The Advent of Hyperbaric Medicine

July, 2024

NYNY

Dr Enrico Camporesi, MD, FUHM

The Brooklyn Bridge:

- Less than 6 miles south
- The western pylon of the Brooklyn Bridge was built using compressed air “caissons” for construction: the workers had to be compressed to the work pressure. They often suffered decompression disease upon returning to the surface!

- Washington Roebling, the main engineer, suffered from severe bends or decompression, but his wife could keep the contract for many years!

- A Scottish Physiologist described the cause:

The western Pylon of the Brooklyn Bridge over the East River,

Build between 1865-1883 using caissons

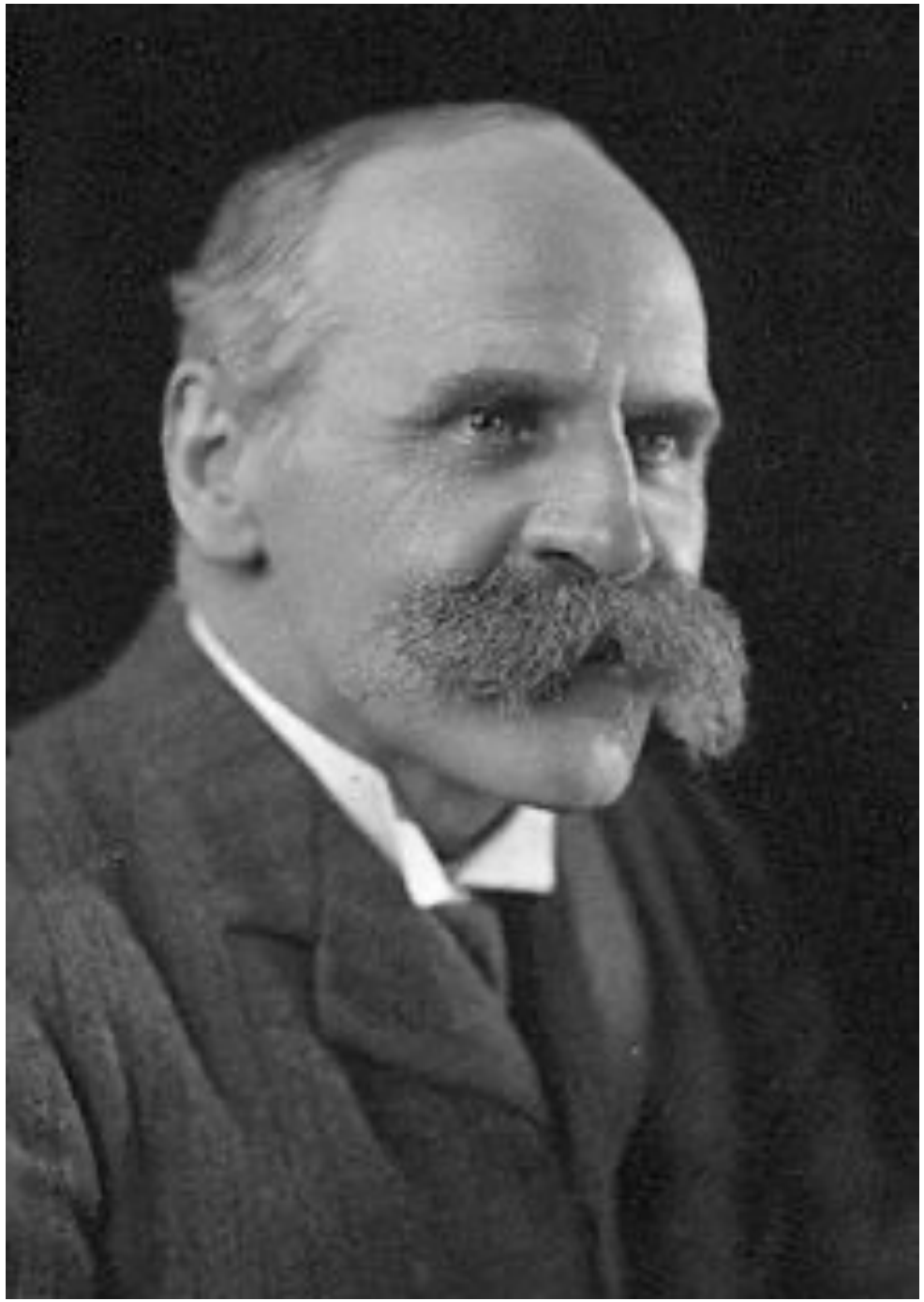
- Washington Roebling
- Engineer:
- suffered from
- severe spinal cord
- Decompression
- Sickness
- for many years

Emily Warren Roebling
His wife kept the contract:
was the first person to cross over the bridge in **1883**

J S Haldane, MD,FRS
Scottish Physiologist

Bureau of Mines

Described the way to avoid Decompression in 1908!



IN: J. Hyg. Camb. 1908; 8:342–443.

THE PREVENTION OF COMPRESSED-AIR ILLNESS.

BY A. E. BOYCOTT, D.M.,

G. C. C. DAMANT,
Lieut. and Inspector of Diving, R.N.,

AND J. S. HALDANE, M.D., F.R.S.

(*From the Lister Institute of Preventive Medicine.*)

[With 7 Figures and 3 Plates.]

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Half Times

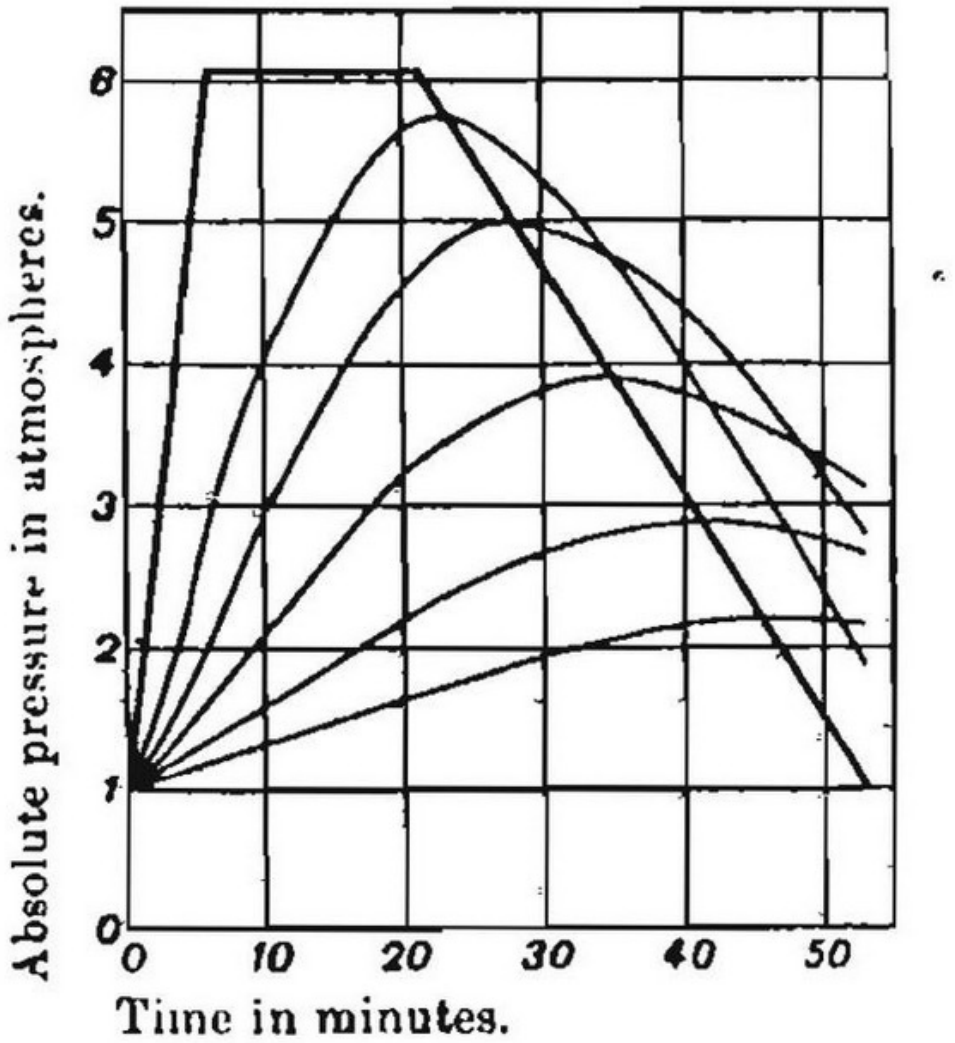


Fig. 5. Desaturation during uniform decompression in 32 minutes after exposure for 15 minutes at 75 lbs. pressure with compression in 6 minutes. Thick line = air pressure. The curves from above downwards represent respectively the variations in saturation with nitrogen of parts of the body which half saturate in 5, 10, 20, 40 and 75 minutes.

INTRODUCTION.

MEN who have been working in compressed air, as in diving, preparing foundations of bridges, etc. under water, or making tunnels or shafts through water-bearing strata, are liable on their return to atmospheric pressure to a variety of symptoms generally known as "diver's palsy" or "caisson disease," but which may more conveniently be designated "compressed-air illness." It was shown experimentally by Paul Bert[1] that these symptoms are due to the fact that gas (chiefly nitrogen) which goes into solution in the blood and tissues during exposure to compressed air is liberated in the form of bubbles on too rapid decompression, and produces local or general blockage of the circulation or other injury.

Goat Spinal Cord

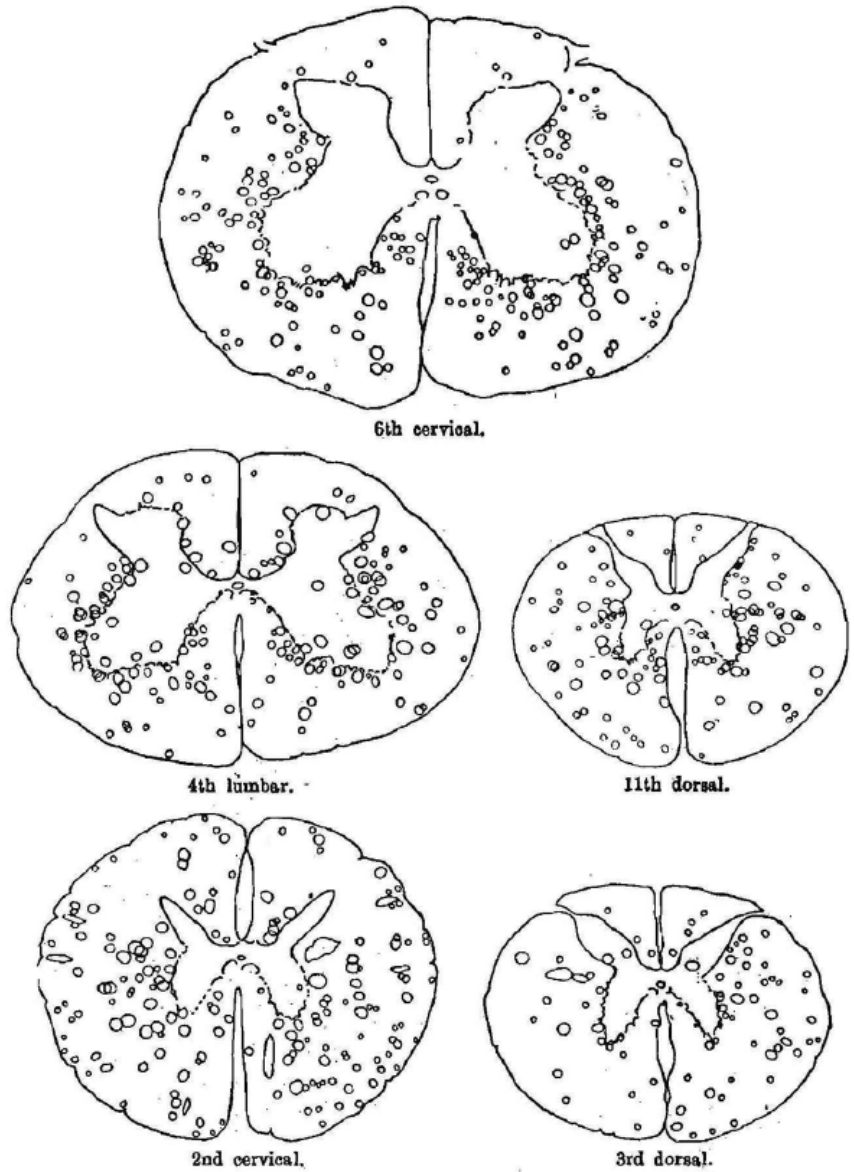


Fig. 7. Shows the distribution of extravascular bubbles in five regions of the spinal cord of goat 3 (series IV). The animal died of oxygen poisoning soon after the beginning of a decompression of 133 minutes duration by stages after 3 hours exposure at 81 lbs. in an atmosphere containing 36 % oxygen. The bubbles are practically confined to the white matter and are there especially concentrated in the boundary zone where the circulation is least good. Each diagram is a composite drawing showing all the bubbles in 0·4 mm. length of cord.

Oxygen use for Decompression: 1935

THE CIRCULATORY AND RESPIRATORY DISTURBANCES OF ACUTE COMPRESSED-AIR ILLNESS AND THE ADMINISTRATION OF OXYGEN AS A THERAPEUTIC MEASURE[1]

ALBERT R. BEHNKE,[2] LOUIS A. SHAW, ANNE C. MESSER, ROBERT M. THOMSON AND E. PREBLE MOTLEY

From the Department of Physiology, Harvard School of Public Health, Boston, Mass.

Received for publication September 28, 1935

Behnke et al, 1935

In treating the compressed-air illness which was deliberately induced in our experiments, the dogs were recompressed at 30-pound gauge pressure, during which procedure some of the animals breathed air, while others breathed oxygen. When oxygen is breathed, the partial pressure of nitrogen in the arterial blood instantly becomes 0, and must approach 0 in the venous blood and tissues. As a result, the effective pressure head of the nitrogen in the embolus is much greater than when air is breathed. By a simple calculation, which cannot be discussed here, we have estimated that when air is breathed under a pressure of 30 pounds the partial

[1] This research was aided by the Miriam Smith Rand Fund.
[2] Member of the United States Naval Medical Corps.

The Birth of Hyperbaric Medicine:

- Ite Boerema: Cardiac surgery; gas gangrene
- Radiation Therapies
- CO intoxications
- Decompression Sickness
- Intravascular Embolism

- …The need of a manual

Ite Boerema First Surgeries
in 1955 !

Fig 1. Ite Boerema (1902–1978), outside University of Amsterdam Surgery Clinic where he was professor, with 2 of his children.

Hyperbaric Oxygen Therapy

Ite Boerema—surgeon and engineer with a double-Dutch legacy to medical technology

Lisa N. Leopardi, BEng (Biomed) Hons, Matthew S. Metcalfe, MBBChir, Allison Forde, RN, *and* **Guy J. Maddern, PhD,** *Adelaide, Australia*

Ite Boerema, 1902-1978: a Dutchman with a brilliant academic surgical career, and war hero, decorated for resistance to the Germans in World War II. As a man who regarded surgery as "engineering in medicine," we still feel his legacy in medical technology today, specifically with regard to his work on esophageal anastomoses and hyperbaric oxygen therapy. This biography places his major contributions to medicine in context of the man himself and of contemporary medicine. (Surgery 2004;135:99-103.)

From the University of Adelaide, Department of Surgery, The Queen Elizabeth Hospital, and the Queensland Institute of Medical Research, Flinders Medical Centre, Adelaide, Australia

Amsterdam

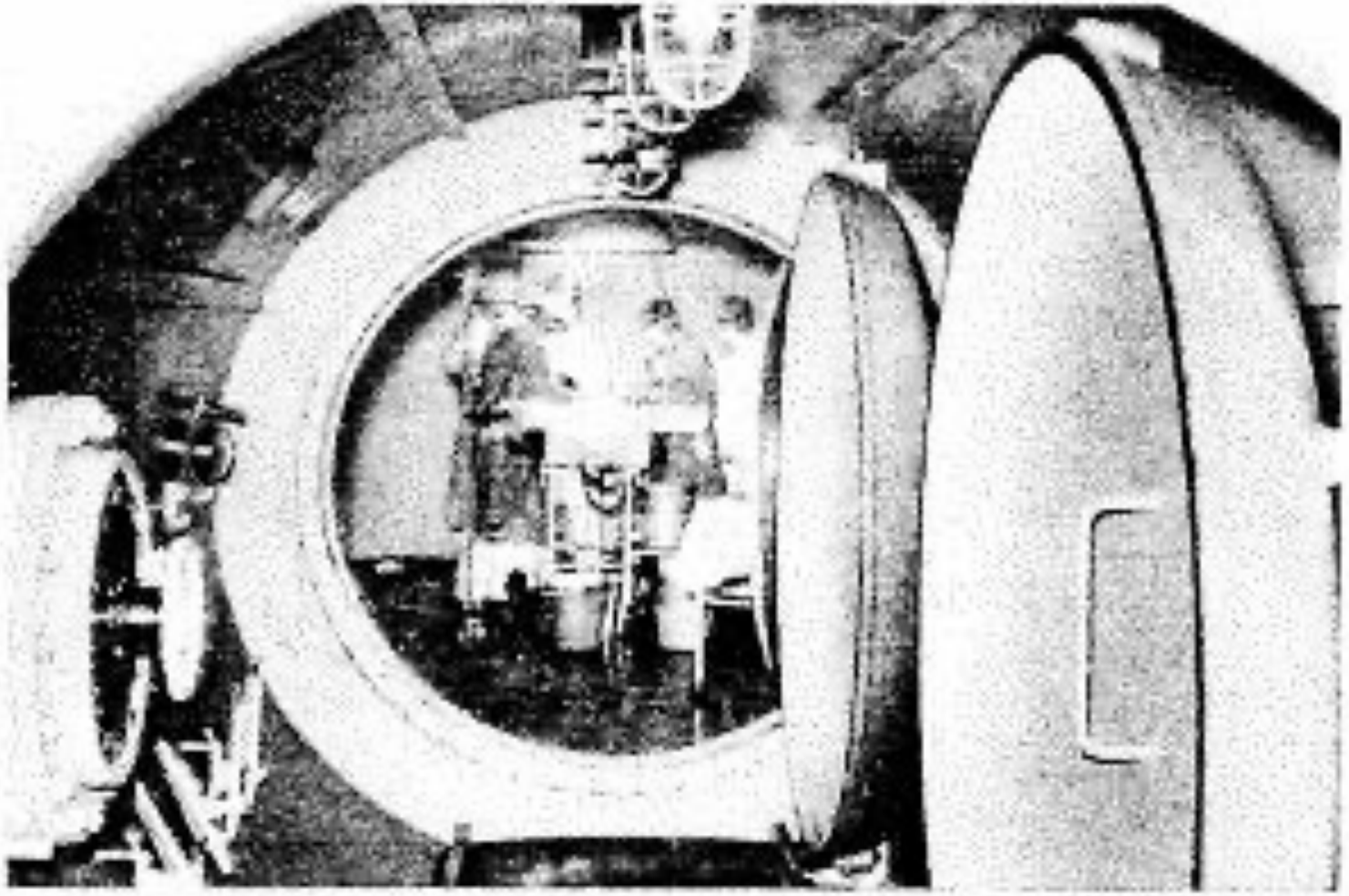


Fig 2. Original hyperbaric chamber at Wilhelmius Gasthius Hospital, Holland.[7]

Volume 49 Number 3

SURGERY

MARCH, 1961

Original communications

An operating room with high atmospheric pressure

I. BOEREMA, M.D.

AMSTERDAM, NETHERLANDS

From the Surgical Department, University of Amsterdam, Wilhelmina Gasthuis

1963

Life Without Blood

(A study of the influence of high atmospheric pressure and hypothermia on dilution of the blood)

by

I. BOEREMA(*), N. G. MEYNE, W. K. BRUMMELKAMP
S. BOUMA, M. H. MENSCH, F. KAMERMANS, M. STERN HANF
and W. VAN AALDEREN
(from the Surgical Department of the University of Amsterdam)

When in 1948 we (first al research) started our experiment on hypothermia[11 13] our ultimate aim was to reduce the metabolism of a warm-blooded animal to such an extent that all the physiological processes would almost come to a standstill.

Lancet February 2nd 1963

TREATMENT OF CLOSTRIDIAL INFECTIONS WITH HYPERBARIC OXYGEN DRENCHING
A REPORT ON 26 CASES

W. H. BRUMMELKAMP
M.D. Amsterdam
FIRST ASSISTANT

I. BOEREMA
M.D. Groningen
PROFESSOR OF SURGERY

L. HOOGENDYK
M.D. Amsterdam
BACTERIOLOGIST

From the University Surgical Clinic, Wilhelmina Gasthuis, Amsterdam, Holland

THE use of oxygen in anaerobic infections is obviously based on the anaerobic nature of the causal organism. The purpose in using a hyperbaric chamber is to increase the amount of oxygen in the tissues particularly the oxygen in physical solution. Under normal atmospheric conditions the amount of oxygen combined with hæmoglobin is already optimal. The quantity of oxygen physically dis-

Churchill-Davidson, **Lancet**, 1955

- High O2 pressure to potentiate the effect of **radiation therapy** in cancer patients

Smith and Sharp, 1960

SMITH, G., SHARP, G. R. (1960): Treatment of Carbon Monoxide Poisoning with Oxygen Under Pressure,
Lancet, ii, 905

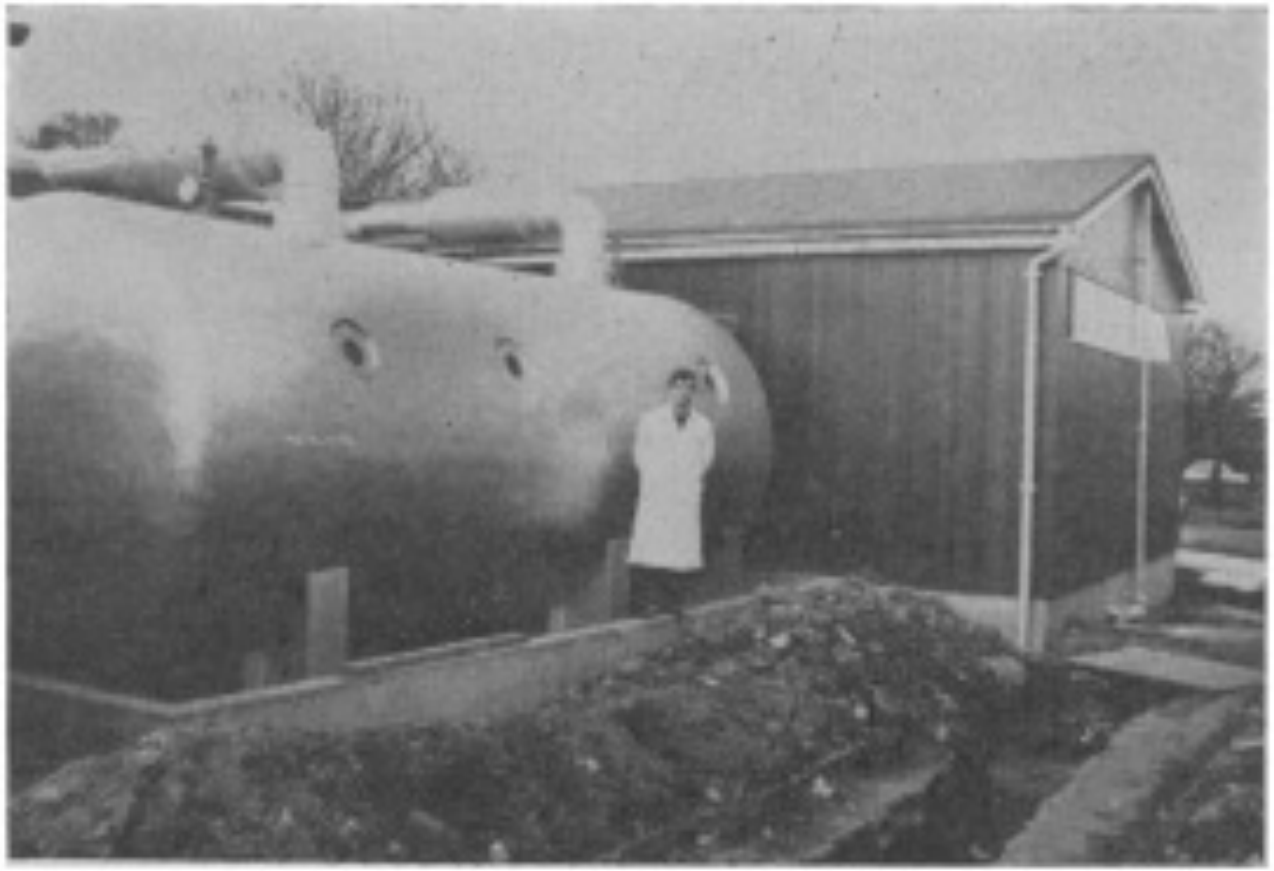


FIG. 1.— External view of pressure chamber at Aberdeen.

C.J. Lambertsen ,MD

Rutger and Penn

SCUBA inventor-Frogmen, 1943

Fostered UHMS, 1970

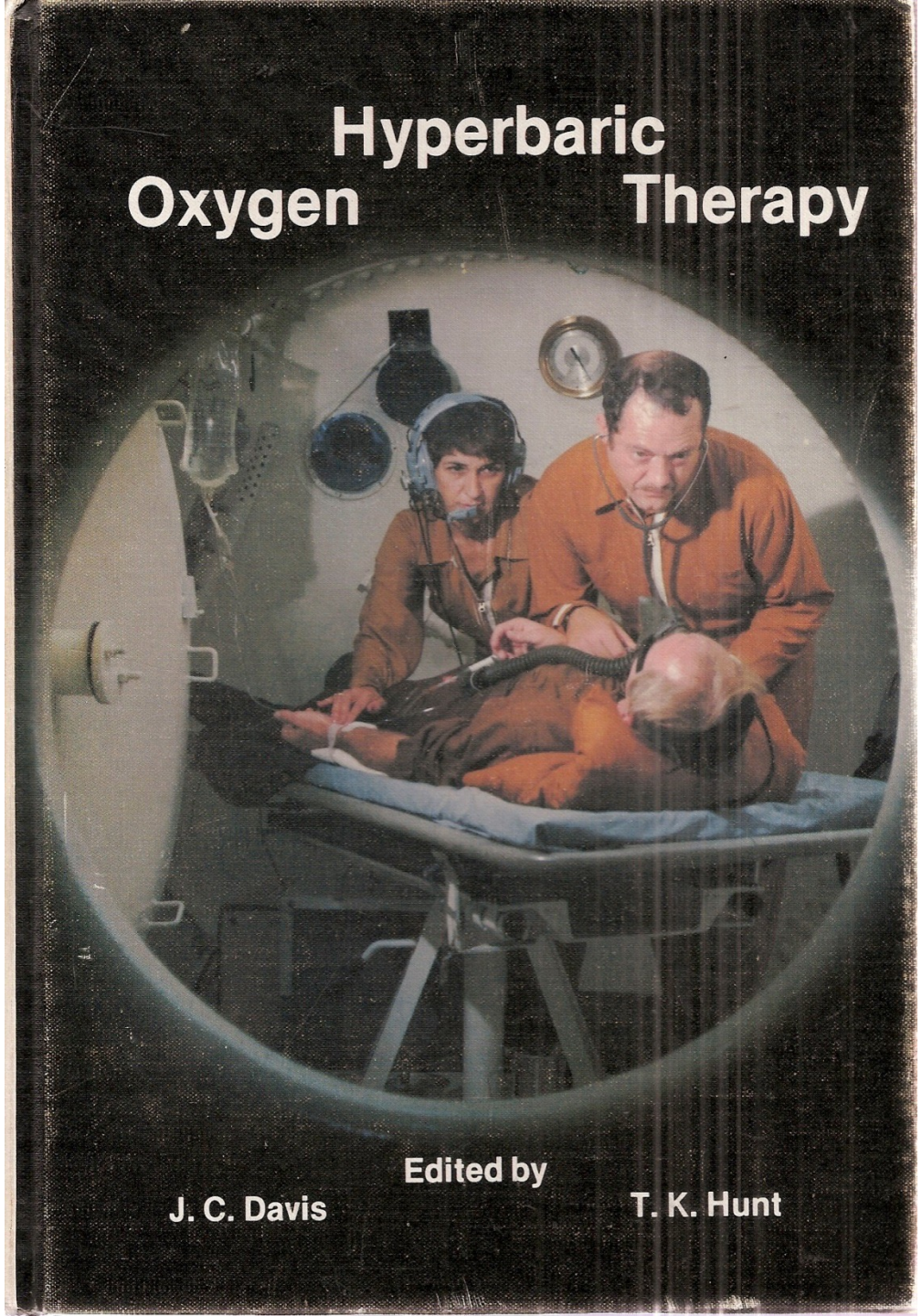
UNDERSEA & HYPERBARIC MEDICAL SOCIETY

Raising the quality of practice one member at a time

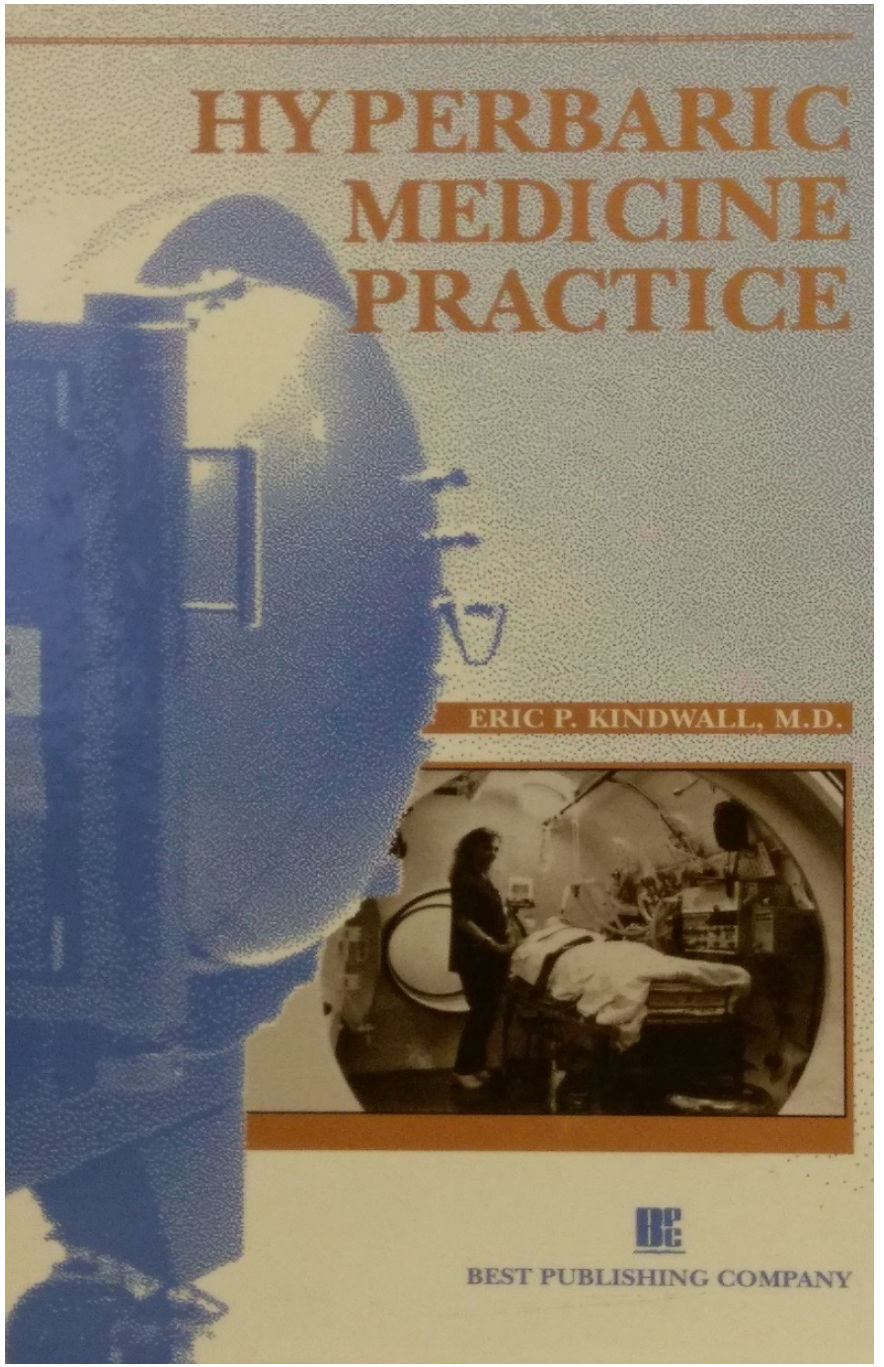
50 plus Year

Young!

A First Textbook, 1975
Jefferson Davis (Airforce)
T.K.Hunt (USF, Surgery)



The Manual, 1994
Eric Kindwall (USNavy)



HBO Report, 1972

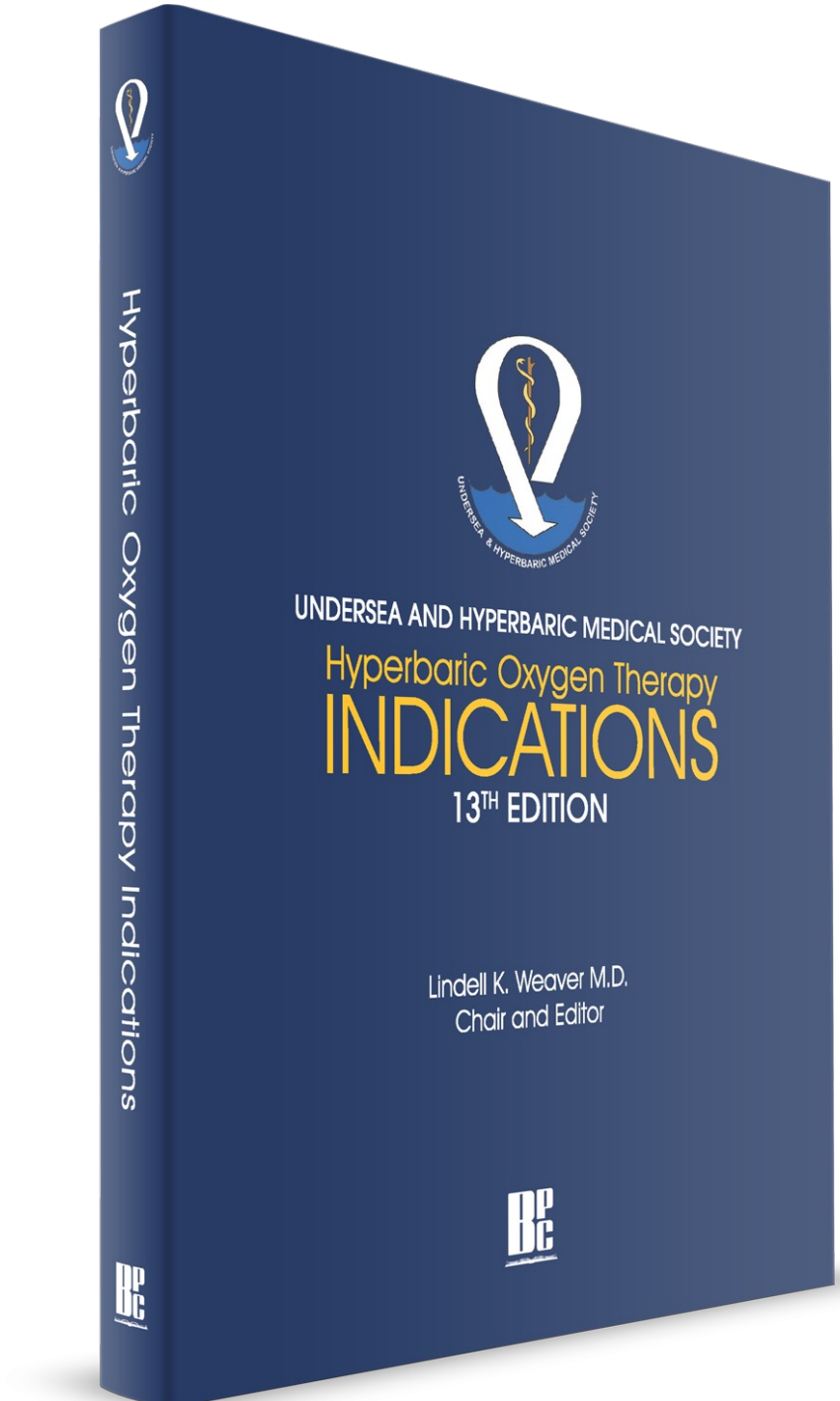
- In 1972, realizing the importance of hyperbaric oxygen administration to individuals other than injured divers, a first unofficial **Hyperbaric Oxygen Report** was published, edited by Drs. **Tom Hunt** and **Jefferson Davis**. The same year the first of a number of annotated bibliographies was published by the UMS, “Physical Methods of Bubble Detection in Blood and Tissues”
- The namesake was updated and reprinted in 1977 as the

- **First** Official list of **Indications**

- **Subsequent Editions were updated from time to time:**

2019: the 14th Edition
also in
Electronic Format

Now 15th edition, 2023!



Indications until 2022

1. Air or Gas Embolism
2. Carbon Monoxide Poisoning
3. Clostridial Myositis and Myonecrosis (Gas Gangrene)
4. Crush Injury, Compartment Syndrome and Other Acute Traumatic Ischemias
5. Decompression Sickness
6. Arterial Insufficiencies
7. Severe Anemia
8. Intracranial Abscess
9. Necrotizing Soft Tissue Infections
10. Osteomyelitis (Refractory)
11. Delayed Radiation Injury (Soft Tissue and Bony Necrosis)
12. Compromised Grafts and Flaps
13. Acute Thermal Burn Injury
14. Idiopathic Sudden Sensorineural Hearing Loss

Today, 15 th Indication:
Accepted 4/22 in Reno,NV

- **Osteonecrosis**

- AVN or Aseptic Necrosis of the Femoral Head and Condili
- aka AFHCN

2002
and education
initiatives

Emerging Indications for Hyperbaric Oxygen Therapy

Enrico Camporesi, MD, FUHM

July 2024

U. of Padova

NYNY: Noah Clinic

Controversies on HBO2 Therapy:

- Despite expanding basic science evidence and peer-reviewed publications:

- Persistent variability exists in the practice and documentation of Hyperbaric Oxygen, raising concerns about the **acceptance** of this therapy in diverse regions worldwide.

Indications for HBO2 Treatments: 2 Levels

- Accepted = sufficient Scientific Evidence to be effective

- Emerging = in the process of accumulating sufficient evidence: how fast, how much:

The process of evaluation and the forum of discussion are variable and can be **adversarial** in different settings:

IMPORTANT DISTINCTION:

- Accepted: can be reimbursed by Insurance if appropriately documented

Schema of this Presentation:

- Definition of Hyperbaric Oxygen Therapy
- Mechanisms of Action
- Great Variety of treated Diseases/Syndromes leading to:

- “Accepted” indications, 1975 to Present: the Acceptance Procedure
- “Emerging” indications …. how to maintain visibility and to progress

Definition and Description of Clinical Hyperbaric Oxygen Therapy: UHMS

In the United States, the discipline of hyperbaric oxygen has been recognized by both the

- The American Board of Emergency Medicine (ABEM) and
- The American Board of Preventive Medicine (ABPM)

as warranting the status of a **subspecialty** under each of their specialty umbrellas.

Scientific Definition of Hyperbaric Oxygen (HBO_2) Therapy, UHMS (6 required tenets)

Hyperbaric oxygen is a medical procedure requiring **a physician's prescription and oversight**.

All patients must have their **entire** body placed within a **hard-sided** hyperbaric chamber that meets the American Society of Mechanical Engineers and Pressure Vessels for Human Occupancy (ASME-PVHO-1) **code** and the National Fire Protection Agency (NFPA 99) code and standards for hyperbaric chambers, at a pressure of **not less than 2.0 ATA** while breathing physician-prescribed

medical grade oxygen for an amount of time that is typically between 90-120 minutes per treatment. Medical grade oxygen (>99.0% oxygen purity) is the only acceptable gas that should be used for the therapeutic delivery of hyperbaric oxygen.*

** Medical grade oxygen should meet the United States Pharmacopeia (USP) or national equivalent standard for purity.*

Proven Indications and Safe Delivery :UHMS

- Scientifically supported hyperbaric treatments are usually delivered at pressures between 1.9 to 3.0 ATA.**
- HBO_2 therapy is a **standard of care** for many medical conditions, including decompression sickness, carbon monoxide poisoning, diabetic wounds, delayed radiation injury, necrotizing fasciitis, gas gangrene, refractory osteomyelitis, and several other conditions proven by peer-reviewed research and **approved by the Hyperbaric Oxygen Committee.**

- Treatment **chambers** should be designed, constructed, operated, and certified to the **standards** established by the NFPA (National Fire Protection Association) and ASME PVHO-1 (American Society of Mechanical Engineers-Safety Standard for Pressure Vessels for Human Occupancy) or other internationally equivalent regulatory agencies.

- The Undersea and Hyperbaric Medical Society (UHMS) has established criteria for **accreditation** of hyperbaric treatment **facilities** designed to ensure safe and clinically appropriate treatments. Most disorders require a series of treatments delivered daily for several weeks.
- EDUCATION: These treatments should be prescribed and supervised by qualified **physicians** with proper training.

Problems with the Process of Approval:

- Difference between UHMS and EUBS

- UHMS: Hyperbaric Oxygen Committee review, mostly q. each Annual Scientific Meeting: structured as a review of published evidence, and presented for a **VOTE** by the Committee members present, after two presentations, by a PRO- and a CON- advocate, defending each side.

- EUBS: periodic "CONSENSUS CONFERENCE" with debates, often yearly, with a ranking of the evidence.

A Problem: Slow Approvals

- UHMS approved 15 indications and published over 15 editions of the “Indications” manual between 1980 and 2024

*(approximately 45 years), **averaging one indication q. 3 years**.

- The last two indications were Sudden Deafness (2011) and Osteonecrosis (2022); this time span shows **irregular** timing.

European “Consensus Conferences”

- The approval process in Europe is usually achieved via
- ” Consensus Conferences,” where scientific evidence is scored in a standard fashion. (*Level : A, B, C, etc, based on strength of evidence)

- Additionally, reimbursement systems in Europe do not depend on multiple Insurance Companies' contracts but rather on each state's Regional Health payments.

University of California at San Diego and
Geisel School of Medicine at Dartmouth Lebanon, US

Emerging Indications for Hyperbaric Oxygen Treatment: A Registry Cohort Study

Hideaki Tanaka, Judy R. Rees, Ziyin Zhang, Judy A. Ptak, Pamela M. Hannigan, Elaine M. Silverman, Janet L. Peacock, Jay C. Buckey

Submitted to: Journal of Medical Internet Research
on: October 20, 2023

REGISTRY: Data Updated until June, 2024

- Hyperbaric oxygen (HBO2) treatment is used across a range of medical specialties for a variety of applications, particularly where **hypoxia and inflammation** are important factors.
- HBO2 **may be useful for new indications** not currently approved by the Undersea and Hyperbaric Medical Society (UHMS) but **with strong published literature.**
- Identifying these new applications for HBO2 is difficult because individual centers may only treat a **few** cases and do not consistently track outcomes.
- The web-based **International Multicenter Registry for Hyperbaric Oxygen Therapy** captures **de-identified** outcomes data for patients treated with hyperbaric oxygen (HBO2) therapy. These data can then be used to identify **new** applications for HBO2

Methods:

- This descriptive study is based on a web-based, multi-center, international **registry** of patients treated with HBO2.
- Centers agree to collect data on all patients treated using standard outcome measures and send de-identified data from individual centers to the central registry.
- HBO2 treatment programs in the **United States, United Kingdom, and Australia** participated.
- Demographic, outcome, complication, and treatment data, including pre-and post-treatment quality of life questionnaires (EQ-5D-5L), were collected on individuals referred for HBO2 treatment.

Results, out of over 7500 entries:

- 354 individuals were treated for 44 emerging indications.
- Post-acute COVID syndrome (**PACS**) (148), ulcerative colitis (45), and Crohn's disease (34), accounted for **64%** of total cases.
- Calciphylaxis (18) and peripheral-vascular-disease related wounds (11) accounted for a further 8%.

RESULTS: 2

- PACS patients reported significant improvement on the **Neurobehavioral Symptom Inventory**.
- Crohn's disease patients reported significantly improved fistula drainage and ulcerative colitis patients reported lower scores on a bowel questionnaire examining frequency, blood, pain, and urgency.
- A subset of calciphylaxis patients also improved

Neurodegenerative Diseases

- Several excellent papers highlight the beneficial effects of repeated HBO2 exposure in cerebral events, from recovery from stroke to improvements in memory and executive function after head trauma and in early degenerative neurological diseases, such as early Alzheimer's and Parkinson's disease. AVIV Clinic materials.

Emerging Syndromes : Conclusions

- HBO2 is being used for a variety of syndromes across several medical specialties for its hypoxia-relieving, anti-inflammatory and regenerative effects.

- Results significantly improve patient-reported outcomes for inflammatory bowel disease and PACS.

- Neuro-degenerative diseases: growing evidence!