13-16 SEPTEMBER

PORTO, PORTUGAL

DIVENTOS

47th Annual Scientific Meeting
ABSTRACT AND CONFERENCE BOOK

EUBS
PORTO 2023

INDEX

WELCOME MESSAGE

With great honour, **I welcome you to Porto for the EUBS 2023** congress where I am sure we will have an exciting and inspiring time.

We have prepared a **high-level scientific program** including keynote lectures by invited expert speakers, selected oral communications, poster displays, and exciting social events where you can enjoy the friendly and beautiful city of Porto.

We strive to make this conference an **unforgettable experience**, where we can all meet old and make new friends, and establish new initiatives and collaborations in this ever-developing field of Hyperbaric and Diving Medicine.

We hope to see you all in Porto!

Oscar Camacho, MD

Secretary-General, Chairman of Local Organizing Committee, 47th Annual Scientific Meeting 2023
Director of Hyperbaric Medical Unit, Hospital Pedro Hispano, Matosinhos
Head of Anesthesiology Department, Hospital Pedro Hispano
Chairman of the Portuguese Hyperbaric and Diving Medicine College

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Our **47th Annual EUBS Scientific Meeting** will be held September **13-16, 2023, in Porto, Portugal**. This city was voted the best urban destination in Europe at the World Travel Awards 2022.

The EUBS hopes to welcome all of its members and many friends and scientists from around the world for this four-day conference.

The scientific program is very rich and interesting with the presentation of research work ranging from basic science to clinical trial without forgetting the experience and work of the different centers. The quality of care of critical patients in the hyperbaric environment will also be discussed, which is a very important subject.

I am sure that you will enjoy your stay in Porto, a modern and romantic city with a diversified and high-quality social program.

I look forward to seeing you soon.

Jean-Eric Blatteau, MD, PhD

President of European Underwater and Baromedical Society
Director of the Department of Diving and Hyperbaric Medicine at the Sainte-Anne military hospital in Toulon, France

CONGRESS ORGANIZATION

ORGANIZATION

EUBS – European Underwater and Baromedical Society

eubs.org

LOCAL CO-ORGANIZATION

UAFA – União Associativa para a Formação em Anestesiologia

uafa.pt

Unidade Local de Saúde de Matosinhos

ulsm.min-saude.pt

COMITTEES

SCIENTIFIC COMMITTEE

Anne Raisanen-Sokolowski
Bengusu Mirasoglu
Costantino Balestra
Carla D`Espiney Amaro
Diogo Alpuim Costa
Jean-Eric Blatteau
Jacek Kot
Oscar Camacho
Paula Ferreira
Pedro Barata
Peter Germonpre
Vangelis Papoutsidakis

ORGANIZING COMMITTEE

António Manjon
António Pedro Ferreira
Clara Gaio Lima
João Castedo
Óscar Camacho
Pedro Barata
Tiago Fernandes

KEYNOTE SPEAKERS

KEYNOTE 1: "PAST, PRESENT AND FUTURE OF HYPERBARIC MEDICINE"

Prof. Jacek Kot, MD, PhD

Head National Centre for Hyperbaric Medicine

Medical University of Gdańsk, Poland

President of European Committee on Hyperbaric Medicine

KEYNOTE 2: "HBOT AND OXYGEN AS A KEY REGULATORY COMPONENT IN SEVERE INFECTIONS TREATMENT"

Ole Hyldegaard, MD, PhD, DMSci

Professor, Senior consultant

Head of HBO Unit and Research Department of Anaesthesiology,

Head-and-Orthopedic Centre

Copenhagen University Hospital - Rigshospitalet, Denmark

Dept of Clinical Medicine, University of Copenhagen, Denmark

KEYNOTE 3: "CHALLENGES IN THE ARCTIC DIVING"

Anne Räisänen-Sokolowski, MD, PhD

Head Physician at the HUS-Diagnostic Center, Pathology, at the Helsinki University Hospital, Helsinki, Finland

Researcher, The Defense Forces, Diving Medical Centre and Military Medicine, Helsinki

KEYNOTE 4: "FERTYOX – HYPERBARIC OXYGEN IN POOR OVARIAN RESPONDERS"

Miguel Raimundo, MD

Gynaecology - Obstetrics Specialist

Reprodutive Medicine Specialist

PhDs at University of Lisbon, Portugal

PROGRAM

SEPTEMBER 13TH

14:00-19:00 – Registration desk open

14:30 – 16:30 – Workshops

- Workshop 1 – Clinical Research in HBO - Firmino Machado
- Workshop 2 – Scientific Writing - Pedro Barata Coelho
- Workshop 3- Management of the critically ill patient in The Hyperbaric Medicine Unit (Nuts and bolts) - Tiago Fernandes, António Pedro Ferreira, Manuel Lopes

17:30 – 19:30 - Welcome Reception - 6 Bridges Cruise

Embarkment of passengers at Rota do Douro Quay in Vila Nova de Gaia

Start of the Bridges Cruise, on a typical Rabelo Boat

Cruise along the banks of Porto and Gaia, passing by the bridges of the Douro River

PROGRAM

SEPTEMBER 14TH

8:00 – 09:00 – Gathering and Registration

09:00 – 09:30 – Opening Ceremony

09:30 – 10:00 – Keynote Lecture 1 – "Past, present and future of Hyperbaric Medicine" - Jacek Kot

10:00 – 10:30 – Coffee Break

10:30 – 12:30 – Session I – Oral Communications – *HBOT*

Chairs: Tiago Fernandes, Peter Germonpré

1. 19372 - Challenges regarding patient inclusion in Hyperbaric Oxygen Treatment research - **Joost R Meijering**
2. 19503 - Safety of hyperbaric oxygen therapy in patients with heart failure: a retrospective review - **Simone Schiavo**
3. 19305 - From a restrospective analysis to setting up a Carbon Monoxide Poinsonning Registry -**Marie-Anne Magnan**
4. 19100 - Tinnitus Evolution in Patients with Sudden Sensorineural Hearing Loss treated with Hyperbaric Oxygen Therapy - **Sofia Teles**
5. 19407 - Hyperbaric Oxygen Therapy in Bisphosphonate-Related Osteonecrosis of the Jaw: the experience of a Portuguese Hyperbaric Medicine Unit - **Ana Rita Aguiar**
6. 19307 – Hyperbaric oxygen therapy in the treatment of late-onset haemorrhagic cystitis after allogeneic haematopoietic stem cell transplantation - **Inês Portugal Rodrigues**
7. 19354 - Economical evaluation of hyperbaric oxygen therapy - **Pasquale Longobardi**
8. 19322 - HBOT in Post-COVID related fatigue, clinical predictors for response: a prospective single-center observational study - **Andreas Koch**

12.30 – 14:00 – Lunch and Poster Walk *(HBOT)*

Session 1

1. 19099 - Hyperbaric Oxygen Therapy as Adjuvant Treatment for Pharyngocutaneous Fistula – A Case Report – ***Sofia Teles***
2. 19230 - Hyperbaric oxygen therapy in the pediatric patients: Experience of the Tunisian hyperbaric center 2015 – 2022 - ***Imen Mezoughi***
3. 19235 - Efficacy and Prognostic Factors for Idiopathic Sudden Sensorineural Hearing Loss patients treated with adjuvant Hyperbaric Oxygen Therapy - ***Imen Mezoughi***
4. 19263 - Hyperbaric Oxygen Therapy in the Treatment of Acute Carbon Monoxide Poisoning During Pregnancy - ***Evangelos Papoutsidakis***
5. 19297 - Adjunctive hyperbaric oxygen therapy for necrotizing fasciitis:a case report – ***Joaquim Borba***
6. 19324 - Carbon Monoxide Poisoning In Children Treated With Hyperbaric Oxygen Therapy - ***Evangelos Papoutsidakis***
7. 19329 - Comparison of two innovative 3D scanning methods for evaluating the efficacy of HBOT in the treatment of chronic wounds - ***Peter Varga***
8. 19389 - Risks to inside chamber attendants during hyperbaric treatment: three case report in a multiplace hyperbaric chamber – ***Carla Amaro***
9. 19408 - Hyperbaric Oxygen Therapy for the Adjuvant Treatment of Pyoderma Gangrenosum: cases treated at a Portuguese Hyperbaric Medicine Unit – ***Rui Ramos***
10. 19411 - Seven times DCS within the last 25 years: why? - ***Jochen D Schipke***
11. 19415 - Carbon monoxide poisoning in children : Contribution of hyperbaric oxygen therapy in the late phase - ***Gharsallah Hedi***
12. 19417 - Hyperbaric Oxygen Therapy in the treatment of necrotising infections of the skin and soft tissues – ***Guilherme Bernardo***
13. 19449 – Clinical impact of hyperbaric oxygen therapy in necrotizing soft tissue infections of the limbs and the infectious challenges presented by it - ***André Silva***

Session 2

1. 19418 - Saving a limb – ***Inês Moreira***
2. 19438 - Hyperbaric oxygen and negative pressure therapy a good option in Fournier's gangrene – ***Inês Barbosa Moreira***
3. 19439 - The use of hyperbaric in a 12th month baby to reduce amputation level – Sofia Teles
4. 19445 - Cerebral arterial air embolism, a rare complication after hyperbaric oxygen treatment – ***Cláudia Pereira***
5. 19448 - Patient with Severe Carbon monoxyde Poisoning and early ischemic lesions of the brain revealed by MRI treated with HBO sessions for 1 week, no delayed neuropsychiatric sequelea observed - ***Marie-Anne Magnan***
6. 19453 - Non-typical neurologic manifestation during hyperbaric oxygen therapy – ***Cláudia Pereira***
7. 19454 - Unexpected and unforeseen asthma exacerbation during initial Hyperbaric Oxygen Therapy (HBOT): a Case Report – ***Andrea Galvani***
8. 19457 - The Experience of a Center for Underwater and Hyperbaric Medicine – ***Ana Pereira***
9. 19458 - Applications of nuclear medicine in the assessment of hyperbaric oxygen therapy response – ***Bárbara Pereira***
10. 19460 - When hyperbaric oxygen therapy surpasses the complications of crohn's disease – ***Rita Fernandes***
11. 19461- Comparing the perceived health status of patients after hyperbaric oxygen treatment – an observational study – ***Paula Rebelo***
12. 19463 - Hyperbaric patient classification – A novel approach to improve stratification of level of care - ***Carla Amaro***
13. 19462 - Outcome of necrotizing soft tissue infections with and without Hyperbaric therapy and correlation with prognostic scores - ***André Silva***

14:00 – 14:30 – Keynote Lecture 2 - "HBOT and oxygen as a key regulatory component in severe infections treatment" - Ole Hyldegaard

14:30 – 16:30 – Session II – Oral Communications – *HBOT*

Chairs: António Pedro Ferreira, Vangelis Poupostadakis

1. 19267- Hyperbaric oxygen treatment regulates inflammatory markers and pathways in patients with necrotizing soft tissue infection, pre-liminary results from the HBOmic study - **Julie Vinkel**
2. 19464 - Evaluation of patients referred for HBOT after high magnitude earthquakes: experience of a university hospital HBOT unit - **Bengusu Mirasoglu**
3. 19450 - Hyperbaric oxygen as an adjuvant treatment in chronic osteomyelitis: results from a single center between 2006 and 2022 - **Catarina Nogueira Pinto**
4. 19502 - High-level education on diving and hyperbaric medicine. A 40 years history from CRIS-UTH, the hyperbaric therapy unit of Barcelona - **Jordi Desola**
5. 19365 - GABA and Sensitivity to Seizures in Repeated Exposure to HBO2 - **Heath Gasier**
6. 19421- Comparing the EMMA capnograph with sidestream capnography and arterial carbon dioxide pressure at 284 kPa - **Xavier Vrijdag**
7. 19395 - Prospective validation of the Portuguese Navy Radiation-Induced Cystitis (PNRC) Scale in the assessment and monitoring of radiation-induced cystitis in response to hyperbaric oxygen therapy - **Carla D'Espiney Amaro**

16:30 – 17:00 – Coffee Break

17:00 – 18:45 – Session III – Oral Communications – *HBOT*

Chairs: Clara Gaio Lima, Michal Hajek;

1. 19452 - The Effects of Hyperbaric Oxygen Therapy in the Treatment of Patients with Central Retinal Artery Occlusion - A Long-term Retrospective Study - **Filipa Maldonado**
2. 19340 - The Effectiveness of Hyperbaric Oxygen Therapy for Managing Radiation-Induced Urethral Late Complications – A Retrospective Study - **Hugo Nunes**
3. 19416 - HOT Bladder; Hyperbaric Oxygen Therapy for radiotherapy induced haematuria of the Bladder - **Wilma Monincx**
4. 19335 - The Effectiveness of Hyperbaric Oxygen Therapy for Managing Radiation-Induced Proctitis – A Retrospective Study- **António Monteiro**
5. 19347 - Hyperbaric oxygen rapidly improves tissue-specific insulin sensitivity and mitochondrial capacity in humans with type 2 diabetes: a randomised placebo-controlled crossover trial - **Sven Dreyer**
6. 19403 - The effects of hyperbaric oxygen therapy on insulin resistance – an approach to physiology - **Mafalda Sampaio-Alves**
7. 19317 - Effect of hyperbaric oxygen therapy on recovery of young well-trained swimmers during high training load training camp - **Frano Marinelli**

PROGRAM

SEPTEMBER 15TH

08:00 – 09:00 – Gathering and Registration

09:00 – 09:30 – Keynote Lecture 3 - "Challenges in the Arctic Diving" - Anne Räisänen-Sokolowski

09:30 – 11:00 – Session IV – Oral Communications – *Diving*

Chairs: Carla Espiney Amaro, Bengusu Mirasoglu

1. 19334 - Review of saturation decompression procedures used in commercial diving – **Jean-Pierre Imbert**
2. 19353 - Medical assistance to a saturation diving project at 1457 meters (4780 feet) above sea level - **Pasquale Longobardi**
3. 19433 - Hypercapnia in normobaric and hyperbaric environments - **Hanna Van Waart**
4. 19303 - The Effect of a Single CCR Decompression Dive in arctic cold water to Cardiac Function - **Laura Tuominen**
5. 19357 - Genomic, Proteomic, and Oxidative Responses Associated with Hypercapnic Hyperoxia - **Luke Belval**
6. 19351- Review of 10 years of Closed-Circuit Rebreather Fatalities - **Frauke Tillmans**

11:00 – 11:30 – Coffee Break

11:30 – 13:00 – Session V - Oral Communications – *Diving*

Chairs: Pedro Barata, Francois Guerrero

1. 19374 - USAP Antarctic Diving Decompression Illness Cases and Treatment - **Kristi Ray**
2. 19419 - Point of care ultrasound (pocus) in injured divers - **Eduardo García**
3. 19344 - Can zebrafish scuba dive? The effect of hyperbaric oxygen on the brain - **Ayelet Hallakoun**
4. 19422 - What is the best treatment for severe spinal cord decompression sickness in hyperbaric center? - **Jean-Eric Blatteau**
5. 19352 - Chronic fatigue/pain syndrome after DCS- a Medical Zebra or a hidden disease? - **Anders Kjellberg**
6. 19505 - A review of 149 Divers Alert Network emergency call records involving diving minors - ***Matias Nochetto***

13.00 – 14:30– Lunch and Poster Walk *(Diving)*

Session 3

1. 19103 - Working abroad: Designing safety, health and well-being also an issue for professional diving and hyperbaric work - ***Silvester Siegmann***
2. 19126 - Exhaled breath markers of pulmonary oxygen toxicity after operational heliox diving to 81 meters - ***Feiko De Jong***
7. 19368 - Analysis of Three Recreational Diver's Nutritional Intake Across Six Identical Dives - **Marie Anderson**
3. 19333 - Lung squeeze as a challenge to the event physician - analysis of injuries during deep freediving competition - ***Dragana Ivkovic***
4. 19364 - Myopization and Nuclear Cataract in Recreational Open-Circuit Diver After Diving Vacation - ***Sofia Sokolowski***
5. 19412 - The critical flicker fusion frequency: illumination matters? Note: This study is currently in progress - ***Jochen D Schipke***
6. 19432 - Nitrogen narcosis causes an dose-dependent increase in EEG functional connectivity - ***Xavier Vrijdag***
7. 19434 - Deep Closed Circuit Rebreather mixed gas diving: Gas emboli, Spirometry changes during a week-long liveaboard safari - ***Sigrid Theunissen***
8. 19016 - Comparison of DNA-damages after ex-vivo exposure to hyperbaric oxygen and UVA in peripheral mononuclear cells (PBMC) - ***Rieke Scharbrodt***
9. 19298 - Transcriptomic analysis of circulating immune cells during hyperoxic and hyperbaric stress reveals differentially expressed genes associated with iron and oxygen binding - ***Staci*** Thornton
10. 19361 - Hyperbaric oxygen preconditioning in postischemic acute kidney injury: Potential mechanisms of beneficial effect - ***Sanjin Kovacevic***

Session 4

1. 19442 - Arterial partial pressures of oxygen and use of arterial/alveolar ratio in SCUBA divers - ***Francesco Schiavone***
2. 19446 - Mild Cognitive Impairment in Hyperbaric Environment - ***Francesco Schiavone***
3. 19455 - Diagnostic approach to the appearance of successive neurological, cutaneous, cardiological and vascular symptoms after a dive. Clinical case - ***Lucile Daubresse***
4. 19479 - Analysis of email correspondence between sport medicine physicians and an expert group of dive medicine in the Netherlands - ***I Reus***
5. 19358 - Effect of hyperbaric stress on rat leukocytes and platelet: the impact on decompression sickness susceptibility - **Jérémy Orsat**
6. 19355 - A single-center retrospective study of complications during hyperbaric oxygen therapy - ***Krasimira Tsankova***
7. 19410 - Implantable Cardiac Devices Function Evaluation in Patients Submitted to Hyperbaric Oxygen Therapy: a retrospective study - ***Tiago Freitas***
8. 19413 - The use of in-situ simulation in hyperbaric medicine - ***Rebai Aicha***
9. 19414 - A prototype of hyperbaric chamber for simulation-based education - ***Gharsallah Hedi***
10. 19470 - Total Quality Management and Key Performance Indicators-KPI's in Hyperbaric Facilities - ***Angeliki Chandrinou***
11. 19321 - Implication of anti-inflammatory effects of HBOT in humans: Hyperbaric oxygenations restore the TH1/Th2 T cell balance and induce CD4posCD39pos. regulatory T cells - ***Sebastian Klapa***

14:30 – 15:45 – Session VI - Oral Communications – *Diving*

Chairs: Anne Räisänen-Sokolowski; Pasquale Longobardi

1. 19420 - Transthoracic echocardiography bubble testing in injured divers - **Eduardo García**
2. 19330 - Returning a Diver with Patent Foramen Ovale to Military Diving - **Ivan Low**
3. 19406 - Capillary leak syndrome triggered by an explosive decompression event - **Semer Wang**
4. 19107 - Distal arterial bubbles and decompression illness - **Ran Arieli**
5. 19323 - A deeper dive into DCS resistant rats allelic frequency modifications - **Dugrenot Emmanuel**

15:45 – 16:15 – Coffee Break

16:15 – 17:30 – Session VII - Oral Communications – *Diving*

Chairs: Karen Hasmiller; Oscar Camacho

1. 19356 - Bloodstream air microbubbles and decompression sickness resistance in rats - **Jérémy Orsat**
2. 19379 – Advanced Microscopic Assessments of Spinal Cord and Lymphatic Tissue in Swine with Severe Decompression Sickness - ***Rachel Lance***
3. 19332 - Swyer-James-MacLeod Syndrome in an Adult Military Diver: A Case Report - ***Haoran Gong***
4. 19318 - Using the dynamics of oxygen and carbon dioxide exchanges to describe nitrogen saturation / desaturation in hyperbaric environments - ***Michael Theron***
5. 19368 - Analysis of Three Recreational Diver's Nutritional Intake Across Six Identical Dives - ***Rhiannon Brenner***

19:30 – Gala Dinner - Caves Ferreira (Port Wine Cellars)

*Dinner will also feature a **Fado** concert. A shawl, a guitar, a voice and a lot of feeling. A recognised symbol of Portugal, this simple image can describe Fado, a music of the world that is Portuguese.*

PROGRAM

SEPTEMBER 16TH

09:00 – 10:00 – EUBS General Assembly

10:00 – 10:30 – Keynote Lecture 5 - "FertyOx – Hyperbaric Oxygen in poor ovarian responders"- Miguel Raimundo

10:30 - 11:00 – Coffee Break

11:00 – 12:45 – Session VIII – Oral Communications - *Free Diving*

Chairs: Jacek Kot; Jordi Desola

1. 19349 - Can a laboratory-based static apnea test predict the diving response during deep diving? - **Eric Mulder**
2. 19331- Quantifying Hyperventilation in Freedivers Using a Force Sensor - **Frank Pernett**
3. 19345 - Adopting equipment and techniques from sports freediving to firemen surface rescuers shortens rescue time - **Erika Schagatay**
4. 19459 - What can a pulmonologist learn from freedivers? - **Igor Barković**
5. 19342 - End tidal carbon dioxide levels prior to serial apneas after the instruction: "Do Not Hyperventilate." - **Erika Schagatay**
6. 19346 - Application of a dry static apnea test to predict oxygen saturation nadir and static apnea performance - **Frank Pernett**
7. 19366 – Combined effects of prolonged fasting and hyperventilation on serial apnoeic performance: do risks outweigh the benefits? - **Antonis Elia**

12:45 - 13:15 – Closing Ceremony

PROGRAM TABLE

TUESDAY , SEPTEMBER 12TH			
	ROOM 1	**ROOM 2**	**ROOM 3**
16:00 - 16:30		**ExCO EUBS Meeting Part 1**	
16:30 - 17:00			
17:00 - 18:00			
WEDNESDAY , SEPTEMBER 13TH			
		ROOM 2	**ROOM 3**
08:30 - 09:00		**ExCO EUBS Meeting Part 2**	**Workshop on Monoplace Hyperbaric Chamber Safety** Sponsored by Perry Baromedical and EU Representatives
09:00 - 09:30			
09:30 - 10:00			
10:00 - 10:30			
10:30 - 11:00		**ExCO EUBS Meeting Part 2**	**Workshop on Monoplace Hyperbaric Chamber Safety** Sponsored by Perry Baromedical and EU Representatives
11:00 - 11:30			
11:30 - 12:00			
12:00 - 12:30		**ExCO EUBS Meeting Part 2**	**Workshop on Monoplace Hyperbaric Chamber Safety** Sponsored by Perry Baromedical and EU Representatives
12:30 - 13:00			
13:00 - 13:30			
13:30 - 14:00			
14:00 - 14:30			
14:30 - 15:00	**WORKSHOP 2** Scientific Writing	**WORKSHOP 1** Clinical Research in HBOT	**WORKSHOP 3** Management of the critically ill patient in The Hyperbaric Medicine Unit (Nuts and bolts)
15:00 - 15:30			
15:30 - 16:00			
16:00 - 16:30			
16:30 - 17:00	**WORKSHOP 2** Scientific Writing	**WORKSHOP 1** Clinical Research in HBOT	**WORKSHOP 3** Management of the critically ill patient in The Hyperbaric Medicine Unit (Nuts and bolts)
17:00 - 17:30			
17:30 - 18:00			
THURSDAY , SEPTEMBER 14TH			
	AUDITORIUM	**ROOM 2**	
08:30 - 09:00	Gathering and Registration		
09:00 - 09:30	Opening Ceremony		
09:30 - 10:00	**Keynote Lecture 1**		
10:00 - 10:30	*Coffee Break*		
10:30 - 11:30	Session I – Oral Communications		
11:30 - 12:30			
12:30 - 13:00	*Lunch and Poster Walk*		
13:00 - 13:30		**EDTC Meeting**	
13:30 - 14:00			
14:00 - 14:30	**Keynote Lecture 2**		
14:30 - 15:00	Session II – Oral Communications		
15:00 - 15:30			
15:30 - 16:00			
16:00 - 16:30		**DAN DMO Meeting**	
16:30 - 17:00	*Coffee Break*		
17:00 - 17:30	Session III – Oral Communications		
17:30 - 17:45			
18:00 - 18:30			
18:30 - 18:45			

PROGRAM TABLE

FRIDAY, SEPTEMBER 16TH		
	AUDITORIUM	**ROOM 2**
08:00 - 09:00	Gathering and Registration	**EBASs Meeting**
09:00 - 09:30	**Keynote Lecture 3**	
09:30 - 10:00		
10:00 - 10:30	Session IV – Oral Communications	
10:30 - 11:00		
11:00 - 11:30	*Coffee Break*	
11:30 - 12:00	Session V – Oral Communications	
12:00 - 12:30		
12:30 - 13:00		
13:00 - 13:30	*Lunch and Poster Walk*	
13:30 - 14:30		
14:30 - 15:15	Session VI – Oral Communications	
14:45 - 15:00		
15:00 - 15:30		
15:30 - 15:45		
15:45 - 16:00	*Coffee Break*	*Coffee Break*
16:15 - 17:00	Session VII – Oral Communications	**ECHM Meeting**
17:00 - 17:30		
17:30 - 17:45		
18:00 - 18:30		
18:30 - 19:00		
19:00 - 19:30		

SATURDAY, SEPTEMBER 16TH	
	AUDITORIUM
09:00 - 09:30	**EUBS General Assembly**
09:30 - 10:00	
10:00 - 10:30	**Keynote Lecture 4**
10:30 - 11:00	*Coffee Break*
11:00 - 11:30	Session VIII – Oral Communications
11:30 - 12:00	
12:00 - 12:45	
12:45 - 13:15	**Closing Ceremony**

ORAL PRESENTATIONS

Clinical HBOT

CL - (19100) - TINNITUS EVOLUTION IN PATIENTS WITH SUDDEN SENSORINEURAL HEARING LOSS TREATED WITH HYPERBARIC OXYGEN THERAPY

Sofia Teles (Portugal)[1]; Luis Freitas (Portugal)[2]; Joana Cardoso (Portugal)[1]; Guilherme Bernardo (Portugal)[1]; Jose Menezes (Portugal)[1]; Rita Fernandes (Portugal)[1]; Carla Amaro (Portugal)[1]

1 - Centro de Medicina Subaquática e Hiperbárica; 2 - Grupo HPA Saude

Abstract

Introduction: Sudden sensorineural hearing loss presents with tinnitus in up to 90% of cases. Tinnitus constitutes a subjective complaint, therefore hard to quantify and evaluate. Hyperbaric oxygen therapy (HOT) constitutes a valuable adjunctive therapy in patients who are only parcially responsive or refractory to corticoid treatment, but the effect it may have on tinnitus remains poorly studied.

Goals: To evaluate HOT effect on tinnitus and audiometric evolution in sudden sensorineural hearing loss with tinnitus, refractory to corticoid treatment.

Methods: This paper presents a prospective non-controlled study that applied Tinnitus Handicap Inventory (THI) before and after treatment with HOT. The study was carried in the Portuguese Navy's Center for Hyperbaric and Subaquatic Medicine, between May and December, 2018. The Center's HOT protocol included on average 20 sessions at 2.5 ATM for 90 minutes. The statistic analysis was performed using IBM SPSS Statistics 26 software. Resuls: 57 patients were included in the study, with ages between 25-78 years (average 51), 50.8% female. The average time between symptom onset and HOT was 34,9 days. We were able to make an inverse correlation between the symptom-treatment window and hearing outcomes (p=0,045). The average hearing outcome was of 17dB. According to Spiegel's hearing outcome classification, there was complete recovery in 19% of patients, parcial recovery in 23%, slight improvement in 33% and no improvement in 25% of patients. Regarding tinnitus, most patients had a THI classification of grade 3 or 4 before treatment (71%). After treatment, 77% of patients presented a THI score <3. We observed an improvement of THI classification even in patients with no audiometric improvement.

Conclusion: This data concludes that, besides improving hearing outcomes, HOT seems to have a positive effect in improving tinnitus and it's impact in the patient's quality of life. Patients should be referred to HOT treatment as soon as possible, since the window between symptom onset and HOT treatment has a significant effect on hearing outcomes.

Bibiographical References

Kuhn M, Heman-Ackah SE, Shaikh JA, Roehm PC. Sudden Sensorineural Hearing Loss: A Review of Diagnosis, Treatment, and Prognosis. Trends Amplif. 2011;15(3):91-105. doi:10.1177/1084713811408349

Schreiber BE, Agrup C, Haskard DO, Luxon LM. Sudden sensorineural hearing loss. Lancet. 2010;375(9721):1203-1211. doi:10.1016/S0140-6736(09)62071-7

Murphy-Lavoie H, Piper S, Moon RE, Legros T. Hyperbaric oxygen therapy for idiopathic sudden sensorineural hearing loss. Undersea Hyperb Med. 2012;39(3):777-792.

Konstantina, G; Fildissis, G; Zyga, S; Baltopoulos G. The Clinical Efficacy of Hyperbaric Oxygen Therapy in Idiopathic SSNHL and Tinnitus. Heal Sci J. 2015;10(1).

Joshua, TG; Ayub, A; Wijesinghe, P; Nunez D. Hyperbaric Oxygen Therapy for Patients With Sudden Sensorineural Hearing Loss: A Systematic Review and Meta-analysis. JAMA Otolaryngol - Head Neck Surg. 2022;Jan 1(148(1)):5-11.

Keywords: Sudden deafness, tinnitus, hyperbaric oxygen therapy, sensorineural hearing loss

Decompression Theory and Mechanisms

CL - (19107) - DISTAL ARTERIAL BUBBLES AND DECOMPRESSION ILLNESS

Ran Arieli (Israel)[1]

1 - Israel Naval Medical Institute

After decompression, at any arterial bifurcation, blood flow decreases in each vessel. With the distance from the heart, the vessel's diameter is reduced, which increases the surface area available for diffusion with respect to blood volume. In addition, the reduced vessel wall thickness reduces the diffusion barrier. Thus, the diffusion of inert gas from the tissue into the blood will rise along the arterial tree. This may cause the expansion of bubbles at an active hydrophobic spot (AHS) within the distal arteries. We calculated the nitrogen tension after decompression along the cerebral arterial tree and found a rise in the distal artery known as the anterior cerebral artery A2. Due to the absence of an oxygen-window in the arterial blood, a distal bubble would remain in place for a long time, and expand further in the next decompression. PFO shunted bubbles may coalesce with the stationary distal arterial bubble and cause further expansion. The mechanism of distal arterial bubble explains Taravana and neurological injury in breath-hold diving, lesions in the white matter and neurological insults in divers and pilots, vestibular DCI and increased vulnerability to DCI in the spinal cord.

Keywords: Diving, breath-hold

Basic research in HBOT

CL - (19267) - HYPERBARIC OXYGEN TREATMENT REGULATES INFLAMMATORY MARKERS AND PATHWAYS IN PATIENTS WITH NECROTIZING SOFT TISSUE INFECTION, PRE-LIMINARY RESULTS FROM THE HBOMIC STUDY

Julie Vinkel (Denmark)[1,4]; Leonor Rib (Denmark)[2]; Alfonso Buil (Denmark)[3]; Morten Hedetoft (Denmark)[1]; Ole Hyldegaard (Denmark)[1]

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Abstract

Background: Necrotizing soft tissue infections (NSTI) are associated with sepsis, septic shock, and multi-organ failure. These systemic manifestations are induced by maladaptive alterations in circulatory, cellular, and metabolic activities, which culminate in a dysregulated host response [1]. The key transcription factor in the hyperinflammatory phase of sepsis is NF-κB [2], and this signaling pathway is known to cross talk with the oxygen sensing pathway HIF-1α, that is activated in response to variations in cellular oxygen levels [3]. The present study explored the systemic effects of hyperbaric oxygen (HBO_2) treatment in the acute phase of NSTI by assessing gene expression responses to HBO_2 treatment in lymphocytes.

Methods: We conducted an observational cohort study using prospectively collected data on 85 NSTI patients hospitalized to the intensive care unit. All patients had received one or two HBO_2 treatments in the acute phase of the disease. One blood sample was collected before and one blood sample after the intervention. Total RNA was obtained from all samples, followed by mRNA purification with rRNA depletion and whole-transcriptome RNA sequencing. The genes that were differentially expressed between the two conditions were annotated by gene enrichment analysis using KEGG (Kyoto Encyclopedia of genes and Genomes) and screened for inflammatory factors. All analysis were corrected for multiple testing with FDR.

Results: More than 300 protein coding genes were significantly differentially expressed between before and after intervention with HBO_2 treatment. The proinflammatory cytokines IL-1β (FDR = 0.008) and TNFSF13B (FDR = 2.45E-05) were downregulated, whereas IL-32 was upregulated at the gene expression level, and the NF-κB pathway was found to be enriched among the downregulated genes. The anti-inflammatory cytokine IL-10 was significantly upregulated (FDR = 6,76E-07).

Discussion: Using a data driven unbiased approach we identified genes coding for inflammatory cytokines and pathways that are altered during HBO_2 treatment in NSTI. The three downregulated cytokines IL-1β, TNFSF13B and IL-10 have previously been demonstrated to be positively correlated with disease severity in severe infections [4-6], and the encoding genes all contain HIF-1α responsive promoters [7-9]. The upregulated IL-23 is a multifaceted cytokine with both proinflammatory and anti-inflammatory actions, that is known to be regulated by HIF-1α at protein expression level [10]. This suggests that HBO_2 treatment may ameliorate the pathological immune response in sepsis brough on by NSTI through HIF-1α mediated signaling.

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Keywords: Hyperbaric oxygen, Necrotizing soft tissue infection, Sepsis, Inflammation

Diving Medicine

CL - (19303) - THE EFFECT OF A SINGLE CCR DECOMPRESSION DIVE IN ARCTIC COLD WATER TO CARDIAC FUNCTION

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Abstract

Introduction: Dive-induced cardiac and hemodynamic changes are caused by various mechanisms, and they are aggravated by cold water (Reid 1986, Muth 2004, Marabotti 2013). Therefore, ageing divers with pre-existing cardiovascular conditions may be at risk of acute myocardial infarction, heart failure or arrhythmias while diving (Asmul 2017, Buzzacott 2021). The aim of this study was to assess the effect of a single decompression CCR dive in arctic cold water on cardiac function in Finnish technical divers.

Materials and methods: Thirty-nine divers performed one identical 45 mfw dive in 2 - 4 °C water. Hydration and cardiac function were assessed before and after the dive. Detection of venous gas embolization was performed within 120 minutes after the dive according to the extended Eftedal-Brubakk scale (Brubakk 2001).

Results: The divers were affected by both pressure and cold water induced hemodynamic changes and fluid loss. During a 64 min dive (IQR 58 - 70 min), a median weight loss was 0.9 kg (IQR 0.5 - 1.1 kg) and a median urine density decrease was 0.004 g/mL (IQR 0.001 - 0.006 g/mL). Pre- and post-dive echocardiography showed worsening in multiple systolic and diastolic parameters, for details please see Table 1. Venous inert gas bubbles were detected in all divers except for one. Venous gas embolism did not affect systolic or diastolic function.

Discussion: A single trimix CCR dive in arctic cold water seemed to debilitate both systolic and diastolic function. It is novel and noteworthy that all the parameters declined. Although the changes were subtle, they appeared parallel over several parameters. This indicates a real post-dive deterioration in cardiac function instead of only volume dependent changes. These changes are without a clinical significance in healthy divers. However, in a population with pre-existing heart problems, such changes may provoke symptomatic problems during or after the dive. Therefore, it is essential to carefully assess possible underlying cardiovascular risk factors in “fit-to-dive” evaluation.

Table 1. Changes in echocardiography.

Variable	Baseline	Post dive	% change	*p*-value
Structures				
LA	35 (33 - 37.5)	34 (31.5 - 36)	-2.5%	0.015
LVEDD	53 (50 - 55.5)	52 (50 - 55)	0.0%	0.677
LVEDD index	26.14 (24.02 - 27.14)	26.13 (24.21 - 26.95)	0.3%	0.530
LVESD	33 (31 - 35.5)	33 (31 - 36)	2.9%	0.049
LVESD index	16.48 (14.87 - 17.02)	16.68 (15.08 - 17.63)	3.2%	0.006
LVLd A4C	94 (89.5 - 99)	93 (89 - 100)	-1.0%	0.084
LVLd A2C	92 (88 - 98)	91 (87.5 - 99)	0.0%	0.166
LVOT	23 (22 - 25)	23 (22 - 24.5)	0.0%	0.824
Ao asc	31 (29 - 32)	30 (29 - 32)	0.0%	0.028
IVC	20 (18.5 - 22.5)	18 (17.25 - 21)	-5.3%	0.396
IVS	9 (8.5 - 10)	9 (9 - 10)	0.0%	0.530
Systolic function				
HR	70 (64.5 - 78.5)	71 (59 - 80)	0.0%	0.255
EF	67 (65 - 69)	65 (62 - 69)	-1.5%	0.019
ET	274 (255 - 292.5)	280 (261.5 - 294)	2.7%	0.002
LV CO	6.74 (5.88 - 7.49)	6.14 (5.53 - 7.05)	-7.3%	0.004
LV CO index	3.26 (3.04 - 3.76)	3.04 (2.74 - 3.48)	-7.0%	0.005
LV SV	94.5 (87.5 - 107.5)	92.5 (81.25 - 106.5)	-3.3%	0.035
LV SV index	46.67 (42.24 - 53.85)	44.96 (40.03 - 52.71)	-2.9%	0.046
MAM	15 (13 - 16)	14 (12 - 15)	0.0%	<0.001
SS'	7 (6.5 - 8)	7 (6 - 7)	-12.5%	0.003
Flow rate	0.340 (0.32 - 0.43)	0.335 (0.29 - 0.4)	-8.5%	0.003
RS	13 (12 - 15)	13 (12 - 14)	-5.6%	0.064
RVOT max	0.79 (0.74 - 0.88)	0.74 (0.69 - 0.82)	-8.5%	<0.001
RVOT time	130 (115.5 - 140.5)	125 (110.5 - 138)	-4.3%	0.021
TAPSE	25 (23 - 27)	24 (22 - 26)	-3.7%	0.003
MPI	0.6 (0.48 - 0.67)	0.63 (0.55 - 0.74)	8.5%	<0.001
Diastolic function				
IVRT	92 (71 - 101.5)	99 (85.5 - 115)	14.6%	<0.001
MV E	0.76 (0.68 - 0.89)	0.69 (0.58 - 0.78)	-13.2%	<0.001
MV E Dect	188 (175.5 - 195)	211 (190.5 - 239.5)	8.2%	<0.001
MV A	0.62 (0.54 - 0.71)	0.59 (0.5 - 0.66)	-8.0%	0.056
MV E/A	1.2 (1.06 - 1.4)	1.1 (0.95 - 1.48)	-8.6%	0.022
SE'	11 (9 - 12)	10 (8 - 10.5)	-11.1%	<0.001
E/E'	7 (6.13 - 8.23)	7.3 (6 - 8.31)	-2.8%	0.777
SA'	10 (8.5 - 11)	10 (8.5 - 11)	0.0%	0.205
LA	35 (33 - 37.5)	34 (31.5 - 36)	-2.5%	0.015
RE'	14 (12 - 16)	13 (11 - 14.5)	-8.3%	0.018
R A	14 (12 - 15)	13 (12 - 16)	0.0%	0.774

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Keywords: Cardiovascular, Echocardiography, Rebreathers, Technical diving

Clinical HBOT

CL - (19305) - FROM A RESTROSPECTIVE ANALYSIS TO SETTING UP A CARBON MONOXIDE POINSONNING REGISTRY

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Abstract

Introduction: Carbon Monoxide Poisoning(CMP) is the first cause of death due to poisoning; in Europe the death rate is about 5%. According to the ECHM's 10th European conensus conference, CMP is an indication for HBO (hyperbaric oxygenotherapy) with Grade 1B recommendation level but medical care protocols vary from center to center.

The Unit Center of Underbaric and Hyperbaric Medecine at the University Hospitals of Geneva, has analyzed retrospective data from 2011 to 2019 on CMP : results have shown 22.6 CMP per year until 2013, 22% of which were suicide attempts. Since 2013, we have noted an exponential increase in the number of patients with CMP (48.6 cases per year of which 11 % were suicides). This significant increase in the number of cases is due to the development and recognition of hyperbaric medicine. However this analysis also shows there is a lack of relevant information in medical files as Spco, Hbco, medical care delay…

Methods: An online registry is a modern way to collect cases from different geographical origins. It should allow working on larger retrospective and prospective series and sharing knowledge amongst different centers. We have set up a standardized and secure registry on RED-CAP file. The goal is to gather relevant data about CMP from multiple centers around the world. This registry reflects different ways of approaching CMP and its sequelae. It compiles all necessary information for a detailed analysis including a medical follow-up month after the CMP to diagnosis delayed neurological sequelae. The Data-base has been validated by Geneva Ethics Committee. From year 2020, all data have been registered propsectively. It allows for new standardized results.

Conclusion: The aim of sharing the CMP registry is to standardize medical practices (medical care protocols, criteria of severity, HBO treatment protocol…). Reliable, objective and multicentric analysis of results could also determine better the incidence of delayed neurological sequelae after HBO versus normobaric oxygentherapy.

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Keywords: Carbon Monoxyde Poisonning,, registry, HBO, Delayed neurological sequelae, medical recommendation

Clinical HBOT

CL - (19307) - HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF LATE-ONSET HAEMORRHAGIC CYSTITIS AFTER ALLOGENEIC HAEMATOPOIETIC STEM CELL TRANSPLANTATION

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Abstract

INTRODUCTION

Hemorrhagic cystitis (HC) is a common complication after allogeneic hematopoietic stem cell transplantation (HSCT), characterized by inflammation and bleeding of the bladder [1]. Late presentation of HC is a severe complication that can lead to reduced quality of life for affected patients [2]. Hyperbaric oxygen therapy (HBOT) has been shown to be effective in the treatment of HC [2-3]. However, limited research has been conducted on the use of HBOT in managing late presentation HC after allogeneic HSCT. The aim of this study was to evaluate the response rate after HBOT in patients with late-onset HC after allogeneic HSCT.

MATERIALS AND METHODS

Data were collected retrospectively from the clinical records of patients who received HBOT for late presentation HC after allogeneic HSCT between 1998-2022 in two centers in Portugal. Complete clinical response was defined as the absence of macroscopic haematuria sustained for at least 2 weeks and partial clinical response was described as a downgrading in the severity of cystitis (CTCAE v5.0). The microbiological response was also evaluated in patients with detection of the BK polyomavirus in the urine, defined as a reduction of at least 1 log in the urinary BK viral load, determined by PCR [4-6]. Statistical analysis using SPSS® included descriptive, sequential, and inferential methods to compare patients with clinical responses to those with no response. T-tests, Mann-Whitney tests, and Fisher's and Chi-square tests were used, with Binary Logistic Regression to determine independent predictors and potential confounders.

RESULTS

The sample included 61 patients with a median age of 30,0 years, 33 males. Table 1 details the clinical characteristics of the patients. Complete response was achieved in 72,1% (n = 44) of patients and partial response in 14,8% (n = 9). Concerning patients with a complete response, the median number of HBOT sessions was 15,5 sessions (range, 4-85 sessions). Patients treated with 10 or more sessions of HBOT had a higher rate of complete or partial response (OR = 13,1; 95% CI: 2,5-69,0; p = 0,003). There was no response in 8 (13,1%) patients and 6 of them interrupted the treatments early due to opportunistic infection, progression of oncological pathology, acute graft-versus-host disease or adverse event of HBOT. Only 2 patients suspended the HBOT due to a lack of benefit. Of the patients with BK polyomavirus detection in the urine, 63,0% (n = 34) had a microbiological response. Additionally, 25,9% (n = 14) had worsening or maintained quantitative viral loads but still exhibited resolution of macroscopic haematuria.

VARIABLE	n (%)
Age (years), median [range]	30,0 [1-66]
Pediatric Age	16 (26,2%)
Sex	
Male	33 (54,1%)
Female	28 (45,9%)
Primary diagnosis	
Malignant Haematological Pathology	55 (90,2%)
Nonmalignant Haematological Pathology	8 (13,1%)
Type of conditioning	
Chemotherapy only	56 (91,8%)
Total Body Irradiation based	5 (8,2%)
Stem cell source	
Peripheral Blood Stem Cells	53 (86,9%)
Bone Marrow	5 (8,2%)
Umbilical Cord Blood	3 (4,9%)
Type of donor	
Unrelated Donor	38 (62,3%)
Related Donor	23 (37,7%)
Time between HSCT and onset of HC (days), median [range]	33,0 [7-145]
Hematuria Degree	
Grade II	42 (68,9%)
Grade III	19 (31,1%)
Virus Identification in Urine*	
BK polyomavirus	54 (88,5%)
Adenovirus	16 (26,2%)
Cytomegalovirus	3 (4,9%)
No virus identification	2 (3,3%)
Time between onset of HC and the beginning of HBOT (days), median [range]	17,0 [4-123]
Number of HBOT Sessions, median [range]	17,0 [4-85]
HBOT treatment profile	
2,5 ATA, 90'	23 (37,7%)
2,4 ATA, 90'	19 (31,1%)
2,1 ATA, 90'	13 (21,3%)
2,4 ATA, 80'	6 (9,8%)
Clinical Response to HBOT	
Complete Response	44 (72,1%)
Partial Response	9 (14,8%)
No Response	8 (13,1%)
Microbiological response to BK polyomavirus after HBOT	34 (63,0%)
HBOT adverse events	6 (9,8%)

TABLE 1 Details of clinical characteristics of the patients, allogeneic hematopoietic stem cell transplantation, hemorrhagic cystitis and hyperbaric oxygen therapy treatments. HSCT - Haematopoietic Stem cell Transplantation, HC - Haemorrhagic Cystitis, HBOT - Hyperbaric Oxygen Therapy, ATA - Atmosphere Absolute. *the number of viral agents exceeds the sample number once several viral agents have been identified in the same individual

CONCLUSION

Our study supports the use of HBOT as an adjunctive treatment for late-onset HC after allogeneic HSCT. The majority of patients achieved a complete or partial response, with better outcomes observed in those who received 10 or more HBOT sessions. However, further randomized controlled trials are needed.

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Keywords: Haematopoietic Stem Cell Transplantation, Bone Marrow Transplant, Haemorrhagic Cystitis, BK Polyomavirus Infection, Hyperbaric Oxygen Therapy

Clinical HBOT

CL - (19317) - EFFECT OF HYPERBARIC OXYGEN THERAPY ON RECOVERY OF YOUNG WELL-TRAINED SWIMMERS DURING HIGH TRAINING LOAD TRAINING CAMP

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Abstract

Aim: In competitive sports, optimizing both exercise as well as recovery components is crucial for progressive performance growth and fitness level maintenance [1]. The proposed mechanisms by which hyperbaric oxygen therapy (HBOT) may increase the rate of recovery from soft tissue injury include reduction of local hypoxia and inflammation, promotion of vasoconstriction, reduction of neutrophil adhesion, free radical quenching, control of edema and many others [2,3]. We hypothesized that treatment with 100% oxygen in a hyperbaric environment will favor the recovery of markers of anabolic/catabolic status and muscular damage as well as the perception of recovery among participating athletes during the 14-days training camp.

Methods: A double-blind, randomized, 1:1 ratio, placebo-controlled study of 16 healthy well-trained youth swimmers of the Croatian National Swimming Team. The swimmers were exposed to daily sessions (Monday to Friday, pause on Saturday and Sunday) in a multiplace hyperbaric chamber of either HBOT (2,4 absolute atmospheres (ATA), breathing 100% oxygen for 1 hour) or SHAM (1,3 ATA, breathing air for 1 hour). Training volume, rate of perceived exertion (RPE), sleeping quality, nutritional intake and continuous glucose monitoring (CGM) parameters were collected daily, cardiopulmonary exercise testing (CPET) was done before and after the training camp while blood parameters (complete blood count, blood urea nitrogen, glucose, creatinine, AST, ALT, CK, LD, GGT, Fe, UIBC, TIBC, ferritin, hs-CRP, hs-troponin T, NTpro-BNP, total proteins, TSH, fT3, fT4, testosterone) were collected every two days in the morning throughout the training camp.

Results: Volume and intensity of training was equal for both groups. RM Anova and Friedman tests showed no significant differences amongst the CGM night parameters (minimum, average and stability) and the sleeping quality of two groups ($p > 0.05$). Regarding the blood parameters, only ferritin showed a significant rise across time in the HBOT group ($p = 0.045$). Daily CGM, CPET and nutritional intake data are still being analyzed.

Conclusions: Temporary inflammatory response and muscle damage was visible in both groups but there was no difference between the experimental conditions. The only statistically significant difference between groups was shown in ferritin values which were higher in the HBOT group. This might support better recovery of athletes during higher training loads often utilized during training camps.

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Keywords: athletes, athletic performance, hyperbaric oxygenation

Decompression Theory and Mechanisms

CL - (19318) - USING THE DYNAMICS OF OXYGEN AND CARBON DIOXIDE EXCHANGES TO DESCRIBE NITROGEN SATURATION / DESATURATION IN HYPERBARIC ENVIRONMENTS.

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Abstract

Introduction/Background: Epidemiological data from the Divers Alert Network (DAN) has shown that decompression sickness can occur in divers even when recommended decompression procedures are followed [1]. Furthermore, changing the physiological state of individuals can significantly affect bubbling variability [2,3]. These studies highlight the need for personalized physiological input to improve decompression models in scuba diving. Therefore, the main objective of this study is to propose a fundamental framework for a new approach to inert gas exchanges.

Materials and Methods: A physiological model of gas exchange has been constructed based on the delivery of oxygen to organs and tissues. The model consists of eight compartments: ambient air, airways, alveolar gas, arterial, capillary, venous and alveolar blood, as well as a single tissue compartment. A major interest of this model is that it can be adapted to inert gas exchange, allowing for the construction of nitrogen and helium models. The validation of the model was made by transferring the N_2 to the well-known respiratory gas CO_2.

Results: Under normobaric conditions (air breathing, oxygen breathing, and static apnea) and hyperbaric conditions, the O_2 model replicates the reference physiological PO_2 in all compartments (Spearman correlation tests $p<0.001$). The inert gas models can simulate inert gas partial pressures in various compartments of the model under normobaric and hyperbaric conditions. However, the lack of reference values prevents direct validation of the new model. Therefore, the N_2 model has been transferred to CO_2. The resulting CO_2 model has been validated by comparing it with physiological reference values (Spearman correlation tests $p<0.01$). The validity of the CO_2 model constructed from the N_2 model demonstrates the plausibility of this physiological model of inert gas exchanges.

Discussion/Conclusion: In the context of personalized decompression procedures, the proposed model is of significant interest as it enables the integration of physiological and morphological parameters (blood and respiratory flows, alveolo-capillary diffusion, respiratory and blood volumes, oxygen consumption rate, fat mass, etc.) into a relatively simple model of nitrogen saturation/desaturation, in which oxygen and CO_2 partial pressures can also be incorporated.

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Keywords: scuba diving, personalized decompression, physiological model, inert gaz, oxygen

Clinical HBOT

CL - (19322) - HBOT IN POST-COVID RELATED FATIGUE, CLINICAL PREDICTORS FOR RESPONSE: A PROSPECTIVE SINGLE-CENTER OBSERVATIONAL STUDY

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Abstract

Introduction

HBOT has been implicated as a therapeutical option in Post-COVID syndrome according to neuro-psychiatric syndromes such as fatigue (1,2). This study aimed at clinical predictors for response to HBOT in Post-COVID related fatigue.

Materials and Methods

We conducted a prospective single-center observational study using HBOT up to 30 sessions (2.4 atmospheres, 130 minutes, three 30-minute exposures to 100% oxygen, interspersed with 10-minute air breaks) at a total of 7 consecutive patients with diagnosed Post-COVID Syndrome by neurological examination, after therapy failure on standard therapy. Clinical data and patient-reported outcomes related to fatigue (chalder fatigue score, CFS) were assessed at the time of starting HBOT and after every single session up to 30 HBOT sessions.

Results

HBOT induced a significant reduction of Post-COVID related fatigue after 18 sessions of HBOT (P=0.0320). Clinical response (DCSF) on HBOT correlated negatively with disease duration and positively with initial level of fatigue (CFS baseline) (DCSF vs. disease duration: r^2=-0.65; DCSF vs. CFS Baseline: r^2=0.35).

Discussion

HBOT reduced Post-COVID related fatigue after 18 of maximum 30 sessions. Disease duration and the level of fatigue (CFS) could be clinical predictors for response.

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Keywords: HBOT, Post-COVID, Fatigue

Decompression Theory and Mechanisms

CL - (19323) - A DEEPER DIVE INTO DCS RESISTANT RATS ALLELIC FREQUENCY MODIFICATIONS.

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1 - Divers Alert Network; 2 - University of Brest

Abstract

Introduction / Background: Susceptibility to decompression sickness 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 3-fold greater resistance to DCS than standard ones after 6 generations. In order to better understand DCS mechanisms, we sought study some SNP tags along the genome that we reanalyzed in parallel of the sequencing of some genes related to inflammation and innate immunity.

Materials and Methods: Liver samples from 96 rats (Wistar and resistant rats) were analyzed through a Kompetitive allele specific PCR genotyping analysis on 48 tagSNPs chosen from a list of Wistar-specific SNPs described by Nijman et al. We have analyzed the genes around the SNP marker identified previously and whose allelic frequency has been modified, to relate them to the genes linked to inflammation and innate immunity that we have also sequenced during previous work.

Results: We identified 527 genes between Tag SNPs 37110132–37110212 and 80329108–80329188. By crossing these 527 genes with the targets of circulating microRNAs (miR) whose levels are modified in the tenth generation of our resistant rats, we have identified 56 potential targets and by crossing these targets against the transcripts whose expression is modified on the resistant rats, we found two matches in males and none in females: Mbtps2 and Vsig 4.

Summary / Conclusions: These results highlight the importance to sequence the whole genome of the resistant's rats and show possible implications of processes like the Endoplasmic Reticulum (ER) stress response or the regulation of T lymphocytes.

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Keywords: DCS, DCS resitant rats, genes, SNP

Diving Medicine

CL - (19330) - RETURNING A DIVER WITH PATENT FORAMEN OVALE TO MILITARY DIVING

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Abstract

Introduction: Patent Foramen Ovale (PFO) is a relatively common condition that increases the possibility of severe Decompression Illness (DCI) in divers due to paradoxical embolism from right-to-left shunt. The South Pacific Underwater Medicine Society (SPUMS) and the United Kingdom Sports Diving Medical Committee (UKSDMC) developed a position statement to provide risk stratification and offer guidance on management of PFO in divers. While this position statement offers guidance, there appears to be no open source reports of PFO in military divers. This case report aims to share a case of a military diver with a small PFO who has returned to diving, and to discuss the medical and occupational considerations.

Case description: A healthy 44-year-old Chinese male military diver, with a 20-year military and recreational diving history with no diving incidents, presented with transient loss of consciousness due to hypoxia during a mixed gas dive at the depth of 4m. As part of his work-up, he underwent extensive investigations, which included an agitated saline study revealing a small PFO. A Transesophageal Echocardiogram (TEE) confirmed the presence of a small PFO; <5 bubbles were seen on Valsalva. His neurological imaging and examinations were normal. The cardiologist also opined that his risk of DCI from PFO was low and advised for it to be managed conservatively. Given that his PFO was an incidental finding and he had no previous history of DCI, in alignment with SPUMS/UKSDMC position statement, the serviceman was allowed to resume diving activities with restrictions.

Discussion: In most established navies, PFO is a contraindication for entry into military diving. However, as screening for PFO via TEE is generally not advised, PFOs may not be picked up during the initial diver medical screening. There are currently no open source reports on the management of military divers with incidental PFOs picked up at later stages. The SPUMS/UKSDMC position statement shares three possible ways to manage PFOs in divers, one of which is to consider diving with restrictions. These restrictions aim to reduce the risk of DCI and range from dive time limitations to gas mixture modifications. Upon considering the position statement and the diver's mitigating factors, we convened a Diving Medical Board comprising Underwater Medicine Specialists, and allowed the diver to return to diving with restrictions.

Keywords: patent foramen ovale, military diving, diving medicine, occupational medicine, decompression illness

Diving Medicine

CL - (19331) - QUANTIFYING HYPERVENTILATION IN FREEDIVERS USING A FORCE SENSOR

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Abstract

Background: Hyperventilation before breath-hold diving (freediving) is a widely accepted risk factor for hypoxic syncope or blackout (BO). Hyperventilation increases the duration of apnea and leads to greater hypoxia. There is no practical way to address hyperventilation on-dives, as CO2 is hard to measure in wet environments. The study aimed to evaluate if the respiratory data obtained from a customized force sensor could predict end-tidal CO2 pressure (PE_TCO_2) before a breath hold.

Methods: Twenty-one healthy freedivers participated. The study was conducted during two national competitions (The data used in this study was collected as part of a larger research on performance prediction). The divers were instructed to breathe normally and to perform three apneas of 1, 2, and 3-minute duration at 2 min intervals in a sitting position while cardiorespiratory variables were recorded. The signal from the force sensor, attached to a chest belt (Fig. 1), was used to record the frequency and amplitude of the chest movements, and the product of those values in the 60 seconds before apnea was used in a model to predict PE_TCO_2.

Results: The mean PE_TCO_2 was below 35 mmHg before all apneas. The mean amplitude of the signal from the force sensor increased from apnea 1 to apnea 3 ($P < 0.001$, Table 1) while the respiratory rate was similar (NS). A linear regression established that the product of respiratory frequency and amplitude from the force sensor could predict PE_TCO_2 before apnea, with an accuracy within 0.5 mmHg (Table 1).

Conclusions: This study provides evidence that increased minute ventilation is primarily attributed to changes in tidal volume in freedivers. Furthermore, our findings demonstrate the feasibility of estimating hyperventilation using a waterproof force sensor attached to a chest belt. This novel approach holds promise for offering real-time guidance on the breathing pattern of freedivers, with a practical application in making a warning system to prevent hyperventilation, to avoid BO and drowning.

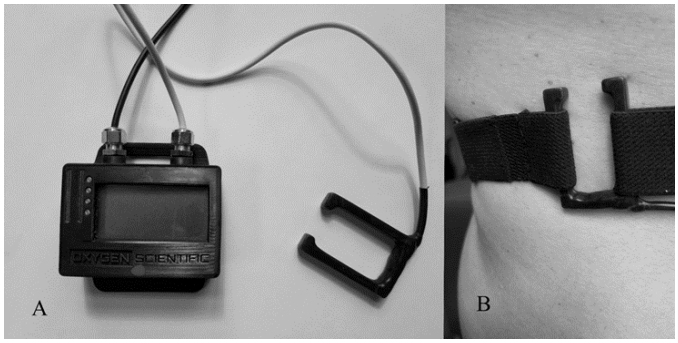

Fig. 1. A) Buckle with force sensor and datalogger. B) Buckle and chest strap in position.

Table 1. Exhaled CO2 pressure and respiratory signal values

	$P_{ET}CO_2$ (mmHg)			F	P	Respiratory rate (bpm)	Amplitude (Newton)
	Measured	Predicted	Difference				
A 1	30.5 ± 5.3	31.0 ± 2.7	-0.4	6.6	0.019	10 ± 3	2.9 ± 1.8
A 2	31.3 ± 6.6	30.9 ± 4.5	0.4	14.0	0.001	8 ± 2	3.7 ± 2.5†
A 3	29.3 ± 6.4*	28.8 ± 3.9	0.5	9.6	0.006	9 ± 3	4.0 ± 2.4†

Mean ± SD values. A, apnea number. mmHg, millimeters of mercury. bpm, breaths per minute. *F,* F-value, and P-values of the specific prediction model. * Significantly different from Apnea 2. †Significantly different from Apnea 1.

Keywords: Freediving, Hyperventilation, Respiratory data, Blackout

Diving Medicine

CL - (19332) - SWYER-JAMES-MACLEOD SYNDROME IN AN ADULT MILITARY DIVER: A CASE REPORT

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1 - Republic of Singapore Navy

Abstract

Introduction

Swyer-James-MacLeod syndrome (SJM) is a rare, complex disease characterised by a unilateral hyperlucent lung or lobe due to the loss of pulmonary vasculature and alveolar overdistention. Typically an acquired disease that follows severe bronchiolitis and pneumonitis in childhood, patients are often asymptomatic but could present with recurrent pulmonary infections. Due to alveolar distension, spontaneous pneumothorax is a potential sequelae of SJM. We report a case of a 22-year-old male military diver who had an incidental diagnosis of SJM and his subsequent management.

Case Description

The diver has had a 1.5-year uneventful diving history and had no previously known lower airway respiratory disease. He had also previously cleared a rigorous dive medical screening which included a normal chest X-ray. Computed Tomography (CT) scan, performed to work up an unrelated abnormality on routine medical screening, revealed the classic hyperlucent appearance with volume loss of the of the right lower lung lobe on which commensurated with SJM. These findings persisted on a repeat CT Thorax scan 3 months later. Due to the association of SJM with the development of spontaneous pneumothorax, the diver has since been excused from military diving.

Discussion / Conclusion

The diagnosis of SJM may not be made till adulthood due to its indolent course. While uncommon, there are multiple case reports of SJM patients presenting with spontaneous pneumothorax. The risk of pneumothorax in diving, with wide changes in ambient pressure, is theoretically even higher. This case highlights the importance for diving physicians to maintain a high index of suspicion for SJM in adults with new onset respiratory signs or symptoms and to employ a careful history taking and appropriate pulmonary imaging to comprehensively evaluate the disease. To the best of our knowledge this is the first report of SJM noted in military diving medicine in available literature.

Keywords: Swyer-James-MacLeod Syndrome, Military Diving

Decompression Theory and Mechanisms

CL - (19334) - REVIEW OF SATURATION DECOMPRESSION PROCEDURES USED IN COMMERCIAL DIVING

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Abstract

Introduction: The purpose of this study is to document the practice of the offshore diving industry after 50 years of saturation diving. The study focuses on the final saturation decompression and excludes pressurization, storage depth and bell excursion dive. The objective is to 1) identify the source of the procedures, 2) trace their evolution, 3) describe the current practice and 4) detect the trends.

Methods: Eleven international commercial diving companies provide their diving manuals for review under a confidentiality agreement.

Results: The review has shown that modern commercial diving saturation procedures are derived from a small number of original procedures: the US Navy, the Comex, and the NORSOK procedures. Because of the lack of significant scientific research since the last Norwegian deep contracts of the 80's, the companies have used Management of Changes to improve their procedures and have empirically adapted these procedures according to their needs and experience. This evolution is responsible for the differences observed in commercial saturation decompression procedures:

· Rest stops versus continuous ascent.

· Continuous bleeding versus step decompression.

· Change in ascent rates shallower than 60 msw.

Nevertheless, the saturation decompression procedures present a surprising homogeneity:

· Similar chamber PO_2 adapted to the decompression duration.

· Similar daily rates of ascent when deeper than 60 msw.

The companies have also developed specific rules of good practice:

· No final decompression should start with an initial upward excursion.

· After an excursion dive, a minimum hold is required before starting a final decompression.

· Recommendation for the divers to exercise during decompression.

Conclusion: We observed the trend towards harmonization that proceeds 1) within the companies that enforce international procedures, 2) between companies through cooperation inside the various committees of the industry associations and 3) under the influence of clients' requirements and governments legislations.

Keywords: Saturation, Decompression, Commercial diving

Clinical HBOT

CL - (19335) - THE EFFECTIVENESS OF HYPERBARIC OXYGEN THERAPY FOR MANAGING RADIATION-INDUCED PROCTITIS – A RETROSPECTIVE STUDY

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Abstract

Background: Despite modern radiotherapy (RT) techniques that allow a reduced volume of normal tissue irradiated, radiation-induced proctitis (RIP) remains one of the most common complications of RT for pelvic organ malignancies. Most of these patients are refractory to medical and/or endoscopic treatments and undergo hyperbaric oxygen therapy (HBOT). This study aims to evaluate the effectiveness and safety of HBOT in the treatment of RIP.

Materials and methods: Clinical records from 151 patients with RIP treated with HBOT at Centro de Medicina Subaquática e Hiperbárica (Armed Forces Hospital – Lisbon, Portugal) from January 2013 to March 2023, were retrospectively analysed, in accordance with the ethics committee´s regulations. Patients were exposed to 100% oxygen at 2.5 ATA, in a multiplace first class hyperbaric chamber, for 100-min periods, once daily, five times per week. Clinical data were analysed using Statistical Package for Social Sciences 23 software.

Results: Eighty-eight patients were included in the final analysis, of whom 38.6% evidenced other concurrent radiation-induced soft tissue lesions. The most reported primary pelvic tumour treated with RT was prostate cancer (77.3%), followed by cervical cancer (10.2%). Haematochezia was the most observed clinical manifestation (86.4%). After a median of 60 HBOT sessions (interquartile range [IQR]: 40-87.5), 62.5% and 31.8% of patients achieved a clinical complete and partial response, respectively, with a haematochezia resolution rate of 93.7% (complete or partial). While partial and complete responses tend to require fewer than 70 sessions of HBOT in terms of overall RIP symptoms (p=0.069), isolated haematochezia tends to require at least 70 sessions (p=0.075) by Fisher's exact test. Only about 5.7% of patients did not respond to the treatment. Eighteen patients developed reversible ear barotrauma. The number of HBOT sessions was a predictor of HBOT side effects (odds ratio: 1.010; 95% confidence interval, 1.000-1.020; p=0.047).

Conclusions: The HBOT proved to be an effective and safe treatment for RIP refractory to medical and/or endoscopic treatments. This real-world evidence study adds value to published data on the management of RIP with HBOT.

Table 1. Sample characterisation considering clinical response rates, refractory symptoms, post-HBOT endoscopic exam results, development of side effects, recurrence of haematochezia, and the necessity to perform a surgical procedure for symptomatic control

Variable	*% (n)*
Overall response rate	**94.3 (83)**
Complete response rate	62.5 (55)
Partial response rate	31.8 (28)
No response rate	5.7 (5)
Resolution of haematochezia	**93.7 (74)**
Complete resolution	64.6 (51)
Partial resolution	29.1 (23)
Refractory haematochezia (no resolution)	**6.3 (5)**
Other refractory symptoms	**15.9 (14)**
Pots-HBOT endoscopic exam	
Yes	34.1 (30)
No	65.9 (58)
Post-HBOT endoscopic findings	
Endoscopic improvement	83.3 (25)
Endoscopic maintenance	13.3 (4)
Endoscopic aggravation	3.3 (1)
Side effects	
Yes	21.6 (19)
No	78.4 (69)
Type of side effect	
Middle ear barotrauma	94.7 (18)
Reversible myopia	5.3 (1)
Necessity to perform a surgical procedure	
Yes	5.7 (5)
No	94.3 (83)
Recurrence of haematochezia	**14.8 (13)**

Abbreviations: HBOT, hyperbaric oxygen therapy.

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Keywords: hyperbaric oxygen therapy, hyperbaric oxygenation, radiation injury, radiation proctitis, radiotherapy

Clinical HBOT

CL - (19340) - THE EFFECTIVENESS OF HYPERBARIC OXYGEN THERAPY FOR MANAGING RADIATION-INDUCED URETHRAL LATE COMPLICATIONS – A RETROSPECTIVE STUDY

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Abstract

Background: Hyperbaric oxygen therapy (HBOT) has been used to treat radiation-induced lesions, such as radiation proctitis, radiation cystitis, and osteoradionecrosis of the mandible. In the urological tract, the structures most affected by radiotherapy (RT) are the ureters, bladder, and urethra.[1] Radiation-induced urethral late complications (RIULC) can be classified as radiation urethritis, urethral stricture, and urethral fistula.[2,3]

Methods: Clinical records from thirteen patients with potential RIULC treated with HBOT at Centro de Medicina Subaquática e Hiperbárica (Armed Forces Hospital – Lisbon, Portugal) from July 2015 to December 2022, were retrospectively analysed, in accordance with the ethics committee´s regulations. Patients were exposed to 100% oxygen at 2.5 ATA, in a multiplace hyperbaric chamber, for 100-min periods, once daily, five times per week. Demographic data, information about cancer treatment, the time between RT and the onset of RIULC symptoms, previous treatments, and the number of HBOT sessions were collected. Patients' symptoms after HBOT were classified into four categories: complete resolution, partial resolution, stabilisation or worsening of symptoms. The Chi-square test was used to assess statistical correlations, and $p<0.05$ was considered relevant. This study aims to evaluate the effectiveness and safety of HBOT in the treatment of RIULC.

Results: Nine patients with a past medical history of prostate cancer were included in the final analysis, of whom 33.3% and 55.5% evidenced urethral stricture and concurrent radiation cystitis, respectively. The most common symptoms were haematuria or urethrorrhagia (n= 8), urinary urgency incontinence (n= 6), dysuria (n= 5), and urinary retention (n= 3). Five patients underwent previous treatments for RIULC before HBOT. The mean time elapsed between RT and the onset of symptoms and between symptoms and HBOT was 63 and 15.8 months, respectively.After a median of 58 HBOT sessions, all patients achieved clinical response to HBOT, including 55% (n= 5) with complete response. Among these patients, 20% underwent previous treatments besides HBOT. Only these previous treatments showed a statistically significant relationship with symptom resolution (p=0.016). No adverse events were reported.

Conclusions: The HBOT proved to be an effective and safe treatment for RIULC. However, further prospective and randomised studies are necessary to validate HBOT´s effectiveness in this setting.

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Keywords: hyperbaric oxygen therapy, radiotherapy, radiation injury, radiation-induced urethral late complications

Diving Medicine

CL - (19342) - END TIDAL CARBON DIOXIDE LEVELS PRIOR TO SERIAL APNEAS AFTER THE INSTRUCTION: "DO NOT HYPERVENTILATE."

Erika Schagatay (Sweden)[1,2]; Filip Johansson (Sweden)[1]; Eric Mulder (Sweden)[1]; Frank Pernett (Sweden)[1]

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Abstract

Introduction Hyperventilation prior to apnea is a known risk factor in freediving because it reduces arterial blood carbon dioxide ($PaCO_2$), the main stimulus leading to diaphragmatic contractions and an urge to breathe. Low $PaCO_2$ can prolong apnea duration, with the consequence that severe hypoxia may develop without the diver´s awareness, which may cause loss of consciousness, or "blackout" (BO). Most freediving schools instruct divers to avoid hyperventilation. Our aim was to determine the extent to which hyperventilation can be voluntarily avoided in freedivers.

Methods Fifty-six freedivers; 22 women and 34 men at different training levels, participated in a test involving simulated diving by face immersion. They performed three sequential apneas (A1 - A3) with a 2-minute breathing interval between each apnea. Participants received written and oral instructions before the test that hyperventilation should be avoided. End-tidal carbon dioxide pressure (E_TCO_2) was measured during the last breathing cycle before each apnea. Divers indicated the occurrence of the first diaphragm contraction with a hand signal.

Results Mean (SD) E_TCO_2 before apneas was 5.0 (0.8) kPa in A1, 4.4 (0.7) kPa in A2, and 4.2 (0.7) kPa in A3 (all differences $p < 0.001$). Among the 56 divers, 38 (68%) reduced their pre-dive E_TCO_2 by at least 0.5 kPa across the series. In A3, 20 divers reached values below 4.0 kPa. Most divers reported diaphragmatic contractions and a negative correlation was observed between their onset and E_TCO_2 in A3 ($r = -0.26$, $p = 0.05$). There were no differences in the absolute E_TCO_2 levels between men and women during any of the dives, but men exhibited a greater reduction in E_TCO_2 (by 0.89 kPa) across the series compared to women (by 0.54 kPa; $p = 0.021$). The tendency to hyperventilate was the same between recreational- and competitive divers.

Conclusions End tidal carbon dioxide levels prior to serial apneas dropped even after the explicit instruction: "Do Not Hyperventilate." As two-thirds of the divers reduced their pre-dive E_TCO_2 throughout the series, we conclude that unconscious hyperventilation is common. Seral dives with short pauses may enhance this effect and delay the urge to breathe, in line with the progressive increase in duration and desaturation across maximal serial apneas (Pernett et al 2023). The observation that men exhibited a more pronounced reduction in E_TCO_2 could reflect a greater susceptibility to BO in men, in accord with BO statistics (Valdivia Valdivia et al 2022). Hyperventilation can thus easily happen despite discouragement by freediving educational agencies, and to effectively reduce the incidence of BO it may be necessary to monitor CO_2 or breathing patterns for enhanced safety.

Funding was obtained through a donation from the Francis family in memory of their son/brother, who drowned from hypoxic blackout while snorkeling and holding his breath to dive underwater.

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Keywords: Drowning, prevention, respiration, breath-hold diving, freediving

Diving Medicine

CL - (19344) - CAN ZEBRAFISH SCUBA DIVE? THE EFFECT OF HYPERBARIC OXYGEN ON THE BRAIN

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Abstract

Cellular respiration requires oxygen (O_2) to produce energy and is vital to the survival of most organisms. However, exposure to high partial pressures of oxygen (PO_2) may lead to the development of a potentially fatal neurological condition - central nervous system oxygen toxicity (CNS-OT). CNS-OT may occur without any premonitory symptoms and is characterized by loss of consciousness, convulsions, and even death. Despite the risk of CNS-OT, breathing hyperbaric oxygen (HBO) has several medical and diving applications. Here, we used a custom-made mini pressure chamber and live imaging in the transparent zebrafish to understand the effect of HBO on brain function in real-time. we examined the CNS, directly and continuously, in an active vertebrate brain during hyperbaric exposure. The zebrafish transparent skull makes it possible to have continuous monitoring of a single cell, in the brain of the living organism. The zebrafish CNS has a highly functional, physiological, and genetic homology with that of mammals. It is estimated that about 70% of disease-causing genes in humans have functional homologous in the zebrafish. However, they have a simpler CNS. For that reason, they are convenient to use in research to study transcriptional regulation, synaptogenesis, genetics and neuronal development in live animals.

Confirming findings in rodents and humans, HBO altered the expression levels of several key genes in zebrafish including the marker to hypoxia (*hif1*) and the marker to oxidative stress (*mmp9*). In addition, as is the case in mammals, the heart rate decrease under HBO conditions compared to the control group. Using video tracking of behavior and 2-photon microscope imaging of genetically encoded calcium indicators (GCaMP6s), we characterized seizure-like brain activity and behavior under HBO compared to normal PO_2. Notably, using double labeling of the vascular system and the blood plasma in live transgenic zebrafish, we imaged changes in the diffusion rates of the blood through the blood-brain barrier (BBB) under HBO, suggesting that BBB leakage is one of the causes to CNS-OT under HBO conditions.

Keywords: CNS-OT, Zebrafish, live imaging, BBB, ROS

Diving Medicine

CL - (19345) - ADOPTING EQUIPMENT AND TECHNIQUES FROM SPORTS FREEDIVING TO FIREMEN SURFACE RESCUERS SHORTENS RESCUE TIME

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Abstract

Background Swedish firefighters are first responders in cases of drowning. In surface lifeguard situations they have for long been using the same equipment and technique for underwater rescue involving breath-hold diving, while sport freediving has developed new techniques and equipment. Our aim was to compare surface lifeguard performance using traditional methods and technique with those used in modern day freediving.

Methods We tested 13 healthy firefighters during rescue exercises in three conditions in an indoor pool; 1) Single divers using traditional equipment (drysuit, diving mask, snorkel and short fins), 2) Single divers using modern freediving equipment (wetsuit, 2kg weight belt, diving mask, snorkel and free-diving fins), and 3) Paired divers using modern freediving equipment, and sharing the task by alternating to dive (Schagatay and Åman 2019). The exercise was identical in all conditions and consisted of 22.5 m swimming at the surface followed by 6 dives to 4.5 metres of depth, each time swimming 10 metres at that depth before resurfacing. In condition 3 the paired divers were accomplishing the same task by making alternating dives with each diver performing 3 dives. Outcome variables were: Time for accomplishment of the exercise, Borg Rating of Perceived Excertion (RPE) scale 6-20, and Arterial oxygen saturation (SaO_2) via pulse-oximetry directly after the exercise.

Results Mean (SD) time for completing the rescue exercise task was 300 (51) seconds in Condition 1, 195 (55) seconds in Condition 2, and 112 (11) seconds in Condition 3 (both $p<0.001$). RPE showed higher rating of perceived strain in Condition 1, with a median of 16 compared to 13 for Condition 2 and 3. There were no differences between conditions in the resulting SaO_2, with mean values of 93% for Condition 1 and 2, and 94% for condition 3 (NS).

Discussion Our results show an improvement in time both when comparing current equipment and modern freediving equipment (gain 1 min 45 s) and when comparing dives using modern freediving equipment between single diver and diving in pairs (gain of another 1 min 23 s). The shortened rescue time between Condition 1 and 3 of 3 min 8 s suggests that changing methods from using the traditional unweighted drysuit to modern wetsuit with weights, and diving in pairs can save lives of drowning victims. Divers also experienced less physical strain using modern equipment and diving in pairs, but no differences in the divers SaO_2 resulted. We conclude that a change of surface rescuer´s methods is motivated, as adopting equipment and techniques from sports freediving could significantly reduce the crucial time window right after a drowning has occurred, potentially shortening time to CPR. Saturation measurements on resurfacing indicated no increased risk to the firefighters. Methods should be further explored in outdoor conditions.

Funded by a donation from the Francis family and by Mid Sweden University.

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Keywords: Drowning, victims, survival, efficient, breath-hold

Diving Medicine

CL - (19346) - APPLICATION OF A DRY STATIC APNEA TEST TO PREDICT OXYGEN SATURATION NADIR AND STATIC APNEA PERFORMANCE

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Abstract

Background: During breath-hold diving (freediving), the ability to stay underwater depends on factors such as oxygen stores, oxygen consumption rate, and tolerance to asphyxia. Monitoring the peripheral oxygen saturation (S_pO_2) profiles may help identify individuals at risk of rapid desaturation and hence hypoxic blackout. The study aimed to determine which physiological and anthropometric variables could be predictors of S_pO_2 nadir in the longest apnea, as measured in a dry apnea test, as well as explore variables associated with static apnea performance.

Methods: Twenty-three healthy adults trained in freediving participated. The study was conducted during two national competitions, at least 12 hours apart from any competition dive. Age, height, and weight were recorded. Vital capacity was measured in triplicate. The divers performed three apneas of 1, 2, and 3-minute durations at 2 min intervals in a sitting position while heart rate (HR) and oxygen saturation (SpO2) were recorded using pulse oximetry. End-tidal pressure of CO2 (PETCO2) was measured before and after every apnea. Changes in the SpO2 curve were detected by partitioning the SpO2 vector in two regions and evaluating the sum of squared deviations from the mean of each segment. In addition, the HR nadir, and the time to reach it was measured. Figure 1 provides a visual representation of key measurements.

Results: A correlation was observed between maximal static apnea duration during competition and the S_pO_2 nadir in the third apnea (r = 0.575, p = 0.042). The SpO2 nadir in the third apnea was correlated with three variables: the first detected change in the slope of the S_pO_2 curve (r = 0.482, p = 0.020), the PE_TCO_2 at the end of the second apnea (r = 0.438, p = 0.037), and age (r = 0.431, p = 0.040). No correlation was found with other variables or anthropometrics. The correlated variables were incorporated into a multiple regression model that predicted S_pO_2 nadir in the third apnea (F= 8.138, p = 0.001), which explained 56% of the variability from the mean. The model suggests that for every 10 seconds of stable oxygen saturation during apnea, the S_pO_2 nadir would be 0.8% units higher in the 3 min apnea.

Conclusions: Monitoring physiological variables in a dry apnea test could serve as the basis for S_pO_2 forecasting models and supports its measurement during actual diving, as an earlier desaturation indicates a higher risk for severe hypoxia The correlation between the S_pO_2 nadir during the dry apnea test and the duration of static apnea in competition indicates that the test is a useful tool for evaluating freedivers' performance.

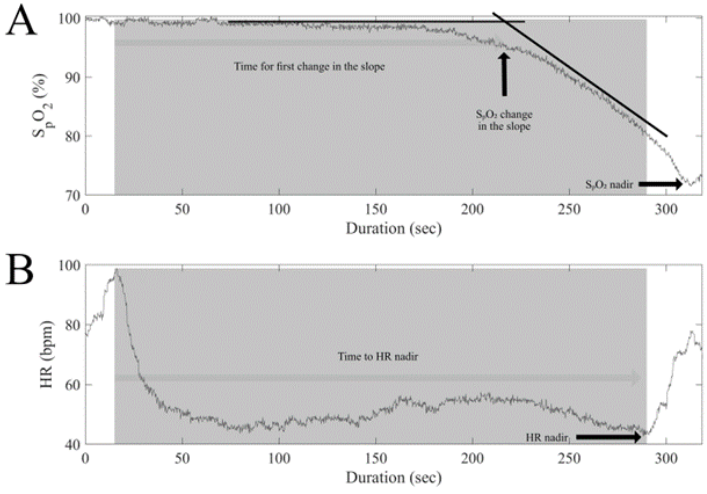

Fig. 1 Example of S_pO_2 (A) and heart rate (B) kinetics during apnea in one diver. The grey box indicates the apnea duration. Pink arrows show the time to reach the first change in the S_pO_2 (A), and the time to reach the lowest heart rate (B). Black lines indicate slope inclination change. Black arrows show the nadir of S_pO_2 (A) and HR(B)

Keywords: Breath-hold diving, Hypoxia, Performance, Prediction model

HBOT Theory and Mechanisms

CL - (19347) - HYPERBARIC OXYGEN RAPIDLY IMPROVES TISSUE-SPECIFIC INSULIN SENSITIVITY AND MITOCHONDRIAL CAPACITY IN HUMANS WITH TYPE 2 DIABETES: A RANDOMISED PLACEBO-CONTROLLED CROSSOVER TRIAL

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Abstract

Aims/hypothesis Hyperbaric oxygen (HBO) therapy may improve hyperglycaemia in humans with type 2 diabetes, but under- lying mechanisms are unclear. Our objective was to examine the glucometabolic effects of HBO on whole-body glucose disposal in humans with type 2 diabetes

Methods In a randomised placebo-controlled crossover trial located at the German Diabetes Center, 12 male individuals with type 2 diabetes (age 18–75 years, BMI <35 kg/m2, HbA1c 42–75 mmol/mol [6–9%]), randomly allocated by one person, underwent 2-h HBO, once with 100% (240 kPa; HBO) and once with 21% oxygen (240 kPa; control, CON). Insulin sensitivity was assessed by hyperinsulinaemic–euglycaemic clamps with D-[6,6-2H2]glucose, hepatic and skeletal muscle energy metabo- lism were assessed by 1H/31P-magnetic resonance spectroscopy, while high-resolution respirometry measured skeletal muscle and white adipose tissue (WAT) mitochondrial capacity. All participants and people assessing the outcomes were blinded.

Results HBO decreased fasting blood glucose by 19% and increased whole-body, hepatic and WAT insulin sensitivity about one-third ($p<0.05$ vs CON). Upon HBO, hepatic γ-ATP concentrations doubled, mitochondrial respiratory control doubled in skeletal muscle and tripled in WAT ($p<0.05$ vs CON). HBO increased myocellular insulin-stimulated serine-473/threonine-308 phosphorylation of Akt but decreased basal inhibitory serine-1101 phosphorylation of IRS-1 and endoplasmic reticulum stress ($p<0.05$ vs CON).

Conclusions/interpretation HBO-mediated improvement of insulin sensitivity likely results from decreased endoplasmic retic- ulum stress and increased mitochondrial capacity, possibly leading to low-dose reactive oxygen species-mediated mitohormesis in humans with type 2 diabetes.

Keywords: Antioxidative defence, Insulin resistance, Mitohormesis, ER stress, Hyperbaric oxygen therapy

Diving Medicine

CL - (19349) - CAN A LABORATORY-BASED STATIC APNEA TEST PREDICT THE DIVING RESPONSE DURING DEEP DIVING?

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1 - Department of Health Sciences, Mid Sweden University, Östersund, Sweden.; 2 - Oxygen scientific; 3 - 2) Swedish Winter Sport Research Centre, Mid Sweden University, Östersund, Sweden.

Abstract

Background A standardized, land-based performance assessment test would be useful for freedivers, as it is more challenging to measure physiological variables underwater. The oxygen conserving diving response which is considered to be correlated with freediving performance (Schagatay and Andersson 1998; Schagatay 2011), is often quantified by the heart rate (HR) reduction during "simulated diving" by apnea and facial immersion. But can a test done on land really predict the individual responses during real dives? We developed an incremental apnea test consisting of three apneas with face immersion. As a first step in evaluating this test, we aimed to reveal whether it could predict the diving response during real deep diving.

Methods Eighteen freedivers, (6 women) with varying experience participated in two separate events at a random order within one week´s time:

1). Three apneas of 1, 2 and 3 min duration (A1-A3) during prone rest and facial immersion in 15 C water while HR was recorded. Divers were told to avoid hyperventilation and to start the apnea after a full expiration followed by a deep but not maximal inspiration (approximately 85% of VC). Time cues were given.

2). Regular freediving training, while HR was recorded using a water- and pressure proof HR chest belt (Mulder et al 2021) during one deep dive per diver (25-88 msw, mean 52(17) msw).

Apnea/diving HR was defined as the minimum HR during 3 subsequent beats. Diving response was defined as the maximal HR reduction during apneas/diving from the baseline recorded during 90-30 s pre apneas/dives. Analysis of correlation between HR reduction during apneas and during the deep training dive were done using Pearson correlation. Student´s t-test was used for paired comparisons.

Results Baseline HR was 77bpm in the lab and 82 bpm in the sea ($P<0.001$), with high individual correlation ($r=0.77$; $P<0.001$). HR reduction occurred in all apneas, by 28% in A1, 31% in A2 and 36% in A3 (all $P<0.001$ from baseline). HR reduction by 54 % occurred in the deep dive ($P<0.001$). While HR reduction during A1 was not significantly correlated with diving HR reduction ($r=0.41$, $P<0.1$), HR reductions in A2 ($r=0.56$, $P<0.05$) and A3 ($r=0.66$, $P<0.01$) were correlated with HR reduction in the deep dive.

Discussion Despite a higher resting HR in the sea, diving response magnitude in the lab test and the sea dives were associated, with an increasing correlation across A1-A3. This consistency is interesting as there is more input from exercise and environmental factors such as pressure changes which could confound responses during real dives. The 3 minute apnea had the highest predictive value, which indicates that a lab based test should include sufficiently long apneas. We conclude that an incremental apnea test is useful in determining individual diving response during real dives.

Funded via a donation from the Francis family in memory of their son/brother, who drowned from hypoxic blackout.

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doi: 10.3389/fphys.2021.651128

Keywords: Snorkeling, breath-hold diving, diving reflex, safety, performance assessment

Diving Medicine

CL - (19351) - REVIEW OF 10 YEARS OF CLOSED-CIRCUIT REBREATHER FATALITIES

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1 - Divers Alert Network

Abstract

Introduction: Closed circuit rebreather (CCR) diving is believed to be inherently more dangerous than recreational scuba diving. Fock's analysis of 12 years of fatality data concluded that the rate of rebreather deaths on recreational CCR was up to 10 times the rate of recreational scuba. This project aimed to assess whether the rate of recreational CCR fatalities has changed in the past 10 years.

Materials and Methods: Fatalities of rebreather divers were continuously collected between 2013 and 2022 using openly accessible online sources and data from Divers Alert Network's fatality and incident surveillance systems. Current estimated demographic data (age, sex, years of certification) of CCR diving community was compared with fatality data. Along with basic information about the dive, the most likely cause of death, underlying disabling injury/agent, trigger event, and contributing factors were determined where possible. Training certifications issued per year and rebreather sales from CCR manufacturers were collected to assess the current state of the rebreather market and population for comparison.

Results: Rebreather divers are 42-46 years of age and certified for an average of six years. 84-95% are male A minimum of 241 deaths involving CCR have occurred between 2013 and 2022. In the majority of cases (51.5%), the information provided or available was insufficient to draw conclusions about the cause of death. Cause of death was determined to be related to cardiac issues in 12.0% of cases, hypoxia in 8.7%, hyperoxia 4.9%, hyperoxia 4.5%.

Discussion / Conclusions: Current estimates of the rebreather market today (25,000 to 35,000 recreational CCR units) and the CCR diving community (15,000 – 20,000 certified divers) suggests a rate of 2-4 deaths per 100,000 dives, which is not significantly different from Fock's estimate in 2013. Promoting a culture of dive safety with an emphasis on diving incident reporting could drastically improve future analysis of diving incidents to inform diving safety recommendations and advances in equipment technology.

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Keywords: safety, diving accidents, human factors, deaths, technical diving

Diving Medicine

CL - (19352) - CHRONIC FATIGUE/PAIN SYNDROME AFTER DCS- A MEDICAL ZEBRA OR A HIDDEN DISEASE?

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Abstract

Introduction: The mechanisms behind Decompression sickness are not fully understood but the cause is related to loading and off-loading of inert gas. The ruling theory is "The bubble theory" with bubbles causing mechanical injury. However, neither the number nor size of bubbles correlate well with symptoms. Activation of the immune system have been shown but still the mechanisms for focal signs and symptoms are obscure. DCS develop within minutes to hours after a dive but late onset DCS have been described. DCS can also "re-appear" days after the dive despite adequate treatment with hyperbaric oxygen. Long term neurological sequelae independent of acute DCS severity have been reported but the consequences of mild to moderate DCS are still largely unknown. Here we present a case series of 8 patients with mild to moderate DCS that show compelling resemblance with Long COVID syndrome and other chronic fatigue/pain syndromes.

Case description: Between Jan 2018- April 2023 35 divers (10 female), mean age 37, Range(21-59) were treated for DCS at Karolinska University Hospital in Stockholm. Mean time to treatment was 33 hours, Range (2-168). Most common symptom was neurological (22), followed by joint pain (18) and fatigue (14). All divers were previously essentially healthy but at clinical follow up with phone interview and/or self-reported health related quality of life (HRQoL) questionnaires 8 divers, 5 female and 3 men had developed some kind of chronic fatigue/chronic pain syndromes with lower-than-normal HRQoL similar to post COVID syndrome and other chronic fatigue/pain syndromes. 6/8 divers were treated with Table 6, 4/8 divers received additional treatments, mean no of treatments 2.5, Range (1-11), mean time to treatment was 44h, range (5-168). One diver was only treated with NBO due to favism and mild residual symptoms and one diver was not treated again since symptoms occurred more than a week after the acute DCS.

Discussion: All eight divers either had late onset DCS or did not have 100% resolved symptoms after HBOT. No difference has been found in treatment effect within or later than 48h and even delayed treatment is recommended in previous case series/retrospective analyses. Micro-bubbles may activate the immune system and coagulation cascade leading to immune-activation and micro-clots. The "bubble theory" cannot fully explain delayed onset DCS and/or non resolving symptoms. After decompression, oxygen is metabolized but inert gas can super-saturate tissue for an extended period and may further dysregulate the immune system and lead to chronic inflammation.

Conclusion: We suggest that divers with DCS should be followed up for late sequelae and if so evaluated for additional treatments. Longitudinal studies are warranted to determine the incidence of long-term sequelae of DCS.

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Keywords: DCS, chronic fatigue syndrome, HBOT, immune response

Diving Medicine

CL - (19353) - MEDICAL ASSISTANCE TO A SATURATION DIVING PROJECT AT 1457 METERS (4780 FEET) ABOVE SEA LEVEL

Pasquale Longobardi (Italy)[1]; Fabio Faralli (Italy)[1]; Enrico Franzino (Italy)[1]; Gian Luca Baroni (Italy)[1]

1 - Diving Doctors Italy

Abstract

In altitude diving, the pressure difference between the ambient pressure on the water and the absolute pressure of the dive must be calculated. For bounce diving, Cross Correction or the Galfetti method are an approach to correct the altitude dive to obtain the equivalent sea level dive, then determine the decompression requirement using standard tables. In the literature, we found no reference for heliox saturation experience at high altitude. In calculating specific decompression tables for use at each altitude, the different ratios between ambient / hydrostatic pressure and the lower density of fresh water will involve variations in the magnitude of upward and downward excursion limits and the ascent rate to the surface. The Authors report~~s~~ the medical assistance to ~~a~~ saturation in a lake at an altitude of 1457 meters above sea level (4780 feet). The storage depth was 75 meters (246 feet) and the working depth was 81-83 meters (266-272 feet). Taking, as a basis for calculation, the U.S. Navy Diving Manual rev.7 and the Normam Manual, the procedures for the altitude saturation were recalculated. The algorithm ZHL16A was adopted for the excursions. The deepest excursion allowed was 9 meters (14 exceptional) than 25 meters allowed by US Navy procedure. The shallowest excursion allowed was 9 meters (14 exceptional) than 22 meters by USN. The Extended Oxygen Window (EOW, J.Kot et al 2015.) concept was adopted to calculate the ascent rate, which during the excursion was 5 meters/minute. The saturation lasted 17 days. The team consisted of two divers, a Supervisor, and a Life Support Technician (LST). On the diving worksite, two doctors (on alternating shifts) performed the pre and post-saturation medical checks, constant health surveillance and the recording of safety data. There was no significant incident or event to report.

Keywords: altitude, decompression, diving medicine, medical assistance, saturation diving

Clinical HBOT

CL - (19354) - ECONOMICAL EVALUATION OF HYPERBARIC OXYGEN THERAPY

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Abstract

Background: Hyperbaric oxygen therapy (HBOT) is an adjunct treatment that expedites the healing of several diseases. While the literature on HBOT indications is growing, few have been subjected to economic evaluation. Comparison of HBOT with other therapies must also consider health economics assessments.

Aim: To evaluate the cost-utility of using HBOT plus standard care as compared to standard care alone, preferably focusing on indications other than wound care already covered by the Authors previously (such as Necrotizing Soft Tissue Infections, Idiopathic Sudden Sensorineural Hearing Loss – ISSH, Delayed Radiation Injury and indications for orthopaedics). The perspective is social in the international context.

Method: A literature search was conducted across MedLine, Scopus and Cochrane Database seeking evaluations published from inception to 2023 using specific key concepts. Eligibility criteria were defined to guide study selection. Articles were identified by screening of titles and abstracts, followed by a full-text review before inclusion. The main outcome measures were incremental quality-adjusted-life-years (QALY) gained, incremental costs, incremental cost-effectiveness ratio (ICER) per negative outcome averted and ICER per QALY gained. Sensitivity and threshold analyses were also done.

Result: 542 records were screened and 39 full-texts assessed for eligibility. A total of 19 papers were included in the final analysis. Most studies concluded the intervention assessed (HBOT) was cost-effective or cost saving. This means HBOT alone or in combination with the standard of care provided more health benefit at a lower incremental cost most of the time. All cost-minimisation analysis (CMAs) showed the intervention (HBOT alone or with the standard of care) achieved health benefit at lower costs versus the comparator (standard of care).

Conclusion: Consistent identification of cost-effective and cost-saving interventions may help to reduce the healthcare burden. Future research should involve clinical implementation of HBOT with parallel economic evaluation rather than only clinical-based evaluations

Keywords: cost effectiveness, economic evaluation, hyperbaric oxygenation, societal perspective, quality adjusted life years

Decompression Theory and Mechanisms

CL - (19356) - BLOODSTREAM AIR MICROBUBBLES AND DECOMPRESSION SICKNESS RESISTANCE IN RATS

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Abstract

Introduction / Background: Decompression sickness is characterised by a wide inter-individual resistance variability which origin is still poorly understood. It is acknowledged that the occurrence of DCS depends on the amount of intravascular gas emboli (VGE) formed during and after decompression. However, beside the wide inter-individual variability of the formation of post-dive VGE the susceptibility to DCS may also depend on the individual ability to cope with VGE. We previously developed a DCS-resistant rat strain [1] which allow us to study the physiological and genetic mechanisms that possibly underpin the resistance to DCS [2]. Here, we aimed to seek whether this resistance to DCS was associated with a difference in the response to VGE.

Materials and Methods : To study the effects of microbubbles independently of the hyperbaric stress induced by diving, Wistar (12 males, 11 females) and DCS-resistant rats (10 males, 12 females) received 5 ml/kg in three times of a NaCl solution 0.9 % filled with air microbubbles through the tail vein. The activation of signalling pathways involved in inflammation, coagulation, cell stress, was assessed in lungs and liver by determining mRNAs expression by RT-qPCR. Wet-dry weight ratio has been measured and a histological evaluation of oedema and leukocyte infiltration has been done to look at histological effects in the lungs.

Results : After the administration of bubbles, TTR mRNA expression was lower in resistant than standard individuals ($p < 0.001$) and higher in males than females ($p < 0.001$) without interaction on the liver. The resistance increases the liver transcription levels of tissue factor ($p < 0.001$) and TFPI ($p = 0.011$), as well as those of HSP27 ($p < 0.001$) and Egr-1 ($p = 0.039$). Lungs assessment didn't reveal any difference between groups on the studied genes. However, on the lung water content, the wet-dry weight ratio was lower in resistant than standard ($p = 0.04$) without interaction with sexe. Oedema induced by bubbles seems to be higher in males than females and in standard rats than in DCS-resistant rats without any interaction.

Summary / Conclusions : This study suggests that intravascular bubbles activate coagulation and stress factors but not inflammation pathways. It would therefore suggest that a stronger reaction to bubbles is related to DCS resistance.

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Keywords: Decompression sickness, Stress, Coagulation, air microbubbles

Diving Medicine

CL - (19357) - GENOMIC, PROTEOMIC, AND OXIDATIVE RESPONSES ASSOCIATED WITH HYPERCAPNIC HYPEROXIA

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Abstract

Introduction: Closed-circuit rebreathers and O_2 enriched air mixtures that supply an increased partial pressure of oxygen allow for a longer duration of diving while minimizing decompression stress. However, this hyperoxia may lead to central nervous system oxygen toxicity (CNS-OT) beyond certain depths and duration. Concomitantly, either due to mechanical or physiological causes, hypercapnia is a common problem for divers. Given the physiological effects of hypercapnia, namely increased cerebral blood flow, previous studies have suggested that hypercapnia increases the risk of oxygen toxicity. However, no study has examined the genomic, proteomic, and oxidative responses to hypercapnic hyperoxia to characterize the interplay of these two stressors. The purpose of this investigation is to test the hypothesis that hypercapnia will modify the genomic, proteomic, and oxidative responses to normobaric hyperoxia.

Methods: 12 U.S. Navy Divers underwent two hours of normobaric gas exposure with varying levels of CO_2 (0%, 1.5%, 3%) with either background air or O_2. We collected blood samples from divers before gas exposure and 15 minutes after gas exposure. We measured antioxidant capacity via static oxidation-reduction potential (sORP). Additionally, total RNA-Sequencing and liquid chromatography with tandem mass spectrometry were performed using whole blood and plasma, respectively. A two-way ANOVA (O_2 x CO2) was utilized to infer the effects of hypercapnia and hyperoxia on the change in sORP across trials. Differential expression of RNA and proteins across exposures were assessed and used to conduct pathway enrichment analyses.

Results: We observed a main effect of O_2 on the change in sORP across trials (Air vs O_2: 4.42 ± 2.07 mV; $F_{1,22} = 5.069$, $p = 0.03$), with no effect of CO_2 detected (p=0.66) nor any interaction effect (p=0.36). Alterations of genomic and proteomic pathways in response to hypercapnia, hyperoxia, and the combination of the two stressors were observed and are still undergoing analysis.

Conclusion: These results imply that under normobaric conditions, hyperoxia affects antioxidant capacity with no discernible effect of hypercapnia. This and future hyperbaric work at our laboratory will support the development of guidelines to mitigate the risk of CNS-OT during diving.

Disclaimer: The views expressed in this abstract are those of the authors and do not necessarily reflect the official policy or position of the DON, DoD, nor the U.S. Government (USG). This work is supported by the Office of Naval Research with funding work unit numbers F2101 and F2103. The study protocol was approved by the Naval Submarine Medical Research Laboratory Institutional Review Board (NSMRL.2022.0008) in compliance with all applicable federal regulations governing the protection of human subjects. LT Babagana, LT Ciarlone, and Dr. Fothergill are military service members or employees of the U.S. Government. This work was prepared as part of their official duties. Title 17, U.S.C., §105 provides that copyright protection under this title is not available for any work of the USG. Title 17, U.S.C., §101 defines a USG work as a work prepared by an employee of the USG as part of that person's official duties.

Keywords: Oxygen Toxicity, Antioxidant, RNA-Seq, Oxidation

Basic research in HBOT

CL - (19365) - GABA AND SENSITIVITY TO SEIZURES IN REPEATED EXPOSURE TO HBO2

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Abstract

Introduction: A single exposure to HBO_2 > 3 atmospheres absolute (ATA) causes a decrease in in brain γ-aminobutyric acid (GABA) content.[1] The rate of decline in brain GABA levels is related to the partial pressure of inspired oxygen and seizure severity.[1,2] Inhibiting GABA reuptake increases extracellular brain GABA concentrations and delays HBO_2 seizures.[3] Repeated exposure to HBO_2 has been reported to increase sensitivity to seizures,[4] however, GABA's contribution has not been studied and the objective of this research.

Methods: Male and female mice (C57BL/6J and *mito*-QC) aged 8-11 weeks were exposed to air or HBO_2 at 4.5 for 60 min. A second exposure was repeated 48 or 72 h after the first. Thirty min before each exposure, mice received an IP injection of 0.9% NaCl + 10% DMSO (vehicle) or tiagabine hydrochloride in vehicle (9.4 µg/g body weight) in a volume of 5 µl/g body weight. Tiagabine is an antiepileptic drug that blocks GABA transporter 1 in presynaptic neurons. Seizure latencies were recorded and analyzed using the Kaplan-Meier method. Seizure latencies are reported as medians.

Results: During the first HBO_2 exposure, 80% of vehicle mice developed seizures at 18.1 (males) and 15.5 (females) min. Tiagabine reduced the number of mice with seizures by 40% and extended the time to seizure onset by a factor of 3.3 in males and 3.9 in females ($p<0.001$). There were no sex differences, leading us to combine data for repeated exposures. When mice underwent a second exposure to HBO_2 after 48 or 72 h, 100% of vehicle mice had seizures at 14.2 and 13.2 min, respectively (no difference from first). In TGB treated mice re-exposed to HBO_2 after 48 h, 93% developed seizures at 37 min ($p=0.007$). When the exposure was repeated after 72 h, 100% had seizures at 28.2 min ($p<0.001$).

Conclusion: Despite seizure latencies being similar in control mice re-exposed to HBO_2 at 4.5 ATA for 60 min after 48 or 72 h, the probability of not developing seizures is zero. When mice are administered tiagabine and HBO_2 is repeated, the antiseizure efficacy is significantly reduced. Potential mechanisms for these observations are currently being explored.

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Keywords: Neurotransmission, Oxygen toxicity, Brain, Tiagabine

Diving Medicine

CL - (19366) - COMBINED EFFECTS OF PROLONGED FASTING AND HYPERVENTILATION ON SERIAL APNOEIC PERFORMANCE: DO RISKS OUTWEIGH THE BENEFITS?

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Abstract

Introduction

During indoor apnoeic competitions, athletes commonly compete fasted and start their maximal attempts after a short hyperventilation period. Previous studies highlighted that apnoeas preceded by either an overnight fast (1,2) or a short hyperventilation period (3) may increase the risk of suffering from a hypoxic blackout through delaying the excitation of ventilatory sensory chemoreflexes. To date, however, no study has explored the combined effects of fasting and hyperventilation on apnoeic performance and associated physiological responses over a series of repeated attempts.

Materials & Methods

Nine healthy adults attended the laboratory on two separate occasions (≥48-h apart) both after a 12-h overnight fast. During each visit the subjects performed a hyperoxic rebreathing trial followed by a series of three repeated maximal static apnoeic attempts preceded by either normal breathing (NORM) or 30s of hyperventilation (HYPER). Blood pressure, heart rate, peripheral oxyhaemoglobin saturation (SpO_2), gas exchange, cerebral and forearm oxygenation were monitored continually whereas splenic volume and haematology were assessed after the hyperoxic rebreathing and apnoeas.

Results

At rest, there were no between protocol differences in haematology, splenic volume, ventilatory and cardiovascular variables ($p \geq 0.09$). Ventilatory reactivity and time taken to reach the 8kPa end-tidal partial pressure of carbon dioxide ($PETCO_2$) were similar between the hyperoxic rebreathing trials ($p \geq 0.91$). Longer apnoeas were recorded in HYPER compared with NORM (34 ± 3s, $p \leq 0.01$). During the apnoeic attempts, HYPER extended phase II by 32 ± 5s ($p \leq 0.04$) and delayed the onset of involuntary diaphragmatic kicks by 45 ± 1s ($p \leq 0.01$). Cerebral deoxy-haemoglobin was higher across the apnoeic repetitions in the HYPER intervention ($p \leq 0.02$). At breaking point, end-tidal partial pressure of oxygen and nadir SpO_2 were lower in HYPER (mean for apnoeas 1-3, 7.2 ± 1.0kPa vs. 8.85 ± 1.1kPa, $p \leq 0.02$; mean for apnoeas 2-3, 71 ± 4% vs. 79 ± 3%, $p \leq 0.03$). A stronger splenic contraction was documented after the third apnoeic repetition in HYPER (114 ± 38mL, $p = 0.01$) compared with NORM (135 ± 44mL). There were no differences in cardiovascular responses, forearm oxygenation nor end-apnoeic $PETCO_2$ and haematology across protocols.

Conclusion

This study demonstrates that fasting combined with hyperventilation improves apnoeic performance but also may increase the risk of sustaining a hypoxic syncope - a risk that is aggravated over a series of repeated maximal apnoeic bouts.

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Keywords: Apnoea, Hyperventilation, Fasting, Spleen, Diving Reflex

Diving Medicine

CL - (19368) - ANALYSIS OF THREE RECREATIONAL DIVER'S NUTRITIONAL INTAKE ACROSS SIX IDENTICAL DIVES

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Abstract

Introduction: There is a general lack of research regarding the effects of nutrition on recreational diving and its ties to decompression stress. It is well known that high-pressure environments are inherently energetically demanding, and therefore, to maximize performance, divers may require a specialized diet to meet metabolic needs. This study aims to understand the variation of nutritional factors, specifically macronutrient deviations, in recreational divers by expanding upon previously published data to produce personalized estimates of the energetic requirements of scuba diving.

Materials and Methods: Three divers completed a 24-hour dietary recall before conducting a standardized dive profile six times across 12 weeks (18 recalls total). Divers completed the recall with a trained interviewer 1-2 hours before diving. Basal Metabolic Rate (BMR) for each diver was estimated using Mifflin-St. Jeor equations [1], and caloric need was calculated by extrapolating from Doubt et al.'s recommendations [2]. An estimated range of additional required Calories (ARC) was calculated by subtracting BMR from the recommended range of caloric need:

(40 Kcal x weight in kg)-BMR=low range of ARC per 3 hrs diving

(50 Kcal x weight in kg)-BMR=high range of ARC per 3 hrs diving

The ARC was further adjusted for the ratio of time spent underwater. For a 30-minute dive, the ARC was multiplied by 0.16 and added to the diver's BMR:

(ARC x 0.16)+BMR= Recommended Daily Caloric Intake for a 30 min dive

The adjusted recommended caloric intake was compared to data from the 24-hour dietary recalls to calculate deviations in Kcals per day. Protein intake was compared to Doubt et al.'s recommendation of 1 g of protein·kg^{-1} of body weight. Results are displayed as mean (SD).

Results: Dietary recalls revealed obvious variation in caloric and protein intake. Divers consumed 2,355.4 (67.8) Kcals·day^{-1}. Based off Doubt et al.'s recommendations, caloric deviation was 119.3 (540.0) Kcals·day^{-1}, range of -1,006.4–1,424.0 Kcals·day^{-1}. Divers consumed 106 (30.4) g of protein, with a deviation of 13.2 (30.8) g, range -62.6 to 67.0 g·day^{-1}. Overall macronutrient distribution consisted of 18.5% (6.3) of total intake from protein, 32.1% (9.3) from fats, 44.1% (11.1) from carbohydrates, and 6.6% (5.4) from alcohol.

Discussion: It has been found that cognitive and vascular efficiency is influenced by available calorie supply and certain micronutrients are known to protect endothelial function under pressure [3-5]. Therefore, proper nutrition is likely important for diver's health and reducing the risk of injury and illness. This study is ongoing and aims to recruit 32 subjects. Further data can help understand the variability between recreational divers' diets, and its implications on fitness and post-dive health. Future research will attempt to compare dietary intake factors with decompression stress.

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Keywords: Diver Health, Macronutrients, Diet, Decompression Stress

Basic research in HBOT

CL - (19372) - CHALLENGES REGARDING PATIENT INCLUSION IN HYPERBARIC OXYGEN TREATMENT RESEARCH

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Abstract

Background: In the last decades, many trials have been performed to assess the effect of Hyperbaric Oxygen Treatment (HBOT) in patients with Diabetic Foot Ulcers (DFUs) [1,2]. Trials commonly face the dilemma of selecting between patients in whom HBOT seems most effective and achieving a sufficient sample size to detect meaningful differences. In the current, international DIONYSIUS-trial, initiated to show convincing evidence for the effects of HBOT for patients with ischaemic DFUs, patient inclusion rate is below expectation.

Method: Records were kept of patients, who decided not to participate in the DIONYSIUS-trial, despite meeting inclusion criteria. Reasons were categorized in various subgroups: HBOT requested, by physician or patient (HR); HBOT deemed too intensive (HI); patient is also a primary caregiver and cannot afford to undergo all scheduled treatments (PC); patient has disabling claustrophobia (DC); other reasons (OR).

Results: Over the past 9 months, of the 32 patients who met the inclusion criteria for the DIONYSIUS-trial, 21 (65.6%) chose not to participate in the trial. Reasons were HI (52.4%); OR in 4 patients (19.0%); HR in 3 (14.3%); DC in 2 (9.5%), and PC in 1 patient (4.8%).

Discussion: Although DIONYSIUS is aiming to answer an important research question as to HBOT, the patient burden of HBOT appears to be the primary reason not to participate. This drawback is likely to prolong inclusion time and should be considered both when performing similar trials in the future, as well as when considering HBOT as a therapeutic option for patients in daily practice.

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Keywords: Challenge, Clinical trial, Inclusion

Diving Medicine

CL - (19374) - USAP ANTARCTIC DIVING DECOMPRESSION ILLNESS CASES AND TREATMENT

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Abstract

Introduction: The United States Antarctic Program (USAP) has a robust Scientific Diving Program that has been active for the past 30 years. During its tenure, there have been decompression cases requiring treatment with hyperbaric oxygen.

Cases: There have been 13 cases of decompression illness (DCI) in the USAP including Type 1 DCS, Type 2 DCS, and an arterial gas embolism. Four of these cases presented in United States Air Force (USAF) aircrew members after rapid depressurization of their C-130 aircraft. The additional 9 cases presented in both military and scientific divers at McMurdo Antarctic Station and all dives were performed on air. Two of these cases presented after a helicopter flight in which diving was done earlier in the day. All cases were treated in the deck decompression chamber (tri-lock) present at the medical clinic. Various treatment tables were utilized including the Catalina Consolidated, US Air Force, and US Navy Dive tables. The average number of treatments across all cases was 1.5 treatments. The most treatments were in a Type 2 DCS which required 7 treatments for full resolution and an arterial gas embolism which required a USN TT6a to 165 fsw. All cases had full resolution of symptoms.

Discussion: Having access to hyperbaric treatment in an austere environment where diving and aviation are present is an important operational factor to consider. Chambers capable of deep treatments (>60 fsw) with mixed gas capabilities greatly help outcomes in this population of scientific diving. Looking at a cost benefit analysis, a med-evac in a USAF C-130 to New Zealand for hyperbaric treatment has an both a significant cost and a time delay of 10 hours due to aircraft pressurization limitations in a dive emergency.

Conclusion: The use of hyperbaric treatments in the USAP has been an important consideration in operations for both the scientific diving and aviation environments. These DCI cases has led to protocol changes within the USAP Antarctic Diving Program to increase safety and training.

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Keywords: Decompression Illness, Scientific Diving, Antarctica, Austere Environment, Aviation Decompression

HBOT Theory and Mechanisms

CL - (19379) - ADVANCED MICROSCOPIC ASSESSMENTS OF SPINAL CORD AND LYMPHATIC TISSUE IN SWINE WITH SEVERE DECOMPRESSION SICKNESS

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Abstract

Introduction

Mechanisms of decompression sickness (DCS) remain poorly understood at the microscopic level, in part because of limited tools available to examine the small-scale pathology. An interventional study was conducted at the Duke University Center for Hyperbaric Medicine & Environmental Physiology to reduce risk of DCS in swine (IACUC #A111-21-05). In this population, novel techniques for imaging and assessment techniques were explored for evaluating mechanisms of DCS.

Materials & Methods

During necropsy, samples were taken from the cervical, thoracic, and lumbar spinal regions. Four sets of samples were fixed in formalin doped with 0.5% gadoteridol (ProHance) for magnetic resonance histology (MRH) (1-2). Additional samples were formalin fixed for conventional histology. One set of cervical and thoracic spinal cord samples were extracted and flash-frozen. Inguinal lymph nodes were extracted and formalin fixed from six swine, and three lymph nodes were flash-frozen.

An evaluation of slices is the conventional approach for identifying DCS pathology on the microscopic scale. The slices from frozen and formalin-fixed H&E-stained samples were compared to the MRH images to assess which method provided the most informative description of DCS.

Results

MRH examinations provided an examination of DCS at a resolution sufficient to identify large spinal cord blood vessels. Minor changes consistent with congestion were observed, in addition to hemorrhagic lesions in the most severe cases (Fig 1, right). Conventional histology provided similar results, although with an apparently higher detection threshold, in addition to difficulty differentiating vascular congestion from hemorrhage (Fig 2).

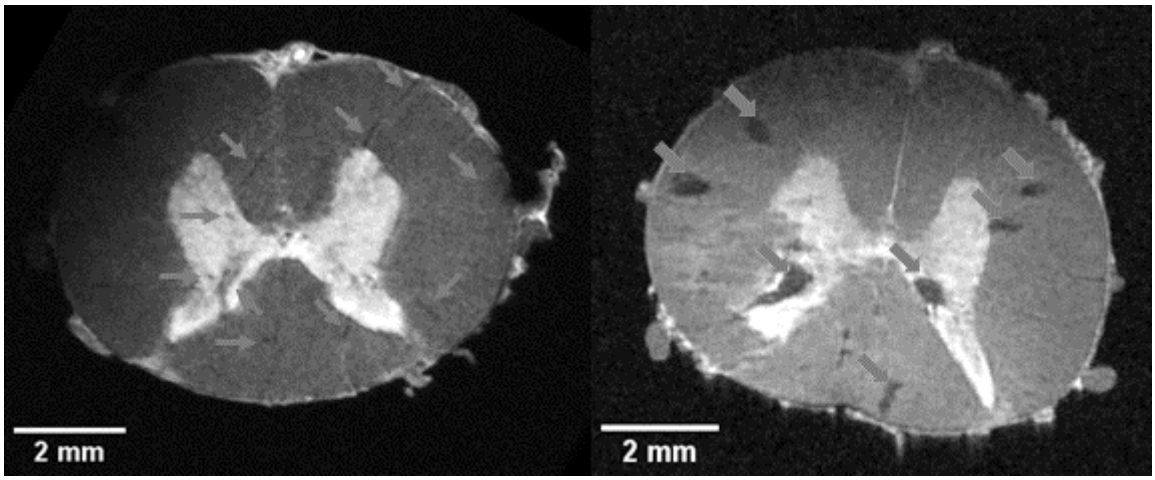

Figure 1. Yellow arrows indicate blood vessels in an apparently normal section (left). Red arrows indicate hemorrhagic lesions in a severe case (right).

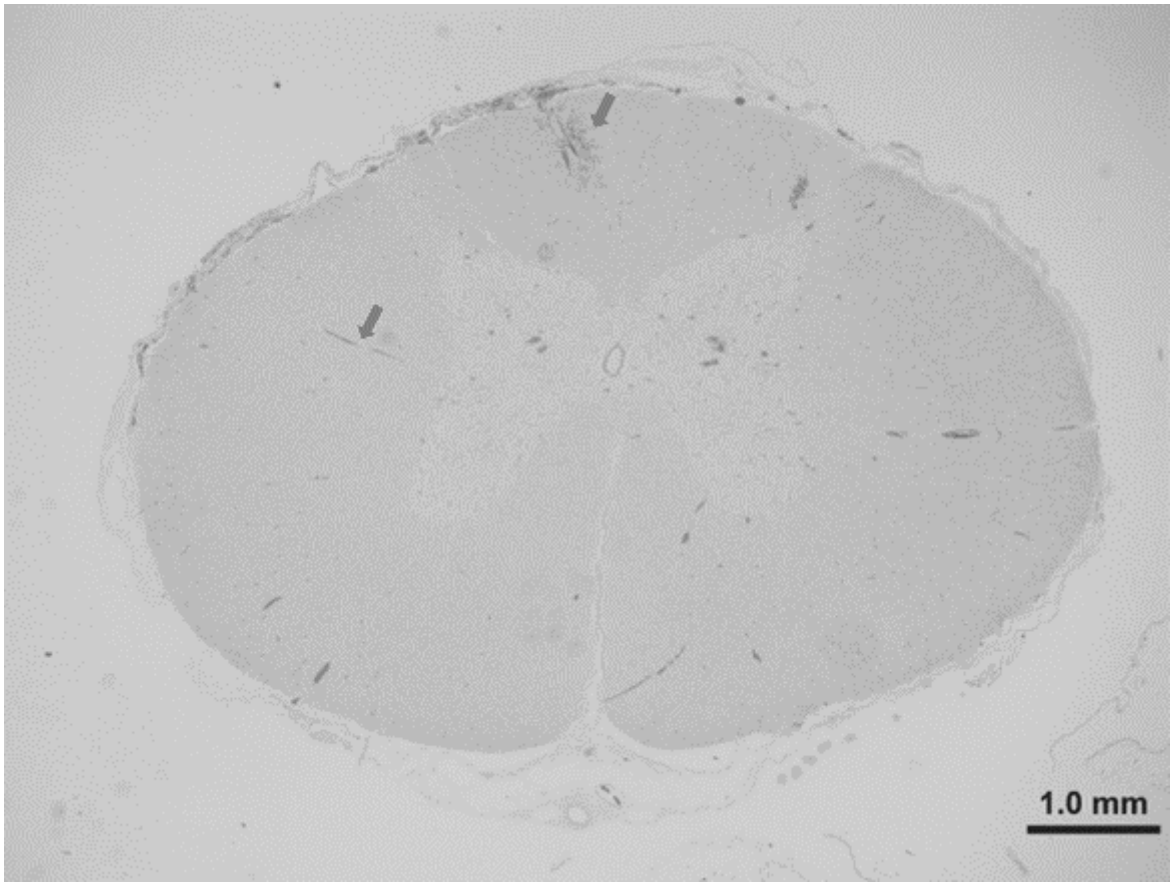

Figure 2. Representative arrows of each type, with convention as above.

The flash-frozen samples revealed bubbles inside spinal cords and lymph nodes, a finding that was not present in MRH or conventional histology.

Discussion/Conclusions

MRH techniques indicate potential for improving understanding of DCS. MRH identified different presentations of acute DCS, and may provide guidance for targeted sectioning. Methods for analyzing frozen tissues may be required to identify presence of DCS-associated bubbles.

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Keywords: DCS, neurotrauma, magnetic resonance

Clinical HBOT

CL - (19395) - PROSPECTIVE VALIDATION OF THE PORTUGUESE NAVY RADIATION-INDUCED CYSTITIS (PNRC) SCALE IN THE ASSESSMENT AND MONITORING OF RADIATION-INDUCED CYSTITIS IN RESPONSE TO HYPERBARIC OXYGEN THERAPY

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Abstract

INTRODUCTION

Radiotherapy (RT) is the backbone of multimodality treatment of more than half of cancer cases. Despite new modern RT techniques, late complications may occur, such as radiation-induced cystitis (RIC).[1] The clinical evolution of RIC is characterised by frequent relapses and complications, ranging from microscopic haematuria with spontaneous resolution to moderate to severe haematuria with clots, obstructive renal failure, transfusion-dependent anaemia, recurrent need for hospitalisation and eventual support of specialised medical-surgical procedures.[2] Over the last decades, a considerable therapeutic armamentarium has been considered in RIC, including hyperbaric oxygen therapy (HBOT).[2,3] The rationale for using HBOT is that it may promote healing by increasing tissue oxygenation, angiogenesis, reepithelialisation, and reversing the radiation-induced fibroatrophic process.[1-3] The literature describes several RIC classifications based on clinical, functional, laboratory, endoscopic criteria and/or the type of therapeutic intervention to be adopted. However, the considerable heterogeneity of the existing classifications makes it challenging to compare studies. Furthermore, none of these classifications has been validated to assess the effectiveness of HBOT in this setting prospectively.[1]

MATERIALS AND METHODS

The Portuguese Navy's Radiation-Induced Cystitis (PNRC) Scale aims to evaluate RIC in response to treatment. This comprehensive classification includes the evaluation of five parameters (haematuria grade, other lower urinary tract symptoms, functional impairment, endoscopic findings and therapeutic interventions) divided by six levels of severity (1-6). The degree of RIC is determined by the worst degree of severity among the various parameters evaluated. The classification was analysed by an independent group of experts that assessed relevance and clarity, using a three-level Liker scale.

RESULTS

After the overall assessment, numerous suggestions were incorporated, followed by the preparation and application of an online questionnaire with the final version of the PNRC Scale. This scale was applied independently and anonymously by a panel of 114 international experts from 30 different countries to a series of 20 clinical cases of patients with RIC. Consensus was considered if there was more than 70% agreement. Consensus was reached in 85% (17/20) of clinical cases. In clinical cases with no consensus (3/20), >62% agreement was observed.

DISCUSSION/CONCLUSIONS

The PNRC Scale has demonstrated clinical usefulness in assessing and stratifying the severity of RIC. Subsequently, our group aims to validate the clinical usefulness of this scale in the assessment and monitoring of RIC in response to HBOT.

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HBOT Theory and Mechanisms

CL - (19403) - THE EFFECTS OF HYPERBARIC OXYGEN THERAPY ON INSULIN RESISTANCE – AN APPROACH TO PHYSIOLOGY

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Abstract

Background: Diabetes mellitus (DM) is a serious, chronic and complex metabolic disease which leads to multiple dysfunctions, including micro and macrovascular complications, which are a major cause of morbidity and mortality. Moreover, complications related to hyperglycaemia are responsible for about 2.2 million deaths per year. Type 2 DM (TDM2) is highly preventable, and the stages that precede it are the ideal target for therapeutic intervention. Hyperbaric oxygenation therapy (HBOT) is an established medical treatment for several conditions, but still lacks formal indications for DM-related comorbidities, other than diabetic foot ulcers. Since DM is one of the most prevalent comorbidities in patients under HBOT, it has allowed the observation and inference of some of its effects on DM, suggesting a clinical benefit in different spectra of the disease. Our main aim was to gather the existing evidence regarding the effects of HBOT on insulin resistance, as this is the best predictor for the development of T2DM. **Methodology:** The scoping review was the methodology of choice to include all available data. Exclusion criteria consisted of articles that did not mention the effects of HBOT on insulin resistance; only described normobaric oxygen use; or with no available translations to English, Spanish, or Portuguese. In addition, all data discussing any effects on insulin, insulin resistance, or insulin sensitivity were included.

Results: Two hundred and thirty studies were found, and 17 were eligible. HBOT seems to improve fasting glycaemia and diminish insulin resistance in patients with DM, with effects appearing after 1 treatment session. Additionally, it lowers the levels of pro-inflammatory cytokines that contribute to insulin resistance. Still, the duration of this sensitisation effect remains unknown, as well as the contributing molecular factors. Conclusions: HBOT seems to improve glycaemic levels and insulin sensitivity, thus presenting as a potential treatment approach for treating insulin resistance and its consequences.

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Keywords: hyperbaric oxygenation, insulin resistance, physiology, glycaemia, type 2 diabetes

Diving Medicine

CL - (19406) - CAPILLARY LEAK SYNDROME TRIGGERED BY AN EXPLOSIVE DECOMPRESSION EVENT

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1 - Aviv-Clinics

Abstract

A 37 year old male diver was delivered to the emergency department after performing an emergency free ascent. Prior to his admission, the diver performed a single technical dive at maximal depth of 64 msw. At 45 msw the diver failed to switch breathing gases and performed an emergency ascent to the surface. At the hospital, the diver exhibited a distended abdomen with global tenderness, abdominal cutis marmorata, nausea and dizziness. His blood tests were abnormal, with hypoxia and hemoconcentration. He was found to be hemodynamically stable, fully conscious and with no neurological deficits. Abdominal CT presented massive gas bubbles in abdominal blood vessels, organs, and muscles. The diver was admitted for hyperbaric treatment and table CX-30 was administered. Approximately 15 minutes into the treatment, the skin discoloration vanished, and the diver reported general improvement in his pain and wellbeing. At the end of the recompression protocol, all symptoms had been resolved. A follow up CT was performed which demonstrated a full resorption of the gas bubbles. The diver was admitted to the hospital for observation. Approximately six hours after successfully completing HBOT with a full resolution of his symptoms, the diver began suffering from a general deterioration, including abdominal pain and hemodynamic instability. The abdominal skin discoloration had returned, anuria was present, the distal extremities were cold, there were diffuse pulmonary rales. The diver was transferred to the ICU, where his blood tests presented a picture of metabolic acidosis, hyperkalemia, hyponatremia, and hemoconcentration. It was decided to move the patient to a tertiary hospital with more advanced intervention and monitoring capabilities. Upon admission, initial assessments revealed severe edema in the extremities and abdomen. Laboratory studies were notable for hemoconcentration, signs of rhabdomyolysis and prerenal azotemia. A diagnosis of capillary leak syndrome was established. To address ongoing abdominal pain, a thoracoabdominal CT was performed. This scan demonstrated bilateral pulmonary infiltrates, and pancreatic and pyloric edema. A gastroscopy showed esophagitis and duodenitis. The diver was treated with appropriate medical protocols and daily HBOT.

On the 12th day following the diving accident, the diver was discharged from the hospital fully recovered.

Discussion: The case presented highlights three different clinical pathologies which can be linearly triggered by an explosive decompression event:

1. Decompression sickness.
2. Capillary leak syndrome.
3. Ischemic reperfusion injury.

This case underscores the importance of considering the severity of the mechanism of a diving accident when deciding on post HBOT monitoring of a diver. Another point to be raised, is looking at abnormal hemoconcentration, as an independent clue for DCS severity.

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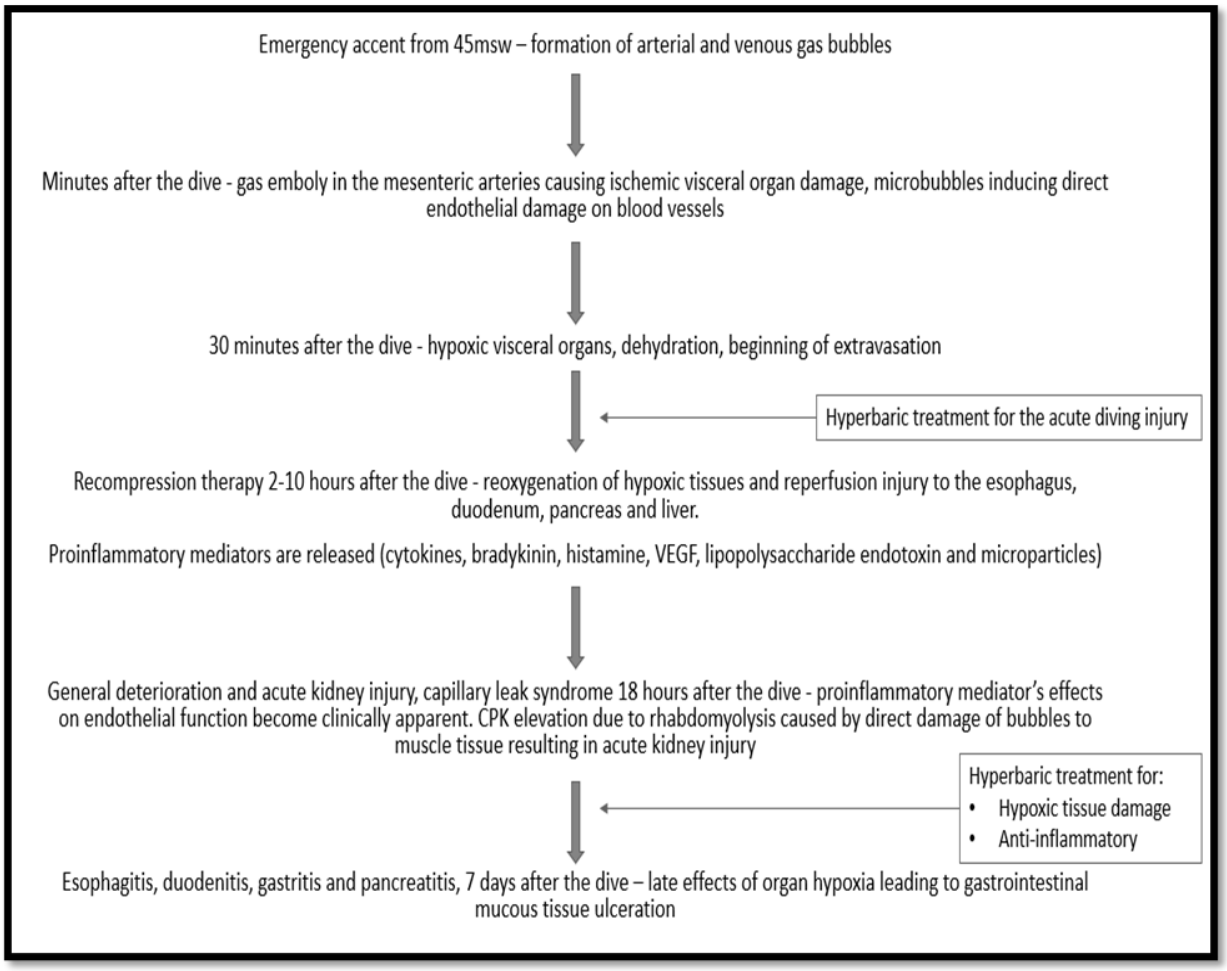

Keywords: decompression sickness, explosive decompression, capillary leak syndrom, reperfusion injury

Clinical HBOT

CL - (19407) - HYPERBARIC OXYGEN THERAPY IN BISPHOSPHONATE-RELATED OSTEONECROSIS OF THE JAW: THE EXPERIENCE OF A PORTUGUESE HYPERBARIC MEDICINE UNIT

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Abstract

Introduction/Background: Bisphosphonate-related Osteonecrosis of the Jaw (BRONJ) is a challenging complication associated with potent bisphosphonate (BP) treatment in malignant and non-malignant skeletal diseases. Hyperbaric oxygen therapy (HBOT) is reported to be effective in the treatment of BRONJ by modulating osteoclastic activity.

Materials and Methods: A single-institutional retrospective observational study was performed and included patients who underwent HBOT for BRONJ between 2006 and 2022. Patients with incomplete medical records were excluded. Demographic and clinical data were collected at baseline, including BP indication, BP length of treatment, and time until HBOT initiation. Data regarding pain intensity, mastication capacity, orofacial inflammatory signs, number of oral lesions, bone exposure area, and the American Association of Oral and Maxillofacial Surgeons (AAOMS) stage were collected before and after HBOT. Additional data after HBOT were obtained, namely relapse rate, time until relapse and complications related to HBOT. The primary outcome was a clinical response to HBOT, defined as AAOMS stage improvement. A descriptive analysis was made, followed by dependent-sample tests comparing clinical variables before and after HBOT. Statistical analysis was performed using SPSS® ($p<0.05$).

Results: A total of 22 patients (86.4% female, mean age of 61.1±12.7 years) were included. Metastatic bone disease was the main indication for BP therapy (77.3%), with a median length of treatment of 2 years. Median number of HBOT sessions was 59. All patients were under antibiotic therapy and 16 (72.7%) had at least one jaw surgery. Clinical response after HBOT was observed in 14 patients (63.6%). In 7 patients (31.8%), BRONJ stage remained stable and worsened in 1 patient (4.5%) after HBOT. There was a significant reduction in pain scores, as well as the number of oral lesions, bone exposure area, orofacial inflammatory signs, and mastication capacity. Six patients (27.3%) relapsed after therapy, with a median time until relapse of 2.5 months. No association was found between the BP length of treatment, or time until HBOT initiation, with clinical response. No association was observed between time until HBOT and relapse rate. HBOT median number of sessions was not significantly different between patients who had or had not relapsed.

Discussion/Conclusions: In this study, clinical improvement was present in most patients, as demonstrated through the significant decrease in pain scores, number of oral lesions, bone exposure area, improvement in AAOMS stage, and mastication capacity. Considering these results, patient referral to HBOT might be beneficial as an adjunct therapy regardless of the disease stage. Nevertheless, considering this is a small sampled retrospective study, further larger sampled and multicentric studies are necessary to confirm these findings.

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Keywords: Osteonecrosis of the Jaw, Bisphosphonate therapy, Hyperbaric oxygen therapy

Clinical HBOT

CL - (19416) - HOT BLADDER; HYPERBARIC OXYGEN THERAPY FOR RADIOTHERAPY INDUCED HAEMATURIA OF THE BLADDER

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Abstract

Haematuria is a well known long-term side effect of radiotherapy (RT) of pelvic organs. RT causes changes in the vasculature of the bladder and typically after several years patients can present with haematuria due to radiotherapy-induced cystitis.

Incidence for haematuria after RT for prostate cancer varies from 5-15% depending on the definition of haematuria.

It can vary from incidental mild haematuria with slightly orange coloured urine to massive blood loss with severe clot formation necessitating surgical evacuation and hemostasis. Hyperbaric oxygen therapy (HOT) is an established therapy for radiation-induced bladder toxicity.

In clinical practice, HOT is elected for persistent hematuria problems after standard therapy like catheterization in combination with bladder wash-out, clot evacuation, embolization, or intervention under general anesthesia including laparotomy to evacuate large clots. HOT is mainly used as a last resort therapy after several of these interventions have failed. It is unknown what the best timing is for the use of HOT. Advancing the initiation of HOT after radiotherapy-induced hematuria might reduce future interventions, improve patient outcomes, and eventually be cost-effective

Objective: To study in patients more than 1 year after radiotherapy of pelvic organs, who present with haematuria and clot retention necessitating any invasive intervention due to radiotherapy-induced cystitis whether early HOT leads to lower recurrence rates of of haematuria associated adverse events during five year follow-up.

Study design: Two-arm randomized controlled trial. Arm 1 – Standard of care: Treatment according to treating physician Arm 2 – Study arm; Direct HOT: starting < 6 months after the first hematuria-associated intervention. Assumptions: We expect 10% risk of recurrent event per year; 60% after 5 year. We expect a hazard ratio of 0.5 in the HOT group; 30% after 5 year.

Study population: Inclusion criteria: Patients (M/F) >18 years and >3 months post radiotherapy of pelvic organs AND presentation with gross hematuria ,grade ≥2 requiring any invasive intervention Exclusion criteria: Active bleeding requiring hospitalization without the possibility to safely make a transfer to and from a HOT-clinic. General contra-indications to undergo HOT:

Intervention: Direct hyperbaric oxygen therapy protocol. Eligible patients are treated with 40 daily hyperbaric oxygen sessions. Sessions consist of administration of a total of 80 minutes of 100% oxygen

Endpoints: Primary: Time to second episode of hematuria associated Adverse Event (HAE) or intervention, AND/OR number and type of HAE's in the first 5 years post-treatment Secondary: Costs effectiveness analysis. Other toxicity according to CTCAE (pain, LUTS, rectal toxicity, etc.). Quality of life analyses (SF-36)

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Keywords: Hyperbaric Oxygen Therapy, Haematuria

Diving Medicine

CL - (19419) - POINT OF CARE ULTRASOUND (POCUS) IN INJURED DIVERS

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Abstract

Introduction: Decompression sickness (DCS) is caused by inert gas bubbles in the tissues and blood vessels of divers. There are no definitive tests to determine the diagnosis of DCS and therefore the diagnosis of DCS is often determined by the dive history and constellation of symptoms. However, there is a correlation between high degrees of circulating bubbles and DCS. With the increased availability of point of care ultrasound (POCUS), looking for gas bubbles in injured divers may assist the clinician in arriving at the diagnosis.

Methods: A protocol for assessing divers using POCUS was created: Bilateral jugular, subclavian, and femoral veins, vena cava, 4-chamber cardiac, liver, and skin. Bubbles were graded from 0 (none), 1 (<15), 2 (15-30) and 3 (>30). Each site was assessed for 15 seconds, and video clips recorded. After clinical diagnosis of DCS, Injured divers were assessed in the Emergency Department prior to hyperbaric oxygen treatment. Retrospective data was collected including injured diver demographics, incident dive details, initial disease severity (mild, moderate, or severe), time to symptom onset post-dive, , time to POCUS, and time to Hyperbaric oxygen therapy and clinical outcome. Outcome was classified as well (no residual signs or symptoms), minor symptoms (no functional significance), residual symptoms (moderate impairment), major incapacity, or death. Significance was accepted at $p < 0.05$.

Results: A total of 182 injured divers were treated from January 2020 to December 2022. Median age of the injured divers was 54 (IQR 37, 62) years. Diver demographics, incident dive history, use of normobaric oxygen, time to symptom onset, hyperbaric oxygen, and POCUS will be reported. Bubble grades will be correlated with initial disease severity, dive profiles, timelines, and outcomes. Sites where bubbles were most frequently detected will be reported. Data extraction and analysis is ongoing.

Conclusion: POCUS ultrasound can be a tool for the emergency and diving physician to assist in the diagnosis and treatment of divers with DCS.

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Keywords: Bubbles, DCS, ultrasound, VGE

Diving Medicine

CL - (19420) - TRANSTHORACIC ECHOCARDIOGRAPHY BUBBLE TESTING IN INJURED DIVERS

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Abstract

Introduction: Decompression illness (DCI) is collective term encompassing both decompression sickness (DCS) and arterial gas embolism (AGE). DCS is caused by inert gas bubbles in the tissues and blood vessels of divers. AGE results from pulmonary barotrauma or arterialization of bubbles passing through a right to left shunt. Divers presenting with central neurological symptoms, cutis marmorata or undeserved DCS are considered at higher risk of having a right to left shunt (RLS) or patent foramen ovale (PFO). A PFO may allow gas bubbles to escape the normal lung filtration system and lead to symptoms of DCI. With improvement in ultrasound capabilities, a bubble test looking for a right to left shunt is easier to perform and can provide valuable information for a clinician to educate divers on steps to take to prevent further episodes of DCI.

Methods: A protocol for performing bubble testing was created. After initial hyperbaric oxygen treatment, injured divers with suspicion of a RLS were approached to have a bubble test performed. An 18-gauge IV canulae was inserted into the left antecubital vein, a 9 ml of agitated normal saline with 1 ml of air was injected into the canulae while performing transthoracic echocardiography. This procedure was performed five times: at rest, with cough and with Valsalva. Shunts were graded as: negative (no bubbles shunting from right to left), small (less than 10 bubbles), moderate (10-20 bubbles) or large (more than 20 bubbles). Retrospective data was collected including injured diver demographics, incident dive details, initial disease severity (mild, moderate, or severe), time to symptom onset post-dive, final diagnosis, and clinical outcome. Outcome was classified as well (no residual signs or symptoms), minor symptoms (no functional significance), residual symptoms (moderate impairment), major incapacity, or death. Significance was accepted at $p < 0.05$.

Results: A total of 182 injured divers presented from January 2020 to December 2022. Median age of the divers was 54 (IQR 37, 62) years, certification, majority from overseas (only 4 Mexicans). Repetitive dives, depth, time, gas, surface interval. Time to symptom onset, normobaric oxygen. A total of 75 divers did not have bubble testing performed. Bubble test results were as follows: Negative 13, inconclusive 3, small (do you want to call this PFO or shunt?) 54, moderate 14 and large 19. PFO = 81, shunt = 3, IPAVA = 3 Initial disease severity and bubble grade.

Conclusion: Bubble grades corresponded to severity of initial symptoms with higher grades seen in divers with higher initial disease severity.

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Keywords: Bubble test, DCI, Scuba diving, Ultrasound, RLS

HBOT Operations, Chambers and Equipment

CL - (19421) - COMPARING THE EMMA CAPNOGRAPH WITH SIDESTREAM CAPNOGRAPHY AND ARTERIAL CARBON DIOXIDE PRESSURE AT 284 KPA

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Abstract

Introduction

Capnography aids the clinician during mechanical patient ventilation. Physical and physiological changes in hyperbaric environments create ventilation challenges which make end-tidal carbon dioxide ($ETCO_2$) particularly important. However, obtaining accurate capnography in hyperbaric environments is widely considered difficult. This study investigated the EMMA capnograph for hyperbaric use.

Methods

We compared the EMMA capnograph to sidestream capnography and the gold standard arterial carbon dioxide blood gas analysis in a hyperbaric chamber. In 12 resting subjects breathing air at 284 kPa, we recorded $ETCO_2$ readings simultaneously derived from the EMMA and sidestream capnographs during two series of five breaths (total 24 measurements). Arterial blood gas (ABG) samples were also simultaneously taken once in five participants.

Results

Across all measurements there was a mean difference of -0.1 kPa (95%-CI -0.2 to -0.07) between the EMMA and sidestream capnographs indicating a very slight over-estimation of $ETCO_2$ by the EMMA capnograph, but fundamentally good agreement between the two end-tidal measurement methods. Compared to ABG measurements the mean difference was -0.3 (95%-CI -0.9 to 0.2) and -0.4 (95%-CI -1.0 to 0.2) kPa for the EMMA and sidestream capnographs respectively.

Conclusions

In this study, the EMMA capnograph performed equally to the sidestream capnograph when compared directly, and both capnography measures gave clinically acceptable estimates of arterial PCO_2.

Keywords: Diving research, Capnography, Carbon dioxide, Patient monitoring, Intensive care medicine

Diving Medicine

CL - (19422) - WHAT IS THE BEST TREATMENT FOR SEVERE SPINAL CORD DECOMPRESSION SICKNESS IN HYPERBARIC CENTER?

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Abstract

Introduction: Neurological forms of decompression sickness (DCS), particularly spinal cord DCS, are frequent and often cause sequelae despite therapeutic management in a hyperbaric center. We present the results of a study aimed at determining the best therapeutic management in a hyperbaric center on the outcome of spinal cord DCS, including the influence of initial recompression and additional sessions at 4 or 2.8 abs atm.

Methods: This is a retrospective study using prospectively collected data that included cases of spinal cord DCS with objective sensory or motor deficit affecting the limbs and/or sphincter involvement, seen at a single hyperbaric center between 2010 and 2020. Information about the dive, clinical presentation (initial severity score and worsening in the first 24 hours), recompression time and hospital management (hyperbaric and drug treatment such as lidocaine) were analyzed as predictors. The primary endpoint was the presence or absence of sequelae at hospital discharge.

Results: 102 divers (52±16 years, 20 women) were included. In this series of selected severe patients, 46% had neurological sequelae at hospital discharge. In multivariate analysis, high initial clinical severity, the presence of worsening in the first 24h and recompression tables at 4 vs. 2.8 abs atm for initial recompression and additional tables were significantly associated with incomplete neurological recovery. Further analysis showed no clinical benefit for the use of lidocaine.

Conclusion: Recompression tables at 2.8 abs atm for initial and additional treatments in the first 48 h should be favored. For the first time, it has been shown that the risk of long-term sequelae is not only linked to initial severity, but also to clinical worsening in the first 24 hours, reflecting the activation of biological cascades that are not stopped despite the elimination of bubbles by recompression.

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Keywords: diving, decompression sickness, spinal cord, HBOT, neurological sequelae

Diving Medicine

CL - (19433) - HYPERCAPNIA IN NORMOBARIC AND HYPERBARIC ENVIRONMENTS

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Abstract

Introduction: Carbon dioxide is produced by human metabolism, which is removed from the body through exhalation. Due to malfunctioning (rebreather) dive equipment and/or high work of breathing carbon dioxide may be inadequately eliminated during diving and subsequently lead to hypercapnia. Symptoms of hypercapnia include shortness of breath, headache, disorientation, confusion, agitation and ultimately loss of consciousness. This study evaluates the effects of hypercapnia in normobaric with hyperbaric environments.

Materials and method: In this randomized cross-over study twelve healthy certified technical divers came in for three visits: 1) normobaric heliox; 2) hyperbaric air at 6 ATA; and 3) hyperbaric heliox at 6 ATA. During each of those visits the participants were exposed to three different relative inspired carbon dioxide levels of about 0, 4 and 7 kPa. During all exposures, inspired and end tidal carbon dioxide, breathing frequency, gas consumption and heart rate were measured continuously. During the normobaric exposures we also continuously measured oxygen saturation, tidal volume, and minute ventilation. At the end of each of the three normobaric exposures participants held their breath for as long as they could. At the end of each exposure participants scored their experienced symptoms on a VAS scale from 0 to 10.

Results: Participants experienced significantly less fatigue, dizziness, headache, and shortness of breath and were significantly less agitated, panicked, and restless when breathing hyperbaric air with high carbon dioxide concentrations compared to both normobaric heliox and hyperbaric heliox with high carbon dioxide concentrations. Gas consumption while breathing carbon dioxide was much higher in normobaric exposures compared to hyperbaric exposures. The breath hold time during normobaric exposures decreased with increased inspired levels of carbon dioxide.

Discussion and conclusion: Both normobaric and hyperbaric heliox exposures were rated worse than the hyperbaric air exposures. Nitrogen narcosis might be masking the experienced symptoms of high levels of carbon dioxide during air breathing. People breathing heliox might be better in recognising hypercapnia symptoms.

Keywords: Hypercapnia, Diving, Hyperbaric, Physiology, Experience

Clinical HBOT

CL - (19450) - HYPERBARIC OXYGEN AS AN ADJUVANT TREATMENT IN CHRONIC OSTEOMYELITIS: RESULTS FROM A SINGLE CENTER BETWEEN 2006 AND 2022

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Abstract

Introduction: Chronic osteomyelitis is defined as the persistence or recurrence of infection following adequate surgical debridement and antibiotic therapy. Although these are the cornerstones of treatment, hyperbaric oxygen therapy (HBOT) has been used as an adjunctive treatment and is currently an AHA class IIa recommendation. However, there are no randomized clinical trials and new data from recent years are scarce. The objective of this work was to report our center experience, and analyze treatment and patient factors that could be associated with one year relapse.

Methods: We conducted an observational retrospective study of all patients aged 17 or older, with a confirmed diagnosis of chronic osteomyelitis, who were submitted to HBOT between 2006 and 2022. Data were collected through medical chart review. Patients with acute osteomyelitis, concomitant diabetic foot, and incomplete data were excluded. The primary outcome was defined as relapse after more than a year and was assessed for patients who completed at least thirty sessions and maintained follow up for at least a year. Secondary outcomes were relapse at 6- and 12-months follow-up. Statistical analysis was performed using IBM SPSS v.29. Chi-square and Wilcoxon-Mann-Whitney tests were used ($p<0,05$ considered significant).

Results: Seventy-five patients performed HBOT: 83% men, with a median age of 47,3 years old, 51% current or ex-smokers, and 30% with dyslipidemia. Three patients received more than one cycle of HBOT and 62% were referred from another hospital. Prior to HBOT, all patients had received antibiotics (73% targeted) and 83% underwent surgical debridement. The bone most commonly involved was the femur (35%), followed by the tibia (28%), and foreign materials were present in 20% of patients. The most common infecting agent was *Staphylococcus aureus*. The median time between the diagnosis of chronic osteomyelitis and the beginning of HBOT treatment was 8,1 months [0,6-454]. Side effects occurred in 6 patients, leading to HBOT suspension in two (3%): hyperoxic convulsion and grade II barotrauma. During HBOT sessions, 99% of patients were treated with antibiotics (67/68, no available data on 7 patients), but only 57% were submitted to an additional surgical intervention (40/70, no data on 5 patients). The outcomes were assessed in 54 patients: at a follow-up of six months 80% of patients were free of disease, 67% at twelve months, and only 46% after more than a year. For the primary outcome, we observed a significant difference in time between diagnosis and referral to our center, with better outcomes with earlier referral (figure 1).

Conclusion: HBOT is a safe adjunctive treatment option, with temporary positive outcomes in the majority of patients, improving quality of life. Controlled studies are needed to understand the impact of this treatment on long-term prognosis. Early referral may have a role in therapeutic success.

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Keywords: Osteomyelitis, hyperbaric oxygen therapy, refractory

Clinical HBOT

CL - (19452) - THE EFFECTS OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF PATIENTS WITH CENTRAL RETINAL ARTERY OCCLUSION - A LONG-TERM RETROSPECTIVE STUDY

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Abstract

Background: Central retinal artery occlusion (CRAO) results in sudden painless vision loss[1]. As an analogous condition to acute ischemic stroke[2], CRAO is an ophthalmological emergency, but a standardized treatment is lacking[3]. Hyperbaric Oxygen Therapy (HBOT) has been widely used however inconsistent results have been reported.

Purpose: To report the visual acuity outcomes in all patients submitted to HBOT with non-arteritic CRAO in our Unit.

Methods: This retrospective study included all adult patients with CRAO and less than 24 hours of evolution submitted to HBOT in the Hyperbaric Medical Unit of a Portuguese Hospital from March 2009 to February 2023. Exclusion criteria were: patent cilioretinial artery, no documented best corrected visual acuity, arteritic CRAO and branch retinal artery occlusion. All patients were submitted to 90-minute sessions with 100% oxygen at 2.4 atm up to 20 sessions. Primary outcome was visual acuity (VA) change (logMAR) after treatment. A clinically significant visual improvement was defined as a decrease in logMAR ≥ 0.3. Patient's medical history, demographic information, time until HBOT, number of sessions, adverse effects, supplementary treatments, fundoscopic changes and patient subjective VA gain were also collected. Data were analyzed using IBM SPSS v.29 ($p<0,05$ considered significant).

Results:114 patients met the inclusion criteria, 68% males, with a median age of 71,5 years, and a median number of 7 HBOT sessions. No serious adverse effects from HBOT were reported. Median time delay from symptoms to treatment was 11 hours, and VA at baseline was counting fingers or worse in 84% of the patients. VA gain was ≥ 0.3 logMAR in 46% of the patients, and 58% reported subjective VA improvement after the treatment. A significant improvement in best-corrected visual acuity between baseline (2.12±0,74 logMAR) and post HBOT (1.67±0,74 logMAR) was observed. Supplementary treatments were performed in 46% of all patients and failed to demonstrate improvements in VA compared with HBOT alone. VA outcome was found to be related with total number of sessions, obesity and age. We did not observe differences regarding time delay from symptoms to treatment or the presence of cherry-red spot macula in respect to VA outcome.

Conclusions: HBOT appears to be safe and have a beneficial effect on VA outcome in patients with non-arteritic CRAO, particularlywith a greater number of sessions. Patient factors such as age and obesity also appear to influence the VA outcome.

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Keywords: Central Retinal Artery Occlusion, Treatment Outcome, Visual Acuity

Diving Medicine

CL - (19459) - WHAT CAN A PULMONOLOGIST LEARN FROM FREEDIVERS?

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Abstract

Introduction: The sport of freediving implies diving underwater without the use of breathing equipment. Freediving is a way of life for some, a competitive sport for others, and a hobby for many. Freedivers voluntarily expose their bodies to an extreme environment where surrounding pressures exceed even tenfold than a normal atmospheric pressure during which they hold their breath for a very long time. In order to achieve best results in their training process they undergo physiological processes similar to pulmonary patients (i.e. hypercapnia, hypoxemia, respiratory acidosis, very low lung volumes etc.).

This talk will focus on two goals:

1. To review possible exercise and training methods that can be used in pulmonary medicine now used by elite free divers,
2. To hypothesize fields in respiratory medicine where freedivers could be a perfect model for further research.

Methods: We followed three elite freedivers, for four years, all world champions and world record holders. From our recent and ongoing research we found many ideas for further research and implementation of their skills in everyday pulmonary medicine practice.

Discussion: Freedivers use different exercises and skills in order to improve breath-holding time and maximal depth such as glossopharyngeal insufflation/exsufflation manoeuvres, stretching, breathing and relaxation techniques, tolerance to hypercapnia and hypoxemia etc. In their training and freediving, they can achieve physiological states similar to some pathophysiological states that we see in patients with lung diseases like hypercapnia, hypoxemia, respiratory acidosis, pulmonary oedema, but they also recover within seconds. When followed and researched, freedivers can be the perfect model for research in basic respiratory physiology, respiratory rehabilitation, hypoventilation syndromes, ventilator induced lung injury, sleep apnoea etc. Methods of respiratory training and use of free diver skills to pulmonary patients in respiratory rehabilitation, improving respiration in hypoventilation syndromes, use of glossopharyngeal insufflation to improve coughing in neuromuscular patients and other methods are not commonly spoken about and are rarely used in everyday pulmonology practice.

Conclusion: Free divers can be of great interest for pulmonologists for future research and implementation of their skills in everyday practice.

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Keywords: freediving, hypercapnia, pulmonary oedema

Clinical HBOT

CL - (19464) - EVALUATION OF PATIENTS REFERRED FOR HBOT AFTER HIGH MAGNITUDE EARTHQUAKES: EXPERIENCE OF A UNIVERSITY HOSPITAL HBOT UNIT

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Abstract

Introduction

This year, two consecutive earthquakes both with magnitudes over 7 according to Richter Scale hit the southeast part of Turkey on the same day, February 6th. The disaster which affected 10 cities killed about 50,000 people and injured more than 100,000 people officially. Many patients were transferred to other cities as the regional hospitals which were also widely affected were not able to meet the demand. Almost all HBOT centers throughout the country received and treated many patients mostly with compartment syndrome and crush injuries. We aim to share our single center experience of treating earthquake related injuries.

Materials and methods

Patients referred our unit for earthquake related injuries after February 6th were reviewed retrospectively. Demographic data, history of injury (time under rubble, site of injury, time to hospital and intervention) history of medical interventions and details about HBOT (time to treatment, number and frequency of sessions) were recorded. Results are presented descriptively. HBOT was administered at 2.4 ATA for a total of 115 minutes involving three 25-minute oxygen periods. Daily protocol and total number of sessions were decided on a case by case basis.

Results

Forty-one patients (19 female, 22 male) were treated for earthquake related injuries. Mean age of the patients was 26.7 and 34.1% (n=13) were under 15 year of age. Thirty seven (90.2%) patients were trapped under rubbles and four patients were injured by falling objects. One patient was rescued at the 261th hour but mean time under rubble for 36 patients was 26.4 hours. Thirty three patients underwent HBOT for compartment syndrome or compromised fasciotomy wounds and related conditions whereas four patients were treated for crush injury with fracture or amputations, one patient for frostbite and three patients for delayed healing or complications. Twenty three patients had fasciotomy and four had an amputated limb at the time they started HBOT. The most common site of injury was crus (n=31) and bilateral injury was present in 14 patients. Five patients had isolated upper extremity injuries. Mean time from rescue to HBOT was 138 hours for primary conditions and mean number of total sessions applied to all patients was 25. Four major amputations one performed after the first session and two performed after first three HBOT sessions and two minor amputations were necessary. Extremity salvage was provided for all other patients.

Discussion

Providing faster healing and so earlier mobilization and discharge of patients in disaster conditions is important. HBOT which is known to be beneficial in the management of acute traumatic injuries would ameliorate quality of life for many patients and help to decrease social and economic burden for health systems.

Keywords: Earthquake, compartment syndrome, crush injury, hyperbaric oxygen

Diving Medicine

CL - (19502) - HIGH-LEVEL EDUCATION ON DIVING AND HYPERBARIC MEDICINE. A 40 YEARS HISTORY FROM CRIS-UTH, THE HYPERBARIC THERAPY UNIT OF BARCELONA

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Abstract

HISTORY. The Medical Department of C.R.I.S. in Barcelona, Catalonia, Spain, started in 1976 a programme of courses on Diving Medicine given on demand for diving physicians of our institution. In 1980, courses were open to medical doctors from other institutions following a scheduled annual programme. Since the 1983 edition, lectures on hyperbaric Medicine were included. In 1985 we received the first students coming from Latin-American countries. Up to 43 editions have been given since 2023.

ACADEMIC ACCREDITATION was obtained from different Universities and High level institutions, among them the Academy of Medical Sciences of Catalonia, University of Barcelona, Continuous Education Foundations, Up-to-date programmes of the Medical organization, and direct recognition from other Universities. Academic Degrees of Diving and Hyperbaric Medicine (D&HM) ranged from University Diploma, Postgraduate Diploma, Continuous education licence, Master on D&HM, currently a Master of Specialization, and final accreditation by the Joint educational subcomission EDTC/ECHM as levels 2D and 2H.

VENUE. The great majority of the courses were given in Barcelona, either in the Medical School, in the Hospital were the Hyperbaric Medical Centre is located, or other venues. Some courses have been given on demand in different locations within Europe or Latin-American countries.

STUDENTS. The overall number is 720, of which 590 (81,94%) came from Spain, 104 (14,44%) from different countries of North and South America, 26 (3,61%) from other European countries, mainly from Portugal.

FACULTY come mainly from our own institution, reinforced with professors from other areas within Spain, and Foreign invited visitors from other European countries.

LANGUAGE. Courses are given in Spanish language with the only exception of foreign invited professors. Some few courses have been given on demand in English language.

TEACHING. During the 30th first years, our courses were taught in presential classroom modality. In the last 10 editions we adopted a semipresential blended modality with a Pre-study phase, then an intensive and immersive Face-to-face classroom phase, and a post-attendance phase based on false-live video-recorded conferences. Students must undergo a practical stage of minimum 100 hours in a Hospital-based Centre of Hyperbaric Medicine, an at least minimal experience on SCUBA diving, and a research project or Master's thesis.

CONCLUSION. We are proud to modestly believe that our teaching effort has contributed to improve the knowledge and education in Diving and Hyperbaric Medicine within the Spanish-Speaking areas.

Keywords: DIVING MEDICINE

HBOT Theory and Mechanisms

CL - (19503) - SAFETY OF HYPERBARIC OXYGEN THERAPY IN PATIENTS WITH HEART FAILURE: A RETROSPECTIVE REVIEW.

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Abstract

Background: Hyperbaric oxygen therapy (HBOT) has several hemodynamic effects including increases in afterload (due to vasoconstriction) and decreases in cardiac output [1]. This, along with rare reports of pulmonary edema during emergency treatment, has led providers to consider HBOT relatively contraindicated in patients with reduced ejection fraction (EF) [2]. However, there is limited evidence regarding the safety of elective HBOT in patients with heart failure (HF), and no reports of complications among patients with HF and preserved EF. We aimed to retrospectively review patients with preexisting diagnoses of HF who underwent elective HBOT, to analyze HBOT-related acute HF complications.

Methods: Research Ethics Board approval was received to examine patient charts. Patients with a history of HF with either preserved ejection fraction (HFpEF), mid-range ejection fraction (HFmEF), or reduced ejection fraction (HFrEF) who underwent *elective* HBOT at two Hyperbaric Centers (Toronto General Hospital, Rouge Valley Hyperbaric Centre) between June 2018 and December 2019 were reviewed.

Results: Twenty-three patients with a history of HF underwent HBOT (Table 1), completing an average of 39 (6-62) consecutive sessions at 2.0 atmospheres absolute (ATA) (n=11) or at 2.4 ATA (n=12); only two patients received less than 10 sessions. Thirteen patients had HFpEF (mean LVEF 55 ± 7), and seven patients had HFrEF (mean LVEF 35 ± 8) as well as concomitantly decreased right ventricle function (n=5), moderate/severe tricuspid regurgitation (n=3), or pulmonary hypertension (n=5). All but one patient were receiving therapy either with loop diuretics or dialysis (Table 2).

21 patients completed HBOT without complications. We observed symptoms consistent with HBOT-related HF exacerbation in two patients. One patient with HFrEF (LVEF 24%) developed dyspnea after the fourth treatment attributed to pulmonary edema. He later admitted to voluntarily holding his diuretics before the session. He was managed with increased oral diuretics as an outpatient and completed a course of 33 HBOT sessions uneventfully. Another patient with HFpEF (LVEF 64%) developed dyspnea and desaturation after six sessions, requiring hospital admission. Acute coronary ischemia and pulmonary embolism were ruled out, and an elevated BNP and normal LVEF on echocardiogram confirmed a diagnosis of pulmonary edema in the context of HFpEF. Symptoms subsided after diuretic treatment, and the patient was discharged home in stable condition but elected not to restart HBOT.

Conclusions: Patients with HF, including HFpEF, may develop HF symptoms during HBOT and warrant ongoing surveillance. However, they can receive HBOT safely after optimizing HF therapy and fluid restriction.

		n= 23
Age (years)		70 ± 12
Body Mass Index (kg/m^2)		31 ± 11
Female		8
Comorbidities		
History of hypertension		21
Baseline Heart Failure classification:		
Preserved EF (LVEF ≥ 50%)		13
Mid-range EF (LVEF 41-49%)		3
Reduced EF (LVEF≤40%)		7
Coronary artery disease		14
Left ventricular hypertrophy		7
Heart valvular disease		6
Diastolic dysfunction		7
Atrial fibrillation		9
Peripheral vascular disease		11
Diabetes mellitus:		
Type 1		2
Type 2		16
Chronic obstructive pulmonary disease		5
Restrictive lung disease		0
Smoking status:		
Never		15
Current		2
Past		6
Renal insufficiency		14
Dialysis		5
Medications		
ACEi/ARBs		11
B-blockers		15
Calcium channel blockers		13
Diuretics		18
Vasodilators		6
HBOT Pressure (2.4 ATA)		10

Table 2 HBOT details. LVEF, HBOT exposure pressure, number of sessions, indications for HBOT.

Pt #	LVEF (%)	ATA prescribed	Total n of treatments	Indication
1	34	2,4	26	AI LL
2	54	2,4	60	DFU
3	66	2,4	35	AI LL
4	33	2,4	35	STRI-RC
5	55	2,4	23	ORN -jaw
6	50	2,4	58	DFU
7	52	2,4	50	DFU
8	45	2,4	40	AI LL
9	31	2,0	49	DFU
10	50	2,4	60	CPHYX
11	24	2,4	33	CPHYX
12	64	2.4	6	DFU
13	40	2.4	8	CPHYX
14	52	2.0	50	DFU
15	56	2.0	60	DFU
16	48	2.0	42	DFU
17	32	2.0	30	DFU
18	51	2.0	62	DFU
19	30	2.0	17	DFU
20	50	2.0	36	DFU
21		2.0	60	STRI-RP
22	50	2.0	41	CPHYX
23	52	2.0	25	DFU

HBOT, hyperbaric oxygen therapy; ATA, atmosphere absolute; LVEF, left ventricle ejection fraction; n, number.

AI LL: arterial insufficiency – lower extremity; DFU: diabetic foot ulcer; STRI: soft tissue radiation injury; RC: radiation cystitis; RP: radiation proctitis; ORN: osteoradionecrosis; CPHYX: calciphylaxis

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Keywords: heart

E-POSTERS

Basic research in HBOT

EP - (19016) - COMPARISON OF DNA-DAMAGES AFTER EX-VIVO EXPOSURE TO HYPERBARIC OXYGEN AND UVA IN PERIPHERAL MONONUCLEAR CELLS (PBMC)

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Abstract

Hyperbaric oxygenation (HBO) is a recognized form of therapy for various indications (Gas gangrene; CO-Intoxication, DCS, necrosis). In this context, damage caused by mitochondrial oxygen radicals formed during hyperoxia is also discussed. Nevertheless, from an occupational medicine point of view, the severity of potential damage caused by the ROS generated during HBO is not clear. In order to estimate the severity of HBO damage we made a comparison with the damage induced by the well-documented exogenous noxious agent UV-A irradiation, whose biochemical mechanism of action inside the cells is also mediated by the formation of ROS similar to HBO.

Method: Peripheral mononuclear cells (PBMC) were obtained from the blood of test subjects (n=20). From one subject at a time, one part of the peripheral mononuclear cells was exposed to hyperbaric oxygen (300kPa O_2, 6h) and the other part to 90min UV-A radiation (365nm, 0.066mJ/cm^2*sec., comparable to sun exposure in a normal winter day). Samples were taken at 10-minute intervals and the number of DNA-damaged PBMCs was determined by alkaline comet assay (CA), calculating the amount (%; average) of DNA damage by a visualized binary scoring system in 200 cells per subject.

Results: The experiments demonstrated that the DNA damage response of UV-A-exposed PBMCs (%) follows a sigmoidal function, with already 77,8±8,7% of DNA-damaged cells after 90 minutes.

In contrast, only 8.8±4,3 % of DNA-damaged cells were observed after 90 minutes of hyperbaric exposure, but the value increased up to 36.4±8% after 360 minutes of exposure.

A correlation between HBO and UV-A exposure shows that the number of DNA-damaged cells of 8.8% is reached after 90 minutes for hyperoxic-loaded PBMCs, but after 27 minutes for UV-A irradiation (corresponding to the cumulative dose of 0.107J/cm^2 UV-A irradiation).

Conclusions: The hyperoxic load of PBMCs used here corresponds to the therapeutic Boerema scheme (300kPa O_2; 90min.). This therapy is mainly used for CO-intoxications and gas gangrene infections. The comparison of the percentages in DNA-fragmentation in PBMCs between exposure to HBO versus UV-A irradiation shows, that comparable levels of DNA-fragmentation by CA were obtained after 90min of exposure to 300kPa O_2, but already after 27min exposure to low-dose UV-A (0.066mJ/cm^2*sec.). Consequently, the UV-A dose used in this experiment constitutes only 0,00066% of a low-dose UV-A therapy (10 J/cm^2) used in practice. For this reason, our experiments indicate that DNA damage by HBO-induced oxidative stress is rather negligible.

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Palavras-chave: HBO, UVA, ROS generation, DNA damage

Clinical HBOT

EP - (19099) - HYPERBARIC OXYGEN THERAPY AS ADJUVANT TREATMENT FOR PHARYNGOCUTANEOUS FISTULA – A CASE REPORT

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Abstract

Pharyngocutaneous fistula is one of the most dreaded complications of total laryngectomy, especially in patients who previously underwent local radiotherapy[1–3]. Its management is usually conservative but it can sometimes prove very difficult to heal, even with surgical treatment. Hyperbaric oxygen therapy has been proposed as an alternative or adjuvant treatment to surgery[4].

We present a case of a 74-year-old patient diagnosed with larynx squamous cell carcinoma (LSCC) in 2015 treated with radiotherapy and a relapse in 2021 (T3N0M0). The patient was treated with total laryngectomy, neck dissection and voice prosthesis placement, having developed a pharyngocutaneous fistula in the post-operative period.

Patient was submitted to conservative treatment followed by three surgical interventions (direct closure, supraclavicular flap and revision of supraclavicular flap).

Due to previous surgical failure, it was decided to try adjuvant hyperbaric oxygen therapy after the third surgery. The patient underwent 17 sessions of hyperbaric oxygen therapy (90 minutes, 2.5 ATM), with complete closure of the fistula. Voice prothesis was later successfully placed and the patient is currently asymptomatic.

In conclusion, hyperbaric oxygen therapy may be a useful tool in the treatment of difficult healing pharyngocutaneous fistula.

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Palavras-chave: pharyngocutaneous fistula, larynx, hyperbaric medicine, radiation

Diving Medicine

EP - (19103) - WORKING ABROAD: DESIGNING SAFETY, HEALTH AND WELL-BEING ALSO AN ISSUE FOR PROFESSIONAL DIVING AND HYPERBARIC WORK

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Abstract

Employees of diving tour operators such as dive centre managers or diving instructors, but also some professional divers and workers on hyperbaric construction sites have contracts at the European company headquarters. Therefore, within the framework of the legally required Europe-wide assessment of working conditions according to the European Framework Directive 89/391/EEC, the special psychological stresses of an occupational assignment abroad must also be taken into account. Both the social and economic importance of the psychosocial health of workers has advanced: In Germany, for example, the number of days of incapacity to work due to mental health diagnoses increased by 70% between 2010 and 2020 and is now the second largest cause of incapacity to work after musculoskeletal disorders with a total share of 17% (Radtke, 2022). Statistics from other Western countries differ only slightly from this and the WHO also summarises in its "World Mental Health Report" published in 2022 that about one in eight adults worldwide lives with a mental illness - a much higher number is to be assumed due to still prevailing stigmatisation and lack of treatment options (WHO, 2022). Particularly when assessing the safety, health and well-being of employees deployed abroad for work, there are sometimes very specific psychological influences. This must be taken into account, especially with regard to a holistic approach in the sense of Vision Zero. Various tools are available to support German company managers and entrepreneurs in the assessment of mental stress and the measures to be taken, which is required by law throughout Europe: Guides such as "Working Abroad Safe and Healthy", "Professional travel abroad and secondments (psychological stress)", ISO 31030:2021 Travel Risk Management - Guidance for Organizations etc.. This paper will present the specific psychological stresses associated with professional assignments abroad, the preventive approach and a number of helpful tools. These tools are not specifically geared to diving or overpressure work, but are aimed at the occupational traveller in general. Nevertheless, they are a valuable aid for the person concerned.

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Palavras-chave: Working abroad, assessment of working conditions, well-being, occupational diving, hyperbaric work

Diving Medicine

EP - (19126) - EXHALED BREATH MARKERS OF PULMONARY OXYGEN TOXICITY AFTER OPERATIONAL HELIOX DIVING TO 81 METERS

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Abstract

Introduction: In recent years, the Royal Netherlands Navy Diving and Submarine Medical Centre conducted various studies about analyzing volatile organic compounds (VOCs) in exhaled breath to find biomarkers associated with pulmonary oxygen toxicity (POT) [1–6]. After shallow hyperoxic in-water dives and hyperbaric oxygen therapy in laboratory setting, an increase of mainly alkanes and aldehydes was observed. In this field study, breath samples were collected after deep heliox (84% helium and 16% oxygen mixture) dives to study if VOCs were similar to the compounds identified in earlier scenarios.

Methods: Three divers of the Royal Netherlands Navy made several heliox dives to 81 msw (meter sea water; 815.6 kPa) using surface-oxygen decompression, based on the DRDC DCIEM heliox diving tables. The dives lasted 62 minutes with an oxidative stress of 119 UPTD [7]. 26 Breath samples were collected before and 30 min, 2 h, and 4 h after the dives. Gas chromatology-mass spectrometry and the NIST library were used to identify the VOCs [8]. Univariate analyses were conducted to test fluctuations of VOCs over time, and multivariate and univariate analyses were employed to test previously identified VOCs associated with POT within the breath samples.

Results: Univariate testing did not result in significant findings. However, targeted sparse partial least squares discriminant analysis (sPLDA) modeling based on previously identified VOCs of interest from the VAPOR library did result in significant (p = 0.004) change over time for dodecane, tetradecane, octane, methylcyclohexane, and butyl acetate [9]. A maximum increase of intensity of circa 175% was observed at the 2 h post-dive measurement. See Figure 1.

Discussion and conclusion: To our knowledge, this is the first study that analyzed VOCs after an operational heliox dive to 81 msw. As in previous studies, a maximum change in VOC intensity was found in the 2 h post-dive samples. However, this could only be found after targeted multivariate sPLDA modeling. The small sample size (n = 26) and relatively short hyperoxic exposure (62 minutes) with a relatively low (119) UPTD, could explain smaller VOC changes compared to previous studies. Also, the exact role of helium in a hyperbaric environment is not yet fully understood, but there have been studies suggesting a protective role on a cellular level [10]. Concluding, these findings indicate a limited and reversible reaction to hyperoxia has been occurring after heliox diving, but no signs of prolonged pulmonary damage were observed. This strengthens the belief that POT is a subclinically developing process before first symptoms are experienced. In addition, the study demonstrated breath samples can be collected in an operational setting. Further research should focus on optimizing sampling techniques for field use and finding dose-response relationships of POT biomarkers after hyperbaric hyperoxic exposures.

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Palavras-chave: Heliox diving, Exhaled breath markers, Volatile organic compounds, Hyperoxia, Pulmonary oxygen toxicity

Clinical HBOT

EP - (19230) - HYPERBARIC OXYGEN THERAPY IN THE PEDIATRIC PATIENTS: EXPERIENCE OF THE TUNISIAN HYPERBARIC CENTER 2015 - 2022

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1 - Military hospital of Tunis

Abstract

INTRODUCTION Pediatric patients are frequently referred to our Hyperbaric Oxygen Therapy center for either life-threatening conditions or chronic diseases.

OBJECTIVE The aim of this study is to identify clinical conditions treated in the pediatric population referred to the hyperbaric unit of the Military hospital of Tunis through the past eight years and to describe treatment outcomes and assess complications related to our treatment.

METHODS This is a retrospective analysis of all records of patients younger than age 16 years treated between January 2015 and December 2022.

RESULTS During the past eight years, a total of 659 pediatric patients aged from 72 days to 16 years (mean, 7.1 years) received HBO treatment at the hyperbaric center of the Military hospital of Tunis. Of these children, 521 (79 %) suffered from acute carbon monoxide (CO) poisoning; 2 (0.3%) had mediastinitis; 1 suffered massive air embolism, twenty (3 %) were treated after crush injury, traumatic ischemia, or compartment syndrome; 15 (2.3%) presented idiopathic hear loss; ; 3 (0.4%) had delayed wound healing; 4 suffered perianal fistulas, 2 children presented osteochondritis of the hip (0,3%) , 1 child was treated for retinal frosted branch angiitis , six for post anoxic encephalopathy and 84 (12.7%) children presented autistic disorders. There were 4 episodes of oxygen induced seizures, 3 episodes of middle ear barotrauma.

Outcome, judged by immediate neurologic sequelae, mortality, and extent of soft tissue infection or limb amputation, was favorable in 645 patients . Two patients died: 1 as a result of severe CO poisoning and the other from massive air embolism and 3 patients in the acute traumatic ischemia group underwent partial limb amputation.

CONCLUSIONS The overall outcome was favorable with the majority of pediatric patients treated for the different indications listed. Yet, Awareness campaigns should be conducted concerning CO poisoning and close collaboration between the pediatrician and the hyperbaric physician is essential to ensure adequate referring of the pediatric patients for treatment when indicated.

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Palavras-chave: Emergency, HBOT, Children

Clinical HBOT

EP - (19235) - EFFICACY AND PROGNOSTIC FACTORS FOR IDIOPATHIC SUDDEN SENSORINEURAL HEARING LOSS PATIENTS TREATED WITH ADJUVANT HYPERBARIC OXYGEN THERAPY

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1 - Military hospital of Tunis

Abstract

Introduction: Idiopathic sudden sensorineural hearing loss (ISSNHL) is a clinical emergency .Several therapeutic methods have been applied so far for the treatment. Hyperbaric oxygen has also been widely used ,however, prognostic factors related to its curative effects are still not clear, which limits its clinical application.

Aim: The aim of this study was to investigate the efficacy and prognostic factors of hyperbaric oxygen therapy (HBOT) associated with drug therapies in the treatment of sudden hearing loss.

Patients and Methods: From January to December 2022 , records of all ISSNHL patients treated with adjuvant hyperbaric oxygen therapy in the Hyperbaric Center of the Military Hospital of Tunis were reviewed to assess hearing recovery and evaluate associated prognostic factors (gender, age, localization, initial hearing threshold, presence of tinnitus, vertigo, hypertension, diabetes, onset of HBOT, number of HBOT, and audiogram). The prognostic factors were analyzed with univariate and multivariate analyses.

Results: One hundred and one patients with sudden hearing loss were enrolled, including 10 cases of bilateral loss and 11 cases of complete hearing loss. After HBOT, there were 54 cases (53.3%) of improvement: 9 cases of complete recovery (8.9%), 22 cases (21.8%) of partial recovery, 23 cases (22.8%) of slight improvement, and 47 cases (46.5%) of no improvement. Two of 11 cases of complete hearing loss showed recovery. According to multivariate analysis, later onset of HBOT, higher initial hearing threshold and presence of vertigo were associated with a poor prognosis in ISSNHL patients treated with HBOT.

Conclusion: Combined HBOT can improve the hearing impairment of sudden hearing loss. The early HBOT showed the most promising therapeutic effects.

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Palavras-chave: HBOT, Multivariate analysis, Idiopathic sudden sensorineural hearing loss, Prognostic factors.

Clinical HBOT

EP - (19263) - HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF ACUTE CARBON MONOXIDE POISONING DURING PREGNANCY

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Abstract

BACKGROUND

The effect of Carbon Monoxide (CO) over pregnancy is well known. The mother and fetus have different sensitivities to the toxic effects of CO. Both abortive and teratogenic effects have been described. The approach to the diagnosis and treatment of Carbon Monoxide Poisoning (CMP) in pregnant women must be very accurate. We have reviewed our experience in the treatment of pregnant women that suffered an acute CMP.

METHODS

This is a retrospective study from January 2009 to August 2022. Asymptomatic pregnant women exposed to the same environment as other intoxicated patients were also included. We performed a descriptive analysis of socio-demographic, toxicological, clinical, and therapeutic profile data as well as the short and medium term follow-up. All patients received normobaric oxygen from the time of rescue. HBO was applied in a multi-place hyperbaric chamber at a pressure ranging from 2.3 to 3 ATA for 60 minutes.

RESULTS

Fourteen patients were included with a mean carboxyhemoglobin (HbCO) level of 12.9 ± 8.477% (1.6-25) n=14. Main symptoms were Headache (n=10; 71.4%), Dizziness (n=7; 50%), Nausea or Vomiting (n=6; 42.8%), Dyspnea (n=3; 21,4%) and Consciousness disturbance (n=2; 14.3%). One woman remained asymptomatic. Eight patients (57.1%) received HBO at 2.5ATA, three (21.4%) at 3ATA and three women (21.4%) at 2.3ATA. The average number of HBO sessions was 1.21 ± 0.425 (1-2) n=14. No side effects were observed. No signs of neurological impairment were detected after a one month follow-up. Two patients (14.2%) presented a first trimester spontaneous abortion four weeks after the CMP. No preterm deliveries were notified during follow-up. All newborns showed a correct Apgar-Score and no congenital abnormalities were observed. One newborn presented low birth-weight.

DISCUSSION

The two registered abortions occurred in women who had a previous history of first trimester spontaneous abortion. The rate of first trimester abortions was within the known range of our population area.

CONCLUSION

HBO was a safe and well tolerated treatment in pregnant women exposed to toxic levels of CO. No harmful effects were observed on the mother or children. Given the serious known effect of CO during gestation, HBO should be considered as a preventive treatment for pregnant women suffering from a CMP as well as for those in contact with toxic levels of CO.

Palavras-chave: Carbon monoxide poisoning, Pregnancy, HBO safety

Clinical HBOT

EP - (19297) - ADJUNCTIVE HYPERBARIC OXYGEN THERAPY FOR NECROTIZING FASCIITIS:A CASE REPORT

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Abstract

Necrotizing fasciitis (NF) is a rare soft tissue infection characterized by rapid bacterial proliferation followed by liquefactive necrosis underlying tissues. NF is life threatening, associated with prolonged hospital stay and carries high risk of long-term loss of function. Immediate radical surgical debridement of all dead tissue is imperative. In addition to antibiotics, hyperbaric oxygen therapy (HBOT) has been used as an adjuvant therapy as it has been shown to improve wound healing, reduce inflammation and improve tissue oxygenation.

A 44-year-old male with history of HIV infection under therapy, cured Hepatitis C and drug abuse presented to the Emergency Department with diffuse abdominal pain, hematochezia, loss of vesical sphincter control and scrotal edema after insertion of a foreign body into the anus at 15 days ago. CT scan identified a 7cm object in the rectal ampulla, air dissecting the perianal tissues, ischiorectal fossa and extending to the scrotum, anterior lower abdomen and Retzius space, suggestive of Fournier's Gangrene.The patient was initiated on large spectrum antibiotics, underwent extensive perineum debridement, infra-umbilical exploratory laparotomy and removal of foreign body, as well as derivative colostomy, with loss of anal sphincter, and was admitted to the intensive care unit. He was then referred for HBOT, which he only started on the 3rd day of hospitalization due to previous hemodynamic instability. The patient underwent a total of 40 HBOT sessions, according to the Hyperbaric Unit Protocol for necrotizing acute infections - gangrenes. The first two sessions were performed with 50'O2 at 2.8 bar + 44'O2 at 2.4bar, followed by daily sessions (90'O2 at 2.4 bar). During his hospital stay, the patient missed a total of 5 HBOT sessions due to surgical complications. When necessary, he was submitted to further surgical debridements and placement of new dressings. The patient experienced good clinical evolution being discharged after 59 days of hospitalization, maintaining regular hospital accompaniment, and performing physiotherapy. 12 months after discharge, the patient was once again admitted due to septic shock originating in intestinal ischemia due to internal hernia and was submitted to an exploratory laparotomy. He has since recovered but has not undergone bowel transit reconstruction as the last anorectal manometry exam showed hypotension and hypocontractility of the anal sphincter.

This case highlights the successful use of HBOT in a patient with NF. Despite the patient's complicated medical history, he responded well to the combination of aggressive surgical debridement, antibiotics and HBOT. Early initiation of HBOT likely contributed to the patient's favorable outcome. This case underscores the potential benefit of HBOT as an adjunctive therapy in the management of NF, particularly in patients with risk factors for poor healing.

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Palavras-chave: Necrotizing fasciitis, Hyperbaric Oxygen Therapy, Fournier's Gangrene

Basic research in HBOT

EP - (19298) - TRANSCRIPTOMIC ANALYSIS OF CIRCULATING IMMUNE CELLS DURING HYPEROXIC AND HYPERBARIC STRESS REVEALS DIFFERENTIALLY EXPRESSED GENES ASSOCIATED WITH IRON AND OXYGEN BINDING

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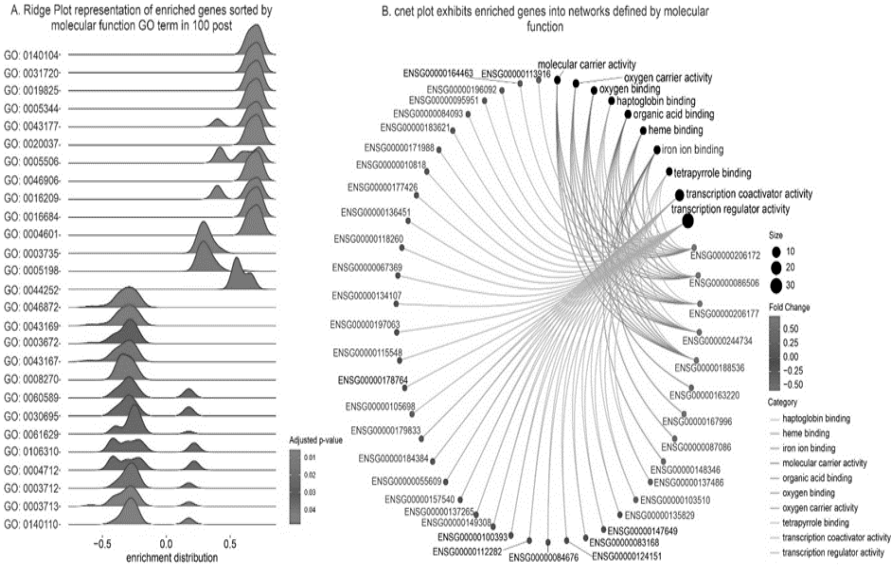
Abstract

Background: High-throughput transcriptomics analyses reveal acute and chronic responses to hyperoxic stress in a variety of tissues (PMID 34417156, 25003466, 31578039) which increase our understanding of how hyperoxic and hyperbaric stress affect lung function, injury risk, and recovery. We aimed to characterize systemic (circulating immune cells) responses to hyperoxic and hyperbaric stress among U.S. Navy Divers.

Methods: We completed a double-blind, randomized, sham-controlled crossover study in 14 male U.S. Navy trained divers (33.1±7.5 years, 84.3±11.8 kg). Each subject completed two dry resting dives in a hyperbaric chamber at the Pressurized Submarine Escape Trainer, Groton, CT. One dive exposed the subjects to 100% oxygen at 2 ATA (O_2) for 6.5 hours. The comparison dive was an enhanced air nitrox (EAN) dive in which the subjects breathed a 30.6% O_2 balance nitrogen mixture at the same depth for the same duration. Venous blood samples were drawn from the antecubital veins of the subjects' arm within 30 min of the start of each dive (PRE) and 30-45 min after the subjects had surfaced from each dive (POST). Total RNA was isolated, purified, and prepared for total RNA sequencing using the Illumina TruSeq™ Stranded Total RNA Sample Preparation kit. Sample libraries were prepared for NextSeq® 500/550 sequencing using version 2 sequencing chemistry (paired end 2 x 75bp read length). Raw reads were processed for quality control and pipeline for alignment (GRCh38) and differential gene expression between time points and conditions using the Tuxedo Suite (PMID 22383036).



Results: 16,623 genes were detected from plasma with 407 differentially expressed (DE) post O_2 and 101 DE post EAN (False Discovery Rate<0.01). Gene ontology (GO) analysis revealed enrichment dependent on hyperbaric oxygen exposure intensity. Gene set enrichment analysis in O2POST (100% exposure) revealed robust enrichment in terms related to oxygen and iron binding (GO: 0031720, GO: 0020037, GO: 0005506, GO: 0019825, GO: 0005344, see Fig. 1).

Conclusion: Gene set enrichment analysis of the significant DE genes in O2POST compared to O2PRE results in upregulation of molecular function GO terms (GO-MF) associated with iron and oxygen binding, including haptoglobin binding, heme binding, iron ion binding, oxygen binding, and oxygen carrier activity, which may be important for protecting the body from oxidative stress.

Fig 1: Gene set enrichment analysis of significant DE genes found in O_2POST.

Palavras-chave: hyperoxic, hyperbaria, genomics, immune, oxygen

Basic research in HBOT

EP - (19321) - IMPLICATION OF ANTI-INFLAMMATORY EFFECTS OF HBOT IN HUMANS: HYPERBARIC OXYGENATIONS RESTORE THE TH1/TH2 T CELL BALANCE AND INDUCE CD4POSCD39POS. REGULATORY T CELLS

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Abstract

Introduction: The balance between pro and anti-inflammatory features of the immune system is known to be essential for functional immune response. The successful use of HBOT in COVID-19 and Post-COVID treatment strategies (1-3) might be explained by re-modelling immunological effects (4). In murine models, frequent exposures to hyperbaric oxygen showed immunosuppressive capacity (5,6).

The study aimed to assess phenotypical and functional changes in the T-cell compartment after single and repetitive hyperbaric oxygenations to identify immunological response to HBOT.

Materials and Methods: 112 healthy non-divers (age 30.88±6.46years, 94.64% male, VO2max 49.30±8.87ml/min/kg) were included. Participants were exposed to a single hyperbaric oxygenation (n=50; 2.8 atmospheres, 30-minute) or 4 sessions of HBOT (n=3; 2.4 atmospheres, 130 minutes, three 30-minute exposures to 100% oxygen, interspersed with 10-minute air breaks). Peripheral blood mononuclear cells (PBMC) and plasma were collected before and after each hyperoxic exposure. PBMCs of 60 participants were exposed to an experimental pressure chamber similar to the *in vivo* experiments. T-cell compartments were phenotypically examined using flow cytometry. Transcription factor - dynamics were assessed using qPCR (Tbet, HELIOS, GATA3, RORgt, FOXP3, HIF1a). The influence of hyperbaric oxygenation on disturbed inflammatory response was determined using CFDA-SE based proliferation assay after magnetic sorting of effector and regulatory T-cells (Treg), triggered by anti-CD3/CD28 stimulation. TH1/TH2 Cytokine production was analyzed by cytometric bead array technics.

Results: Hyperbaric oxygenation induced only in the CD4 T-cell compartment elevated numbers of CD45ROposCD197pos central T cells and CD45ROposCD197neg effector memory T cells (TEM)(P=0.0061, P=0.0250 respectively), with a restore four days after the last hyperoxic exposure. The majority of TEM reflects features of TH1 (CD183posCD196neg T cells), with a consecutive reduction of TH2 TEM (P=0.0018) and reduced mRNA levels of TH2-related transcription factor GATA3 (P=0.0016). CD39pos Treg was increased (P=0.0019) until 24 hours after the last exposure. *In vitro*, the capacity of immunosuppression by Treg was increased by hyperbaric oxygenation (P=0.0019).

Discussion: The clinical effects of HBOT in disturbed immune response might be explained by restoring the TH1/TH2 balance and by induction of anti-inflammatory CD39pos. regulatory T-cells.

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Palavras-chave: HBOT, Immune response, hyperbaric oxygenation, Post-COVID, T-cells

Clinical HBOT

EP - (19324) - CARBON MONOXIDE POISONING IN CHILDREN TREATED WITH HYPERBARIC OXYGEN THERAPY

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Abstract

INTRODUCTION

Carbon monoxide (CO) is an important cause of intoxication in pediatric patients which is often treated with hyperbaric oxygen therapy (HBO). The aim of this study is to perform a descriptive review of children who suffered a Carbon Monoxide Poisoning (CMP) and received HBO in CRIS-UTH during the period 2010-2022.

METHODS

This is a descriptive study of CMP in pediatric patients (age <18 years) between January 2010 and December 2022. The data included sociodemographic features, characteristics and clinical presentation of the CMP, HBO therapy and adverse effects as well as posterior follow-up. Asymptomatic children exposed to the environment in which other family members presented symptoms received prophylactic HBO as well. HBO was applied in a multi-place hyperbaric chamber at a pressure ranging from 2.3 to 3 ATA for 60 minutes excluding compression and decompression periods.

RESULTS

A total of 199 patients were included of which 100 (50.3%) were female and 99 (49.7%) male. Mean age was 9.68 ± 4.69 years (1 - 17 years) n=190. Nine were infants less than 1 year old. Intoxications occurred in the household (n=193; 97.0%) during the winter (n=113; 56.8%) and the most common source of CO was a malfunctioning furnace (n=111; 55.8%). Clinical symptoms included headache (n=108; 54.3%), dizziness (n=85; 42.7%), consciousness disturbance (n=84; 42.2%), nausea or vomiting (n=58; 29.1%), somnolence (n=30; 15.1%), irritability (n=13; 6.5%) and other symptoms in less than 4% of cases. Three patients (1.5%) required orotracheal intubation due to consciousness impairment. No signs or symptoms were observed in 10 children (5.0%). The mean carboxyhaemoglobin percentage was 13.4 ± 9.352 (range = 0.4-41.1) n=199. Most patients received normobaric oxygen (n=196, 98.5%) prior to HBO. Ninety-three patients (46.7%) received HBO at 3ATA, 92 (46.2%) at 2.5ATA, 12 (6.0%) at 2.3ATA and two (1.0%) at 2.8ATA. The average number of HBO sessions was 1.46 ± 0.691 (1-5). Six patients (6.0%) suffered middle ear barotrauma, no other adverse effects were observed. A one month follow-up visit is available for 113 (56.7%) children. Two patients showed persistent personality changes after the CMP. A patient who presented a Glasgow Coma Scale of 6 upon rescue and required orotracheal intubation referred amnesia as well as persistent short-term memory difficulties. Given the continuous time interval from the CMP to the displayed symptoms, the cases were oriented as persistent neurological sequelae. No cases of delayed neurological sequelae were reported.

CONCLUSION

The use of HBO in children who suffered CMP was safe and well tolerated with little side effects. Given the seriousness of CMP with high morbidity and mortality, HBO should be considered as the primary therapeutic alternative for CMP in children.

Palavras-chave: Carbon monoxide poisoning, Pediatrics, HBO safety

Clinical HBOT

EP - (19329) - COMPARISON OF TWO INNOVATIVE 3D SCANNING METHODS FOR EVALUATING THE EFFICACY OF HBOT IN THE TREATMENT OF CHRONIC WOUNDS

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Abstract

Introduction: Hyperbaric Oxygen Therapy (HBOT) is a rapidly developing branch of medicine based on providing patients with 100% oxygen at elevated pressure to significantly increase oxygen levels in blood plasma and other body fluids. As an immediate effect, the intermittent change from hyperoxia to normoxia causes an increase in HIFα, leading to further gene expression-dependent tissue regeneration processes, which are among the long-term effects of HBOT [5,6,7,8,9]. One of the most extensively researched evidence-based indications for HBOT is the treatment of chronic wounds. Classically, two-dimensional imaging data, clinical observations (exudation, ulcer bed scoring, presence of granulation tissue) and viability assessment using transcutaneous pO2 monitoring can be used to assess the efficacy of the procedure[1,4]. In this feasibility study, we introduced and compared two innovative 3D scanning methods to evaluate the efficacy of HBOT in the chronic wound management of a patient with a diabetic leg ulcer, providing deeper information not only on ulcer volume changes, but also on colour and surface texture.

Case description: We applied HBOT (2.5ATA for 120 min, 20 times by 5 sessions/weekly) to a 56-year-old diabetic patient who had a grade 1 diabetic leg ulcer on the Wagner scale. The chronic wound healing process was monitored using imaging techniques that provide high resolution 3D models in colour [2,3].Such models can be obtained using handheld 3D scanners that provide metrological quality scale models. The Artec Space Spider industrial handheld scanner, with a working distance of 20 cm and a 3D resolution of 0.1 mm, is a suitable tool for this purpose. Taking into account the involuntary movements of patients and the visual characteristics of their wounds, the expected models can be produced with a 3D resolution of 0.3 mm. This allows the full extent, colour and texture of the wounds to be captured and tracked. Photogrammetry achieves a similar result but uses photographs. The advantage is that it does not require expensive hardware and provides higher quality textures. Disadvantages are that the acquisition and modelling time is longer, the result is of lower resolution and the measurement of the resulting 3D model requires the capture of a known reference dimension during the measurements. Photographs can be taken with any camera and processed in the AliceVision Meshroom software.

Discussion: Both methods are potentially suitable for the assessment of chronic wounds treated with HBOT. Handheld 3D scanners are able to provide more detail and accuracy and are considered to be a quick, fast solution, however they require more technical skills from the user and the equipment is costly, whereas photogrammetry can provide a more user-friendly, cost-effective and widely available solution with better texture quality.

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Palavras-chave: 3D scanning, Photogrammetry, Chronic wound, HBOT

Diving Medicine

EP - (19333) - LUNG SQUEEZE AS A CHALLENGE TO THE EVENT PHYSICIAN - ANALYSIS OF INJURIES DURING DEEP FREEDIVING COMPETITION

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Abstract

Introduction

Lung squeeze, as a serious lung injury, represents a major challenge to the diving physicians. During the world championships, the urgency is a return to diving as soon as possible after such injury with the minimal possible risk of the further lung damage. As members of the medical team, we monitored 350 dives of over 110 competitors during 15 days of the deep freediving competition. The aim of this report is to evaluate the frequency and severity of lung injuries, recovery time and overall safety of all attendants.

Methods: All dives, including training, pre-competition and 170 competition dives, involving 50 males and 30 females were monitored. Depth range was 33-120m; Mdn was 65m and 52m for females. All divers with respiratory symptoms were checked immediately after the dive. We evaluated oxygen saturation (SpO_2) and pulmonary function tests (PFTs). The same PFTs were repeated and carefully analyzed after lung squeeze and also in a group of 7 safety divers who practiced a series of repeated dives to a depth of 40m, over a period of 2 hours.

Results: During the pre-competition, we registered 7 blackouts (BO) in 180 dives (3, 8%). 5/7 had lung squeeze, 4 with severe form; 2 were hospitalized; 2 refused hospitalization and were disqualified. 3/5 recovered in the next 2-7 days and completed the competition. We report the case of the hospitalized male diver who returned to dive 7 days after lung squeeze. He was carefully monitored daily, also with lung ultrasound B line measurements later, thanks to the presence of the research team on scene, with portable ultrasound device (Patrician et al., 2021). The diver successfully completed the competition in 3 disciplines (CWT, CNF and FIM), on the second position of the Male Overall – Complete Results. During 170 competition dives (Mdn depth 81m men, 60m female), we registered 15 BO (8,8%), 12 lung squeezes (7%), one serious form. 7 divers (4,1%) has low SpO_2 and possible mild squeeze, without symptoms. Recovery period was 2-7 days. PFTs were significantly improved. In safety divers, we found a significant reduction in mean and minimum SpO_2 (p=0,001) and mean FEF75 (p=0,019) when compared to pre dive values.

Conclusions: We found a significant improvement in the mean SpO_2 and PFTs in a very short time interval after the serious lung squeeze. However, the serious doubts remain about “so fast full recovery”. It is good that medical rules for freediving competitions become more restrictive nowadays. We need much more data related to further follow up of injured divers. The presence of on-site portable ultrasound device was helpful to us. Safety free divers should be carefully medically checked too.

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Palavras-chave: lung squeeze hemoptysis pulmonary function

HBOT Operations, Chambers and Equipment

EP - (19355) - A SINGLE-CENTER RETROSPECTIVE STUDY OF COMPLICATIONS DURING HYPERBARIC OXYGEN THERAPY

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Abstract

Introduction: Hyperbaric oxygen therapy (HBOT) is a useful and usually safe treatment for various diseases. However, there are some specific risks related with the pressure variations, environment and breathing mixtures inside the hyperbaric chamber, which may affect patients and staff. The aim of this study is to analyze the incidence of complications during HBOT in one hyperbaric medical center for a 17 years period.

Materials and Methods: A retrospective study of 2239 patients with 39822 treatments between 2004 and 2020 was conducted. Medical records were reviewed to determine the number and profile of hyperbaric sessions, occurrence and type of complications related to the therapy and affecting patients and attendant personnel. Patients were treated for various indications within a multiplace hyperbaric chamber at a pressure of 2.0 – 2.5 atmospheres absolute (ATA).

Results: Ear pain or discomfort due to the problems of middle ear pressure equalization were observed in 177 (7,9%) of all patients, and in nine cases (0,02%) of all treatment sessions in attendant staff. Most of documented barotraumas or ear discomfort were mild and were observed during initial sessions. No inner ear or pulmonary barotraumas were identified during hyperbaric treatments. Mild tooth pain was documented in four cases of all patients. Oxygen toxicity of central nervous system or lung was no observed. Forty-six patients experienced anxiety and claustrophobic reactions and 11 of them ceased HBO therapy because of these problems. No incidents of decompression sickness in inside attendant were identified. Three cases of sinus pain in patients and only one case of frontal sinus barotrauma (0,003%) in attendant were reported.

Conclusions: These findings indicate that pressure equalization problems of the middle ear are the most often occurred during hyperbaric oxygen treatment, and serious complications are rare. Appropriate training, pre-treatment education and evaluations of the patients and staff are a key factor for safety operations. Strictly following safety rules and preventive measures help to reduce the HBOT related complications and incidents.

Palavras-chave: Hyperbaric oxygen therapy, complications, safety

Decompression Theory and Mechanisms

EP - (19358) - EFFECT OF HYPERBARIC STRESS ON RAT LEUKOCYTES AND PLATELET: THE IMPACT ON DECOMPRESSION SICKNESS SUSCEPTIBILITY

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Abstract

Introduction / Background: The onset of decompression sickness (DCS) is characterised by different mechanisms which are now fairly well recognised. Among them, there is the activation of inflammation and coagulation cascade. Previous studies suggested that DCS resistance could be associated with an increased inflammatory capacity and that these resistance mechanisms could be different between males and females [1]. However, we don't yet have a clear understanding of the impact of hyperbaric stress. We showed that VGE alone activates coagulation and stress pathways but not inflammation. Conversely, it was reported that hyperbaria induces inflammation, we hypothesized that resistance to DCS could be associated with a stronger inflammatory reactivity to high pressure. So, in this study, we aimed to evaluate, in vitro, the effect of hyperbaric exposure without bubbles on leukocytes and platelet activation.

Materials and Methods: We isolated leukocytes and platelets from the blood of 40 Wistar rats (20 males and 20 females). Leukocytes and platelet were then exposed to a hyperbaric protocol before being analysed by flow cytometry. For the flow cytometry analysis, the cells were stained with antibodies to identify different sub-population and some activation markers. Platelets were marked with CD61-BV710 (F11) and the activation was assessed thanks to CD62P-PE-Cy7 (RMP-1). Anti-rat CD45-APC/Fire 750 (OX-1) has been used to mark leukocytes. Neutrophils and monocytes have been discriminated thanks to their expression of CD11b-R718 (OX-42) and RP1-PE-CF594 (RP-1). B cells were marked by CD45R-BV605 (HIS24) and T cells by CD3-BV421 (1F4). Different activation markers have also been studied like CD69-FITC, CD40L-Cy5, CMHII-Viogreen (REA510) and CD142-PE. 4 weeks later, the rats from which the cells were collected, have been exposed to the same hyperbaric protocol to distinguish DCS-susceptible ones from the resistant ones.

Results: Preliminary results from 6 males and 5 females do not indicate differences between the cells exposed to hyperbaric protocol and SHAM cells. However, these preliminary results showed that the median fluorescence intensity for monocytes CMHII+ was higher in cells exposed to hyperbaric protocol than SHAM cells ($p = 0.0038$).

The complete analysis on the 40 rats will allow us to compare cells exposed to hyperbaric protocol to SHAM cells but also the possible link between the susceptibility to DCS of the animal and the basal state of the cells or their diving induced activation capacity.

Summary / Conclusions: This study is still in process but at the end of these experiments, we will be able to assess if the hyperbaric stress influences the activation of leukocytes and platelets. We will also aim to see if there is a correlation between this activation of leukocytes and platelets and the susceptibility to DCS.

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Palavras-chave: Decompression sickness, Platelets, Leukocytes, Hyperbaric stress, In vitro

Basic research in HBOT

EP - (19361) - HYPERBARIC OXYGEN PRECONDITIONING IN POSTISCHEMIC ACUTE KIDNEY INJURY: POTENTIAL MECHANISMS OF BENEFICIAL EFFECT

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Abstract

Introduction: Renal ischemia/reperfusion injury (IRI) is common cause of acute kidney injury (AKI). In our previous studies we showed beneficial effects of hyperbaric oxygen (HBO) preconditioning in IRI in hypertensive rats, so the aim of this study was to explore potential mechanisms by which HBO achieves its beneficial effects in this experimental setting.

Materials and Methods: The animals (spontaneously hypertensive rats) were randomly divided into three experimental groups: sham-operated rats (SHAM), rats with induced postischemic AKI (AKI) and group with HBO preconditioning before AKI inducing (AKI+HBO). HBO preconditioning was performed by exposing to pure oxygen (2.026 bar) twice a day for two consecutive days for 60 minutes and 24 hours before AKI induction. AKI was induced by removal of the right kidney and atraumatic clamp occlusion of the left renal artery for 45 minutes.

Results: In our previously reported results, we showed that HBO precounditioning is capable to improve renal function and hemodynamics, primarily accompanied by a decrease in the plasma concentration of urea and creatinine or an increase in their clearances, followed with a decrease of novel kidney biomarkers, such as plasma KIM-1, as well as a decrease of NGAL immunohistochemical expression in kidney tissue. Also, classic histopathological features of AKI were diminished after HBO preconditioning. Further, we wanted to explore potential mechanisms.Western blot analysis showed that AKI induction significantly decreased Bax and HIF-1α expression. On the other hand HBO preconditioning, significantly increased Bax, HO-1 and HIF-1α expression, compared to AKI group. Immunohistochemical expression of 3-Nitrotyrosine, oxidative stress biomarker, in kidney tissue was significantly increased in AKI group, while HBO preconditioning significantly decreased its intensity and extent in all observed kidney tissue structures. These results are in agreement with previously reported reduction of 4-hydroxinonenal expression in kidney tissue after HBO preconditioning in same experimental setting.

Conclusions: HBO preconditioning upregulates cytoprotective HO-1 and HIF-1α expression in renal tissue and and reduces levels of oxidative stress.

Also, HBO preconditioning is capable to increase expression of the anti-apoptotic Bcl-2 protein, which can prevent release of mitochondrial cytochrome c, thereby suppressing apoptosis in renal tubule cells induced by hypoxia/reoxygenation. On the other hand, HBO preconditioning normalizes pro-apoptotic Bax protein expression and possible reason for this finding may be very subtle interaction of Bax and Bcl-2 proteins, but also the fact that during the time after the ischemic insult, apoptosis and necrosis distributed in proximal and distal tubules are represented at different extent.

Palavras-chave: hyperbaric oxygen, preconditioning, acute kidney injury, spontanously hypertensive rats

Diving Medicine

EP - (19364) - MYOPIZATION AND NUCLEAR CATARACT IN RECREATIONAL OPEN-CIRCUIT DIVER AFTER DIVING VACATION

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Abstract

Introduction

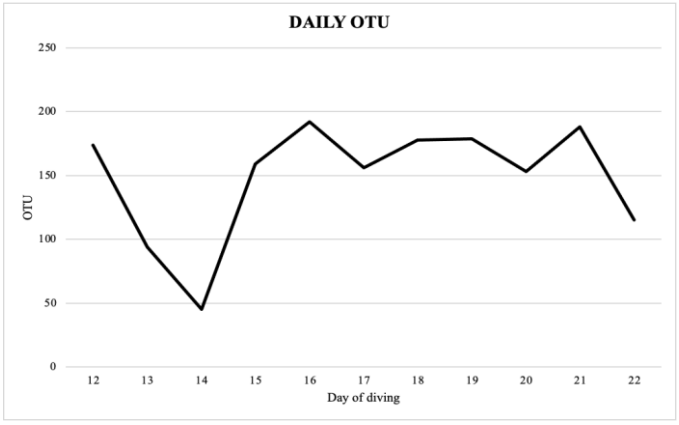
The effects of oxygen toxicity in hyperbaric conditions have been well studied, especially the effects during hyperbaric oxygen therapy (HBOT) are well documented. Myopization and nuclear cataracts are known to develop after prolonged hyperoxic exposure in both HBOT patients and technical divers. However, these adverse effects have not been recorded in the exposures of recreational open circuit divers.

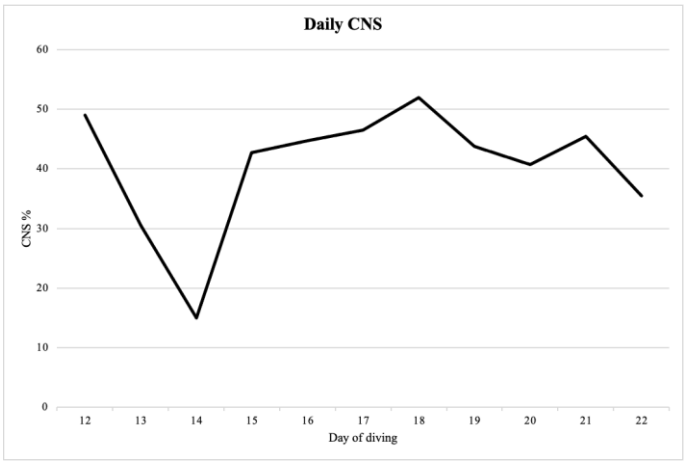
Case description

A 54-year-old, previously healthy male diver was on a 22-day-long liveaboard diving vacation. During this time he performed 75 open-circuit dives of which 72 with EAN 32 breathing gas and 3 with air. The specifications of the dives are presented in Table 1. The detailed dive log data was available only for the last 35 dives due to memory limitation of the old model dive computer. Development of oxygen toxicity units (OTU) is shown in Figure 1 and central nervous system exposure (CNS%), for the last 11 days of diving (available data), is presented in Figure 2. In the days measured, the diver's maximum CNS exposure was 52% and OTU 192. The accepted oxygen toxicity limits by NOAA are 80% and 300 OTU for more than 9 days of consecutive diving, respectively. After the trip he noticed visual impairment and visited an ophthalmologist. The examination showed vision changes from his baseline -3.75/-5.75 diopters to -5.5/-7.75 diopters and an early nuclear cataract was diagnosed. After 5 weeks the vision had re-improved in both eyes with 0.75 diopters, and after 13 weeks no further improvement was observed. Thus, his vision stayed impaired compared to his baseline, but could still improve over time.

Table 1. Specifications of the dives (n=75) during the 22-day-long diving trip.

	Dive time/min	Maximum depth/msw	Average depth/msw
mean	68	25.9	15.6
median	68	27.0	17.0
minimum	49	12.0	7.0
maximum	93	36.0	22.0





Discussion and Conclusion

Throughout the trip the diver stayed well below the generally accepted NOAA oxygen toxicity limits concerning the lungs and the CNS. The diver did multiple dives per day, but the dives were relatively short (median dive time 68 min) and shallow (median maximum depth 27 msw and median average depth 17.0 msw). However, he developed typical symptoms associated with lenticular oxygen toxicity. Previously, these symptoms have been described in technical divers, who perform longer and deeper dives that have long exposure times to oxygen, or after long and repetitive HBOT treatments in clinical hyperbaric medicine. In both of the aforementioned cases, the OTU accumulation of oxygen is substantially higher, but as shown in this case report the symptoms can develop also well below previously accepted risk levels such as during usual diving vacations. Fortunately, myopia is usually reversible, at least partially. In addition, myopization may reoccur during subsequent diving trips. The diving community should become more aware of this possible complication so that the divers experiencing symptoms would know to seek appropriate medical evaluation.

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Palavras-chave: lenticular oxygen toxicity, cataract, recreational diving, myopization

Clinical HBOT

EP - (19389) - RISKS TO INSIDE CHAMBER ATTENDANTS DURING HYPERBARIC TREATMENT: THREE CASE REPORT IN A MULTIPLACE HYPERBARIC CHAMBER

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Abstract

Introduction: Inside attendants in a hyperbaric chamber are exposed to several risks related to hyperbaric environment. Those risks are due to exposure of the body to an increased ambient pressure, leading to possible barotraumas and disorders concerning different breathing mixtures.

Case reports: In this work we report three cases of decompression sickness affecting inside attendants during hyperbaric treatment in a multiplace chamber. All the cases occur after the same standard treatment table, but with differences in the adopted safety protocols. The attendants presented symptoms of *Curtis marmorata*, with complete recovery after a USN6 treatment table.

We present the clinical evaluation of the three cases, including eventual causes and predisposing factors for the occurrence of the accidents. The diving profile was also analyzed to evaluate the effectiveness of security measures.

Conclusion: Our medical unit modified and adapted the pressure/surface time intervals procedures, in order to guarantee the safety of the inside attendants. It is suggested that international recommendations regarding pressure protocols, number of maximum treatment sessions per day and per week, should be created and published.

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Palavras-chave: Decompression sickness, hyperbaric, attendant, oxygen, occupational risks

Clinical HBOT

EP - (19408) - HYPERBARIC OXYGEN THERAPY FOR THE ADJUVANT TREATMENT OF PYODERMA GANGRENOSUM: CASES TREATED AT A PORTUGUESE HYPERBARIC MEDICINE UNIT

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Abstract

Introduction: Pyoderma Gangrenosum (PG) is a rare neutrophilic dermatosis of unknown etiology that presents with rapidly developing, painful cutaneous ulcers, often immune-mediated. Hyperbaric Oxygen Therapy (HBOT) can be used as adjunctive therapy in managing refractory PG because of its primary mechanism of tissue hyperoxia, resultant angiogenesis, and reduction of edema and inflammation. This case series aims to describe the potential benefits of HBOT in this challenging population.

Case Description: We analyzed pre-existing medical data of every patient diagnosed with refractory PG who underwent HBOT in one Portuguese Hyperbaric Medicine Unit from 2014 to 2019, which included 6 patients. Data regarding demographics, comorbidities, previous treatments, and associated side effects were collected. Information about the cutaneous lesions, including size and used HBOT protocol, associated complications, and outcomes after HBOT was gathered. Additional data after HBOT was obtained, namely relapse rate, time until relapse, and complications related to HBOT. A descriptive analysis was conducted. The patients' age ranged from 25 to 63 and 5 were female. All patients were previously diagnosed with an autoimmune disease and had tried multiple treatments, and 5 of them presented with conservative treatment's side effects. PG diagnosis was confirmed by skin biopsy in all patients before starting HBOT. Ulcers were present for a mean time of 11,58 months (ranging from 1 to 48 months) before patient referral. In all patients, HBOT was performed at 2.4 ATA, 100% oxygen, in a regular 80-minutes length session. Patients were submitted to a mean of 44 ± 18 sessions during a mean period of 80,33 ± 24,43 days. Standard wound care, compressive therapy, and/or surgical debridement were also provided as needed. Ulcers remission was partial in 3 patients and complete in 2; one patient experienced PG progression despite treatment. Two patients suffered from HBOT-associated short-term complications, namely middle ear barotrauma, and hyperoxic crisis, both having immediate resolution and no long-term sequelae. In all patients, pain improvement was reported, and drug dose reduction or even withdrawal was achievable. At the time of this publication, 4 patients who had complete and partial resolution - 2 and 2, respectively - had PG relapse within a mean time of 1,25 years after HBOT completion, two of them entailing more sessions as adjuvant treatment, for which an earlier referral was observed, as well as good outcomes.

Discussion/Conclusions: In our series, HBOT contributed positively to wound healing and pain reduction, minimizing the associated disease burden and leading to a drug dose reduction. Hence, clinicians should recognize the potential benefits of HBOT as an ancillary treatment for PG and consider early referral in refractory cases.

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Palavras-chave: Hyperbaric oxygen therapy, Pyoderma gangrenosum

HBOT Operations, Chambers and Equipment

EP - (19410) - IMPLANTABLE CARDIAC DEVICES FUNCTION EVALUATION IN PATIENTS SUBMITTED TO HYPERBARIC OXYGEN THERAPY: A RETROSPECTIVE STUDY

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Abstract

Introduction: Hyperbaric oxygen therapy (HBOT) is widely used for various medical conditions. While HBOT is generally considered safe, there is a potential risk of cardiac device malfunction in patients with pacemakers, implantable cardioverter-defibrillators (ICDs), and Cardiac Resynchronization Therapy (CRT) devices, data on which is scarce (1-5). The aim of this study is to investigate possible alterations in device function during or after HBOT.

Methods: A retrospective study was conducted at a Portuguese hospital which included all patients who underwent HBOT with implantable cardiac devices between 2012 and 2023. Data on patient demographics, cardiac device characteristics, HBOT indication, number of sessions, and any alterations related to the cardiac device during HBOT session, or after, at device interrogation follow-up consultation, were collected from medical records. Descriptive statistics were used to summarize the data.

Results: Out of the initial 28 patients with implantable cardiac devices proposed for HBOT, four were excluded due to pacemaker incompatibility based on device manufacturer instructions. The final study sample comprised 24 patients (mean age 73±11 yrs., 79.2% males), predominantly with pacemaker devices (n=22). The median number of HBOT sessions received was 27±20.

During an HBOT session, one patient with an ICD experienced tachycardia (185-195 bpm) followed by a device shock delivery. The patient was immediately removed from the hyperbaric chamber and returned spontaneously to his atrial fibrillation rhythm (75 bpm).

Additionally, despite normal pacemaker function evaluated at the follow-up pacemaker consultation, one patient was found to have atria arrhythmias' detection capability deactivated, another required generator replacement, and two patients had de novo atrial fibrillation detected.

Conclusion: This study highlights the importance of assessing cardiac device function in patients undergoing HBOT and the need for follow-up device evaluation. While HBOT is generally safe, patients with pacemakers, ICDs, and CRT devices should be carefully monitored for any changes in device function during and after HBOT. Further research is warranted to establish definitive associations between the observed alterations and specific device characteristics, as well as to provide comprehensive guidelines for managing patients with cardiac devices undergoing HBOT.

Variable	Total	Mean ± SD	Median (range)
Age (years)		73± 11	74
Sex (n, %)			
Male	19 (79,2%)		
Female	5 (20,8%)		
Type of device (n, %)			
Pacemaker	22 (91,7%)		
ICD	1 (4,2%)		
CRT	1 (4,2%)		
Brand of device (n, %)			
St Jude Medical/Abbott	12 (50%)		
Medtronic	7 (29,2%)		
Boston Scientific	4 (16,7%)		
Sorin	1 (4,2%)		
Pacing mode			
DDDR	13 (54,2%)		
VVIR	3 (12,5%)		
DDD	2 (8,3%)		
VVI	1 (4,2%)		
WIRD	1 (4,2%)		
n.a.	4 (16,7%)		
Reason for device implantation (n, %)			
Arrhythmias	20 (83,3%)		
Cardiomyopathy	3 (12,5%)		
Other	1 (4,2%)		
Reason for HBO (n, %)			
radic cystitis	8 (33,3%)		
sudden deafness	8 (33,3%)		
hard-to-heal wound	4 (16,7%)		
central retinal artery occlusion	2 (8,3%)		
other	2 (8,3%)		
Total number of HBO sessions		27± 20	20
Device function evaluated in the follow-up consultation			
Normal function	17 (70,8%)		
n.a	7 (29,2%)		

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Palavras-chave: implantable cardiac devices, Cardiac device Function, safety

Clinical HBOT

EP - (19411) - SEVEN TIMES DCS WITHIN THE LAST 25 YEARS: WHY?

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Abstract

Introduction: The male diver (D) is approximately 50 years old. His height of 1.98 m and body mass of 95 kg result in a BMI of 26.6 kg/m². D has been diving since the age of 9 and has completed around 5,500 dives. He works as a professional cave dive instructor. Over the years, he has experienced 6 neurological decompression illness (DCI) accidents. To identify any underlying causes, a TEE was conducted after a PFO had been excluded in a previous medical examination. This time, a PFO was discovered, which showed spontaneous bubble transfer but no pulmonary shunts. Consequently, the PFO was subsequently closed.

Accident: Following a regular cave dive on one day, D performed four dives the next day, with a maximum depth of 25 m and an average dive time of 40 min. Dive number 4 involved the use of a rebreather with on-the-fly nitrox mixing. Although it was a no-decompression dive, a safety stop was observed. Approximately 20 to 30 min after that dive, D experienced a slight tingling sensation below the belly button, i.e. he experienced his deco accident number '7'. Taking a warm shower caused reddening in that area, while the tingling sensation intensified, and the inner thighs felt cold. Nevertheless, D proceeded to perform additional dives with similar profiles one and four days later.

Therapy: Five days after the accident, D underwent 7 successful HBO sessions (2 hours each at 2.4 bar) in a hyperbaric chamber. As a result, his symptoms significantly improved, leading to his discharge. Prior to this treatment, no neurological intervention was deemed necessary.

Around 4 weeks later, D sought a fitness-to-dive certificate at a different hospital. There, he continued to experience occasional tingling sensations and verifiable dorsal column complaints, but without pain or motor impairment. Consequently, future diving activities were discouraged, and neurological monitoring was recommended.

Approximately 7 weeks after accident '7', a MRI scan of the lumbar spine and spinal canal revealed no signs of disc protrusion, prolapse, or stenosis in the spinal canal or the foramen.

About 10 weeks after the accident, a neurologic examination found no evidence of central damage.

Summary/Conclusion: Firstly, the most recent case of decompression sickness/ arterial gas embolism (DCS/AGE) occurred after the PFO closure. This suggests either that bubbles may have entered the arterial system through pulmonary shunts or maybe D remains a high-bubbler and has chronically damaged tissues regarding to bubble load and impaired microperfusion performance. Factors such as volume shift, cold exposure, repetitive dives, oxygen-toxicity (high and long CCR pO_2) or physical activity might have triggered the accidents. Secondly, despite D's history of diving accidents, he wishes to continue diving as an instructor and requires a fitness-to-dive certificate. Thus, a decision needs to be made regarding his diving future.

Palavras-chave: DCS, HBO, cave diving, rebreather

Diving Medicine

EP - (19412) - THE CRITICAL FLICKER FUSION FREQUENCY: ILLUMINATION MATTERS? NOTE: THIS STUDY IS CURRENTLY IN PROGRESS.

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Abstract

Introduction: The critical flicker fusion frequency (cFFF) refers to the frequency at which one perceives a regularly recurring change of light stimuli as steady. In diving and hyperbaric medicine, cFFF was utilized to assess alertness and cognitive functions. However, the role of confounders like inspiratory oxygen partial pressure (PIO_2) and different illumination levels is still unclear. P_IO_2 increases with depth, O_2 fraction, and high pressures are common for Nitrox- and rebreather diving. On the other hand, open-water diving involves reduced lighting conditions with possible effects on cFFF over the time-course of the dive.

Methods: (1) cFFF was measured in the morning for 85 consecutive days in the same individual in artificial light, sunlight, or cloudy conditions. (2) 19 divers were investigated on the effects of wearing a mask. (3.1) In a group of 25 divers, cFFF measurements were conducted in two settings: at the poolside during daylight and in a darkend setting within the pool at a depth of 4 m. During the 'darkness' measurements, participants looked into a tube (Æ: 25 cm; length: 1.5 m) form one side, while on the other side, the flicker device was placed. (3.2) In order to simulate the established maximum PIO_2 of 1.4 bar for OC and CCR diving, these measurements were repeated analogously but after the divers having breathed 100% oxygen for 10 min.

Heart rate (HR), HR variability (Polar V800 and Kubios HRV, ver. 3.5.0, respectively), and ventilation (V'E) were assessed throughout the dive to explore potential interactions between cFFF and the autonomous nervous system.

Results: (1) Depending on the lighting conditions, cFFF values were 43.1±1.5 Hz, 44.0±1.7 Hz, and 43.2±1.9 Hz under artificial light, sunlight, and cloudy conditions, respectively. (2) No significant difference was observed between wearing a mask or not (35.6 Hz vs. 36.4 Hz). Note: (3.1) and (3.2) require further completion.

Discussion: …… When utilizing the cFFF, the effects of illumination and PIO2 need to be taken into account for proper interpretation. During dark adaptation, the eye adjusts from a bright environment to a dark one: the cones are relieved of their duty, and the rods take over. As a result, the cFFF decreases significantly. However, in darkness, the pupil dilates, allowing more light to enter the eye, which, in turn, raises the cFFF threshold.

Palavras-chave: cFFF, illumination, oxygen, HRV

HBOT Operations, Chambers and Equipment

EP - (19413) - THE USE OF IN-SITU SIMULATION IN HYPERBARIC MEDICINE

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Abstract

Background: In situ simulation is carried out in a clinical setting using the tools and equipment provided on-site by the medical staff. Despite the fact that in situ simulation growing in popularity and become more and more common,hyperbaric medicine still use very little of it.In this study we aimed to assess the potential value of in-situ simulation in hyperbaric medecin.

Material and method: Two high fidelity training sessions were realized in hyperbaric oxygen service of military hospital of Tunis in May 2023 (Photo n°1).The topics that were taught during this course were "hyperoxic crisis" and "cardiac resuscitation."At the end of the training, a questionnaire test was given out asking participants to rate the scenario, the teaching strategy, the tools employed, the material shared, their feelings and any inconveniences.

Results: We included during this evaluation seventeen participants (6 doctors and 11paramedics), among them only five participants have been active during the scenario. All participants are aware of this learning strategybut it had only been practiced by four of them. We noticed even that the entire staff felt involved in this activity.In terms of realism, 67.7% of the participants were convinced by the material (Mannequin Sim MAN 3G) and 100% of the actors reported "forgetting'' concerning the use of this model. According to 76.3% of the participants, the training had an effect on teamwork, individual performance, and service organization.The six doctors claimed that it made them feel "embarrassed" that their peers were watching them during the scenario.

Conclusions: The need for simulation among caregivers is growing, yet there is very little access to this technology in the laboratory in hyperbaric medicine. In situ simulation could therefore be the solution.

Palavras-chave: simulation, evaluation, hyperbaric medicine

HBOT Operations, Chambers and Equipment

EP - (19414) - A PROTOTYPE OF HYPERBARIC CHAMBER FOR SIMULATION-BASED EDUCATION

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Abstract

Introduction: Simulation-based education is effective for imparting technical and non-technical skills to Healthcare workers across many disciplines, particularly in acute care *[1].* Thought, what about simulation in hyperbaric medicine? Hyperbaric chambers may be an environment at high risk of major incidents for patients and caregivers justifying the necessity of a training program's implementation by in-situ and laboratory simulation. We report our experience of building a hyperbaric chamber (Figure n°1) for the 3rd French International scientific congress in Subaquatic and hyperbaric medicine held in Tunisia.

Methods: We set up two high-fidelity simulation sessions for two distinct scenarios: cardio-respiratory arrest (scenario 1) using a high-fidelity mannequinand convulsions (scenario 2) using a standardized patient.

After outlining technical and non-technical educational objective and defining the primary points to be debriefed, we ensured the implementation of an environment similar to reality using a false Hyperbaric chamber and an audio-visual system mimicking compression and decompression noises.

A learner satisfaction survey and a debriefing evaluation survey were used to appraise the sessions.

Results: Thirty learners participate to the simulation session and answered the questionnaire. The sex ratio of participants was 2,7 males/females. The mean aye was 41,6 years (±12,85). Fifty percent of the participant had previously attended a high-fidelity simulation session. Nine participants experienced the high-fidelity simulation for the first time while six of the participants were expert trainers. 24 of the 30 participants had never taken part in a simulation session with a hyperbaric chamber-extra professional site.

The simulation session was globally well received by all of the participants (Figure 2), and they all stated that the environment's realism was satisfying.Similarly, all the participants found the simulation session enriching and interesting, while only two of them considered this simulation session not essential.

Conclusion: Providing education by simulation in hyperbaric medicine, both in situ and in the laboratory using a factice chamber allow team training in realistic situations.

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Palavras-chave: hyperbaric medicine, simulation, evaluation

Clinical HBOT

EP - (19415) - CARBON MONOXIDE POISONING IN CHILDREN : CONTRIBUTION OF HYPERBARIC OXYGEN THERAPY IN THE LATE PHASE

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Abstract

Introduction: Carbon monoxide poisoning in children can disrupt brain function and lead to serious neuropsychiatric sequelae [1].

Case report: We report the case of a 5-year-old child admitted to intensive care for severe CO poisoning.

Examination on admission revealed altered consciousness requiring intubation.

The child received a single session of HBOT (60 minutes at 2 ATA), sedation was discontinued 48 hours later and he was extubated at H72. At H12 after extubation, he presented with generalised seizures, indicating reintubation. The brain scan showed multiple bilateral fronto-parieto-temporal ischaemic lesions.

He was kept under sedation for 12 days. A follow-up MRI showed anoxic-ischaemic encephalopathy with diffuse bilateral cortical lesions. The child was extubated on day 19. He did not communicate, did not obey simple commands and had advanced spastic tetraparesis.

The child received hyperbaric treatment consisting of 60 consecutive sessions of HBOT. He was sent home on anticonvulsants and muscle relaxants, with functional motor rehabilitation and speech therapy.

He was monitored every 6 months in consultation. The indication for a second treatment of 60 sessions (60 minutes at 2 ATA) was given one year after the event (December 2020). Given the improvement in clinical condition, with a child now able to communicate, say a few words (dad, mum, etc.) and carry out simple commands, and a clear improvement in functional assessment with a much less spastic child. 3rd course of treatment was started in September 2022, consisting of 35 sessions of HBOT. The assessment noted an improvement in the child's clinical condition in terms of motor acquisition, as he now sits unaided and walks with assistance.

Conclusion: Our case report suggests the benefit of HBOT in the treatment of neurological sequelae in the late phase of CO poisoning, but this assertion needs to be confirmed by comparative prospective studies.

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Palavras-chave: CO poisoning, cerebral injury, HBOT

Basic research in HBOT

EP - (19417) - HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF NECROTISING INFECTIONS OF THE SKIN AND SOFT TISSUES

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1 - Centro de Medicina Subaquática e Hiperbárica

Abstract

HBOT has anti-infective effects through various mechanisms, namely the elevation of tissue oxygen (O2) tensions has a bactericidal and bacteriostatic effect on certain bacteria, there is an increase in phagocytic activity and lysis of bacteria by neutrophils and there is also synergism in relation to certain antibiotics.

Methods: This was a retrospective, descriptive study. A review of the files of patients treated with HBOT between December 1989 and December 2020 at the CMSH with the diagnosis of soft tissue necrotizing infection. The following parameters were analyzed: characterization of the population, etiology, comorbidities, surgical debridement with more aggressive measures (amputation, intestinal transit derivation or orchidectomy), antibiotherapy used, ICU admission, need for invasive ventilation, need for Renal Replacement Therapy (RRT) and mortality at one year. The therapeutic protocol used in the Centro de Medicina Medicina Subaquática e Hiperbárica (CMSH), recommends an initial phase of administration of O2 at 100% at 2.8 atmospheres for 90 minutes daily until the progression of the infection is controlled (without the need to visit to the OR). In the continuity of treatment, the standard treatment table is applied (2.5 atmospheres) is applied until tissue healing is achieved.

Results: A total of 91 patients were treated, an average of 3 patients/year. The average age of the patients treated was 50 years (22 months to 82 years).

Seventy-nine were male (86%) and 12 female (14%). The average number of OHB sessions was 12, ranging from one to 40 sessions. Mean BMI was 28.5, ranging from 23 to 34 and mean CRP value at admission was 24.7, ranging from 9 to 57.6. 30% of the patients were diagnosed with diabetes. The mortality rate mortality rate at one year after the first treatment was 12%. One patient underwent upper limb amputation (3.4% of the patients) and one patient underwent orchidectomy in the context of the debridements. In 6 patients a bypass of the intestinal transit was performed to prevent contamination of the wound (12% of Fournier Gangrene).

Discussion: The mortality rate in this series is 12%, which is in line with the rates reported in more recent studies on the use of HBO in soft tissue necrotizing infections. soft tissue necrotizing infections. Compared with mortality values that are around 25-35%, there was a clear positive trend in survival rate (without OHB). This trend is due to a considerable improvement in the medical care for these patients. In this series, as in other studies, diabetes was the main comorbidity found,.

Conclusion: Necrotizing soft tissue infections are a rare entity but, given their fatal potential, they deserve to continue to be studied so that the best treatment can be offered to patients. The use of HBOT is recommended as an adjuvant in the treatment of soft tissue necrotizing infections and, when this resource is available, it should be considered.

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Palavras-chave: HBOT, necrotizing infections

Clinical HBOT

EP - (19418) - SAVING A LIMB

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1 - CHULN; 2 - CMHS HFAR

Abstract

Introduction Necrotizing fasciitis is a rare clinical condition with a high morbidity and mortality rate. The classic treatment consists of extensive surgical debridement and antibiotic therapy. The use of hyperbaric oxygen, not as an isolated treatment, but always as a complement of the necessary surgical debridement and the adjusted antibiotic therapy, helps to reduce the high index of mortality of these diseases.

Case Description Male 52 years, hit-and-run victim which resulted in minor TBI (GSC13) and multiple fractures of the left lower limb. Submited to reduction and nailing of comminuted femur fracture, developing in the immediate postoperative period acute ischemia of the right lower limb. He underwent a bypass of superficial femoral - popliteal artery and fasciotomies. After eight days, the patient progresses to necrotizing fasciitis of the entire right lower limb, left lower limb, perineum and right hemithorax. Extended surgical debridement of the affected areas and protective colostomy was performed and adjuvant hyperbaric treatment was started. He went on six sessions of hyperbaric treatment, with good response, allowing, after 10 days, the partial closure of the fasciotomies, skin grafts and placement of a negative pressure dressing.

Discussion/Conclusions Early diagnosis associated with surgical treatment and aggressive clinical approach to Necrotizing fasciitis is critical to preventing progression of the disease and the consequent tissue destruction with serious functional and anatomical damage, and progression to sepsis and death.

The hyperbaric oxygen therapy has important role in the acute phase of the disease and can reduce complications, shorten hospitalizations, prevent limb loss and enhance recovery.

The combination of hyperbaric oxygen with antibiotic improves the prognosis because it increases the concentration of the antibiotic in areas of low vascularization by promoting angiogenesis.

Palavras-chave: Necrotizing fasciitis, hyperbaric oxygen therapy

Diving Medicine

EP - (19432) - NITROGEN NARCOSIS CAUSES AN DOSE-DEPENDENT INCREASE IN EEG FUNCTIONAL CONNECTIVITY

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Abstract

Introduction 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, culminating in accidents due to poor decision making. It is commonly known that the symptoms of nitrogen narcosis increase in severity with increased partial pressure of nitrogen, as with increased diving depth. Helium is known to have no narcotic effect. This study continued the development of an electroencephalogram (EEG) functional connectivity metric to measure narcosis produced by nitrogen at hyperbaric pressures.

Methods 32-channel EEG recordings and psychometric impairment from three studies (each twelve participants) was combined to further optimize the EEG metric. Exposures at 284 kPa (12 recordings of air an heliox each), 608 kPa (24 recordings of air an heliox each), and 811 kPa (12 recordings or air only) were used to calculate the degree of spatial functional connectivity, estimated using mutual information and summarized with global efficiency.

Results Air-breathing caused a dose-dependent increase in global efficiency. Functional connectivity was modestly associated with psychometric impairment. Heliox breathing did not cause a significant change in functional connectivity.

Conclusions In conclusion, functional connectivity increased during hyperbaric air-breathing in a dose-dependent manner, but not while heliox-breathing. This suggests sensitivity to nitrogen narcosis specifically.

Palavras-chave: functional connectivity, EEG, nitrogen narcosis, diving, cognitive impairment

Diving Medicine

EP - (19434) - DEEP CLOSED CIRCUIT REBREATHER MIXED GAS DIVING: GAS EMBOLI, SPIROMETRY CHANGES DURING A WEEK-LONG LIVEABOARD SAFARI

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Abstract

The study aims to evaluate spirometry and bubble production after deep CCR mixed gas dives (over 100m depth). It follows three previously published manuscripts (Balestra *et al.*, 2022; Arya *et al.*, 2023; Gouin *et al.*, 2023) reporting divers' parameters evolution after one week of deep CCR. Ten healthy divers (age: 46.9±9.4years; height: 177±4.5cm; weight: 84.1±10.5kg) performed 9 deep dives included 21 dives deeper than 100m (presented in table 1).

	Oxygen	Helium	Depth (m)	Time (min)
	6	88	102	135
	6	76	103	157
	8	73	105	156
	6	78	100	127
	6	76	102	125
	10	70	102	127
	13	59	100	84
	6	88	101	67
	6	76	102	125
	10	70	102	127
	13	59	100	84
	6	88	100	107
	9	75	122	250
	7	79	122	280
	10	70	103	116
	13	59	102	120
	8	72	122	206
	10	68	118	240
	7	81	102	190
	7	81	101	190
	8	77	121	261
Mean	8,3	74,4	106,3	155,1
SD	2,5	8,7	10,1	62,1

Table 1 : Caracteristics of all dives deeper than 100m (n=21).

Bubbles production was evaluated during an apical 4 chamber view, echocardiographic VGE signals were evaluated by frame-based bubble counting as described earlier (Germonpre *et al.*, 2014). Measurement were made at rest (without flexion) and following active provocation by two deep knee bends (with flexion). In total, 5 videos of 15 cardiac cycles were recorded for each dive at 15 minutes post dive, 30, 45, 60 and 120 minutes. The analysis of 10 consecutive frames in end-diastolic/protosystolic position was used to perform a formal bubble counting procedure. VGE peak count per heartbeat were averaged over these 10 frames. The bubbles evolution after the first dive of the day all over the week is presented in figure 1.

Spirometry parameters (including FVC, FEV1, FEV1%,PEF, and FEF25-75) were recorded outside the water using a portable spirometer according to GLI standards (Global Lung Initiative 2017 for Caucasian adults). All measurements are resting measurements, they were obtained by a trained operator (CL) with subjects being seated erect and not wearing diving suit. The reported values are the best of three eligible tests.

All measurements were taken at rest the first day before and 30 min after surfacing each recorded dive, the final measurements were performed after the last dive.

RESULTS

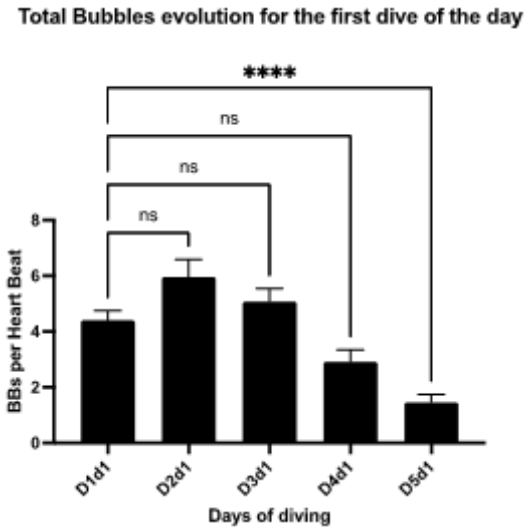

Figure 1. Total bubbles evolution for the first dive of the day all over the week. Total bubble count per heart beat for rest and flex conditions is calculated for every first dive of the day (d1) and every diver. Data are expressed as means ± SD. (NS = Not Significant **** = highly significant) (RM-Anova with Dunnett post test).

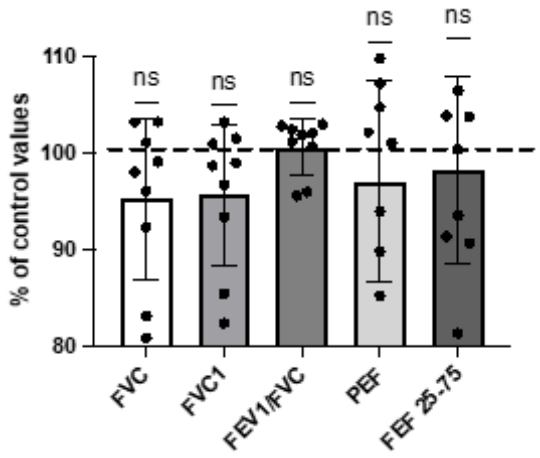

Figure 2. Percentual changes of spirometry parameters after a week of cumulated deep diving with CCR (9 dives). Pre-dive values are taken as reference (100%). Data are expressed as means ± SD. (ns = not significant).

DISCUSSION/CONCLUSION Our data are following 3 previous reports (Dugrenot *et al.*, 2021; Balestra *et al.*, 2022; Arya *et al.*, 2023). Surprisingly, bubble production was decreasing during the week, probably due to a depletion in gas nuclei along the dives. Spirometry changes were not significant. Further investigations are needed to better understand how much the increasing inflammatory/oxidant stress during a week of diving can interfere with spirometry or bubble production.

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Palavras-chave: Decompression illness, adverse effects, spirometry, venous gas emboli, human

Clinical HBOT

EP - (19438) - HYPERBARIC OXYGEN AND NEGATIVE PRESSURE THERAPY A GOOD OPTION IN FOURNIER'S GANGRENE

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Abstract

Introduction: Fournier's gangrene (FG) is a sporadic, life threatening, necrotizing infections affecting the perineum, perineal region, and genitals. Management of FG includes broad-spectrum antibiotics with adequate surgical debridement, which should be performed within the first 24 hours of onset. However, this treatment may cause significant loss of tissue and may delay healing with the presence of ischemia. When the infection involves the perineal region, diverting colostomy and urostomy should be considered. According to the World Society of Emergency Surgery (WSES) and the Surgical Infection Society Europe (SIS-E), negative pressure wound therapy (NPWT) is recommended after the complete removal of necrotic tissue. Hyperbaric oxygen therapy (HBOT) improve tissue perfusion, promotes angiogenesis and collagen synthesis so can be used as an adjunct therapy to prevent an increased risk of mortality in patients with FG.

Case description: Male, 68 years old, uncontrolled type 2 DM, presenting sepsis from perianal abscess, unresponsive to targeted antibiotic therapy and later evolution to FG extending to the testicular region, left inguinal canal, retroperitoneum till the prerenal fascia. Underwent surgery to control the peri-anal infectious focus and abdominal fasciotomy to decrease abdominal wall pressure. Negative pressure therapy (NPT) was applied with instillation of saline solution to reduce local contamination. Local surgical control allowed the patient to remain without ventilatory support and to initiate treatment with hyperbaric oxygen. He performed 11 HBOT at 2ATM, with it being possible to close the abdominal wall 8 days after fasciotomy, due to a marked decrease in local inflammatory signs and a good response to targeted antibiotic therapy, without the need for new surgical debridement.

Discussion/conclusions: HBO as initial therapy for FG with sepsis criteria allows to achieve quickly control of the infectious focus, less need for surgical debridement and consequently tissue loss, avoiding functional consequences in the perineum and in the abdominal wall. The patient did not need ventilatory support and allowed treatments to be performed in scheduled sessions of the hyperbaric chamber on a daily basis, being one of the factors that contributed to the rapid reversal of inflammatory parameters. Our experience allows us to say that the use of NPT concomitantly with HBOT is a preponderant factor in the control of the infection and in the reduction of the destruction of tissues by this type of syndrome, allowing recovery with less time in intensive care units and with less functional impact.

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Palavras-chave: Abdominal wall, Negative Pressure therapy, Fournier's Gangrene, HBOT

Clinical HBOT

EP - (19439) - THE USE OF HYPERBARIC IN A 12TH MONTH BABY TO REDUCE AMPUTATION LEVEL

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1 - Centro de Medicina Subaquática e Hiperbárica

Abstract

INTRODUCTION: Patients with septic shock with or without vasopressor therapy may develop finger necrosis, with tissue hypoxia and edema being significant in the pathophysiology of the illness. Hyperbaric oxygen therapy plays an important role in the management of traumatic ischaemia, with its use being reasonable in the management of limb ischaemia in the context of shock or vasopressor treatment.

METHODS: We present the clinical case of a 12 month old baby with peripheral upper and lower limb ischaemia in the context of septic shock and vasopressor use. The child was submitted to daily sessions at 2.5 ATM.

RESULTS: The patient presented with necrotic tissue in both hands and feet upon arrival. Although the damage to the child's toes and four distal phalanges of the left hand were beyond repair, hyperbaric oxygen therapy helped to limit the necrosis and salvage both hands and feet.

CONCLUSIONS: In children, peripheral limb ischaemia develops and progresses particularly fast. In these situations, hyperbaric oxygen therapy should be considered and initiated as soon as possible.

Palavras-chave: baby, necrosis, septic shock

Diving Medicine

EP - (19442) - ARTERIAL PARTIAL PRESSURES OF OXYGEN AND USE OF ARTERIAL/ALVEOLAR RATIO IN SCUBA DIVERS

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Abstract

Background: current diving physiology postulates that SCUBA divers at depth experience arterial blood gas (ABG) levels variations proportional to environmental pressure. A recent systematic review [1] demonstrated that arterial partial pressures of oxygen (PaO2) under hyperbaric conditions can be predicted from PaO2 measurement at 1 atmosphere absolute (ATA) assuming a constant arterial/alveolar PO2 ratio (a:A). However, regarding SCUBA divers, this systematic review only retrieved simulated dives. This work describes ABGs obtained for the first time in SCUBA divers at depth and aims to verify the validity of a:A ratio in predicting PaO2.

Methods: the study was approved by the local ethics committee. After placing an arterial cannula on the non-dominant limb [2,3], ABG samples were obtained at four steps (Figure 1): at surface before the dive (A); at depth (-15 mfw or -42 mfw) before (B) and after (C) a standardized exercise; at surface (D). The underwater exercise consisted of pedaling on a submersed bicycle set at 100 W (plus 50 W to move legs underwater = 150 W total effort) at a rate of 60 rpm for 10 minutes. After calculating alveolar PO2 at surface (1 ATA) as previously reported [1], the a:A was obtained and used to predict PaO2 at depth. The measured PaO2 was plotted against the predicted PaO2, using Spearman's rho; a linear regression between measured and predicted PaO2 was reported to assess significance of the results, along with the goodness-of-fit F test.

Results: 6 subjects performed the dive at -15 mfw, and other 2 at -42 mfw. The PaO2 increased as predicted at both depths, and more at -42 than at -15 mfw (Figure 1), without differences before and after the exercise at -15 mfw ($p = 0.519$). The a:A calculated from the baseline ABG obtained before the dives at rest, out of the water, seemed to adequately predict the PaO2 in the other conditions ($r = 0.939$, $p<0.0001$; Figure 2).

Discussion: ABGs have been obtained for the first time in SCUBA divers in real underwater conditions, confirming the predicted rise in PaO2. Also, the a:A ratio showed to accurately predict the PaO2 at depth; however, as showed in the plot (Figure 1) the a:A ratio seems to lose accuracy at higher depths and higher partial pressures, as already emerged in the previous systematic review. Such results should be verified in the future on a wider cohort and possibly during different diving conditions (e.g., using closed-circuit rebreathers or breathing gas mixtures).

Figure 1 – Arterial partial pressures of oxygen (PaO2) values in SCUBA divers at different depths

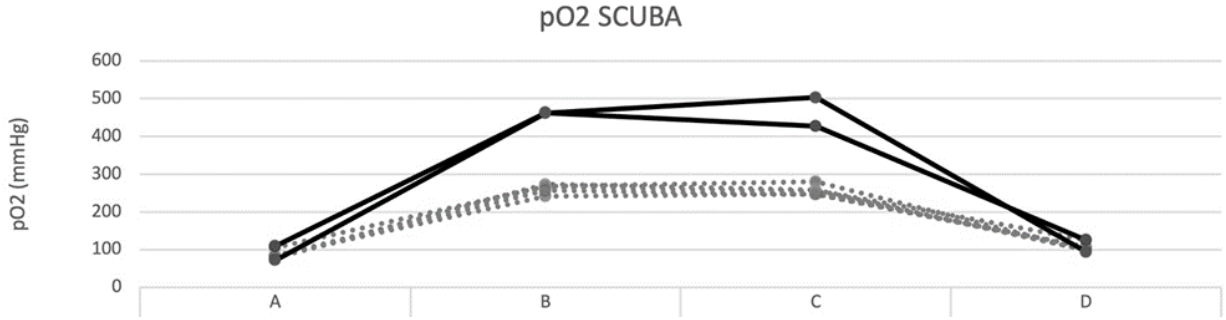
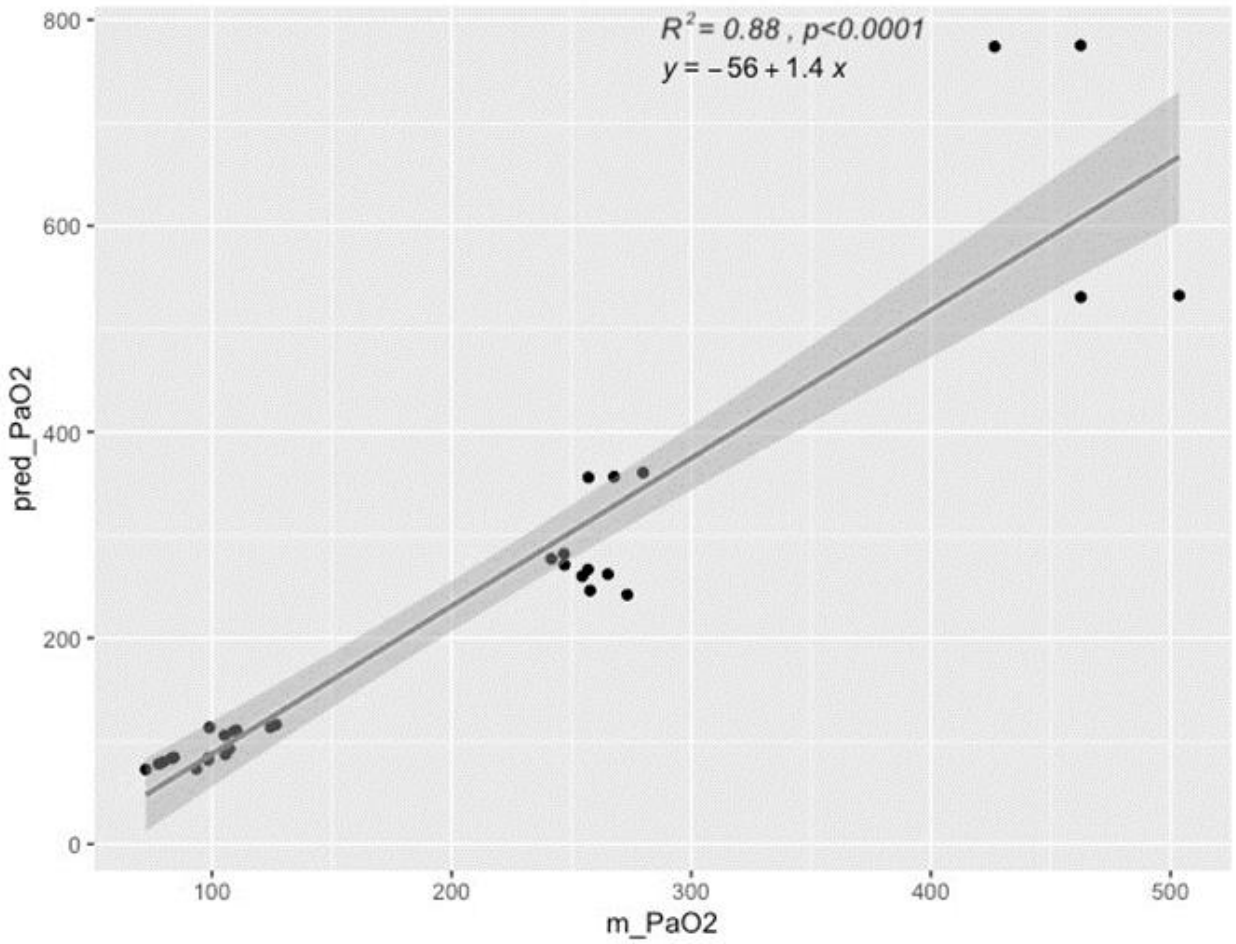


Figure 2 – Scatter plot of arterial partial pressures of oxygen (PaO2; in mmHg): predicted (pred_PaO2) vs. measured (m_PaO2).



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Palavras-chave: Diving Medicine, SCUBA diving, Hyperoxia, Hypoxia, Blood gas analysis

Clinical HBOT

EP - (19445) - CEREBRAL ARTERIAL AIR EMBOLISM, A RARE COMPLICATION AFTER HYPERBARIC OXYGEN TREATMENT

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Abstract

Introduction

Hyperbaric oxygen treatment (HBOT) is a safe and mostly well-tolerated treatment. The most common neurologic complication after HBOT is oxygen toxicity seizures. To this date, there is only one case of ischemic stroke associated with HBOT. We describe a unique case of a stroke following depressurization of hyperbaric chamber.

Case Description

A 59-year-old man, without significant medical history, was under HBOT for sudden deafness. At the end of the 18th session, he experiences general malaise, pallor, difficulty speaking, and weakness in the left side during decompression. In the emergency room, neurological examination showed slight psychomotor slowing, mild left central facial palsy, and hypoesthesia of the left side of the face. Despite normal segmental strength in both upper limbs, during the arm test he had pronation of right hand without drift and mild drift of the left arm, he also obeyed orders with left hand when asked to perform tasks with right hand. Computed tomography (CT) of the head had no evidence of ischemia, hemorrhage, air, or mass effect. Lung CT showed a previously known air cyst of 28 mm in the right apex. Antiseizure drugs were administered on suspicion of epileptiform activity, but there was no clinical response. Despite not having evidence of thrombotic ischemic stroke, we decided to perform intravenous thrombolysis. After exclusion of other diagnoses, we presumed diffuse air embolism not visible in the CT as the most likely cause of the symptoms and started high-concentration oxygenotherapy followed by HBOT protocol with a duration of 4 hours and 35 min and a longer depressurization. Immediately after HBOT, neurological examination remained the same as before. The patient was admitted to level 2 unit care unit with progressive improvement of neurological deficits in the first hours. Seventy-two hours after the event, the patient was discharged with a normal neurological examination except for hypoesthesia to a prick in the 5th finger of the left hand, which was still present at the six-month reevaluation. Because of the risk associated with HBOT and the improvement of sudden deafness, we decided to stop HBOT.

Conclusion

We present a rare case of stroke due to air embolism after HBOT. Cerebral arterial air embolism is a rare complication after HBOT, but one we should consider in patient presentig with signs of stroke since the treatment should be swift to ensure recuperation of neurological funtions.

Palavras-chave: Hyperbaric Oxygen Therapy, Complications, Stroke

Diving Medicine

EP - (19446) - MILD COGNITIVE IMPAIRMENT IN HYPERBARIC ENVIRONMENT

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Abstract

Introduction Hyperbaric environment and breathing gases at high pressure can induce changes in consciousness levels, neuromuscular function and behaviour in humans. Its manifestation are highly variable among divers, starting from the depth of 30m (4 ATA) and becoming more evident increasing the depth.

Divers may experience a feeling of euphoria. Alterations in higher functions such as judgment, reasoning, short-term memory, and concentration are common. At greater depths symptoms include alterations in manual dexterity and further mental decline, idea fixation and hallucinations, eventually leading to stupor and coma.

In our study we used a neurocognitive test to evaluate the effects of hyperbaric environment exposition, and in particular of nitrogen narcosis.

Materials and Methods Participants were seven healthy volunteers that attend the Italian Navy Hyperbaric Medical School in Portovenere (Italy). They underwent a simulated dive in dry conditions in an Hyperbaric Chamber (Divers and Raiders Group Command "Teseo Tesei" COMSUBIN, Portovenere, Italy). The dive consisted of a compression at 40 meter simulated depth, 5 ATA, breathing air. Diving profile and timing is reported in figure 1, panel A. Bottom time was of 15 minutes, therefore a decompression stop of 2 minutes were performed at 3 meter . A cognitive assessment were performed using the Montreal Cognitive Assessment test (MoCA), only at depth. The instruction to complete the test were read from the outside in Italian language.

Results Participants' mean age was 30,7 years, 71% of them were male, six of them were untrained for hyperbaric environment. Subjects' characteristics are reported in table 1.

Subject (n=7)	Mean - SD
Sex (% male)	71,3
Age (years)	30,7 - 8,5
Height (meters)	1,7 - 0,1
Weight (kilograms)	69,9 - 9,2
Body Mass Index	23,8 - 2,2

Table 1. Demographic characteristics of the subjects of the study.

As show in figure 1, panel B, only 14% (n=1) of them was able to performed a normal test. Remain participants show a mild cognitive impairment in global results. Female score was higher than male score in the test (female vs male: 24 vs 22,6).

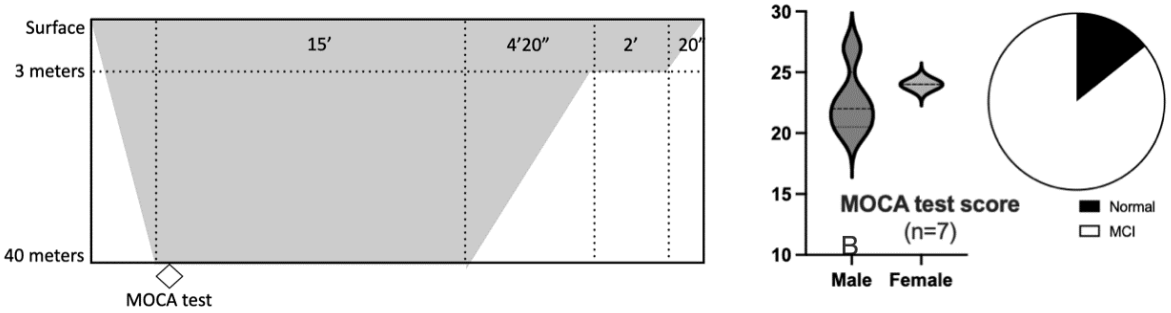

Figure 1: Test results. Panel A shows the pattern immersion. Panel B shows test results; six over seven do not reach a normal score at the test. Female score was higher than male score in the test (female vs male: 24 vs 22,6)

Most affected areas were visual-spatial and esecutive functions, that were tested immediately after the descend. Examples of the drawings are reported in figure 2.

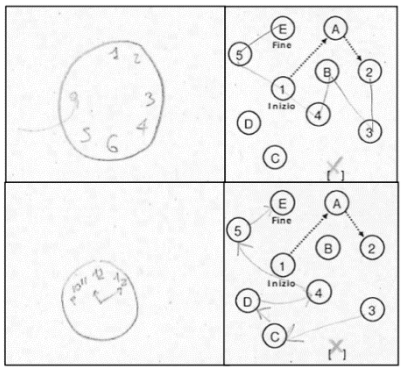

Figure 2: Visual-spatial/esecutive functions. Drawing shown a reduction of these higher functions.

The data confirm a well kwon phenomena of reduction of cognitive abilities in untrained healthy individuals in hyperbaric environment, as already described by Bosco et al.

This study has several limitations, limited sample size can affect the results, we have not been able to recruit a control group of trained scuba divers and the test were not performed at ambient pressure. Moreover there were no biomarker analysis associated or electroencephalogram associated at the test.

Conclusions The data confirm a reduction of cognitive functions of untrained subjects that are exposed to hyperbaric environment, specifically at 40m simulated depth or 5 ATA. We demonstrated that MoCA test can be used to screen scuba divers. We need further studies to better understand the neurotransmitters and molecular patterns involved in this phenomena.

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Palavras-chave: Cognitive Impairment, Inert gas narcosis, MoCA test

Clinical HBOT

EP - (19448) - PATIENT WITH SEVERE CARBON MONOXYDE POISONING AND EARLY ISCHEMIC LESIONS OF THE BRAIN REVEALED BY MRI TREATED WITH HBO SESSIONS FOR 1 WEEK, NO DELAYED NEUROPSYCHIATRIC SEQUELEA OBSERVED.

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Abstract

Introduction: Carbon monoxyde poisoning (COP) is the first cause of death due to poisoning (death rate in Europe : 5%). The antidote of CO is oxygen, that can be given in normobaric(NBO) or hyperbaric conditions (HBO). Even if the ECHM recommends HBO with type 1B recommendation level, medical protocols vary from center to center. Delayed neuropsychiatric sequelae(DNS) can occur weeks after COP. The incidence of DNS is not adequately assessed because it is not sufficiently diagnosed.

We will describe the case of 2 patients, siblings, who suffered from COP and were treated in Geneva University hospital (GUH) HBO center.

Case report: Brother and sister, 33 and 27 years old respectively were adressed for HBO. They were found unconscious after more than 20h exposure to CO.

The brother, with intubation and artificial ventilation, was immediately flown to GUH for HBO (HbCO 18% after 1h of NBO). He had 3 HBO sessions within 24h (Weaver protocol). In the absence of neurological awakening in ICU, he had an early brain MRI that showed early signs of severe COP. Currently, he suffers from DNS.

The sister, intially regained consciousness with NBO and stayed in a local hospital before being transferred to GUH. Her HBCO level was 25% after 1h of NBO. Clinically, her Glasgow score (G) was 11-12, she was mute and had clinical aspect of cerebral palsy. She also had 3 HBO sessions initially within 24h and a brain MRI that showed ischemic-like lesions of white matter of the corpus callosum and the pallidi. We decided to continue HBO for her, twice a day for a week (totalof 14 HBO sessions).

Her clinical condition improved (slow disappearance of confusion syndrome, speech regained, G15). She left hospital without any neurological deficit. At 6 months, we called her back to track DNS. The cognitive complaint assessment test was normal and the brain MRI done 1 year afterwards was no longer pathological.

Discussion/ conclusion: This case report raises the question of the relevance of continuing HBO sessions over 24h in severe COP showing hypoxic suffering on the early brain MRI. Today, the brother suffers from DNS and the sister does NOT.

To Collect and share medical data in A registry allowing further retrospective or prospective analysis could help to standardize and protocolize medical care of COP.

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Palavras-chave: Carbon monoxide poisoning, Hyperbaric oxygen therapy, Acute ischemia, Brain MRI, Delayed Neuropsychiatric sequelae

Basic research in HBOT

EP - (19449) - CLINICAL IMPACT OF HYPERBARIC OXYGEN THERAPY IN NECROTIZING SOFT TISSUE INFECTIONS OF THE LIMBS AND THE INFECTIOUS CHALLENGES PRESENTED BY IT

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Abstract

Introduction: Necrotizing soft tissue infections (NSTIs) are rare life-threatening bacterial infections characterized by extensive necrosis of skin and subcutaneous tissues [1-3]. Initial urgent management relies on broad-spectrum antibiotic therapy, rapid surgical debridement of all infected tissues, adjunctive hyperbaric oxygen therapy ($HB0_2T$) and organ support in the intensive care unit [1-3]. The aim of our work was to evaluate clinical impact of $HB0_2T$ in limb NSTI (L-NSTI) and infectious challenges posed by it.

Methods: Ethics committee approved a retrospective single-center study for a 10-year period between 2010 and 2020 including 30 patients with L-NSTI. A diagnosis of L-NSTI was defined by case documentation during surgical debridement, supported by clinical and laboratory confirmation of an infective process. Quantified microorganisms were assayed for every surgical procedure. Treatment was provided at 2,8 bar for 60 minutes with a 30-minute decompression.

Results: 30 patients were initially included, 16 patients underwent $HB0_2T$ and 14 patients were not illegible to $HB0_2$. From this pool 4 patients were excluded, 3 from the $HB0_2T$ group and 1 from non- $HB0_2T$ pool, due to insufficient microbiologic data. These 26 patients grew on average 3,3 microbes from original wound cultures although a single pathogen was responsible in 15% of the cases. In 85% of patients the isolate was polymicrobial, the most common organisms being, in order, *Bacteroides species*, *Escherichia coli*, *Klebsiella Pneumoniae*, *Aerobic Streptococci*, *Staphylococci*, *Enterococci*. 91% of all patients received a combination of two antibiotics and 9% received a combination of 3 antibiotics. Before surgery, the group treated with dual antibiotic therapy, 98% received a combination with Meropenem and Vancomycin and 2% received Amoxicillin with Clavulanic Acid plus Metronidazole, and after obtaining the antibiogram the antibiotic regimen was adjusted accordingly. $HB0_2T$ patients had a mortality rate of 3%, amputation rate 13% and a median hospital length of 28 days. Non- $HB0_2T$ patients had a mortality rate of 43,4%, amputation rate 35% and a median hospital length of 38 days. The incidence of multiorgan dysfunction syndrome (MODS) was lower in $HB0_2T$ group (23% vs 56%).

Conclusion: Clinical data suggest a survival benefit and limb savage with $HB0_2T$ in the treatment of L-NSTI, however due to the retrospective nature of the study the evidence is weak and further research is needed.

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Palavras-chave: Limb salvage, Antibiotics, HB02T, L-NSTI

Clinical HBOT

EP - (19453) - NON-TYPICAL NEUROLOGIC MANIFESTATION DURING HYPERBARIC OXYGEN THERAPY

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Abstract

Introduction:

Hyperbaric oxygen treatment (HBOT) is a safe and well-tolerated treatment. The most common neurologic complication after HBOT is oxygen toxicity seizures. To this date, there is only one case of ischemic stroke associated with HBOT.[1] We describe a unique case of a stroke following depressurization of hyperbaric chamber.

Case Description:

A 59-year-old man, without significant medical history, was under HBOT for sudden deafness with partial hearing recovery. At the end of the 18th session, he experienced general malaise, pallor, difficulty speaking, and weakness of the left limbs during decompression. In the emergency room, neurological examination showed slight psychomotor slowing, mild left central facial palsy, and hypoesthesia of the left side of the face. Despite normal segmental strength in both upper limbs, during the arm test he had pronation of right hand without drift and mild drift of the left arm. Additionally, he executed tasks with the left hand when asked to do so with the right hand. Computed tomography (CT) of the head had no evidence of ischemia, hemorrhage, air, or mass effect. Lung CT showed a previously known air cyst of 28 mm in the right apex. Antiseizure drugs were administered based on a suspicion of epileptiform activity, but there was no clinical response. A decision was made to perform intravenous thrombolysis based on the clinical manifestations and therapeutic window, without immediate improvement. After exclusion of other diagnoses, a diffuse air embolism not visible on the CT scan was presumed as the most likely cause of the symptoms. High-concentration normobaric oxygen therapy was initiated, followed by recompression treatment with a USN table 6 treatment table modified with an extended final decompression period. Immediately after HBOT, neurological examination remained the same as before. The patient was admitted to a High Dependency Unit with progressive improvement of neurological deficits in the first hours. A magnetic resonance scan showed bilateral signs of unspecific ischemic injury. Seventy-two hours after the event, the patient was discharged with a normal neurological examination except for pin prick hypoesthesia in the 5th finger of the left hand, which was still present at the six-month reevaluation. The HBOT protocol was stopped after the event considering the hearing improvement and potencial risk of recurrence.

Conclusion:

We present a case of a non-typical neurological complication during a HBOT session, with uncertain etiology - acute ischemic stroke vs diffuse gas embolism secondary to a pulmonary cyst. The clinical presentation of gas embolism is heterogenous and difficult to rule out as a cause. Management of these patients is, therefore, complex, especially regarding the decision to initiate recompression therapy and the unknown risk of barotrauma and decompression sickness from pulmonary air-filled cavities.

Palavras-chave: Hyperbaric Oxygen Therapy, Complications, Stroke

Clinical HBOT

EP - (19454) - UNEXPECTED AND UNFORESEEN ASTHMA EXACERBATION DURING INITIAL HYPERBARIC OXYGEN THERAPY (HBOT): A CASE REPORT

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1 - HYPERBARIC CENTRE "DOMUS MEDICA"

Abstract

Hyperbaric oxygen therapy (HBOT) is considered effective and generally safe.

Mild and compensated asthma is not considered an absolute contraindication to HBOT but a relative one. For patients who need to undergo HBOT, asthma is a condition that requires careful evaluation by the physician during the initial visit, as the dry oxygen used in the hyperbaric chamber can act as trigger for an acute asthma attack, potentially resulting in peripheral bronchial air trapping. This event is sudden and potentially dangerous for patients, especially during the decompression phases of the chamber.

Based on studies' results found in reference databases, the risk of acute asthma attack during HBOT varies depending on the patients and their clinical conditions. The average risk percentage has been estimated to be around 3%.

In Italy, patients with a positive history of asthma, as recommended by the current SIMSI guidelines, should undergo a detailed pulmonary objective examination, Administering the ACT-TM test is also recommended (indicating optimal control and complete compensation of asthma.

With this clinical case REPORT, we aim to present an acute case of asthma that occurred during the first HBOT treatment in a patient who had not experienced acute attacks for over 20 years. a 48 Y.O. patient, D.F., presented for a visit at our hyperbaric center due to a diagnosis of avascular necrosis in the right knee.

She was affected by mild childhood asthma controlled at that time with Salbutamol inhaler on an as-needed basis, and no other pharmacological treatment for asthma since then. The patient reported a modest asthma exacerbation approximately 23 years ago but no other episodes since then. The ACT-TM test score was 25 at the time of the initial medical visit.

During the first HBOT session, the patient feels retrosternal pain and cough. Immediately after the decompression, the patient still experienced the symptoms reported during the HBOT treatment. Lung fields auscultation did not reveal any wheezing or abnormal lung sounds. The ECG was normal.

In the emergency department, the patient underwent arterial blood gas analysis, blood tests (D-dimer, CRP, and troponin, all within normal ranges), and chest CT angiography (negative for pulmonary embolism). The chest CT showed some findings consistent with acute alveolar damage in the right lower lung lobe.

We find this case interesting because what happened was statistically very unlikely.

Stratifying the risk of asthma flare-up in more detail, as well as evaluating the best remedial measures to use during HBOT for individuals with a positive history of mild asthma and in good compensation, would merit further discussion and structured scientific investigation given the serious potential consequence behind episodes such as the one described above.

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Palavras-chave: ASTHMA SIDE EFFECT CLINICALHBOT

Diving Medicine

EP - (19455) - DIAGNOSTIC APPROACH TO THE APPEARANCE OF SUCCESSIVE NEUROLOGICAL, CUTANEOUS, CARDIOLOGICAL AND VASCULAR SYMPTOMS AFTER A DIVE. CLINICAL CASE

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Abstract

Introduction: We describe the case of a female diver who treated at the hyperbaric center of Toulon, presenting the signs of a decompression sickness. Case description: She presented various symptoms that followed one another over a 24 hour period. Immediately following a saturating dive neurological symptoms appear and then regress, a few hours later skin signs and cardiac abnormalities are present and then regress after recompression. The next day diffuse oedema of the limbs appeared and gradually disappeared. Discussion/Conclusion : We discuss work-up carried out to orientate the different diagnoses and mechanisms, in particular the contribution of circulating bubbles linked to decompression in the form of arterial embolisation via a right-left shunt of pulmonary origin. We recall the interest of searching for a right-left when this mechanism is suspected by a sensitive and minimally invasive method such as trans-cranial Doppler-Echo, which sometimes allows to demonstrate a significant pulmonary shunt in the absence of patent foramen ovale.

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Palavras-chave: Bubble, diving, decompression sickness, capillary leak syndrome, livedo racemosa, right-to left shunt

Clinical HBOT

EP - (19457) - THE EXPERIENCE OF A CENTER FOR UNDERWATER AND HYPERBARIC MEDICINE

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Abstract

Introduction: The Center for Underwater and Hyperbaric Medicine of Lisbon was created in 1989 and was the first organism in our country to use Hyperbaric Oxygen Therapy (HBOT). This therapy has been used not only in the treatment of diving accidents, but also as an adjunct therapy in various diseases, both in the military context and in support of civil society. This Center also collaborates in several operational diving missions and with the training of the military.

Objective: It is intended to demonstrate the growing demand to treat more complex patients, who require a differentiated team, with knowledge about the critically ill patient, its specificity, and the handling of invasive devices, such as the arterial line and equipment, the ventilator.

Material methods: Retrospective analysis of the portuguese miltary Centre for Underwater and Hyperbaric Medicine's database of patients undergoing hyperbaric oxygen therapy from January 2021 to the end of April 2023. It was used the ICD-10 Classification of the pathologies.

Results: From 2021 to April 2023, a total of 22992 sessions were held, of which 648 were in an emergency context. In critically ill patients, 201 sessions were performed, 109 of which were under invasive mechanical ventilation. Regarding the ages of patients undergoing routine sessions, these vary between 1 and 91 years. Regarding the ages of patients undergoing emergency sessions, these vary between 1 and 88 years.

The most common pathologies in routine sessions are: sudden deafness (about 40%) and diabetic foot (about 10%). The most common pathologies in emergency sessions are: carbon monoxide poisoning (38%). In ventilated patients the prevalent pathology is necrotizing fasciitis (about 80%).

Conclusion: It is fair to conclude that there has been an increase in clinical indications for the use of hyperbaric oxygen and that the success of its use has been recognized. The request for HBOT, has significantly increased and, in parallel, the severity and clinical complexity of the patients treated. Therefore, it is necessary a continuous commitment to update the theoretical and practical knowledge of the teams.

Palavras-chave: urgency, critically ill, hyperbaric oxygen

Clinical HBOT

EP - (19458) - APPLICATIONS OF NUCLEAR MEDICINE IN THE ASSESSMENT OF HYPERBARIC OXYGEN THERAPY RESPONSE

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Abstract

Background: Nuclear medicine is a medical specialty that uses radiopharmaceuticals to assess physiological processes. Its procedures are among the most valuable tools available today, providing functional combined with anatomical information. However, its availability is limited compared to other diagnostic imaging techniques.

We aimed to highlight the usefulness of nuclear medicine procedures to hyperbaric oxygen therapy (HBOT).

Materials and methods: A systematic search of the PubMed database was conducted. Primary outcomes were the application of nuclear medicine procedures in assessing response to treatment with HBOT.

Results: A total of 228 non-duplicate records were identified, and based on the inclusion criteria, 66 studies were considered. Most of the studies considered were prospective (22/66), case reports (24/66), retrospective (14/66) and literature reviews (6/66).

Nuclear medicine procedures were most frequently used for the assessment of brain (64%), bone (18%), heart (9%) and lung (3%) related pathologies.

Brain SPECT with a perfusion radiopharmaceutical (ECD-Tc-99m in 19 studies or HMPAO-Tc-99m in 7 studies) was used to assess the response to HBOT in patients suffering from post-traumatic stress syndrome, blast-induced chronic traumatic brain injury, decompression disease in commercial divers, and secondary progressive multiple sclerosis. Moreover, perfusion SPECT has been used as a valuable tool in assessing perfused, non-perfused, and penumbra areas in patients who suffered an ischemic stroke before and after HBOT. In fibromyalgia patients, brain perfusion SPECT has demonstrated changes in brain activity after being treated with HBOT.

The functional assessment of brain metabolism using FDG-F-18 PET/CT has been useful in the evaluation response to HBOT in Alzheimer's disease and chronic fatigue syndrome patients.

Myocardial perfusion gated scintigraphy was used to evaluate changes in perfusion and ejection fraction in patients with myocardial infarction who underwent HBOT.

Additionally, in studies evaluating HBOT after an acute carbon monoxide poisoning, myocardial perfusion SPECT was used to evaluate cardiac toxicity, and brain SPECT to evaluate the brain perfusion alterations and dopamine transporter loss.

Regarding the skeletal system, 12 studies focused on the use of FDG-F-18 and bone scintigraphy with bisphosphonates in patients with bisphosphonate-related osteonecrosis of the jaw, and osteomyelitis, treated with HBOT.

In 3 of the included studies, lymphedema changes after HBOT were evaluated by limb lymphoscintigraphy.

Conclusion: This review highlights the importance of considering nuclear medicine diagnostic procedures when evaluating responses to HBOT. SPECT and PET are non-invasive imaging techniques that provide valuable information on assessing the effectiveness of HBOT, mainly in brain and bone related pathologies.

Palavras-chave: Nuclear Medicine, Hyperbaric oxygen therapy, HBOT, SPECT, PET

Clinical HBOT

EP - (19460) - WHEN HYPERBARIC OXYGEN THERAPY SURPASSES THE COMPLICATIONS OF CROHN'S DISEASE

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Abstract

1. Introduction: Crohn's disease is a chronic condition characterized by permanent intestinal inflammation with an etiology that is not yet fully understood. However, genetic, immunological and environmental factors are known to be involved. The main objective is to control symptoms and complications to achieve disease remission through therapeutic interventions according to the severity and individual response of each patient.

2. Case Description:The authors describe a case of a 23-year-old man with Crohn's disease diagnosed in 2010 and tobacco use history. Daily medicated with azathioprine, infliximab, alprazolam and folic acid.The patient went to the 1st appointment at Hyperbaric and Underwater Medicine Center on 15th of April 2022 due to a case of perianal fistula associated with complications of Crohn's disease. It should be noted that there have been 6 post-surgical episodes associated with disease progression with the most recent intervention taking place in January 2021. Since then, the patient has been undergoing biological therapy and drainage with no evidence of new fistulas. After completing 4 months of antibiotic treatment without clinical improvement adjuvant hyperbaric oxygen therapy was initiated with antibiotic treatment. A total of 40 treatment sessions were prescribed starting on 20th of June 2022 which proceeded without any complications. It is worth mentioning that the treatment was prescribed according with the recommendations on the table 2 – of the EUBS (European Underwater and Baromedical Society) guidelines - "*Diving and Hyperbaric Medicine Volume 47 No. 1 March 2017*". After completing 20 out of 40 sessions a reduction of approximately 50 to 80% in exudate and improvement in pain complaints were observed. On 29th of August 2022 upon completing 40 out of 40 sessions the patient was discharged as no further improvement was observed. It is crucial to emphasize that the patient exhibited detrimental habits during this period, specifically acute alcohol consumption which contributed to the exacerbation of symptoms and progression of disease complications. Due to worsening symptoms the patient returned for a follow-up appointment in January 2023 and reinitiated treatment in March 2023. After completing an additional 20 sessions with a total of 60 a new improvement in the clinical condition was detected.

3. Conclusions: This case emphasizes the importance of adjuvant treatment with hyperbaric oxygen therapy along with antibiotic and surgical treatment in controlling inflammatory bowel disease. It is crucial to highlight the importance of adhering to positive daily habits in order to optimize treatment efficacy and effectively manage complications, particularly in cases involving fistula tracts with evident infectious conditions that are resistant to conventional therapy.

Palavras-chave: FISTULA TRACTS, CROHN'S DISEASE, HYPERBARIC OXYGEN THERAPY

Clinical HBOT

EP - (19461) - COMPARING THE PERCEIVED HEALTH STATUS OF PATIENTS AFTER HYPERBARIC OXYGEN TREATMENT – AN OBSERVATIONAL STUDY

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Abstract

Background / Objectives Hyperbaric Oxygen Treatment (HBOT) is an established approach for different medical conditions [1]. This study aimed to explore the implications in perceived health status and quality of life of patients that underwent HBOT.

Table 1 – Scores for EQ-5D-5L and GHS before and after HBOT

	Motive for treatment	Mean	SD	N
EQ-5D-5L				
Before	Other motives	0.859	0.199	69
	Sudden deafness	0.929	0.106	184
After	Other motives	0.833	0.171	69
	Sudden deafness	0.926	0.109	184
Before	Other motives	68.4	20.2	81
	Sudden deafness	76.1	18.4	209
After	Other motives	77.3	18.3	81
	Sudden deafness	80.4	16.5	209

Methods An observational study was carried out at the hyperbaric medicine unit of Matosinhos Local Health Unit. Data was obtained from patients who underwent HBOT sessions between 2021 and 2022 regarding sociodemographic variables (gender and age), treatment motive (sudden deafness vs other motives), and health status assessed using the EQ-5D-5L measured before and after HBOT. This questionnaire consists of six questions, assessing five dimensions (Mobility, Self-care, Usual activities, Pain/Discomfort, Anxiety/Depression) measured on a five-point scale, and general health status (GHS) measured between 0-100 points on a visual analog scale. The results of each domain were transformed based on norms for the Portuguese population [2]. Data exploration included descriptive statistics and repeated measures ANOVA.

Results Of the 452 patients that underwent HBOT, 290 (64.2%) completed the EQ-5D-5L twice. The mean age was 53.8±15.0 years and 149 (51.4%) were women.

The average health status score (n=253) before HBOT was 0.910±0.141 and after was 0.900±0.135, ($F(1,252)=1.48$, $p=0.225$). For GHS (n=290) the mean scores were 73.9±19.2 and 79.5±17.1 before and after HBOT, respectively ($F(1,289)=35.80$, $p<0.001$).

Comparison by treatment motive revealed a statistical difference in time and for the interaction with assessment moments for GHS (Before-After: $F(1,288)=40.57$, <=0.001; GHS * Motive: $F(1,288)=4.78$, $p=0.030$).

Discussion / Conclusion

Although the EQ-5D-5L results did not reveal statistically significant differences between the initial and final time points of HBO treatment, the patient's subjective assessment of their overall health status was statistically significant.

In this particular indicator (GHS), this result is confirmed when comparing the participants according to the motive for treatment (sudden deafness vs. other motives), which reveals an increase in the results for both groups between the first and second evaluations, but with the sharpest rise being met in the 'other motives ' group.

Future research may improve response rates and explore differences for health status in other conditions.

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Palavras-chave: hyperbaric oxygen therapy, health status, quality of life

Basic research in HBOT

EP - (19462) - OUTCOME OF NECROTIZING SOFT TISSUE INFECTIONS WITH AND WITHOUT HYPERBARIC THERAPY AND CORRELATION WITH PROGNOSTIC SCORES

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Abstract

Introduction: Necrotizing soft tissue infections (NSTIs) are among the most difficult disease processes encountered by physicians and surgeons [1-3]. The aim of this study is to evaluate the diagnostic challenges and the outcome of NSTI with and without hyperbaric oxygen therapy ($HB0_2T$).

Methods: Ethics committee approved a retrospective single-center study for a 10-year period between 2010 and 2020 including 73 patients with necrotizing fasciitis. Lirinec scale was used to estimate the risk of NSTI at hospital admission. At hospital admission predicted survival scores were calculated, and used to characterize $HB0_2T$ and non-$HB0_2T$ patients . A diagnosis of NSTI was defined by case note documentation during surgical debridement of necrosis of fascia and/or muscle along with variable skin and subcutaneous tissue, supported by clinical and laboratory confirmation of an infective process. Treatment was provided at 2,8 bar for 60 minutes with a 30-minute decompression.

Results: During 10-year period 73 patients were diagnosed with NSTI, 41 males and 32 females. 40 patients (20 men and 20 women) were treated with surgical debridement, IV antibiotics and $HB0_2T$, the remaining 33 patients (21 male and 12 female) underwent only surgical debridement and IV antibiotics (non-HB02). Time elapsed between symptoms initiation and diagnosis was 8 days for $HB0_2T$ group and 7 days for non- $HB0_2T$ group. The time between hospital admission and surgical debridement was approximately 1hour in booth groups. At hospital admission, $HB0_2T$ patients, presented a median Lrinec scale 6,6, APACHE II score 7, SAPS II score 42, SOFA score 4. At hospital admission, non-$HB0_2T$ patients, presented a median Lrinec scale 7,69, APACHE II score 20, SAPS II score 49, SOFA score 8. Mortality rate in $HB0_2T$ patients is 5% and in non- $HB0_2T$ is 36,4%. Non survivors HB02 patients, 100% males, median age 58 years, and a median Charlson comorbidity index (CCI) 9. Non survivors non-HB02 patients 66,7% males, 33,3 females, male average age 59 years, female average age 80 years, and median CCI 11.

Discussion/Conclusion: NSTI poses a diagnostic challenge for the medical community, showed by an average recognition delay of 8 days. Mortality was lower in $HB0_2T$ group, however this data should be analyzed carefully because, on one hand $HB0_2T$ as a growing role as un adjunctive therapy in NSTI, but on the other hand the prognostic scores were in favor of an increased survival in the $HB0_2T$ group.

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Palavras-chave: NSTI, Diagnosis, HB02T, Mortality

Clinical HBOT

EP - (19463) - HYPERBARIC PATIENT CLASSIFICATION – A NOVEL APPROACH TO IMPROVE STRATIFICATION OF LEVEL OF CARE

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Abstract

Introduction The hyperbaric patient is exposed to a specific environment with limitations on assessment and level of care. The authors presenta novel classification to access level of complexity and care of the hyperbaric patient inside the hyperbaric chamber.

Materials and Methods The patient is stratified by the specialist physician into 6 levels of complexity being the sixth the most complex. If the patient's condition fits into several levels of complexity, the highest level of complexity should be selected, alhough this level it is dynamic throughout time (e.g. change in hemodynamic status after an initial assessment).

Results

	Level of Complexity		Details and Examples
Non-critical Care Hyperbaric Patient	1		Stable, autonomous and ambulatory patient: · With no need for extra care or monitoring during sessions; · Comorbidities stabilized.
	2		Stable, autonomous and ambulatory patient, that needs one or more of the following: · Ambulation support; · Drugs administration during session; · Comorbidities surveillance, even though stabilized.
Critical Care Hyperbaric Patient Without Organ Support	3		Ambulatory or hospitalized patient, that needs one or more of the following: · Support in maintenance of medical device; · Permanent or sporadic surveillance; · Vital signs monitoring.
Critical Care Hyperbaric Patient With Organ Support	4		Hospitalized patient, that needs one or more of the following: · Continuous assistance by a nurse; · Respiratory support: Oxygen therapy or NIV; · Cardiac support: decompensated cardiac failure; electric instability; recent acute coronary syndrome; Patient with implanted Pacemaker or ICD; · Renal support: renal replacement therapy (continuous or intermittent); · Neurological support: GCS≤14; · Pharmacological support: o IV Vasopressors; o IV Vasodilators; o IV Inotropics; o Continuous IV analgesia; o IV Antiarrhythmics; o IV Bicarbonate; o IV Thrombolytics; o IV Anticonvulsants; o IV General anesthetics;
	Mechanical ventilated Patient	5	Mechanical ventilated Patient (1 organ failure)
		6	Mechanical ventilated Patient with >1 organ failure simultaneously

Discussion

First level patients can have an attendant with training on first aid and emergency procedures.

The attendant or hyperbaric nurse constitutes second level of care, at the description of the diving physician.

On third level of complexity the attendant must be a hyperbaric nurse.

Fourth level of complexity team is made up of a hyperbaric nurse with or without de hyperbaric physician, at the description of the latest.

The team that attends fifth and sixth level of care is composed by a hyperbaric physician and an attending nurse, both with critical care experience.

With this novel approach to the hyperbaric patient, the authors hope to increase the level of security of the procedures inside the hyperbaric chamber worldwide.

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Palavras-chave: novel classification, Level of Care

HBOT Operations, Chambers and Equipment

EP - (19470) - TOTAL QUALITY MANAGEMENT AND KEY PERFORMANCE INDICATORS-KPI'S IN HYPERBARIC FACILITIES

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1 - EBAss Board of Directors

Abstract

Introduction / Background: Quality management in Diving and Hyperbaric Medicine facilities has received a significant approach in recent decades and this is clearly evident in the number of international accreditation programs. However, quality management in Diving and Hyperbaric Medicine Centers has not yet been defined in such a way that systematic quality improvement models and unified external inspection procedures can be developed.

Methods / Materials: The purpose of this literature review was to analyze the term "quality" in the Diving and Hyperbaric facilities and relate it to a variety of metrics, including services, safety, good clinical practice and Key Performance Indicators-KPI's, in order to implement a Quality Management System in those facilities.

Results: Scientific studies or books were searched in databases such as PubMed, Jama, as well as in services that propose quality control procedures, which propose unified quality assurance systems in Diving and Hyperbaric Medicine Units. A limited number of studies and books were identified that focused on safety within the decompression chamber and on specialized medical conditions such as quality assurance in the management of diabetic ulcers.

Discussions / Conclusions: The main tool for evaluating and controlling Quality is the KPI's, which is considered tool for measuring the performance of specific persons and activities of a unit or an organization. The Quality Manual is part of the overall Quality Management System (QMS) of a Diving and Hyperbaric Unit and is drawn up in accordance with the certification standard (e.g. ISO 9001, EN 15224) and includes the Purpose of the manual, the Quality Policy, the Organizational Structure and operating framework of the Quality Management System. It is suggested that in the context of the operation of a Diving and Hyperbaric Unit, KPI's should be implemented and categorized into Structure Indicators (resources, personnel, facilities, equipment, information systems), Process Indicators (preventive care, diagnosis, treatment, rehabilitation, information and training) and Effectiveness Indicators (health status, care outcomes, patient health status, patient satisfaction, resource utilization efficiency).

Palavras-chave: Quality, Quality Management System, Hyperbaric facility, Key Performance Indicators

Diving Medicine

EP - (19479) - ANALYSIS OF EMAIL CORRESPONDENCE BETWEEN SPORT MEDICINE PHYSICIANS AND AN EXPERT GROUP OF DIVE MEDICINE IN THE NETHERLANDS

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Abstract

Dive medical assessments are the cornerstone of preventive medicine in diving. In the Netherlands, these assessments of recreational divers are performed by (sports) physicians with the Medical Examiner of Divers (MED) qualification. Additionally, a 'counsel of experts' has been established to provide advice (free of charge) for these physicians in difficult cases.
From 2013 to 2023 around 300 cases have been reviewed by this counsel. This information has helped to improve the MED-course as provided by the Dutch Society of Diving and Hyperbaric Medicine (DSDHM) and which guidelines are lacking or need reviewing to serve our community.
In this presentation we would like to share our experience from working with this method. We give a quantitative overview which pathology proves to be the most challenging in dive medical assessments for our community and share best practises in regards to forming and maintaining such a counsel of experts.

Palavras-chave: diving medicine, fitness to dive, recreational diving

Diving Medicine

EP - (19892) - ANALYSIS OF THREE RECREATIONAL DIVER'S NUTRITIONAL INTAKE ACROSS SIX IDENTICAL DIVES

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Abstract

Introduction: There is a general lack of research regarding the effects of nutrition on recreational diving and its ties to decompression stress. It is well known that high-pressure environments are inherently energetically demanding, and therefore, to maximize performance, divers may require a specialized diet to meet metabolic needs. This study aims to understand the variation of nutritional factors, specifically macronutrient deviations, in recreational divers by expanding upon previously published data to produce personalized estimates of the energetic requirements of scuba diving.

Materials and Methods: Three divers completed a 24-hour dietary recall before conducting a standardized dive profile six times across 12 weeks (18 recalls total). Divers completed the recall with a trained interviewer 1-2 hours before diving.

Basal Metabolic Rate (BMR) for each diver was estimated using Mifflin-St. Jeor equations [1], and caloric need was calculated by extrapolating from Doubt et al.'s recommendations [2]. An estimated range of additional required Calories (ARC) was calculated by subtracting BMR from the recommended range of caloric need:
(40 Kcal x weight in kg)-BMR=low range of ARC per 3 hrs diving
(50 Kcal x weight in kg)-BMR=high range of ARC per 3 hrs diving
The ARC was further adjusted for the ratio of time spent underwater. For a 30-minute dive, the ARC was multiplied by 0.16 and added to the diver's BMR:
(ARC x 0.16)+BMR= Recommended Daily Caloric Intake for a 30 min dive
The adjusted recommended caloric intake was compared to data from the 24-hour dietary recalls to calculate deviations in Kcals per day. Protein intake was compared to Doubt et al.'s recommendation of 1 g of protein·kg-1 of body weight. Results are displayed as mean (SD).

Results: Dietary recalls revealed obvious variation in caloric and protein intake. Divers consumed 2,355.4 (67.8) Kcals·day-1. Based off Doubt et al.'s recommendations, caloric deviation was 119.3 (540.0) Kcals·day-1, range of -1,006.4–1,424.0 Kcals·day-1. Divers consumed 106 (30.4) g of protein, with a deviation of 13.2 (30.8) g, range -62.6 to 67.0 g·day-1. Overall macronutrient distribution consisted of 18.5% (6.3) of total intake from protein, 32.1% (9.3) from fats, 44.1% (11.1) from carbohydrates, and 6.6% (5.4) from alcohol.

Discussion: It has been found that cognitive and vascular efficiency is influenced by available calorie supply and certain micronutrients are known to protect endothelial function under pressure [3-5]. Therefore, proper nutrition is likely important for diver's health and reducing the risk of injury and illness. This study is ongoing and aims to recruit 32 subjects. Further data can help understand the variability between recreational divers' diets, and its implications on fitness and post-dive health. Future research will attempt to compare dietary intake factors with decompression stress.

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Palavras-chave: Diver Health, Macronutrients, Diet, Decompression Stress

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