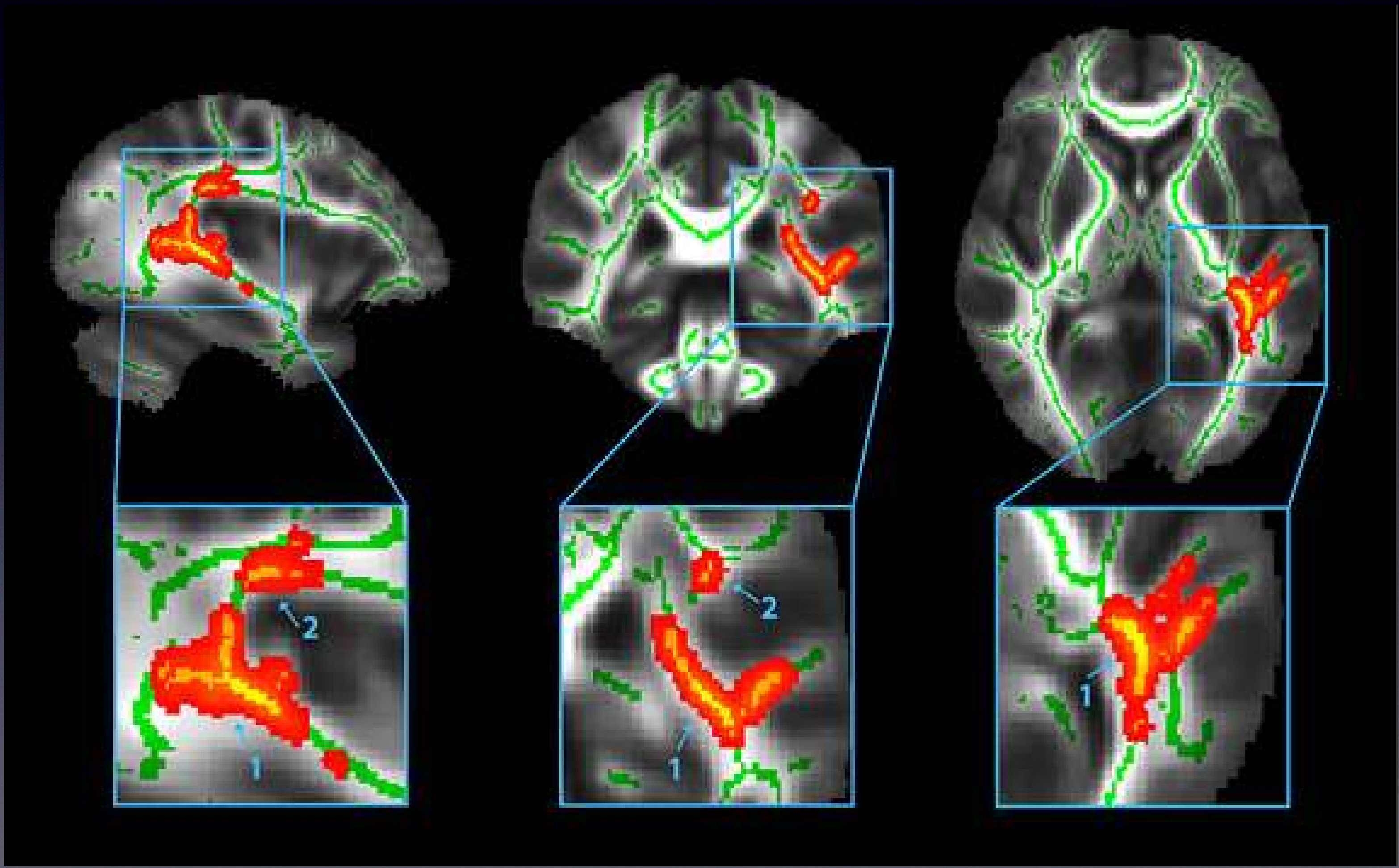
Background

- T2-weighted MRI imaging has been used in suspected spinal DCS patients and has identified micro-hemorrhage or edema in the spinal cord
- However, many DCS patients suffer significant neurologic deficits despite normal T2 MRI scans
- Diffusion Tensor MRI (DTI) is an advanced MR imaging technique that may be ideally suited for investigation of spinal DCS

What is DTI?

- Quantifies the diffusion of water within tissue to infer micro-structural properties
- Has been used to clinically monitor white matter degeneration in TBI, MS, cerebral ischemia.
- **Fractional Anisotropy (FA)** - used to report abnormalities in myelination and axonal integrity in brain and spinal cord
- **Mean Diffusivity (MD)** - measure sensitive to cytotoxic edema and vascular changes that can occur

Used in the studies of concussion and TBI



Objective of the Study

- <u>Primary</u>: Identify and describe potential DTI markers of DCS-related spinal cord damage in a *sheep model* (animal) study of hyperbaric exposure
- <u>Secondary</u>: Examine Oxygen Pre-breathing (O2PB) as alternative to lengthy staged decompression from large depths in emergency situations (i.e. Dis-Sub, disabled submarine)
- Hypothesized that spinal DCS would translate to reductions in DTI parameters and O2PB would result in less spinal cord DTI abnormalities

TABLE 1. Sample characteristics and clinical outcome data

Depth	O_2PB duration	No.	Survival outcomes (min)	Limb DCS rating	Respiratory DCS grade	Doppler bubble score Surface	Doppler bubble score 1 hour
60 fsw	0 min	1	56	II	IV	4	-
		2	34	-	IV	4+	-
60 fsw	15 min	3	survived	III	0	2	3+
		4	1230	III	III	4+	4+
		5	survived	III	I	2	3+
		6	survived	III	0	2-	4
60 fsw	180 min	7	survived	II	0	3+	4+
		8	survived	I	0	3	4
		9	survived	I	0	3	4+
		10	survived	I	0	2	4
132 fsw	180 min	11	8	-	IV	-	-
		12	75	-	IV	-	-
		13	0	-	-	-	-
		14	0	-	-	-	-

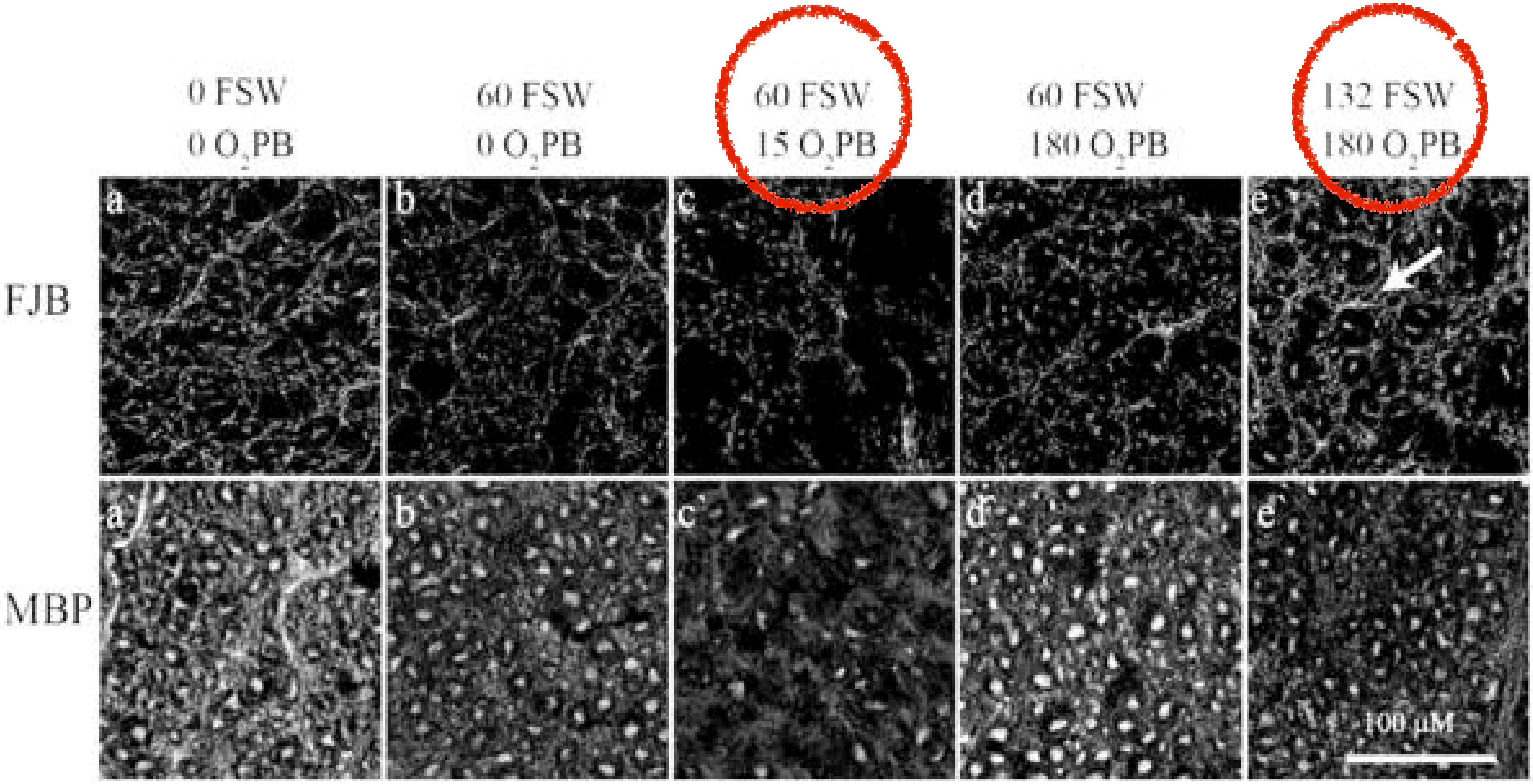
The four experimental groups were defined by depth of dive and length of O_2PB. The clinical outcome data includes survival duration (animals that survived for six-week duration of study are denoted by "survived" and animals that died prior to completion of decompression are denoted by "0"), limb DCS rate from least to most severe (I-III), respiratory DCS grade from least to most severe (I-IV) and doppler bubble score from least to most bubbles (0-4+) upon surfacing and one hour after surfacing. Clinical scores were unable to be assessed in some animals with early mortality.

Results...

- O2PB is protective in decompression from depth of 60 fsw
- Decompression from 132 fsw results in reduced DTI FA values (decreased myelin and axonal integrity) in spinal cord white matter regions
- 180 minutes of O2PB results in MD alterations (decreased cytotoxic edema and vascular changes) in spinal gray matter
- Decompression from 132 fsw results in cell death and alterations in myelination in spinal cord white matter (confirmed via IHC)

Immunohistochemistr
y

FIGURE 3

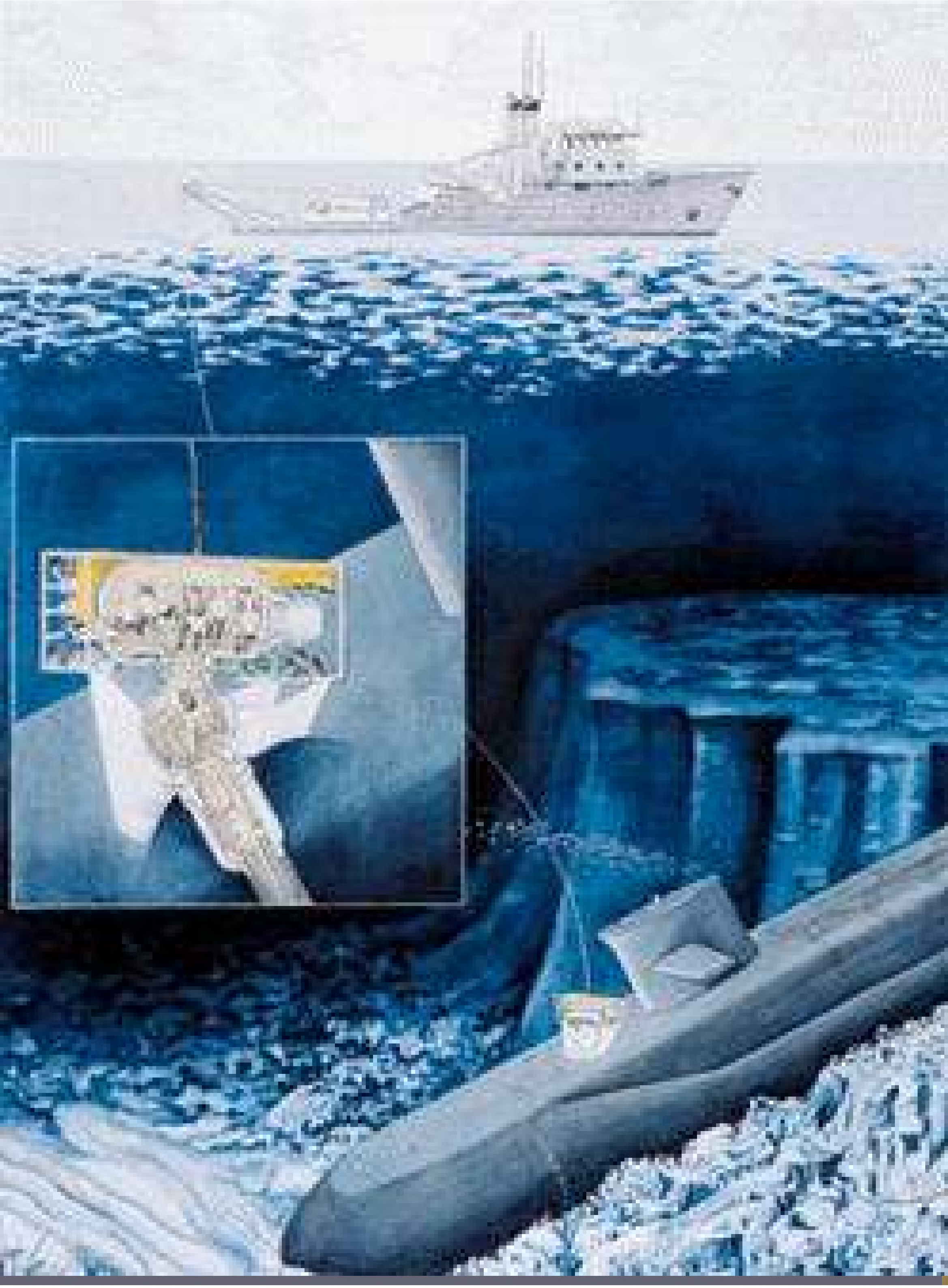


Summary

- Decompression from > or = 60 fsw induced spinal cord white matter injury, cell death and disrupted tissue microstructure
- Animals exposed to prolonged O2PB treatment prior to decompression demonstrated reduced MD (DTI changes) in spinal gray matter regions regardless of dive depth
- FIRST STUDY TO UTILIZE DTI BIOMARKERS TO IDENTIFY SPINAL DCS!

Overall

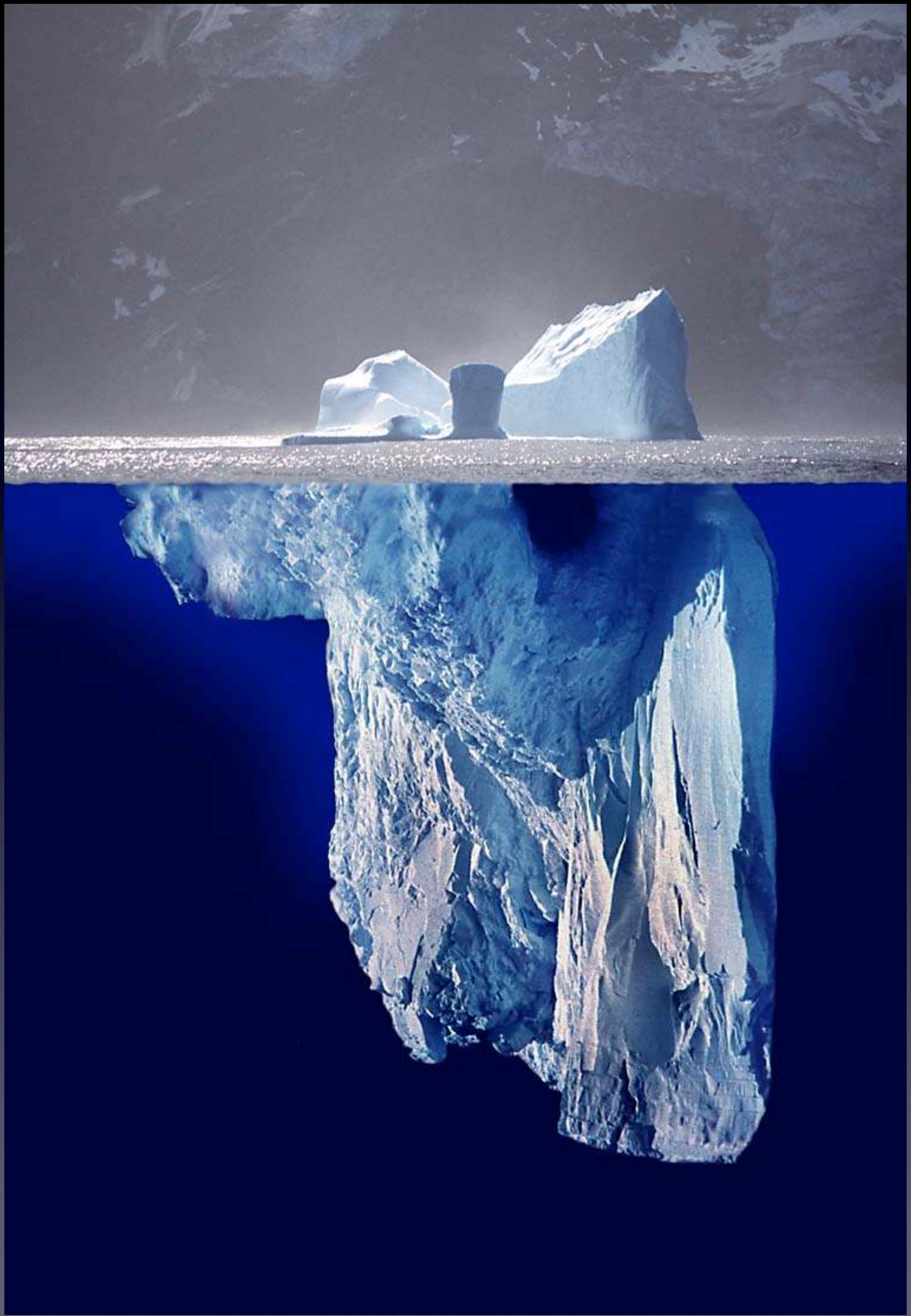
- Recompression will remain the mainstay of treatment for DCS
- Clinical use of DTI may prove useful in prognosis and directing long-term treatment strategies for DCS
- Also may provide objective imaging modality for borderline cases of DCS***



Potential Applications of Results

Take Home Points

- Turkey now OFFICIAL with field of UHM
- NO concentration and availability as potential intermediary of endothelial dysfunction looking at SCUBA/BH divers
- CT finding of PVG in DCS more common than thought; abdominal pain may be absent
- DTI (MRI) useful for ex-vivo study of DCS; implications for in-vivo/clinical study, diagnostics or prognosis of spinal DCS



We are still only scratching the surface of something very large!

What Will Be Our Higgs-Boson Particle for DCS?