Sunday, May 22:
- The ORCA Project: Operational Resilience and Cognitive Awareness: 8 am – 5 pm: Tuscany 1
- Wound Care for the Hyperbaric Provider: 8 am – 5 pm: Tuscany 2
- Welcome to Reno: 6:30 pm - 8:30 pm: Naples Ballroom

Monday May 23:
- General Session with AsMA: 8:30 am – 10 am: Tuscany C-D-E
- UHMS Breakout: 10:30 am – 5:30 pm: Tuscany 1 & 2
- STOP THE BLEED®: 12 pm – 1 pm: Tuscany 1 & 2
- Committee Meetings/Luncheons: See schedule

Tuesday, May 24:
- General Session: with AsMA 8:15 am – 10 am: Tuscany C-E & 9-11
- UHMS Breakout: 10 am – 5:30 pm: Tuscany 1 & 2
- STOP THE BLEED®: 12 pm – 1 pm: Tuscany 1 & 2
- Committee Meetings/Luncheons: See schedule

Wednesday, May 25:
- General Session with AsMA: 8:15 am – 10 am: Tuscany C-E & 9-11
- UHMS Breakout: 10:30 am – 3:30 am: Tuscany 1 & 2
- STOP THE BLEED®: 12 pm – 1 pm: Tuscany 1 & 2
- General Session with AsMA: 4 pm – 5:30 pm: Tuscany C-E & 9-11
- Committee Meetings/Luncheons: See schedule

Thursday, May 26:
- General Session with AsMA: 8:15 am – 0915 am: Tuscany C-E & 9-11
- UHMS Breakout: 10:30 am – 5:00 pm: Tuscany 1 & 2
- STOP THE BLEED®: 12 pm – 1 pm: Tuscany 1 & 2
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- AsMA Bauer Lecture in Tuscany C-D-E .......................................................... 14
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- UHMS Breakout in Tuscany 1 & 2: 2pm-5:30pm
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  - Plenary: The hyperoxic-hypoxic paradox and its application in regenerative medicine .......... 17-18
  - Plenary: CMS billing records of hyperbaric oxygen for radiation cystitis reveal some interesting findings ... 18
- UHMS Posters in Tuscany 5 & 6:
  - 3pm-3:30pm: B16-B30 & F93-F94
  - 4:30pm-5pm: C46-D60
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- UHMS Breakout in Tuscany 1 & 2: 10:30am-5:30pm
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  - Plenary: Filling the gaps: Future name diving needs .................................... 20
  - Plenary: Enhancing safety through mishaps and significant incidents lessons learned ....................................................... 20-21
  - Plenary: Manned testing of rapid pressure fluctuations associated with naval aviation (SIPE) ....... 21-23
- UHMS Posters in Tuscany 5 & 6
  - 2pm-2:30pm: D61-D75
  - 2:30pm-3pm: D76-F90
  - 3pm-3:30pm: A1-B15 & F92
  - 4pm-4:30pm: F91 & F95-F107
  - 4:30pm-5pm: F108-F122

**Wednesday, May 25** ...................................................................... 24-26

- UHMS Lambertsen Memorial Lecture in Tuscany C-D-E ...................................... 24-25
- UHMS Breakout in Tuscany 1 & 2: 10:30am-3:30pm
  - Plenary: Update on emergency use of HBO2 and what if any traction we’ve received through our congressional efforts ............................................................... 25-26
  - Plenary: UHM Fellow: Top articles in Undersea Medicine ................................ 26
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- AsMA Ram Bowl in Tuscany C-D-E .................................................................... 27

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- Armstrong Lecture with AsMA in Tuscany C-D-E ........................................... 28
Undersea & Hyperbaric Medical Society

Committees

Board of Directors
Marc Robins, President
Kaighley Brett, Vice President
Pete Witucki, President-Elect
Nick Bird, Immediate Past President
Helen Gelly, Treasurer
Bruce Derrick, Member at large
Derek Covington, Member at large
Peter Lindholm, Member at large
Jason Kelly, Member at large
Jay Ducknick, Assoc. Nurse Rep-Elect
Julio Garcia, Assoc. Nurse Rep. 2022*
John Peters – UHMS Executive Director*
* (non-voting)

2022 Organizing & Scientific Program Committee
Marc Robins
Pete Witucki
John Feldmeier
Laurie Gesell
Bruce Derrick
Stephen Thom
Zachary Schadler
Brian Keuski
Julio Garcia, Associates Program
Phil Schell, Associates Program
Thomas Bozzuto & Owen O’Neill, CME Representative
Lisa Tidd, Meeting Planner
Stacy Harmon, CME Coordinator

2022 ASM Staff
Sherrill White-Wolfe
Eric vanBok
Derrall Garrett
Tom Workman (photographer)

Past Presidents
Robert D. Workman: 1968-1969
Heinz R. Schreiner: 1970-1971
Earl H. Ninow: 1971-1972
David H. Elliott: 1972-1973
Dennis N. Walder, 1974-1975
Peter B. Bennett: 1975-1976
James Vorosmarty, Jr.: 1977-1978
Herbert A. Saltzman: 1978-1979
Jefferson C. Davis: 1979-1980
Alfred A. Bove: 1983-1984
Paul G. Linaweaver: 1984-1985
Mark E. Bradley: 1985-1986

Tom S. Neuman: 1989-1990
Paul Cianci: 1991-1992
James M. Clark: 1993-1994
Caroline Fife: 1998-2000
Enrico Camporesi: 2000-2002
Neil Hampson: 2002-2004
Lindell K. Weaver: 2004-2006
Bret Stolp: 2006-2008
Laurie Gesell: 2008-2010
Brett Hart: 2010-2012
John Feldmeier: 2012-2014
James Holm: 2014-2016
Enoch Huang: 2016-2018
Nick Bird: 2018-2020

Committee Chairpersons
Accreditation Council: Devin Beckstrand
ASM Program: Marc Robins & Pete Witucki
Associates Council: Jay DUCHNICK & Jaqueline Hocking
Awards: Kaighley Brett
Audit/Finance: Helen Gelly
By-Laws: Pete Wituki
DCI & Adjunctive Therapy: Richard Moon & Frank Butler
Diving: Charlotte Sadler & Jim Chimak
Education: Tom Bozzuto & Owen O’Neill
FUHM: Nick Bird
GME: Enoch Huang
Registry: Jay Buckey
QUARC: Caroline Fife/Helen Gelly/Marc Robins
Safety: Andrew Mlynyczenko
Hyperbaric Oxygen Therapy: Richard Moon
Material Testing Advisory (Ad Hoc): Richard Barry
Membership-Chapters/AFFiliate: Pete Witucki
Nominations: Pete Witucki
Publications: Matthew Kelly & Dag Shapshak
Research: John Kirby & John Feldmeier

Chapter Presidents
Gulf Coast: Kaye Moseley
Mid-West: Risa Anderson
Northeast: Ryan Patrylak
Pacific: Brenda Freymiller

Affiliates
Canadian Undersea and Hyperbaric Medical Association (CUHMA)
European Underwater and Baromedical Society (EUBS)
Sociedade Brasileira de Medicina Hiperbárica (SBMH)
Società Italiana di Medicina Subacquea ed Iperbarica (SIMSI)
South Pacific Underwater Medicine Society (SPUMS)
## SCHEDULES

### SUNDAY, MAY 22

**The ORCA Project: Operational Resilience and Cognitive Awareness**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-8:15</td>
<td>Welcome/ Introduction to ORCA</td>
<td>Jim Chimiak, Dick Sadler, Frauke Tillmans</td>
</tr>
<tr>
<td>8:15-9:45</td>
<td>Cardiac Surgery: Lessons in Self Awareness</td>
<td>Dick Sadler</td>
</tr>
<tr>
<td>9:45-10:15</td>
<td>History of Interventions</td>
<td>Michael Lang</td>
</tr>
<tr>
<td>10:15-10:45</td>
<td>Diving Incident Reporting at DAN and the vision of participative learning</td>
<td>Frauke Tillmans</td>
</tr>
<tr>
<td>10:45-11:00</td>
<td>BREAK</td>
<td></td>
</tr>
<tr>
<td>11:00-11:30</td>
<td>Using human factors to mitigate risk and improve operational effectiveness</td>
<td>Lt. Com. Michael Shipman</td>
</tr>
<tr>
<td>11:30-12:00</td>
<td>Operator/Physician Lessons for Sea, Air and Land</td>
<td>Henry Casey</td>
</tr>
<tr>
<td>12:00-1:00</td>
<td>LUNCH (on own)</td>
<td></td>
</tr>
<tr>
<td>1:00-1:30</td>
<td>USN HRO Leadership: The Linchpin of Safe Systems</td>
<td>Jon Clark</td>
</tr>
<tr>
<td>1:30-2:00</td>
<td>Lessons from Breath Hold Diving</td>
<td>Kirk Krack</td>
</tr>
<tr>
<td>2:00-2:30</td>
<td>The 4 Rs: Recognition-Recovery-Resilience-Right Stuff</td>
<td>Michael Gernhardt</td>
</tr>
<tr>
<td>2:30-3:00</td>
<td>Culture of Safety</td>
<td>Petar Denoble</td>
</tr>
<tr>
<td>3:00-3:15</td>
<td>BREAK</td>
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<tr>
<td>3:15-3:45</td>
<td>Checklists</td>
<td>Simon Mitchell</td>
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<td>3:45-4:15</td>
<td>ORCA Dashboard (DD/DABOS/GAR)</td>
<td>Jim Chimiak; Lt. Josh Frederick</td>
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<td>4:15-4:45</td>
<td>Training</td>
<td>Carl Shreeves</td>
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<td>4:45-5:15</td>
<td>The Secret to Teaching Human Factors in Diving Is...</td>
<td>Jeff Seckendorf</td>
</tr>
<tr>
<td>5:15-5:30</td>
<td>SUMMARY</td>
<td></td>
</tr>
</tbody>
</table>

### SUNDAY, MAY 22

**Wound Care for The Hyperbaric Provider**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0800-0810</td>
<td>Welcome / Intro</td>
<td></td>
</tr>
<tr>
<td>0810-0900</td>
<td>That Pesky Wound: Whatcha’ Gonna Do About It?</td>
<td>Becca Mackintosh APRN, FNP-C, CWCN</td>
</tr>
<tr>
<td>0900-0950</td>
<td>Infectious Disease Lecture</td>
<td>Todd Vento, MD</td>
</tr>
<tr>
<td>TIME</td>
<td>DAY</td>
<td>COMMITTEE</td>
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<tr>
<td>0950-1000</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>1000-1050</td>
<td>CY 2022 Coding/ Billing / Documentation Requirements for: Wound Care &amp; Hyperbaric Oxygen Therapy Services</td>
<td>Michael Crouch, CHT, CPC, CPMA</td>
</tr>
<tr>
<td>1050-1140</td>
<td>Vascular procedures</td>
<td>John Kirby, MD</td>
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<tr>
<td>1140-1200</td>
<td>Panel</td>
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<td>1200-1300</td>
<td>Lunch (on own)</td>
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<tr>
<td>1300-1350</td>
<td>Offloading</td>
<td>Clint Larson, MD</td>
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<td>1350-1445</td>
<td>Lymphedema and Wound Care: Synergies, Pitfalls and Pearls for Success</td>
<td>Susie Ehmann, PT DPT, CWS, CLT-LANA</td>
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<td>1445-1500</td>
<td>Break</td>
<td></td>
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<tr>
<td>1500-1700</td>
<td>Hands-on: casting/wraps/offloading</td>
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Committee Meetings / Luncheons / Stop the Bleed Workshops

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<td>1730-1830</td>
<td>Sunday, May 22</td>
<td>UHMS Diving Committee</td>
<td>Tuscany 1</td>
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<td>1200-1300</td>
<td>Monday, May 23</td>
<td>UHMS Education Committee</td>
<td>Executive Boardroom 1735</td>
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<tr>
<td>1200-1300</td>
<td>Monday, May 23</td>
<td>Stop the Bleed Workshop</td>
<td>Tuscany 1&amp;2</td>
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<tr>
<td>1300-1400</td>
<td>Monday, May 23</td>
<td>UHMS Research Committee</td>
<td>Executive Boardroom 1735</td>
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<tr>
<td>1300-1400</td>
<td>Monday, May 23</td>
<td>ACEP UHM section</td>
<td>Tuscany 1&amp;2</td>
</tr>
<tr>
<td>1800-2000</td>
<td>Monday, May 23</td>
<td>UHMS HBO2 Therapy Committee</td>
<td>Tuscany 1&amp;2</td>
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<tr>
<td>0700-0800</td>
<td>Tuesday, May 24</td>
<td>UHMS Presidents Breakfast (UHMS BOD Current &amp; Past Presidents Only – Ticket required for meal)</td>
<td>Executive Boardroom 1735</td>
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<tr>
<td>1200-1300</td>
<td>Tuesday, May 24</td>
<td>Annual Business Meeting / Luncheon (advance purchase only) (Free Attendance; Ticket required for meal)</td>
<td>Naples 7</td>
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<td>1200-1300</td>
<td>Tuesday, May 24</td>
<td>Stop the Bleed Workshop</td>
<td>Tuscany 1&amp;2</td>
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<td>1300-1400</td>
<td>Tuesday, May 24</td>
<td>Publications Committee</td>
<td>Executive Boardroom 1735</td>
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<td>1300-1400</td>
<td>Tuesday, May 24</td>
<td>UHMS QUARC</td>
<td>Tuscany 1&amp;2</td>
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<tr>
<td>1200-1300</td>
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<td>Stop the Bleed Workshop</td>
<td>Tuscany 1&amp;2</td>
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<tr>
<td>1200-1300</td>
<td>Wednesday, May 25</td>
<td>BNA Luncheon</td>
<td>Executive Boardroom 1735</td>
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<tr>
<td>1300-1400</td>
<td>Wednesday, May 25</td>
<td>BNA General Meeting</td>
<td>Executive Boardroom 1735</td>
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<tr>
<td>1300-1400</td>
<td>Wednesday, May 25</td>
<td>REDCap Committee</td>
<td>Tuscany 1&amp;2</td>
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<td>1600-1700</td>
<td>Wednesday, May 25</td>
<td>BNA Board Meeting</td>
<td>Executive Boardroom 1735</td>
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<td>1130-1330</td>
<td>Thursday, May 26</td>
<td>UHMS Accreditation Council</td>
<td>Executive Boardroom 1735</td>
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<td>1200-1300</td>
<td>Thursday, May 26</td>
<td>UHMS Associates Luncheon</td>
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<tr>
<td>1200-1300</td>
<td>Thursday, May 26</td>
<td>Stop the Bleed Workshop</td>
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## UHMS BREAKOUT SCHEDULE

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<tr>
<td>6:30 PM</td>
<td>Welcome Reception with AsMA (ticket is required for this event)</td>
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### MONDAY, MAY 23

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<tbody>
<tr>
<td>7:00 AM</td>
<td>Registration</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>Opening Ceremony / Welcome with AsMA in Tuscany C-D-E</td>
</tr>
<tr>
<td>8:30 AM</td>
<td>Bauer Lecture with AsMA in Tuscany C-D-E: Historical Issues in U.S. Aerospace Medicine: What did we know? When did we know it? Could we have predicted it? Michael Berry, MD, MS</td>
</tr>
<tr>
<td>9:30 AM</td>
<td>AsMA-UHMS Exhibits / Break</td>
</tr>
<tr>
<td>10:30 AM</td>
<td>UHMS Kindwall Keynote with AsMA in Tuscany C-D-E: Decision making for HBO₂ for brain injury: Lindell Weaver, MD</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>Lunch (on own) / Committee meetings / Luncheons-ticket required / Stop the Bleed Workshop: 12:00-1:00: ticket required</td>
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### UHMS Breakout: Tuscany 1 & 2 / Posters will be in Tuscany 5 & 6

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<tr>
<td>2:00 PM</td>
<td>Plenary: Protocols for spacewalk: Neal Pollock. PhD</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>Plenary: The hyperoxic-hypoxic paradox and its application in regenerative medicine: Shai Efrati, MD</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>A1: Astrocyte-derived microparticles initiate a neuroinflammatory cycle due to carbon monoxide poisoning: Stephen Thom, MD</td>
</tr>
<tr>
<td>3:10 PM</td>
<td>B15: Oxygen Dose: A new perspective: Kent MacLaughlin, MS, PhD</td>
</tr>
<tr>
<td>3:20 PM</td>
<td>A4: GABA and oxidative brain injury: Heath Gasier, PhD</td>
</tr>
<tr>
<td>3:30 PM</td>
<td>AsMA-UHMS Exhibits / Break</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Plenary: CMS Billing Records of Radiation Cystitis Patients: What do they tell Us about Hyperbaric Oxygen Effectiveness? John Feldmeier, DO</td>
</tr>
<tr>
<td>4:30 PM</td>
<td>B9: Retrospective cohort study of thyroid, bowel, and autoimmune diseases after carbon monoxide poisoning: Lindell Weaver, MD</td>
</tr>
<tr>
<td>4:40 PM</td>
<td>B10: Determining the recovery rate of hearing thresholds across audiometric frequencies with use of hyperbaric oxygen treatment: Nicole P. Harlan, MD</td>
</tr>
<tr>
<td>4:50 PM</td>
<td>B11: A cardiovascular strategy for management of carbon monoxide-poisoned patients: Sue Churchill, NP</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>B12: Hyperbaric oxygen treatment appears to be safe for patients with severe COVID-19 and moderate ARDS. Interim safety results from the clinical trial COVID-19-HBO: Anders Kjellberg, MD</td>
</tr>
<tr>
<td>5:10 PM</td>
<td>B13: Retrospective analysis of radiation cystitis: mortality and transfusion requirements with and without hyperbaric oxygen: Kayla Deru</td>
</tr>
<tr>
<td>5:20 AM</td>
<td>B14: Hyperbaric oxygen therapy for the treatment of perianal fistulas in 20 patients with Crohn’s disease: results of the HOT-TOPIC trial after 1-year follow-up: CA Lansdorp, MD</td>
</tr>
</tbody>
</table>

### TUESDAY, MAY 24

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
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<tbody>
<tr>
<td>7:00 AM</td>
<td>Registration</td>
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<tr>
<td>Time</td>
<td>Event</td>
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</tr>
<tr>
<td>8:30 AM</td>
<td>Registration / coffee / Vendors</td>
</tr>
<tr>
<td>8:30 AM</td>
<td><strong>UHMS Lambertsen Keynote with AsMA in Tuscany C-D-E:</strong> Undersea medicine is out of this world! - Hyperbaric medical support at NASA’s Neutral Buoyancy Lab: Bob Sanders, MD</td>
</tr>
<tr>
<td>8:45 AM</td>
<td><strong>UHMS Breakout:</strong> Tuscany 1 &amp; 2 / Posters will be in Tuscany 5 &amp; 6</td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>Announcements with AsMA in Tuscany C-D-E</strong></td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>Reinhart Panel with AsMA (shared history) in Tuscany C-D-E:</strong> &quot;Overcoming Barriers on the Pressure Spectrum: From the Past to the Future&quot;. Joseph P. Dervay, MD MPH, MMS, FACEP (Moderator); Jonathan Clark, MD, MPH (Panelist); Jay Dean, PhD (Panelist); NASA Astronaut Michael Gernhardt, PhD (Panelist); Richard Moon, MD, CM, MSc, FRCP(C), FACP, FCCP (Panelist)</td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>AsMA-UHMS Exhibits / Break</strong></td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>AsMA-UHMS Exhibits / Break</strong></td>
</tr>
<tr>
<td>11:00 AM</td>
<td><strong>Plenary:</strong> Filling the gaps - Future Navy diving needs: Capt. David Regis, MD</td>
</tr>
<tr>
<td>11:00 AM</td>
<td><strong>Plenary:</strong> Enhancing safety through mishaps and significant incidents lessons learned: Jon Clark, MD</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>Lunch (on own) / Committee meetings / Luncheons-ticket required / Stop the Bleed Workshop: 12:00-1:00: ticket required</td>
</tr>
<tr>
<td>2:00 PM</td>
<td><strong>A2:</strong> Oxidative stress after administration of oxygen at different pressures and concentrations: Enrico Camporesi, MD</td>
</tr>
<tr>
<td>2:10 PM</td>
<td><strong>C32:</strong> Gas bubble mechanics in the spinal cord: Jens-Christian Meiners, PhD</td>
</tr>
<tr>
<td>2:20 PM</td>
<td><strong>C33:</strong> Decompression sickness rates in underwater divers utilizing air surface decompression vs. oxygen surface decompression: Christine Lee</td>
</tr>
<tr>
<td>2:30 PM</td>
<td><strong>C34:</strong> Capsule Project: A physiological survey during 3 days of shallow saturation dives in a very limited space: Emmanuel Dugrenot, PhD</td>
</tr>
<tr>
<td>2:40 PM</td>
<td><strong>C35:</strong> SWEN 21 the approach to suggest new air dive tables for the Swedish Armed Forces: Marten Silvaniu</td>
</tr>
<tr>
<td>2:50 PM</td>
<td><strong>D1:</strong> Shared Medical and performance challenges in the naval undersea and aerospace operational domains: Ben Lawson, PhD</td>
</tr>
<tr>
<td>3:00 PM</td>
<td><strong>D52:</strong> Evaluations of Divers after COVID-19 Infection: Charlotte Sadler, MD</td>
</tr>
<tr>
<td>3:10 PM</td>
<td><strong>D53:</strong> DAN looks at longitudinal return to diving and vaccination results from divers with COVID-19 infection: Frauke Tillmans, PhD</td>
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<td>3:20 PM</td>
<td><strong>E79:</strong> High oxygen tension takes its toll: Disparate effects of hyperbaric oxygen and hyperoxia on viral entry gene and toll-like receptor pathway gene expression in normal and COPD-diseased: Yu-Chia Tsao, RRT</td>
</tr>
<tr>
<td>3:30 PM</td>
<td><strong>D54:</strong> Chest CT analysis of lung cysts after SARS-COV-2 / <strong>D58:</strong> Prevalence of underlying lung cysts by chest computed tomography: Lin Weaver, MD</td>
</tr>
<tr>
<td>3:40 PM</td>
<td><strong>F92:</strong> Clinical and immunological effects of hyperbaric oxygen therapy (HBO₂T) in severe non-intensive COVID-19 patients: Randomized control trial: Jacek Kot</td>
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<tr>
<td>3:50 PM</td>
<td><strong>F93:</strong> Test of cross corrections for altitude air and nitrox diving at 8,000, 10,000 and 12,000 ft: Timothy Beck</td>
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<tr>
<td>4:00 PM</td>
<td><strong>F94:</strong> Clinical trial of sildenafil to prevent swimming-induced pulmonary edema (SIPE); Timothy Beck</td>
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<td>5:00 PM</td>
<td><strong>Plenary:</strong> Manned testing of rapid pressure fluctuations associated with Naval aviation physiological events (PE): LT Travis Doggett</td>
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**Wednesday, May 25**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
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<tbody>
<tr>
<td>8:30 AM</td>
<td>Registration / coffee / Vendors</td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>UHMS Lambertsen Keynote with AsMA in Tuscany C-D-E:</strong> Undersea medicine is out of this world! - Hyperbaric medical support at NASA’s Neutral Buoyancy Lab: Bob Sanders, MD</td>
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<tr>
<td>10:00 AM</td>
<td><strong>AsMA-UHMS Exhibits / Break</strong></td>
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<td>Time</td>
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<tr>
<td>10:30 AM</td>
<td>Plenary: Update on Emergency use of HBO₂ and what if any traction we've received though our</td>
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<td>congressional efforts: Richard Moon, MD</td>
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<tr>
<td>11:00 AM</td>
<td><strong>E80:</strong> Hyperbaric oxygen exposure disparately affects lineage-specific and apoptosis-asso-</td>
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<td>ciated marker expression in differentiated normal and COPD-diseased human bronchial epithelial</td>
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<td>11:10 AM</td>
<td><strong>E81:</strong> Quantification of indications received at two emergency-capable hyperbaric medicine</td>
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<td>centers: Michael Tom, MD</td>
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<tr>
<td>11:20 AM</td>
<td><strong>B20:</strong> Hyperbaric oxygen therapy improves symptoms, brain's microstructure and functiona-</td>
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<td>lity in veterans with treatment resistant post-traumatic stress disorder: Keren</td>
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<td>Doenys-Barak, MD</td>
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<td>11:30 AM</td>
<td><strong>F95:</strong> Hypoxic exercise performance (VO2max) at 15,000 ft altitude vs. surface baseline:</td>
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<td>Aashay P. Patel</td>
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<td>11:40 AM</td>
<td><strong>F97:</strong> Central retinal artery occlusion outcomes after treatment with hyperbaric oxygen:</td>
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<td>a single: Christopher Allen</td>
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<td>11:50 AM</td>
<td><strong>F99:</strong> Cognitive enhancement of healthy older adults using hyperbaric oxygen: a ran-</td>
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<td>domized controlled trial: Amir Hadanny</td>
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<tr>
<td>12:00 PM</td>
<td>Lunch (on own) / Committee meetings / Luncheons-ticket required / Stop the Bleed Workshop:</td>
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<td></td>
<td>12:00-1:00: ticket required</td>
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<tr>
<td>2:00 PM</td>
<td><strong>F88:</strong> Electroencephalogram functional connectivity is sensitive for nitrogen narcosis in</td>
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<td>air breathing at 608 kPa: Xavier Vrijdag, PhD</td>
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<td>2:10 PM</td>
<td><strong>F89:</strong> Comparison between arterial blood gases, SpO₂ and ORI in a scuba diver breathing</td>
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<td>air: Enrico Camporese, MD</td>
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<td>2:20 PM</td>
<td><strong>Plenary:</strong> UHM Fellows: Top articles in Undersea Medicine: Ian Kirby, MD: UCSD Fellow</td>
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<tr>
<td>2:55 PM</td>
<td><strong>Plenary:</strong> UHM Fellows: Top articles in Hyperbaric Medicine: Russell Gray, MD: Brooke Army</td>
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<td></td>
<td>Medical Center Fellow</td>
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<tr>
<td>3:30 PM</td>
<td><strong>AsMA-UHMS Exhibits / Break</strong></td>
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<tr>
<td>4:00 PM</td>
<td><strong>RAM Bowl with AsMA in Tuscany C-D-E</strong></td>
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<td><strong>THURSDAY, MAY 26</strong></td>
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<tr>
<td>7:00 AM</td>
<td>Registration</td>
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<tr>
<td>8:15 AM</td>
<td><strong>Armstrong Lecture with AsMA in Tuscany C-D-E:</strong> Medical &amp; Human Factors Challenges of New</td>
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<td>Aerospace Transportation Systems. Melchor Antuñano, MD, MS</td>
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<tr>
<td>9:15 AM</td>
<td><strong>ASSOCIATES BREAKOUT SESSION in Tuscany 1 &amp; 2</strong></td>
</tr>
<tr>
<td>10:00 AM</td>
<td><strong>B31:</strong> Under Pressure: A Case Study of violence while at depth in the hyperbaric chamber:</td>
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<td></td>
<td>Melissa Schroeder presenting for Beth Cipra, DNP, RN, APRN-CNS, CCRN-K</td>
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<tr>
<td>10:30 AM</td>
<td><strong>E86-E87:</strong> Pneumatic device to assist patients with middle ear pressure equalization:</td>
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<td>Geness Koumandakis, RRT / Fredric Ashton, RRT</td>
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<tr>
<td>11:00 AM</td>
<td><strong>Hyperbaric Oxygen Risk Assessment with Inhaled Cannabis History:</strong> Anthony Johnston BSN,</td>
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<td>RN, ACHRN</td>
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<tr>
<td>11:30 PM</td>
<td>Lunch (on own) / Committee meetings / Luncheons-ticket required / Stop the Bleed Workshop:</td>
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<td></td>
<td>12:00-1:00: ticket required</td>
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<tr>
<td>1:30 PM</td>
<td><strong>E82:</strong> ZOLL Z-Vent ventilator use under hyperbaric conditions: Greg Brown, CHT</td>
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<tr>
<td>2:00 PM</td>
<td><strong>E83:</strong> Recruitment and retention outcomes in a study on hyperbaric oxygen for persistent</td>
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<td>symptoms after brain injury: Rosemary Ziemnik</td>
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<tr>
<td>2:30 PM</td>
<td><strong>Gunshot Testing to a pressurized monoplace hyperbaric chamber:</strong> Lindell Weaver, MD</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>break</td>
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<tr>
<td>3:30 PM</td>
<td><strong>Hearing aid compatibility for Class A hyperbaric environment:</strong> Ian Kirby, MD; UCSD Fellow</td>
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<tr>
<td>4:00 PM</td>
<td><strong>Carbon monoxide, COVID and Kids:</strong> Jay Duchnick, RN</td>
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<tr>
<td>4:30 PM</td>
<td><strong>B28:</strong> Mass casualty carbon monoxide poisoning in a Spanish-speaking population resulting</td>
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<td>in some with lasting sequelae: Dr. Lin Weaver presenting on behalf of Mariesa Norton, NP</td>
</tr>
<tr>
<td>6:00 PM</td>
<td><strong>AsMA / UHMS honors night (must have a ticket to attend)</strong></td>
</tr>
</tbody>
</table>
**Overall Goal of the UHMS Annual Scientific Meeting**

The primary goal of the Undersea and Hyperbaric Medical Society ASM is to provide a forum for professional scientific growth and development to the participants. The meeting provides a basis for exchange of ideas, both scientific and practical, among physicians, researchers, and other health professionals. It affords an opportunity for participants to meet and interact with past and present leaders of the Society, and to become active in societal affairs.

**CONTINUING EDUCATION**

**Accreditation Statement:** The Undersea and Hyperbaric Medical Society is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

**Designation Statements:**
- **The ORCA Project: Operational Resilience and Cognitive Awareness: Sunday, May 22:** The Undersea and Hyperbaric Medical Society designates this live activity for a maximum of 7 AMA PRA Category 1 Credit(s)™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.
- **Wound Care for the Hyperbaric Provider: Sunday, May 22:** The Undersea and Hyperbaric Medical Society designates this live activity for a maximum of 8 AMA PRA Category 1 Credit(s)™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.
- **2022 AsMA-UHMS Annual Scientific Meeting: May 23-26:** The Undersea and Hyperbaric Medical Society designates this live activity for a maximum of 23 AMA PRA Category 1 Credit(s)™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

**Nursing CEU:**
License Types Approved: Advanced Registered Nurse Practitioner; Clinical Nurse Specialist; Licensed Practical Nurse; Registered Nurse; Certified Nursing Assistant; Respiratory Care Practitioner Critical Care; Respiratory Care Practitioner Non-Critical Care; Registered Respiratory Therapist; Certified Respiratory Therapist

- **The ORCA Project: Operational Resilience and Cognitive Awareness: Sunday, May 22** is approved by the Florida Board of Registered Nursing Provider #50-10881. Credit hours approved 7.
- **Wound Care for the Hyperbaric Provider: Sunday, May 22** is approved by the Florida Board of Registered Nursing Provider #50-10881. Credit hours approved 8.
- **2022 AsMA-UHMS Annual Scientific Meeting: May 23-26** is approved by the Florida Board of Registered Nursing Provider #50-10881. Credit hours approved 23.

**NBDHMT:**

- **The ORCA Project: Operational Resilience and Cognitive Awareness: Sunday, May 22:** The NBDHMT does not recognize this educational program as meeting their requirements and scope for credit.
- **Wound Care for the Hyperbaric Provider: Sunday, May 22:** The NBDHMT does not recognize this educational program as meeting their requirements and scope for credit.
- **2022 AsMA-UHMS Annual Scientific Meeting: May 23-26:** This live activity is approved for 7 Category A credit hours by National Board of Diving and Hyperbaric Medical Technology, 9 Medical Park, Suite 330, Columbia, South Carolina 29203.

**Lectures that are approved:**
- **Monday, May 23**
  - 5pm-5:10pm: **B12:** Hyperbaric oxygen treatment appears to be safe for patients with severe COVID-19 and moderate ARDS. Interim safety results from the clinical trial COVID-19-HBO: Anders Kjellberg, MD
- **Tuesday, May 24**
- 11:30am-12pm: **Plenary:** Enhancing Safety through Mishaps and Significant Incidents Lessons Learned: Jon Clark, MD
- 2pm-2:10pm: Oxidative Stress after Administration of Oxygen at Different Pressures and Concentrations: Enrico Camporesi, MD

**Wednesday, May 25**

- 10:30am-11am: **Plenary:** Update on Emergency use of HBO2 and what if any traction we've received though our congressional efforts: Richard Moon, MD
- 2:20pm-2:55pm: **Plenary:** UHM Fellows: Top articles in Undersea Medicine, Ian Kirby, MD, UCSD Fellow
- 2:55pm-3:30pm: **Plenary:** UHM Fellows: Top articles in Hyperbaric Medicine, Russell Gray, MD, Brooke Army Medical Center Fellow

**Thursday, May 26**

- 10am-10:30: **B31:** Under Pressure: A Case Study of Violence While at Depth in the Hyperbaric Chamber: Melissa Schroeder presenting on behalf of Beth Cipra, DNP, RN, APRN-CNS, CCRN-K
- 10:30am-11am: **E86 -E87:** Pneumatic Device to Assist Patients with Middle Ear Pressure Equalization: Geness Koumandakis, RRT / Fredric Ashton, RRT
- 11am-11:30am: **B16:** D-dimer elevations with acute carbon monoxide poisoning: Kayla Deru presenting on behalf of Nina Davis, APRN
- 1:30pm-2pm: **E82:** ZOLL Z-Vent Ventilator Use Under Hyperbaric Conditions: Greg Brown, CHT
- 2pm-2:30pm: **E83:** Recruitment and Retention Outcomes in a Study on Hyperbaric Oxygen for Persistent Symptoms after Brain Injury: Rosemary Ziemnik
- 2:30pm-3pm: Gunshot Testing to A Pressurized Monoplace Hyperbaric Chamber: Lindell Weaver, MD
- 3:30pm-4pm: Infection Prevention in the Hyperbaric Environment: Gus Gustavson, RN
- 4pm-4:30pm: Carbon monoxide, COVID and Kids: Jay Duchnick, RN
- 4:30pm-5pm: **B28:** Mass casualty carbon monoxide poisoning in a Spanish-speaking population resulting in some with lasting sequelae: Mariesa Norton, NP

**Full Disclosure Statement:** All faculty members and planners participating in continuing medical education activities sponsored by Undersea and Hyperbaric Medical Society are expected to disclose to the participants any relevant financial relationships with ineligible companies. Full disclosure of faculty and planner relevant financial relationships will be made at the activity.

**Disclosure:**

The following individuals have disclosed a relevant financial relationship with ineligible companies. Financial relationships are relevant if the following three conditions are met for the individual who will control content of the education:

A financial relationship, in any amount, exists between the person in control of content and an ineligible company and;

1. The content of the education is related to the products of an ineligible company with whom the person has a financial relationship and;
2. The financial relationship existed during the past 24 months.
3. All of the relevant financial relationships listed for these individuals have been mitigated

None of the individuals in control of content (planners/faculty/reviewers/authors) for this educational activity have relevant financial relationship(s) to disclose with ineligible companies whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

- AsMA 92nd / UHMS Annual Scientific meeting: May 23-26
- The ORCA Project: Operational Resilience and Cognitive Awareness: May 22

The following individuals in control of content (planners/faculty/reviewers/authors) for this educational activity have relevant financial relationship(s) to disclose with ineligible companies whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

- Wound Care for the Hyperbaric Provider: May 22
  - Suzie Ehmann, PT, DPT, CWS, CLT-LANA
  - 3M: Consultant/Speakers Bureau
Compression Dynamics: Consultant/Unrestricted Educational Grant
Milliken: Consultant/Speakers Bureau
Jobst/Essity: Consultant/Speakers Bureau
L&R: Consultant/Speakers Bureau
Urgo: Consultant/Speakers Bureau/Advisory Board
Medline: Consultant/Speakers Bureau

No commercial support was received for the following activities:
- The ORCA Project: Operational Resilience and Cognitive Awareness: May 22
- AsMA 92nd / UHMS Annual Scientific meeting: May 23-26

Commercial support was received for the following activity:
- Wound Care for the Hyperbaric Provider: May 22
  - Smith & Nephew:
    - Educational grant: $1,500
    - In-Kind: four-layer compression wraps
  - Milliken Healthcare Products, LLC
    - Financial support: $2,133
    - In-Kind: CoFlex TLC Compression kits and the wound dressings (TRITEC Silver and AGILE).

Disclaimer: The information provided at this CME activity is for Continuing Medical Education purposes only. The lecture content, statements or opinions expressed however, do not necessarily represent those of the Undersea and Hyperbaric Medical Society.

EVALUATION LINK: The evaluation link is below. It will require answering questions and providing feedback on the educational program to help with future planning. Your credit certificate will be provided to your inbox of the email provided immediately upon submitting your evaluation.
https://www.uhms.org/asma-uhms-2022-evaluation
Monday, May 23

WELCOME / OPENING CEREMONIES
0800-0830
Tuscany C-D-E

UHMS PRESIDENT
Speaker: Marc Robins, DO
Tuscany C-D-E

About the Lecture:
Provide a brief welcome and overview of UHMS.

About Marc Robins, DO
Marc Robins, DO, MPH, FUHM is the Senior Medical Director for the Wound & Hyperbaric Shared Services for the Intermountain Healthcare System in Utah. He is the current President of the UHMS and has served as Co-Chair for the Quality Utilization, Authorization and Reimbursement Committee and on the Education Committee for the UHMS. He is an Associate Fellow of the Aerospace Medical Association (AsMA) and has served on the Science and Research committee AsMA since 2001-20. He is boarded in Hyperbaric Medicine, Aerospace and Occupational Medicine and Family Practice and retired as a Colonel from the USAF after a 20-year career in Aerospace Medicine.

AsMA’s Louis H. Bauer Lecture
Speaker: Michael Berry, MD, MS
0830-0930
Tuscany C-D-E
(Sponsored by KBR)

Historical Issues in U.S. Aerospace Medicine: What did we know? When did we know it? Could we have predicted it?
Dr. Weaver will discuss “Decision making for HBO₂ in brain injury.” He will review hyperbaric oxygen for diving-related disorders affecting the central nervous system, carbon monoxide poisoning, hypoxic brain injury and traumatic brain injury. Clinicians are typically aggressive at accepting and treating compressed gas divers and aviators with decompression illness who exhibit central nervous system injury yet have much more variable interest and willingness to treat non-diving, or decompression-related disorders that affect the central nervous system. Fundamentally the injury that occurs with dysbarism may be similar to the cascade of injuries from non-dysbarism causes. Dr. Weaver plans to discuss these differing clinician behaviors.

About Dr. Weaver:
Dr. Weaver received a BS in Engineering Science from Arizona State University followed by medical school from the University of Arizona. He served a rotating internship in the US Navy, then went through the medical officer’s course in Undersea and Submarine medicine and was an Undersea Medical Officer on the USS Canopus (AS-34) for two years. After discharged he served in the Naval Reserves with SEAL Team 1-3-5 for a few years. After discharge from Active Duty he trained in Internal Medicine, with fellowship training in pulmonary and critical care at the University of Utah. After completion of fellowship, he became the Medical Director of Hyperbaric Medicine and Co-director of the Shock Trauma Respiratory ICU at the Level One trauma center, LDS Hospital, Salt Lake City, Utah for 20 years. He was a co-investigator for the ARDSnet of the NIH and was the principle investigator of a randomized controlled trial of hyperbaric oxygen for acute carbon monoxide poisoning, published by the New England Journal of Medicine. He is a former president of the Undersea and Hyperbaric Medical Society. He has authored and co-authored hundreds of papers, abstracts, and book chapters. For 10 years he had a senior leadership role in the DoD effort to conduct blinded randomized trials of hyperbaric oxygen for post-concussive syndrome due to War-related mild traumatic brain injury. Research activities include study of neural auto-antibodies following carbon monoxide poisoning and a randomized trial of hyperbaric oxygen for sequelae months to years after brain injury. He enjoys off-road UTV and adventure motorcycle riding, SCUBA diving, and spending time with his family.
ABOUT ERIC P. KINDWALL, MD

Dr. Kindwall is known by many as the “Father of Hyperbaric Medicine.” Whether you knew him personally or simply by reputation, we have all benefited from his efforts, passion, wisdom, knowledge, energy and vision. Dr. Kindwall has played a great role in growing and shaping the specialty of Undersea and Hyperbaric Medicine. He was likewise instrumental in molding the UHMS into what it is today. Dr. Kindwall began diving in 1950. He cultivated his interest in the field and during the Vietnam War served as the Assistant Director of the U.S. Navy School of Submarine Medicine. He also was the Senior Officer responsible for the Diving Medicine Program. In 1969, after leaving the Navy, Dr. Kindwall became Chief of the Department of Hyperbaric Medicine at St. Luke’s Medical Center, Milwaukee, Wis. Shortly after the Undersea Medical Society was created in the mid-1960s, Dr. Kindwall identified the need for standardized education in the field. He created the UMS Education and Standards Committee to help elevate course content and ensure instructor competence. This committee later became our Education Committee. When the AMA initiated its Continuing Medical Education program, Dr. Kindwall persuaded the organization to recognize the UMS as a grantor of CME credits. In 1972, Dr. Kindwall felt that the Society’s members would benefit from improved communication. He created our first newsletter and was named editor. Dr. Kindwall chose the name Pressure because clinical hyperbaric medicine was rapidly developing. Even though the UHMS had not yet incorporated “Hyperbaric” into the Society’s name, he wanted a title for the newsletter that would encompass all who worked with increased atmospheric pressure. He stated: “The Society’s goal then, as it is now, is to serve all who deal with the effects of increased barometric pressure.” That same year, Dr. Kindwall recognized the need to have a relationship with Medicare to help provide insight on reputable clinical management. The UMS followed this lead, and a Medicare Panel was created. The recommendations were presented to the U.S. Public Health Service. The challenge was that no reliable hyperbaric medicine clinical guidelines were available that addressed appropriate applications of Hyperbaric Medicine. To remedy this deficit, the UMS Executive Committee created an Ad Hoc Committee on hyperbaric oxygen therapy. Dr. Kindwall was named Chair. The committee created the first Hyperbaric Oxygen Therapy Committee Report. Again, this text was published 10 years before the UHMS incorporated “Hyperbaric” into its name. The report was sent to HCFA and the Blues and became their source document for reimbursement. Dr. Kindwall updated the text two more times and thus was the Editor and Chair of the Committee and text for three of its 12 editions. Dr. Kindwall later worked to expand the available information on the specialty by creating one of the first complete texts on the field. He created Hyperbaric Medicine Practice in 1994 and later updated and revised his text two more times. The Society’s first journal, Hyperbaric Oxygen Review, has also been influenced by Dr. Kindwall. His love for research and education was clear: He became the initial editor, creating a journal that at first consisted of review articles and one original contribution. Over the years, it has grown to one full of original research. Dr. Kindwall’s presence is felt in so many of the UHMS’ activities and initiatives. Much of what we all take for granted – what is just “there” and “available” – has his touch and influence.

Plenary: Protocols for space walk
Speaker: Neal Pollock, PhD
1400-1430
Tuscany 1-2
About the Lecture
Decompression for divers is a concept far more ingrained in the public psyche than decompression for spacewalking astronauts. This presentation will contrast the two, provide a review of the research leading to current prebreathe protocols used for spacewalking in the US program, and consider the exchange of insight between diving and aerospace experience.

About Dr. Pollock
Dr. Neal Pollock is an Associate Professor in Kinesiology at Université Laval in Québec, QC and conducts research at the Centre de médecine de plongée du Québec, Hôtel-Dieu de Lévis, QC. He was previously Research Director at Divers Alert Network (DAN) in Durham, NC. His academic training is in zoology, exercise physiology and environmental physiology. His research interests focus on human health and safety in extreme environments. He currently serves on the executive board of the Canadian Undersea and Hyperbaric Medical Association (CUHMA), as scientific director of Undersea Medicine Canada, and on the diving control board of the University of the Virgin Islands. He is also Editor-in-Chief of the journal Wilderness & Environmental Medicine, an Associate Editor for the journal Environmental, Aviation and Space Physiology, and on the editorial board of the journal Diving and Hyperbaric Medicine. He lectures extensively, locally through internationally.

Plenary: The hyperoxic-hypoxic paradox and its application in regenerative medicine
Speaker: Shai Efrati, MD
1430-1500
Tuscany 1-2

About the Lecture
The intermittent increase of oxygen concentration induces many of the mediators and cellular mechanism that are usually induced during hypoxia but without the hazardous hypoxia - termed Hyperoxic-Hypoxic Paradoxes. Among other, the intermittent hyperoxic exposure during HBO₂T can affect HIF-1 levels, matrix metalloproteinases (MMP) activity, VEGF, induce stem cells proliferation, augmented circulating levels of endothelial progenitor cells (EPCs) and angiogenesis factors, as well as induce angiogenesis and improved blood flow in the ischemic area. In addition to stimulation of EPCs, HBO₂T can decrease the inflammatory response in endothelial cells mediated by TNF-alpha, and thus, promote vascular recovery. Both animal and human studies have demonstrated the beneficial effects of HBO₂T on mitochondrial function and its related metabolism.

In this lecture we will review the physiological effect of the so called "Hyperoxic - Hypoxic Paradox" and the newly cumulative data on brain injuries, age related functional decline and cardio-muscular performance.
About Professor Shai Efrati, MD:
Director of the Sagol Center for Hyperbaric Medicine and Research, Shamir (Assaf-Harofeh) Medical Center, Israel; Director of Research & Development, Shamir (Assaf-Harofeh) Medical Center, Israel; Professor at Sackler School of Medicine and the Sagol School of Neuroscience of Tel Aviv University.

Dr. Shai Efrati is a professor at Sackler School of Medicine and the Sagol School of Neuroscience of Tel Aviv University and the director of the Sagol center for hyperbaric medicine and research at Shamir (Assaf-Harofeh) Medical Center in Israel. The center, under Prof. Efrati management, has become one of the largest hyperbaric centers worldwide, currently treating more than 300 patients per day. Prof. Efrati is also the director of Research & Development at the Medical center, affiliated to Tel-Aviv University. Taking the two passions/positions together Dr. Efrati has initiated a research program focusing on the neuroplasticity (regeneration of damage brain tissue) by the use of Hyperbaric Oxygen Therapy (HBO₂T). In the first clinical studies it was demonstrated that HBO₂T can induce neuroplasticity in post stroke and Traumatic Brain Injury even years after the acute Insult. The important clinical results gained from the research program have led to fruitful ongoing cooperation including multidiscipline team focusing on the regenerative effects of hyperbaric oxygen in anoxic brain injuries, central sensitization syndrome and other types of chronic brain injuries, Post-Traumatic Stress Disorder (PTSD), post-COVID condition and age-related functional decline.

Plenary: CMS billing records of hyperbaric oxygen for radiation cystitis reveal some interesting findings
Speaker: John Feldmeier, DO, FACRO, FUHM
1600-1630
Tuscany 1-2

About the Lecture
Dr. Feldmeier has chaired a research project carried out by members of the UHMS Research Committee in cooperation with a for-profit research corporation named Dobson/DaVanzo Health Economics Consulting. This project used a unique and original methodology employing CMS billing records to compare and contrast the cost of managing radiation-induced cystitis with and without hyperbaric oxygen in Medicare beneficiaries. Groups were well matched after application of the Charlson Morbidity Index. Without access to the HIPPA protected medical records we were able to construct the interventions and cost thereof for the treatment of radiation-induced cystitis in both populations. More than 3200 patients were enrolled, approximately 1000 in the hyperbaric treatment group and 2200 in the non-hyperbaric group. With assumptions that we made based on billing records after treatment we were able to determine patient outcome. Several interesting differences in outcome resulted suggesting several distinct advantages for the hyperbaric group. One unexpected result was an improved frank survival of the hyperbaric group compared to the non-hyperbaric group. Incurred medical expenses following the treatment period demonstrate a definite advantage for the hyperbaric-treated patients. The results also demonstrate a dose response curve showing a better outcome for patients treated with a total of 40 or more treatments compared to fewer than 40. The study suffers from a limited number of years of CMS clinical billing data, but the study design entering all those diagnosed with radiation cystitis avoids some of the drawbacks of certain randomized controlled trials which impose entry exclusions due to intercurrent disease or other demographic patient characteristics. The authors believe that this design may actually provide a better picture of real-world results compared to randomized controlled trials where exclusion criteria may impact a broad application of results. This study was supported in part by an unrestricted grant from Healogics LLC.
About the Dr. Feldmeier
Dr. Feldmeier is professor emeritus of radiation oncology at the University of Toledo from which he has retired as the long-term chairman. He has been recognized as a “Best Doctor” since 2007 until his retirement in 2014. He is the past chairman of the Hyperbaric Medicine Facility at Wright-Patterson AFB. He is a past president of the Undersea and Hyperbaric Medical Society. He is the Editor of the UHMS Indications Manual, 11th Edition. He is recognized as an expert in applying hyperbaric oxygen to the management of radiation injuries. He is board certified in both radiation oncology and hyperbaric medicine. He currently serves as a co-chair of the UHMS Research Committee. He is a member of the Accreditation Council and a Surveyor for the UHMS Accreditation Program. He co-chairs the FDA Liaison Committee. He is the 2021 recipient of the prestigious Albert Behnke Award of the UHMS.

Tuesday, May 24

ANNOUNCEMENT WITH AsMA
0830-0845
Tuscany C-D-E

Joint AsMA-UHMS Eugen Reinartz Panel
0845-1000
Tuscany C-D-E
(Educational support by Eugen Reinartz Memorial Fund)

“Overcoming Barriers on the Pressure Spectrum: From the Past to the Future”
Joseph P. Dervay, MD MPH, MMS, FACEP (Moderator)
Jonathan Clark, MD, MPH (Panelist),
Jay Dean, PhD (Panelist)
NASA Astronaut Michael Gernhardt, PhD (Panelist)
Richard Moon, MD, CM, MSc, FRCP(C), FACP, FCCP (Panelist)

Plenary: DCS/bubble dynamics and related content
Speaker: Michael Gernhardt, PhD
1030-1100
Tuscany 1-2

About the Lecture
This lecture will focus on decompression and bubble dynamics, with the theme of how subsea and altitude decompression are related, and how data from each environment increase our understanding of decompression stress.

About the Dr. Gernhardt
Expertise: NASA Astronaut, Manager of Environmental Physiology Laboratory and Principle Investigator of Prebreath Reduction Program, Johnson Space Center
Affiliation: NASA JSC
Certification/Education: Ph.D. Bioengineering, University of Pennsylvania
M.A.Sc. Bioengineering, University of Pennsylvania
B.Sc. Physics, Vanderbilt University

Dr. Gernhardt was selected by NASA in March 1992 and reported to the Johnson Space Center in August 1992. Technical assignments to date include: flight software verification in the Shuttle Avionics Integration Laboratory (SAIL); development of nitrox diving to support training for the Hubble Space Telescope repair and on a variety of Space Station EVA developments; member of the astronaut support team at Kennedy Space Center, Florida, responsible for Shuttle prelaunch vehicle checkout, crew ingress/egress; spacecraft communicator (CAPCOM) at Mission Control Center, Houston, during various Shuttle missions; lead an international research team in developing a new exercise prebreathe protocol that improved the safety and efficiency of space walks from the ISS. Gernhardt presently serves as a member of the astronaut office EVA branch, Project Scientist of the EVA Physiology System and Performance Project (EPSP), Manager of JSC’s Environmental Physiology Laboratory, and Project Manager of the Small Pressurize Rover project.

A four-flight veteran, Dr. Gernhardt has logged over 43 days in space, including 4 spacewalks totaling 23 hours and 16 minutes. He was a mission specialist on STS-69 in 1995, STS-83 in 1997, STS-94 in 1997 and STS-104 in 2001. Additionally, he was a crewmember on the NEEMO (NASA Extreme Environment Mission Operations) One, and Commander of the NEEMO eight multi-day underwater missions. He also served as a submersible pilot on the Pavilion Lake Expedition focused on exploring a deep-water lake in western Canada where unusual life forms called microbiolites have very recently been discovered.

Plenary: Filling the gaps - Future Navy diving needs
Speaker: Capt. David Regis, MD
1100-1130
Tuscany 1-2

About the Lecture
This lecture will be geared towards the medical/physiological aspects of what the Navy needs are to fill knowledge and capability gaps in diving.

About Capt. Regis
David Regis, MD CAPTN US Navy, Undersea Medical Officer and Program Manager - Deep Submergence Biomedical Development Program Naval Sea Systems Command Code 00CM.

Plenary: Enhancing safety through mishaps and significant incidents lessons learned
Speaker: Jonathan Clark, PhD
About the Lecture

About the Jonathan Clark
Jonathan Clark is an adjunct Associate Professor of Neurology and Space Medicine at Baylor College of Medicine. Dr. Clark served 26 years on active duty with the U.S. Navy, and qualified as a Naval Flight Officer, Naval Flight Surgeon, Navy Diver, U.S. Army parachutist and Special Forces Military Freefall Parachutist. His assignments including heading a research centrifuge facility, and the Neurology and Hyperbaric Medicine divisions at the Naval Aerospace Medical Institute where he treated diving and altitude decompression sickness and studied divers exposed to high intensity sonar. During Operation Desert Storm he was the 3rd Marine Air Wing Special Projects Officer responsible for Chem/Bio Defense Plan and the Sustained Operations Plan. He flew combat medical evacuation missions and was in the first air element into Kuwait City with the Marine Corps. He ran the aeromedical department at Marine Aviation Weapons & Tactics Squadron One, and participated in Marine Recon and ANGLICO team HAHO and HALO jumps. Dr. Clark worked at NASA from 1997 to 2005, was a Space Shuttle Crew Surgeon on six shuttle missions, Chief of the Medical Operations Branch and a senior FAA Aeromedical Examiner (AME). He was a Member of the NASA Spacecraft Survival Integrated Investigation Team from 2004 to 2007 and a Member of the NASA Constellation Program EVA Systems Project Office Standing Review Board from 2007 to 2010. He was the Space Medicine Advisor for the National Space Biomedical Research Institute from 2005 to 2017. In 2008 he was an expedition physician supporting the Haughton Mars Project on Devon Island in the high Canadian Arctic. He was Chief Medical Officer for the orbital commercial space company Excalibur Almaz from 2007 to 2012, and Chief Medical Officer for the Inspiration Mars Foundation since 2013. Dr. Clark was Medical Director of the Red Bull Stratos Project, a manned stratospheric balloon freefall parachute flight test program, which on 14 October 2012 successfully accomplished the highest stratospheric freefall parachute jump (highest exit altitude) from 127,852 feet, achieving human supersonic flight (Mach 1.25) without a drogue chute at 843 miles per hour. In 2012 Dr. Clark joined the StratEx Space Dive project as the lead flight surgeon and medical advisor, and this project culminated in the new high altitude exit freefall record of 135,890 feet and reaching Mach 1.22 at 822 miles per hour in 2014. He currently is a consultant for Virgin Galactic, Heinlein Prize Trust, Paragon Space Development Corp, JAG Human Performance, Space Perspectives, Operator Solutions, and the Foundation for Aerospace Safety and Training. Dr. Clark is board certified in Neurology and Aerospace Medicine and is a Fellow of the Aerospace Medical Association. Recreational activities include scuba diving, flying aircraft, and spending time in the wilderness. His professional interests focus on the neurologic effects of extreme environments, crew survival, and resilience.

Plenary: Manned testing of rapid pressure fluctuations associated with Naval aviation physiological events (PE)
Speaker: LT Travis Doggett
1700-1730
Tuscany 1-2

About the Lecture
The U.S. Navy's premier tactical aircraft platforms, the F/A-18 and EA-18G, are experiencing physiological episodes (Phys Eps) of unexplained rapid cockpit pressure fluctuations. Some of these Phys Eps have resulted in Naval Aviator injuries collectively termed Physiological Events (PEs). In 2010 the number of hazard reports related to PEs increased compared to the previous years and have continued to rise sharply each year since 2012. F/A-18 reports of PEs increased from 57 in 2012 to 114 in 2016.
Although associated with rapid pressure fluctuations, the root cause of these PEs remains elusive. Additionally, the lack of understanding in the subtle differences between hypoxia, hypocapnia, and altitude decompression sickness, has hindered prompt recognition, diagnosis, and treatment of PEs. According to the current Clinical Practice Guidelines, Aviation PEs occurring in the presence of rapid cockpit pressure fluctuations often result in aviators and aircrew being treated with hyperbaric oxygen therapy. Unfortunately, because the root cause remains elusive, it is unclear what pathology is being treated with hyperbaric oxygen. The Navy Experimental Diving Unit (NEDU) partnered with the Naval Air Systems Command (NAVAIRSYSCOM) F/A-18 and EA-18G Program Management Office (PMA-265) and the Naval Surface Warfare Center - Panama City Division (NSWC-PCD) to investigate pressure-related PEs currently impacting the operational readiness of Naval Aviation. NEDU conducted the first-ever human subject research study utilizing a unique purpose-built pressure vessel for human occupancy (PVHO) hypobaric chamber. This hypobaric chamber known as the Fluctuating Altitude Simulation Technology (FAST) System is capable of replicating the rapid pressure fluctuations observed in both asymptomatic F/A-18 Phys Eps and symptomatic PEs.

The primary objective of this study was to elucidate whether manifestations resembling PEs would occur subsequent to rapid pressure oscillations in the absence of confounding factors such as breathing system resistance and to characterize any physiological symptoms that may result. Simultaneously, the study was designed to place bounds on the probability of decompression sickness (DCS) as the cause of PEs while also identifying areas and physiological symptoms worthy of future study. Seventy human subject volunteers were exposed to one of three randomly selected pressure profiles provided by PMA-265. Clinical and physiological data collected consisted of history and physical examinations, physiologic monitoring (heart rate, oxygen saturation, and 3 lead electrocardiogram tracings), nystagmus assessment via direct observation and eye-tracking movements, Doppler venous bubble monitoring, tympanograms, and cognitive function screening.

About LT Doggett:
Lieutenant Doggett was born in Little Rock, AR and raised in Lafayette, Louisiana. He holds a BS in Anthropology and Biology from Louisiana State University (2004) and Our Lady of the Lake College (2008), and a PhD in Medical Physiology from Louisiana State University Health Sciences Center, Department of Physiology (2014).

LT Doggett was commissioned in the Medical Service Corps of the United States Navy in 2016 and reported to the Navy Experimental Diving Unit (NEDU) in Panama City, FL. Since 2017, LT Doggett served as the Program Manager and Principal Investigator of the Aviation Hypobaric Research Group. Here, he worked to enhance the readiness and lethality of all aviators and directed the first-of-its-kind human subjects research investigating the CNO #1 safety concern of Physiological Events (PE) in the Naval Aviation Enterprise. He worked with engineers and active-duty at NEDU and Naval Surface Warfare Center Panama City Division (NSWC-PCD) to design and acquire the Fluctuating Altitude Simulation Technology (FAST), providing NEDU with a new hypobaric research capability. The data and information he collected helped restore operational tempo, enhanced mission readiness, significantly contributed to determining the root cause of PE, and provided much-needed guidance and reassurance to fleet aviators and leadership.

At NEDU, LT Doggett served as Deputy Department Head assisting in the leadership and management of the N32 Biomedical Department; comprising of a yearly budget of over $6 million, 18 GS and uniformed PhD scientists, and 32 research personnel; producing multiple technology and procedure transitions, enhancing operational readiness and lethality of Navy Divers, Submariners, and SPECWAR personnel. As department asset manager, LT Doggett directed the Navy Material Accountability Campaign (NMAC) inventory of N32; tracking and accounting over $3.3 million in assets; including 94
NMCI and RDTE computers, and over 250 specialized research and data collection devices. He was Contracting Officer’s Representative (COR) on the NEDU SeaPort Contract since 2019. In this time-intensive collateral duty, he oversaw over $1.4 million per year in the funding, employment, and management of 9 highly skilled contractors providing vital expertise and sustaining the command’s operational tempo. Additionally, he served as NEDU Wardroom Coordinator and Treasurer. He was named the 2018 Medical Service Corps Research Physiologist of the year.

In April 2021, LT Doggett reported to the Naval Air Warfare Center Aircraft Division (NAWCAD) as Senior Human Physiology Program Manager with the Aeromedical Monitoring & Analysis Division. In this role he leads over $3.8M in critical human factors research across 6 projects addressing procedures to mitigate neck/back pain, optimally fit gear, and reduce PE impacting safety and survivability of USN & USMC aircrew and producing an annual >$161M health & >$250M mishap/damage burden. Additionally, he provides expertise in human physiology for the validation of over $2.5M potential acquisitions in simulated operational environment tests to enhance fleet safety & survivability guidance. He organizes discussion panels at national meetings to establish essential partnerships between NAWCAD, Defense Health Agency (DHA) and the private sector, improving the acquisition enterprises of NAVAIR and Navy Medicine.

LT Doggett is currently completing Joint Professional Military Education Level 1 and the Graduate Degree Program leading to a Master of Arts Degree in Defense and Strategic Studies through the Naval War College. He holds DAWIA certification in Level II Program Manager, Level II Engineering. Additional professional duties have included serving on multiple Scientific Review and Institutional Review Board committees across over 10 projects and human subjects research protocols with over 50 military subject volunteers. His individual military awards include the Navy and Marine Corps Achievement Medal and Navy and the Marine Corps Commendation Medal.
Wednesday, May 25

**UHMS’ Christian J. Lambertsen Lecture**

**Speaker:** Robert Sanders, MD, DMT, FACEP, FUHM

0830-1000

**Lecture Title:** Undersea Medicine is Out of this World! - Hyperbaric Medical Support at NASA’s Neutral Buoyancy Lab

Tuscany C-D-E

**About the Lecture:**

**About Dr. Sanders:**

Bob Sanders diving career began in 1983 training through both NAUI and LA County. Passionate about the sport he attended the NAUI college and became a certified SCUBA diving instructor in 1987. Dr. Sanders’ medical “career” began in 1989 as an EMT & Ski Patrol member, and in 1993 he ventured into hyperbarics as a technician and supervisor at the USC Catalina Hyperbaric Chamber. He also served as a scientific diver and field safety officer in Antarctica for 4 seasons diving in 28º water below 12’ of ice.

* Needing to learn more, Sanders received his MD degree from the Chicago Medical School. After residency in Emergency Medicine at the University of Pittsburgh, and additional training at the University of Hawaii’s Hyperbaric Treatment Center, he became boarded in both Emergency Medicine and Undersea & Hyperbaric Medicine. He is a nationally recognized speaker and has authored multiple book chapters and peer-reviewed journal articles.

Currently, Sanders is a Crew Health and Safety Flight Surgeon at the University of Texas Medical Branch and KBR on contract to NASA’s NBL as their Medical Director and lead physician for the exploration class spacesuit development project. He has been the Medical Director for American Hyperbaric Centers in Anchorage AK (overseeing clinical hyperbarics & commercial dive operations) and was the Undersea and Hyperbaric Medicine Fellowship director at the Hennepin County Medical Center. He works as an Attending Emergency Physician since 2008 and has served as a Flight Physician for STAT MedEvac.

Dr. Sanders also serves as the tactical medicine physician for the Harris County Sheriff’s Office Dive Team, after many years diving with Pittsburgh River Rescue and the LA County Sheriff conducting search and recovery of bodies and evidence. He is an avid technical and scientific diver; has conducted shark diving & tagging operations and worked as a set medic and water safety coordinator for the Motion Picture Industry. In 2017 Sanders was awarded NASA’s prestigious “Early Career Public Achievement Medal”, The UHMS Gulf Coast Chapter’s most prestigious award, the Jefferson C. Davis MD Memorial Award presented for clinical excellence and research in clinical hyperbaric medicine, and the UHMS
ABOUT CHRISTIAN J. LAMBERTSEN, MD, DSc (Hon)

Dr. Christian J. Lambertsen received a B.S. Degree from Rutgers University in 1938 and a M.D. Degree from the University of Pennsylvania in 1943. During his medical school period, he invented and first used forms of the initial U.S. self-contained closed-circuit oxygen rebreathing apparatus, for neutral buoyancy underwater swimming and diving. As a student, he aided the early Office of Strategic Services (O.S.S.) in establishing the first cadres of U.S. military operational combat swimmers. Dr. Lambertsen became a U.S. Army medical officer on graduation from medical school in early 1943, and immediately joined the O.S.S. Maritime Unit on active duty through its period of function in World War II. He joined the University of Pennsylvania Medical Faculty in 1946 and became Professor of Pharmacology in 1952. While a faculty member he combined diving research and further underwater rebreathing equipment developments for the Army and Navy. In 1967 he served as Founding President of the Undersea Medical Society (now Undersea and Hyperbaric Medical Society.) Dr. Lambertsen is recognized by the Naval Special Warfare community as “The Father of U.S. Combat Swimming.” His hand has touched every aspect of military and commercial diving. Dr. Lambertsen’s active contributions to diving began during WWII and became even more progressive in the post-war period through the evolutions of the U.S. Navy Deep Submergence and Naval Special Warfare developmental programs.

Plenary: Update on Emergency use of HBO2 and what if any traction we've received though our congressional efforts:
Speaker: Richard Moon, MD
1030-1100
Tuscany 1-2

About the Lecture
Several indications for hyperbaric oxygen approved by the Undersea and Hyperbaric Medical Society require urgent treatment. Nevertheless, treatment after hours, particularly for critically ill patients, is unavailable in most cities. Transportation of patients requiring urgent hyperbaric care is often difficult and inevitably leads to delayed treatment. Efforts to improve the situation have been made by the UHMS, but to date unsuccessful. The lecture will be followed by a discussion regarding methods to resolve this situation.

About the Dr. Moon
Dr. Richard Moon trained in internal medicine, biomedical engineering, pulmonary and critical care medicine and anesthesiology. He has been a faculty member at Duke University and practicing anesthesiologist since 1983. He is currently Medical Director of the Duke Center for Hyperbaric Medicine & Environmental Physiology and performs research in the physiology of extreme environments (altitude and diving), perioperative respiratory function, mechanisms of pulmonary edema during swimming and diving, and investigation
of sudden death during triathlons. He has received awards for Excellence in Medical Student Education and twice been nominated Teacher of the Year by Duke Anesthesiology, and mentorship recognition by the AMA-Women Physicians Congress.

Plenary: UHM Fellows: Top articles in Undersea Medicine
Speaker: Ian Kirby, MD, UCSD Fellow
1420-1455
Tuscany 1-2

About the Lecture
A discussion on recent undersea medicine publications and how they impact clinical practice.

About Dr. Kirby
Prior to medicine Lieutenant Commander Kirby was employed as a Canadian Armed Forces Reserve Diesel Mechanic and then as a Naval Ships Officer specialized in Naval Mine Warfare and Navigation. In the civilian community he obtained a Masters in Kinesiology degree and practice in Physical Rehabilitation. After serving 15 years as a Naval Reserve Ships Officer and civilian Kinesiologist, he pursued a career in Medicine. Dr Kirby attend the University of British Columbia Medical School followed by a Family Practice Residency at McGill University. He has been in clinical practice since 2013 as a full practice Family Physician employed full time with the Canadian Military. Dr Kirby has been trained in Dive Medicine, Submarine Medicine, Flight Surgeon, and deployed to the Middle East, Baltic, Mediterranean and South Asian seas. Dr Kirby was fortunate to serve as the Canadian Pacific Fleet Surgeon where he oversaw medical preparations for deployments and provided professional technical oversight for deployed clinical practices. He was appointed the Base Surgeon accepting the Medical Director role for a multi-site and multi-disciplinary clinic. Dr Kirby is now an Undersea and Hyperbaric Medicine Fellow at University California San Diego. After completing fellowship training, he will support Canadian military Divers and Submariners as a “Consultant in Dive and Submarine Medicine” and plans to add wound care and hyperbaric medicine to his Family Medicine practice.

Plenary: UHM Fellows: Top articles in Hyperbaric Medicine
Speaker: Russell Gray, MD, Brooke Army Medical Center Fellow
1455-1530
Tuscany 1-2

About the Lecture

About Dr. Gray
About the Lecture:
The 11th Annual RAM Bowl
The 11th Annual RAM Bowl features teams from the Air Force, Navy/Army, Mayo Clinic, Wright State and University of Texas competing for the Louis H. Bauer Trophy. International residents will be able to participate. Aerospace Medicine Residents are required to demonstrate multiple competencies to satisfy the requirements of ACGME and ABPM and serve as specialists in the field. Multiple tools are available for developing appropriate didactic knowledge in aerospace medicine, public health, epidemiology, biostatistics and health care management. Teams complete in a college bowl format that tests aerospace medicine competencies, recall speed, teamwork and individual knowledge. Topics include the specialty aerospace medicine competencies including the flight environment (atmosphere, radiation, vibration, acceleration, and microgravity), clinical aerospace medicine, aircraft and space vehicle systems/operations, accident investigation, historical events, aerospace physiology, human factors, ergonomics, medical standards, federal aviation regulations, passenger transport, restraint and escape, cockpit resource management and AeroMedical transportation. Questions are divided into toss-up questions and bonus questions. Multiple rounds of competition will lead to the selection of this year’s victor and awarding of the Louis H. Bauer Trophy, sponsored by the American Society of Aerospace Medicine Specialists.

Learning Objectives:
1. The contest will enable participants to prepare for ABPM examinations in Aerospace Medicine.
Thursday, May 26

**AsMA’s Harry G. Armstrong Lecture**
0830-0930
Tuscany C-D-E
*(Sponsored by Environmental Tectonics Corporation)*

Medical & Human Factors Challenges of New Aerospace Transportation Systems.
Melchor Antuñano, MD, MS

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**UHMS Breakout Session**
Tuscan 1-2

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<tr>
<th>Time</th>
<th>Session</th>
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<tr>
<td>10:00 AM</td>
<td><strong>B31</strong>:</td>
<td>Under Pressure: A Case Study of Violence While at Depth in the Hyperbaric Chamber:</td>
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<td>Beth Cipra, DNP, RN, APRN-CNS, CCRN-K</td>
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<tr>
<td>10:30 AM</td>
<td><strong>E86-E87</strong>:</td>
<td>Pneumatic Device to Assist Patients with Middle Ear Pressure Equalization:</td>
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<td>Geness Koumandakis, RRT / Fredric Ashton, RRT</td>
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<td>11:00 AM</td>
<td><strong>B16</strong>:</td>
<td>D-dimer elevations with acute carbon monoxide poisoning: Nina Davis, APRN</td>
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<td>11:30 AM</td>
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<td>Lunch (on own)</td>
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<td>1:30 PM</td>
<td><strong>E82</strong>:</td>
<td>ZOLL Z-Vent Ventilator Use Under Hyperbaric Conditions: Greg Brown, CHT</td>
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<td>2:00 PM</td>
<td><strong>E83</strong>:</td>
<td>Recruitment and Retention Outcomes in a Study on Hyperbaric Oxygen for Persistent Symptoms</td>
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<td>after Brain Injury: Rosemary Ziemnik</td>
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<td>2:30 PM</td>
<td><strong>B28</strong>:</td>
<td>Mass casualty carbon monoxide poisoning in a Spanish-speaking population resulting in some</td>
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<td>with lasting sequelae: Mariesa Norton, NP</td>
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<td>3:30 PM</td>
<td><strong>B28</strong>:</td>
<td>Infection Prevention in the Hyperbaric Environment: Gus Gustavson, RN</td>
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<td>4:00 PM</td>
<td><strong>B28</strong>:</td>
<td>Carbon monoxide, COVID and Kids: Jay Duchnick, RN</td>
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<td>4:30 PM</td>
<td><strong>B28</strong>:</td>
<td>Mass casualty carbon monoxide poisoning in a Spanish-speaking population resulting in some</td>
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<td>with lasting sequelae: Mariesa Norton, NP</td>
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Astrocyte-derived microparticles initiate a neuroinflammatory cycle due to carbon monoxide poisoning
Thom SR, Walia D, Bhopale VM, Kalakonda S
Department of Emergency Medicine, University of Maryland School of Medicine Baltimore, MD
Presenting Author: Stephen R Thom MD
sthom@som.umaryland.edu

Introduction/Background: We hypothesized that carbon monoxide (CO) establishes an inflammatory cycle mediated by microparticles (MPs) based in part from our prior work.

Materials and Methods: Using a mouse model of CO poisoning, we evaluated nuclear factor (NF)-κB activation in brain by immunohistochemistry, brain inflammation by Western blot, and generation of MPs by flow cytometry.

Results: Following CO poisoning, MPs co-expressing thrombospondin (TSP)-1 and astrocyte-specific glial fibrillary acidic protein (GFAP) are elevated in deep cervical lymph nodes (CLN) that drain the brain lymphatic system and also in the blood. These MPs gain access to the bloodstream where they activate neutrophils to generate a new family of MPs, and also stimulate endothelial cells disturbing the blood-brain barrier as assessed by leakage of intravenous 2000 kDa dextran. At the brain microvasculature, neutrophil and MPs sequestration, and myeloperoxidase activity result in elevations of the p65 subunit of NF-κB, serine 536 phosphorylated p65, CD36, and loss of astrocyte aquaporin-4 that persist for at least seven days after a one-hour CO exposure. Knockout mice lacking the CD36 membrane receptor are resistant to all CO inflammatory changes. Mice exposed to 2.8 ATA O2 for 45 minutes following CO poisoning also fail to exhibit all inflammatory changes. Events triggered by CO are recapitulated in naive wild-type mice injected with cervical node MPs from CO-exposed mice, but not control mice. All MPs-mediated events are inhibited in mice infused with a NF-κB inhibitor, a myeloperoxidase inhibitor, or anti-TSP-1 antibodies.

Summary/Conclusions: Astrocyte-derived MPs expressing TSP-1 establish a feed-forward neuroinflammatory cycle involving endothelial CD36-to-astrocyte NF-κB crosstalk. Hyperbaric oxygen appears to function as a novel anti-inflammatory agent to abrogate CO-initiated events.
Oxidative stress after administration of oxygen at different pressures and concentrations

Paganini M 1, Mrakic-Sposta S 2, Vezzoli A 2, Giacon TA 1, Dellanoce C 2, Balestra C 2, Camporesi E 3, Bosco G 1

1 Nutrition and Exercise Physiology Laboratory, Department of Biomedical Sciences, University of Padova, Padova, Italy; 2 Institute of Clinical Physiology, National Research Council (CNR), Milan, Italy; 3 Dept. of Surgery, Univ. of South Florida, Tampa, FL

Presenting Author: Enrico Camporesi MD
ecampore@usf.edu

Introduction/Background: While regular training induces beneficial effects by stimulating the expression of antioxidant mechanisms, an inadequately intense exercise can be detrimental. Reactive oxygen species (ROS) increase during exercise, creating a redox imbalance toward oxidation [1] and, potentially, cellular damage. Normobaric and hyperbaric oxygen (HBO 2) breathed while not exercising previously demonstrated to induce antioxidant enzymes [2], but literature is still poor. This study tested the effectiveness of oxygen breathed (O 2) at different mixtures and pressures in mitigating oxidative stress.

Materials and Methods: Twenty-two well-trained, consenting adult athletes from different disciplines were included and assigned to five groups: controls; 30%, or 50% O 2; and 100% O 2 at 1.5 or 2.5 ATA. Subjects trained at least three times/week, and a total of 20 treatments were administered every other day. Samples of venous blood, saliva, and urine were obtained at basal state (T0), at the end of treatments (T1), and one month after the end (T2). ROS production, antioxidant capacity (TAC), lipid peroxidation (8-isoPGF 2α) total and reduced aminothiols (cysteine - Cys; cysteinyl glycine - CysGly; homocysteine - Hcy; and glutathione - GSH), creatinine, neopterin, and uric acid concentrations were determined.

Results: Treatments with both 30% and 50% O 2 mixtures and both HBO 2 groups showed an increase in ROS levels and lipid peroxidation (T1), along with a decrease in TAC (T1) and counterbalancing ROS-related damages at T2. Furthermore, 50% O 2 and both HBO 2 at 1.5 and 2.5 ATA showed a higher level of total and reduced GSH (T2) resulting from a positive shift in redox balance toward a more reduced state.

Summary/Conclusions: The results suggest that HBO 2 at 1.5 and 2.5 ATA both induce protective mechanisms against ROS, despite the latter could expose the body to higher ROS levels and neopterin concentration. Further applications should be investigated in the future, especially targeting frail or sarcopenic subjects.

References
Hyperbaric oxygen induced overexpression of coronaviral and influenza viral entry genes and toll-like receptor pathway genes and may exacerbate virus-associated cytokine storm in COPD airway epithelial cells
Li YM, Chang Y, Chen CM, Chen YH
Graduate Institute of Aerospace and Undersea Medicine, National Defense Medical Center, Taipei City, Taiwan
Presenting Author: Yu-Ming Li MD
ndmctsgh1114@gmail.com

Introduction/Background: Recent studies have demonstrated that TLR2 and TLR4 respectively interact with the SARS-CoV-2 envelope and spike proteins, and both are positively correlated with exacerbations of chronic obstructive pulmonary disease (COPD). Therefore, we were interested in illuminating whether increased oxidative stress would further aggravate the cytokine storm in the COPD airway compared to the normal (healthy) airway.

Materials and Methods: Normal (NHBE) and COPD-diseased (DHBE) human bronchial epithelial (HBE) cells derived from Caucasian age-matched (59~67-year-old) donors were obtained from Lonza Biotechnology Company and cultured on the air-liquid interface under normoxia or daily exposure to hyperbaric oxygen (HBO$_2$) with 100% O$_2$ at 2.5 ATA for 40 minutes for 28 days in total.

Results: Consistent with the significant increases in the mRNA levels of the SARS-CoV-2 entry genes ACE2 and TMPRSS2, other coronaviral receptor genes ANPEP and DPP4, and the influenza viral receptor gene ST3GAL4 in the HBO$_2$-exposed DHBE tissues, expression of TLR2 and its co-receptor MD-2 and adaptor MYD88 as well as the downstream kinase-binding adaptor TAB2 and regulatory kinases PI3K catalytic subunits α and β (PIK3CA and PIK3CB genes), TPL2, and MAPK14, all exhibited significantly increased mRNA levels in the HBO$_2$-exposed DHBE tissues. Interestingly, the pro-inflammatory cytokine genes CXCL8 (IL-8), IL12A, CCL3 (MIP-1α), CCL4 (MIP-1β), and CCL5 (RANTES) as well as the interferon and interferon receptor genes IFNA7, IFNB1, IFNAR2, and IFNAR2 all showed dramatically increased expression in the HBO$_2$-exposed DHBE tissues compared to the normoxia-exposed DHBE tissues.

Summary/Conclusions: Here we show for the first time that HBO$_2$-induced oxidative stress causes significantly greater increases in the mRNA levels of multiple adaptor proteins, regulatory kinases, pro-inflammatory cytokines and interferons downstream of Toll-like receptors in the COPD-diseased compared to normal HBE cells, which are correlated with significantly increased coronaviral entry gene expression and aggravated cytokine storm in the COPD airway.
GABA and oxidative brain injury
Gasier HG, Suliman HG, Demchenko IT, Piantadosi CA
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Introduction/Background: In hyperbaric oxygen (HBO₂) at ≥ 3 atmospheres absolute (3 ATA), GABA production declines and the ratio of glutamate-to-GABA increases, neurochemical changes that are related to shortened seizure latencies. Administering GABA or antiepileptic GABAergic drugs decreases seizure severity and delays onset. How GABA influences oxidative cellular injury responses remains unknown and is the focus of this research.

Materials and Methods: Anesthetized Sprague Dawley rats were instrumented for measurement of mean arterial blood pressure, heart rate, EEG, cerebral blood flow (CBF) and neurotransmitters in HBO₂ at 6 ATA. Rats received artificial cerebral spinal fluid (aCSF) or tiagabine (TGB, 0.6 mM), a selective inhibitor of GABA transporter 1 (GAT1). Conscious mice were provided 0.9% NaCl or TGB (4.8 mg/kg) and exposed to HBO₂ at 5 ATA. Glutamate and GABA were determined using HPLC and immunoassays. DNA oxidation, astrocyte reactivity (cell injury) and activation of mitochondrial removal (mitophagy) were determined in the hippocampus and cerebellum by measuring the fluorescence of 8-hydroxy-2'deoxyguanosine (8-OHdD), glial fibrillary acid protein (GFAP) and LC3-II, respectively.

Results: In anesthetized rats interstitial GABA levels decreased by 29% at 30 minutes and further declined throughout HBO₂. Seizure latency was 52 minutes. In TGB-treated rats, tachycardia, hypertension and cerebral hyperemia were prevented, and seizure latency was extended by 34%. In conscious mice, HBO₂ led to pronounced increases in the brain glutamate-to-GABA ratio, DNA oxidation, astrocyte reactivity and mitophagy activation. Seizure latency was 12 ± 9 minutes. In TGB-treated mice, these parameters were significantly reduced except for LC3-II that was further augmented in the cerebellum, responses that were accompanied by a 98% extension in time to seizure onset.

Summary/Conclusions: These data provide new insight into the brain’s cellular responses to extreme HBO₂ and an expanded role of GABAergic transmission. The preservation of CBF may account for the reduction in DNA oxidation and astroglial injury.
Finding the beneficial targeted hyperbaric oxygen treatment pressure in acute carbon monoxide poisoning in a rat model
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Introduction/Background: Poisoning with carbon monoxide (CO) remains a significant cause of accidental and intentional injury worldwide. The progressive delayed neuropsychological damage in CO poisoning may be due to neuron apoptosis. Applying high-concentrated oxygen is a standard and widely used treatment for CO poisoning. Several studies have suggested that hyperbaric oxygen (HBO2) therapy prevents the development of delayed neuropsychological sequelae. However, different treated target pressures used after CO exposure for evaluating the effects of HBO2 for injured neuron recovery and reducing neuronal cell apoptosis have not been well studied thus far. In addition, the function of mitochondria according to the oxygen pressure difference also has not been evaluated. This study aims to evaluate the efficacy of HBO2 based on the different treated target pressures in neurological functions related to mitochondria function after CO poisoning by using the rat model.

Materials and Methods: For this study 30 male Sprague Dawley (SD) rats were divided into five groups: post-CO-treated with room air (RA); 100% O2; HBO2 at 2.5 ATA; HBO2 at 2.7 ATA; and HBO2 at 3.0 ATA. The rats were exposed to continuously 2700 ppm CO and for 25 min in the HBO2 chamber. Following CO poisoning, we treated with RA, 100% O2, 2.5 ATA HBO2, 2.7 ATA HBO2, and 3.0 ATA HBO2 for 90 minutes. We performed the open field test and the plus-maze test to evaluate the neurobehavioral function of rats before and after CO poisoning. Within one hour after HBO2, rats were sacrificed, and histological analysis and Western blot analysis were performed to confirm the neuronal cell death and mitochondrial function.

Results: HBO2 treatment immediately improved CO-induced pathologic conditions, including motor and mood performance, compared to the RA group. In particular, 3.0 ATA HBO2 showed the best improvements among the other interventions. The mitochondrial function increased in 2.5, 2.7, and 3.0 ATA HBO2 groups rather than in the RA group. However, there was no significance in histologic findings to confirm neuronal cell death among the interventions.

Summary/Conclusions: HBO2 has a pressure-dependent protective effect on CO-induced neurobehavior and mitochondrial function, with the highest effect in 3.0 ATA after CO poisoning. Because CO-poisoned rats immediately were sacrificed after HBO2, we could not confirm the histological differences among groups, but considering the mitochondrial response, it could be presumed that there will be an effect related to neuronal protection during long-term follow-up.

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Theranostic potential of ultrasound-stimulated phase-change contrast agents to eradicate methicillin-resistant Staphylococcus aureus biofilm infections in a diabetic wound model

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Introduction/Background: Bacterial biofilms perpetuate the inflammatory phase of wound healing and are the leading cause of delayed wound healing. Chronic wound biofilms are remarkably difficult to treat due to the presence of antibiotic-tolerant persister cells and poor drug penetration through the bacterial-produced biological barriers. Here we propose a novel approach with therapeutic potential to eradicate a chronic wound infection; utilizing ultrasound-stimulated phase change contrast agents to improve the penetration of anti-persister drugs.

Materials and Methods: A novel diabetic wound model of methicillin-resistant Staphylococcus aureus (MRSA) infection was established. Briefly, SKH-1 hairless mice were treated with streptozocin to induce diabetes, then a 4mm circular wound was created on the back of the mice and infected with bioluminescent MRSA. A total of 50 mice were treated topically with gentamicin (Gent), and/or palmitoleic acid (PA), or the vehicle twice daily for four days. One daily antibiotic treatment was combined with ultrasound (US), topically administered phase-change contrast agents (PCCA), combined US+PCCA, or left without additions. On day 5, mice were euthanized and the wound area was excised, homogenized and plated to enumerate colony-forming units (cfu). Statistical significance was determined using Kruskal Wallis one-way ANOVA with Dunn’s multiple comparison test.

Results: Histopathology of MRSA-infected wounds confirmed the presence of biofilm. Neither Gent nor Gent/PA significantly reduced bacterial burden in the wound. Similarly, Gent/PA combined with ultrasound alone or PCCA alone did not reduce bacterial burden. However, combining Gent with US+PCCA caused a significant reduction in bacterial burden compared to the untreated control. The anti-persister drug combination Gent/PA with US+PCCA caused the greatest decrease in bacterial burden and, importantly, three out of eight mice had no detectable bacteria left.

Summary/Conclusions: These data demonstrate that MRSA biofilm eradication in diabetic wounds may be achieved by using a combined approach of increasing drug penetration and targeting persister cells.
Hyperbaric oxygen therapy does not alleviate tourniquet-induced acute ischemia-reperfusion injury in mouse skeletal muscles
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Introduction/Background: During tourniquet application, blood flow is restricted to a limb to stop excessive limb hemorrhage in a trauma setting and to create a bloodless operating field in the surgical setting. During tourniquet-related ischemia, aerobic respiration stops, and adenosine triphosphate (ATP) is depleted, and during subsequent reperfusion, there is an increase in reactive oxygen species (ROS) production and other endogenous substances, which leads to acute ischemia-reperfusion (IR) injuries, including tissue necrosis and skeletal muscle contractile dysfunction. Hyperbaric oxygen (HBO₂) therapy can increase the arterial oxygen tension in the tissues of patients with general hypoxia/anoxia, including carbon monoxide poisoning, circulatory arrest, and cerebral and myocardial ischemia. Here, we studied the protective effects of HBO₂ pretreatment with 100% oxygen at 2.5 ATA against tourniquet/IR injury in mice.

Materials and Methods: After one hour of HBO₂ therapy with 100% oxygen at 2.5 ATA was administered to C57/BL6 mice, a rubber band was placed at the hip joint of the unilateral hindlimb to induce three hours of ischemia and then released for 48 hours of reperfusion. We analyzed gastrocnemius muscle morphology and contractile function and measured the levels of ATP and ROS accumulation in the muscles.

Results: HBO₂ pretreatment did not improve tourniquet/IR-injured gastrocnemius muscle morphology and muscle contraction. Tourniquet/IR mice with HBO pretreatment showed no increase in ATP levels in IR tissues, but they did have a decreased amount of ROS accumulation in the muscles, compared to IR mice with no HBO₂ pretreatment.

Summary/Conclusions: These data suggest that one hour of HBO₂ pretreatment with 100% oxygen at 2.5 ATA increases the antioxidant response to lower ROS accumulation but does not increase ATP levels in IR muscles and improve tourniquet/IR-injured muscle morphology and contractile function.
Retrospective cohort study of thyroid, bowel, and autoimmune diseases after carbon monoxide poisoning
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Introduction/Background: Mining of large population datasets has revealed long-term health consequences of carbon monoxide (CO) poisoning.

Materials and Methods: Using the MDClone ADAMS platform, we searched our hospital system’s databases to identify patients aged 18-74 years with acute CO poisoning or influenza who presented to hospitals (emergency visits or inpatient admissions). We identified occurrence of hypothyroidism, bowel, and autoimmune diseases before and after the visit of interest. Patients with a prior history of each condition were excluded, and only patients with new diagnoses were considered in the analyses for each condition. Chi-squared tests were used for univariate analyses.

Results: We identified 2,562 patients with CO poisoning (58% male, mean age 39) and 4,605 controls (41% male, mean age 41 ± 16).

The rate of new hypothyroid disease was 5.5% in the CO group and 2.9% in the influenza group (odds ratio 1.94, 95% confidence interval 1.50-2.50, p<0.001).

The rate of new bowel disease (bowel ischemia/infarction, necrotizing enterocolitis, bowel ileus/obstruction, irritable bowel syndrome, functional diarrhea, neurogenic bowel, nontraumatic intestinal perforation, or abdominal migraine) was 5.1% in the CO group vs 3.1% in the influenza group (OR 1.67, 95% CI 1.30-2.15, p<0.001).

The rate of new autoimmune disease (fibromyalgia, rheumatoid arthritis, multiple sclerosis, lupus erythematosus, Addison’s disease, Graves’ disease, Hashimoto’s thyroiditis, Sjogren’s syndrome, and myasthenia gravis) was 3.3% in the CO group and 2.4% in the influenza group (OR 1.38, 95% CI 1.03-1.85, p=0.03). When the diseases were then tested individually, only multiple sclerosis had a statistically significant difference (0.4% vs 0.1%, OR 4.96, 95% CI 1.58-15.6, p=0.002).

Summary/Conclusions: In this retrospective cohort study, patients with CO poisoning were more likely than patients with influenza to develop new hypothyroid, bowel, or autoimmune disease following their hospital visit.
Determining the recovery rate of hearing thresholds across audiometric frequencies with use of hyperbaric oxygen treatment
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Introduction/Background: Hyperbaric oxygen treatment (HBO2) was first reported to improve auditory outcomes following sudden sensorineural hearing loss (SSNHL) in the early 1970s. The proposed mechanism of action is a reversal in the oxygen deficit within the cochlea. Despite more than 40 years of interest in the delivery of HBO2, the therapeutic mechanism and frequency-specific recovery show considerable variability. Further investigation of frequency-specific results of HBO2 for SSNHL may provide a better understanding of the therapeutic mechanism. This study seeks to investigate amount of recovery (in dB) across tested audiometric frequencies (250 to 8000 Hz) before and after HBO2. The overall goal is to retrospectively analyze patient outcomes to better understand how specific frequency regions are affected after HBO2. This work will aid in the understanding of the recovery rate (in dB) of audiometric thresholds with HBO2 and provide future directions for HBO2 therapy for SSHL.

Materials and Methods: A retrospective study was conducted at Dartmouth-Hitchcock Medical Center in Hanover, New Hampshire. Inclusion criteria comprised adults (age range 18-90) with SSNHL and seen for HBO2. SSNHL was defined as a greater than 30dB sensorineural hearing loss occurring in at least three neighboring audiometric frequencies with confirmation by an audiologist. Primary outcome variables were audiometric thresholds from 500 to 8,000 Hz before and after HBO2. The analysis included amount of recovery in dB as a response variable in a linear mixed effect model with fixed effects including age, gender, and time between onset of symptoms and first HBO2 session.

Results: HBO2 resulted in a significant recovery of audiometric thresholds across the audiogram. Increased recovery of low frequency thresholds (250-2000 Hz) was more profound compared to high frequency thresholds (3000-8000 Hz) (Figure 1). Time between onset of symptoms and HBO2 was also found to be inversely correlated with audiometric threshold recovery.

Summary/Conclusions: HBO2 was shown to be an effective treatment of SSNHL with recovery of thresholds across the audiogram. Increased recovery of low-frequency thresholds was apparent in our study, but the reason for these results remains unknown. Possible interpretations include the change in vasculature of the cochlea from base to apex, but future studies will need to confirm this interpretation. Future studies should also assess the combined effect of oral steroids with HBO2 and possible
spontaneous recovery of thresholds after SSNHL.
A cardiovascular strategy for management of carbon monoxide-poisoned patients
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Introduction/Background: Carbon monoxide (CO) poisoning causes cardiac injury, warranting a management strategy.

Materials and Methods: Retrospective review of CO-poisoned patients, only including patients with elevated troponin I (Trp1) and subsequent cardiac testing.

Results: From 8/2005 to 9/2021, 732/1,178 patients with acute CO poisoning had Trp1 measurement (62%). Of these, 164 (22%) had an elevated Trp1 (>0.04 ng/ml); 119 (73%) on the first and 45 (27%) only on a subsequent measurement. Patients with elevated Trp1 were older than those without an elevation (mean difference 5.5 years, 95% CI 2.7-8.3 years), and without gender differences (women, 20% vs. men, 23%, p=0.36). Women were less likely to have Trp1 measured (53% vs. 69%, p<0.001). A total of 304 patients (42%) were admitted to the hospital; 507 (69%) received hyperbaric oxygen.

A total of 163 patients had echocardiography, and 114 of these (70%) had elevated Trp1; 62 patients had a left ventricular ejection fraction <55% (38%), and nine had additional cardiac testing (MRI, PET/CT, or stress). Five patients underwent cardiac catheterization.

Elevated Trp1 was associated with elevated hsCRP, WBC, CK, and CK-MB. By multivariable logistic regression, increased age and history of hypertension were associated with elevated Trp1, while gender, diabetes, hyperlipidemia, tobacco use, and coronary artery disease were not.

64/732 patients (9%) died in the interval to analysis, of which 19 (30%) had elevated Trp1, and 6/19 died within 14 days of CO poisoning. Of the remaining 13, two deaths were cardiovascular-related, and three others were living with cardiovascular disease at the time of death. Significant predictors of death beyond the acute period included older age at poisoning, pre-existing diabetes, increased WBC, and intentional CO poisoning.

Summary/Conclusions: Cardiac injury from CO poisoning is common. We propose serial testing of Trp1 and ECG in poisoned patients, including those without cardiovascular symptoms. Abnormal findings warrant cardiology consultation, echocardiography and, potentially, studies investigating reversible ischemia and follow-up.
Hyperbaric oxygen treatment appears to be safe for patients with severe COVID-19 and moderate ARDS: Interim safety results from the clinical trial COVID-19-HBO2

Introduction/Background: Mortality in severe COVID-19 has decreased from 60% to about 20%. Possible causes include the introduction of low-molecular-weight heparin and cortisone. Individual antiviral, immunomodulatory and other anti-inflammatory drugs are not conclusively effective on mortality or hospital length of stay, which are still major concerns. Hyperbaric oxygen (HBO2) is a potent anti-inflammatory drug with few side effects.


This is a randomized clinical trial, open-label, multicenter, with 200 patients with severe COVID-19 (PFI < 26.7 kPa) randomized to HBO2 or best practice. HBO2 protocol is 240 kPa/60 minutes, maximum five treatments within seven days after inclusion. Primary outcome ICU admission, safety endpoints are adverse events (AE), vital parameters (NEWS) and oxygenation (PFI). Statistical analysis was performed with the analysis of covariance, ANCOVA, including baseline levels as a covariate, and treatment as a fixed factor in the models.

Results: So far, 30 subjects were randomized; two subjects withdrew consent; and three subjects died. Patients were seriously ill at inclusion; the HBO2 group was slightly older, mean (SD) age 66.4 (11.1) versus 63.3 (8.2) years and slightly more ill: NEWS 5.4 (1.7) versus 5.3 (2.0), PFI 14.0 (3.5) versus 17.3 (6.4). HBO2 showed greater improvement compared to best practice in NEWS on day 7, mean (SE) -2.14 (0.52) versus -0.72 (0.46) and day 14 -2.34 (0.94) versus -0.58 (0.84) and PFI day 7 16.51 (4.51) versus 9.25 (4.16) and day 14 23.61 (3.15) versus 13.26 (2.90).

Adverse events were common, with 42 AEs in the HBO2 group versus 54 AEs in control. Serious adverse events (SAE) related to hypoxia/respiration where 6 in HBO2 and 11 in control. An independent safety committee assessed the safety of the first 20 patients and recommended the trial to be continued.

Summary/Conclusions
HBO₂ treatment in monoplace chambers appears to have similar or slightly better safety outcome than best practice for patients with severe COVID-19 and moderate ARDS (PFI <26.7kPa).
Retrospective analysis of radiation cystitis: Mortality and transfusion requirements with and without hyperbaric oxygen
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Introduction: Radiation cystitis can be debilitating and difficult to treat and can contribute to mortality. We retrospectively reviewed patients with radiation cystitis examining the impact of hyperbaric oxygen (HBO2) on mortality and transfusion requirements.

Methods: Using the MDClone ADAMS platform, we searched our health care system’s databases for patients diagnosed with radiation cystitis. Patients with bladder cancer were excluded.

Results: 574 patients were diagnosed with radiation cystitis from 2006 to 2021. Mean age was 72 ± 12 years, 75% were male. 199 (35%) received HBO2; 216 (38%) died in the interval to analysis. In 76 patients with known cause of death, 42% died from cancer, 25% from heart disease, and 33% due to other causes.

In univariate analyses, HBO2 conferred survival benefit in patients who completed 20 (n=180, survival odds ratio (OR) 1.51, 95% confidence interval (CI) 1.04-2.20, p=0.03), 30 (n=165, OR 1.84, 95% CI 1.24-2.73, p=0.002) or 40 sessions (n=158, OR 2.07, 95% CI 1.38-3.11, p<0.001). By multivariable logistic regression, increased age, lower hematocrit, and decreased estimated glomular filtration rate were associated with an increased risk of death, while death risk decreased as HBO2 session count increased. Gender, diabetes, and coronary artery disease were not associated with mortality.

Transfusion needs in the six months pre-diagnosis and up to two years after were not significantly different between patients who began HBO2 ≤30 days of diagnosis and patients who did not receive HBO2. However, patients beginning HBO2 >30 days after cystitis diagnosis were more likely to need transfusion before diagnosis (21% vs. 7%, OR 3.64, 95% CI 1.52-8.72, p=0.002). 30% needed transfusion in the six months pre-HBO2, and 21% in the first six months after beginning HBO2.

Conclusions: In this analysis, a course of HBO2 was associated with decreased mortality, with more sessions conferring greater survival. Delays in diagnosis and referral for HBO2 may increase transfusion needs.
Hyperbaric oxygen therapy for the treatment of perianal fistulas in 20 patients with Crohn's disease: Results of the HOT-TOPIC trial after one-year follow-up

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Introduction/Background: Previously published short-term results (week 16) of this trial showed a significant improvement in clinical, radiologic and biochemical outcomes in Crohn’s disease patients with therapy-refractory perianal fistulas after treatment with hyperbaric oxygen therapy. Here, the long-term (week 60) outcomes of the study are presented.

Materials and Methods: Crohn’s disease patients with high perianal fistula(s) failing conventional treatment > six months were included. Exclusion criteria were presence of a stoma, rectovaginal fistula(s) and recent changes in treatment regimens. Patients received 40 hyperbaric oxygen sessions (243-253 kPa, 110 minutes per session) and outcomes were assessed at week 16 and week 60.

Results: Twenty patients were included (median age 34 years). At week 16, median scores of the perianal disease activity index and modified Van Assche index (co-primary outcomes) decreased from 7.5 (95% CI 6-9) to 4 (95% CI 3-6, p<0.001) and 9.2 (95% CI 7.3-11.2) to 7.3 (95% CI 6.9-9.7, p=0.004), respectively. At week 60 the respective scores remained significantly lower than baseline: 4 (95% CI 3-7, p<0.001) and 7.7 (95% CI 5.2-10-2, p=0.003). Perianal disease activity index score of 4 or less (representing inactive perianal disease) was observed in 13 patients at week 16 and 12 patients at week 60. Using fistula drainage assessment, 12 and 13 patients showed a clinical response at week 16 and 60, respectively, and clinical remission was achieved in four patients for both time points. At week 16, a statistically significant biochemical improvement (CRP and fecal calprotectin levels) was found, but this effect was no longer significant at week 60.

Eight out of 20 patients experienced trouble equalizing middle ear pressure during HBO, three patients needed tympanostomy tubes.

Summary/Conclusions: The clinical and radiologic improvement that was found at week 16 after treatment with hyperbaric oxygen therapy is maintained at one-year follow-up.
Oxygen dose: A new perspective
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Introduction/Background: This study follows up on our findings, published in 2019, of pro-angiogenic stem progenitor cell mobilization subsequent to intermittent low-level hyperoxia (42%) in an animal model. However, this study is done in humans using a small dose of hyperbaric air. This oxygen level in the hyperbaric air is similar to 28% oxygen concentration. We hypothesized that this low dose of hyperoxia would mobilize pro-angiogenic stem progenitor cells similar to published findings in hyperbaric oxygen research.

Materials and Methods: Eight adult humans were exposed to 1.3 atmospheres absolute (ATA) of room air in a portable hyperbaric chamber (mountain sickness chamber) daily for 60 minutes, 10 times (M-F) over a 12-day period. Venous blood draws were taken at four time points: (1) immediately preceding the first treatment (control); (2) immediately following the first treatment; (3) just prior to the 10th treatment; and (4) 72-hours after final treatment. The blood samples were analyzed using flow cytometry for changes in the expression of surface markers CD45, CD34 and CD133. Statistical analysis was done using a paired Wilcoxon signed-rank test.

Results: We found a nearly twofold increase in the expression of CD45\textsuperscript{dim}CD34\textsuperscript{+}CD133\textsuperscript{−} prior to the 10th treatment (9.8% to 18.9% = 194% increase) and a threefold increase 72 hours after the 10th treatment (9.8% to 29.6% = 303% increase).

Summary/Conclusions: We conclude that breathing room air at 1.3 ATA daily for 90 minutes over a two-week period mobilizes pro-angiogenic stem progenitor cells similar to hyperbaric oxygen. These findings suggest that 1.3-ATA hyperbaric air breathed daily is a dose treatment and not a placebo nor a sham. These data suggest a re-evaluation of its use as a placebo control in scientific research is warranted.
D-dimer elevations with acute carbon monoxide poisoning
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Introduction/Background: Carbon monoxide (CO) poisoning causes inflammation. Inflammation can cause activation of coagulation, followed by fibrinolysis. D-dimer reflects this fibrinolysis but is not routinely measured in CO poisoning.

Materials and Methods: Under an IRB-approved biorepository research protocol we collected plasma from patients with acute CO poisoning (before hyperbaric oxygen) into sodium citrate vacutainers, which was frozen at -80°C. At six-month intervals we performed D-dimer testing on these samples.

Results: D-dimer was measured in 37 patients (29 men, eight women). Mean patient age was 37 ± 14 years. Mean carboxyhemoglobin was 21 ± 13% (estimated carboxyhemoglobin when CO exposure stopped was 30 ± 14%); 16 (47%) had loss of consciousness, and three (8%) were intubated; eight (22%) had elevated Troponin 1, 18 (49%) elevated high sensitivity C-reactive protein, and 11 (30%) elevated white blood cell count. D-dimer was elevated (>0.5 μg/mL) in six patients (16%).

By univariate analysis (Student’s t-test), an elevated D-dimer was associated with increased age (mean difference 16 years, 95% CI 5-28 years, p=0.007), and intubation (two of three patients with elevated D-dimer were intubated, p=0.013). D-Dimer was not associated with maximum carboxyhemoglobin, other markers of inflammation, electrocardiography abnormalities, or loss of consciousness.

A multivariable logistic regression examining for gender, age, and carboxyhemoglobin found only increased age was related to elevated D-dimer (odds ratio 1.13, 95% CI 1.01-1.25, p=0.03).

Summary/Conclusions: D-dimer was elevated in 16% of these patients, likely reflecting fibrinolysis caused by coagulation due to CO-related inflammation. These patients were not considered to have thromboembolism. These are research findings. We do not recommend checking D-dimer unless clinically indicated. CO poisoning severity, systemic disease, cardiac injury, and rhabdomyolysis may contribute to increased D-dimer, but the small cohort limits correlations to other factors. An increased sample size may enhance our understanding of the pathophysiology of CO poisoning.
Prognostic biomarkers of mitochondrial and oxidative stress in acute carbon monoxide poisoning: Prospective hyperbaric oxygen therapy intervention study

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Introduction/Background: Mitochondrial and oxidative stress participate in the pathogenic mechanisms of carbon monoxide (CO)-induced toxicity. This study aimed to demonstrate whether serum mitochondrial and oxidative stress biomarkers can reflect the brain injury and predict the neurocognitive sequelae of CO poisoning.

Materials and Methods: This prospective observational study of consecutive patients requiring hyperbaric oxygen (HBO2) therapy for acute CO poisoning to an emergency department (ED) (a single academic medical center in Wonju, Republic of Korea) between January 2020 and January 2021.

Results: We analyzed the data of 51 adult patients and measured serum biomarkers of mitochondrial (growth differentiation factor 15 [GDF15], fibroblast growth factor 21 [FGF21]), oxidative (8-Oxo-2'-deoxyguanosine [8-OHdG] and malondialdehyde [MDA]) stresses at hospital arrival (0 hours) and at 24 hours and seven days post-HBO2 therapy. Global Deterioration Scale (GDS) scores were measured at one month and were dichotomized into favorable (1-3) or poor outcomes (4-7).

Thirteen (25.5%) had poor-outcome GDS scores. Initial serum GDF15 and 8-OHdG concentrations were significantly higher in the poor-outcome group than in the favorable group. All stress biomarkers were decreased at one day post-HBO2 therapy (p<0.001), which were maintained or further decreased by one week. Notably, the percentage of change (Δ%) of GDF15 (p=0.005, area under the receiver operating characteristic curve [AUROC] = 0.757), FGF21 (p=0.06, 0.676), 8-OHdG (p<0.001, 0.885), and MDA (p<0.001, 0.828) between baseline and 24 hours post-HBO2 completion were markedly higher in the poor outcome group, reflecting greater CO-associated stress. We established a prediction model for the prognosis of neurocognitive outcomes (AUROC = 0.974).

Summary/Conclusions: Post-CO poisoning serum mitochondrial and oxidative stress biomarker levels and their decrement changes by HBO2 are proportional to the imposed stress. Models based on these levels may predict neurocognitive prognosis post-CO poisoning.

Clinical Trial Registration Number: NCT05088005
A systematic review of iatrogenic air gas embolisms
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Introduction/Background: Arterial gas embolisms can be caused iatrogenically, commonly from benign procedures such as venipuncture to significantly invasive procedures such as pulmonary nodule biopsy. To date, these events have not been categorically assembled. Our best data on incidence has been by case reports and series reported in academic journals and is sparse. Moreover, medical education does not routinely teach about these complications, thus care is varied and often delayed or omitted.

Materials and Methods: A systematic review of published literature using PRISMA was performed to quantify iatrogenic arterial gas embolisms (iAGEs). Titles and abstracts were assessed for eligibility. Screening and data extraction were performed independently by three researchers. iAGE case reports and case series that were written in English or translated into English were included. Experimental studies, animal studies, and non-iatrogenic causes of air gas embolisms were excluded. PubMed and the Cochrane databases were searched using the terms “iatrogenic gas embolism” and “iatrogenic air embolism.”

Results: PubMed search through July 1, 2020, identified 223 articles of interest from 1964 to 2020. The Cochrane database did not yield any articles. Only 63 met inclusion parameters. The three most common procedures associated with iAGEs were open heart surgery, extracorporeal membrane oxygenation, and esophagogastroduodenoscopy.

Of the 208 iAGE cases, 51 (24.5%) received hyperbaric oxygen (HBO₂) therapy, 65 (31.2%) did not receive HBO₂, and 92 (44.2%) cases had undetermined treatment. Of the 51 cases treated, 38 (74.5%) had clinical improvement, three (5.9%) died, and 10 (19.6%) had unknown outcomes. Of 65 who were untreated, 32 (49.2%) had improvement, 28 (43.1%) died, and five (7.7%) had outcomes unlisted.

Summary/Conclusions: iAGEs are likely under-recognized and undertreated. Education, prompt identification, and early HBO₂ may prevent morbidity and mortality. Further tracking of this diagnosis is advocated.
Hyperbaric oxygen therapy improves symptoms, brain's microstructure and functionality in veterans with treatment-resistant post-traumatic stress disorder

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Introduction/Background: Post-traumatic stress disorder (PTSD) is characterized by changes in both brain activity and microstructural integrity. Cumulative evidence demonstrates that hyperbaric oxygen (HBO₂) therapy induces neuroplasticity, and case-series studies indicate its potentially positive effects on PTSD. The aim of the study was to evaluate HBO₂’s effect in veterans with treatment-resistant PTSD.

Materials and Methods: Veterans with treatment-resistant PTSD were 1:1 randomized to HBO₂ or control groups. All other brain pathologies served as exclusion criteria. Outcome measures included clinician-administered PTSD scale-V (CAPS-V) questionnaires, brief symptom inventory (BSI), BECK depression inventory (BDI), and brain microstructural integrity evaluated by MRI diffuse tensor imaging sequence (DTI). Brain function was evaluated by an n-back task using functional MRI (fMRI). The treatment group underwent 60 daily hyperbaric sessions. No interventions were performed in the control group.

Results: Thirty-five veterans were randomized to HBO₂ (N=18) or control (n=17), and 29 completed the protocol. Following HBO₂ there was a significant improvement in CAPS-V scores and no change in the control (F = 30.57, p<0.0001, Net effect size = 1.64). Significant improvements were also demonstrated in BSI and BDI scores (F=5.72, p=0.024 Net effect size = 0.89, and F=7.65, P=0.01, Net effect size = 1.03). Improved brain activity was seen in fMRI in the left dorsolateral prefrontal, middle temporal gyri, both thalami, left hippocampus and left insula. The DTI showed significant increases in fractional anisotropy in the frontolimbic white-matter, genu of the corpus callosum and fornix.

Summary/Conclusions: HBO₂ improved symptoms, brain microstructure and functionality in veterans with treatment-resistant PTSD.
Seven-year retrospective review of carbon monoxide poisonings treated with hyperbaric oxygen
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Introduction/Background: Carbon monoxide (CO) causes many intoxications every year. CO poisoning can mimic other pathologies, sometimes delaying treatment. CO clearance treatment options include normobaric oxygen and hyperbaric oxygen therapy (HBO2T). HBO2T accelerates CO clearance dramatically. We reviewed patient care and outcomes of HBO2T in one clinical center serving eastern Quebec (regional population 2.4 million).

Materials and Methods: We retrospectively reviewed CO intoxications referred for HBOT at Hôtel-Dieu de Lévis hospital. Relevant information was retrieved from hospital patient records. Data are reported as mean±SD with range, or counts, as appropriate.

Results: A total of 210 cases were included (170 male/40 female; 167 accidental/43 intentional), aged 49±17 (8-85) years, mostly in winter months (n=126 December-March). Internal combustion engines operating in insufficiently ventilated spaces were the main source of intoxication (88/207), followed by motor tools (35/207) and power generators (19/207). COHb saturation at initial hospital assessment was 25±10 (1-58)%. Symptoms included headache (121/675), loss of consciousness (101/675), dizziness (93/675), nausea (81/675), weakness (36/675), and ataxia (36/675). Patients were in a comatose state in 7% of cases. Cardiac issues included nonspecific ECG changes (10/210), non-ST-elevation myocardial infarction (8/210), and arrhythmias (1/210). Time between the end of exposure and start of HBO2T was 7.1±4.2 (2-44) hours. The HBO2T protocol was 2.8 ATA for 90 minutes; usually one session, with only 9 patients receiving multiple sessions. In-HBO2T complications were recorded in 26% of cases, mostly ear problems (44/58; primarily mild barotrauma, pain, and equalization difficulty). Complete recuperation was reported in 85% of cases at 6-week post-HBO2T telephone follow-up. Residual symptoms at 6-week follow-up included memory loss (10/48), fatigue (8/48), dizziness (8/48), attention-concentration decrease (8/48), and headache (7/48).

Summary/Conclusions: CO poisoning, largely from internal combustion engines operating in insufficiently ventilated spaces, represents a hazard requiring ongoing public education. HBO2T provided effective treatment with generally modest complications.
Hyperbaric oxygen for stereotactic radiotherapy-related radiation necrosis
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Case Description: A 45-year-old male was referred to Hyperbaric Medical Services for consideration of HBO$_2$ for radiation necrosis of the brain. The patient had undergone stereotactic radiotherapy 17 months prior for a large arteriovenous malformation (AVM) of his right frontal lobe. Open surgical therapy was not considered a viable option due to proximity to a large portion of the motor cortex. Imaging prior to referral showed some persistence of the AVM as well as a large area of edema around the treatment site despite high-dose dexamethasone therapy. During the initial stereotactic radiotherapy, the patient suffered a tonic/clonic seizure and subsequently suffered from anxiety and intermittent ongoing partial complex seizures.

Intervention: After informed consent the patient was offered hyperbaric oxygen therapy at 2.4 ATA for a total of 90 minutes on oxygen with a five-minute air break after 30 and 60 minutes. Lorazepam 1mg sublingual pre-HBO$_2$ followed by 0.5mg PRN during HBO$_2$ was used to elevate seizure threshold. Unfortunately, treatment pressure had to be reduced to 2 ATA after the first HBO$_2$ due to an anxiety attack or possible partial complex seizure. The patient completed a total of 60 sessions with no further adverse events.

Outcome: MRI examination was performed after 35 treatments and demonstrated some interval collapse of the region of non-enhancement/necrosis with a decrease in size of this abnormality and some improvement of the surrounding edema. Follow-up MRI three months post HBO$_2$ showed further reduction in necrosis area, with reduction in edema.

Discussion: This case shows the benefit of HBO$_2$ in reducing cerebral edema and necrosis related to stereotactic radiotherapy that is resistant to dexamethasone. Cerebral radiation necrosis responds well to HBO$_2$ and should be approved under the delayed radiation injury category.
Reduced globus pallidus area following carbon monoxide poisoning
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Introduction: Carbon monoxide (CO) poisoning is the most common form of acute poisoning resulting in Emergency Department visits. Imaging studies of patients experiencing CO poisoning show diffuse and focal damage to brain tissues. The globus pallidus (GP) region of the basal ganglia appears particularly affected by CO poisoning. This study examined GP area in poisoned patients using structural magnetic resonance imaging (MRI).

Materials and Methods: CO patients (n=83) were an average of 45 years old (range: 11-78 yrs) and were scanned months-to-years after poisoning (avg=3.0 yrs, range: 0.3-12.2 yrs). Forty patients (48%) were exposed for less than 24 hours and forty-three (52%) for more than 24 hours; most common symptoms were headache (n=58) and nausea (n=42). The CO patient group was compared to mild traumatic brain injury (mTBI) patients (n=246). They were scanned at 3T using an axial T2-weighted fluid-attenuated inversion recovery (FLAIR) sequence. The GP was identified manually in each patient using a trained hand-tracing method developed by a board-certified radiologist. Left and right GP area measurements were generated for single-slice regions of interest. An unpaired t-test was used to compare GP area between CO and mTBI groups.

Results: CO patients had smaller GP areas (L,R=1.77,1.78 mm²) as compared to mTBI patients (L,R=1.85,1.87 mm²). There was a significant difference between the groups in the right GP area (p=0.024). There was no significant asymmetry between left and right GP in either group.

Conclusions: CO poisoning can result in basal ganglia abnormalities. Our study found reduced GP volumes, particularly in the right GP, determined from area measures months to years after CO poisoning. MTBI is not associated with GP abnormalities, so these patients serve as a reasonable control for this study. While GP abnormalities typically have been reported days after acute CO poisoning, this study supports abnormalities much later after poisoning.
Compassionate use of hyperbaric oxygen therapy as an adjunct treatment for COVID-19 with severe acute respiratory distress syndrome: A retrospective case series of 15 patients
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Case Description: Given the high disease burden of SARS CoV2, a Compassionate Use of Hyperbaric Oxygen Treatment (HBO₂T) protocol was utilized to serve as an adjunct in the management of COVID – 19 with severe acute respiratory syndrome (ARDS). We enrolled fifteen positively confirmed COVID – 19 patients, by RT-PCR, with ages ranging 39-68 (mean age 52yrs old), both genders, non – pregnant, with co-morbid conditions. All patients presented with severe ARDS based on Berlin Criteria.

Intervention: Patients with estimated PaO₂/FiO₂ Ratio (PF Ratio) of less than 100, were identified, and screened for eligibility. Inflammatory and morbidity markers (Ferritin, CRP, LDH, D-Dimer), and ABG, were monitored on a daily basis, as well as pre and post HBO₂T CXR. We instituted HBO₂ at 2.4 ATA for 90 mins for 5-8 sessions, using Mono-place PAHI 3800.

Outcome: Immediate, and progressive improvement in well – being were observed. There was reduction of the inflammatory markers from baseline measure and increasing trend in [(SaO₂/FiO₂)/RR] (ROX Index) and PaO₂/FiO₂ Ratio. On the other hand, there was no obvious directional trend for D-Dimer. Significant relationship between ROX index and PaO₂/FiO₂ Ratio correlated with the frequency of hyperbaric sessions. CXR comparison before and after treatment revealed improvement in 13/15 patients. 14/15 patients survived and were never mechanically ventilated during their ICU and hospital admission, 1/15 patient was intubated and ultimately died.

Discussion: HBO₂ mitigated the complications and effects of hypoxia, oxygen debt, and the initiation of hyperinflammatory state in COVID Critical patients. Improvements in well – being, and oxygenation correlated with HBOT session frequency. This treatment modality is safe, if carried out by trained clinicians, and staff.
Report of the International Multicenter Registry for Hyperbaric Oxygen Therapy: Results through March 2022

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Introduction/Background: In 2011, the Multicenter Registry for Hyperbaric Oxygen Therapy was established to collect data on patient outcomes, complications, and the use of hyperbaric oxygen (HBO₂) therapy for UHMS-approved indications and emerging indications. Twenty-two centers in the UK, Australia, and the U.S. are enrolled and entering patient data.

Materials and Methods: Data is collected through a research electronic data capture (REDCap) template, which includes measures of quality of life, wound outcomes, vision changes, complications, head and neck radiation questionnaires, and information on the use of HBO₂ in emerging outcomes. This research was approved by the Institutional Review Board at each site. Data were analyzed using the Wilcoxon signed-rank test.

Results: Thus far, results have been published through June 2021, and we will have more data by the time of presentation in May 2022. De-identified data from 2088 were entered in the Registry. Quality of life outcomes improved for all indications, including emerging indications. Patients with non-healing wounds had the least improvement in quality of life after HBO₂. There was significant improvement in patients with hearing loss. Seizure rates were similar to previously published rates. Reports on vision changes will be reported separately.

Summary/Conclusions: The Registry reports important outcome data on patients receiving HBO₂, which supports its use and helps further refine the populations for whom it might be most useful.
Association between DTI and MR spectroscopy findings months to years after carbon monoxide poisoning

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Introduction: Carbon monoxide (CO) poisoning is a significant health risk in the United States, resulting in more than 50,000 Emergency Department visits annually. This study summarizes diffusion tensor imaging (DTI) and magnetic resonance spectroscopy (MRS) findings of 38 CO-poisoned patients.

Methods and Materials: CO-poisoned patients (mean age: 48.7 yrs; range: 11-78 yrs) with brain-injury symptoms including headache (n=24) and nausea (n=19) were imaged month-to-years later (mean: 2.5 yrs; range: 0.3-12.2 yrs) on a Philips Achieva 3T scanner using a 16-channel head coil. Fractional anisotropy (FA) values were derived from DTI images in five hand traced regions of the corpus callosum (CC). MRS data was obtained from the supraventricular area using multiple voxel point resolve spectroscopy (PRESS) technique. A Pearson’s correlation was performed on FA and MRS metabolite ratios in the CC.

Results: We found 18 patients (47%) to have abnormal DTI and 22 patients (58%) with abnormal MRS. Sixteen (42%) had both DTI and MRS abnormalities. Significant correlation was found between FA and NAA/Cr (N-acetylaspartate/creatine) ratio in the mid-body region (r=0.39, p=0.017), as well as an overall correlation for the whole CC (r=0.47, p=0.0032). Partial correlations remained significant when controlling for age. Patients with (n=15) and without (n=23) white matter (WM) abnormalities were also compared. No significant age difference was found between WM sub-groups (p=0.62). The group with known WM abnormalities showed a correlation between whole CC FA and whole CC NAA/Cr within group, while this difference was not significant in those without WM abnormalities.

Conclusions: CC DTI abnormalities and supratentorial MRS were commonly abnormal in these CO-poisoned patients scanned months-to-years after poisoning. We found significant associations between FA and NAA/Cr ratios in the mid-body and whole CC in all patients. When divided by presence of known WM abnormality, the same association remained for the whole CC only among those with WM abnormalities.
A hoax refuted: The 1.4-ATA hyperbaric treatment for chronic ulcers
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Introduction/Background: Hyperbaric oxygen (HBO₂) treatment is a common technique to treat chronic wounds, and in other indications. A common threshold for treatment at HBO₂ facility is transcutaneous partial O₂ pressure (TCPO₂) of at least 200 mmHg.

Public media advertise private “pressure chambers” where patients undergo a treatment with up to 1.4 ATA of pressure. The benefits advertised include chronic wound treatment, anti-aging treatment, cerebral function enhancement and more.

Materials and Methods: The Rambam-Elisha Hyperbaric Pressure Chamber (REHPC) is the only pressure chamber (PC) in northern Israel who serves chronic ulcer patients. During this study, 130 consecutive patients intended to undergo hyperbaric treatment for chronic ulcers where tested. TCPO₂ was measured in the ulcer area at 1.4 ATA after breathing O₂ for five and 10 minutes, as well as the regular measurements of TCPO₂ at 2 ATA.

Results: A total of 130 patients underwent a PC test. Average TCPO₂ at 1.4 ATA after 10 minutes of O₂ breathing was 161 mmHg (1-601 mmHg, standard deviation 137.91), compared to 333 mmHg in 2 ATA (1-914, ±232.56), p<0.001. Each electrode tested was also statistically significant, both after five minutes of O₂ breathing and after 10 minutes.

Summary/Conclusions: The 1.4-ATA hyperbaric treatment is claiming many advantages, including anti-aging effect and more. While the anti-aging cannot be measured, the wound healing effect can certainly be assessed. Our study found no evidence to support the claim that 1.4-ATA treatment can benefit a chronic ulcer patient. The local health authorities should treat those who offer such a treatment as the fraud it is and warn the public about such treatments.

The field of HBO₂ constantly evolves. It is important to take notice that as in every changing field, the charlatans can take advantage of a naïve public, and sell – with a high price – the hope for better health.
Mass casualty carbon monoxide poisoning in a Spanish-speaking population resulting in some with lasting sequelae
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Case Description: Twenty-two Spanish speaking patients (21 females, one male) presented to emergency departments with headache, blurry vision, nausea, dizziness, breathlessness, and chest pain due to acute carbon monoxide (CO) poisoning caused by boiling water indoors with a makeshift propane fire without adequate ventilation. All worked together shredding uncooked meat to make jerky.

Intervention: Seventeen patients were transported by ambulances and treated with hyperbaric oxygen (HBO2) in our multiplace chamber at one hospital; five were treated elsewhere in monoplace chambers. In-person interpreters assisted due to language barriers. All were treated once uneventfully within hours, using our CO protocol and sent home with anticipated follow-up.

Outcome: Throughout the following days to weeks, patients returned due to persistent and developing headache, fatigue, weakness, nausea, lightheadedness, breathlessness, and back/neck pain. We treated eight with additional HBO2 (2.0 ATA, 90 minutes) until symptoms subsided or clinical plateau (one to four treatments/patient). Over the next several months, nine patients (four not receiving subsequent HBO2) reported problems: coordination, balance, memory, concentration, vision, muscle aches/pain, facial nerve palsy, fatigue, and breathlessness/chest pain. We referred them to Spanish-speaking neuropsychologists (n=5), neuro-optometrists (n=8), neurology (n=1), and vestibular (n=6) for management. Further evaluation included pulmonary function (n=4), cardiac stress MRI (n=2), and brain MRIs (n=3). Workman’s Compensation is involved for coverage as they do not have health insurance. OSHA has investigated their place of work.

Discussion: This experience illustrates treating many non-English-speaking patients in one night, with the unique aspect of follow-up over months after poisoning in a challenging population. Of these 22 patients, at least nine have continued problems. These problems can be from injury, but their psychosocial situation and repetitive, manual labor as they work together may influence outcome, too.
Hyperbaric oxygen for post SARS-CoV-2 problems
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Case Description: A 52-year-old previously healthy executive, mountain runner male with presumed SARS-CoV-2 (before PCR testing was available) resulting in “long-haul” problems presented for treatment. His long-haul symptoms included fatigue, sleep difficulty, cognitive and affective complaints and neurological examination findings, forcing him to sell his business. Over the next months, he was evaluated by neurology, immunology, infectious disease and pulmonary.

Intervention: One year after infection he began a course of hyperbaric oxygen (HBO\textsubscript{2}): 1.5 ATA x 60 minutes x 40; then 2.0 ATA x 90 minutes (same as Tel Aviv) x 20. Three weeks later he was treated elsewhere with six random sessions at 1.8 ATA x 60 minutes, then two weeks later at 2.0 ATA x 90 minutes x 10, and six weeks later at 1.8 ATA x 60 minutes x 10 (total=86). The patient paid the cost of treatment.

Outcome: Before HBO\textsubscript{2} he had neuropsychology, speech, auditory processing and neurology (diplopia, left partial hemiparesis, slight left leg weakness and motor rigidity) evaluations. After the first 35 HBO\textsubscript{2} sessions, his neurological examination was normal.

At 60 HBO\textsubscript{2} sessions, his ANAM score increased from 0.34 (baseline) to 1.34, the Neurobehavioral Symptoms Inventory decreased from 46 to 8; Headache Impact Test-6 decreased from 61 to 0; Pittsburg Sleep Quality Index decreased from 18 to 10. He was running again, reporting better sleep, less fatigue and better cognition.

Two months later, his fatigue and focus had worsened, and he received repetitive courses of HBO\textsubscript{2} until reaching a plateau, still with some minor complaints. Overall, he is much improved compared to before HBO\textsubscript{2}, now back to work, running, and no longer requiring sleep medication.

Discussion: These results support that a course of HBO\textsubscript{2} more than a year after SARS-CoV-2 infection may improve infection-related brain injury.
Under pressure: A case study of violence while at depth in the hyperbaric chamber
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Introduction/Background: Violent patient outbursts are not unexpected in an urban trauma setting. However, aggressive patient actions could not be anticipated in the multiplace hyperbaric chamber while at depth. No protocols or guidelines existed to identify patients who could be potentially aggressive or violent during lengthy pressurizations in the hyperbaric chamber. Staff lacked training in managing this type of situation.

The aims of this project were to establish standardized processes for assessing patients before entering the chamber, improving communication inside and outside the chamber, having emergency medications available to the chamber nurse, and ensuring patient and staff safety at all times.

Materials and Methods: A multidisciplinary team addressed action items from the incident using root cause analysis (RCA). The team included nursing, respiratory therapy, chamber manager, medical director, plant operations, and senior leadership. Action items were prioritized based on urgency. Action item categories included: patient assessment, communication, medication, and safety. Hyperbaric oxygen (HBO₂) nurses now perform the Broset Violence Assessment on each patient prior to entering the chamber. Any positive on the assessment tool requires a follow-up behavioral assessment to identify potentially risky behaviors. A dedicated phone was installed at the control console, and staff utilize wireless headsets to communicate during all phases of the treatment course. Three staff members (nurse, RT, physician) attended TeamStepps training to facilitate communication. A bundle of emergency medications was created in collaboration with pharmacy and placed in the pyxis to easily retrieve during unforeseen situations. HBO₂ staff developed and refined a “Pre-Dive Safety Stop” huddle form that requires staff consensus prior to initiating treatment.

Results: No further episodes of violent behavior have occurred in the hyperbaric chamber over the last 16 months. It is difficult to determine whether the actions taken directly affected the outcome. No studies currently exist addressing violent behavior in a multiplace hyperbaric chamber. Confinement anxiety has been noted in the literature but without aggressive behaviors.

Summary/Conclusions: Without available research, this case study addressing violent patient behavior in a hyperbaric chamber can serve as the impetus for organizations to collaborate and develop guidelines, policies, and procedures aimed at keeping patients and staff safe while pressurized in a confined space. Research and evidence-based practice programs are needed.
Gas bubble mechanics in the spinal cord
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Introduction/Background: Spinal cord decompression sickness (SC-DCS) is caused by the growth of gas bubbles in the spinal cord. It is widely assumed that this leads to a reduction in blood flow and an infarction of the surrounding tissue. We present evidence for an alternative injury mechanism in which the growing bubble tears the surrounding spinal cord tissue and discuss bubble nucleation mechanisms.

Materials and Methods: High-resolution magnetic resonance imaging (MRI) is used to observe the formation of decompression gas bubbles in ex-vivo bovine spinal cords inside a specially constructed MRI-compatible pressure cell in real time. Rapid pressure cycling of a decompression bubble combined with volumetric analysis allows us to interrogate the mechanical response of the tissue to a pressure-driven expansion of the bubble and separate this effect from gas diffusion. Experiments on phantom gels are used for validation and nucleation studies. Finite-element simulations yield the mechanical stress in the tissue in response to the growing bubble.

Results: We observe that the decompression bubbles grow substantially with each rapid pressure cycle and do not return to their previous size. This matches observations in phantom gels where tearing of the gel in response to a growing bubble is apparent, and the finite-element simulations where bubble growth can easily generate stress in excess of the yield stress of the tissue. We note that bubble formation in our ex-vivo tissues is quite rare, which suggests that vascular circulation provides additional bubble nuclei to the tissue. This corresponds to observations in the phantom gels where we can suppress bubble formation by removing gas nuclei from the gel.

Summary/Conclusions: We conclude that decompression bubble formation in the spinal cord is not a reversible elastic process but involves an irreversible deformation of the surrounding tissue. This suggests that SC-DCS may be understood in some cases as a form of traumatic spinal cord injury.
Decompression sickness rates in underwater divers utilizing air surface decompression versus oxygen surface decompression
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Introduction/Background: Military and commercial underwater divers are at increased risk for decompression sickness (DCS). Surface decompression (Sur-D) is a technique in which decompression is first completed in the water, and then in a deck decompression chamber (DDC). Sur-D can use either air, mixed gas, or pure oxygen. During oxygen Sur-D, the diver breathes 100% oxygen, resulting in oxygen-rich, nitrogen-poor blood. This theoretically decreases the probability of nitrogen bubble formation, thus decreasing the risk for DCS.

Materials and Methods: Case reports for 1,886 air and nitrogen-oxygen dives from Naval Medical Research Center report NMRC 99-02, were retrospectively analyzed, to compare the rates of DCS between air Sur-D and oxygen Sur-D. Logistic regression was performed to examine the relation between DCS and type of Sur-D utilized.

Results: Of the 261 dives using air Sur-D, 27 cases of DCS occurred. Of the 1,625 dives using oxygen Sur-D, 40 cases of DCS occurred. Logistic regression was performed to correlate the relation of air versus oxygen Sur-D, with the likelihood of developing DCS, while controlling the effects of depth and bottom time. The logistic regression model was statistically significant, $\chi^2(3) = 37.338$, p<.001. The model explained 7.4% (Nagelkerke R²) of the variance in DCS and correctly classified 96.4% of cases. The odds of having DCS was 5.662 times greater for air Sur-D as opposed to oxygen Sur-D (95% CI 3.286-9.756).

Summary/Conclusions: DCS remains a concern for military and commercial divers. Oxygen Sur-D decreased the rate of DCS compared to air Sur-D.
Capsule Project: a physiological survey during 3 days of shallow saturation dives in a very limited space

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Introduction/Background: Saturation dives are used in the offshore industry when the risk of decompression sickness (DCS) becomes unacceptable. Although they remain very safe, saturation dives are expensive due to heavy installations and long decompressions. To make them accessible to smaller industries or scientific diving, we tried a light 4.5m³ habitat made for three divers maximum (living space five times more confined than in professional diving), while monitoring divers’ conditions to assess their tolerance to this environment.

Materials and Methods: We monitored 12 divers before, during and after 17 saturations dives at 20 msw for three days, measuring their Spencer bubble grades (with a Doppler on the subclavian artery), pulmonary function, hemoglobin saturation, heart rate variability (HRV), critical fusion flicker test (CFF), positive and negative affects schedules (PANAS) and body mass. The divers breathed heliox at PO₂ 0.4 to 0.5 bars at depth and at 1.3 b during the four-hour decompression phase.

Results: The mean bubble grade was 0.71 ± 0.77; forced expiratory flow (FEF) at 25% and 75% was temporarily increased under helium and not affected by breathing 1.3 bara PO₂ before it returns to normal upon surfacing; hemoglobin O₂ saturation was increased during the stay at depth; HRV increased for at least 24 hours after the dives: the parasympathetic activity decreased during saturation, decompression and 24 hours beyond while sympathetic activity increased; endothelium independent vasorelaxation decreased at 2 hours after the dive; CFF increased at day 3; body mass was slightly decreased just after the dive and increased 24 hours after surfacing.

Summary/Conclusions: Despite the significant increase in ascent rate, decompression seems to be well tolerated, and HRV changes suggest moderate deconditioning, which is probably due to the living space.
**Introduction/Background:** The Swedish Armed Forces, SwAF currently use air dive tables from *U.S. Navy Diving Manual*, USN DM, Rev.6. These tables are derived from the decompression model EL-DCM Thalmann with VVAL18M parameters but with manual adjustments, which have been identified as a potential weakness. The latest revision of the USN DM, rev. 7, incorporates tables calculated with the new parameters VVAL79. The aim of this study was to offer the SwAF flexibility in the choice of future air dive tables by replicating EL-DCM Thalmann, increasing the U.S. Navy probabilistic model database for direct ascent air dives, using statistical methods to define direct ascent profiles that correlate with acceptable risk, determining the best fit of parameters for the maximum permissible tissue tension, MPTT, which corresponds with suggested direct ascent times.

**Materials and Methods:** A MATLAB replica of EL-DCM Thalmann proved accurate in correlation with USN DM rev.7. Assembling dive data from previously published U.S. Navy probabilistic model dive profiles from peer-reviewed articles and SwAF test dives increased the database to 2,941 direct ascent air dives. These were used to determine the direct ascent time correlating with the statistical risk of decompression sickness DCS type I (1%) and type II (0.1%) using the maximum likelihood method. The MPTTs were determined from the statistically suggested time limitations of direct ascent.

**Results:** New tables were produced with parameters called SWEN21B. A total of 163 validation air dives by 48 divers between 18-57 msw were performed. Direct ascent, repetitive and decompression stop dives were conducted with the result of two cases of DCS type I (18 msw/59 minutes), one DCS type II (51 msw/10 minutes with deco-stop) and five marginal DCS cases.

**Summary/Conclusions:** The outcome of the validation dives is within the statistical rage of the expected risk of DCS for SWEN21 tables.
On comparing and matching different venous gas emboli assessment scales
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Introduction/Background: Venous gas emboli (VGE) are typically measured in divers after surfacing using ultrasound as a biomarker of decompression stress. Different assessment scales exist to assess both echocardiography and Doppler audio for this purpose. As some are easier to computer-automate than others, a quantitative comparison and matching analysis are needed to interpret the automation accuracy in different contexts.

Materials and Methods: A total of 196 previously acquired echocardiography recordings were graded on the Efftedal-Brubakk (EB) scale and also bubble-counted (BC) using the Germonpré method. The correspondence between the two scales was investigated by determining the corresponding BC mean and standard deviation for each EB grade. Data from a previously conducted study by DAN were also obtained, where each subject was measured with both echocardiography and Doppler ultrasound at set times post-dive. Echocardiograms were graded on the EB scale and subclavian Doppler recordings graded by an expert on the Kisman-Masurel (KM) scale. A total of 40 such EB-KM pairs were analyzed from subjects, with both measurements occurring within five minutes of each other in a random order. Specificity and sensitivity of KM to EB grade 0 is computed as an initial metric of agreement.

Results: The corresponding BC mean and standard deviation for each EB grade was as follows: 0.5 ± 0.5 for grade 0 (n=8), 1.5 ± 0.8 for grade 1 (n=21), 2.3 ± 1.1 for grade 2 (n=20), 4.3 ± 2.0 for grade 3 (n=65), 9.8± 4.8 for grade 4 (n=73) and 28.2 ± 13.5 for grade 5 (n=9), showing an ascending trend as expected. The sensitivity of KM to bubble presence as assessed by EB was 0.5 and specificity 0.5, suggesting poor preliminary agreement.

Summary/Conclusions: This study constitutes an initial comparison of different VGE assessment scales for the purpose of quantifying their relationship. This may assist with VGE computer-automation efforts in allowing adequate interpretation of accuracy confidence intervals for practical use.
Risk assessment of SWEN21 a suggested new dive tables for the Swedish armed forces: Bubble scores by ultrasonography

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Introduction/Background: Operational diving experience in the Swedish armed force (SAF) has identified that certain depth-time combination in the current dive regulation, RMS-dyk 13 table 1 and 2 (RT 1/2), cause a higher than anticipated occurrence of decompression sickness (DCS). To further develop the diving capacity and create safer diving procedures the SAF created a new dive table named SWEN 21, which a projected risk level of 1% for DCS.

The aim of this study was to evaluate the safety of SWEN 21 through the measurement of intravascular bubbles and DCS events in a dive series.

Materials and Methods: A total 154 dives were conducted in a hyperbaric wet chamber. As a proxy for DCS risk, serial bubbles measurements by precordial ultrasonography were conducted and graded according to the ordinal 6-point Eftedal-Brubakk scale. Low grades correlate with few observed bubbles and a low risk of DCS and higher grades vice versa. Measurements was done every 15 minutes for at least two hours after each dive. Symptoms of DCS was continually observed and graded as Type I or Type II accordance with prespecified classification.

Results: Median maximum bubble score for a majority of the time-depth combinations and of SWEN-21 as whole was 3, with the expiation of two profiles which resulted in scores of 3, 5 and 4 respectively. Three persons (2% incidence) were diagnosed with DCS. Two divers had symptoms consistent with Type I DCS (joint pain) and one with Type II (neurological). All symptoms resolved with hyperbaric oxygen therapy.

Summary/Conclusions: This evaluation of the novel SWEN 21 dive table, using bubble formation measured with precordial ultrasonography, suggests that the DCS risk may be higher than the projected 1% for the dive table. However, there are numeral confounders that make a direct comparison difficult.
Diving into decompression sickness-resistant rats gene expression through a miRNome/transcriptome crossed approach
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\textbf{Introduction/Background:} Susceptibility to decompression sickness (DCS) is characterized by a wide interindividual variability; its origin is still poorly understood. This hampers reliable prediction of DCS by decompression algorithms. We previously selectively bred rats with at least a threefold greater resistance to DCS than standard rats after six generations. In order to better understand DCS mechanisms, we sought study the expression of the genes of these resistant rats.

\textbf{Materials and Methods:} We focused on the 10th generation of our strain, by a transcriptomic approach coupled and crossed with a miRNome study and a bioinformatic approach.

\textit{Transcriptomic:} Liver samples from Wistar (four males, four females) and DCS-resistant rats (four males, four females) on Agilent SurePrint rat G3 GE 8x60 k microarrays followed by a PCR validation.

\textit{MiRNome:} The animals were the same as for the transcriptomic approach, but with these we studied circulating miRNome with Qiagen miRNeasy serum and plasma kit.

\textit{Bioinformatic tools:} We used ToppGene for the Gene Ontology and STRING v11.5 for the functional protein association networks.

\textbf{Results:} We have identified 14 genes whose expression is modified between females of the Wistar strain and females of the 10th generation (G10) of our selected strain, as well as 13 genes in males. We then crossed these transcripts with the respective targets of the 44 microRNAs (miRs) whose expression is modified in the G10 females and the 47 miRs whose expression is modified in the G10 males; we obtained 14 results.

\textbf{Summary/Conclusions:} These results highlight pathways involved in inflammatory responses, cell signaling and motricity, phagocytosis or apoptosis, confirming the paramount importance of inflammation in DCS physiopathology.
Heart rate detection in post-dive Doppler ultrasound audio recordings

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Introduction/Background: Grading of post-dive Doppler ultrasound recordings is based on the frequency of venous gas emboli per cardiac cycle. Computer-automated scoring therefore also requires automated estimation of the instantaneous heart rate (IHR).

Materials and Methods: Short-term autocorrelation was implemented in MATLAB, and its accuracy for estimation of the IHR assessed using 21 previously acquired precordial post-dive Doppler recordings (10 to 32 seconds/length), at rest (Rest, 11 recordings), or after movement (Flex, 10 recordings), spanning Kisman-Masurel (KM) grades 0–4, split into Low and High (corresponding to KM 0–2 and 3–4). A bandpass filter was used to remove noise, and data were split into two-second moving segments with 50% overlap. IHR was defined as the peak between 50 to 120 beats per minute (bpm) after performing the autocorrelation on each segment. Mean heart rate (HR) was also calculated for each recording. Accuracy was assessed by comparing the results with those of an expert who manually annotated all recordings. We computed mean absolute errors in IHR and HR, as well as correlation coefficients of each IHR time-series/recording. Missing IHRs in any given segment were omitted from the means, but the percentage of time that missing values and incorrect estimates (> 10 bpm error) occurred were calculated for each recording. Differences in IHR errors between Rest/Low, Flex/Low, Rest/High and Flex/High subgroups were compared using ANOVA and Holm-Sidak multiple-comparison test.

Results: The mean IHR error was 4.54 ± 6.30 bpm (from 345 segments). Based on the 21 recordings tested the mean HR error was 1.82 ± 1.73 bpm, the mean correlation coefficient was 0.94 ± 0.04, the IHR missing rate was 11.1 ± 7.67%; and the rate of incorrect calculation was 5.08 ± 5.79%. Only the Flex/High IHR errors were significantly higher than that of the other subgroups.

Summary/Conclusions: Short-term autocorrelation is well suited to IHR estimation in post-dive Doppler ultrasound recordings, although high bubble grades and motion artifacts decrease performance.
Matching web-based frames to original frames: A workaround for the inconsistent rendering of frames on the Decobubbles website
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Introduction/Background: Decobubbles.com is an initiative to crowdsource the location of bubbles in cardiac ultrasounds of divers for machine learning. After completing a training module, users can “rate” videos, pausing when they see bubbles and marking their locations. The locations of the bubbles and the corresponding frame are saved, then rejected or accepted based on the ratings’ consistency with other ratings of the same video.

Nearly all modern videos are compressed, and video players render this compressed footage in slightly varied ways, leading to inconsistencies in how video players render footage. Frame indices on the web video player, therefore, do not always correspond exactly to those in our development environment. Here we present a workaround to this by grabbing the frames from decobubbles.com, and matching them to the frames in the offline video based on their cross-correlation coefficient.

Materials and Methods: The web driver Selenium was used to grab screenshots of each rated frame on decobubbles.com and these were automatically cropped to omit unwanted background. Individual screenshots were matched to their respective frames in the original video (± 2 frames since this was the maximum mismatch error observed) by maximizing the cross-correlation coefficient between them in Python using OpenCV’s \texttt{TM_CCOEFF_NORMED} algorithm. Accuracy was manually verified for 100 screenshots to assess performance.

Results: In the sample of 100 screenshots we visually verified, the algorithm correctly matched the frame between the website and the development environment 100% of the time.

Summary/Conclusions: We have developed a matching frame algorithm to correctly identify the frame selected by the rater on decobubbles.com to its equivalent in the development environment, so that bubble locations can correctly translate between the two. Crowdsourced data is therefore available for integration into our AI pipeline.
Comparison of ultrasonic bubble scores from a handhold self-positioned Doppler product with 2D cardiac bubble scores

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Introduction/Background: The load of bubbles in the body after decompression can, to some extent, be evaluated and scored using ultrasound techniques that measure venous gas emboli (VGE). The primary aim of this study was to analyze the agreement between ultrasonic bubble scores from a handheld self-positioned product, O’Dive, with cardiac 2D images after decompression. The secondary aim was to correlate the scores from O’Dive and cardiac 2D images to DCS.

Materials and Methods: In 152 dives we graded VGE with both bilateral Doppler over the subclavian veins (Spencer scale) and 2D cardiac images (Eftedal Brubakk scale), a total number of 1,113 matched measurements. The agreement was then analyzed with weighted kappa (Kw). Then we took each of the two method’s maximum scores after each dive and analyzed them with Kw. Finally, we took all the maximum scores and categorized them to low or high scores and analyzed the agreement with Cohen’s kappa. To investigate the correlation of the bubble scores to DCS we calculated positive and negative predictive value (PPV/NPV), sensitivity and specificity of high versus low scores, for each of the two methods.

Results: The agreement between the ultrasonic scores from these two methods were fair. The handheld self-positioned product from O’Dive had a lower sensitivity to detect bubbles comparing to 2D cardiac image scoring. O’Dive had a significantly higher specificity but PPV, NPV and sensitivity were not significantly different.

Summary/Conclusions: O’Dive’s Doppler has lower sensitivity to VGE than 2D cardiac image. It is, however, easy to use for the diver themselves and high scores gives valuable information regarding the risk assessment of DCS.
Underwater ultrasonic imaging of microbubbles for real-time control of decompression procedures using wearable CMUT arrays

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Introduction/Background: Decompression sickness (DCS) remains one of the major risks for scuba divers unless they follow strict prevention schedules to stage their decompression. Current decompression bubble assessment is limited to post-dive ultrasonic detection of circulating venous gas emboli (VGE) and therefore inadequate for real-time dive ascent modification. We propose a low-power wearable ultrasound imaging system using capacitive micromachined ultrasound transducer (CMUT) arrays with a wideband operation capability supporting multiplexed imaging for concurrent anatomical, traditional VGE (B-mode/Doppler) and microbubble-specific imaging.

Materials and Methods: To assess the feasibility of CMUT arrays for this purpose, we first evaluate their performance for multiplexed imaging and operation at increased ambient pressure. We developed cryogel-based tissue-mimicking materials (TMM) with a wall-less vessel inclusion for circulating gas bubbles, as well as embedded phase-change nanodroplets that can be activated with ultrasound to mimic stationary tissue microbubbles (1-5 μm). We also investigated the effect of increased ambient pressure on CMUT sensitivity in both simulations (up to 9 ATA) and experiments (up to 5 ATA). A single-element CMUT was first electrically characterized at atmospheric pressure (1 ATA) and mounted on a custom-designed printed circuit board (PCB) for immersion testing. Pulse-echo tests were performed in a small decompression chamber using a custom feedthrough connector to power the device and record signals. We also packaged a 1D array and connected it to a programmable ultrasound research system to test the imaging performance.

Results: We showed that the devices can effectively perform both B-mode and microbubble-specific imaging using our TMM. We demonstrated that CMUTs can reliably operate at increased pressure and that the DC voltage requirement becomes lower with increased ambient pressure, with excellent agreement between experimental and simulation results.

Summary/Conclusions: CMUTs offer an attractive and flexible platform for real-time wearable ultrasound that may provide useful information toward personalizing decompression algorithms to prevent DCS. CMUTs offer an attractive and flexible platform for real-time wearable ultrasound that may provide useful information toward personalizing decompression algorithms to prevent DCS.
Evaluation of the cross correction method for different diving decompression methods at 5000 ALTFT
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Introduction/Background: Diving at altitude requires more decompression time than equivalent dives performed at sea level. To account for this the U.S. Navy Diving Manual Rev 7 uses the “cross-correction” method, where the depth of the table selected (and any associated in-water decompression stops) is increased by multiplying the depth of the dive at altitude by 14.7psi/altitude pressure. The selection of a deeper table results in extra decompression time to offset the effects of diving at altitude. This is a preliminary investigation to assess the efficacy of the cross correction for different decompression methods at 5,000 feet in altitude.

Materials and Methods: The tissue bubble dynamics model (significant prediction (p<0.01) and goodness of fit (Hosmer-Lemeshow goodness of fit = 0.77) of 430 DCS cases in 6,437 laboratory diving exposures) was used to assess the decompression stress associated with a depth of 140 feet for 35- and 60-minute bottom times at sea level in salt water compared to the same depth and time in fresh water at 5,000 feet of altitude using the cross correction. The decompression methods investigated included in-water/air, in-water/O₂, air SurDO₂, and heliox SurDO₂.

Results: Results show the decompression stresses (defined by the bubble growth index (BGI)) using the cross correction at altitude were considerably higher than sea level for in-water/air, in water/O₂, and heliox SurDO₂. Air SurDO₂ most closely matched the decompression stress at sea level. For reference, a BGI of 3.5 is associated with very low decompression stress (~1/10,000 DCS cases) (University of Pennsylvania Diving Records Data System).

<table>
<thead>
<tr>
<th>Decompression Method</th>
<th>BGI at Altitude</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Sea Level</td>
</tr>
<tr>
<td>In Water/Air</td>
<td>5.8</td>
</tr>
<tr>
<td>In Water/O₂</td>
<td>4.37</td>
</tr>
<tr>
<td>SurDO₂</td>
<td>3.23</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Decompression Method</th>
<th>BGI at Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sea Level</td>
</tr>
<tr>
<td>SurDO₂</td>
<td>4.06</td>
</tr>
<tr>
<td>HeliOx SurDO₂</td>
<td>4.54</td>
</tr>
</tbody>
</table>

Summary/Conclusions: This preliminary investigation suggests that the decompression stress (BGI) of the cross correction depends on the decompression method, with air SurDO₂ providing the best control of stress at altitude compared to sea level. A more systematic evaluation of various depth/time and altitude combinations, in addition to human trials would be recommended before making any changes to current diving practice.
Separating operator speech from Doppler ultrasound data in audiofiles containing sequential experiments: A speech recognition-based program

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Introduction/Background: Doppler ultrasound has been used extensively in diving research to detect venous gas emboli. Thousands of hours of audio post-dive were historically recorded in cassettes, with some later digitized using audio software tools. Data are usually superimposed with human voice descriptions and recorded back-to-back on the same cassettes in single-audio channels, making separation a cumbersome manual task. We hypothesized that recent advances in speech recognition can be leveraged to automatically separate digitized cassettes.

Materials and Methods: A graphical user interface (GUI) was developed in Python with the tkinter package to automatically separate the spoken descriptions of experiments (Headers) from their corresponding Doppler ultrasound audio (Data). Briefly, a noise reduction algorithm was applied in pre-processing, then shorter audio segments generated to be parsed through Google’s speech-to-text application programming interface (API). The API processing creates timestamps for spoken words so that the GUI can output timestamps for all Headers and Data in each cassette. Results were displayed to the user for confirmation and saving as separate files.

The performance of the GUI was tested on two previously acquired and digitized cassettes consisting of two hours post-dive Doppler recordings from two different subjects. Recognition of Long Headers of at least three seconds were tested (to ensure these were the introductory descriptions of the experiment) and the GUI’s timestamps compared to manually annotated timestamps from the same cassettes.

Results: The algorithm was able to detect and label all Long Headers over the two hours of digitized data; 74% of the total speech duration was detected, and the absolute difference in starting timestamps was 2.58 ± 1.68 seconds.

Summary/Conclusions: A novel GUI was developed to effectively, and automatically separate the spoken experimental description and Doppler ultrasound audio data from digitized single-channel audio cassette recordings.
Blood pressure in rats selectively bred for their resistance to decompression sickness

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**Introduction/Background:** Susceptibility to decompression sickness (DCS) is characterized by a wide interindividual variability which origin is still poorly understood. This hampers reliable prediction of DCS by decompression algorithms. We previously selectively bred rats with at least a threefold greater resistance to DCS than standard ones. Based on its previously reported relations with decompression outcomes, we assessed whether resistance to DCS is associated with modification in vascular function.

**Materials and Methods:** To this end we compared arterial pressure response to IV administration of acetylcholine (Ach, 5µg.kg\textsuperscript{-1}) and adrenalin (5 and 10 µg.kg\textsuperscript{-1}) in anesthetized DCS-resistant rats (seven females, seven males) and standard Wistar rates (seven females, 10 males) aged 14-15 weeks. None of these individuals had been previously exposed to hyperbaric treatment.

**Results:** Results showed a non-significant tendency for a lower diastolic (DBP) and mean (MBP) blood pressure in DCS-resistant rats than in standard rats. After ACh administration MBP was significantly lower in resistant rats rather than standard animals, for both males (p=0.007) and females (p=0.034). After administration of adrenaline 10 µg.kg\textsuperscript{-1}, DCS-resistant animals exhibited lower maximal DBP (p=0.016) and MBP (p=0.038) than standard rats. Systolic and pulse blood pressure remained unchanged throughout all the experiment.

**Summary/Conclusions:** Resistance to DCS is associated to a trend toward a lower vascular tone. Data support the hypothesis of an enhanced endothelial function in small arterioles and microcirculation of DCS-resistant animals. Nevertheless, whether these differences are a component of the susceptibility to DCS remains to be confirmed.
Agreement of newer handheld ultrasound devices for post-dive venous gas emboli quantification compared to standard 2D echocardiography
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Introduction/Background: Venous gas emboli (VGE) presence post-dive can vary significantly between subjects who complete identical dives. Many datasets are needed to statistically evaluate intra- and intersubject variability, thus there is a need for small devices with long battery lives to detect VGE. Here we compare the VGE classification of the Butterfly iQ™ (Butterfly Network) and the O’Dive™ (Azoth Systems) to the standard Vivid Q™ (GE Healthcare).

Materials and Methods: Volunteer divers underwent VGE monitoring with all three devices before and at 20, 40, and 60 minutes after unrestricted dives, resulting in 97 full datasets. VGE data obtained from the 2D ultrasound devices were graded on the Eftedal-Brubakk (EB) scale and binarized based on the presence of VGE. In addition to calculating the Butterfly IQ’s sensitivity and specificity to VGE compared to the Vivid Q, EB grading agreement was calculated as both absolute agreement and linearly weighted kappa statistic. O’Dive data was analyzed using the manufacturer’s proprietary 0-4 grading, then binarized and compared to the Vivid Q for sensitivity and specificity to the presence of VGE.

Results: The percent absolute agreement between the EB grades of the Vivid Q and Butterfly iQ was 73.3%. The kappa value for the Vivid Q and Butterfly iQ was 0.53 ± 0.15. After binarization, the Butterfly iQ sensitivity and specificity to VGE presence, as compared to the Vivid Q, were 73.0% and 90.8%, respectively, and those of the O’Dive were 26.5% and 98.4%.

Summary/Conclusions: There is only moderate agreement between the VGE grades of the Butterfly iQ compared to the Vivid Q, which may be due to lower-quality acquisitions with the Butterfly iQ in the field. Nevertheless, both specificity and sensitivity to VGE presence remain high with the Butterfly iQ compared to the Vivid Q, whereas sensitivity was significantly lower with the O’Dive.
Enriched-air/oxygen for pre-flight surface intervals

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Introduction/Background: Current guidelines for pre-flight surface intervals (PFSI) of 12-18 hours represent a delay if urgent medevac is required. This study seeks to investigate the potential use of enriched air mixtures and oxygen to decrease PFSI.

Materials and Methods: Simulated dive profiles assumed a descent rate of 30 meters/minute and an ascent rate of 10 meters/minute. Dive times included descent plus time at maximum depth. Six single dive profiles were selected, at three popular recreational diver certification depths: three profiles at or near the no-decompression time limits for those depths, and three with shorter times. Inert gas pressures at the end of the dives and at six, 12, 18 and 24 hours breathing air post-dive were estimated for ZH-L16B compartments using the R package ‘scuba.’ Then, still assuming the dives were made on air, surface interval times were estimated to reach equivalent (or less) pressures while breathing EANx32, EANx36, or 100% oxygen.

Results: Oxygen-rich gases accelerated removal of inert gas, at least halving the six-hour times with EANx32 (mean 2:59 vs 6:00 hours), and reducing the 24-hour PFSI across all tested dives to a mean of 1:07 hours with 100% O₂ (Table 1).

<table>
<thead>
<tr>
<th>Dive Profile</th>
<th>EANx32</th>
<th>EANx36</th>
<th>100% Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 hr</td>
<td>12 hr</td>
<td>18 hr</td>
</tr>
<tr>
<td>40(12) / 60</td>
<td>2:54</td>
<td>4:15</td>
<td>5:21</td>
</tr>
<tr>
<td>60(18) / 20</td>
<td>2:05</td>
<td>2:42</td>
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D'=depth in feet of seawater, ~'=approximate depth in metres of seawater, mins=total dive time in minutes from descent to start of ascent, EANx32=Enriched air nitrox containing 32% oxygen, EANx36=Enriched air nitrox containing 36% oxygen, hr=hours of surface interval breathing normobaric air

Summary/Conclusions: The estimated PFSI from breathing EANx36 decreased to a mean of 42% the equivalent of six hours breathing air, and to a mean of 19% the equivalent time for 24 hours of post-dive breathing air. There was some variance with respect to the dive profile, with longer profiles showing less improvement due to greater saturation in slower tissues. This study presents PFSI time estimates for breathing various gases to reach equivalent estimated compartment pressures after six to 24 hours of breathing normobaric air. These estimated times do not take into account physiological factors such
oxygen-induced vasoconstriction, exercise, hydration, and other factors; the results will need confirmation by actual human trial(s) before practical adoption.

C 48
ORAL PRESENTATION TIME: n/a
POSTER PRESENTATION TIME: Monday, May 23: 1630-1700
RESIDENT COMPETITION: No

Inspiring the next generation studying and optimizing human performance under pressure
Papadopoulou V¹, Tillmans P², Denoble P³, Lance R³, Moon S⁴, Thom S⁴, Lindholm P⁵, Grover I⁵, Tanaka H⁵, Sadler C⁶, Van Hoesen K⁶, Doolette D⁶
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Presenting Author: Virginie Papadopoulou PhD
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Introduction/Background: Undersea biomedical research is a unique and specialized research field. Attracting and retaining a diverse pool of scientists and researchers is a priority to keep up with technological advances and increase cross-disciplinary translation of basic discoveries.

Materials and Methods: This pipeline need and accompanying threat of expertise loss has been documented in the research and defense communities in both the United States and abroad for some time. We review key discussions to date and summarize major themes.

Results: In 1994 the yearly U.S. National Defense Authorization Act stated that “erosion of the undersea medicine community (of the Navy) and the universities that support the program may be accelerating.” In 2002 and as part of an initiative that helped establish Undersea Medicine as a National Naval Program, the UHMS evaluated Naval research needs and program development. It estimated that the number of investigators had dropped from 299 in 1980 to 58 in 2000 in the United States, with a similar trend worldwide. The age distribution of experienced investigators active in 2001—defined as having more than five years’ research experience—was also heavily skewed toward retirement age, with only two investigators younger than 40 years of age. The report noted that retaining trained investigators is a challenge, with many stopping their work in the field in their 20s and 30s. In 2009, the international “100 years from Haldane workshop” laid out similar sustained concerns. It included a presentation on International Cooperation in Diving Research noting “more importantly, none of these [existing] meetings encourage young scientists to pursue a career in undersea medicine research.”

Summary/Conclusions: Recruitment of new scientists is a priority that could be met by provision of summer opportunities for high school and undergraduate students and mechanisms to allow them to attend UHMS and Navy scientific meetings, as well as increased funding for doctoral and postdoctoral students and young investigators. We propose as a first step to update the census of current investigators to reflect the current landscape in 2022. The UHMS is well positioned to assist in this endeavor and help develop tailored STEM initiatives to address some of these issues.
Deep learning approaches to automated bubble analysis in post-decompression 2D echocardiography and Doppler audio ultrasound

Le DQ\(^1\), Azarang A\(^1\), Karimpour K\(^1\), Hoang A\(^1\), Dayton PA\(^1\), Balestra C\(^2\), Germonpré P\(^3\), Lance R\(^4\), Blogg L\(^5\), Natoli M\(^4\), Gatrell A\(^4\), Tillmans F\(^6\), Moon RE\(^4\), Lindholm P\(^7\), Papadopoulou V\(^1\)

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Presenting Author: David Q Le
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**Introduction/Background:** Ultrasound detection of decompression bubbles is often used as a metric for decompression stress. Analysis of 2D echocardiography and Doppler ultrasound grades the degree of bubbling and is performed by trained operators who are subject to both inter- and intra-operator variability. Automated systems for bubble analysis have been previously explored to differing degrees of success due to limited dataset availability and large variability between studies. We hypothesize that deep-learning frameworks using large databases and synthetic data will be robust and reproducible for bubble analysis in decompression research.

**Materials and Methods:** A convolutional neural network with region proposals (R-CNN) was developed using 205 videos acquired over four institutions to detect the right heart chambers and identify and count individual bubbles. A convolutional neural network with recurrent layers (CNN-RNN) was trained to classify low-high bubbling (0-4 vs. 5+ bubbles).

Synthetic data (20361 5s samples) based on the Spencer scale was procedurally generated using human cardiac audio and in-vitro bubbles recorded by a clinical ultrasound scanner. A 1-D CNN was used to classify Spencer grade without additional processing.

**Results:** Echocardiogram classification of low versus high bubbling achieved 84% accuracy using the CNN-RNN. Bubble detection yielded a mean average error of 2.34 bubbles per frame. Degree of bubbling using the bubble detector was 73% accurate when classifying between three groups (0, 1-6, and 6+ bubbles).

Doppler analysis using CNN achieved 76% accuracy classifying Spencer grades and 97% accuracy for low-versus-high grades (0-2 vs. 3-4) in synthetic data.

**Summary/Conclusions:** Deep learning is a powerful tool that can automate tedious and time-consuming tasks for researchers. We show that our deep-learning techniques can achieve good performance in automated echocardiogram and Doppler analysis. As we receive additional data from collaborating research groups, acquire more labels, and fine-tune our systems, we expect to see greater performance for robust and fully automated bubble analysis.
Gas exchanges in hyperbaric environments: A physiological oxygen-based model of nitrogen saturation/desaturation
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1Laboratory ORPHY, European University of Bretagne, University of Brest, Brest, France; 2Tek Diving SAS, Brest, France; 3LaTIM (Laboratoire de Traitement de l'Information Médicale), Brest, France; 4Unité de Médecine Hyperbare CHRU Brest
Presenting Author: Michael Theron PhD
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Introduction/Background: Despite the progress of decompression sickness (DCS) prevention DCS still occur while divers following decompression recommendations. Furthermore, preconditioning demonstrated that bubble formation depends on the physiologic state of individuals. These elements point out the need for physiological inputs to improve decompression models and DCS prevention. The main goal of this work is to propose a new approach of inert gas exchanges: a physiological model of gas exchange based on oxygen delivery to organs and tissues.

Materials and Methods: This model is proposed here in its simplest form and integrates eight compartments: ambient air, airways, alveolar gas, arterial, capillary, venous and alveolar blood, and a tissue compartment. Diffusive and convective physiological steps are expressed as a set of differential equations solved using Euler’s discretization method.

Results: The O2 model reproduces physiological PO2 in all its compartments in normobaric (oxygen breathing, static apnea) and hyperbaric conditions (Spearman p<0.001). This model can be transposed to inert gas to build a nitrogen model. The N2 model can simulate PN2 in the different compartments, in normobaric and hyperbaric conditions. The lack of reference values of PN2 precludes the possibility of directly validating this new model. The N2 model has hence been transposed to another respiratory gas: CO2. The obtained CO2 model has been validated by comparison to physiological reference values (spearman p<0.01). The validity of the CO2 model built from the N2 model is proposed as evidence of the likelihood of the N2 model.

Summary/Conclusions: In the perspective of personalized decompression procedures, the model presented here has the major interest of opening the possibility to integrate physiological and morphological parameters (blood and respiratory flows, alveolo-capillary diffusion, respiratory and blood volumes, oxygen consumption rate ...) in a simple model of nitrogen saturation/desaturation where PO2 and PCO2 can be integrated.
Shared medical and performance challenges in the naval undersea and aerospace operational domains
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¹Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT; ²Naval Medical Research Unit Dayton, Area Wright-Patterson Air Force Base, Dayton, OH
Presenting Author: Ben D. Lawson PhD
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Case Description: As part of this shared symposium between the Undersea and Hyperbaric Medical Society and the Aerospace Medical Association, it is appropriate to discuss shared human challenges and research solutions across both domains. To that end, representatives of the Naval Submarine Medical Research Laboratory (NSMRL) and the Naval Medical Research Unit Dayton (NAMRU-D) compared and contrasted their two domains of inquiry.

Intervention: Approach: Four lab directors and one principal investigator considered human physiological/performance challenges (e.g., in their respective specialty textbooks and lab portfolios) with a strong environmentally mediated contribution (e.g., atmospheric changes), as well as factors with a strong endogenous component (e.g., psychological challenges). They agreed upon 12 issues of greatest overlap in their two mission domains.

Outcome: Key environmental stressors/challenges that occur in both undersea and aerospace operations include: 1) atmospheric pressure changes (e.g., decompression); 2) noise; 3) breathing atmosphere changes (e.g., due to excess/insufficient oxygen or contaminants); 4) human factors challenges; 5) temperature extremes; 6) escape/rescue challenges. Shared issues that have an especially strong endogenous contribution include: 7) loss of situation awareness; 8) high/prolonged cognitive workload; 9) fatigue associated with sleep restriction/alteration; 10) teamwork; 11) motion sickness; 12) suboptimal psychological fit to the job.

Discussion: These dozen shared undersea/aeromedical challenges will be compared and contrasted in this presentation. We will provide in-depth discussion of a subset of these problems which are areas of focus for both laboratories, namely: 1) shared physiological challenges associated with abnormal atmospheric changes (e.g., in pressure, oxygen, or contaminants); 2) shared human factors psychology challenges and solutions (e.g., need for improved interfaces/cues to maintain situation awareness). The discussion will conclude with those research findings or solutions from the undersea or aerospace medical domains that show greatest promise for testing and transition across domains.

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Evaluations of divers after COVID-19 Infection
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Introduction/Background: The emergence of the novel SARS-Co-V-2 virus and subsequent COVID-19 pandemic raised significant concerns about fitness to dive due to potential lingering damage to the pulmonary and cardiovascular systems. Sadler et al. published guidelines for medical assessment of divers who have had COVID-19 (DHM 2020). We present preliminary results to an ongoing study evaluating recovered divers.

Materials and Methods: This was an IRB-approved prospective, observational study. Divers (a mix of recreational, scientific, and commercial) who had fully recovered from COVID 19 were consented and enrolled. We used the aforementioned guidelines which guided their clinical workup.

Results: Twenty divers were enrolled in our study. All divers were fully recovered, asymptomatic and reported to be at their baseline exercise tolerance. One was asymptomatic (Category 0), 17 (85%) had mild disease (Category 1), and two (10%) had moderate disease (Category 2). Category 1 and 2 divers underwent pulmonary function tests and chest imaging. Eighty-five percent had normal chest X-rays. Two divers with moderate disease underwent exercise stress testing and CT chest imaging. Exercise stress testing did not show ischemia, but both divers showed residual lung scarring on their CT scans. Two divers (one mild, one moderate) had abnormal spirometry. There have not been any subsequent adverse events such as barotrauma or immersion pulmonary edema.

Summary/Conclusions: COVID 19 has provided new challenges in evaluating divers. We studied divers in order to identify patterns of residual disease after recovery from COVID-19 that may place divers at increased risk for barotrauma or cardiac events. Our study highlights that while most patients had normal post-COVID evaluations, residual disease was seen on both imaging and spirometry. Based on our results, lack of current symptoms and return to exercise baseline alone is insufficient screening after COVID-19. Residual disease on CT imaging was directly correlated to initial disease severity.
DAN looks at longitudinal return to diving and vaccination results from divers with COVID-19 infection
Tillmans F1*, Helfrich E1*, Nochetto M1, Saraiva C1, Lindholm P2, Chimiak J1
1Divers Alert Network, Durham, NC; 2Department of Emergency Medicine, School of Medicine, University of California, San Diego, La Jolla, CA; *contributed equally to this study.
Presenting Author: Frauke Tillmans PhD ftillmans@dan.org

Introduction/Background: COVID-19 is an infection caused by SARS-CoV-2. To look at impacts on infected divers Divers Alert Network created the five-year Diver Return After COVID-19 (DRACO) study. From the first year of data we will discuss preliminary return to diving and vaccination results.

Materials and Methods: DRACO is an observational, survey-based study housed on Momentive™ (SurveyMonkey). Participants enrolled in DRACO by completing an initial survey covering details of their medical history, infection, current return to diving status, and fitness-to-dive exam. Participants also receive follow up surveys that ask for updated return-to-dive and fitness-to-dive information and vaccination results.

Results: From the 1,291 divers enrolled in DRACO, 785 divers indicated they returned to diving: 96 (12%) of these divers had issues on return to diving; 65 divers (68%) reported pulmonary issues; 19 (20%) reported neurological issues; 16 (17%) reported ENT issues; four (4%) reported psychological issues; and three (3%) reported DCI-related issues. Ninety-two (96%) divers reported moderate cases of COVID-19, and four (4%) reported severe cases of COVID-19.

Of the 106 divers who completed the one-year questionnaire, 99 (93%) reported they had received a partial or complete COVID-19 vaccination. Of these, 98 divers had no residual effects from the vaccine, and one reported new onset anxiety. Of these 99 divers who received the vaccine, 10 initially reported an asymptomatic infection, 79 a moderate infection, and 10 a severe infection.

Summary/Conclusions: While many divers returned to diving with no issues, there is a population who experienced several symptoms on return to diving. Before return to diving, divers should have a fitness-to-dive examination to evaluate potential residual symptoms of COVID-19 and on return to diving, divers should dive conservative profiles with a buddy to help mitigate any issues.
Chest CT analysis of gas cavities/cysts, emphysematous changes, and bronchiectasis after SARS-CoV-2
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¹ Division of Hyperbaric Medicine, Intermountain Medical Center, Murray, Utah, and Intermountain LDS Hospital, Salt Lake City, Utah; ² University of Utah School of Medicine, Salt Lake City, Utah; ³ MDClone Ltd, Beer Sheva, Israel
Presenting Author: Lindell Weaver MD
lindell.weaver@imail.org

Introduction/Background: SARS-CoV-2 infection can cause lung injury, including pulmonary cysts. One recent paper described a prevalence of 13% (28 of 209 patients) in hospitalized survivors (PMID: 34609153), not fully explained by mechanical ventilation. Patients with such abnormalities may have increased risk for pulmonary barotrauma while compressed-gas diving. Since SARS-CoV-2 infection is common, individuals surviving infection may dive.

Materials and Methods: Using the MDClone ADAMS platform we searched the Intermountain Healthcare system’s databases for adult patients with chest computed tomography (CT) scans from June 1, 2019, to October 9, 2021, where chest CT was performed at least three months after SARS-CoV-2 diagnosis. Using the MDClone natural language processing (NLP) studio, we isolated mention of incidental findings of gas cavities (including cyst, bullae, bleb, bullous disease, pneumatocele), emphysema (emphysematous change, bullous emphysema), and bronchiectasis (distal dilated bronchi, dilated bronchii). Patients with pre-infection history of asthma, emphysema, cystic fibrosis, chronic obstructive pulmonary disease, and lung cancer were excluded from analysis.

Results: We identified CT studies from 1,109 adult patients: 568 (51%) were male, mean age 55 ± 18 years; 67 (6%) had air cavities, emphysematous changes, or bronchiectasis on chest CT. Of these, gas cavities were most frequently reported (61%), followed by emphysematous change (27%) and bronchiectasis (12%). Six had findings identified by more than one classification criterion. Mechanically ventilated patients had higher rates of gas cavities (10.3% vs. 5.8%).

Summary/Conclusions: In patients with chest CTs at least three months after SARS-CoV-2 infection, we found a lower incidence of pulmonary gas-filled spaces than in a prior report of hospitalized patients. The prevalence of this finding after SARS-CoV-2 is similar to a larger study of non-SARS-CoV-2 patients without pulmonary disease (4.7%, n=76,176). These results possibly support that SARS-CoV-2 is not a likely risk for pulmonary barotrauma but decisions about diving after SARS-CoV-2 require clinical judgment.
Cognitive and hysiogetic findings in healthy volunteers developing CNS O2 toxicity
Derrick BJ1,2, Posada-Quintero H7, Chon K7, Allen CM1,2, Ellis MC1, Gonzalez S1, Kuchibhatla M3, Luedke M5, Natoli M7, Richardson C5, D’Agostino D6, Sayers MP8, Winstead-Derlega C1, Keuski B8, Moon RE2, Freiberger JJ2

1Duke University, Department of Surgery, Division of Emergency Medicine; 2Duke University, Department of Anesthesiology, Center for Hyperbaric Medicine & Environmental Physiology; 3Duke University, Department of Biostatistics & Informatics; 4Duke University, Department of Neurology; 5Richardson Keto Consulting, LLC; 6University of South Florida, Department of Molecular Pharmacology & Physiology; 7University of Connecticut, Department of Biomedical Engineering; 8Broward Health, Emergency Medicine; 9United States Navy

Presenting Author: Bruce Derrick MD
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Introduction/Background: Central nervous system O2 toxicity (CNSOT) is a limiting factor for Navy diving operations. Development of mitigation strategies for CNSOT depends on a better understanding of CNSOT and oxygen narcosis physiology.

Materials and Methods: Healthy volunteers were immersed to the shoulders (head out) while breathing 100% O2 at 35 fsw (PO2 = 2.06 ATA) while exercising on an underwater cycle ergometer at approximately 100 watts’ output. The dive terminated upon the onset of any CNSOT symptoms, or a when a maximum dive time of 120 minutes was reached. NASA’s Multi-Attribute Task Battery-II was used to evaluate continuous cognitive performance. Subjects were instrumented with an arterial catheter or intravenous catheter to measure serum blood gases. Electrocardiogram (ECG), heart rate (HR), blood pressure (BP), respiratory rate (RR), tidal volume (TV), minute ventilation, (MV), electrodermal activity (EDA), and electroencephalogram (EEG) were monitored during the study. Time-varying analysis (TVSymp) of EDA and quantitative analysis of EEG were performed after each dive.

Results: Ninety-three of 100 planned dives were completed, with the remainder of the dives aborted due to safety or subject withdrawals. Seventy-two of the 93 completed dives resulted in CNSOT, with one generalized seizure. EEG data was collected on all dives, including the dive ending in a convolution where four seconds of pre-generalized seizure activity was observed. Increase in electrodermal activity and a spike in TVSymp was observed in some subjects experiencing CNSOT.

Summary/Conclusions: Real-time EEG does not appear to be an effective means of monitoring for CNSOT. Monitoring for changes in EDA could prove beneficial for detection of CNSOT. Cognitive performance on the MATB-II is being compared with physiologic parameters such as EDA and EEG.

Funded by: NAVSEA Contract #N0002418C4315, ONR Grant #N0002418C4315
Rehydrating after prolonged cold-water immersion maintains thermoregulation during a 60-minute weighted ruck march in a warm environment
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Introduction/Background: Cold-water immersion leads to hypohydration upon egress and aerobic performance is reduced when body mass reduction exceeds 2%, which is especially important when working in the heat. The purpose of this study is to determine if two fluid replacement strategies maintain performance in a warm environment following cold water immersion.

Materials and Methods: Five males (23 ± 2 years; BF: 10.7 ± 4.0%; VO₂ max: 50.5 ± 6.2 ml/kg·min⁻¹) completed a non-immersed control trial (CON) and two four-hour cold water immersion (18.0 ± 0.2°C) trials. Following immersion, they completed a 60-minute weighted (20.4 kg) ruck march (5.6 kph) at 50% VO₂ max in a warm environment (29.6 ± 0.1°C; 50.1 ± 0.3% RH), during which they were either partially (50%; HALF) or fully (100%; FULL) rehydrated with fluid lost during immersion. Heart rate (HR) and core temperature (T₉) were recorded every 10 minutes during immersion and the ruck. A five-minute average for oxygen consumption (VO₂), respiratory exchange ratio (RER) was measured, and rating of perceived exertion (RPE), and thermal comfort (TC) were recorded during the first five minutes, from 25-30 minutes, and the last five minutes of the ruck march.

Results: During immersion, body mass was reduced 2.2 ± 0.5 and 2.3 ± 0.6% for HALF and FULL, respectively. Subjects were rehydrated with 0.74 ± 0.3 L (HALF) and 1.6 ± 0.5 L (FULL). HR and T₉ decreased throughout immersion (both: p<0.01) and increased during the ruck march (all: p<0.01). T₉ during the ruck march was lower for HALF and FULL compared to CON (p=0.03). Throughout the ruck march, VO₂, RER, RPE, and TC were not different compared to CON for either trial.

Summary/Conclusions: Partial and full rehydration strategies were effective for maintaining HR, T₉, VO₂, RER, RPE, and TC during a 60-minute weighted ruck march in a warm environment.
Inland decompression sickness at a 24/7 DAN hyperbaric facility: A descriptive analysis
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Introduction/Background: Decompression sickness (DCS) is a clinical syndrome secondary to inert gas after a reduction in ambient pressure. Data reported on DCS is typically coastal. We report on DCS presentations to an inland DAN hyperbaric facility.

Materials and Methods: This is a retrospective case series of DCS patients who presented to a 24/7 inland DAN hyperbaric facility. Analysis included DCS type, time to treatment, distance, and outcome.

Results: A total of 27 patients were identified: 92.6% made dives in local fresh water. Cases were classified as Type I (18.5%), Type II (74.1%), and Type III (7.4%) DCS. The average time to treatment from onset of symptoms was 15.18 hours (median 10.88 hours) and a range of four to 47 hours. 40.7% of cases required transfer as they had an initial evaluation at a hospital without hyperbaric capabilities. Hyperbaric oxygen treatment outcomes were 59% with complete resolution, 37% were improved, and 4% showed no improvement. Patients were treated with zero to six trailing treatments. There was a statistically significant difference in the median number of trailing treatments and outcome. Patients with complete resolution had a median of zero trailing treatments (81% none; maximum of 2), while those with partial/no response had a median of one trailing treatment (41% none; rest 1-6), p=0.042. The average distance from dive site to chamber was 216.85 miles (median of 99 miles). There was an association between distance to chamber and time to treatment (R = 0.737)

Summary/Conclusions: More than 80% of the inland DCS cases were more advanced Types II and III. The lack of access to 24/7 hyperbaric facilities resulted in long transport distances and average time from symptom onset to treatment of more than 15 hours. This resulted in a complete resolution rate of only 59%. Not surprisingly, most with complete resolution required only one treatment, while those requiring trailing treatments had a complete resolution rate of only 41%.
Prevalence of underlying gas cavities/cysts, emphysematous changes, and bronchiectasis by chest computed tomography
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¹Division of Hyperbaric Medicine, Intermountain Medical Center, Murray, Utah, and Intermountain LDS Hospital, Salt Lake City, Utah; ²University of Utah School of Medicine, Salt Lake City, Utah; ³MDClone Ltd, Beer Sheva, Israel
Presenting Author: Lindell Weaver MD
lindell.weaver@imail.org

Introduction/Background: Pulmonary cysts, blebs, bullae, pneumatoceles, and emphysema may be risk factors for gas embolism in compressed-gas diving. One autopsy study demonstrated findings in 33.8% of their sample (PMID 31459963).

Methods: Using the MDClone ADAMS platform, we searched Intermountain Healthcare’s databases for adults with chest computed tomography (CT) scans from January 1, 2018 to October 9, 2021. We excluded scans from patients with known cystic fibrosis, asthma, chronic obstructive pulmonary disease, emphysema, SARSCoV-2 infection, and lung cancer. Using MDClone’s natural language processing (NLP) studio, we isolated mention of gas cavities (cyst, bullae, bleb, bullous disease, pneumatocele), emphysema (emphysematous change, bullous emphysema), and bronchiectasis (distal dilated bronchi, dilated bronchi).

Results: We included 79,176 chest CTs: mean age 57 ± 19 years, 51% male, and 19% had current/prior tobacco use. A total of 3,758 (4.7%) of the reports contained positive use of terms for air cavities, emphysematous changes, or bronchiectasis. Of these, gas cavities were most frequent (54%), followed by emphysematous change (43%) and bronchiectasis (3%).
Patients with evidence of pulmonary cavities were older (odds ratio (OR) 1.02 per year increase, 95% confidence interval (CI) 1.019-1.023, p<0.001) and were more likely to be men (OR 1.42, 95% CI 1.32-1.52, p<0.001) or current or prior tobacco users (OR 2.11, 95% CI 1.96-2.27, p<0.01).

Conclusions: In this review of 79,176 chest CTs in patients without documented pre-existing pulmonary disease, pulmonary cysts/cavities were identified by radiologists in only 4.7% of patients, much lower than findings in the autopsy study (33.8%). Our study suggests that underlying pulmonary cavities are rare and unlikely to be present in healthy individuals wishing to dive, yet decisions to dive require clinical judgment. Limitations include the possibility that cavities were present but not discovered. We did not visually inspect all these chest CTs. In addition, this cohort may not represent the general population who did not undergo chest CT.
Preliminary evidence that resting spleen volume is related to the magnitude of apnea-induced increases in total hemoglobin mass in humans without a history of breath-hold diving

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Introduction/Background: Indigenous populations renowned for breath-hold diving have comparatively large spleen volumes. It is speculated that a larger spleen translates to heightened apnea-induced splenic contraction and elevations in circulating hemoglobin mass (Hbmass), thereby improving oxygen-carrying and/or pH buffering capacity. This speculation assumes that pre-apnea spleen volume is associated with apnea-induced increases in total Hbmass. Therefore, this study tested the hypothesis that pre-apnea spleen volume is positively related to apnea-induced increases in total Hbmass.

Materials and Methods: Total Hbmass (CO rebreathing) was measured in eight healthy adults without a history of breath-hold diving (27 ± 4 years, three women). 6 ± 4 days later, subjects completed five maximal apneas seated in air. Before and after the fifth apnea, spleen length, width and thickness were measured (ultrasound) and spleen volume was calculated (Pilström equation, test-retest CV: 2 ± 2%). At these timepoints, hemoglobin concentration [Hb] and hematocrit were measured from capillary blood samples. Blood volume was calculated from total Hbmass pre-apneas. Post-apneas, total Hbmass was estimated from post-apnea [Hb] and pre-apnea blood volume. Data are mean ±SD.

Results: Apnea duration increased from the first (73 ± 24 seconds) to second (99 ± 36 seconds, p=0.027) apnea and was sustained thereafter (p>0.468). Spleen volume decreased from pre- to post-apneas (241 ± 75 vs. 201 ± 64 cm³, p=0.001). [Hb] (14.6 ± 0.9 vs. 15.0 ± 1.0 g/dL, p=0.006) and total Hbmass (876 ± 204 vs. 899 ± 211 g, p=0.018) increased, but hematocrit did not change (pre: 46 ± 4%, post: 46 ± 3%, p=0.532) from pre- to post-apneas. There was a moderate, positive relation between pre-apnea spleen volume and increases in Hbmass (r=0.505, p=0.101) and a weak, negative relation between the magnitude of splenic contraction and increases in Hbmass (r=-0.144, p=0.367). Pre-apnea spleen volume explained more variance in Hbmass than the magnitude of splenic contraction (p=0.054).

Summary/Conclusions: A larger spleen volume is associated with a greater rise in total Hbmass following apneas.
Reversal of altitude acclimatization and recurrence of acute mountain sickness following a high-PO\textsubscript{2} dive at 15,000 feet of altitude
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Presenting Author: Timothy Beck STUDENT
timothy.beck@duke.edu

Introduction/Background: Acute mountain sickness (AMS) is part of a spectrum of acute altitude illness caused by the reduction in ambient PO\textsubscript{2} and resulting hypoxic stress, consisting of headache, gastrointestinal upset, fatigue/weakness, dizziness/light-headedness, and sleep disturbance. This study tested the effects of high PO\textsubscript{2} exposure, such as might be experienced during a dive, on altitude-acclimatized subjects and its impact on AMS symptom recurrence.

Materials and Methods: After IRB approval and informed consent, subjects (M=7, F=1, age: 29, 22-37, mean, range) spent 48 hours at a simulated 15,000-foot altitude (0.56 ATA) in a hypobaric chamber, with AMS scores obtained every eight hours. They then performed a dry simulated dive breathing 100% O\textsubscript{2} for 120 minutes at 1.3 ATA (24 ftsw relative to altitude, 10 ftsw relative to surface), after which they returned to air breathing at 15,000 feet, where they remained for 24 hours for AMS assessment.

Results: During the 48-hour acclimatization, there was significant hypoxemia, with occasional desaturation to the 40s on continuous SpO\textsubscript{2} monitoring. Seven of eight individuals experienced significant AMS (see Table 1) and required treatment: acetaminophen (N=6), ibuprofen (N=6), ondansetron (N=5), intermittent nasal O2 (N=2). Immediately post-dive there was almost complete resolution of AMS. However all seven previously symptomatic individuals experienced significant recurrence.

| Table 1. 2018 Lake Louise score vs. time from start of altitude exposure |
|--------------------------|------------|----------|----------|----------|----------|----------|----------|
|                         | pre-dive   | post-dive|
|                         | 0 h       | 8 h      | 16 h     | 24 h     | 32 h     | 40 h     | 48 h     | 56 h     | 64 h     | 72 h     |
| median                  | 0         | 4        | 5.5      | 6        | 2.5      | 1.5      | 2        | 0        | 1        | 2.5      |
| interquartile range     | 0-0       | 3-5.25   | 3.25-8   | 4.25-7   | 1-4      | 0.75-3.5 | 0.75-4   | 0-0.25   | 0-2      | 1-4      |
| min-max                 | 0-0       | 3-6      | 0-13     | 1-10     | 0-5      | 0-10     | 0-8      | 0-4      | 0-5      | 0-6      |

Summary/Conclusions: Our results support the recurrence of AMS after a high-PO\textsubscript{2} dive at 15,000 feet of altitude.

This study was supported by NAVSEA Contract N0002418C4318.
The ventilatory response to carbon dioxide in novice rebreather divers increased after a 20 week dive training course
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Introduction/Background: Divers are reported to have a lower ventilatory response to elevated levels of carbon dioxide (CO\textsubscript{2}) than non-divers. Hypoventilation with CO\textsubscript{2} retention during diving is potentially dangerous. It is unknown if CO\textsubscript{2} retention is largely inherited or develops during diving training. We aimed to investigate if a military dive training course would lower the ventilatory response to CO\textsubscript{2}.

Materials and Methods: Cohort study of novice rebreather divers in the Swedish navy with amphibious rangers as controls were planned for three tests: at baseline, after 12 weeks of water confidence training, after 20 weeks of diving. During the test, participants rebreathed in a Douglas bag filled with an initial 100% oxygen, resulting in increasing levels of inspiratory CO\textsubscript{2} (FiCO\textsubscript{2}). The test was performed until symptom-limitation or an FiCO\textsubscript{2} of 8.0 kPa. Minute ventilation (MV), expiratory and inspiratory CO\textsubscript{2} were measured continuously. To decrease conscious control of breathing, participants were distracted with a memory game during the test. Differences between groups and time points were analyzed using independent and paired t-tests.

Results: Ten divers and six amphibious rangers completed baseline testing, and seven divers completed all tests. At baseline, amphibious rangers had a trend to significant higher MV compared to divers at higher levels of FiCO\textsubscript{2}, mean difference (MD) 7.9L (95% CI, -0.6-16.3; p=0.064) at FiCO\textsubscript{2}: 6-6.9kPa, MD in MV 9.5L (95% CI, -2.2-21.2; p=0.097) at FiCO\textsubscript{2}: 7-7.9kPa. Divers had a significant higher MV after dive training at both low and high levels of FiCO\textsubscript{2}; MD in MV 2.7L (95% CI, 1.3-4.1; p=0.003) at FiCO\textsubscript{2}: 1-1.9kPa, and 7.2L (95% CI, 2.6-11.9; p=0.013) at FiCO\textsubscript{2}: 7-7.9kPa.

Summary/Conclusions: A military rebreather diving program was associated with increased ventilatory response to CO\textsubscript{2}, which may be related to increased respiratory muscle strength or conditioned hyperventilatory response to repeated testing.
The effect of arterial bubbles on cerebral autoregulation in humans
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Introduction/Background: Greater exposure to arterial emboli (mainly bubbles) in open-chamber cardiac surgery compared to closed-chamber operations (particularly after aortic cross-clamp removal) provides an opportunity for an ethical natural experiment to investigate the effect of arterial bubble exposure on cerebral vasoreactivity and autoregulation in humans. We hypothesized that greater arterial bubble exposure in open-chamber surgery might promote dysautoregulation.

Materials and Methods: Forty adult patients underwent closed- (n=20) or open-chamber surgery (n=20). Transcranial Doppler detected emboli and measured bilateral middle cerebral artery flow velocities. Cerebral autoregulation was assessed by averaging the “mean velocity index” (a continuous moving correlation between cerebral blood flow velocity and mean arterial pressure) over 30 minutes before and after aortic cross-clamp removal.

Results: Median (interquartile range) emboli counts were 775 (415, 1211) and 2,664 (793, 3,734) in the closed-chamber and open-chamber groups. Most appeared after the removal of the aortic cross-clamp (open-chamber 1631 (606, 2296)), (closed-chamber 229 (142, 384)), with emphasis on the right hemisphere (open-chamber: 826 (371, 1622)), (closed-chamber 181 (66, 276)). Linear mixed-model analyses of mean velocity index change showed no significant overall effect of group (0.08, 95% CI: -0.04, 0.21; p = 0.19) or side (0.01, 95% CI: -0.03, 0.05; P = 0.74). However, there was an interaction between group and side (p = 0.001), manifesting as a greater increase in the open group in the right hemisphere (mean difference: 0.15, 95 % CI: 0.02, 0.27; p = 0.03).

Summary/Conclusions: There was no overall difference between groups in change in mean velocity index before and after cross-clamp removal. However, most emboli entered the right cerebral hemisphere in the open-chamber group where there was a significantly greater increase in the index. This suggests a possible association between embolic exposure and disordered autoregulation.
COVID-19 complications in Mumbai saturation divers
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Case Description: Multiple saturation divers (SDs) developed COVID-19 (C19) in Mumbai after decompression. SDs reported everyone on board became infected, including at least five SDs (SD1-5): SD1 was hospitalized and developed transverse myelitis with paralysis; SD2 was hospitalized for low O_2sat and was later able to return to Europe; SD3 was managed with daily medical and O_2sat checks in a hotel and later returned to Canada; SD4 was able to return to the United States; SD5 tested positive upon return to Canada.

Intervention: The surge of Delta variant C19 in Mumbai created challenges providing advanced care and oxygen. Remote medical advice was important in supporting and assisting the divers, including the arrangements for transfer back to home countries.

Outcome: SD1 was transferred by air ambulance back to Canada too late to receive advanced treatment (plasmapheresis or IVIG), but despite good neurologic recovery has not yet been able to return to work. SD2 initially improved after return home and was exercising to regain fitness. However, his condition deteriorated with extreme fatigue, and he is suspected to have developed narcolepsy and possible postural orthostatic tachycardia syndrome (POTS) requiring hospitalization and is unfit to work. SD3 had satisfactory cardiac exercise stress test, pulmonary function tests with DLCO (diffusing capacity of the lungs) and CT chest about six months post-C19 and has been approved to work as SD. No further information is available for SD4 or SD5.

Discussion: Cardiorespiratory fitness has been the main focus for SD fitness concerns after C19. However, it is remarkable to have such serious neurologic complications in a small group of divers and for these to be the reason for SDs being unable to work. It is not known if SDs face increased risks of neurologic complications after C19. POTS is an autonomic neurologic complication that may occur after C19 and may be responsible for many of the longer-term effects.
Arterial blood gas measurements during deep open-water breath-hold dives
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Introduction/Background: Arterial blood gas (ABG) measurements at both maximum depth and at resurfacing prior to breathing have not previously been measured during breath-hold dives conducted to extreme depth in cold open-water conditions. Such measurements could help explain the phenomenon of “shallow-water blackout.”

Materials and Methods: An elite freediver was instrumented with a left radial arterial cannula connected to two sampling syringes through a low-volume splitting device. He performed two open-water dives to 60 meters depth (197 feet 7 atmospheres absolute pressure) in the constant weight with fins competition format. On each dive ABG samples were drawn at 60 meters (by a mixed-gas scuba diver), and again on resurfacing before breathing. Both dives lasted approximately two minutes. An immersed surface static apnea, of identical duration to the dives and with ABG sampling at identical times, was performed.

Results: PaO$_2$ increased during descent from an indicative baseline of 15.8 kPa (118 mmHg) (after hyperventilation and glossopharyngeal insufflation) to 42.8 kPa (321 mmHg) and 33.3 kPa (250 mmHg) (dives one and two), and decreased precipitously (to 8.2 kPa [61.5 mmHg] and 8.6 kPa [65 mmHg]) during ascent. PaCO$_2$ also increased from a low indicative baseline of 2.8 kPa (21 mmHg) to 6.3 kPa (47 mmHg) and 5.1 kPa (38 mmHg) at bottom on dives one and two; an increase not explained by metabolic production of CO$_2$ alone since PaCO$_2$ actually decreased during ascent (to 5.2 kPa [39 mmHg] and 4.5 kPa [34 mmHg]). Surface static apnea caused a steady decrease in PaO$_2$ and increase in PaCO$_2$ without the inflections provoked by depth changes.

Summary/Conclusions: Lung compression and expansion provoke significant changes in both PaO$_2$ and PaCO$_2$ during rapid descent and ascent on a deep breath-hold dive. These findings generally support predictive hypotheses and previous findings in less extreme settings.
Classifying physiological response of the middle-ear using otoscopy after submarine escape tower training (SETT)

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Introduction/Background: Submarine escape tower training (SETT) is a safety procedure for submariners. It involves submersion in a closed compartment and free ascent to the surface wearing a submarine escape suit. Since 2013 the Royal Netherlands Navy has used a diving tower specifically designed for SETT (Triton 12, Den Helder), with a gradual training programme the day prior to free ascent SETT from 12 msw (2.2 ATA). Only mild medical complaints occurred in the past eight years, predominantly problems equalizing and otalgia. Assessment of these complaints usually involves otoscopy. However, the (patho)physiological response to SETT has, to our knowledge, never been described.

Materials and Methods: Submariners who were medically fit according to NATO ANEP/MNEP-86 standards were eligible for inclusion. SETT took place in aforementioned conditions using Armadillo submarine escape suits (Texcon GmbH). Otoscopic images were captured using a Welch Allyn Marcoview otoscope. Three dive medical physicians independently scored the pre- and post-SETT images on a Teeds-scale. The mode was used in non-matching scores. A Wilcoxon signed-rank test was used to analyze the results.

Results: Twenty-two submariners were included, generating 82 otoscopic images (three one-sided, as the other image was not clear enough). Four submariners (18%) experienced equalization problems during SETT. One submariner failed to report equalizing problems prior to SETT, resulting in post-SETT Teeds-score of 3 and a vagal collapse a few minutes later. The mean pre-SETT Teeds score increased statistically significant from 0.51 (range 0-3) to 1.29 post-SETT (range 0-4), with p=0.000. No difference was observed between left and right ears.

Summary/Conclusions: SETT is generally well tolerated. Although Teeds scores statistically significantly increase post-SETT, the relation to clinical ENT-complaints remains unclear. Based on this small sample a Teeds score of ≥4 suggests a pathophysiological response to SETT. The Royal Netherlands Navy will continue research to substantiate these findings.
A final update on pulmonary edema in special operations assessments at Hurlburt Field: A look inside U.S. Air Force Special Warfare
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Case Description: The United States Air Force assessed hundreds of candidates annually for selection into Air Force Special Warfare assignments at Hurlburt Field. Assessments are designed to identify successful candidates, with a key piece of evaluation revolving around pool work (underwater swimming, drown-proofing, buddy breathing, etc.) due to the intrinsic stress exposure of water. Swimming-induced pulmonary edema and immersion pulmonary edema are recognized risks, along with negative-pressure pulmonary edema due to snorkel and breath-holding activities. Evaluating these conditions in this population is ideal, as all participants are rigorously medically screened and without comorbidities.

Intervention: This case series previously was reported in two prior abstracts, initially spanning three years and subsequently four years. With COVID-19 and other strategic alignments, further assessments at Hurlburt Field have terminated. In addition to the previously reported 12 healthy individuals, we now present three additional cases who developed pulmonary edema during pool phase of special operations assessment, their resultant clinical evaluation, care and follow-up.

Outcome: All 15 individuals were diagnosed with pulmonary edema in varying severity; some were hospitalized; all survived. None have had permanent sequelae to date.

Discussion: Pulmonary edema in special operations assessments is a known risk associated with water events. We advocate mitigation of risk by having physicians and medics present at all times, with the ability to intervene when candidates display symptoms of hypoxia and/or hemoptysis. Pulmonary edema in our assessments are related to exertion, vigorous pre-event hydration, cold exposure, submersion, breath-holding, and snorkel-breathing. Most also present with concomitant rhabdomyolysis and acute kidney injury, complicating treatment options. These cases are separate from aspiration or near-drowning. Increased education enables medical personnel to correctly identify cases and avoid morbidity and mortality. Non-cardiogenic pulmonary edema is a physiological response to stress and does not appear to have genetic predisposition or increased risk of recurrence.
Inhibiting aluminum scuba cylinder corrosion via sacrificial magnesium anodes: A countermeasure to decrease diving accidents

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Introduction/Background: Extended-range cave diving utilizing closed-circuit rebreathers (CCR) requires abundant open-circuit bailout (BO) gas. As depths and penetration distances increase, the logistics of each diver carrying enough BO gas for a safe exit may become impractical. As such, divers may stow BO cylinders within the cave system for extended periods of time, which can lead to corrosion and failure of this equipment. Sacrificial anodes (SA), which are used on ships for cathodic protection, may inhibit this corrosion and maintain equipment/gas integrity [1]. We hypothesize that attaching an SA to a cylinder will prevent or inhibit the corrosion of the cylinder, valve and regulators.

Materials and Methods: Two aluminum cylinders with regulators and stage kits were filled to 3,000 psi with air. A magnesium anode was attached to one cylinder (AC) via a hose clamp. A magnesium anode was chosen as they are most effective for freshwater cathodic protection [2]. The other cylinder was used as a control (CC). These cylinders were stowed in a submerged freshwater cave for 172 days before retrieval and inspection.

Results: Extensive corrosion was noted on the CC where the hose clamp made contact with the cylinder and along the junction the cylinder neck and tank valve. The AC demonstrated degradation of the SA only and superficial corrosion of the cylinder wall in the area surrounding the SA. It was also noted that the CC had lost 1,500 psi of gas, while the AC had not leaked any gas.

Summary/Conclusions: Galvanic corrosion occurs when two dissimilar metals make contact underwater. Not surprisingly, the CC demonstrated corrosion along two sites of dissimilar metal contact points and gas loss, while the AC did not show this same corrosion pattern nor the gas loss. Thus, we conclude that an SA may extend the service life of stowed underwater cylinders and regulators, which improves diver safety.

References
Uhthoff's phenomenon after CNS DCI
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Case Description: A 52-year-old recreational scallop diver performed a 26-minute dive to 80 fsw with an estimated five-minute stop at 25 fsw. Within five minutes of surfacing, he experienced nausea, vomiting, leg weakness, sensory changes, and balance disturbance; then bilateral girdle pain and severe priapism after 20 minutes. The diver was at a remote cabin accessible only by boat. He attempted in-water air-self-recompression the next morning and then was transferred on oxygen to the hyperbaric chamber.

Intervention: Monoplace HBO2 treatment comprised USN Table 6 (x2), then 45 fsw (x5) for 90 minutes over seven days with good but incomplete resolution.

Outcome: After nine months symptoms still precluded working. He commenced occupational therapy (OT) but after each session debilitating symptoms developed, including profound visual disturbances, fatigue, pain, cognitive difficulty, and dizziness that required him to lie down for hours. Due to visual changes with HBO2 the diver was seeing an optometrist. Assessment immediately after OT confirmed symptoms which were identified as Uhthoff phenomenon (UP). This was supported by improvement with cold packs behind his neck. There was no MRI or other evidence for multiple sclerosis (MS). Ophthalmologist assessment did not reveal any further problem but he later developed a coincidental detached retina and underwent successful posterior vitrectomy and laser treatment.

Discussion: UP is generally attributed to demyelination in MS but may occur due to other causes of demyelination. Symptoms are provoked by even minor increased temperature such as with exercise or a hot shower and may be mitigated by cooling. UP has not been previously reported to be due to DCI. In this case CNS DCI likely led to some degree of demyelination in the diver’s brain. Interestingly, neuropsychology assessment did not identify any deficits. The diver is also undergoing psychotherapy for PTSD. It is important to listen to diver complaints of symptoms after DCI.
Deep rebreather dive results in high-grade venous gas emboli arterialization without clinical decompression sickness symptoms
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Case Description: We present a case of a middle-aged male diver with a history of a cerebral decompression sickness (DCS) incident and subsequent patent foramen ovale (PFO) closure who presented with high-grade bubble scores (5 and 3 for right and left heart respectively, using Eftedal-Brubakk scale). He had no DCS symptoms within 24 hours after a rebreather dive to a maximum depth of 115 msw with a total dive time of 250 minutes.

Intervention: As part of a larger observational study across multiple diving days, the following was collected in addition to the dive profile on this dive day: transthoracic echocardiography (TTE) videos, heart rate (HR), and oxygen saturation (SpO2) post-dive at intervals spanning 80 to 180 minutes. Urine specific gravity (USG) and osmolality, neurocognitive performance tests via an iPad-based, validated test battery, and subjective fatigue level via a visual analogue scale were collected between 90-120 minutes post-dive.

Outcome: TTE revealed venous and arterial gas emboli post-dive at different time points. The osmolality post-dive measurement was higher (1,060 Osm/kg H2O) than both post-dive measurements recorded on previous days (700 and 870 Osm/kg H2O). HR was found to be slightly increased at the 100-, 120-, and 140-minute time points compared to previous dive days with comparable dive exposure. The diver’s subjective post-dive fatigue was increased compared to previous days. When compared to previous results, neurocognitive performance did not appear to be adversely affected.

Discussion: We present a case in which grade 3 arterialization was present without clinical DCS symptoms. The case is of further interest due to the diver’s previous DCS and PFO repair since it suggests recurrence of a right-to-left shunting mechanism.
Spontaneous pneumomediastinum with pneumorachis after diving: Air around the spinal cord
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Case Description: A 19-year-old male with a past medical history of seasonal allergies presented to his local hospital experiencing chest pain after a commercial flight. Prior to this he had been working on a marine conservation project in the Seychelles. There, he made one to two dives per day, four days per week. Dive profiles were between 5-15 meters for approximately 45 minutes while breathing compressed air. There were no clear overinflation events. He stopped diving after experiencing a sinus squeeze and returned home. Initial radiologic evaluation demonstrated pneumomediastinum and extradural pneumorachis. He had no neurologic deficits.

Intervention: No immediate intervention was needed. His chest pain improved over four days, and the patient was discharged with return precautions. He then requested clearance to return to dive four weeks after event.

Outcome: Diving clearance workup was obtained for spontaneous pneumomediastinum and pneumorachis related to diving. Repeat CT chest demonstrated resolution of pneumorachis and no gross pulmonary parenchymal abnormalities. He was counseled and cleared to return to diving with overinflation injury precautions.

Discussion: Pneumorachis, or air within the spinal canal, is often an incidental finding on imaging. It is primarily caused by traumatic, pulmonary overinflation or iatrogenic etiologies. Pneumorachis is typically detected in concurrence with air in other compartments, most commonly with pneumothorax, pneumopericardium, or pneumomediastinum. Its presence can be a marker of more severe injuries, notably following trauma. Pneumorachis usually does not cause symptoms and reabsorbs within a few days, similar to our patient. However, the air may compress adjacent structures, manifesting as symptoms suggestive of spinal cord injury. Interventions with surgery or hyperbaric oxygen may be necessary to prevent permanent neurological damage. When signs typical of pulmonary overinflation are found on imaging, clinicians should consider pneumorachis and its unique complications.
Rebreather divers’ responses to hyperalkaline hydroxide ingestion and aspiration (‘caustic cocktail’) events
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Introduction/Background: Rebreathers recycle exhaled air using soda-lime scrubber material to remove carbon dioxide and injecting oxygen into the normally closed breathing loop. When water enters the system it generates a hyperalkaline hydroxide solution, commonly known as a “caustic cocktail.” Unexpectedly ingesting or aspirating this solution can potentially result in serious harm. The gold standard first-aid treatment for hyperalkaline ingestion/aspiration is to flush the mouth with water. This study surveyed caustic cocktail experiences of rebreather divers.

Materials and Methods: Rebreather divers were recruited through DAN’s social media, website or by research team members attending dive-related events. Participants were directed to an online survey that collected information on the participants’ training, equipment, diving history, caustic cocktail incidents, and consequential actions.

Results: Of 413 respondents, 394 (95%) identified as male. Mean age was 46 years (SD 10) and median length of CCR certification six years (IQR 3-12). Reported rebreather diving experience ranged from 20 years (median = six years, IQR 3-12). Median self-reported dives experience was 200 (IQR 100-500) and median reported hours of rebreather diving was 300 (IQR 120-750). Forty-four participants (11%) reported 50 hours’ experience or less. The three most common sources of information for treating caustic cocktail ingestion came from rebreather instructors (322), manufacturers (117), and other divers (112). Of the 249 first-aid treatments applied, 191 involved flushing with salt/fresh water. Other treatments include flushing with mildly acidic solutions such as soda (24), juice (7), or other mild acids (5). Pain scores of divers who sought medical attention (n=34, mean=4.9, SD=2.6,) was almost twice that of divers who did not (n=203, mean=2.6, SD=2.3).

Summary/Conclusions: Although most divers treated caustic cocktail ingestion/aspiration by flushing with water, many did not. Additionally, very few divers reported seeking professional medical advice, although those experiencing greater pain were more likely to seek medical assistance.
Efficiency of a 24-hour on-call system for early recompression therapy for acute decompression sickness
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Introduction/Background: Early recompression therapy is suggested for the better clinical outcome of decompression sickness (DCS) patients. This study analyzed the efficacy of our 24-hour on-call system for early recompression therapy.

Materials and Methods: We conducted a single-center five-year retrospective cohort study. Patients were classified into Type I versus Type II DCS groups, duty time versus non-duty time groups based on the time of emergency department (ED) admission, and hospitalization versus discharge groups according to clinical outcomes. Baseline characteristics, diving variables, and in-hospital course were analyzed.

Results: This study investigated 341 acute DCS patients. A total of 81 and 260 patients had Type I and Type II DCS, respectively. While 198 patients accessed the center during duty time, 143 presented during non-duty time. Fifty patients were admitted, and 291 patients were discharged. Total median time from symptom onset to HBO₂ therapy was 259 minutes: 240 minutes for the duty group and 292 minutes for the non-duty group (p=0.161); 251 minutes for the discharged group and 291 minutes for the hospitalized group (p=0.001). The median time from ED admission to HBO₂ therapy was 65 minutes: 60 minutes for the duty group and 69 minutes for the non-duty group (p=0.229); 63.4 minutes for the discharged group and 92 minutes for the hospitalized group (p=0.050).

Summary/Conclusions: The 24-hour on-call system was able to provide acute DCS patients with early recompression therapy even during non-duty time. However, in terms of the outcome of treatment of patients, quicker arrival at the hospital and swifter recompression therapy are needed.
Proposed novel severity scale for freediving-related incidents
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Introduction/Background: The statistics of mental status changes in freediving-related incidents have been published before in this same format and meeting in 2021, showing the accumulated data in a 10-year period from 2009 to 2019. It shows the importance of awareness and preparation for neurological events related to competitive freediving. We recognized the need to design a tool to assess the severity of a freediving-related event, for purposes of sign-out from physicians to physicians, medic to medic, and for purposes of documentation and tracing of incidents. An aid to the Glasgow Coma Scale, or the modified trauma scale, previously published and still in use, this tool serves the medical professional to understand the severity of a freediving-related event and use to assess the return to dive and clearance to dive. We hope this scale serves for future generations to determine how severe an incident was, recognize the risks factors and track it over time. A “unifying” theory or concept is in order, instead of looking at incidents as isolated neurological incidents (“blackout” of freediving-related syncope) or isolated pulmonary incidents (“lung squeeze” or pulmonary barotrauma), we aim to describe a new concept of “neuropulmonary event” consistent with current experience in the freediving community.

Materials and Methods: The main factors determining severity were analyzed, and identified:

1. Syncope at the surface.
2. Loss of motor control (LMC) at surface.
3. Syncope at depth.
4. Dyspnea and/or low saturation below 93%.
5. DCS suspected (abnormal neurological findings).
6. Comorbidity: diver over 65 years old.
7. Comorbidity: recent neuropulmonary event related to freediving in the last month.

Results
BO: LMC-1 point; surface-2 points; UW-3 points
DCS suspected: Yes=1
Comorbidities over 65 years old = 1
Recent neuropulmonary event = 1
Dyspnea and/or low sat: Yes=1
Airway compromise (either trismus or laryngospasm or bronchospasm): yes=1
Severity Scale/Points-Scale
0=Normal
1=Mild
2=Moderate
3=Severe
4-10=Extremely severe
**Summary/Conclusions:** This scale would serve for medical communication, future clearance to dive, and reporting purposes as well as for documentation in a medical chart or past medical history for freedivers.

**D 74**
ORAL PRESENTATION TIME: n/a
POSTER PRESENTATION TIME: Tuesday, May 24: 1400-1430
RESIDENT COMPETITION: No

**Common carotid artery hemodynamics during cool water immersion are similar to thermoneutral water immersion**
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**Introduction/Background:** Hot head-out water immersion (HOWI) increases common carotid artery (CCA) blood flow (BF) and shear rate (SR), which are important for cerebral function and cerebral vascular health. However, it is not known how HOWI in cool water influences CCA hemodynamic responses versus thermoneutral HOWI. We tested the hypotheses that CCA BF and SR would be lower during cool (COOL; 25°C) versus thermoneutral (TN; 35°C) HOWI.

**Materials and Methods:** Seven healthy participants (age: 22 ±3 years; four females) completed two randomized 45-minute HOWI visits. Core temperature (Tcore), end-tidal CO2 tension (PETCO2), mean arterial pressure (MAP), and right CCA diameter, blood velocity, BF, and SR were recorded at baseline, at 30 minutes of HOWI (HOWI), immediately post HOWI, and 45 minutes after HOWI. Values are reported as mean ± SD.

**Results:** Tcore and PETCO2 were not different between conditions (P≥0.74 and P=0.38, respectively). MAP increased during COOL (baseline: 86 ± 6 vs. HOWI: 101 ± 5 mmHg; P<0.01) and TN HOWI (baseline: 87 ± 5 vs. HOWI: 99 ± 7 mmHg; P<0.01) but was not different between conditions (P=0.65). CCA diameter was lower at baseline in COOL vs. TN (0.54 ± 0.09 vs. 0.59 ± 0.06 cm; P=0.05) but it was not different between conditions during HOWI (COOL: 0.56 ± 0.05 cm vs. TN: 0.61 ± 0.06 cm; P=0.07) or following HOWI (P>0.12). CCA blood velocity (P=0.89) and BF (P=0.10) were not different between conditions during or following HOWI. CCA SR was not different between conditions during or following HOWI (P≥0.86) but was lower than baseline during TN HOWI (310 ± 92 vs. 274 ± 86 s⁻¹; P=0.05) but not COOL HOWI (322 ± 72 vs. 282 ± 76 s⁻¹; P=0.06).

**Summary/Conclusions:** These data indicate that CCA hemodynamics during 30 minutes of COOL HOWI were similar to TN HOWI, and neither condition elicited hemodynamic responses that are thought to enhance cerebral vascular health.

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**Physiology of pulmonary B-lines in NASA NBL divers**
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**Introduction/Background:** Immersion pulmonary edema (IPE) is a rare but life-threatening phenomenon that occurs in scuba diving. Our previous study supports the hypothesis that IPE is the pathologic end of a physiologic spectrum. This study completed at NASA’s Neutral Buoyancy Laboratory (NBL) addressed whether particular demographic and health factors were predictive of pulmonary B-line formation in divers.

**Materials and Methods:** Thirty divers at the NASA NBL were evaluated for symptoms of IPE and the presence of pulmonary B-lines pre- and post-dive using ultrasound at 12 pulmonary points. Additional parameters including BMI, blood pressure, pulse, pulmonary function tests (PFTs), and smoking status were collected.

**Results:** Pulmonary B-lines were found in 57% of divers. All divers were asymptomatic, and no cases of IPE were seen. There was no statistically significant difference between the presence of B-lines and sex (p= 0.249). With regard to smoking status there was no statistical significance between current, former, and non-smoker status and B-lines (p=0.691). Of the additional health parameters including BMI (B-line (+) average 25.81, no B-line (-) avg 25.99, p=0.522), systolic blood pressure ((+)124, and (-)126, p=0.465), diastolic blood pressure ((+)72, and (-)74, p=0.599), pulse ((+) avg 70, (-) avg 68, p= 0.737), and PFT (FVC (+) avg 4.29, FVC (-) avg 4.26, p=0.373), there was no statically significant difference between those with B-lines and those without.

**Summary/Conclusions:** While pulmonary B-lines were found in the majority of our divers, no subgroup had a statistically significant difference in incidence. Although the study was not powered to definitively answer these questions, the results support our hypothesis that pulmonary B-lines are a normal physiologic response to diving exposures, and IPE is just the pathologic end of this spectrum.
An echo from the past: A Doppler repository for big data in diving research


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Introduction/Background: Decompression sickness (DCS) remains a major concern for commercial and recreational diving. Venous gas emboli (VGE) detected with ultrasound post-dive are a marker of decompression stress. Being non-invasive, portable, and non-ionizing, ultrasound (Doppler and echocardiography) is suited to regular monitoring and can help elucidate inter- and intra-subject variability in VGE and DCS susceptibility. However, analyzing these recordings remains cumbersome.

Materials and Methods: The development of machine learning algorithms requires well-curated large data sets for training, testing and validation. Thus, research collaborations are important to reach the necessary quality and data number thresholds. Diving medicine has a wealth of Doppler recordings from past studies that could be congregated and annotated, reporting data from bounce, saturation, submarine saturation, and submarine escape dives, all to varying depths, dive times, and with different breathing gases. We are collecting de-identified Doppler data for publication in an accessible repository with ethical standards upheld by current review boards.

Results: The currently processed audio Doppler data includes 505 recordings from 26 male subjects who made simulated dives in a wet hyperbaric chamber. Dives were made to 80 feet (~24 meters) n=180 measurements, 100 feet (~30 meters) n=70, 120 feet (~36.5 meters) n=97, and 180 feet (~55 meters) n=158, using a heliox gas mixture (O2 set point of 0.7 ATA). Total dive time ranged from 20 to 90 minutes, with no cases of DCS recorded. The maximum Doppler Kisman-Masurel grade (precordial or subclavian) was 4.

Summary/Conclusions: These data represent a small sample of those to be included; approximately 300 datasets (90-minute tapes) will be provided by QinetiQ, and around 5,000+ files are available from Duke University. Further large data sets will be shared by DRDC, Canada, and DAN U.S. These data will provide a resource for research on DCS worldwide and help to develop future diving algorithms.
Neurocognitive performance during recreational lobster harvesting dives
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Introduction/Background: Competitive harvest diving often involves cognitive and physical exertion. While performance may initially improve from increased arousal, cognitive resources may eventually become taxed, leading to performance decrements and safety threats. Effects of harvest diving on neurocognitive performance are not known. We conducted an observational field study to assess effects of recreational lobster diving during Florida’s two-day lobster sport season ("mini-season") on neurocognitive performance.

Materials and Methods: Divers who were already participating in a two-dive boat charter to approximately 85 fsw (maximum depth) were recruited to provide a urine sample, perform a validated neurocognitive test battery (included a motor praxis test [MPT], digit symbol substitution test [DSST], fractal NBACK, and three-minute psychomotor vigilance test [PVT]). They also filled out a questionnaire about their perceived fatigue level (visual analogue scale for fatigue [VAS-F]) pre-dive, during the surface interval (SI), and post-dive.

Results: Data from 16 participants (average age [SD] = 50 yrs [10 years]; 11 males) were analyzed. DSST accuracy decreased across timepoints (predive mean [SD] = 98.71% [1.51%]; SI = 98.10% [3.25%]; post-dive = 97.96% [2.28%]), and reaction time (RT) was highest post-dive [1065.27 ms [248.58 ms]] compared with predive (1041.14 ms [222.82 ms]) and SI (1027.28 ms [211.61 ms]). For PVT and NBACK accuracy and speed, SI scores indicated improved performance compared to pre- and post-dive. Pre-dive (529.92 ms [81.85 ms]) and SI MPT (529.92 ms [81.85 ms]) RTs were longer than post-dive (558.74 ms [106.81 ms]).

Summary/Conclusions: Our results suggest that complex scanning and visual tracking as indicated by DSST performance may be affected by repeated harvest diving. The increase at SI and then decrease post-dive of several parameters may suggest arousal effects and subsequent cognitive resource taxing. These results may especially have implications for commercial and competitive harvest diving.
Effect of short-term nutritional ketosis on latency to CNS O₂ toxicity
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Introduction/Background: Central nervous system O₂ toxicity (CNSOT) continues to be a risk to Navy diving operations by impairing mission performance and diver safety. Aside from adherence to PO₂ and time restrictions, no effective mitigation strategy exists. Nutritional ketosis (NK) has been shown to increase latency to CNSOT seizures in animal models and can be effective in managing refractory pediatric epilepsy. This study examines the effect of short-term NK on latency to CNSOT in human volunteers.

Materials and Methods: This was a randomized, investigator blinded, crossover design with 50 planned subjects, two dives each in random order (one on conventional diet, the other after three days of ketogenic diet), breathing 100% O₂ at 2.06 ATA (35 fsw), immersed in water to shoulders while exercising. Dive terminated at onset of CNSOT or maximum time of 120 minutes (Navy limit = 25 minutes). Primary endpoint was latency (time) to CNSOT. Serum beta-hydroxybutyrate was measured prior to each dive.

Results: Study concluded on October 31, 2021 after 93/100 dives were completed for the 50 planned subjects. Twenty-one dives did not result in CNSOT before the 120-minute limit, with six subjects who did not develop CNSOT on either dive. One subject experienced a convulsion, while 71 dives resulted in less severe manifestations of CNSOT. Overall mean dive time was 65.4 ± 35.4 minutes.

Summary/Conclusions: All but three dives surpassed the 25-minute Navy limit for this profile, and 77.4% of dives ended in CNSOT symptoms. Unblinding and final analysis of conventional versus ketogenic diet dives will occur after blinded expert adjudication of “Definite, Probable, or Unlikely” determination of oxygen toxicity symptoms. Kaplan-Meier survival curve will be generated for conventional and ketogenic diet groups to depict the effect of NK on latency to CNSOT.

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High oxygen tension takes its toll: Disparate effects of hyperbaric oxygen and hyperoxia on viral entry gene and toll-like receptor pathway gene expression in normal and COPD-diseased human airway epithelial cells

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Introduction/Background: Given that hyperbaric oxygen (HBO2) and hyperoxic exposures are both effective procedures for mitigating the hypoxic situation in the COVID-19 patients with pneumonia, and whereas HBO and hyperoxic exposures have both been shown to increase oxidative stress and inflammatory response, we were interested in illuminating whether HBO2 and hyperoxic exposures influence the expression levels of viral entry genes and toll-like receptor (TLR) pathway-associated cytokine genes in human airway epithelial cells.

Materials and Methods: Normal (N-SAECs) and COPD-diseased (D-SAECs) human small airway epithelial cells were respectively exposed daily to 100% O2 at 2.5 ATA for 90 minutes for three days in total, or cultured under 21% O2 for three days consecutively; they were then subsequently cultured under hyperoxia (85% O2) for another three days consecutively. Total mRNAs were then extracted for quantitative PCR (qPCR) analyses.

Results: We found that HBO2 exposure significantly increased TLR4 expression in N-SAECs whereas decreased TLR3 and TLR4 expression in D-SAECs, while significantly increased IL1B, IL6 and IL12A expression in N-SAECs only. In addition, HBO exposure significantly increased TLR2 expression in both N-SAECs and D-SAECs, whereas exerted opposite regulations on IRF7 expression in N-SAECs and D-SAECs. We also found that hyperoxia significantly increased expression of the viral entry genes TMPRSS2, DPP4 and ST3GAL4, as well as the innate immunity genes ASS1, DUOX2, IDO1, OAS1 and S100P, and the antioxidant gene NRF2 (NFE2L2) in the D-SAECs, while increased expression of the innate immunity genes MDK, MX1 and PI3, as well as the interferon receptor genes IFNAR2 and IFNGR2 in the N-SAECs.

Summary/Conclusions: Taken together, our results demonstrate that the expression of viral entry genes, TLR pathway genes and pro-inflammatory cytokine genes are disparately regulated in N-SAECs and D-SAECs by the HBO2 and hyperoxic exposures.
Hyperbaric oxygen exposure disparately affects lineage-specific and apoptosis-associated marker expression in differentiated normal and COPD-diseased human bronchial epithelial cells

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Introduction/Background: Hyperbaric oxygen (HBO₂) exposures have been reported to promote migration, proliferation, and differentiation of various types of tissue-specific stem/progenitor cells. HBO₂ exposure have also been found to significantly ameliorate the severity of central airway stenosis after lung transplantation and increase oxidative stress and damage in the lung tissue. To investigate the applicability of HBO₂ on airway tissue engineering, we studied the effects of HBO₂ exposures on both proliferation and differentiation of normal (healthy) human bronchial epithelial (NHBE) cells and diseased HBE cells (DHBE) from patients with chronic obstructive pulmonary disease (COPD).

Materials and Methods: NHBE and DHBE cells were obtained from Lonza Biotechnology Company and respectively cultured at the air-liquid interface (ALI) under normoxia (21% O₂) or daily 40-minute HBO₂ exposure to 100% O₂ under 2.5 ATA for 28 days in total, followed by immunostaining analyses for different marker expression.

Results: Under normoxia, the ALI-cultured differentiated DHBE tissues showed significantly increased expression of the basal cell marker TP63, proliferation marker MKI67 and inflammatory marker NFκB compared to the differentiated NHBE tissues. After HBO₂ exposures for 28 days, the expression levels of the basal cell marker TP63 and Clara cell marker CC10 were significantly increased in the NHBE tissues and decreased in the DHBE tissues; the expression levels of the ciliated cell marker FOXJ1 and goblet cell marker MUC5AC were significantly decreased in the NHBE tissues and increased in the DHBE tissues. Daily HBO exposures also significantly increased bronchosphere formation and NFκB expression in the NHBE tissues and increased expression of the apoptosis marker cleaved caspase-3 in the DHBE tissues.

Summary/Conclusions: Our study shows for the first time that HBO₂ exposure affects lineage-specific airway differentiation by increasing basal and Clara cell numbers and bronchosphere formation in the differentiated NHBE tissues whereas increasing apoptosis and mucociliary differentiation in the differentiated DHBE tissues.
Quantification of indications received at two emergency-capable hyperbaric medicine centers
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Introduction/Background: Emergency hyperbaric oxygen treatment capability is limited in the United States. There are an estimated 70,000 patients per year with indications for emergency hyperbaric oxygen therapy, and there is a present concern for inadequate access to facilities with emergency hyperbaric oxygen capabilities. Current numbers and types of emergency hyperbaric consultations have not been documented. Timing, quantity, and distribution of calls might aid in better understanding health care needs regarding emergent hyperbaric oxygen therapy.

Materials and Methods: A log of calls received by two academic 24/7 hyperbaric facilities in the United States was documented. Date, time, diagnosis, need for emergent care (within 12 hours) were collected.

Results: The first center had 174 calls over 291 logged days: 51% of patients were treated; 94% of treated patients were considered “emergent treatment.” The three most common indications at center one were carbon monoxide, necrotizing soft tissue infections, and central retinal artery occlusion. At the second center, 165 calls were received in 280 logged days: 29.1% of patients were treated; 69% of treated patients were considered “emergent treatment.” The most common indication was carbon monoxide. Peak month of calls was March.

Summary/Conclusions: Emergency HBO2 calls are common, and more centers need to accept emergency cases. Additional data from centers that are geographically diverse would add generalizability to these results and capture diving-related emergencies.
The ZOLL Z-Vent ventilator for hyperbaric chambers
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Case Description: This is a case study on a new hyperbaric ventilator, starting with the multiphase chambers. Multiple area were research to determine if the ventilator would even be able to handle the various environmental changes associated with multiple depths that it could be subject to. First the battery was reviewed and tested. Then the patient breathing system was tested for possible leaks and durability. Next the internal compressor and compressed gas delivery system was tested. Finally multiple settings were cycled through for deviation at multiple depths.

Materials and Methods: The first thing that was done at surface was to calibrate the tidal volume delivery and compare the measurements for accuracy. This same method was done at depths of 33 feet, 48 feet, 60 feet, and 165 feet. Once the calibration tests were complete we started the cycle tests. The variables included: respiratory rate, tidal volume, compliance, resistance, PEEP, PIP, and I:E ratios.

Outcome: The battery is a lithium ion battery that did not get hot, did not bulge or deform, and could be inspected before and after every use. The respiratory rate stayed the same no matter what depth the ventilator was brought to. The other settings were predictable and repeatable depending upon the depth the patient was being treated. In case of an emergency or malfunction, the ventilator can be disconnected, shut off, and the patient manually ventilated with a bag valve mask.

Discussion: The research and testing done to the Zoll Z-Vent ventilator batteries, patient breathing circuit, and settings were successful. The only variable that could not compensate for the pressure was the tidal volume. However; knowing the depth at which the patient is being treated it is possible to compensate for this by dialing in a higher tidal volume before compressing the chamber. Adjusting the settings for better patient care also proved to be easier and quicker than with other hyperbaric ventilators. It has a compact size and could easily be assembled before patient arrival. The ventilator has proven to be a very useful ventilator for both multiphase hyperbaric chambers, and patient transport. It might even be useful for monoplace hyperbaric chambers.
Recruitment and retention outcomes in a study on hyperbaric oxygen for persistent symptoms after brain injury
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Introduction/Background: Identifying recruitment and retention strategies and the impact of SARS-CoV-2 on our randomized trial of hyperbaric oxygen for symptoms after brain injury may inform future studies of hyperbaric oxygen (HBO2).

Materials and Methods: Adult participants were recruited through IRB-approved flyers distributed to local hospitals, clinics, advocacy groups, brain injury and sports-focused clinicians, public health fairs, and internal and public media releases. Interested individuals were screened by phone. We documented reasons for ineligibility, declining enrollment, and withdrawal. Participants were randomized to either 40 active (1.5 ATA x 60 minutes) HBO2 sessions or 40 sham chamber sessions (blinded). All participants then completed 40 HBO2 sessions (unblinded) and underwent outcome assessments five times over 12 months. Chamber sessions were provided at no cost. Research activities were paused for five months due to the pandemic with assessments completed virtually.

Results: Of 233 individuals contacting us, 206 underwent phone screening. Among 98 participants deemed eligible, reasons for not proceeding with the study included: Inconvenience (n=36), not returning calls/emails (n=10), transportation (n=1), chose treatment elsewhere (n=1), and compliance (n=1). Forty-nine participants randomized (n=43% female; 98% Caucasian; mean education = 15.7 years). Eight withdrew due to inconvenience/non-compliance. Three withdrew following the COVID-19 hiatus due to worsening pre-existing health (n=2) or lack of contact (n=1).

<table>
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Summary/Conclusions: This study garnered wide interest. Despite no charge to participants, the time demands and inconvenience of the study significantly impeded participation and completion. No participants that withdrew from the study cited safety concerns related to the COVID-19 pandemic.
Introduction/Background: Electronic devices remain highly restricted from use during hyperbaric oxygen treatment (HBO₂) due to risk of fire in a pressurized, oxygen-rich environment. Over the past two decades, point-of-care ultrasound (POCUS) has established utility as a bedside imaging modality in most clinical environments, not including multiplace hyperbaric chambers. The benefit of treating hyperbaric patients, particularly in critical care cases, is undeniable as evidenced by our prior work. Only heavily modified POCUS devices have been used until recently. Here we demonstrate proof of concept, safety, and successful performance of a wireless off-the-shelf handheld POCUS device in the hyperbaric environment.

Materials and Methods: The GE Vscan Air was initially tested for safety in a Class C chamber in a 100% nitrogen atmosphere. Image quality was tested before and after compression to 280kPa (2.8 ATA). Temperature was monitored and evidence of overheating or off-gassing was evaluated. Second, the Vscan was paired with an encased Apple iPad tested previously for hyperbaric use and both were pressurized to 240 kPa (2.4 ATA) in a multiplace chamber (21% oxygen) while simulating clinical use for approximately 45 minutes. Device temperature, image quality, touchscreen functionality, and wireless connection were tested continuously.

Results: The GE Vscan Air automatically shut off due to power button depression during initial compression; thus the rubberized cover overlying the button was punctured with an 18-gauge needle to equalize gas pressure. Thereafter, the system performed well throughout all tests without degradation in functionality or image quality. The device did not overheat, nor did it reach temperatures concerning for fire hazard. Further, wireless connection to out-of-chamber devices was maintained.

Summary/Conclusions: Our results suggest that the GE Vscan Air can be used with only minor modification in a multiplace hyperbaric chamber. Wireless pairing with a tablet or mobile phone is still required for use.
Safely reduce oxygen costs without compromising patient safety
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Introduction/Background: The cost of therapeutic oxygen is a significant enduring expense at $0.745 per 100 ft$^3$. A Class B chamber is filled and ventilated with 100% oxygen. While it is possible and safe to fill a monoplace with air and give oxygen via mask or hood, a couple of factors make that less than ideal. In a monoplace chamber the mask must be donned by the patient rather than a trained technologist. Ensuring 100% oxygen delivery through a BIBS device requires minimum physical and mental abilities many patients will not possess due to physical or mental limitations. Poor or improper placement of a BIBS device and a lack of monitoring could prove ineffective or hazardous. We decided to attempt to reduce costs by managing ventilation rates.

Materials and Methods: Our chambers have a floodable volume of 50.62 ft$^3$ and the average person displaces 1.76 ft$^3$ meaning at 2.0 ATA the chamber holds 97.52 ft$^3$ of oxygen. A human will produce approximately 1 ft$^3$/hr of CO$_2$ and a concentration of 3% CO$_2$ is toxic therefore, an inadequately ventilated chamber would become toxic in 2.93 hours. Our practice was to vent at 275 standard cubic feet per minute (SLPM) or 4.86 actual cubic feet per minute (ACFM) at 2.0 ATA. The NFPA requires 3 ACFM per person for a Class A and 1 ACFM for Class B chambers. We reasoned we could safely vent at 180 SLPM which is more than the higher, Class A standard of 3 ACFM.

Results: Our typical annual cost is $24,456.96 US. By reducing the vent to 180 SLPM we could reduce the cost by $7,603.20. We further believe we could reduce a portion of our patients to 80 SLPM, thereby amassing a potential savings of $12,736.80.

Summary/Conclusions: It is possible to reduce oxygen costs by adjusting the ventilation rate in Class B chambers while maintaining patient safety.
Pneumatic device from respiratory care equipment to assist patients with middle ear pressure equalization
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Introduction/Background: Politzerization devices are safe and effective to facilitate middle ear pressure equalization during hyperbaric pressurization. Commercially manufactured politzerization devices work by means of a battery-powered pump that creates approximately 1psi insufflated into the oropharynx to temporarily open Eustachian tubes. Such devices are prohibited in oxygen-filled chambers. We constructed a device that can insufflate the middle ear using common respiratory care consumables to provide a reproducible and cost-effective aid for middle ear equalization.

Materials and Methods: We assembled a device powered by an oxygen flowmeter connected to the hospital system to insufflate the oropharyngeal pressure slightly and safely with pressures comparable to a commercial device. A flowmeter was connected via oxygen extension tubing to the stem of a 22mm tubing “bleed-in” adapter. One end of the adapter was terminated with three 20 cmH₂O PEEP valves assembled in a “stacked” configuration with a fourth, adjustable PEEP valve placed at the distal outlet. The remaining opening was fitted with a hose barb and 1/8-inch tubing was adapted to a patient nostril interface. Target pressure was achieved with a flow of 6lpm from the flowmeter. Patients were instructed to swallow normally while applying the interface to one nostril and occluding the other.

Results: From 7/1/2021 to 10/29/2021 seven patients utilized the device in a multiplace chamber compressed to 2 ATA. Six of these patients were able to successfully achieve middle ear equalization, allowing for uneventful hyperbaric chamber compression.

Summary/Conclusions: Our limited experience to date indicates that a politzerization device constructed from common respiratory care consumables can be helpful in facilitating middle ear equalization.
Pneumatic device to assist patients with middle ear pressure equalization
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Presenting Author: Geness Koumandakis RRT
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Introduction/Background: Difficulty equalizing middle ear pressure is common during hyperbaric compression. We developed a pneumatic middle ear insufflating device utilizing the Politzer maneuver (insufflating the middle ear by blowing gas into the nose and swallowing) that can be used in multiplace and monoplace chambers.

Materials and Methods: The device consists of a four-way cross-pipe fitting with a pressure gauge, an adjustable pressure relief valve set to pop-off at 1.5 psi, and a nosepiece connected to an oxygen flow meter. The patient is instructed to place the nosepiece firmly against one nostril while occluding the other. Oxygen at 4-6 lpm flows through the device into the nasal cavity. The patient is instructed to close their glottis or swallow. This increases pharyngeal pressure, allowing the Eustachian tubes to open, insufflating the middle ear. Pressures generated by device use are significantly lower than pressures required to cause tympanic rupture (>12 psi) or round window membrane rupture (>30 psi). The device was used by patients reporting difficulty with middle ear pressure equalization.

Results: Between 9/13/2021 and 10/15/2021, 19 clinical patients were compressed to 2 or 3 ATA in a monoplace chamber totaling 178 treatments. Nine patients (47%) attempted using this device with a total of 40 uses (22%). Mean age of patients using device was 52 ± 21 years, (56%) were male. All patients, including one 6-year-old child, used the device correctly and were successful at equalizing their ears with each use. 8 patients tolerated the device (89%). An O’Neill score of 0 was confirmed after 38 uses (95%) and a score of 1 after 2 uses (5%). Other methods used during these sessions were yawning, swallowing, nose pinching and blowing. Four patients reported pain during compression but not during device use. No adverse effects were observed.

Summary/Conclusions: This simple pneumatic device is safe and effective at aiding middle ear pressure equalization.
Electroencephalogram functional connectivity is sensitive for nitrogen narcosis in air breathing at 608 kPa
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Introduction/Background: Divers commonly breathe air, containing nitrogen. Nitrogen, under hyperbaric conditions, is a narcotic gas. In dives beyond a notional threshold of 30 meters’ depth (405 kPa) this can cause cognitive impairment and accidents due to poor decision-making. Helium is known to have no narcotic effect. There is currently no electroencephalogram algorithm capable of measuring the effects of nitrogen narcosis. Functional connectivity of the electroencephalogram (EEG) may be a sensitive indicator of these effects.

Materials and Methods: Twelve human participants (five female) breathed air and heliox (20.8% oxygen) in well-separated and randomly ordered exposures. with measurements (32-channel EEG and psychometric function) made at 284 and 608 kPa. The degree of spatial functional connectivity, estimated using mutual information, was summarized with the global efficiency network measure.

Results: Air-breathing at 608 kPa (experienced as mild nitrogen narcosis) caused a 35% increase in alpha-band brain global efficiency compared to surface air-breathing (mean increase=0.17, 95% CI 0.09 to 0.25, p=0.001). Air-breathing at 284 kPa trended in a similar direction. Functional connectivity was modestly associated with psychometric impairment (mixed-effects model r2=0.60, receiver-operating-characteristic area [95%CI], 0.67 [0.51,0.84], p=0.02). Heliox breathing did not cause a significant change in functional connectivity.

Summary/Conclusions: Functional connectivity increased during hyperbaric air-breathing in a dose-dependent manner, but not while heliox-breathing. This suggests that this EEG metric is sensitive to nitrogen narcosis specifically.
Comparison between arterial blood gases, $\text{SpO}_2$ and ORI in a scuba diver breathing air
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Introduction/Background: The conditions of hypoxia and hyperoxia represent two diverse problems to which a scuba diver is exposed. Various diving exposures with blood gas analysis have been completed [1]. The pulse oximeter has already been used during immersion to evaluate hypoxia [2,3]. In a non-invasive and real-time way, $\text{SpO}_2$ and ORI (oxygen reserve index) transcranial monitoring could highlight the oxygen status of a subject while diving to avoid hypoxia or hyperoxia.

Materials and Methods: The radial artery of one informed diver was cannulated, and blood sampled during one dive at -15 m (at rest; at the bottom, after 15 minutes of pedaling on a scuba-bike; and at the end of the dive). Arterial SaO2 and PO2 levels were measured using a point-of-care blood gas analyzer. Two different marinized devices for pulse oximetry were applied to the diver, to measure heart rate, $\text{SpO}_2$, and ORI (with a forehead sensor inside the mask, and through a special sensor inside a waterproof glove).

Results: The diver was normoxic before the dive. After pedaling, at the time of the second sampling, the diver was slightly hyperoxic. On the surface, as soon as he emerged, the diver was again normoxic. SaO2 from sampling and $\text{SpO}_2$ from pulse oximeter were comparable in the sampling on the bottom. The increase in PaO2 on the bottom was correlated with an increase in the ORI index during physical exercise on the bottom. Even the ORI on return to the surface returned to normal.

Summary/Conclusions: These results confirm that SaO2 and $\text{SpO}_2$ during immersion are useful to avoid hypoxia, that ORI can be used to get information on the diver’s initial hyperoxia, but above all, that it will be possible to use only non-invasive methods for the study of hypoxia and hyperoxia in scuba divers as well as in breath-hold divers.
Hyperbaric oxygen for two fighter pilots with brain injury, gas embolism and hypoxia years after the events
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Case Description:
We present two fighter pilots with aircraft-related brain injury treated with hyperbaric oxygen (HBO\textsubscript{2}). Pilot A likely had occult arterial gas embolism from the aircraft cabin increasing and decreasing pressure quickly. He complained of headache, body aches, restlessness, attention problems, reduced cognition, difficulty reading and tinnitus. A couple weeks later he was treated empirically with a US Navy TT6 without improvement. Brain MRI showed a 7 mm T2 cortical signal, abnormal diffusion tensor imaging and occipital decreased perfusion. He received vestibular, cognitive, occupational and physical therapy rehabilitation.

Pilot B had hypoxia complicated by carbon monoxide exposure while flying at night. Following, he complained of forgetfulness, concentration problems, dizziness, difficulty focusing, headaches, and ill-feeling. Eighteen months later neuropsychological testing was abnormal. Brain MRI showed supratentorial atrophy and an ischemic lesion in the cerebellum. Brain SPECT showed diminished left basal ganglia activity.

Just before and after HBO\textsubscript{2} they both had comprehensive brain injury evaluations demonstrating dizziness, headaches, coordination problems, sensitivity to light/sound, concentration and thinking problems, left sided weakness, ataxic tandem gait, positive Romberg’s and Sharpened Romberg’s signs and EEGs showing diffuse slowing.

Intervention:
Both received HBO\textsubscript{2} (1.5 ATA, 60 minutes): Pilot A 74 sessions at 19 months, Pilot B received 80 sessions at 46 months.

Outcome:
After HBO\textsubscript{2}, both were normal in: neurological examinations, EEGs, neuro-optometry, and auditory processing. Both had improved neuropsychological and speech testing, and brain-injury questionnaire results (e.g. Neurobehavioral Symptom Inventory, Pilot A: 14 to 6; Pilot B: 48 to 0). The ANAM z-score went from -0.06 to +3.02 in Pilot A and from -1.67 to +1.28 in Pilot B. 2.5 years later, Pilot A has returned to flight status.

Discussion:
These results support that a course of HBO\textsubscript{2} years later can improve brain injury.
Improved acquired auditory processing skills following hyperbaric oxygen treatment in two pilots after hypoxic event while flying fighter aircraft

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Case Descriptions: A 35-year-old male was piloting a fighter aircraft and sustained squeezing episodes five times. A 32-year-old male suffered a hypoxic event while flying aircraft. Both suffered brain injury manifested by several related problems including persistent tinnitus, noise sensitivity and hearing complaints. Both were referred for auditory processing testing. Both pilots had demonstrated tinnitus, sound sensitivity, and auditory processing deficits, which are problems encountered by brain-injured individuals.

Intervention: Pilot one received 74 hyperbaric oxygen sessions each at 1.5 ATA x 60 minutes over three months with baseline auditory processing testing afterward. Pilot two received two sets of 80 hyperbaric oxygen treatments at 1.5 ATA x 60 minutes. The first 80 were received prior to auditory processing testing. The second hyperbaric oxygen treatment set was received two years following the first session, with auditory processing testing prior to treatment. Final auditory processing testing was completed 19 weeks following treatment.

Outcome: Final testing for both pilots demonstrated improved overall auditory processing skills. Pilot 1 experienced resolved tinnitus in one ear. Both pilots demonstrated improved sound sensitivity and speech-in-noise discrimination for words and sentences.

Discussion: There is a growing awareness of auditory processing deficits in military personnel, but it has been associated with blast or traumatic injury. Hyperbaric oxygen for acquired auditory processing deficits has not been published. Both pilots in this review were evaluated and subsequently received courses of hyperbaric oxygen. Following hyperbaric oxygen, both pilots reported improved “hearing” and demonstrated improvements in tinnitus, sound sensitivity, and auditory processing skills, a likely reflection that hyperbaric oxygen improved their brain injury.
Clinical and immunological effects of hyperbaric oxygen therapy in severe non-intensive COVID-19 patients: Randomized control trial
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Introduction: SARS-CoV-2 (severe acute respiratory syndrome coronavirus - 2) is a virus that causes severe acute respiratory syndrome, leading to the disease known as coronavirus disease-19 (COVID-19). It has been hypothesized that the primary pathomechanisms for the severe inflammation in the lungs with massive macrophage activation is the so-called “cytokine storm”, which can be modulated by hyperbaric oxygen therapy (HBO₂T). The aim: The aim of the study is to assess the impact of hyperbaric oxygen therapy (HBO₂T) on the inflammatory process (“cytokine storm”) in moderate COVID-19 cases leading to respiratory failure.

Material and Methods: In 2021 we started the Randomized Controlled Trial on using Hyperbaric Oxygen Therapy in COVID-19 patients (EudraCT 2020-002722-90). Until this interim analysis, 30 patients were recruited (24 males and six females, average age of 55 years ± 13.4 [SD]). Twenty-eight were successfully randomized to receive either standard treatment (Control group) or standard treatment group with adjunctive Hyperbaric Oxygen Therapy (HBO₂T group). HBO₂T was given once daily (60 minutes 100% oxygen at 2.5 ATA) for five consecutive days in a multiplace chamber. The safety and efficacy of HBO₂T were assessed with blood gas analysis, general biochemistry, blood morphology and markers of inflammatory process measured for ten days of observation.

Results: The groups were similar when comparing all parameters except for IL-6 (see below) during randomization.

There was a statistically significant difference in the level of Interleukin 6 (IL-6) between groups C and HBOT in the initial studies (p<0.05), with high values in those patients who died (all were in the C group).

In both groups, the set parameters of oxygenation were maintained (SpO₂> 92%), but in the HBOT group, this was achieved by using a lower normobaric oxygen dose (p<0.05).

In the C group, 3 of the 14 participants (21.4%) died, while in the HBO₂T group, there were no deaths (0.0%). The difference in the death rate did not reach statistical significance (p = 0.067), but the trend is worth emphasizing.

Both groups showed a statistically significant increase in the percentage of eosinophilia and lymphocytes and a decrease in neurocytes. These changes did not differ between groups.

Statistically significant changes in the HBO₂T group were observed only in decreasing CRP, ferritin and LDH with an increase in the CD3 population of cells.

Summary/Conclusions: In conclusion, in this preliminary interim analysis of the RCT, we confirmed the effectiveness of randomization with the safe conducting of HBO₂T in moderate COVID-19 pulmonary infection. A tendency to reduce the number of deaths in the HBO₂T group was observed with lower demand for normobaric oxygenation in the group of patients treated with HBO₂T. We also observed a significant beneficial effect of HBO₂T on CRP, ferritin, LDH and the population of the CD3 cells.
Acknowledgement: The study was funded by the Polish Medical Research Agency (grant 2020/ABM/COVID19/0043).
Test of cross corrections for altitude air and nitrox diving at 8,000, 10,000 and 12,000 feet
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Background: Diving at altitude requires modified algorithms due to the increased PN₂ ratio (breathing air) between depth and the surface. One untested but commonly used algorithm is cross corrections. (Undersea Biomed Res 1976;3:1-23) This study tested cross corrections for air and enriched O₂ dives at altitudes of 8,000, 10,000, and 12,000 ft.

Materials and Methods: After IRB approval and informed consent four exposures were performed as shown in the Table. Prior to each dive, volunteer subjects 18-45 years of age were exposed to simulated altitude in the Duke hypobaric chamber for 24 hours (8,000 feet) or 48 hours (10,000 and 12,000 feet) to allow tissue PN₂ to reach steady state and for acute mountain sickness to resolve. They then performed a single dive fully submersed while exercising moderately on an electrically braked ergometer in 28°C water. They were then monitored for 12 hours at altitude for DCS and venous gas embolism using 2D echocardiography and graded with the modified Eftedal-Brubakk (EB) Scale. After returning to sea level they underwent a complete neurological exam with telephone follow-up the next day.

Results: We studied 46 subjects (M/F=26/20, Caucasian=40, Asian=3, Hispanic=3, mixed race=3), completing a total of 75 dives. There was no DCS in any divers. Dives are summarized in the Table.

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Breathing Gas</th>
<th>Dive Depth (fsw)</th>
<th>Time at Max Depth (min)</th>
<th>Age (y): Mean, Range</th>
<th>M/F</th>
<th>n Dives</th>
<th>n DCS</th>
<th>n VGE (max. E-B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000</td>
<td>Air</td>
<td>60</td>
<td>30</td>
<td>27, 21-38</td>
<td>8/4</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10,000</td>
<td>Air</td>
<td>60</td>
<td>30</td>
<td>27, 24-38</td>
<td>8/8</td>
<td>16</td>
<td>0</td>
<td>2 (3)</td>
</tr>
<tr>
<td>10,000</td>
<td>35% O₂</td>
<td>100</td>
<td>25</td>
<td>29, 22-38</td>
<td>11/5</td>
<td>16</td>
<td>0</td>
<td>5 (4a)</td>
</tr>
<tr>
<td>12,000</td>
<td>35% O₂</td>
<td>100</td>
<td>20</td>
<td>26, 21-37</td>
<td>17/14</td>
<td>31</td>
<td>0</td>
<td>6 (4a)</td>
</tr>
</tbody>
</table>

Summary/Conclusions: Our results are consistent with the adequacy of cross corrections for these no-stop dives at 8,000-12,000 feet of altitude. This study was supported by NAVSEA Contract N0002418C4318.
Clinical Trial of Sildenafil to Prevent Swimming-Induced Pulmonary Edema (SIPE)
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Background: SIPE is acute pulmonary edema during swimming or scuba diving, commonly affecting young, healthy individuals. During submersed exercise in cold water, SIPE-susceptible individuals have higher-than-normal pulmonary vascular pressures (PAP, PAWP), which are reduced with sildenafil (Circulation. 2016;33:988-96). This randomized clinical trial aimed to determine if sildenafil can prevent SIPE in susceptible individuals.

Materials and Methods: After IRB approval and informed consent, individuals with at least one previous episode of SIPE drank 2 L Pedialyte after taking either 50 mg of oral sildenafil or placebo, followed by up to 40 minutes of head-out immersed cycle ergometer exercise in 20°C water, previously shown to produce manifestations of pulmonary edema in 80% of susceptible individuals. Exercise was terminated at the subject’s request or with occurrence of cough, dyspnea, or decreased SpO₂ (oxygen saturation). Physical exam, spirometry and lung ultrasound were performed before and after exercise. Chest radiographs were obtained as indicated. Each subject was studied twice, receiving sildenafil or placebo in random order at least seven days apart. Primary outcome was pulmonary edema after exercise, defined as one or more of: hypoxemia (SpO₂< 95% breathing room air), productive cough, wheezing, or radiographic pulmonary edema. Secondary outcomes were voluntary premature cessation of exercise due to dyspnea, post-exercise 10% decrease in forced vital capacity (FVC) or forced expiratory volume in one second (FEV1), and/or B lines on lung ultrasound. The study was double-blinded, with allocation concealment.

Results. Eighteen subjects were studied (M/F=13/5, Caucasian=18). Seven (39%) subjects experienced the primary outcome after placebo and nine (50%) after sildenafil. Eight subjects never experienced the primary outcome and six met the primary outcome on both drugs. (OR (95% CI) 1.71 (0.32, 9.09); p=0.505. One or more secondary outcomes occurred in 15/18 subjects after sildenafil and all subjects after placebo (p=0.08).

Summary / Conclusions. We found no statistically significant difference between the effect of sildenafil 50 mg versus placebo on occurrence of SIPE in this setting.

This study was supported by NAVSEA Contract N0002419C4301.
Hypoxic exercise performance (VO$_{2\text{max}}$) at 15,000 feet in altitude versus surface baseline
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$^3$ Diffusion Pharmaceuticals, Charlottesville, Virginia

Introduction/Background: As part of a double-blinded, randomized clinical trial to investigate the effects of the novel pharmaceutical trans sodium crocetinate (TSC) on exercise under hypoxic conditions, we aim to add to the existing body of literature of human performance at altitude.

Materials and Methods: Subjects are screened prior to exposure, including baseline VO$_{2\text{max}}$ (maximal oxygen uptake) testing. On the experimental day, subjects are instrumented with a radial arterial catheter and perform two VO$_{2\text{max}}$ test protocols (separated by at least three hours) at 15,000 feet in altitude in a hypobaric chamber. Subjects are randomized to receive either placebo or study drug prior to each altitude VO$_{2\text{max}}$ testing (crossover design). Arterial blood gases are measured at three-minute intervals. This abstract aims to illustrate change from baseline to first altitude exposure for VO$_{2\text{max}}$, maximum heart rate (HR), respiratory exchange ratio (RER) and arterial PO$_2$ (PaO$_2$), regardless of whether subjects received the study drug or placebo.

Results: Fifteen of 30 planned subjects (11 males, 4 females, mean ± SD age 24.6 ± 5.6) have completed the experimental protocol. Time from baseline VO$_{2\text{max}}$ to altitude exposure was 13.0 ± 9.1 days. Mean baseline VO$_{2\text{max}}$ was 46.0 ± 9.3 ml/kg/min vs. 30.5 ± 5.4 ml/kg/min at altitude (33.3% ± 4.6% decrement). Peak HR was 184 ± 7 at baseline versus 174 ± 9 at altitude (5.2% ± 3.7% decrement). Peak RER was 1.26 ± 0.06 at baseline versus 1.47 ± 0.18 at altitude (17.4% ± 15.0% increase at altitude). PaO$_2$ was 111 ± 7 at surface versus 48 ± 4 prior to start of exercise at altitude and 46 ± 4 at completion of exercise.

Summary: This project will add to the existing literature demonstrating the effects of hypoxia on human performance at altitude. Unblinding and analysis of the effects of TSC on PaO$_2$ and VO$_{2\text{max}}$ under hypoxic conditions will not occur until study completion, anticipated March 2022.

Funding: Diffusion Pharmaceuticals, NCT05036980
The antiepileptic drug tiagabine does not prevent acute lung injury in mice exposed to extreme HBO$_2$

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Introduction / Background: Breathing HBO$_2$ at pressures ≥ 3 ATA can cause pulmonary damage quickly, and is characterized by transpulmonary leakage of fluid, protein and erythrocytes. This type of acute lung injury (ALI) is exacerbated with HBO$_2$ seizures. Agents that extend seizure latency should also reduce ALI, leading us to test the antiepileptic drug tiagabine in HBO$_2$.

Materials and Methods: Fifty-six C57BL/6 mice were assigned to air vehicle, air tiagabine, HBO$_2$ vehicle or HBO$_2$ tiagabine. Vehicle (NaCl) and tiagabine (9.4 µg/g) were given IP 30 minutes before exposure to air or HBO$_2$ at 5 ATA for 60 minutes. Seizure latencies were recorded. After exposures and euthanasia, the left lung was excised for wet-to-dry ratios (lung edema). Right lungs were fixed for H&E staining to score ALI, or lavaged with PBS to measure bronchoalveolar lavage fluid (BALF) protein (alveolar-capillary integrity) and myeloperoxidase (inflammation) levels.

Results: Although tiagabine increased seizure latencies by 86% (p=0.007), the proportion of mice that demonstrated tonic-clonic seizures was greater in this group (p=0.001) and was accompanied by an 18% increase in the wet-to-dry ratio (p<0.001). HBO$_2$ caused an increase in BALF protein content independent of treatment (P = 0.008) and was 85% greater in mice that exhibited tonic-clonic seizures. There were no between group differences in ALI score or BALF myeloperoxidase levels; however, the latter was 143% greater in those that displayed tonic-clonic seizures (p<0.001).

Summary / Conclusions: These data confirm that in mice exposed to extreme HBO$_2$, lung edema, compromised alveolar-capillary integrity and inflammation are magnified when tonic-clonic seizures are present. While tiagabine delays seizure latencies, it does not offer protection against ALI in HBO$_2$. 
Central retinal artery occlusion outcomes after treatment with hyperbaric oxygen: a single center retrospective study

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Introduction/Background: Central retinal artery occlusion (CRAO) is a treatable cause of permanent, disabling vision loss. There are no widely available means of treatment. Hyperbaric oxygen (HBO₂) therapy may improve vision recovery.

Materials and Methods: We performed a retrospective, observational study enrolling consecutive patients treated for CRAO at our institution from July 2011 until August 2021. Patients were included if diagnosed with CRAO and at least one hyperbaric treatment was completed. Patients received one to two treatments in the first 24 hours (range 2.0-2.8 ATA for 90-120 minutes) and continued until clinical plateau per institutional best practice.

The primary endpoint was final visual acuity change defined as “No improvement,” “Minimal Improvement” (any improvement at all but worse than 20/100) or “Substantial Improvement” (final visual acuity at least 20/100). Endpoints were compared based on time to treatment and presence of a cherry-red spot on dilated fundus exam.

Results: 45 patients were analyzed representing 46 cases (one patient with recurrent CRAO in contralateral eye); 37 (79%) patients had a cherry-red spot; five (11%) of patients had a confirmed cilioretinal artery. Patients received a mean of 3.6 ± 2.6 treatments. Mean time to treatment was 22 ± 23.8 hours (range 3-137 hours). Ten patients (22%) were treated in ≤ 8 hours, 23 (50%) from 8-24 hours and 13 (28%) in ≥24 hours.

<table>
<thead>
<tr>
<th></th>
<th>Total Patients</th>
<th>No Improvement N (%)</th>
<th>Minimal Improvement N (%)</th>
<th>Substantial Improvement N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All CRAO</td>
<td>46</td>
<td>16 (35)</td>
<td>19 (41)</td>
<td>11 (24)</td>
</tr>
<tr>
<td>No cherry red spot (CRS)</td>
<td>9</td>
<td>2 (22)</td>
<td>2 (22)</td>
<td>5 (56)</td>
</tr>
<tr>
<td>With cherry red spot (+CRS)</td>
<td>37</td>
<td>14 (38)</td>
<td>17 (46)</td>
<td>6 (16)</td>
</tr>
<tr>
<td>Treated ≤ 8 hours</td>
<td>10</td>
<td>5 (50)</td>
<td>1 (10)</td>
<td>4 (40)</td>
</tr>
<tr>
<td>No CRS</td>
<td>3</td>
<td>1 (33)</td>
<td>0 (0)</td>
<td>2 (67)</td>
</tr>
<tr>
<td>+ CRS</td>
<td>7</td>
<td>4 (57)</td>
<td>1 (14)</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Treated 8-24 hours</td>
<td>23</td>
<td>6 (26)</td>
<td>12 (52)</td>
<td>5 (22)</td>
</tr>
<tr>
<td>No CRS</td>
<td>3</td>
<td>1 (33)</td>
<td>0 (0)</td>
<td>2 (67)</td>
</tr>
<tr>
<td>+ CRS</td>
<td>20</td>
<td>5 (25)</td>
<td>12 (60)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Treated &gt;24 hours</td>
<td>13</td>
<td>5 (39)</td>
<td>6 (46)</td>
<td>2 (15)</td>
</tr>
<tr>
<td>No CRS</td>
<td>3</td>
<td>0 (0)</td>
<td>2 (67)</td>
<td>1 (33)</td>
</tr>
<tr>
<td>+ CRS</td>
<td>10</td>
<td>5 (50)</td>
<td>4 (40)</td>
<td>1 (10)</td>
</tr>
</tbody>
</table>

Summary/Conclusions: The majority of patients showed an improvement in visual acuity. The presence of a cherry-red spot and time to treatment > 8 hours were both negatively correlated with improvement. Natural improvement rates for CRAO are reported near 18%. In this series, NNT for substantial improvement of visual acuity ≥ 20/100 is 16.1 for all CRAO patients, 4.5 for treated < 8 hours, 2.6 for those without cherry-red spot. Hyperbaric oxygen therapy is a compelling treatment for CRAO. This study provides critical foundational data in advance of a fully powered randomized-controlled clinical trial.
Bone coverage in mandibular osteoradionecrosis with hyperbaric oxygen therapy
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Introduction: Up to 8% of radiation-treated patients with head and neck cancer develop mandibular osteoradionecrosis (ORN). Visually quantifying bone exposure allows diagnosis, severity staging, and treatment response assessment. Without treatment, 15% spontaneously cover exposed bone, 42% stabilize without further coverage, and 20% progress. While hyperbaric oxygen (HBO₂) and surgical debridement (Marx protocol) can result in 80% resolution rate, variable treatment regimens and inconsistent efficacy data confound the effect of HBO₂ compared to no treatment.

Materials and Methods: The Multicenter Registry for Hyperbaric Oxygen Therapy allows comparison of bone coverage rates in exposed-bone ORN between historical controls without treatment and those who receive daily HBO₂. Surgical treatment details and long-term outcomes are not uniformly available in the registry. Additional variables assessed include total radiation dose, concomitant diabetes or smoking, and number of HBO₂ treatments.

Results: Included were 34 radiation-treated head-and-neck cancer patients (71% male, mean radiation dose 69.2 ±22.6 Gy) with exposed mandibular bone: 19 (56%) stage I, 4 (12%) stage II, 5 (15%) stage III, and six with unknown staging. Most were non-diabetic (85%, 29 patients), current (8.8%, three) or prior (53%, 18) smokers and were scheduled for tooth extraction or mandibular resection during or after HBO₂ (74%, 25). Immediately upon HBO₂ completion (mean 33.9 ± 10.6 treatments), 76% (26) achieved >50% bone coverage, and 35% (12) had complete coverage, which is significantly better than 15% coverage in untreated historical controls (p<0.0001). Among 23 stage I or II patients, >50% coverage rate was 74% (17), with 26% (6) complete coverage. All stage III patients achieved >50% coverage, which was complete for most (80%).

Conclusions: Patients receiving HBO₂ for ORN have greater immediate bone coverage than untreated patients. Long-term follow-up may demonstrate reduced need for aggressive treatments by preventing ORN progression. This could translate to meaningful improvements in functional outcomes, psychological well-being, and quality of life.

The Multicenter Registry for Hyperbaric Oxygen Therapy received support from the Dartmouth-Hitchcock Medical Center Department of Medicine Scholarship Enhancement in Academic Medicine (SEAM) Award Program.
Cognitive enhancement of healthy older adults using hyperbaric oxygen: A randomized controlled trial
Sagol Center for Hyperbaric Medicine and Research
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Introduction/Background: More than half of community-dwelling individuals 60 years and older express concern about declining cognitive abilities. The current study’s aim was to evaluate hyperbaric oxygen (HBO₂) therapy effect on cognitive functions in healthy aging adults.

Materials and Methods: A randomized controlled clinical trial randomized 63 healthy adults (> 64) either to HBO₂ (n=33) or control arms(n=30) for three months. Primary endpoint included the general cognitive function measured post intervention/control. Cerebral blood flow (CBF) was evaluated by perfusion magnetic resonance imaging.

Results: There was a significant group-by-time interaction in global cognitive function post-HBO₂ compared to control (p=0.0017). The most striking improvements were in attention (net effect size=0.745) and information processing speed (net effect size=0.788).Voxel-based analysis showed significant cerebral blood flow increases in the HBO₂ group compared to the control group in the right superior medial frontal gyrus (BA10), right and left supplementary motor area (BA6), right middle frontal gyrus (BA6), left middle frontal gyrus (BA9), left superior frontal gyrus (BA8) and the right superior parietal gyrus (BA7).

Summary/Conclusion: In this study, HBO₂ treatment was shown to induce cognitive enhancements in healthy aging adults via mechanisms involving regional changes in CBF. The main improvements include attention, information processing speed and executive functions, which normally decline with aging.
Successful left ureteral reimplantation with resolution of recurrent infection and calcification in a patient with a history of soft tissue radionecrosis including radiation cystitis s/p radiation therapy to pelvis with combination of hyperbaric oxygen therapy and OR cystoscopic fulguration, stent, and micronized allograft injection
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Case Description: A 62-year-old female with a history of rectal cancer who was treated with chemotherapy and radiation in 1987 presented with a five-year duration of gross hematuria and left ureteral stricture which required a distal left ureteral implant. Patient subsequently developed distal left ureteral stenosis, complicated by associated bladder wall calcification, retroperitoneal leak, and recurrent infection secondary to radiation changes.

Intervention: The patient was treated with hyperbaric oxygen (HBO₂) treatment at 2.5 ATA for a total of 60 treatments in conjunction with OR cystoscopic stent placement, bladder fulguration and micronized allograft injection.

Outcome: The patient has been followed by Urology since she completed HBO₂. Cystoscopy was performed prior to HBO₂, after 20 treatments and in follow-up years after the patient completed hyperbaric treatment. Ultrasound showed the left ureteral reimplantation functional without hydronephrosis. Cystoscopy showed normal bladder tissue with a patent ureteral reimplantation site without calcification. The patient had full resolution of her gross hematuria, pelvic pain and recurrent UTIs.

Discussion: HBO₂ is used successfully in the treatment of radiation cystitis. The current case suggests HBO₂ may have a role in ureteral reimplantation with associated leak in previously irradiated tissue. In addition, HBO₂ used in conjunction with tissue substitute products in the treatment of radiation injury would be worth investigating.
Iatrogenic arterial gas embolism treated with hyperbaric oxygen
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Introduction/Background: Iatrogenic arterial gas embolism (AGE) is an uncommon but significant event that can occur in patients undergoing invasive procedures or managing invasive medical devices at home. It is a clinical diagnosis and requires a high index of suspicion. Definitive treatment is emergency compression with hyperbaric oxygen \((\text{HBO}_2)\) therapy. One of the key factors in the treatment of this condition is time to treatment.

Materials and Methods: We reviewed our experience using \(\text{HBO}_2\) for iatrogenic arterial gas embolism in 44 patients treated in our department from 2000 to 2021. We performed a retrospective chart review using electronic medical records. Patients were clinically evaluated before and after treatments. Outcomes were based on response to therapy. One of the factors examined in this review was time to chamber (TCC) for initial emergent therapy and whether patients were transferred from an outside hospital facility.

Results: Patients who showed significant clinical improvement had an average TCC of five hours, 23 minutes. Patients treated with \(\text{HBO}_2\) which did not result in any meaningful recovery had an average time to chamber of 15 hours, 26 minutes. Based on patient data, those who were transferred from an outside hospital (OSH), tended to have longer times before treatment began. Faster TCC showed more favorable outcomes. Unfortunately, transfers tended to lead to worse patient outcomes.

Summary/Conclusions: Although the diagnosis of iatrogenic AGE is not common, it is associated with significant morbidity and mortality if not treated emergently. This review illustrates the importance of early recognition and treatment in a hyperbaric chamber. Early recognition can provide patients the benefit of shorter TCC and ultimately improved outcomes. Transferring from an outside hospital can lead to a delay in treatment and subsequently result in poor patient outcomes.
Treating carbon monoxide poisoning patients after Hurricane Ida
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Case Description: Carbon monoxide poisoning accounts for approximately 50,000 emergency room visits annually and an estimated 450 fatalities from accidental CO exposure. CO poisoning is a common cause of morbidity and mortality in post-disaster situations due to widespread power outages and subsequent generator use. In late September 2021 Hurricane Ida made landfall on the 16th anniversary of Hurricane Katrina and caused much damage to Louisiana and surrounding states as a Category 4 hurricane. West Jefferson Medical Center was the only acute hyperbaric medical center open from New Orleans to the Baton Rouge region to treat acute CO poisoning.

Intervention: Hyperbaric oxygen treatments with two monoplace chambers were performed at WJMC. Due to the continuing COVID-19 pandemic, transportation delays, and staffing limitations, a new protocol was created to treat CO patients based on severity of symptoms. Each patient received between one and three treatments. Patient neurocognitive exam consisted of using the Folstein Mini Mental Examination and a detailed neurologic examination.

Outcome: Thirty patients were treated during this time, manifesting various symptoms of acute CO poisoning. The most common symptoms were headache and cognitive difficulty. One pediatric patient had complications of mild TM (tympanic membrane) barotrauma after HBO₂, with no additional post-treatment complaints. Patients ranged from 17 months to 64 years of age, with one pregnant patient in the second trimester. Following each treatment each patient was reassessed for residual symptomatology.

The treatment team consisted of one tech, one nurse, a hyperbaric physician, and a hyperbaric fellow. The situation was further complicated by structural damage to the roof and areas adjacent to the hyperbaric center after the storm. Time available for treating patients was reduced due to fatigue of our ancillary staff, but with some modifications all patients had the opportunity to receive three treatments.

Discussion: 141 people were recorded by Louisiana Health Department to have been hospitalized and treated for accidental CO poisoning. Our experience shows the importance of adequate chamber staffing and prompt evaluation of patients. The abbreviated protocol created for optimization of available chamber staff and patient load had successful results.
Low-volume infusions of viscous medications in a hyperbaric environment
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Introduction/Background: Many Class A hyperbaric chambers can treat ICU-level patients who are on carefully titrated low-volume infusions such as propofol or argatroban. We studied the Medsystem III, a pump that has been previously evaluated in the hyperbaric setting and is one of a handful of systems routinely used during hyperbaric treatment. There is paucity of data in this model demonstrating the accuracy of low-volume infusions in the hyperbaric setting. Additionally, while most infusion studies use distilled water or 0.9% normal saline (NS), we included infusions of D50, which is highly viscous, to assess for an impact on pump performance when using viscous medications such as propofol or intralipid.

Materials and Methods: To account for any error within a single pump, we used two Medsystem III pumps, each running two channels simultaneously, one with a solution of normal saline (0.9%) and the other with D50 (relative effective viscosity 3.83). Infusions were performed over one hour, into 25mL Class A graduated cylinders with a tolerance of 0.17. Conditions tested were at 1 ATA and our common treatment pressures of 2.36 ATA (45 fsw) and 2.81 ATA (60 fsw). Pumps were run at depth and not during pressurization or depressurization. Univariate analysis was performed on the results and were compared with the factory standard deviation ±5%.

Results: No individual values measured for D50 or NS under normobaric or hyperbaric conditions exceeded the manufacturer standard of ±5%. There were no appreciable differences in infusion rates between D50 and NS (p = 0.78) or between the two treatment depths (p=0.27).

Summary/Conclusions: In our study of small-volume infusions the Medsystem III operated within the system specifications. There were no significant differences when tested at 1 ATA, 2.36 ATA and 2.81 ATA, and no significant difference in infusion rates between high viscosity medications (D50) and NS.
Timely hyperbaric oxygen therapy of a traumatic lip flap - A case report of a facial dog bite treated within 24-hours

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Case Description: A 26-year-old female presented to an outside hospital after sustaining a dog bite to her lip with complete avulsion of approximately 1.5 cm x 1 cm involving the vermillion border. The patient was promptly transferred for plastic surgery and a reimplantation of composite skin graft to her right upper lip. The UC-San Diego Hyperbarics Department was consulted by the emergency physician for duskeness of the graft and location of the injury. The total time from traumatic injury to hyperbaric consultation was 18 hours.

Intervention: The patient was treated twice daily at 2.4 ATA for 90 minutes utilizing U.S. Navy Treatment Table 9. The first treatment was performed at approximately 20 hours after the initial trauma. Subsequently, the patient was treated twice daily for five days and transitioned to once daily, totaling 24 treatments.

Outcome: Plastic surgery follow-up noted excellent granulation tissue and viability. At time of completion of her treatments, the graft was successful and routine scar prevention and management performed. At the nine-month follow up patient reported minimal scarring to the area of trauma and was very happy with the cosmesis.

Discussion: Facial disfigurement has shown significant psychological and social stress in patients, with significant risk of depression and anxiety. Outside of primary closure, additional tools to aid in flap salvage and mitigate risk of failure are sadly limited. In addition, there is significant lack of case reports on expedited or timely treatment of traumatic flaps with hyperbaric oxygen therapy from the emergency room. Yet, data on time-sensitive response to hyperbaric oxygen in flap outcome is well supported in the murine and large animal models. We present this case report as an example of a traumatic facial flap created by a dog bite that underwent prompt initiation of hyperbaric oxygen therapy (< 24-hours) from the emergency room and offers additional support for timely hyperbaric consultation by emergency physicians for tissue salvage.
Hyperbaric oxygen for multiple non-healing leg wounds secondary to calciphylaxis: A case report
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Case Description: A medically complex 60-year-old female with a history of hypertension, heart failure with reduced ejection fraction, obesity, breast cancer, and calciphylaxis presented with significant non-healing wounds on her bilateral lower extremities. The wounds from calciphylaxis can be painful and disfiguring and are often refractory to treatment.

Intervention: Multiple interventions including surgical debridement, collagen, compression dressings, antibiotic ointments as well as systemic broad-spectrum antibiotics, therahoney and thiosulfate were given over several months with little improvement in her wounds. Hyperbaric oxygen (HBO₂) therapy (2.0 ATA, 90-minute sessions (1x daily), 100% O₂ with no air breaks) was given for a total of 60 sessions for four months.

Outcome: Wound photographs were used to assess clinical progression. Clinically significant improvements were first apparent after a few weeks of HBO₂, with marked improvement by Day 47. Improvement in the patient’s mental health and ambulatory function were also noted.

Discussion: The role of hyperbaric oxygen in treating non-healing wounds associated with calciphylaxis is not established, with a scarcity of literature evaluating its efficacy. This patient’s wounds were minimally responsive to standard therapies until HBO₂ was initiated. While further research is needed to support these findings, HBO₂ may an effective therapy for treating non-healing wounds secondary to calciphylaxis.
Hyperbaric oxygen therapy for post-concussive symptoms after TBI from high-performance aircraft ejection: A case report.
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Case Description: A 32-year-old active-duty male pilot suffered a single mild traumatic brain injury (TBI) with post-concussive symptoms after ejection from a high-performance military aircraft. The patient suffered persistent symptoms of decreased concentration, short-term memory, and impaired word-finding 14 months after the initial injury. Automated Neuropsychological Assessment Metrics (ANAM) testing noted a substantial loss of his reaction time compared to his pre-injury baseline.

Intervention: Patient underwent 46 separate HBO2 treatments at 2.2 ATA for 90 minutes each over the course of 39 days. ANAM testing was used intermittently to measure cognitive performance and compare it to his pre-injury baseline and throughout his treatments.

Outcome: ANAM testing demonstrated improvement in the patient’s simple reaction time to near pre-injury levels despite 451 days since the TBI in addition to the patient’s reported subjective improvements.

Discussion: All U.S. military personnel undergo ANAM testing during pre-deployment training. This provides military ANAM testing the unique ability to identify subtle cognitive deficits after a mild TBI. Previous randomized trials have utilized ANAM testing, but the difference before and after injury was not included in the study. If a subject demonstrates no difference in ANAM scores after a TBI, HBO2 therapy would not be expected to change those scores. Therefore, loss of performance on ANAM testing should be considered in military mild TBI patient selection.

The views expressed herein are those of the author(s) and do not reflect the official policy or position of Brooke Army Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Army, the Department of the Air Force, or the Department of Defense, or the U.S. Government.
Impact of focused education on internal medicine resident knowledge and likelihood to refer to undersea and hyperbaric medicine
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Introduction/Background: Growth and integration of undersea and hyperbaric medicine (UHM) into other specialties continues to be challenging, as referring clinicians lack knowledge about UHM and hyperbaric oxygen (HBO\textsubscript{2}) therapy. Those clinicians providing primary clinical care could benefit from routinely partnering with UHM clinicians, as we regularly share mutual patients. Therefore, this study sought to evaluate the knowledge of internal medicine residents regarding the physiology of HBO\textsubscript{2}, HBO\textsubscript{2}-approved indications, and referral criteria.

Materials and Methods: A questionnaire-based study was designed to assess knowledge gained during a didactic lecture about UHM and HBO\textsubscript{2} indications for internal medicine residents. All internal medicine residents within our health care system were asked to participate on a voluntary and anonymous basis. Pre- and post-surveys following the lecture were summarized to see if knowledge was gained from the didactic lecture and a T-test was used to compare comfort level with referring to UHM.

Results: Overall, 42 residents were asked to participate; 26 and 20 completed the pre- and post-survey, respectively. Following the lecture, mean comfort level (1 [unsure] – 10 [confident]) with UHM referrals significantly increased (5.0 pre- vs. 8.0 post-survey; p<.01). Knowledge regarding the physiology and indications of hyperbaric medicine clearly increased in all questions when comparing pre- and post-surveys.

Summary/Conclusion: Hyperbaric medicine is a growing subspeciality that is under-represented in medical education. By recognizing this gap, efforts were made to educate internal medicine residents to improve knowledge base and comfort level for referrals to UHM. Our study showed statistically significant short-term knowledge gain and improved comfort level with referrals. Knowledge and referral likelihood durability will be reassessed three months post-lecture.
Assessment of video laryngoscopes for use in the hyperbaric environment
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Background: Hyperbaric oxygen (HBO₂) therapy is an indicated treatment for patients with some life-threatening conditions such as carbon monoxide poisoning, decompression illness, and necrotizing infections. Additionally, with the expanding use of thrombolytic therapy (tPA) for patients with CRAO, centers providing emergency hyperbaric care must have the ability to manage tPA-induced angioedema, potentially while inside the multiplace chamber. This study assessed the performance of different video-assisted endotracheal intubation devices in the multiplace hyperbaric environment.

Materials and Methods: Four different systems were assessed in this study: the Storz C-MAC 8401; the King Vision aBlade; the Airtraq SP with wi-fi camera; and the McGrath Mac. Each device’s optical integrity and light intensity were directly assessed by medical providers using an airway mannequin, a standardized image, and a DrMeter digital light meter at standard prescribed treatment depths (2 ATA, 2.45 ATA, 2.8 ATA and 6 ATA). The devices were then subjected to a modified Navy p9290 protocol involving 30 rapid cycles of pressurization/depressurization to 2.8 ATA and 6 ATA, then prolonged air soaks to 2.8 ATA and 6 ATA.

Results: The McGrath Mac’s function remained intact throughout all hyperbaric exposures. The CMAC screen displayed minor yet reversible irregularities following rapid cycling to 6 ATA. The King Vision initially failed to turn on after the first compression to 2 ATA but worked after subsequent compressions. The light within the initial Airtraq device was unusable following ascent from a manned dive at 6 ATA, but a different Airtraq device functioned adequately following cycling and soak at 6 ATA.

Conclusions: Although all four devices’ light intensity and image resolution remained intact overall with hyperbaric exposure, only the McGrath Mac showed no dysfunction during any of the protocols. Repeat testing of multiple devices of each type should be done to confirm replicability of their performance.
Saturation diving during a global pandemic
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Introduction/Background: The coronavirus 2019 (COVID-19) pandemic poses unique challenges to conducting military operations. In response, the U.S. Navy implemented COVID-19 mitigation policies across the fleet in an effort to maintain a state of strategic readiness. These mitigations included pre-operational quarantines, testing protocols, and preventive practices such as mandated universal mask-wearing, social distancing to include teleworking when possible, enhanced hand-washing, and more rigorous sanitizing procedures. Specific guidance tailored to deployment, travel, at-sea shipboard evolutions and submarine embarkation was also released; however, these policies could not be directly applied to saturation diving evolutions. While saturation diving is not performed widely in the military, the Navy Experimental Diving Unit (NEDU) conducts both shore-based research and at-sea saturation diving operations. Conducting these operations during the COVID-19 pandemic is uniquely challenging, as a diver’s access to higher levels of medical care is often hours or days away.

Materials and Methods: NEDU incorporated mitigation strategies from the Department of Defense, Centers for Disease Control, commercial diving platforms, and historical interventions for respiratory viruses to reduce the risk of COVID-19 infection and transmission during saturation diving operations. Mitigation strategies have included requirement of COVID-19 immunization for divers and support personnel, clinical and laboratory screening of divers and support personnel, enhanced hygiene and food-handling practices, modified quarantine procedures, and separation of support personnel into teams with limited interaction.

Results: Since July 2020, NEDU has successfully conducted 14 saturation dives utilizing mitigation plans specifically tailored to each dive evolution. To date, these measures resulted in only two COVID-19 cases that affected mission timeline and no cases among divers in saturation; these mitigations ultimately contributed to mission success on every dive.

Summary/Conclusions: Mitigation strategies and lessons learned from this pandemic may be applied to enhance the success and safety of future saturation diving operations conducted during respiratory disease outbreaks.
Hearing aid compatibility for the Class A hyperbaric environment
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Introduction/Background: Hearing-impaired patients are placed at a disadvantage when required to remove hearing aids prior to hyperbaric treatments because of difficulty hearing instructions. This creates safety concerns, as patients will struggle to understand inside attendants completing safety checks, clinical assessments, and emergency procedures. Locked-in hearing impaired clinicians will have difficulty assessing patients and communicating with outside teams. Factors affecting hearing-impaired individuals are chamber background noises and high-pitched voice tone at depth. These factors are compounded by high-frequency hearing loss that is common among older adults.

Materials and Methods:
1. Zinc air 1.4V hearing aid mechanics and material flash points reviewed for hyperbaric environment
2. Baseline hearing aid function assessment
3. Oticon Alta2 Pro Ti hearing aids stressed using three protocols:
   • Deep: 1 x 6 ATA for 15 min in Class C hyperbaric chamber with 100% nitrogen
   • Serial TT9: 30 treatments in Class A hyperbaric multiplace chamber with 100% oxygen
   • TT6: Class C hyperbaric chamber with 100% oxygen
4. Hearing aid temperature recorded during two TT9 treatments
5. Post-protocol hearing aid function assessments
6. Hyperbaric safety committee review for “approved items” list

Results: Zinc air batteries release electrons by utilizing ambient oxygen reactions with a cathode to form hydroxyl ions and zincate; zincate decays into zinc oxide and water. Hearing aid material peak temperature was 28.4 degrees Celsius and remained within 4.5 degree Celsius of ambient temperature during protocols. Post-protocol hearing aid function assessments were the same as the baseline. Hearing aid materials flash points were within NFPA guidelines.

Summary/Conclusions: Oticon Alta2 Pro Ti hearing aids functioned normally after each hyperbaric protocol in comparison to baseline. The hyperbaric oxygen environment likely increased battery reactions, but battery life remained similar. Temperature and material flash points remained within published standards. The 1.4V hearing aids were added to the hyperbaric “approved items” list.
A case of inner ear decompression sickness in the setting of concomitant middle ear barotrauma
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Case Description: A 30-year-old female presented to the emergency department (ED) with vertigo following scuba diving. She reported four freshwater dives.
• 1st - 102 ffw; nitrox 32; 30 minutes; surface 1.25 hours
• 2nd - 73 ffw; nitrox 32; 38 minutes; surface 2.5 hours
• 3rd - 56 ffw; air; 80 minutes; surface 3 hours
• 4th - 68 ffw; air; 56 minutes
The patient had difficulty equalizing on the descent of her final dive, and symptom onset occurred 20-40 minutes after surfacing. The patient presented to the ED the next day.

Initial neurologic examination showed bilateral horizontal nystagmus, but the patient refused to stand, ambulate, or perform a sharpened Romberg due to nausea. Otoscopy showed right pinpoint perforation and erythematous tympanic membrane. Differential diagnoses included inner ear decompression sickness (DCS) versus inner ear barotrauma.

Intervention: She was treated with a U.S. Navy Table 6 less than 24 hours after her symptom onset. She had improvement in vertigo and ambulation following treatment. She received four USN TT5 trailing treatments once daily.

Outcome: There was gradual improvement with treatments until plateau with mild vertigo on discharge. She had complete resolution of symptoms at one-month follow-up. Echo bubble study showed a patent foramen ovale with a grade 3 right-to-left shunt.

Discussion: Inner ear DCS is relatively rare in recreational diving. A dive history and physical exam are important in differentiating between inner ear barotrauma and inner ear DCS. It is possible to have inner ear DCS in the setting of middle ear barotrauma. When doubtful, a trial of HBO$_2$ may be warranted. Indeed, the current case presentation had both a history of difficulty with equalization and evidence of middle ear barotrauma. Yet, the patient was found to have inner ear DCS that improved with HBO$_2$. One key clue may be symptom onset, which occurred after surfacing.
Unsuccessful treatment of pediatric pulmonary mucormycosis with hyperbaric oxygen
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Case Description: A 16-year-old male was diagnosed with B-ALL (B-cell acute lymphocytic leukemia and precursor B-lymphoblastic leukemia) after months of progressive vague health concerns and was transferred to a regional pediatric center for initiation of chemotherapy. Afterward, the patient developed a persistent pneumonia, and antibiotic coverage was broadened, antifungals were started, and a bronchoalveolar lavage was performed. The culture grew out high levels of Rhizopus, and the patient was diagnosed with pulmonary mucormycosis on Day 18 after initiation of chemotherapy.

Intervention: Amphotericin B and posaconazole were initiated prior to culture results, and hyperbaric medicine was consulted at a nearby facility on Day 19. Surgical intervention was not a possibility at this point due to involvement of the right middle and lower lobe, as well as the diaphragm and dome of the liver. On day 20, the patient had his first hyperbaric treatment with a U.S. Navy Treatment Table 9. After further discussion, hyperbaric treatments were resumed on Day 24 with a USN TT9, with another uneventful treatment on Day 25. Due to deteriorating vital signs, and new fevers, oxygen periods had been transitioned to 20-minute periods to reduce seizure risk. On Day 25 the patient had a closely monitored USN TT9.

Outcome: Despite broad antibacterial and antifungal coverage, in addition hyperbaric treatments as tolerated, the patient developed empyema necessitans, worsening invasion of the liver, obliteration of the right pulmonary vasculature, and pericardial involvement. The patient died on Day 27 after induction chemotherapy.

Discussion: While hyperbaric oxygen therapy has been discussed as an adjunct treatment for rhinocerebral disease, there is a paucity of clinical experience in treating pulmonary mucormycosis. While the outcome of this case was still tragic, the experience may help to provide a reference for future practitioners and seed the foundation of our understanding in the role of hyperbarics for pulmonary mucormycosis.
Suspected neurocardiogenic syncope on arrival to altitude in healthy research subjects
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Case Description: Two previously healthy human research subjects experienced sudden loss of consciousness upon ascent to 15,000 feet in a hypobaric chamber. Subject one was a 25-year-old male who had abrupt onset of lightheadedness and diaphoresis, with loss of consciousness 50 seconds after arrival to altitude. We noted hypotension with a mean arterial pressure (MAP) of 60, SpO₂ (oxygen saturation) of 88%, sinus bradycardia to 30 bpm and a significant sinus pause. Subject two was a 25-year-old female with lightheadedness then syncopal event 7.5 minutes following arrival to altitude. We again noted hypotension with MAP of 30, SpO₂ of 84% and sinus bradycardia to 55 bpm, but no sinus pause.

Intervention: Upon occurrence of the syncopal event both subjects were given 100% oxygen via mask. SpO₂ never dropped below 80%. Both subjects regained consciousness in less than 30 seconds.

Outcome: Subject one described residual headache and lightheadedness and did not complete the study. He later reported a prior event of brief syncope with public speaking. Subject 2 was able to complete the exercise protocol after recovery. She had no prior syncopal events.

Discussion: Syncope upon arrival at altitude has frequently been described in healthy persons. Causal mechanisms remain unclear with postulated peripheral vasodilation and reduced preload. The presentation in both subjects is typical of a vasovagal phenomenon. Both subjects were seated and not engaged in stressful or vigorous activity. While both were hypoxic, their SpO₂ was higher than our typical experience at 15,000 feet, and neither had shortness of breath. Our center has seen prior cases of syncope at altitude with orthostatic stimuli, but these recent episodes had no such trigger. All such events tend to occur soon after ascent to altitude. Researchers performing studies requiring sudden ascent to altitude should monitor for and mitigate the risks of sudden neurocardiogenic syncope in otherwise healthy subjects.
Cognitive assessment of injured divers survey
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Introduction/Background: During the evaluation of divers suspected of having a decompression-related illness, associated cognitive abnormalities may be subtle and difficult to detect. There are many different cognitive testing tools that are validated in alternative settings to detect neurocognitive dysfunction, but none that are specifically validated for the purpose of assessing or monitoring injured divers. This leaves the ultimate choice of assessment to individual departments and providers. The understanding of current practice patterns for cognitive assessment in divers may reveal areas where we can improve or collaborate on methods of detecting or monitoring diving-related injuries.

Materials and Methods: A survey was developed and distributed to hyperbaric providers through the UHMS listserv as well as monthly educational meetings between hyperbaric departments. Respondents were screened by whether they partake in the assessment of injured divers, and if they have a departmental affiliation. Questions were focused toward primary and secondary cognitive assessment methods used, and whether there was consistency among methods within their institutions.

Results: Of the 145 respondents to the survey, 68 respondents (46.9%) evaluate injured divers. These 68 respondents represent 41 different departments or health care delivery systems internationally. The Mini Mental Status Exam (MMSE) was the most utilized cognitive assessment tool at 35.3%, followed by the Montreal Cognitive Assessment (MoCA) at 5.9%. There were 26.5% of respondents that had a variable exam based on diver presentation, and 20.6% of respondents had no standardized tool. There was no departmental consistency or standard for 60.3% of respondents.

Summary/Conclusion: The MMSE was the most commonly used tool of those surveyed, but the majority of respondents indicate that there is a lack of consistency or standardization to the approach of assessing an injured diver’s cognitive status. Further research may be beneficial in understanding whether there is an optimal method for cognitive assessment in our patient population.
Monitoring oxygen and carbon dioxide levels by saturation probe and transcutaneous monitor while breath-holding with air and oxygen
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Introduction/Background: Apnea is the temporary cessation of breathing on land or underwater. One of the factors affecting the duration of apnea is breathing oxygen before apnea. In this study we aimed to compare the oxygen and carbon dioxide levels in the apnea duration and recovery phase of the groups that breathed oxygen and air before apnea. As another aim of the study, we compared the effect of apnea on oxygen levels with two different non-invasive measurement methods – saturation probe (pulse oximetry) and transcutaneous oxygen and carbon dioxide monitor.

Materials and Methods: Eight sedentary volunteers who were healthy and whose breath-holding time did not exceed three minutes participated in the study. Two separate breath-holding protocols with air and oxygen were applied to each participant in a single-blind fashion. Oxygen and carbon dioxide values of the volunteers were measured with a saturation probe and a transcutaneous monitor before, during and after apnea.

Results: We observed that the total apnea times were significantly longer in oxygen-induced apnea than air-induced apnea. We observed that TcPCO₂ (transcutaneous partial pressure of oxygen) levels did not change significantly in apneas performed with air (p=0.356), while TcPCO₂ levels were observed to increase significantly in apneas performed with oxygen (p=0.002). TcPO₂ and SpO₂ (oxygen saturation) values proved that hyperoxic apnea preserves O₂ levels, regardless of apnea duration. As the duration of normoxic apneas increased, SpO₂ values were still high and remained at the same value in the seconds when the TcPO₂ level decreased.

Summary/Conclusion: In our study it was concluded that in sedentary volunteers, pre-apnea oxygen inhalation significantly prolonged the apnea duration, and oxygen inhalation affected the chemoreflex mechanism. In hyperoxic apnea, O₂ levels were observed to be preserved regardless of the apnea duration. In normoxic apneas, as the apnea duration increased, TcPO₂ measurement gave faster results.
Successful employment of a diet and exercise regimen in clearance to dive for long-haul COVID
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Case Description: A 49-year-old male who had been hospitalized for acute COVID-19 pneumonia presented requesting return-to-dive clearance. In the months following illness he had ongoing physical and neurocognitive dysfunction. Patients with symptoms lasting longer than four weeks after acute COVID-19 are said to have long-haul COVID. Prior to illness, he was recreational scuba-certified to the level of divemaster and was working toward his scuba instructor certification.

Intervention: Upon his initial evaluation he felt improved but not quite back to baseline. We recommended starting a regular exercise and diet regimen with an eventual goal of reaching 10 metabolic equivalents (METS). At follow-up his symptoms had completely subsided, and he had built up an exercise tolerance that was improved from his baseline. His pulmonary function test (PFT) revealed that his forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) were more than 20% below predicted values. He was not cleared for scuba diving; however, he was cleared for pool sessions with restrictions.

Outcome: He continued his diet and exercise regimen and had a noticeable decrease in air consumption with pool work. His neuropsychiatric symptoms resolved. He underwent cardiac stress testing with a satisfactory work level and no evidence of ischemic changes. His resting and exercise PFT revealed an improvement to acceptable levels, and he was cleared to dive.

Discussion: Exercise has been proven to improve neurocognition and cardiopulmonary fitness. It has not been formally studied as a tool for re-introducing long-haul COVID patients back into recreational scuba diving. We tailored a clearance-to-dive approach utilizing diet and exercise until our patient had resolution of symptoms and restoration of his exercise ability. We must acknowledge that there will be a greater number of these patients arriving to dive clinics requesting dive clearance. Preparation and shared knowledge of our experiences will allow us to provide our patients with a safe and acceptable return to dive plan.
Radiation proctitis: A case of a large non-healing rectal ulcer
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Case Description: This is a case presentation of a large non-healing rectal ulcer in a previously radiated field that benefited from a multidisciplinary approach that included hyperbaric oxygen therapy. Ionizing therapeutic radiation is a potent physical entity with dramatic effects in both malignant and surrounding normal tissues. Severity is related to the total radiation dose and the total time of treatment. Radiation injuries are classified as acute, subacute and delayed radiation injuries. Delayed radiation injury is distinguished by vascular changes characterized by obliterative endarteritis. Hyperbaric oxygen (HBO₂) therapy promotes angiogenesis in hypoxic tissue, the known impact of hyperbaric oxygen in stimulating angiogenesis continues to be an important therapeutic mechanism.

Intervention: Hyperbaric therapy profile was 2.0 ATA, two hours oxygen, five-minute air break, for a total of 60 session. At the initial consultation, surgical intervention for colonic diversion was addressed. The subsequent benefits of bowel rest to positively impact ulcer healing were discussed.

Outcome: Pain management was an integral part of the interdisciplinary care team. Prior to HBO₂, the patient required complex tiered analgesics, including multiple narcotics. The analgesic regimen was required through the first 30 treatments. On utilization review at 40 sessions, pain management had begun a narcotic taper. At 50 sessions the patient had been able to discontinue all narcotic medications, with significant improvement in quality of life. Post-treatment flexible sigmoidoscopy showed diminished rectal ulcer size “... with granulation tissue coming from mucosa.” In post-HBO₂ follow-up, patient related an improved quality of life, stating “few days with pain, more days without pain.” He has not required further narcotic medications to date.

Discussion: The processes of obliterating endarteritis, hypoxia and fibrosis are already recognized as fundamental factors for the development for acute radiation injuries. Review literature by Feldmeier and Hampson in 2002 reporting the results of hyperbaric oxygen therapy in radiation proctitis indicate that of 114 patients, 36% were treated with complete resolution, 60% had improved symptoms, while 4% had no benefits. The American Society of Colon and Rectal Surgeon included hyperbaric oxygen therapy as part of the clinical intervention in their guidelines, Recommendation IB. Radiation proctitis must have a multidisciplinary approach to management according to clinical condition and severity. Hyperbaric oxygen therapy for patients with chronic refractory radiation proctitis has resulted in significantly improved and enduring healing responses and enhanced quality of life.
Hyperbaric oxygen treatment of liquid nitrogen frostbite: A case report and literature review

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Case Description: This paper reports a case of a man who suffered frostbite in his right finger after his right hand was exposed to liquid nitrogen for several seconds. He experienced pain, and small blisters appeared on the wound surface, with serumlike exudate and purplish-brown base (Figure a).

Intervention: He immediately moved fingers from the liquid nitrogen environment, placing his hand in room-temperature tap water. On the first day, he underwent debridement, physical therapy, and medication against inflammation. On the second day after the accident, the patient underwent hyperbaric oxygen (HBO₂) therapy for frostbite, in a multiplace chamber at 2.5ATA for 100 minutes.

Outcome: After 20 sessions of HBO₂ over two weeks the blisters on the wound surface gradually absorbed and the wound gradually healed: His pain level changed from a severity of 5 points to 1 point, sensory disturbance was improved, and functional activities of the fingers were restored (Figure b). One month follow-up and tests of somatosensory evoked potential showed no influence on sensation or movement of fingers.

Discussion: The outcome of this patient with grade 2-3 of frostbite with no abnormality on sensation of fingers is satisfying due to proper immediate treatment and early intervention of HBO₂. HBO₂ has a potential application prospect in the treatment of frostbite, and it may benefit wound healing, peripheral nerve damage or sensation restoration, as well as drug use for frostbite. The earlier HBO₂ treatment starts, the better the long-term outcome. The regimen is supposed to be 2.4-2.5 ATA at least once per day from animal experiments and case reports of frostbite treated with HBO₂. HBO₂ is an effective treatment for frostbite patients; further exploration of courses and regimen need to be conducted.
Case Description: We present a case series of four divers who were diagnosed with arteriole gas embolus (AGE) or decompression sickness (DCS) who received hyperbaric oxygen (HBO₂) therapy and one diver who was evaluated for dive injury but was assessed not to have AGE or DCS. Each diver’s cognition was evaluated with a modified sport concussion assessment tool 5 (mSCAT5) and Mini Mental State Exam (MMSE).

Intervention: Four divers were examined pre- and post-HBO₂ therapy with mSCAT5 and MMSE. The non-treated diver received pre-HBO₂ mSCAT5 and MMSE evaluations.

Outcome: The mSCAT5 were completed within 10 minutes and the MMSE took five minutes. Treated divers scored “normal” on MMSE pre- and post-HBO₂ therapy. Pre-HBO₂ mSCAT5 showed measurable impairment of cognitive domains: cognitive symptom evaluation, immediate memory, balance and delayed memory recall, while orientation and concentration cognitive domains were “normal.” Post-HBO₂ mSCAT5 showed measurable improvement in impaired cognitive domains. Non-treated divers scored “normal” on both tools.

Discussion: Cognition is often impaired in AGE and DCS, with patients reporting difficulty identifying symptoms and commonly describing “being in a fog.” Literature review produced little on recommended assessments tools for dive-related mild cognitive impairment (MCI). MMSE has often been chosen to evaluate injured diver cognition due to familiarity and brevity despite general recognition that MMSE is likely inadequate to detect dive-related cognitive impairment. The SCAT5 has been employed to identify sport concussions in professional sports. Pre-HBO₂ mSCAT5 was more sensitive in identifying diver impaired cognition across multiple domains, suggesting the mSCAT-5 better assessed dive-related MCI. Post-HBO₂ mSCAT5 showed measurable improvement in injured cognitive domains, likely demonstrating treatment effect. Non-treated diver scored “normal” on both tools, suggesting mSCAT5 is appropriately sensitive. Further study is recommended to confirm these observations.
Presence of patent foramen ovale in certain types of decompression illness: A case series
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Introduction/Background: Patent foramen ovale (PFO), a condition in which a fetal passageway between the atria of the heart does not close upon birth, is present in approximately 30% of the general population. It has been associated with certain types of decompression illness (DCI), including neurologic and inner ear decompression sickness (DCS) as well as with the rash of cutis marmorata. PFO has been thought to be a contributing factor to DCI in otherwise non-provocative dive profiles by allowing the arterialization of venous bubbles.

Materials and Methods: We reviewed data available from 1978 to 2020 from the archives of the LSU Hyperbaric Department for cases of Type II DCS, inner ear DCS, cutis marmorata, and the incidence of PFO. This data set was comprised of primarily commercial, offshore diving cases.

Results: 861 divers were identified as receiving treatment for Type II DCS between 1978 and 2020. Among these cases 73 divers were identified as unprovoked Type II DCS, inner ear DCS or cutis marmorata. All 73 divers were referred for PFO testing. A total of 41 of the 73 obtained the PFO study (56%); 19 of the 41 divers who obtained the study were confirmed to have a PFO (46%).

Summary/Conclusion: In this sample of all referred cases of Type II DCS between 1978 and 2020, we found an increased likelihood of PFO associated with unprovoked Type II DCS, inner ear DCS and cutis marmorata as compared to the general population. This suggests PFO may increase the risk of these diving etiologies and is consistent with prior literature on the subject. We recommend testing for PFO in divers with cases of cutis marmorata, unprovoked Type II DCS and inner ear DCS.
Save the dates

Future Annual Meeting Dates & Locations

**June 16-18, 2023***
SHERATON SAN DIEGO HOTEL & MARINA
SAN DIEGO, CA
Rate: $219
*shift pattern (Friday-Sunday)
More information coming soon.

**June 14-16, 2024**
ASTOR CROWNE PLAZA NEW ORLEANS, LA
Rate: $209

2022 CHAPTER TOWN HALL MEETINGS

- MID-WEST CHAPTER: JUNE 11:
  - Topic: Safety
- PACIFIC CHAPTER: AUGUST 13:
  - Topic: Wound Care
- NORTHEAST CHAPTER: OCTOBER 15:
  - Topic: Diving

2023 CHAPTER TOWN HALL MEETINGS: DATE TO BE ANNOUNCED