40th Wiesbaden, September 24th-27th

EUBS 2014

40th Annual Scientific Meeting of the
European Underwater & Baromedical Society (EUBS)

Abstract & Conference Book

40th Annual Meeting of the European Underwater and Baromedical Society

Editors:
P. Mueller
K. Haszmiller
J.D. Schipke
P. Germonpré

Congress Secretariat:
AIM EUBS2014 Office
Schiersteiner Str. 42
65187 Wiesbaden
Tel: +49 611- 847 27 170
Fax:+49 611- 847 27 179
E-Mail: info@eubs2014.org

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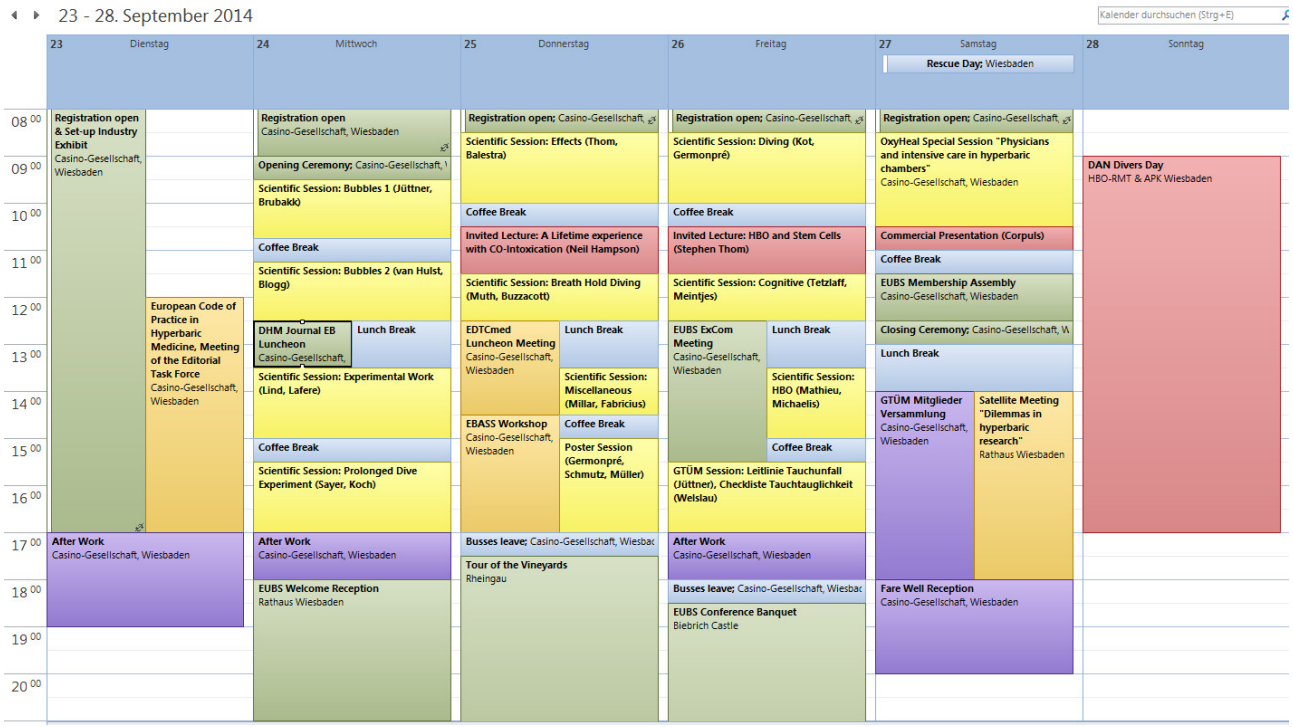

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	Wilhelm Weslau	Checkliste Tauchunfall		
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18:30 - 24:00	EUBS 2014 Conference Banquet Biebrich Castle			
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08:00 - 17:00	Registration open			
08:30 - 10:30	**OxyHeal Special Session:** **Physicans and intensive care in hyperbaric chambers** **Chair: Karin Hasmiller & Michael Lang**			
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	Chair: Shai Efrati	Plenary discussion International Committee of Medical Journal Editors		

		(ICMJE) Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals – a short review		
	** In order to make the session more usable, a practical example for study design will be used on the topic of: "Hyperbaric Oxygen Therapy in Patients Suffering from Mild Cognitive Impairment Vascular Subcortical Ischemia"*			
18:00 - 20:00	EUBS & GTÜM Farewell Reception			
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O-01 ARTERIAL BUBBLES AND DECOMPRESSION SICKNESS: BUBBLE SIZE ON DETACHMENT FROM THE LUMINAL ASPECT OF OVINE LARGE BLOOD VESSELS, AND EVIDENCE OF "ACTIVE SPOTS"

R. Arieli [1] and A. Marmur[2]

[1] Israel Naval Medical Institute, IDF Medical Corps, Haifa, Israel
[2] Department of Chemical Engineering, Technion-Israel Institute of Technology, Haifa, Israel
Contact: rarieli@netvision.net.il

Introduction

Nanobubbles formed on the flat, hydrophobic, luminal surface of ovine blood vessels were shown to be the source of gas micronuclei from which bubbles evolved during decompression The risk of neurological decompression illness should be related to the size of the bubble on detachment, especially when this occurs in the arterial circulation.

Methods

Four ovine blood vessels: aorta, pulmonary vein, pulmonary artery, and superior vena cava, were compressed to 1013 kPa for 21 h. They were then decompressed, photographed at 1-s intervals, and bubble size was measured on detachment.

Results

Bubble production was seen in all types of blood vessels, with high variability between the different sheep and vessels. In most cases, there were certain spots at which bubbles appeared, either singly or in a cluster. Mean detachment diameter was between 0.7 and 1.0 mm, with bubble volume on detachment from the aorta greater than in the other blood vessels. Bubbles were produced throughout the whole hour, but it took only 12 min for a bubble to grow from a diameter of 1 μm to 10 mm.

Conclusions

A diameter of 1 mm on detachment from the aorta may already predict the potentially serious effect of these arterial bubbles; blockage of a single, deep penetrating artery 0.2 to 0.8 mm in diameter may cause lacunar stroke. These large arterial bubbles, and not the more profuse venous bubbles, may be the main cause of severe neurological decompression sickness. The transformation of nanobubbles into gas micronuclei with a diameter of about 1 μm is a slower process. The finding of active spots at which bubbles nucleate is a new, hitherto unreported observation. It is possible that these are the hydrophobic spots at which nanobubbles nucleate, stabilise, and later transform into the gas micronuclei that grow into bubbles.

Keywords: Nanobubble, decompression bubble size, hydrophobic surface, arterial bubbles, nucleation

O-02 A TRINARY MODEL OF DECOMPRESSION SICKNESS IN THE RAT

Peter Buzzacott[1], Kate Lambrechts[1], Aleksandra Mazur[1], Qiong Wang[1], Virginie Papadopoulou[2], Michael Theron[1], Costantino Balestra[3], François Guerrero[1]

1. Université de Bretagne Occidentale, Laboratoire Optimisation des Régulations Physiologiques (ORPhy), UFR Sciences et Techniques, 6 avenue Le Gorgeu, CS 93837, 29200 Brest Cedex 3, France
2. Department of Bioengineering, Imperial College London, London, United Kingdom
3. Biophysiology and Environmental Physiology Lab at the Haute Ecole Paul Henri Spaak (University of Brussels, Belgium);

Introduction

Decompression sickness (DCS) in the rat is most commonly modelled as a binary outcome. The present study aimed to develop a trinary model of predicting probability of DCS in the rat, (as no-DCS, survivable-DCS or death), based upon the compression/decompression profile.

Methods

A literature search identified dive profiles with outcomes no-DCS, survivable-DCS or death by DCS. Inclusion criteria were that at least one rat was represented in each DCS status, not treated with drugs or simulated ascent to altitude, that strain, sex, breathing gases and compression/decompression profile were described, and that weight was reported. A dataset was compiled (n=1602 rats) from 16 studies using 22 dive profiles and two strains of both sexes. Inert gas pressures in five compartments were estimated. Model-fit of the calibration dataset was optimised by maximum log likelihood and likelihood ratio test. Two validation datasets (one interpolation, one extrapolation) assessed model robustness.

Results

$$\Pr[DCS = j \mid x_i] = \underline{\alpha} + 0.0152 Weight_i + 1.4349 Female_i - 42.9559 Max.1_i$$
$$+ 43.3495 Max.1b_i + 2.1662 Bubble.3_i$$

Where α_1=-25.4827, α_2=-26.8382

In the interpolation dataset the model predicted 10/15 cases of nDCS, 3/3 sDCS and 2/2 dDCS, totalling 15/20 (75% accuracy) and 18.5/20 (92.5%) were within 95% confidence intervals. Mean weight in the extrapolation dataset was more than 2 SD outside of the calibration dataset and the probability of each outcome was not predictable.

Discussion

This model is reliable for the prediction of DCS status providing the dive profile and rat characteristics are within the range of parameters used to optimise the model. The addition of data with a wider range of parameters should improve the applicability of the model.

Keywords

Decompression illness, logistic regression, modeling, marginal decompression sickness, animal model

O-03 POSSIBLE RISK FACTOR CORRELATED WITH GAS BUBBLES FORMATION IN DIVING: ANALYSIS OF DAN EUROPE DSL DATA BASE.

M. Pieri[1], D.Cialoni [1,2], C. Balestra [1,2,3] and A. Marroni[1, 2,3].

1 DAN Europe Research Division
2 Phypode Project: physiopathology of decompression (FP7 Marie Curie, grant no. 264816)
3 Haute Ecole Paul-Henri Spaak Bruxelles

Introduction

The popularity of SCUBA diving is steadily increasing together with the number of dives per year and the correlated diseases. The rules governing correct decompression are well known and silent circulating gas bubbles have been observed in many divers without any DCI, However is also known that the pathogenetic mechanism of DCI is linked to gas bubbles. The scope of this study was to identify possible risk factors correlated with an increase in gas bubble formation and DCI incidence.

Materials and Methods:

An original dive database was developed and specific questionnaires were provided to 2615 divers who completed 39,522 dives, 970 of which including precordial Doppler recording. Bubble grades were compared to several possible risk factors.

Results:

There was no gender, age or anthropometric related difference $p>0.05$
A clear relationship between high bubble grades (HBG and HBG+) depth ($p<0.0001$) and dive time ($p<0.0001$) was found.
Lower bubble grades in divers who used nitrox with respect to those who used air ($p= 0,03$) and statistically significant higher grades in those who used Trimix vs. air ($p< 0,0001$) were observed.
We found an increase of high grade bubbles when current was reported in the questionnaire ($p=0.001$), and a decrease of HBG and HBG+ in lower visibility $p<0.0001$.
High bubble grades were significantly increased when the Gradient factor exceeded 60 percent of maximum tolerated value $p=0.019$
In low dives depth and time were significant reduced ($p<0.0001$ for both variables).
No other relationships between bubble grade and other possible risk factors were found.

Conclusion

Our data confirm that bubble formation is caused by complex mechanisms, not only related to depth and time, but also to other so far probably neglected factors, such as behavioral patterns, environmental conditions as well as very likely individual predisposition variables.

Keywords

Gradient Factor, compartmental model, Diving, Ascent speed, M-value

O-04 HEMODYNAMIC CHANGES ARE DETECTABLE BY ECHOCARDIOGRAPHY AND ARE ASSOCIATED WITH DIVE PROFILE AND BREATHING GAS

R. Pudil[1], L. Horakova[1], M. Rozložník[2], C. Balestra[2]

(1) Charles University Prague, Faculty of Medicine in Hradec Kralove, 1st Department of Medicine, Hradec Kralove, Czech Republic (2) Haute Ecole Henry Spaak, Environmental, Ageing & Occupational Physiology (Integrative) Laboratory, Brussels, Belgium

Introduction

The aim of the study was to evaluate the change in morphology and function of the right heart after scuba dive with compressed air and to compare it with trimix dive.

Methods

7 experienced divers (42.1±4.1 yrs., 28-56yrs) performed scuba dive with compressed air (depth: 40 meters, bottom time 20 min., water temperature 5°C). The same group performed trimix dive (70m depth) on the day two. Echocardiography was performed just before and immediately after the dive, and every 60 minutes after surfacing with the aim to evaluate the presence of microbubbles (iVivid, GE).

Results

After the air dive, left ventricle systolic and diastolic, left atrium, right ventricle and inferior vena cava diameters significantly decreased (LA: 32.4±2.2 vs. 26.1±1.3 mm, $p<0.05$; LVEDD: 56.5±4.8 vs. 52.1±4.4 mm, p 0.01; LVESD: 37.5±3.3 vs. 33.7±2.4 mm, p 0.02; RV: 28.3±2.7 vs. 23.8±2.9 mm, $p<0.01$; IVC: 18.1±0.9 vs. 16.4±1.4 mm, p 0.03). LV ejection fraction, fractional shortening and myocardial performance index remained unchanged (LVEF: 62.7±6.8 vs. 61.2±8.4, p ns; FS: 42.6±6.1 vs. 40.9±8.6, p ns). We found significant decrease in mitral and tricuspid E/A ratio (mitral E/A: 1.4±0.2 vs. 1.1±0.1 m/s, p 0.01; tricuspid E/A: 1.3±0.1 vs.1.1±0.1 m/s, p 0.05). RV functional parameters decreased (TAPSE: 29.4±3.8 vs. 25.5±1.8 mm, p 0.03). After trimix dive, there were no significant changes in size of the atrias and ventricles. IVC diameter decreased (17.7±1.9 vs. 15.5±1.6 mm, p 0.01). Also, less functional changes were noticed (mitral E/e: 4.1±0.7 vs. 5.2±0.7 mm, p 0.01; TAPSE: 27.5±4.9 vs. 22.1±2.9 mm, p 0.05). In all air dives, there were detectable microbubbles in the right heart.

Conclusion

Dive with compressed air is associated with decrease of the size and diastolic LV function and global RV function. Despite the bigger depth, the trimix dives are less associated with microbubble formation and hemodynamic changes.

O-05 VALIDATION AND ANALYSIS OF TISSUE MECHANICS IN DCS MODELLING

C. Walsh[1,2,3], U. Cheema[2], N. Ovenden[3], E. Stride[4]

[1] Centre for Mathematics and Physics in the Life Sciences and Experimental Biology (CoMPLEX), University College London, London UK.
[2] UCL Institute of Orthopaedics and Musculoskeletal Science, London, UK.
[3] Department of Mathematics, University College London, London, UK
[4] Institute of Biomedical Engineering, Old Road Campus Research Building, University of Oxford, Oxford UK.

Introduction

Predicting the nucleation and growth of bubbles in tissue is a key factor in understanding decompression sickness (DCS). The growth of gas nucleus deforms the surrounding tissue resulting in an additional stress on the bubble surface. This additional stress (σ), must be included in the Young-Laplace equation describing the subsequent growth or dissolution of the bubble and will depend upon the tissue's mechanical properties.
The two approaches currently prevailing to this additional tissue stress in the literature are: (i) to exclude the mechanical force exerted by the tissue entirely[1] or (ii) to use a term initially derived by Nims[2] which considers the bulk modulus of the tissue only[3]. Although another more consistent model from the work of Gent[4] has been available in the literature for some time[5], it has not been widely used and there has been little validation of any of these models.

Methods

This work presents a comparison of the above models with experimental measurements made in a collagen type I hydrogel. A miniature pressure chamber, designed specifically for this work decompressed the gels within which bubble dynamics were monitored. In addition, a model based on continuum mechanics approach to tissue mechanics was derived.

Results and Discussion

It was found that implementation of the Gent et al. pressure term in a simple diffusion limited model, captures basic bubble expansion as well as previous models. However, all the models treat the tissue as an elastic solid are all are unable to account for the long term stability (<12 hrs) of large bubbles post expansion. Long term stability is clearly highly significant for understanding pathology DCS and in order to capture this particular behaviour features such as tissue plasticity in the near-field and/or poroelasticity need to be considered computational models.

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O-06 VENOUS GAS EMBOLI AFTER A CHAMBER DIVE TO 18 MSW FOR 100 MIN – IMPLICATIONS FOR MEASUREMENT PROTOCOLS.

Andreas Møllerløkken[1]; Lesley Blogg[2]

[1]Department of Circulation and Medical Imaging, Faculty of Medicine, Norwegian University of Science and Technology, Trondheim, Norway
[2]SLB Consulting, Winton, UK.

Introduction

Observation of post-dive vascular gas bubbles is a recognized method for assessing the level of stress inferred by a dive. Although the importance of the measurement protocol has been highlighted (Blogg and Gennser 2011), there are still differences in the timing of measurements among research groups.

Methods

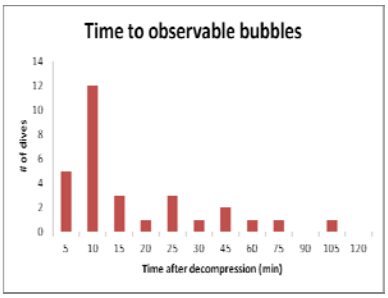
Eleven divers performed a total of 37 dives in a dry hyperbaric chamber. The profile was taken from the Norwegian Dive Tables (18 m for 100 min, decompression rate 90 kPa/min, stops at 6 msw for 5 min, then 3 msw for 15 min). Divers sat or lay at rest in the chamber. Post-dive, bubble monitoring was carried out with the subjects in the left lateral decubitus position. Observations were made every five minutes for the first 30 min, and then every 15 min for a total of 120 min, although if many bubbles were still present at 120 minutes, monitoring continued until a clear trend in bubble reduction was observed.

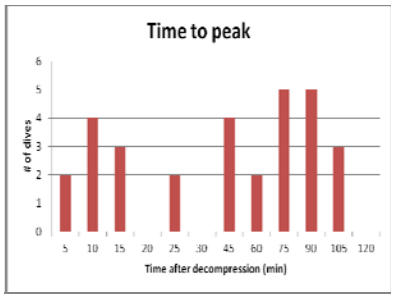
Results

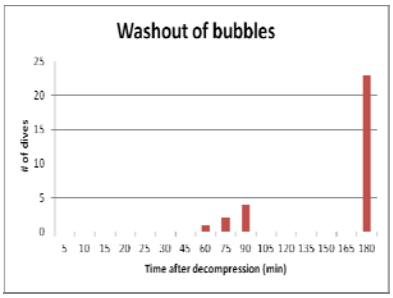
The majority of divers produced observable bubbles within 15 minutes post-decompression. However, in one diver it was 105 minutes before any bubbles could be detected. The time to peak bubble grades also varied between the divers. The majority showed a peak at around 90 minutes after surfacing; however peaks were also noted after 105 minutes and within five minutes after decompression. Bubbles persisted for 180 min in majority of the divers.

Conclusion

The variations in bubble evolution and washout show that the measurement protocols are of great importance. Both the number of observations and the length of the observation period must be increased above today's common practice. Observations should start as soon as possible to note the onset of bubbling, then should continue, preferably at 15 min intervals, for a total observation time of 180 minutes for similar bounce dives.







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O-07 POST-DIVE REHYDRATION PROVOKED BUBBLE FORMATION IN DIVERS? - BUBBLE FORMATION IN DECOMPRESSION DIVING STUDY (BUDDY)-

Schlorhaufer C[(1)], Temps T[(1)], Schill B[(1)], Kurowski V[(1)], Capewell M[(1)], Ahrens J[(1)], Hanke A[(1)], Eismann H[(1)], Sieg L[(1)], Zwadlo C[(2)], Jüttner B[(1)]

[(1)] Hannover Medical School, Department for Anesthesiology and Intensive Care, Germany
[(2)] Hannover Medical School, Department of Cardiology and Angiology, Germany

Introduction:

The present study investigated whether oral rehydration after a dive could influence bubble formation and to evaluate bubble induced platelet aggregation.

Methods:

After signed informed consent according to the ethics committee, 33 healthy scuba divers (23 male; mean age 43, range 25-56 years; mean BMI 24.6, range 18.7-31.6) were included in the study. Divers were randomly allocated using post-dive a intensive rehydration (protocol 1, 15ml/kg KG, osmolality = 271mOsmol/kg) or a more restrictive rehydration (protocol 2, 5ml/kg KG).
The diving protocol simulated air dives in a wet recompression chamber to a depth of 50 msw with 12 minutes bottom time. Circulating bubbles in the right ventricular outflow tract were monitored precordially before diving and 0, 30, 60 and 90 min after the dive by Doppler ultrasound and quantified using the Spencer scoring algorithm. Rotation thrombelastometry (ROTEM) after extrinsically activation and fibrin polymerization was tested. Platelet aggregation was determined by impedance aggregometry (Multiplate).

Results:

The diving protocol elicited bubbles in most subjects (range Spencer 0-4). None of the divers had clinical signs or symptoms suggestive of DCS. Bubble activity was significantly higher for protocol 1 than for protocol 2. Platelet aggregation slightly decreased post-dive without any significant change.

Discussion:

There was no decrease in bubble formation in subjects following the permissive hydration protocol. Conversely, post-dive oral rehydration with hypotonic fluid appeared to enhance bubble activity. In conclusion, by improving perfusion and microcirculation intensive fluid intake may induce bubble formation.

O-08 IN-VIVO EMBOLIC DETECTOR (I-VED): EXPLOITATION OF ELECTRICAL IMPEDANCE SPECTROSCOPY MEASUREMENTS FOR BUBBLES DETECTION IN HUMAN BODY

A. Mesimeris[1], S.P. Evgenidis[1], K. Zacharias[1], T.D. Karapantsios[1], T. Mesimeris[2], G. Karagiannis[2], S. Stefanidou[2], M. Kotsiou[2]

[1]Department of Chemical Technology, School of Chemistry, Aristotle University of Thessaloniki, Greece
[2]Lab of Hyperbaric Medicine, St. Paul General Hospital, Thessaloniki, Greece
Contact: karapant@chem.auth.gr

Introduction

I-VED (In-Vivo Embolic Detector) deals with the development of an innovative electrical impedance spectroscopy device capable of detecting bubbles in astronauts' bloodstream during DCS. Decompression Sickness (DCS) is a clinical syndrome caused by rapid reduction of environmental pressure in the body that results in formation of bubbles within body tissues, creating symptoms of variable severity that range from joint pain to permanent deficits or even death.

Methods

I-VED technique measures for varying excitation frequency values the electrical impedance of a medium composed of dispersed phases having different electrical properties, such as gas bubbles in blood or other tissues. The innovative hardware and signal analysis/processing have improved sensitivity and accuracy about two and one orders of magnitude, respectively, comparing to any other conventional method allowing for capturing considerably slight impedance changes as those expected due to bubbles presence in the human body. A series of impedance measurements was performed for bubbles detection applying self-adhesive ECG pads at the sites of chest (**Figure 1a**) and forearm of twenty divers, according to relevant European safety regulations. Bubbles were either injected in the blood circulation through the cephalic vein, or generated due to decompression as a result of divers' treatment in the Decompression Chamber (**Figure 1b**).

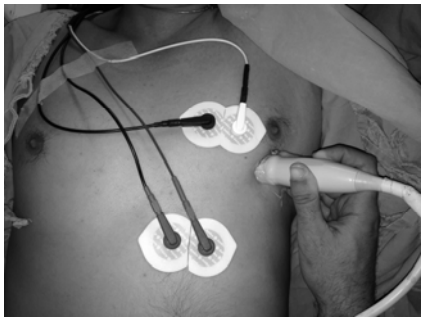
a)  **b)** 

Figure 1. a) ECG pads placement at the human chest, **b)** Decompression Chamber.

Results

I-VED technique detects successfully the presence of a few bubbles injected through the cephalic vein when ECG pads are placed at the forearm. For the case of ECG pads placement at the chest, preliminary signal analysis in both time and frequency domain provides promising results concerning bubble sensing. It is noted that in all cases the presence of bubbles is validated by means of ultrasound measurements.

Discussion

Based on ultrasound measurements, bubbles due to decompression are generated only in the body of a few divers. Although the presence of very few bubbles does not constitute a DCS incident, advanced signal analysis (such as FFT and STFT, wavelets, spectrograms, HHT, etc) is currently carried out in an effort to find out any features associated to the presence of bubbles.

O-09 BODY FAT SEEMS NOT TO INFLUENCE VENOUS BUBBLE FORMATION AFTER AIR DIVES: NITROGEN-LOAD MODEL AND EXPERIMENT

N.A.M. Schellart

Biomedical Engineering and Physics, Academic Medical Centre, University of Amsterdam, Amsterdam

Introduction/aims

Ever since Haldane, one thinks that more body fat (BF) increases VGB since more N_2 dissolves during the dive. Because in general, multicollinearity between age, BF, and VO_{2max} was not taken into account, studies on the effect of BF in DCS-risk and VGE show inconsistencies. For a 40min/3.1bar(a) profile N_2-tensions and loads were calculated, using a novel model with 8 parallel Bühlmann compartments, preceded by a 0.5 s halftime blood compartment in series. Calculations were done for a lean and a fat subject. Outcomes were checked indirectly in a simulated dive (40min/3.1bar(a)).

Methods

Modeling was performed numerically. Every minute the N_2-load of the blood compartment was corrected for the parallel compartments N_2-load to calculate the current $PN_{2,blood}$. The fat-lean difference was transformed to a bubble grade difference. Of 52 male divers with a small range in age (10y) and VO_{2max} (35-51 ml O_2/kg.min) to minimize multicollinearity, a novelty, precordial Doppler KM scores were determined 4x after surfacing to calculate KISS values and log{# bubbles/cm^2} (logB).

Results

Compared to Haldanian models, this model showed a substantial delay in N_2 uptake and release. One hour after surfacing, a diver with 2x more BF (reference 14%) gave only 15% increase in the blood compartment. This would result in an increase in bubble grade of only 0.01 “KM unit”. The outcomes hold for substantial changes in halftimes, compartment volumes and profiles. With saturation dives the difference is about 1/8 KM unit, also too small to be relevant in practice. All statistical outcomes of (partial) correlations between logB or KISS and BF were highly non-significant, supporting the model.

Conclusions

This work suggests that BF does not influence VGE. It is doubtful whether BF should remain a leading DCS-risk factor in the medical examination. (Partly published in Schellart et al., J Appl Physiol 2013;114:602-610).

Keywords

Adiposity, Doppler bubble score, deterministic series-parallel model, blood nitrogen tension, delayed nitrogen release.

O-10 DO PLASMA SURFACTANTS PLAY A ROLE IN DIVING? THE INTERRELATIONSHIPS BETWEEN PLASMA LIPIDS AND PROTEINS, SURFACE TENSION AND POST-DIVE VENOUS GAS EMBOLISM

Nico A.M. Schellart[1], Miroslav Rozloznik[2] and Costantino Balestra[2]

[1]Biomedical Engineering and Physics, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands; *n.a.schellart@amc.nl*.
[2] Environmental and Occupational Physiology Laboratory, Haute Ecole ‘‘Paul Henri Spaak’’, Brussels, Belgium

Introduction/Aims

Decompression sickness (DCS) of divers is caused by bubbles of inert gas. When DCS occurs, most bubbles occur in the venous circulation; vascular gas bubbles (VGB). The classic surfactant theory states that bubbles are stabilized by low molecular weight surfactants, reducing the plasma-gas surface tension (γ). We hypothesize that proteins may also play a role. We studied the interrelations between VGB and γ, total protein, albumin, triglycerides, total cholesterol and free fatty acids (FFAs), measured before and after a dry (air-)dive simulation.

Methods

Of 52 divers executing 63 simulated dives (21msw/40min profile) VGB was determined 40, 80, 120 and 160 min after surfacing (precordial Doppler method) and recalculated to the logarithm of the Kisman Integrated Severity Score (logKISS). Total protein, albumin, lipids and γ (dynamic bubble method) were determined pre- and post-dive. To manipulate plasma composition half of the subjects obtained fat rich and half fat poor meals. Eleven subjects got both.

Results

Triglycerides and FFAs varied substantially both intra- and inter-subject and pre-versus-post simulation; proteins do not. In statistical analysis, including sub-group comparisons and (partial) correlations, a consistent pre-post behaviour of the compounds could not be established. Nor did VGB scores show correlation with the compounds and γ. Similar findings hold true for the paired differences between the double exposures of the 11 subjects. The difference between γ_{water} and γ_{plasma} was only about15 mN/m.

Conclusions

Proteins, triglycerides, cholesterol and FFAs don’t seem to modulate γ and hence they cannot play a predominant role in post-dive bubble formation. The measured γ_{plasma} suggests that proteins are possibly the main compounds that lower surface tension. Since these findings do not agree with the classic surfactant hypothesis, some rephrasing seems necessary.

Keywords

Diving, surface tension, surfactant, lipids and proteins, Doppler bubble score.

This study was partially supported by the Netherlands Society of Diving Medicine and an EU Marie Curie Programme (FRP/2007-2013/REA grant 264816).

O-11 EXERCISE BEFORE SCUBA DIVING AMELIORATES DECOMPRESSION-INDUCED NEUTROPHIL ACTIVATION.

Dennis Madden, Stephen R. Thom, Tatyana N. Milovanova, Ming Yang, Veena M. Bhopale, Marko Ljubkovic, Zeljko Dujic

Introduction

The goals of this study were to investigate the difference in responses between a SCUBA dive preceded by aerobic exercise (EX) and a non-exercise control dive (CON), and further evaluate the potential relationship between venous gas emboli (VGE) and microparticles (MP). We hypothesized that exercise would alter the quantity and subtype of annexin Vpositive MPs and VGE.

Methods

Nineteen divers performed 2 dives to 18 m sea water for 41 min separated by at least 3 days, one of which was preceded by 60 min of treadmill interval exercise. Blood was obtained before exercise, before diving, and 15 min, 2, 4, and 24 h after surfacing. Intravascular bubbles were quantified by transthoracic echocardiography at 15, 40, 80, and 120 min.

Results

The median VGE remained unchanged between the 2 dives; however, there was a significant increase in VGE in the exercise dive at 40 and 80 min at rest. MPs were significantly elevated by approximately 2x at all time points following CON compared to EX. Markers of neutrophil and platelet activation were elevated by both dives and these elevations were attenuated in the EX dive.

Conclusions

We conclude that some of the differences observed between the EX and CON related to MPs, platelet, and neutrophil activation provide additional insight to the potential protective benefits of exercise, however, further study is needed to understand the mechanism and true potential of these benefits.

O-12 USE OF ANTIPLATELET AGENTS IN A RAT MODEL OF DECOMPRESSION SICKNESS: A THERAPEUTIC POTENTIAL WITH THE GLYCOPROTEIN IIB/IIIA INHIBITORS.

Kate Lambrechts, Jean-Michel Pontier, Aleksandra Mazur, Hubert Galinat, Qiong Wang, Peter Buzzacott, Marc Belhomme, Michaël Theron, François Guerrero.

Orphy Labolatory, Universite de Bretagne Occidentale, 6 Av. Le Gorgeu - CS 93837, 29238 BREST Cedex 3 - FRANCE

Introduction

Decompression sickness (DCS) can occur when a subject is subjected to a variation in environmental pressure and can have deleterious consequences. Blood platelet consumption after decompression is clearly linked to bubble formation in humans and in animal model. Previous studies highlighted a predominant involvement of platelet activation in bubble-induced platelet aggregation that is related to the pathology of DCS. To study the mechanism of platelet activation after decompression, we examined the effect of several anti-platelet treatments targeting various platelet activation pathways on DCS outcome: Acetyl Salicylate (ASA), Prasugrel (PRA), Abciximab (ABX) and Enoxaparin (ENO).

Methods

Male Sprague-Dawley rats were randomly assigned to six groups: 1/ control non-diving group (n=10); 2/ control diving group (n=30); 3/ PRA group (n=10); 4/ ASA group (n=10); 5/ ENO group (n=10) and 6/ ABX group (n=10). Groups 3 to 6 were treated before hyperbaric exposure (HBE). Blood sample were taken for PF4, TBARS and vWf analysis. Onset of DCS symptoms and death were recorded during a 60-min observation period after HBE.

Results

We showed a significant fewer outcome of DCS in the ABX group compared with the controls (CDG) (20% vs 73%, respectively, p = 0,007). There was no significant difference in DCS outcome among the control group and PRA, ASA and ENO groups. We highlighted a significant higher level of plasmatic PF4 in ABX and (8.14 ng/ml ± 1.4; p=0.004) and ENO groups (8.01 ng/ml ± 0.8; p=0.021) comparing to control group (6.45 ng/ml ± 1.9). We found a significantly higher plasmatic level of TBARS in control group group after HBE comparing to controls (49.04 µM ± 11.2 vs 34.44 µM ± 5.7, p=0.002) conversely to treated groups that had lower levels of TBARS. VWf concentrations were similar in all the six groups.

Conclusions

Our results suggest that only ABX pretreatment, a powerful GPIIb/IIIa receptor antagonist, has a protective effect on decompression risk, by significantly improving DCS outcome.
Besides the powerful platelet inhibition action of ABX, we presume that effects of ABX on vascular function, oxidative stress and inflammation could also play a protective role against DCS.

O-13 A STUDY OF DECOMPRESSION INDUCED BUBBLE DYNAMICS ON DIFFERENT TISSUE SURFACES WITH A NOVEL EXPERIMENTAL SET-UP

V Papadopoulou[1,2], S Evgenidis[3], RJ Eckersley[4], T Mesimeris[5], C Balestra[2,6], MX Tang[1], T Karapantsios[3]

[1]Department of Bioengineering, Imperial College London, London, UK; [2]Environmental & Occupational Physiology Lab. Haute Ecole Paul Henri Spaak, Brussels, Belgium; [3]Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece; [4]Imaging Sciences & Biomedical Engineering Division, King's College London, London, UK; [5]Hyperbaric Department, St Paul General Hospital of Thessaloniki, Thessaloniki, Greece; [6]DAN Europe Research Division, Belgium
Contact: virginie.papadopoulou07@imperial.ac.uk

This study was supported by the COST MP1106 action and the PHYPODE project EU-FP7-ITN-264816.

Introduction

Vascular gas bubbles are routinely observed after SCUBA dives using ultrasound imaging, however the precise formation mechanism and site of these bubbles is still debated [1] and growth from decompression in vivo has not been extensively studied, due in part to imaging difficulties [2].

Methods

An experimental set-up (fig.1) was developed for optical recording of bubble growth and density on tissue surface area measurement *during* hyperbaric decompression. Muscle and fat tissues (rabbits, ex-vivo) were covered with nitrogen saturated distilled water and decompression experiments performed, from 3 to 0 bar, at a rate equivalent to 10msw/min. Optical data was automatically acquired every 5s from the start of the decompression and for 1h. Data analysis was performed off-line in a custom-written MatLab code implementing a circular Hough transform for bubble tracking.

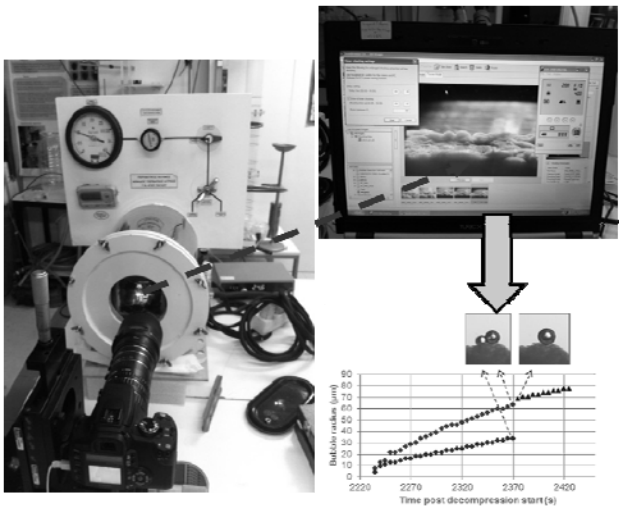


Fig. 1: Experimental set-up

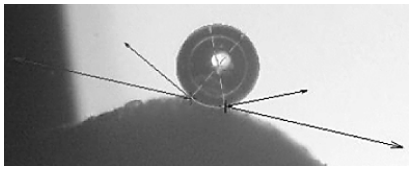


Fig. 2: Bubble tracking result from custom analysis in MatLab.

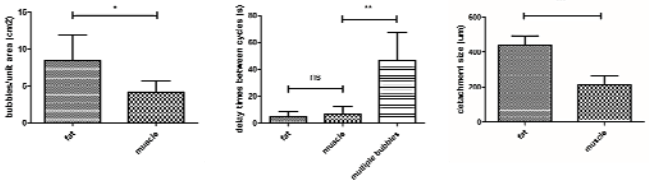


Fig. 3: Data presented as mean ± std dev. Statistical significance levels were set at $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***).

Results

The semi-automated analysis code is able to track bubble growth sequences successfully including bubble centre, radius, contact line and contact angles over time of bubble growth with a resolution of 1.75 μm (fig.2). Bubble density, nucleation threshold and detachment size, as well as coalescence behaviour, were shown significantly different for muscle and fat tissues surfaces, whereas growth rates after a critical size were governed by diffusion as expected (fig.3).

Discussion

Heterogeneous nucleation is observed from preferential sites on the tissue substrate, where the bubbles grow, detach and new bubbles form from the same site in turn. No new nucleation sites are observed after the first 10min post decompression start so bubble density does not vary after this point in the experiment. In addition, a competition for dissolved gas between adjacent (multiple) bubbles is demonstrated in increased delay times as well as slower growth rates for non-isolated bubbles.

References:

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O-14 ROLE OF ROS IN DIVE-DERIVED ENDOTHELIAL DYSFUNCTION AND DCS *IN VITRO* AND *IN VIVO*

Aleksandra Mazur,[1,#] Qiong Wang,[1,#] François Guerrero,[1] Kate Lambrechts,[1] Peter Buzzacott,[1] Marc Belhomme,[1] Michaël Theron[1,*]

[#]Aleksandra Mazur and Qiong Wang contributed equally to this work.
*Corresponding author: Michaël Theron.

Introduction

Reactive oxygen species (ROS) are known to be involved in post-dive endothelial dysfunction which is itself thought to be associated with decompression sickness (DCS). In this context, the aims of this study were to assess the impact of antioxidant protection both *in vitro* and *in vivo* and to investigate the link between ROS and DCS.

Methods

The effect of N-acetyl cysteine (NAC) on superoxide and peroxynitrite productions, NO generation and cell viability were observed during *in vitro* diving simulation of cultured bovine arterial endothelial cells. During *in vivo* dive simulation in rats, the effects of NAC and Vitamin C upon plasmatic levels of glutathione thiol and TBARS, plasmatic ACE activity and angiotensin-II level as well as DCS occurrence, were examined.

Results

During *in vitro* diving simulation, endothelial cells showed excessive production of superoxide and peroxynitrite, obvious attenuation of NO generation and promotion of cell death. All these effects were then prevented by NAC treatment. During *in vivo* diving simulation, plasmatic ACE activity and angiotensin-II level were not affected significantly. Plasmatic level of glutathione thiol was reduced after diving. This last effect was ameliorated by NAC treatment. Plasmatic TBARS level was up-regulated by diving but neither NAC nor Vitamin C treatment prevented this. DCS prevalence was not modified by either antioxidant treatment.
During *in vitro* dive simulation, endothelial perturbations (superoxide overproduction, decrease of NO and cell death) were prevented by antioxidant treatments. However, in the *in vivo* simulation no direct link between oxidative stress and DCS was observed.

Discussion

This first study into the link between ROS, antioxidants and DCS tends to show that diving-induced oxidative stress might not in itself be an important trigger of DCS. Given the protective effect of NAC at the cellular level, however, the utility of augmenting Hyperbaric Oxygen Therapy with antioxidents, particularly in chronic wound care, deserves further research.

Keywords

oxidative stress, nitric oxide, vasodilation and vasoconstriction, endothelial dysfunction, decompression sickness, SCUBA diving.

O-15 ENDOTHELIAL MITOCHONDRIAL CA^{2+}/$ONOO^-$ PATH AND EXCESS ROS DURING SIMULATED DIVING

Qiong Wang,[1] François Guerrero,[1] Huan Zhang,[1] Qianying Zhang,[1] Zijing Zhou,[1] Kate Lambrechts,[1] Aleksandra Mazur,[1] Peter Buzzacott,[1] Marc Belhomme,[1] Michaël Theron,[1,*]

[1]Laboratoire ORPHY, UFR Sciences et Techniques, Université de Bretagne Occidentale, 6 Av. Le Gorgeu - CS 93837, 29238 BREST Cedex 3, FRANCE
*Corresponding author: Michaël Theron.

Introduction

Excessive generation of mitochondrial superoxide during air diving simulation is involved in mitochondrial depolarization and the death of vascular endothelial cells. This work is focusing on the mechanism of diving-induced overproduction of mitochondrial superoxide, through the analysis of the effects from the following perspectives, peroxynitrite formation, nitric oxide production and mitochondrial calcium mobilization.

Methods

In vitro diving simulation was performed with bovine arterial endothelial cells under real time observation. The effects of peroxynitrite, NO and mitochondrial calcium mobilization on mitochondrial superoxide excess were examined during the simulation.

Results

During diving simulation endothelial cells showed excessive mitochondrial superoxide and peroxynitrite, attenuation of NO production and up-regulation of mitochondrial calcium mobilization. MnTBAP (peroxynitrite scarvenger) suppressed excess superoxide, recovered NO production and promoted stronger mitochondrial calcium mobilization. The overproduction of superoxide and peroxynitrite were inhibited by L-NIO (inhibitor of eNOS), but were promoted by Spermine (NO donor). L-NIO induced stronger mitochondrial calcium mobilization than Spermine or non-treatment. The excesses of superoxide and peroxynitrite were also inhibited by Ruthenium Red (blocker of mitochondrial Ca2+ uniporter), but were promoted by CGP (antagonist of mitochondrial Na+-Ca2+ exchanger).

Discussion

Peroxynitrite generated during diving enhances mitochondrial superoxide production through the inhibition of mitochondrial respiration. Mitochondrial calcium mobilization activates mitochondrial NO generation during diving and therefore promotes peroxynitrite formation and superoxide overproduction. Conversely peroxynitrite suppresses mtNOS activity and partly promotes mitochondrial $Ca2^+$ discharging. This work is the first to elucidate the links between mitochondrial calcium uptake, nitric oxide, peroxynitrite and superoxide during diving. These findings hold new implications in studies of diving-derived oxidative stress.

Keywords

SCUBA diving, oxidative stress, superoxide, peroxynitrite, nitric oxide, mitochondrial calcium.

O-16 AIMS AND ORGANIZATION OF THE VERY LONG DURATION IMMERSION STUDIES

Blatteau JE, , Desruelle V, Vallée N, Schmid B, Peny C Regnard J, Castagna O.

Abstract

In 2006, the physiological consequences of static and air breathing whole body immersion during 6 hours were assessed in studies organized and implemented by the IMNSSA (institute of naval medicine, of the French armed forces health services) and other research groups (Robinet et.al. EJUHM Vol.7.No.4, December 2006).

Upon request of the French Navy command, a new study was undertaken to study the effects of longer duration (8 to 12 hours) of immersed missions in 17°C water, and the capacity of military divers to safely achieve such duties. To better match realistic conditions, divers breathed an oxygenated mixture using a semi closed circuit military rebreather. They followed a diving profile with hydrostatic pressures ranging from 1.7 to 3 bar, and performed a 2 h fining bout embedded in each session. Experimental sessions were implemented in the French navy hyperbaric center (CEPHISMER). This set of experiments provided a unique opportunity to analyse various consequences of the combined physiological strains of immersion, cold exposure, exercising, hyperoxia. The study assessed hydromineral balance, heat balance, effects on the cardiovascular system, on lung function, on ophthalmic and cognitive functions. The results should provide landmarks useful for the preparation of prolonged dives and management of their recovery.

This presentation describes the general methodological aspects of this study, which are the common frame of the presentations of results harvested in different physiological and functional fields.

O-17 FLUID BALANCE DURING PROLONGED SCUBA DIVING: EFFECT OF HYDRATION DURING IMMERSION.

Castagna O [1-2], Blatteau JE[1], Peny, Ruby X, Chopard R[3], Barrot L[3], Belon F[3], Blanchard JC[3], Desruelle A-V[1], Vallée N[1], Schmitt B[1], Regnard J[3] .

1 Underwater research team (ERRSO). Military biomedical research institute (IRBA) - Toulon, France.
2 The Laboratory of Human Motricity, Education Sport and Health, LAMHESS (EA 6309) UFR STAPS de Toulon, France
3 EA3920, Franche Comté University, and University Hospital Besançon, France

Introduction

With prolonged immersion, fluid loss may cause functional impairment. We assessed hydromineral changes during dives in 18 °C water.

Methods

Three groups of 6 military divers spent 8, 10 and 12 hours immersed in a wet hyperbaric chamber, fin swimming for 2h bouts between sitting rests at different depths (ranging 7 to 20 msw). Urine was collected hourly and after drinking 200 ml of beverage containing 240 mg salt and 10 g carbohydrate in water. Body weight was assessed before and after dives, and blood collected to survey haemoglobin (Hb), hematocrit (Ht), plasma sodium, potassium, aldosterone and renin.

Results

During the 8h session, technical difficulties prevented blood and urine analysis.
• Body weight was similarly decreased at the end of 8h, 10h and 12h dives. Total urine volumes did not differ during 10h and 12h dives.
• Plasma volume (PV) decreased over the first 2h of each session ($p<0.05$), then slower till 4h ($p=0.76$), then levelled off until after immersion. During the first recovery hour PV remained lower than baseline but was no different from baseline 15h after diving. Fin swimming tended to increase PV ($p=0.069$), concomitant with slight increases in plasma renin and aldosterone (NS). ΔPV on recovery morning vs baseline were consistent with a longer recovery of PV after longer dive duration ($p=0.08$).
• Plasma sodium and potassium were never different from baseline.
• Urinary flow was 6 times baseline over the first 2h of the 10h and 12h dives, and thereafter 3 times baseline until diving ended.

Discussion

During the first 2h of cold water diving, urinary output increased with simultaneous PV lowering. Afterwards urine output decreased and PV lowering slowed. Beyond 8h these parameters remained steady until diving ended. Exercising bouts tended to reduce urine output and rise PV (NS).

dive duration	subjects	mass loss g	urine volume mL	Δ plasma volume (%)		
				last immersed sample	1 h post-dive	following morning
8 h	6	2 030 ± 777	-	-	-15.6 ± 7.4	1.9 ± 4.2
10 h	6	2 600 ± 758	4 544 ± 1 111	-17.1 ± 5.8	-14.8 ± 3.6	-1.5 ± 2.2
12 h	6	2 133 ± 445	4 366 ± 1 028	-18,7 ± 9.3	-10,2 ± 7.9	-3,7 ± 6.4

Table 1. Mass, urine and plasma volume changes over 8, 10 and 12 h dives and following recovery

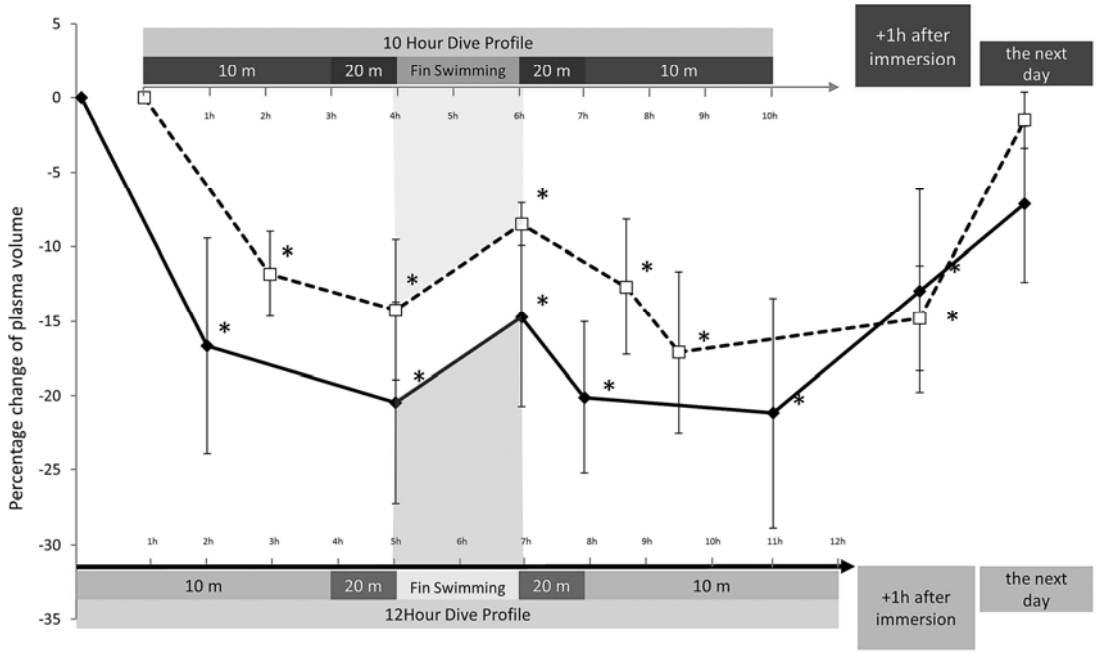

Figure 1. Changes in percentage plasma volume during the 10 and 12 h immersion, and their recovery. Solid black line for 12 h immersion; dotted line for 10h immersion
* Significantly different to the baseline values at rest ($p < 0.05$)

O-18 THERMAL ASPECTS OF LONG-TERM IMMERSION AT 18°C IN COMBAT SWIMMERS.

Desruelle AV, Schmid B and Castagna O
Underwater research team (ERRSO). Military biomedical research institute (IRBA) - Toulon, France.
Contact: castagna.olivier@gmail.com

Introduction

In cold or temperate water, hypothermia remains a major risk for military divers wearing wet suit. This study aimed at evaluating physiological effects of long-term dives performed in 18°C water temperature. Particular interest was given to thermal effects of exercise bouts and depth changes during the dive.

Methods

Three groups of 6 military divers participated to this experimentation. Their neoprene suit (7.5 mm of thickness) covered the entire body surface. They were immersed in a wet hyperbaric chamber for 8, 10 or 12 hours during which they fin swam or rested (sitting) at different depths. Mean skin (Tsk) and internal (Ti) temperatures were continuously measured. Thermal comfort and shivering were subjectively assessed at different times during each dive session.

Results

Ti values changed similarly in the 3 durations sessions. The average Ti and Tsk were respectively 37.4(0.4)°C and 32.5(1.3)°C at the beginning and 36.6(0.4)°C and 28.0(1.2)°C at the end of all immersion sessions. Tsk increased significantly ($p<0.05$) during the fining bout, with no concomitant Ti change. Conversely, the duration and depth of sitting periods had no significant effect on Ti and Tsk. The intensity and rate of shivering increased slightly throughout the dives. Global thermal judgements changed only in the last 2 questionnaires of the 12h sessions ($p < 0.05$).

Discussion

The lack of significant changes in body temperatures may result from the small number of divers in every duration dive series and from great heterogeneity of individual responses. Also, the set point value for control of internal temperature depends on the thermal history of each diver. The environmental conditions (water temperature, depth and duration of immersion, exercise) do not directly influence this set value, but mainly determine the time during which this value can be maintained, according to initial status, capacity to limit heat loss into environment... Assessing this time and developing equipments supporting its lengthening shall be a forthcoming objective.

O-19 EFFECTS OF LONG DURATION DIVE (8, 10 AND 12 HOURS) WITH HYPERBARIC HYPEROXIA ON NAVY DIVERS' EYE AND VISUAL FUNCTION

Valero Bernard[1], Castagna Olivier[2], Brugier Aurélie[1], Vignal Rodolphe[1], De Faria Alexandra[1], Bourniquel Marie[1], Sekfali Rim[1], Blatteau Jean-Eric[2], Giraud Jean-Marie[1].

1- Sainte-Anne Military Hospital, Toulon, France
2- Underwater research team (ERSSO), Military biomedical research (IRBA), Toulon, France

Introduction

The study aimed at assessing anatomical and functional effects of long duration dive (8, 10 and 12 hours) on the eye, by reproducing all the constraints undergone by professional divers, so as to prevent potential hazard to diver visual function.

Methods

18 professional male Navy divers performed prolonged dive sessions (8, 10 and 12 hours), breathing 50% Nitrox or 100% O2, according to immersion depth (7 to 20 msw), and amounting to 1.54 to 1.7 bar inhaled PO_2.
For each diver, we studied several parameters 24 hours before and 15 hours after immersion: visual acuity, low spatial contrast sensitivity, color vision (desaturated 15 Hue® test), eye refraction, ocular examination, visual field (Metrovision®, studying 24° and 10° central visual field), full-field clinical electroretinography (Metrovision®) using a short protocol (pupillary dilation, photopic response with 16 white standard flashes and 16 red flashes, 4 minutes to dark adaptation, scotopic response with 8 blue flashes and 8 attenuated white flashes), and multifocal electroretinography (Metrovision®).

Results

None of the 18 divers had any loss of visual acuity. No change occurred following dive in spatial contrast sensitivity, color vision, eye refraction, visual field parameters (corrected mean deviation, foveolar threshold). Ocular examination was normal for all the divers, before and after immersion. Regarding full-field clinical electroretinography, b-wave was significantly decreased after immersion (286,64 µV ± 60,34 vs 270,07 µV ± 57,64, p = 0,015) on scotopic response with white attenuated stimulation. No significant modification occurred in multifocal electroretinography.

Discussion

Thus long duration hyperoxic dive did not cause any clinically significant eye modification. No immediate harm to diver eye and visual function appeared. The slight modifications on electroretinography tests are not easy to understand, due to intra and inter-individual variations inherent to the tests, but they raise question about subclinical functional effects of hyperoxia that could affect rod-cells function.

O-20 CHANGES IN MYOCARDIAL FUNCTION FOLLOWING 8 TO 12 H REBREATHING COLD WATER DIVES

Chopard R, Barrot L, Belon F, Brocq F, Blanchard JC, Blatteau JE, Peny C, Schmitt B, Vallée N, Desruelle AV, Regnard J, Castagna O.

Background and objectives

The study assessed haemodynamic changes and myocardial function after prolonged dynamic cold water immersions with hyperbaric hyperoxic exposure. Conventional and speckle tracking imaging transthoracic echocardiography (TTE) were used.

Methods

Trained military divers were studied during 8 h (6 subjects) and 12 h (6 subjects) dives in a hyperbaric chamber (1.7 and 3 bar) in 18°C water. Subjects were breathing hyperoxic gas (100% oxygen or up to 1.7 bar PO2) and performed bouts of physical exercise. TTE were performed before, immediately after, and 15 hours after dives.

Results

Decrease in left and right ventricular preloads plus a lowered stroke volume were evidenced immediately after dives. These parameters remained below baseline values 15 h dive termination. These changes were not significantly different after the 8 h and 12 h dives. Speckle tracking analysis assessed altered function of left and right ventricles as evidenced by transient decrease of the following parameters within 1 h after immersion :

	Baseline (a)	Immediately after immersion (b)	15 h after immersion (c)	P value b vs. a	P value c vs. a
Longitudinal strain. %	-22.1±1.2	-18.4±2.0	-23.0±1.6	<0.01	NS
Radial strain. %	35.4±9.4	32.4±11.2	34.1±6.4	<0.05	NS
Circumferential strain. %	-16.5±2.5	-13.4±2.1	-16.1±2.1	<0.01	NS
Systole					
Longitudinal SR. S^{-1}	-1.02±0.11	-0.96±0.10	-1.01±0.20	<0.01	NS
Circumferential SR. S^{-1}	-1.00±0.25	-0.94±0.12	-0.99±0.28	<0.01	NS
Diastole					
Longitudinal SR. S^{-1}	1.28±0.20	1.10±0.12	1.30±0.15	<0.05	NS
Radial SR. S^{-1}	-1.78±0.38	-1.51±0.25	1.82±0.25	<0.05	NS
Circumferential SR. S^{-1}	1.12±0.40	0.99±0.21	1.10±0.25	<0.01	NS

SR : strain rate

Discussion

Haemodynamic changes and transient alterations in strain and strain rate myocardial parameters were assessed immediately after 8 to 12 h dives. Immersion-linked changes in blood volume were likely involved in lowering cardiac preload and stroke volume. Altered ventricular strain and strain rates might result of blood volume lowering, hyperoxic breathing and enlarged cardiac pre- and after-load.

O-21 CARDIOVASCULAR STRAINS ASSESSED FROM CARDIAC PEPTIDES AND MARKERS OF ENDOTHELIAL FUNCTION DURING 8 TO 12 H REBREATHING COLD WATER DIVES

Regnard J[1], Bouhaddi M[1], Barrot L[1], Belon F[1], Dehecq B[1], Garnache-Ottou F[2], Blatteau JE[3], Peny C[4], Chopard R[1], Schmitt B[3], Vallée N[3], Desruelle AV[3], Dumoulin[1], Castagna O[3].

1- EA3920 Université de Franche comté, and University hospitals of Besançon, France
2- Inserm UMR1098, Université de Franche Comté, and French Blood Establishment, Besançon, France
3- Underwater research team (ERRSO). Military biomedical research institute (IRBA) - Toulon, France.
4- Cephismer, Hyperbaric experimental center, Toulon, France

Background and objectives

Diving increases vascular filling and cardiac preload[1]. Endothelial function has been found altered following dives[2,3]. Short-term hyperoxic breathing impairs endothelial nitric oxide function[4]. Cardiac peptides have been said to alter the endothelial lumen.

Methods

18 trained military divers were studied during 8 h 10 h and 12 h dives implemented in 18 °C water, with 1.5 to 1.7 bar inhaled P_{O_2}. Plasma concentrations of Nt-proANP, Nt-proBNP and GMPc, of NOx (nitric oxide derivatives), Syndecan-1 (a piece of altered glycocalyx) were assessed before, during and following the dives. Baseline and post-ischaemic changes in tissue haemoglobin saturation (StO2) were assessed before and after the dives.

Results

Plasma Nt-proANP increased significantly rapidly at the begining of dives (peak 2,7 times baseline ; $p<0.05$) and continuously decreased after the first 3 hours. Plasma GMPc changes paralleled ANP changes. Nt-proBNP was increased after 2 h ($p<0.05$) and then rose continuously up to the end of dives (5 times baseline). There was a trend (NS) for increase in plasma NOx after fining bouts and thereafter no significant difference with baseline values until the end of dives. Plasma Syndecan-1 did not change significantly along the dive. Baseline tissue oxygen saturation was significantly lower within one hour after dives ($p<0.05$) and had resumed baseline values 15 h later.

Conclusion

The early rise in plasma ANP reflected the dive-increased cardiac preload. BNP rose as a result of increased cardiac work likely due to firstly an early enlarged preload, secondly the exercise duty and thirdly the cold-induced afterload[4]. The absence of significant lowering of plasma NOx despite hyperoxia and immersion conditions do not support significant alteration of endothelial function during such dives[5]. The absence of increase in plasma Syndecan-1 argues against any conspicuous alteration of the endothelial glycocalyx.

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O-22 DIVING IN MODERATELY WARM WATER EFFECTS CORE TEMPERATURE IN DIVERS AFTER SPINAL CORD INJURY

Urska Gajsek[1,2], Zare Finderle[1], Arne Sieber[3,4]

[1]Universtiy Clinical Center Maribor, Slovenia,[2]University of Ljubljana, Medical Faculty, Institute of Physiology, Ljubljana, Slovenia, [3]Seabear Diving Technology, Graz, Austria,[4]Chalmers University of Technology, Gothenburg, Sweden
Corresponding author: urska.gajsek@gmail.com

Introduction

Spinal cord injury (SCI) divers perform recreational diving activities similar to able-bodied divers. It is known that in SCI people thermal regulation is impaired. Previously we demonstrated that cold water diving in a 6°C lake led to hypothermia in SCI divers. The present study investigates core temperature changes in SCI divers while diving in moderately warm water.

Methods

International Association for Handicapped Divers (IAHD) Adriatic organized 2 days of diving in Kostrena, Croatia. The subject group consisted of 8 SCI and 8 able-bodied controls. Two consecutive recreational no decompression dives were planned by IAHD Adriatic for each day. All divers used 5mm neoprene suits. Core temperature was measured using ingestible pills.

Results

The maximum depth of the dives was 30.8m±2.3mand mean dive duration was 37min ±3min.Water temperature was 18°C. The able-bodied divers did not show any significant core temperature change. The SCI divers all showed significant core temperature changes after diving, however the results are twofold. 5 SCI divers had a decreased core temperature and 3 SCI divers showed an increased body core temperature.

Discussion and Conclusion

In contrast with abled divers, the core temperature in SCI divers was not constant even when diving in moderately warm water. The 5 SCI divers with decreased body core temperature were experienced divers. In contrast, the 3 SCI divers with increased body core temperature were less experienced. They possibly used more physical effort to maintain balance and/or buoyancy, which may explain the temperature increase.
The present results are alarming, as core temperature influences inert gas uptake and release, which dive computers do not currently account for. SCI divers with impaired thermal regulation and core temperature changes during a dive thus potentially face a risk for DCS that differs to abled divers.

Keywords

SCI, diving, core temperature, SCUBA

O-23 CARDIAC BENEFITS OF DIVING WITH SPINAL CORD INJURY: A CLINICAL TRIAL

Dominik Graczyk[1], Peter Buzzacott[2,3]

[1]Department of Rehabilitation, IBIS Medical Clinic, Warsaw, Poland
[2]Marie Curie Experienced Research Fellow, Université de Bretagne Occidentale, Laboratoire Optimisation des Régulations Physiologiques (ORPhy), UFR Sciences et Techniques, 6 avenue Le Gorgeu, CS 93837, 29200 Brest Cedex 3, France, and
[3]Adjunct Lecture at the School of Sports Science, Exercise and Health, the University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia.
E-mail: peter.buzzacott@uwa.edu.au

Introduction

Diving is an increasingly popular activity among people with disabilities, including paraplegia. Motivations to participate and quality of life benefits among disabled divers are well documented but there is little in the literature on the influence of diving on disabled people's physiology. This study assessed function of the autonomic nervous system (ANS) in the area of circulatory system regulation by Heart Rate Variation (HRV) analysis in healthy and after spinal cord injury (SCI) divers. Our hypothesis was that HRV may detect rehabilitation in heart regulation among disabled divers with SCI.

Methods

38 males were equally divided into two groups, healthy and with SCI, both making two 20-minute dives. The first dive was recreational without exercise and the second with an exercise program underwater. Measurements were made 10 minutes before diving, during diving and 10 minutes after diving. Spectral and time-domain markers of HRV were recorded.

Results

In the SCI group, diving caused increases of sympathetic nervous system (SNS) activity. In the healthy group both diving activities caused an increase of parasympathetic nervous system (PNS) activity. During diving both groups experienced an increase of SNS and a decrease of PNS. In both dives, the divers with SCI had higher autonomic activity and lower PNS activity than the healthy divers.

Discussion

Previous reports suggest that diving has positive effects upon cardiac rehabilitation. This study found that HRV analysis was a useful tool for monitoring changes of ANS in heart rate regulation among disabled persons with SCI and that recreational diving (with or without exercise) can have a positive influence, both on cardiac wellbeing and in a relative reduction of emotional activity. Further research is, however, needed before diving might be recommended for SCI rehabilitation.

Key words

Heart rate variation, diving, paraplegia, autonomic nervous system, disabled divers

O-24 DIFFERENT EFFECT OF L-NAME TREATMENT ON SUSCEPTIBILITY TO DECOMPRESSION SICKNESS IN MALE AND FEMALE RATS

A. Mazur[1], P.Buzzacott[1], K. Lambrechts[1], Q. Wang[1], M.Belhomme[1], M.Theron[1], G. Popov[2], G. Distefano[2], F. Guerrero[1]

[1]Orphy Labolatory, Universite de Bretagne Occidentale, 6 Av. Le Gorgeu - CS 93837, 29238 BREST Cedex 3 - FRANCE
[2]Mares Italy, Salita Bonsen 4, Rapallo Genova - Italy

Introduction

Decompression sickness (DCS) is thought to result from undisolved gas forming bubbles in tissues and blood as an individual moves from higher to lower ambient pressure. Risk factors for DCS include: increased age, weight/fat mass, decreased maximal oxygen uptake, chronic diseases, dehydration and nitric oxide (NO) bioavailability. Production of NO is often affected by diving and its expression/activity varies between sexes. Little is known about the influence of sex on risk of DCS. To study this relationship we used an animal model of Nω-nitro-L-arginine methyl ester (L-NAME) induced decreased NO production.

Methods

Male and female rats (n=105) with diverse age and weight were divided into two groups: L-NAME treated (in a tap water; 0.05 mg/ml for 7 days) and a control group. To vary the distribution of nitrogen among tissues, two different compression/decompression protocols were used. The relevance of covariates was assessed with logistic regression.

Results

L-NAME was significantly associated with increased DCS in female rats ($p=0.039$) only. Weight was associated with DCS in both sexes ($p=0.01$). The protocol with higher estimated tissue pressures in the slower compartments was 2.6 times more likely to produce DCS than the protocol with greater estimated tissue pressures in faster compartments.

Conclusions

This study found that reduced NO bioavailability, induced by treatment with L-NAME, and provoked significantly higher susceptibility to DCS in female rats but not in male rats. The analysis also showed that the most significant factors for the appearance of DCS were type of protocol and weight, both of which may relate to fat mass in female rats. Caution is urged to consider sex when interpreting rat research.

Key words

Decompression illness, L-NAME, diving, gender, risk factors, nitric oxide bioavailability, rat

O-25 EFFECT OF NITRIC OXIDE SYNTHESIS INHIBITATION ON CEREBRAL CYANIDE POISONING AND HYPERBARIC OXYGEN BREATHING IN RATS

Polzik P[1], Hansen MB[1], Olsen NV[2,3] and Hyldegaard, O[1]

[1]Centre and Laboratory of Hyperbaric Medicine, Dept. of Anesthesia, Head- and Orthopedics Centre, University Hospital of Copenhagen (Rigshospitalet), Denmark. [2] Department of Neuroscience and Pharmacology, University of Copenhagen, Denmark. Department of Neuroanaesthesia, The Neuroscience Centre, University Hospital of Copenhagen (Rigshospitalet), Denmark.

Background:

Hyperbaric oxygen therapy (HBOT) ameliorates the deleterious effects of cyanide (CN) intoxication. This effect may be due to increased bioavailability of nitric oxide (NO) during HBOT, because NO has been shown to restore aerobic metabolism by competing with CN binding to cytochrome complexes in mitochondria. The present study tested whether unspecific NO synthesis blockade with L-NAME affects cerebral metabolism in a model of cyanide intoxication in rats. In addition, we tested whether L-NAME interacts with the beneficial effect of HBOT.

Methods:

Anaesthetized female Spraque Dawley rats were exposed to CN intoxication (5.4 mg/kg by intra-arterial injection) with- or without previous NOS inhibition by L-NAME injection. Microdialysis catheters were inserted into the corpus callosum and intracerebral microdialysis was used to measure the interstitial brain concentration of lactate.

Results:

L-NAME potentiated CN intoxication as suggested by higher maximum lactate concentration (mean 0.534 mmol/l ± 0.186) compared with only cyanide poisoned rats (0.468 mmol/l ± 0.281). During HBOT, the trajectory is steeper with a sustained reduction in mean lactate levels in spite of NOS blockade by L-NAME.

Conclusion:

L-NAME potentiates the effect of CN poisoning suggesting a protective effect of NO in CN poisoning. Furthermore, HBOT may have multiple vectors of beneficial action overriding the blocking of NOS.

O-26 DUAL EFFECT OF FLUOXETINE IN NEUROLOGICAL ISCHEMIA HIGHLIGHTED IN A TREK-1-DEFICIENT MICE MODEL OF DECOMPRESSION SICKNESS

N. Vallée, S. De Maistre, C. Ramdani, J-J. Risso, J-E. Blatteau

Equipe Résidente de Recherche Subaquatique Opérationnelle. Institut de Recherche Biomédicale des Armées, Département Environnements Opérationnels. Toulon, BP 610, 83800 Toulon Cedex 9, France.

Background

We previously demonstrated that 1) the anti-inflammatory effect of fluoxetine treatment[1] and 2) the presence of TREK-1 channels[2] are associated with increased survival in mice subjected to neurological DCS from rapid decompression. However, fluoxetine is known to inhibit TREK-1 channels[3] and the question arises as to whether fluoxetine might compromise the protection afforded by the TREK-1 channels in DCS.

Methods

We studied the effects of fluoxetine (per os, 50 mg/Kg) in wild-type (WT) mice and TREK-1 deficient mice (knockout homozygous KO and heterozygous HET) after rapid decompression from a simulated dive to 90 msw for 45 min. Clinical assessment, including grip tests, was realized during a period of 30 min after surfacing.

Results

Of 45 mice that were wild type ($WT_{controls}$) for TREK-1, 22.3% showed no DCS symptoms, 15.5% failed a grip-test, and 62.2% died. Of 46 WT mice that received fluoxetine ($WT_{fluoxetine}$), 45.7% showed no DCS symptoms, 13.0% failed a grip-test, and 41.3% died. Of 30 mice that were heterozygous ($HET_{fluoxetine}$) for TREK-1 and treated with fluoxetine, 60.1% showed no DCS symptoms, 23.3% failed a grip-test, and 16.6% died. Of 46 TREK-1 knockouts treated with fluoxetine ($KO_{fluoxetine}$), 78.3% showed no DCS symptoms, 15.2% failed a grip-test, and 6.5% died.

Conclusion

Mice that did not express TREK-1 were less susceptible to when treated with fluoxetine and were less likely to develop neurological DCS symptoms. This suggests that fluoxetine-induced TREK-1 inhibition mitigates the neuroprotective effect of fluoxetine.

References

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"A Lifetime Experience with Carbon Monoxide Poisoning"

Neil B. Hampson, MD
Emeritus Physician, Section of Hyperbaric Medicine
Virginia Mason Medical Center
Clinical Professor of Medicine, University of Washington

Raising Public Awareness

- Pick-up trucks
  - *JAMA* 1992
- Charcoal
  - *JAMA* 1994
- Storms
  - *J Emerg Med* 1997
  - *MMWR* 2005
  - *UHM* 2006
  - *Am J Public Health* 2008
  - *Pediatrics* 2009
- Generators
  - *Am J Prev Med* 1995
- Automobiles in garages
  - *Am J Emerg Med* 2011
- CO Alarms
  - *J Environ Health* 2011
  - *J Emerg Med 2012*

Epidemiology

- Pediatric
  - *UHM* 2005
- Influence of race
  - *Pub Health Rep* 2000
- Suicide and weather
  - *UHM* 2000
- Suicide & co-ingestions
  - *J Emerg Med* 2013
- Online reporting system
  - *UHM* 2012

Diagnosis

- Pulse oximetry
  - *Chest* 1998
- Symptoms
  - *Headache* 2002
  - *Am J Emerg Med* 2008
  - *UHM* 2012

Diagnosis, cont.

- Pulse CO-oximetry
  - *UHM* 2005
  - *UHM* 2006
  - *Respir Care* 2007
  - *Emerg Med J* 2008
  - *Am J Emerg Med* 2012

Treatment

- Selection criteria
  - *J Emerg Med* 1995
  - *UHM* 2001
  - *Ann Emerg Med* 2001
  - *UHM* 2006
- Treatment protocols
  - *J Hyperbaric Med* 1992
  - *UHM* 1996
  - *UHM* 2001
  - *UHM* 2005
  - *UHM* 2006

AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 186 2012

Concise Clinical Review

Practice Recommendations in the Diagnosis, Management, and Prevention of Carbon Monoxide Poisoning

Neil B. Hampson[1], Claude A. Piantadosi[2], Stephen R. Thom[3], and Lindell K. Weaver[4]

[1]Virginia Mason Medical Center, Seattle, Washington; [2]Duke University Medical Center, Durham, North Carolina; [3]University of Pennsylvania Medical Center, Philadelphia, Pennsylvania; and [4]Intermountain Medical Center, Salt Lake City, Utah

"Myth Busting in Carbon Monoxide Poisoning"

Neil B. Hampson, MD
Emeritus Physician, Section of Hyperbaric Medicine
Virginia Mason Medical Center
Clinical Professor of Medicine, University of Washington

Topic for Today

Dispel 10 myths about CO poisoning to demonstrate why you should be skeptical about "common knowledge" and not believe everything you hear or read.

Rules: 1. Disprove the myth.
2. Determine the correct facts and publish them.

Dispelling Myths About CO

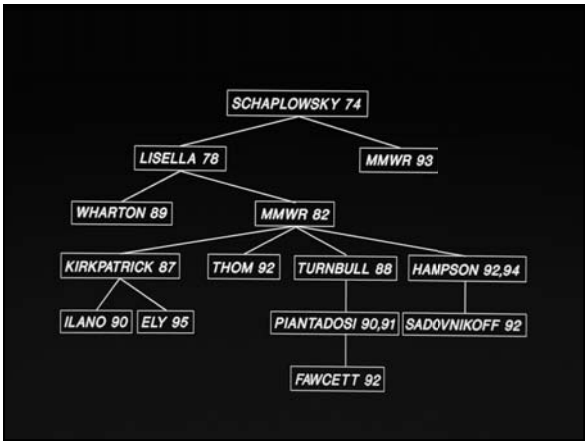
1. "10,000 cases in US per year"

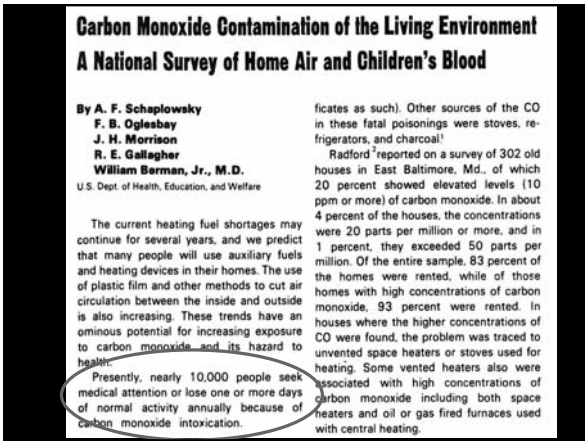
Incidence of CO Poisoning in the US Commonly Quoted Figure 1990's

"10,000 poisonings in the US annually sufficiently severe to cause individuals to seek medical attention or lose one or more days of normal activity"

"10,000 Cases in US Annually" Papers Referencing this Number

Bozeman 1997
Ely 1995
Hampson 1992,94
Ilano 1990
Lisella 1978
Kirkpatrick 1987
Meredith 1988
MMWR 1982,84,93
Mofenson 1984
Sadovnikoff 1992
Schaplowsky 1974
Silvers 1995
Thom 1992
Turnbull 1988





Carbon Monoxide Contamination of the Living Environment
A National Survey of Home Air and Children's Blood

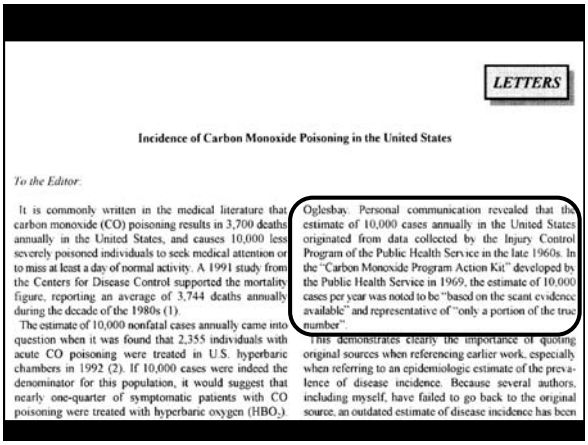
By A. F. Schaplowsky
F. B. Oglesbay
J. H. Morrison
R. E. Gallagher
William Berman, Jr., M.D.
U.S. Dept. of Health, Education, and Welfare

The current heating fuel shortages may continue for several years, and we predict that many people will use auxiliary fuels and heating devices in their homes. The use of plastic film and other methods to cut air circulation between the inside and outside is also increasing. These trends have an ominous potential for increasing exposure to carbon monoxide and its hazard to health.

Presently, nearly 10,000 people seek medical attention or lose one or more days of normal activity annually because of carbon monoxide intoxication.

ficates as such). Other sources of the CO in these fatal poisonings were stoves, refrigerators, and charcoal.[1]

Radford[2] reported on a survey of 302 old houses in East Baltimore, Md., of which 20 percent showed elevated levels (10 ppm or more) of carbon monoxide. In about 4 percent of the houses, the concentrations were 20 parts per million or more, and in 1 percent, they exceeded 50 parts per million. Of the entire sample, 83 percent of the homes were rented, while of those homes with high concentrations of carbon monoxide, 93 percent were rented. In houses where the higher concentrations of CO were found, the problem was traced to unvented space heaters or stoves used for heating. Some vented heaters also were associated with high concentrations of carbon monoxide including both space heaters and oil or gas fired furnaces used with central heating.



LETTERS

Incidence of Carbon Monoxide Poisoning in the United States

To the Editor:

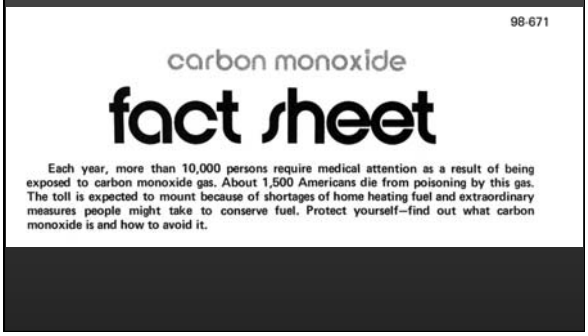
It is commonly written in the medical literature that carbon monoxide (CO) poisoning results in 3,700 deaths annually in the United States, and causes 10,000 less severely poisoned individuals to seek medical attention or to miss at least a day of normal activity. A 1991 study from the Centers for Disease Control supported the mortality figure, reporting an average of 3,744 deaths annually during the decade of the 1980s (1).

The estimate of 10,000 nonfatal cases annually came into question when it was found that 2,355 individuals with acute CO poisoning were treated in U.S. hyperbaric chambers in 1992 (2). If 10,000 cases were indeed the denominator for this population, it would suggest that nearly one-quarter of symptomatic patients with CO poisoning were treated with hyperbaric oxygen (HBO_2).

Oglesbay. Personal communication revealed that the estimate of 10,000 cases annually in the United States originated from data collected by the Injury Control Program of the Public Health Service in the late 1960s. In the "Carbon Monoxide Program Action Kit" developed by the Public Health Service in 1969, the estimate of 10,000 cases per year was noted to be "based on the scant evidence available" and representative of "only a portion of the true number".

This demonstrates clearly the importance of quoting original sources when referencing earlier work, especially when referring to an epidemiologic estimate of the prevalence of disease incidence. Because several authors, including myself, have failed to go back to the original source, an outdated estimate of disease incidence has been

"Carbon Monoxide Program Action Kit" (USPHS 1969)



98-671

carbon monoxide

fact sheet

Each year, more than 10,000 persons require medical attention as a result of being exposed to carbon monoxide gas. About 1,500 Americans die from poisoning by this gas. The toll is expected to mount because of shortages of home heating fuel and extraordinary measures people might take to conserve fuel. Protect yourself—find out what carbon monoxide is and how to avoid it.

Carbon Monoxide poisoning: A new incidence for an old disease.

N. B. HAMPSON[1], L.K. WEAVER[2]

Submitted - 2-15-07; accepted - 3-22-07

[1]Center for Hyperbaric Medicine, Section of Pulmonary and Critical Care Medicine Virginia Mason Medical Center, Seattle, Washington; [2]Pulmonary and Critical Care Division, Department of Internal Medicine, LDS Hospital Center, Salt Lake City, Utah

Hampson NB, Weaver LK. Carbon Monoxide Poisoning: A new incidence for an old disease. Undersea Hyperb Med 2007; 34(3):163-168. Purpose: While carbon monoxide (CO) poisoning is common in the USA, its incidence is uncertain. Fatal poisonings are counted with relative accuracy from death certificate data, but estimates of the more common nonfatal poisonings are either old or limited. This study was performed to estimate the number of emergency department (ED) visits annually in the USA for carbon monoxide poisoning. Basic Procedures: ED visit rates in five states (Idaho, Maine, Montana, Utah, and Washington) from three prior studies, each using different methodology, were used to extrapolate independent estimates of national ED visits. Main Findings: After correcting for regional differences in CO poisoning incidence, estimates of national ED visits per year ranging from 32,413 to 56,037 were obtained. Excluding the estimate derived from the Maine rate because it did not include intentional and fire-related poisonings, the national average is 50,558 ± 4,843 visits per year. Conclusions: There are approximately 50,000 ED visits for CO poisoning in the USA annually, 3 times the numbers previously estimated. As this disease can result in significant long-term morbidity even when treated, enhanced prevention efforts are warranted.

Dispelling Myths About CO

1. ~~10,000 cases in US per year~~
   - *UHM* 1999
   - *Am J Emerg Med* 2005
   - *UHM* 2007
2. "Since most CO-poisoned patients are cherry red, COHb measurement may not be necessary for diagnosis"

Do we need to measure COHb or can we rely on cherry-red coloration to diagnose CO poisoning?

S: Was reportedly in closed garage + motor running x 45 minutes. Unresponsive when EMTs arrived; somnolent and intermittently combative since

O: Cherry red skin - somnolent, arouses to voice + can mumble his first name only

HbCO = 21% (1 hour after removal from CO) mostly on 100% O2

A: Carbon monoxide poisoning, peak levels of HbCO probably > 40%

P: Transfer, Virginia Mason for hyperbaric [illegible] 90506

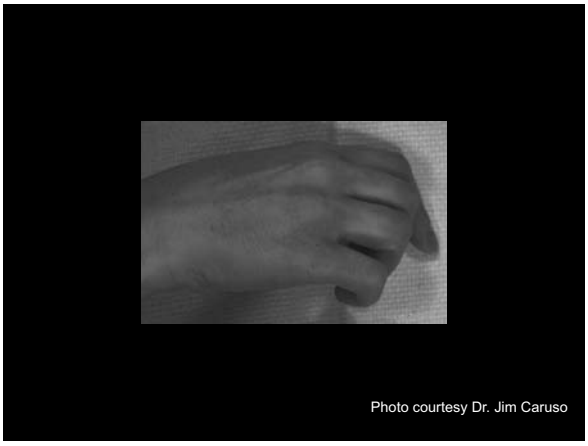
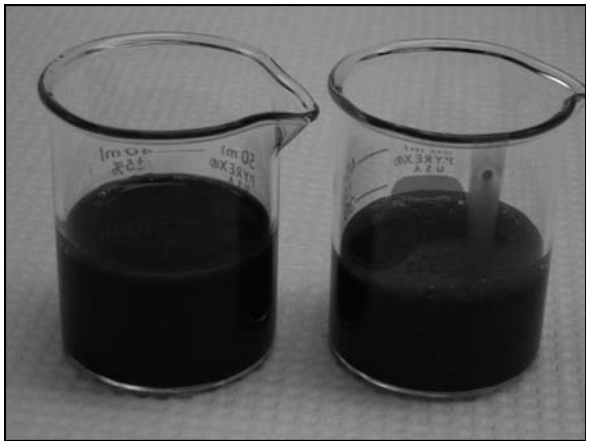
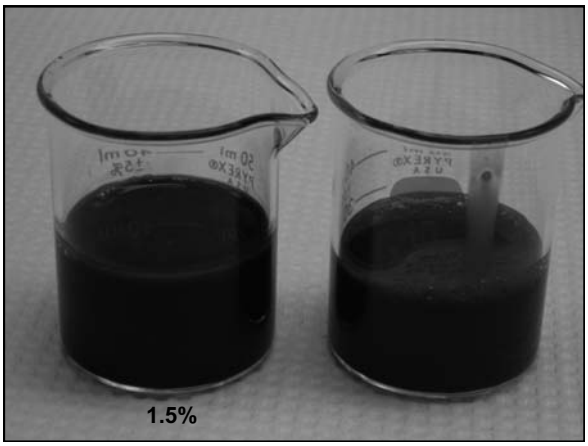
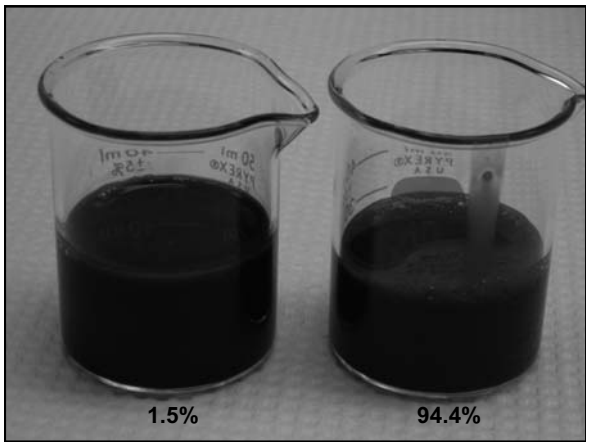


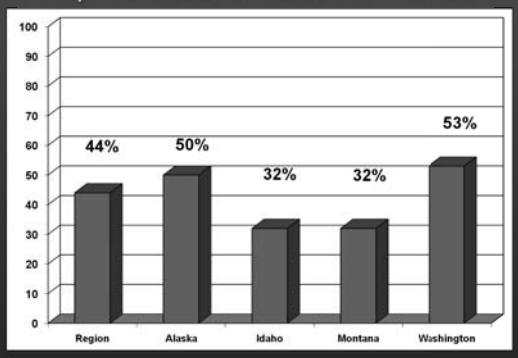
Photo courtesy Dr. Jim Caruso





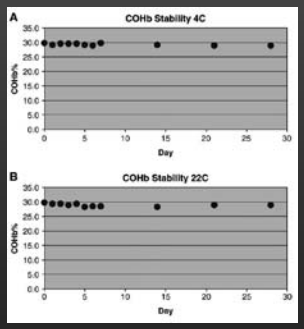


Hospitals able to Measure COHb



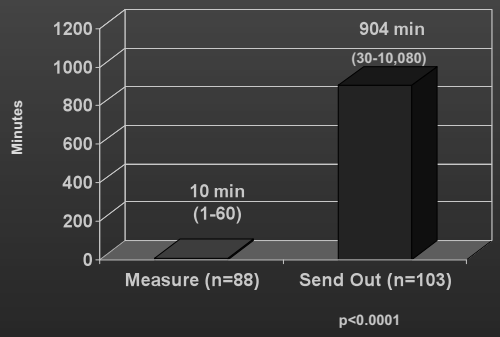
Hampson N. *J Emerg Med* 2006

Stability of COHb in Heparinized Blood Samples

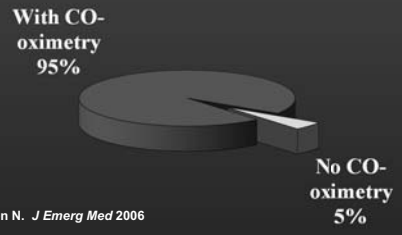


Hampson NB.
Am J Emerg Med 2007.

Time Required for COHb Result



Hospitals Referring CO-Poisoned Patients to VMMC for HBO_2 (2003-2004, n=85)

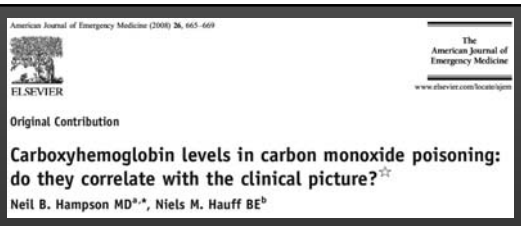


Hampson N. *J Emerg Med* 2006

Dispelling Myths About CO

1. ~~10,000 cases in US per year~~
2. ~~Most CO-poisoned patients are cherry red~~
   J Emerg Med 2006
   Am J Emerg Med 2007
3. "COHb level is the best predictor of short-term mortality in CO poisoning"

American Journal of Emergency Medicine (2008) 26, 665–669



Original Contribution

Carboxyhemoglobin levels in carbon monoxide poisoning: do they correlate with the clinical picture?☆

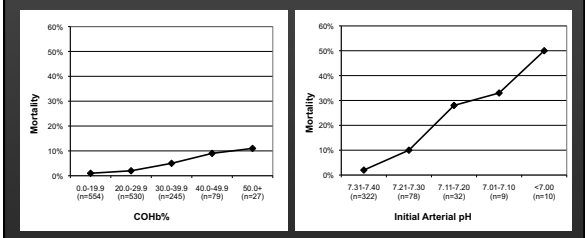
Neil B. Hampson MD[a,*], Niels M. Hauff BE[b]

	n	COHb % Mean ± SD (95% CI of the mean)	COHb % Range
All patients	1407	22.3 ± 11.0 (22.7-23.9)	2.1-72.3
Died (<30 d)	37	32.1 ± 12.8 (27.9-36.4)	3.0-60.0
Survived (>30 d)	1370	23.1 ± 10.9 (22.5-23.6)	2.1-72.3

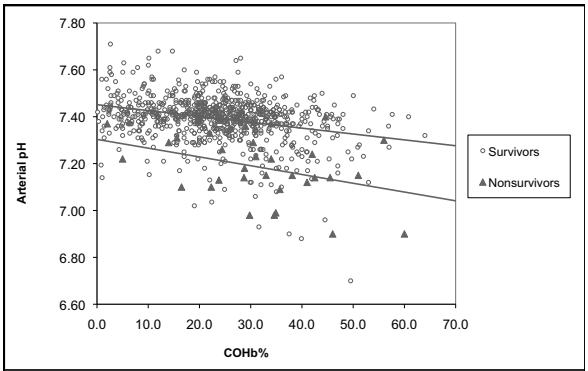
CI indicates confidence interval.

Risk factors for short-term mortality from carbon monoxide poisoning treated with hyperbaric oxygen*

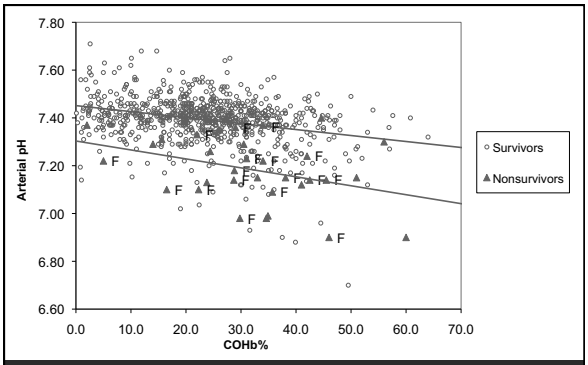
Neil B. Hampson, MD; Niels M. Hauff, BE



Crit Care Med 2008.



Crit Care Med 2008.



Crit Care Med 2008.

Dispelling Myths About CO

1. ~~10,000 cases in US per year~~
2. ~~Most CO-poisoned patients are cherry red~~
3. ~~COHb level is the best predictor of short-term mortality~~
   Crit Care Med 2008
4. "COHb level correlates with symptoms"

Common Table Correlating COHb with Symptoms

Table 1—*Symptoms Commonly Found with Different CO Levels*

Blood Level of COHb, percent	Symptoms
0-10	Usually none in healthy individuals; reduced exercise tolerance in patients with pulmonary disease; decreased threshold for angina in patients with coronary heart disease
10-20	Headache; dyspnea on mild exertion; angina in patients with coronary heart disease; dilation of cutaneous vessels
20-30	Throbbing headache; nausea or vomiting (or both); easy fatigability and irritability; difficulty with concentration
30-40	Severe headache; dizziness; fatigue and weakness; syncope on exertion; impaired thought processes
40-50	Tachypnea; tachycardia; syncope; confusion
50-60	Respiratory failure; collapse; intermittent convulsions or seizures; coma
60-70	Respiratory failure; severe hypotension; coma, frequently fatal
>70	Coma, rapidly fatal

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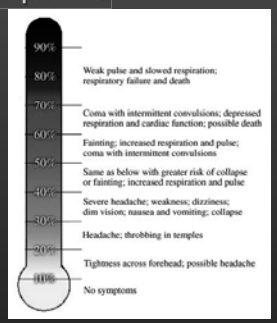
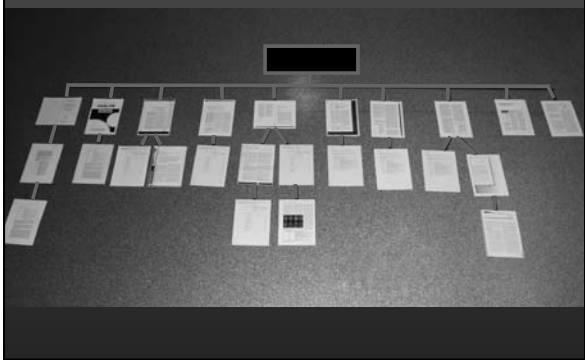
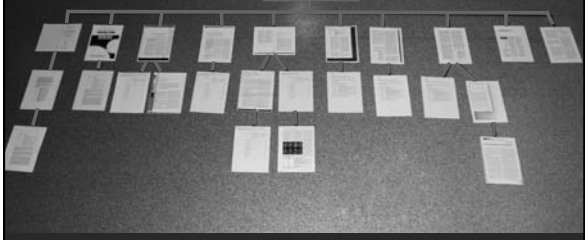


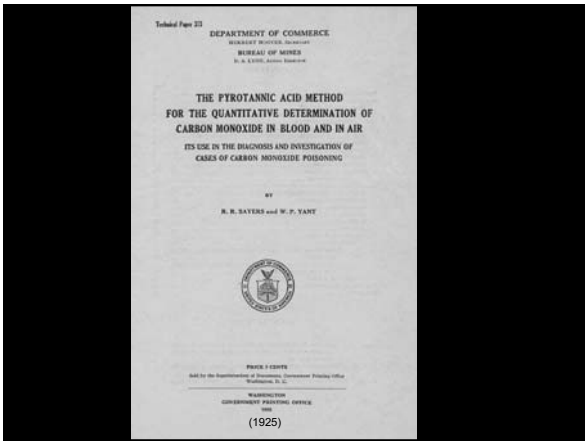
Origin of COHb vs Symptoms Table



Origin of COHb vs Symptoms Table

No Citation





Technical Paper 213

DEPARTMENT OF COMMERCE

HERBERT HOOVER, Secretary

BUREAU OF MINES

H. M. LEAKE, Acting Director

THE PYROTANNIC ACID METHOD FOR THE QUANTITATIVE DETERMINATION OF CARBON MONOXIDE IN BLOOD AND IN AIR

ITS USE IN THE DIAGNOSIS AND INVESTIGATION OF CASES OF CARBON MONOXIDE POISONING

BY

R. R. SAYERS and W. P. YANT

PRICE 5 CENTS

Sold by the Superintendent of Documents, Government Printing Office Washington, D. C.

WASHINGTON GOVERNMENT PRINTING OFFICE 1925

(1925)

Symptoms caused by various percentages of carbon monoxide in the blood

Blood saturation. Per cent	Symptoms
0—10	None.
10—20	Tightness across forehead; possibly slight headache.
20—30	Headache; throbbing in temples.
30—40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting, collapse.
40—50	Same as previous item with more possibility of collapse and syncope, increased respiration and pulse.
50—60	Syncope; increased respiration and pulse, coma with intermittent convulsions; Cheyne-Stokes' respiration.
60—70	Coma with intermittent convulsions, depressed heart action and respiration, possibly death.
70—80	Weak pulse and slowed respiration; respiratory failure and death.

32126°—25——2

May, 1923.

REPORTS OF INVESTIGATIONS

DEPARTMENT OF THE INTERIOR - - BUREAU OF MINES

0 - 10	No symptoms.
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Blood Level of COHb, percent	Symptoms
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CHEST / 97 / 1 / JANUARY, 1990 167

PUBLIC HEALTH REPORTS

VOL. 37 MAY 12, 1922 No. 19

PHYSIOLOGICAL EFFECTS OF EXPOSURE TO LOW CONCENTRATIONS OF CARBON MONOXIDE.[1]

By S. H. Sayers, Passed Assistant Surgeon, United States Public Health Service, Chief Surgeon, United States Bureau of Mines; F. V. Meriwether, Acting Assistant Surgeon, United States Public Health Service, Car Surgeon, United States Bureau of Mines; and W. P. Yant, Assistant Chemist, United States Bureau of Mines.

CO Exposures 1922

- 16 total exposures on 3 authors (Sayers 8)
- COHb 14-28%

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0 - 20	Tightness across forehead; possibly slight headache, dilatation of cutaneous blood vessels.
20 - 30	Headache; throbbing in temples.
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70 - 80	Weak pulse and slowed respiration; respiratory failure and death.

COHb	N	Headache	Dizziness	N/V	Confusion	Chest Pain	LOC
0.0-10.0%	98	65 (66%)	34 (35%)	49 (50%)	32 (33%)	9 (9%)	36 (37%)
10.1-20.0%	313	181 (58%)	131 (42%)	130 (42%)	88 (28%)	26 (8%)	142 (45%)
20.1-30.0%	368	243 (66%)	195 (53%)	158 (43%)	114 (31%)	36 (10%)	163 (44%)
30.1-40.0%	183	85 (46%)	61 (33%)	60 (33%)	51 (28%)	17 (5%)	130 (71%)
40.1-50.0%	63	17 (27%)	19 (30%)	15 (24%)	20 (32%)	6 (10%)	52 (82%)
>50.0%	10						10 (100%)
	1025	526	406	363	273	85	533

Hampson et al. *UHM*, 2012.

Dispelling Myths About CO

1. ~~10,000 cases in US per year~~
2. ~~Most CO-poisoned patients are cherry red~~
3. ~~COHb level is the best predictor of short-term mortality~~
4. ~~COHb level correlates with symptoms~~
   UHM 2012
5. "CO-induced headache is throbbing and temporal in location"

Prospective Evaluation of Headache

- Standardized HA questionnaire administered to 100 consecutive patients with CO poisoning and headache
- Location - frontal 66%, temporal 52%, occipital 47%, bitemporal alone 13%
- Constant 74%, throbbing 41%

Characteristics of Headache Associated With Acute Carbon Monoxide Poisoning

Neil B. Hampson, MD; Lindsay A. Hampson

Objective.—To evaluate systematically the characteristics of headache due to acute exposure to carbon monoxide.

Background.—Headache is the most commonly reported symptom in acute carbon monoxide poisoning. While it is often described as throbbing and diffuse, a systematic characterization of carbon monoxide-associated headache has never been published.

Methods.—Patients referred for hyperbaric oxygen treatment of acute carbon monoxide poisoning were asked whether headache was part of their symptom complex. When present, specific details about the nature of the headache were collected from 100 consecutive patients through use of a standardized questionnaire.

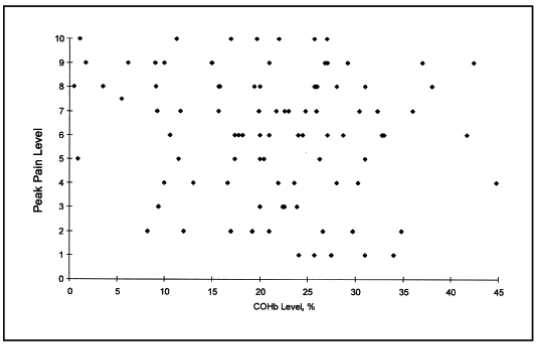
Results.—Information on carbon monoxide-associated headache was collected from 34 female and 66 male patients with a mean carboxyhemoglobin level of 21.3% ±9.3%. The most common location for pain was frontal (66%), although more than one location was involved in 58% of patients. Nature of the pain at any time during its course was dull in 72% of patients and sharp in 36%. Headache was throbbing in 41%, continuous in 74%, and intermittent in 16% of those evaluated. Peak intensity of pain did not correlate with the carboxyhemoglobin level. Headache improved prior to hyperbaric oxygen treatment in 72%, resolving entirely in 21%. Of those with residual headache, pain improved with hyperbaric oxygen in 97%, resolving entirely in 44%.

Conclusions.—The headache accompanying acute carbon monoxide poisoning is extremely variable in nature. "Classic" throbbing, diffuse headaches were rarely described by patients. There are no patterns which can be considered characteristic to aid in the diagnosis of carbon monoxide-induced headache. Similarly, no trait was identified which might allow elimination of carbon monoxide poisoning from the differential diagnosis of headache.

Key words: headache, carbon monoxide, poisoning

Abbreviations: CO carbon monoxide, HBO_2 hyperbaric oxygen, COHb carboxyhemoglobin

(*Headache*, 2002;42:220-223)



Relationship of blood carboxyhemoglobin level to peak head pain intensity.

Dispelling Myths About CO

5. ~~CO-induced headache is throbbing~~
   Headache 2002
6. "Hyperbaric oxygen therapy can be effective following resuscitation from CO-related cardiac arrest."

2001 Survey of North American Hyperbaric Medical Directors

- Presented scenario of patient resuscitated from CO-associated cardiac arrest

Would you recommend HBO_2 treatment for this patient?	Yes 100%	No 0%
If treated with HBO_2, what likelihood would you predict for the following 3 possible outcomes?		
1. Death during hospitalization	26%	
2. Survival to hospital discharge with permanent neurologic sequelae	46%	
3. Survival to hospital discharge with eventual complete recovery	28%	

Outcome of Patients Experiencing Cardiac Arrest With Carbon Monoxide Poisoning Treated With Hyperbaric Oxygen

Patient No.	Sex	Age (y)	Initial Cardiac Rhythm	COHb	ED ABG (pH; Pco_2; Po_2)	Outcome
1	M	72	Bradydysrhythmia	22.0	Not available	Died
2	M	41	Bradydysrhythmia	24.9	7.09; 23; 507	Died
3	F	45	Bradydysrhythmia	23.8	7.13; 20; 474	Died
4	F	45	Asystole	14.6	6.92; 15; 486	Died
5	F	49	Bradydysrhythmia	20.5	7.45; 23; 533	Died
6	F	5	Bradydysrhythmia	34.0	7.08; 31; 275	Died
7	F	47	Ventricular fibrillation	44.6	7.40; 21; 385	Died
8	M	37	Asystole	34.6	6.98; 47; 371	Died
9	M	31	Bradydysrhythmia	28.7	7.14; 37; 391	Died
10	F	41	Bradydysrhythmia	29.0	7.36; 23; 554	Died
11	F	34	Ventricular fibrillation	28.8	7.30; 29; 502	Died
12	M	3	Unknown (pulseless)	16.5	7.10; 14; 662	Died
13	M	37	Bradydysrhythmia	55.6	7.12; 22; 457	Died
14	F	47	Ventricular fibrillation	34.9	6.99; 39; 532	Died
15	M	5	Bradydysrhythmia	42.0	7.24; 37; 381	Died
16	F	31	Asystole	31.0	7.23; 36; 519	Died
17	M	28	Asystole	35.7	7.09; 44; 662	Died
18	F	33	Bradydysrhythmia	49.5	6.70; 27; 154	Died

Hampson NB. *Ann Emerg Med* 2001

Dispelling Myths About CO

5. ~~CO-induced headache is throbbing~~
6. ~~Hyperbaric oxygen therapy can be effective following resuscitation from CO-related cardiac arrest.~~
   Ann Emerg Med 2001
7. "CO-poisoning predisposes to increased long-term risk for cardiac death"

Myocardial Injury and Long-term Mortality Following Moderate to Severe Carbon Monoxide Poisoning

Christopher R. Henry, BS
Daniel Satran, MD
Bruce Lindgren, MS
Cheryl Adkinson, MD
Caren I. Nicholson, RN
Timothy D. Henry, MD

Context Carbon monoxide (CO) poisoning is a common cause of toxicological morbidity and mortality. Myocardial injury is a frequent consequence of moderate to severe CO poisoning. While the in-hospital mortality for these patients is low, the long-term outcome of myocardial injury in this setting is unknown.

Objective To determine the association between myocardial injury and long-term mortality in patients following moderate to severe CO poisoning.

Design, Setting, and Participants Prospective cohort study of 230 consecutive adult patients treated for moderate to severe CO poisoning with hyperbaric oxygen and admitted to the Hennepin County Medical Center, a regional center for treatment of CO poisoning, between January 1, 1994, and January 1, 2002. Follow-up was through November 11, 2005.

Main Outcome Measure All-cause mortality.

Results Myocardial injury (cardiac troponin I level ≥0.7 ng/mL or creatine kinase-MB level ≥5.0 ng/mL and/or diagnostic electrocardiogram changes) occurred in 85 (37%) of 230 patients. At a median follow-up of 7.6 years (range: in-hospital only to 11.8 years), there were 54 deaths (24%). Twelve of those deaths (5%) occurred in the hospital as a result of a combination of burn injury and anoxic brain injury (n=8) or cardiac arrest and anoxic brain injury (n=4). Among the 85 patients who sustained myocardial injury from CO poisoning, 32 (38%) eventually died compared with 22 (15%) of 145 patients who did not sustain myocardial injury (adjusted hazard ratio, 2.1; 95% confidence interval, 1.2-3.7; *P*=.009).

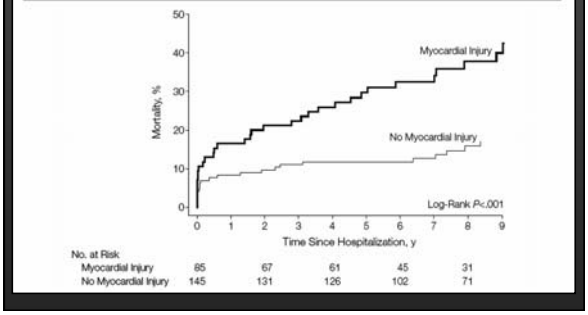
Conclusion Myocardial injury occurs frequently in patients hospitalized for moderate to severe CO poisoning and is a significant predictor of mortality.

JAMA. 2006;295:398-402 www.jama.com

Carbon monoxide (CO) poisoning is a common cause of toxicological morbidity and mortality. From 1968 through 1998, the Centers for Disease Control and Prevention reported that CO poisoning contributed to an average of 1091 unintentional deaths and 2385 suicidal deaths per year in the United States.[1,2] Although the annual death rate from CO poisoning has declined over time, CO remains the most common type of accidental poisoning in the Unites States, contributing to 40 000 emergency department visits annually.[3] Carbon monoxide poisoning can occur with expo-

Henry 2006 "Long-term" Mortality

Figure. Mortality of Patients With and Without Myocardial Injury



Henry's Analysis of "Long-term" Mortality

	Total Deaths (n=54)	Known Cause (n=41)		Unknown cause (n=13)
		Cardiac	Noncardiac	
Myocardial injury (n=85)	32/85 (38%)	14	12	6
No myocardial injury (n=145)	22/145 (15%)	4	11	7

Henry's Analysis of "Long-term" Mortality

	Total Deaths (n=54)	Known Cause (n=41)		Unknown cause (n=13)
		Cardiac	Noncardiac	
Myocardial injury (n=85)	32/85 (38%)	14	12	6
No myocardial injury (n=145)	22/145 (15%)	4	11	7

My Analysis of Henry's Data

	Total Deaths (n=54)	In Hospital Deaths (n=12)		
		Total	Cardiac	Noncardiac
Myocardial injury (n=85)	32/85 (38%)	6	4	2
No myocardial injury (n=145)	22/145 (15%)	6	0	6

	Long-term deaths (n=42)			
	Total	Cardiac	Noncardiac	Unknown
Myocardial injury (n=85)	26	10	10	6
No myocardial injury (n=145)	16	4	5	7

Myocardial Injury and Long-term Mortality Following Moderate to Severe Carbon Monoxide Poisoning

Christopher R. Henry, BS
Daniel Satran, MD
Bruce Lindgren, MS
Cheryl Adkinson, MD
Caren I. Nicholson, RN
Timothy D. Henry, MD

Context Carbon monoxide (CO) poisoning is a common cause of toxicological mortality and morbidity. Myocardial injury is a frequent consequence of moderate to severe CO poisoning. While the in-hospital mortality for these patients is low, the long-term outcome of myocardial injury in this setting is unknown.

Objective To determine the association between myocardial injury and long-term mortality in patients following moderate to severe CO poisoning.

Design, Setting, and Participants Prospective cohort study of 230 consecutive adult patients treated for moderate to severe CO poisoning with hyperbaric oxygen

CARBON MONOXIDE (CO) poi... poisoning is a common cau... toxicological morbidity ... mortality. From 1968 thr... 1998, the Centers for Disease Co... and Prevention reported that CO ... poisoning contributed to an average of ... unintentional deaths and 2303 sui... deaths per year in the United Stat... Although the annual death rate from ... poisoning has declined over time, ... remains the most common type o... cidental poisoning in the United St... contributing to 40 000 emergency ... partment visits annually.[1] Carbon ... oxide poisoning can occur with a...

Increased long-term mortality among survivors of acute carbon monoxide poisoning*

Neil B. Hampson, MD; Rose Anne Rudd, MSPH; Niels M. Hauff, BE

Objective: Recent data suggest that patients surviving acute carbon monoxide (CO) poisoning (COP) may have increased risk for long-term mortality. The objective of this study was to analyze long-term mortality of a large population of CO-poisoned patients treated at one medical center over three decades.

Design: Retrospective cohort study of patients treated with hyperbaric oxygen and surviving the acute poisoning episode. Long-term mortality was compared to a standard population. Comparison of mortality within the cohort by clinical indicators of poisoning severity was assessed using Cox proportional hazards regression analysis.

Setting: Regional referral center for hyperbaric treatment of COP.

Patients: One thousand seventy-three patients aged ≥18 years treated from 1978 to 2005.

Interventions: All patients received hyperbaric oxygen treatment.

Measurements and Main Results: During 11,741 person-years of follow-up, 162 subjects died. The expected number of deaths was 87 (standardized mortality ratio [SMR]), 1.9; 95% confidence interval [CI], 1.6–2.2). Most of the excess mortality was in the group treated initially for intentional COP (58 excess deaths; SMR, 3.7; 95% CI, 2.9–4.6) vs. those treated for accidental COP (17 excess deaths; SMR, 1.3; 95% CI, 1.01–1.6). For the entire cohort, the major causes of death with significantly raised mortality were *mental and* psychiatric disorders, injuries, and violence. More specific causes of death with significantly raised mortality were alcoholism, motor vehicle accidents with pedestrians, motor vehicle accidents of unspecified type, accidental poisonings, and intentional self-harm. Within cohort comparisons showed that no difference in survival was observed by measure of CO poisoning severity, after controlling for age at poisoning, sex, race, and intent of CO poisoning.

Conclusions: Adult survivors of acute CO poisoning treated with hyperbaric oxygen were at increased risk for long-term mortality. Such patients should be followed closely after discharge with consideration given to psychiatric and/or neurocognitive evaluation, as appropriate. (Crit Care Med 2009; 37:1941–1947)

Key Words: carbon monoxide; poisoning; mortality; cause of death

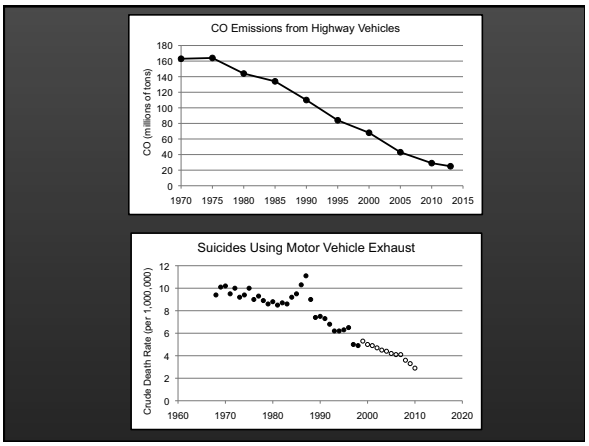
Long-Term Mortality in CO Poisoning

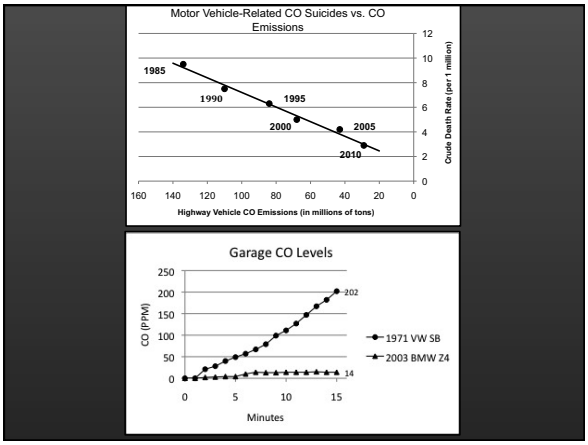
- Analyzed 1,073 patients 1978-2005 *(vs. 230)*
- 11,742 person-years at risk *(vs. 1,748)*
- 162 deaths with 87 expected (SMR 1.9)
- Intentional SMR 3.7, accidental 1.3
- Causes of death: completed suicide, MVA, falls, accidental poisoning
- No increase in cardiac mortality

Hampson NB. *Crit Care Med* 2009

Dispelling Myths About CO

5. ~~CO-induced headache is throbbing~~
6. ~~Hyperbaric oxygen therapy is effective following resuscitation from CO-related cardiac arrest.~~
7. ~~CO-poisoning predisposes to increased long-term risk for cardiac death~~
   Crit Care Med 2009
8. "It remains as easy to commit suicide with motor vehicle exhaust as it ever was."



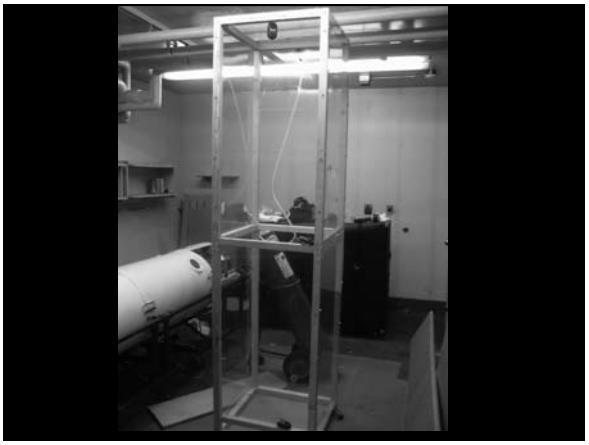


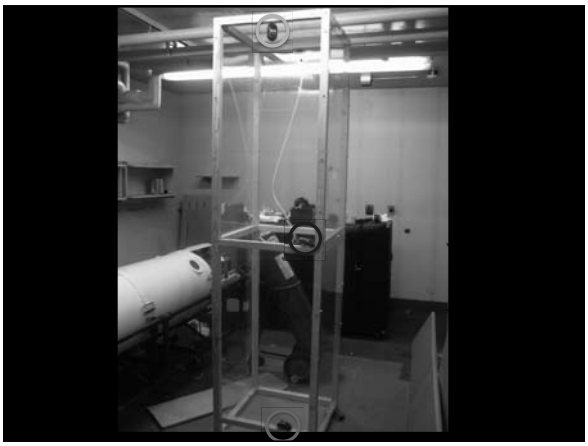
Dispelling Myths About CO

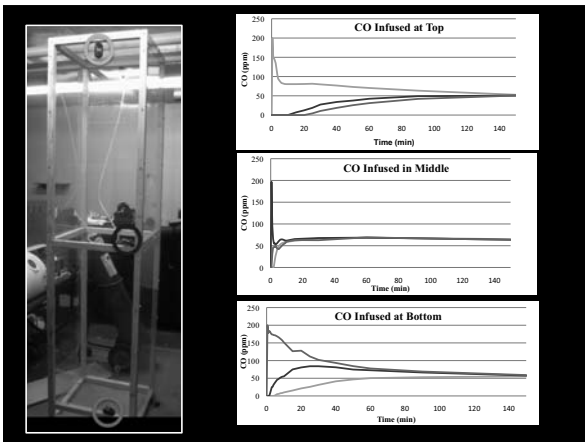
8. ~~It remains as easy to commit suicide with motor vehicle exhaust as it ever was.~~
   Manuscript under review
9. "CO is lighter than air so it accumulates near the ceiling."

The Internet tells you whatever you want to find

- "Plugging CO alarms into sockets near the floor is less effective because CO rises." (shopwiki.com)
- "Carbon monoxide is heavier than air and will pool in lower areas." (askville.amazon.com)







Dispelling Myths About CO

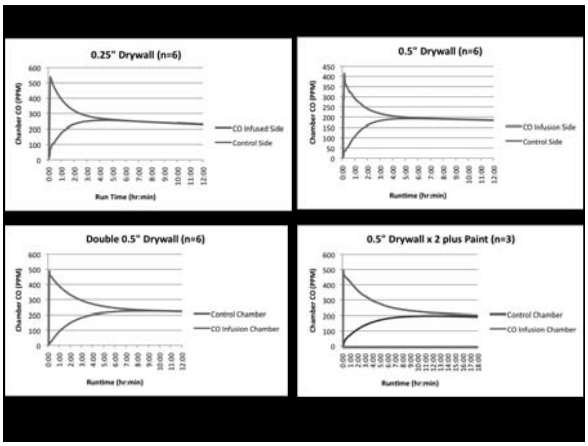
8. ~~It remains just as easy to commit suicide with motor vehicle exhaust as it ever was.~~
9. ~~CO is lighter than air so it accumulates near the ceiling.~~
   J Emerg Med 2012
10. "Without fuel-burning appliances in the home, there is no risk for CO exposure"

Of 46 states mandating residential CO alarms, 33 (73%) exclude residences without fuel burning appliances, fireplaces and/or the presence of an attached garage

CO Poisonings in More than One Unit of a Multifamily Dwelling

- Typically explained by CO diffusion through public spaces or ductwork
- But sometimes CO appears to pass through walls
- Can CO diffuse through gypsum wallboard (drywall)?

CO Diffusion Chamber



How could CO diffuse across gypsum wallboard?

- Gypsum is porous
- 0.5" board manufactured by US Gypsum has average pore size of 466 ± 112 micrometers (Rosen 2009)
- Average CO molecule has diameter 0.387 nanometers
- It should therefore not be surprising that CO molecules could pass through pores one million times their diameter

Dispelling Myths About CO

8. ~~It remains just as easy to commit suicide with motor vehicle exhaust as it ever was.~~
9. ~~CO is lighter than air so it accumulates near the ceiling.~~
10. ~~Without fuel-burning appliances in the home, there is no risk for CO exposure~~.

JAMA 2013

A *Bonus Myth* Involving CO

"The best tuna for sashimi is the brightest red."

O-27 CELLULAR GLUCOSE UPTAKE AND OTHER CORRELATED METABOLIC RESPONSES IN BREATH-HOLD DIVING

Nicola Sponsiello[1, 2,3], Danilo Cialoni[1, 3,4], Massimo Pieri[2, 5], Alessandro Marroni, [2,3,4,5]

1. Apnea Academy Research, Padova, Italy
2. Italian Society of Sport Nutrition and Wellness
3. DAN Europe Research Division, Roseto degli Abruzzi, Italy
4. Phypode Project: physiopathology of decompression (FP7 Marie Curie, grant no. 264816)
5. Master in Underwater & Hyperbaric Medicine, University of Palermo-Trapani, Italy
6. Contact Information: Cialoni Danilo, DAN Europe, Contrada Padune 11, 64026 Roseto degli Abruzzi (TE), Italy. Phone: 39.085.8930333; Fax: 39.085.8930050; E-mail: dcialoni@daneurope.org

Introduction

The secretion of Insulin does not increase during exercise in fasting and blood glucose homeostasis is assured by neo-hepatic glucose production. Several authors demonstrated during exercise increased glucose transporters assures in uptake increase.
Scope of this study was to investigate changes in glycaemia, insulin and ACTH response as well as in body- weight and muscle mass during Breath-hold Diving (BHD).

Methods:

Thirty-four male healthy Breath-hold divers were studied. Information on age, height, weight and BMI were obtained.
Glycaemia, insulin, ACTH body weight and muscle mass data before, during and after a week of Breath-hold training were studied.
The same subjects were also investigated about changes in weight and muscle mass between before the test and the next week of training.

Results:

We found a statistically significant decrease in glycaemia after dives in constant weight $p=0.0040$ and in static apnoea $p<0.0001$.
We also found a statistically significant increase in insulin after dives in constant weight ($p<0.0001$) and in Static apnoea ($p<0.0001$), and a decrease of ACTH value ($p=0.005$).
Weight and muscle mass were decreased in all the investigated subjects.

Discussion:

The increase of insulin blood value during Breath-hold diving associated with the decrease of glycaemia confirms that the up-regulating cellular uptake is not caused by activation of the specific glucose transporters GLUT4 and that in Breath-hold diving the muscle effort is limited. Diving reflex, hypoxia and the adaptation to the environmental condition could explain the decrease of glycaemia in accordance to the change of ACTH and the reduction of body Weight and Muscle mass.
Our data confirm that the adaptations to BHD are caused by complex mechanisms and involve many largely unknown hormonal responses.

O-28 FLOW MEDIATED DILATION AS A PREDICTIVE TOOL TO BREATH-HOLD DIVING INDUCED PULMONARY EDEMA IN SUBJECTS WITH GENETIC PREDISPOSITION: PRELIMINARY STUDY.

D. Cialoni[1,2,3], M. Pieri[1], N. Sponsiello[3], C. Balestra[1,2,4]; and A. Marroni[1,2]

1 DAN Europe Research Division
2 Phypode Project Phypode Project: physiopathology of decompression (FP7 Marie Curie, grant no. 264816)
3 Apnea Academy Research
4 Haute Ecole Paul-Henri Spaak Bruxelles

Introduction

Flow-mediated dilation (FMD) is commonly used to investigate endothelial function and enable a measure of vasodilation mediated by nitric oxide (NO).
Breath-Hold Diving Induced Pulmonary Edema (BH-DIPE) is related to specific predisposing genetic variants of endothelial Nitric oxide synthase (eNOS), a group of enzymes that catalyses the synthesis of nitric oxide (NO).
The aim of this study is to investigate if BH-DIPE positive subjects with the "bad" genetic variant of eNOS show a reduction of FMD response vs. BH-DIPE negative subjects.

Materials and Methods:

36 male and female experienced healthy BHD were studied, all subjects were included in previous studies and their eNOS G894T and T786C phenotype was known.
Measuremants of brachial artery diameter were performed before and after 5 minute of ischemia and changes were analyzed.

Results

We found an increase in FMD low response in BH-DIPE positive subjects (17%) versus BH-DIPE negative subjects (5%), (Fisher Exact Test p=0,029).
BH-DIPE-p subjects showed, in a previous studies, prevalence of genotype "TT" of eNOS G894T (p=0.0038) and eNOS-T786C (p=0.0048),

Conclusions:

Our results showed a reduced FMD response in BH-DIPE positive subjects with a known BH-DIPE genetic predisposition.
If our results will be confirmed by further studies FMD could be a simple non-invasive predictive test to help intercepting predisposed subjects and improving breath-hold diving safety through better individual awareness of possible risk factors.

Keywords

Acute respiratory distress syndrome; breath-hold diving; diving; hemophtisis

O-29 GENETIC PREDISPOSITION TO BREATH-HOLD DIVING INDUCED PULMONARY EDEMA: UP-DATE

D. Cialoni[1,2,3], M. Pieri[1], N. Sponsiello[3], Vittorio Lucchini[4], and A. Marroni[1,2]

1 DAN Europe Research Division
2 Phypode Project Phypode Project: physiopathology of decompression (FP7 Marie Curie, grant no. 264816)
3 Apnea Academy Research
4 NGB Genetics srl Spinoff Università di Ferrara

Introduction

Breath-Hold Diving Induced Pulmonary Edema (BH-DIPE) has been reported in about in 25% of breath-hold divers and is characterized by dyspnoea, coughing, haemoptysis, chest pain.
The aim of this study is to investigate if eNOS G894T, eNOS T786C and ACE insertion/deletion I/D genetic variants are possible BH-DIPE risk factors in statistically relevant numbers of subjects.

Materials and Methods:

108 male and female experienced healthy BHD were studied, 22.2% of them reported at least one episode of BH-DIPE episode (BH-DIPE-p), while 77.7% never reported BH-DIPE (BH-DIPE-n).
We investigated differences in BH-DIPE occurrence in subjects with two variants of the endothelial nitric oxide synthase gene (eNOS), the G894T polymorphism, implicated in vasodilatation regulation and regulating blood flow and pressure, and polymorphism T786c implicated in the pathogenesis of cardiovascular deseases.
We also investigated angiotensin-converting enzyme (ACE) ACE I/D genetic variants.

Results

We found an increase in BH-DIPE-p in subjects with genotype “TT” of eNOS G894T ($p=0.0038$) and eNOS-T786C ($p=0.0048$), while 100% of BH-DIPE-n showed ACE “II” genotype ($p=0.0032$).

Conclusions:

Our data showed that the majority of BH-DIPE-p subjects have a significant increase of the predisposing genetic variants “TT” at eNOS G894T, “TT” at eNOS T786C e “ID” at ACE. This data also confimed that BH-DIPE is related to intrapulmonary pressure changes as in High Altitude Pulmonary Edema.

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Keywords

Acute respiratory distress syndrome; breath-hold diving; diving; hemophtisis

O-30 DIVE PATTERNS IN JAPANESE AMA FROM THE 2ND TO THE 9TH DECADE

Erika Schagatay, Cecilia Schenk and Angelica Lodin Sundström
Dept of Health Sciences, Mid Sweden University, Östersund, Sweden.

Introduction

Diving women in Japan are known to continue their careers up into the 9th or even 10th decade. They breath-hold dive for clams and other seafood using mask, fins and neoprene suits. Previous studies of age-effects on their diving capacity have not included older still active age groups and our aim was to reveal if diving performance changes with high age.

Methods

We studied diving patterns; maximal dive depths and durations and percentage of working time spent under water in 39 working Ama at Hegurajima and Wajima, Japan. Their mean(SD) age was 55(16) years. They worked as usual during a 4 h diving shift collecting mollusks, while wearing dataloggers (Sensus Ultra, ReefNet Inc, Ontario, Canada) at their waists.

Results

When six age groups were compared (≤35:n=5); 36-45:n=7; 46-55:n=7; 56-65:n=8; 66-74:n=6; ≥75:n=6 years) the youngest and oldest groups tended to dive shallower and for shorter durations than other groups, with the deepest and longest dives at age 36-45 years followed by a slow decline. Divers over 75 years made shallower (6.5m) and shorter (37 s) maximal dives than the 36-45 years age group (12.5m and 62sec; $P<0.05$). Individual maximal depth tended to increase up to age 50 ($r=0.447$; $P=0.08$), and declined after age 50 ($r=0.582$; $P=0.002$). There was no difference between age groups in percentage of time spent submerged and both depth and duration tended to increased across the 4 h daily shift in all age groups.

Discussion

Diving ability – as reflected by diving depth and duration – was best at mid-life, but did not seem to be much affected by age until over 75 years of age. Irrespective of age, divers did not reduce diving depth or durations across their shifts. We conclude that divers can continue productive diving until at least the 7th decade without physical limitations.

O-31 POTENTIAL RISK OF DYSBARIC OSTEONECROSIS IN SUBMARINE ESCAPE AND RESCUE TRIALS

Sobakin AS, Lehner CE, Wilson MA, Gendron-Fitzpatrick, Crump PM, Eldridge MW

Departments of Pediatrics, Radiology, Research Animal Resources Center, Computing and Biometry, University of Wisconsin – Madison, Madison, WI 53706, U.S.A.

Objectives

Emergency escape by submariners from disabled submarines with its rapid decompression after prolonged hyperbaric exposure can involve significant risk of decompression injury. We investigated the potential risk of emergency decompression from submarines using the UW sheep model to assess potential human risks of decompression sickness (DCS), and dysbaric osteonecrosis (DON) that can lead to secondary osteoarthritis.

Methods

Thirty-six adult female sheep (mean weight 95.3 kg ± 10.5 SD) underwent a 24-hour compressed air exposure of 60 fsw (2.81 atm abs) and were decompressed in 2 minutes to atmospheric pressure after 88% - 92% oxygen pre-breathe for either 15 min, 1 hour, 2 hours, 3 hours, or 3 hours plus a 1 hour of air break. We observed the surviving sheep for clinical signs of DCS for more than 24 hours after initial decompression. All surviving sheep were administered IV alizarine complexone, a fluorochrome marker of bone repair before they were later euthanized and evaluated for potential DON.

Results

Thirty-four sheep survived (94.4%) the decompression but 2 sheep required euthanasia at 20 and 23 hours after decompression; four sheep showed clinical signs of CNS-DCS (11%); 7 developed signs of chokes, a respiratory DCS (19.4%); and 28 developed sustained signs of limb bends (77.7%). These limb bends sheep had all sustained DON in their long bones, with severe cortical bone and marrow lesions. Alizarin complexone deposition was greater in sheep experiencing 15-min O_2 pre-breathe dives than other dives ($P<0.05$), and sheep DCS incidence was lowest in the 3- h oxygen pre-breathe group. Proximal radii accumulated more alizarin complexone in the 15-min O_2 pre-breathe group than in the 3-h plus a 1-h of air break group ($P<0.05$). The proximal tibia appeared most affected in the 2-h and 3-h O_2 pre-breathe dive group ($P<0.05$).

Conclusions

Our research strongly suggests that 3-h O_2 pre-breathing of emulated submarine escape and rescue will enhance survival and reduce DON in the UW sheep model of the decompressed human. Interruption of O_2 pre-breathing prior to dropout decompression appears to decrease the protective effect of the O_2 pre-breathing for both respiratory DCS and DONs in sheep undergoing an accelerated decompression profile following a simulated saturation dive.

Funding

Research was funded by the Deep Submergence and Biomedical Development Program, NAVSEA, U.S. Navy. We wish to acknowledge the advice of Dr. Edward Flynn.

O-32 PHYPODE PROGRAM

Costantino Balestra[1], Peter Buzzacott[2], Danilo Cialoni[3], Giovanni Distefano[4], Nicola Donda[5], Zeljko Dujic[6], Bernard Gardette[7], Peter Germonpré[8], François Guerrero[2], Walter Hemelryck[8], Jacek Kot[9], Kate Lambrechts[2], Dennis Madden[6], Alessandro Marroni[3], Aleksandra Mazur[2], Jack Meintjes[10], Mirac Memisoglu[5], Virginie Papadopoulou[1], Jean-Michel Pontier[11], Georgi Popov[4], Miroslav Rozloznik[1], Andreas Schuster[12], Arne Sieber[12], Adel Taher[13], Michael Théron[2], Frauke Tillmans[1], Yurii Tkachenko[9], Qiong Wang[2]

[1] Biophysiology and Environmental Physiology Lab at the Haute Ecole Paul Henri Spaak, University of Brussels, Belgium. [2] Laboratoire Optimisation des Régulations Physiologiques (ORPhy), UFR Sciences et Techniques, Université de Bretagne Occidentale, 6 avenue Le Gorgeu, CS 93837, 29200 Brest Cedex 3, France. [3] DAN Europe, Malta. [4] MARES SPA, 4 Salita Bonsen, 16035 Rapallo, Italy. [5] AQUA 3, 3 Via Valmartinaga 34135 Trieste, Italy. [6] Department of Integrated Physiology, University of Split School of Medicine, Croatia. [7] COMEX, France. [8] Hyperbaric Oxygen Center, Queen Astrid Hospital, Brussels, Belgium. [9] National Center for Hyperbaric Medicine, University of Medicine, Gdynia, Poland. [10] Department Interdisciplinary Health Sciences Stellenbosch University, Faculty of Health Sciences. [11] French Navy Diving School ; French Navy, Toulon, France. [12] Seabear GmbH, Peter Tunner Strasse 19, 8700 Leoben, Austria. [13] Hyperbaric Medical Center, Sharm El Sheikh, Egypt.

Introduction

In August 2011 the Phypode consortium commenced research into the pathophysiology of decompression sickness. 14 fellows from 13 countries, age 22 to 46 years, 10 male, speaking 15 languages, commenced projects in nine partner institutions within six different countries.

Methods

Fellows listed combined total research outputs between August 2011 and 2014. Duplicate listings were removed.

Results

There have been 29 peer reviewed papers published and 19 more have been submitted, 42 distinct abstracts presented at European Undersea Baromedical Society conferences and 19 more submitted, 26 separate abstracts presented at other peer reviewed conferences, a book in preparation, a total of 15000€ in funding applications was granted and 560000€ more applied for by the fellows. In addition, there were 29 outreach events including conference talks, magazine articles and Divers Alert Network diver day's participation. 5 of the research fellows are expected to earn their PhD this year.

Discussion

With (at the time of submission) still six months remaining before the last fellows complete their contracts, and considering the delay to publication that follows submission, we estimate an eventual 20-50% further research output over the above figures. An update will be presented at the EUBS 2014 meeting.

Acknowledgements

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FRP/2007-2013/ under REA grant agreement n° 264816 PHYPODE.

O-33 ACUTE BRAIN ANOXIC INJURY IN PREVIOUSLY HEALTHY PERSONS. ANALYSIS OF 31 CASES.

Jordi Desola*, Evangelos Papoutsidakis*, Veronica Martínez-Espinosa**.

* CRIS-UTH, the Hyperbaric Therapy Unit of Barcelona, Moisès Broggi Hospital, 08970 Sant Joan Despí, BARCELONA.

** Orthopaedic and Traumatology Department, Central Military Hospital, Mexico DF, Mexican United States.

Background.

Acute Brain Anoxic Injury (ABAI) is a cause of serious and permanent neurological deficits. No treatment has proved to be effective. Some limited data suggests the possible efficacy of Hyperbaric Oxygenation in these cases enhancing oxygen diffusion to the apoptotic cells still alive but remaining in the hypoxic penumbra.

Methods.

Analysis of previously healthy patients that suffered an ABAI, who were sent to CRIS-UTH during the period 1982-2010. Results were qualified as healing, ameliorance, no change, or worsening, in relation to the effect on their neurological deficits and/or Glasgow Coma Score (GCS). This is a descriptive, retrospective, not randomized study focussed in personal data (age, gender, origin), description of the disorder, latency, delay in HBO, and outcome. HBO was applied in a multiplace hyperbaric chamber, at 2.3-2.5 ATA during 90 minutes, 7 days a week, until obtaining a clear and stable improvement, or achieving the conviction that no favourable effect would be obtained. Chi-Square and Student test for matched samples were measured.

Results

28 patients, considered non recoverable from departments of neurology of primary hospitals, 10 men (35.7%) and 18 women (64.3%), who suffered ABAI up to 3 months before admission. 24 patients (85.7%) had a permanent consciousness alteration with GCS average of 6.2 ± 2.8 (3-12); 4 patients (14.3%) had other serious neurological deficits. HBO therapy was started within a delay of 25.6 ± 17.8 (1-71) days; the number of HBO sessions was 40.1 ± 24.9 (8-100). Seven patients (25.0%) underwent a full recovery of their neurological deficiency and/or a final GCS of 15 ($p<0.001$); 18 (64.3%) experienced a significant improvement with a final GCS of 13.4 ± 2.3 (7-15) $p<0.001$; 3 patients (10.7%) experienced no change; no one ended in a worse condition than when HBO was started. There was neither significant difference in the outcome of the patients related to gender, type of accident, GCS on admission, nor to delay in starting HBO.

Conclusions

A big majority of the patients (80.6%) experienced a favourable outcome, in spite of having applied HBO therapy within a delay up to 2 months. There was no case of deterioration. This study suggests that HBO can be a valid alternative in the treatment of brain sequelae after acute anoxic injuries in previously healthy patients, even when it is applied with several weeks of delay. This would give a real hope for these patients and a diminution of social and health expenses. HBO should be not only supported but stimulated by National Health Systems and private insurance companies.

O-34 ADVANCES IN THE MANAGEMENT OF NEUROLOGICAL DISEASE WITH HBO

Jorge Pisarello and Jose Vila
Catholic University of Argentina, Buenos Aires, Argentina

Introduction:
HBO is capable of influencing acute and chronic neurological disease, resulting in recovery of neurological function. This effect is, however, far from being a general and predictable result of HBO. Only scattered groups of patients with neurological dysfunction respond to HBO treatment. Thus, the challenge faced by clinical investigators has been to identify groups of patients with neurological disease that are likely to respond to HBO.

Methods:
We recorded the results of treatment of a well-defined group of patients with a specific form of symptomatic chronic cerebrovascular disease. In this group, improvement was conclusively determined in a single blind crossover experimental model, with results determined by routine functional testing and observation recorded on film.

Results:
Indirect evidence provided by histological data suggests that hyperoxia at the tissue level likely improves oxygen delivery to neural cells during treatment, causing a local tissue effect that improves function. This functional improvement persists for several months after completion of treatment, suggesting that tissue hyperoxia for the period of treatment (90 minutes) operates via a thermodynamic and/or a signaling effect resulting in partial tissue repair, perhaps through remodeling and/or neuroplasticity. This effect appears to stimulate dormant areas (penumbra) that persist for approximately 6 months after completion of treatment (10-20 daily sessions). This hypothesis receives further support in cases of symptomatic spinal cord pathology secondary to vascular malformation. In these patients, transient recovery of function after HBO predicts complete resolution after surgical correction, while lack of response to HBO is associated with failure of resolution after surgery.

Discussion:
Clinical cases will be presented as well as basic information that, in connection with analysis of clinical results, permits constructing the above mentioned mechanistic hypothesis. This may assist in the identification of subsets of patients with neurological dysfunction that could benefit from the use of HBO.

O-35 NORWEGIAN DIVER 2011: FEMALE PROFESSIONAL DIVERS – WHO ARE THEY AND WHAT DO THEY DO?

Å Irgens [1], K Troland [1], M Grønning [123]

1 Norwegian Centre for Diving Medicine, Department of Occupational Medicine, Haukeland University Hospital, Bergen, Norway; 2 Department of Clinical Medicine, University of Bergen, Norway; 3 Neuro Clinic, Haukeland University Hospital, Bergen, Norway

Introduction.

A descriptive study of female professional divers.

Methods.

Since 1980, the Norwegian Labor Inspection Authority has operated the Norwegian Inshore Diving Registry which comprises data on all divers who have held a certificate valid for occupational diving. One hundred and eighty five out of 359 female divers included in the registry (51.5%) completed the "Norwegian diver 2011" questionnaire. Among these, 77 provided information about the year they started and ended their professional diving career, or answered that they were still active professional divers.

Results.

The age span was 25 to 69 years, with mean age 39 (SD 8.5). The educational level was college or university degree for the majority of the participants (83%).Their professional diving career lasted from 1 to 21 years; less than five years for 57% and more than ten years for 13%. Median number of dives was 400, lower and upper quartiles were 198 and 1000 respectively. Thirty three participants (43 %) were fully certified professional divers, i.e. held certificates without restrictions.

For previous or present work as professional divers, 39 were diving instructors, 22 carried out marine research, 38 performed inspections, and 14 had been involved in construction work. About 50% reported more than one alternative.

About 11% reported negative health effect due to diving. Sixty four percent had experienced dangerous or scaring events and 50.6% psychologically challenging work in connection with diving.

At present 26 (34%) were still active professional divers. As reasons for ending their diving career, the majority reported getting a better job elsewhere (20) or taking additional education (16). Six divers reported not being pleased with working conditions while 11 stopped due to health condition and 2 because they did not get their certificates renewed.

Discussion / Conclusion.

Compared to the male divers in "Norwegian diver 2011", female divers had fewer dives, shorter professional careers and had chosen less strenuous diving jobs. The educational level was higher in female than male professional divers.

Key words:

Female, professional divers, demography

P-01 IN TYPE-1 DIABETES NEW TECHNOLOGY CREATES OPPORTUNITIES TO DIVE WITH INCREASED SAFETY

P Adolfsson[1], J Jendle[2], H Örnhagen[3]

1) Halland Hospital, Kungsbacka, Sweden. 2) Endocrine and Diabetes Center, Karlstad Hospital, and Faculty of Health Sciences, Örebro University Hospital, Sweden. 3) Swedish Sportsdiving Federation, Idrottshuset, Farsta, Sweden
Contact: <hans@ornhagen.se>

Introduction:

In type 1 diabetes glucose control has been assessed by self-monitoring of blood glucose. Continuous glucose monitoring (CGM) offers an alternative, complementary method. Studies have been conducted where CGM have been used during scuba diving and in a pressure chamber, providing a basis for the updated Swedish recommendations on recreational diving and diabetes mellitus.

Methods:

CGM was used during five repetitive scuba air dives during three days using dry suit. Later CGM was evaluated in a pressure chamber including both an *in vitro* and an *in vivo* study. Sensors, attached to two different CGM systems, were immersed into three different glucose concentrations and exposed to scheduled pressure changes between 100 and 400 kPa. The performance of 12 sensors was also evaluated attached in one healthy individual who was exposed to the same scheduled pressure changes.

Results:

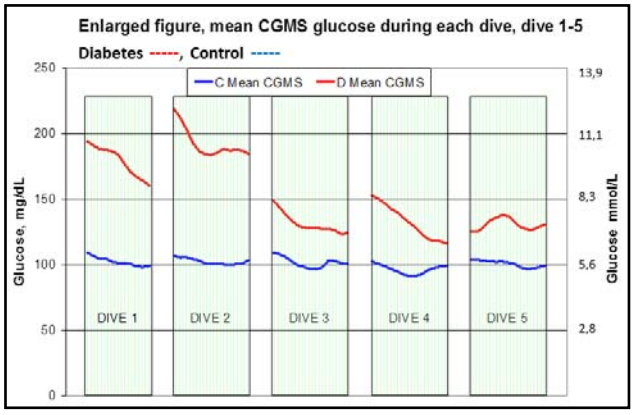
Used under a dry suit, CGM recordings were available during a total of 117 dives. Mean Absolute Relative Difference (MARD) between plasma and interstitial glucose was 14.4 ± 6% and 13.1 ± 5.4%, whereas coefficient of correlation (r) was 0.93 ± 0.04 and 0.95 ± 0.02. Hypoglycemia without symptoms was detected. In the pressure chamber all sensors worked. No significant differences in sensor signal were noticed depending on applied pressure conditions, glucose concentration, pre-wetted sensor or sensor insertion site in these studies.

Discussion:

CGM offers a potential advantage revealing hypoglycemia unawareness when assessing FTD. In close relation to, and before a dive, CGM, provide a useful tool improving the knowledge base whether a dive should be conducted or not. The fact that the CGM technique can be used dry, but pressurized, under a diving suit, without the use of pressure proof containers, makes it simpler to collect information regarding blood glucose also during diving. This will increase diving safety in divers with diabetes.

Key words:

Glucose, Continuous Glucose Monitoring, Diabetes Mellitus, Diving, Barometric Pressure



P-02 INFLUENCE OF WATER TEMPERATURE ON DIVING REFLEX – HEART RATE VARIABILITY EVALUATION

A. Anão, F. Guerreiro, Neusa Parente, Alexandre Jacinto

Subaquatic and Hyperbaric Medicine Center of the Portuguese Navy, Lisbon, Portugal
Contact: oliveira.anao@gmail.com

Introduction:

Heart rate variability (HRV) analysis can be a useful tool in elucidating autonomic response and triggering mechanism of diving reflex.

Methods:

16 healthy volunteers (3 females), age 39±6.8, evaluated in wet environment in four sequential phases (Ph) of 5 minutes in the prone position using a snorkel tube. Ph1: Regular breathing with no water stimulation. Ph2: Facial submersion in thermoneutral water (22-24^0 Celsius). Ph3: Facial submersion in water at 10^0 Celsius. Ph4: Regular breathing with no water stimulation. Arterial blood pressure was registered at minutes 1 and 4 of each Ph. ECG monitoring was used for safety purposes and register of ectopic beats. HRV was continuously registered (RR interval - sampling rate 1000Hz). Breathing frequency was visually counted in all Ph. The following HRV variables were evaluated: SDNN, RMSSD, "Poincare plot" (SD1, SD2), autoregression and fast Fourier transformation of Low (LF) and High frequency (HF) specter normalized units (nu), total power (T.Pow.) and LF/HF. One factor repeated measures analysis of variance (ANOVA) was applied to each variable. Further analysis was performed with paired samples T-Tests to show differences between two phases.

Results:

There were no significant differences in breathing frequency variation. After facial submersion a significant attenuation in mean heart rate and increase in arterial blood pressure was registered. During phases 2 and 3 there was a significant increase in the generality of markers of HRV and a tendency for parasympathetic prevalence that was more evident during phase 3. Statistical significance was reached for SDNN, RMSSD, SD1, SD2, LFnu, HFnu, LF/HF. For the generality of markers of HRV the variation was most pronounced with cold water submersion– Table1.

Conclusions:

Thermoneutral facial submersion is capable of triggering diving reflex physiological patterns. Cold water facial submersion (10ºCelsius) promotes an exacerbation of the physiologic response with an increase in HRV markers and a general tendency for parasympathetic modulation dominance.

	iRR(ms)	SDNN(ms)	RMSSD(ms)	SD1(ms)	SD2 (ms)	T.Pow.*(ms^2)	LF*nu	HF*nu	LF/HF*
Phase 1	**850**±210,9	**58,5**±26,5	**41,3**±27,6	**29**,3±19,6	**76,7**±33,2	**3310,2**±2801,6	**55,7**±12,6	**44,1**±12,7	**1,46**±0,79
Phase 2	**869**±206,0	**67,3**±30,2	**47,6**±23,1	**33,4**±16,4	**88,4**±40,32	**4117,1**±3766,6	**51,5**±23,8	**48,3**±23,8	**2,30**±3,72
Phase 3	**911**±209,2	**71,6**±35,6	**52,7**±31,4	**37,3**±22,2	**93,4**±45,7	**4334,4**±3958,2	**55,5**±24,3	**47,4**±24,2	**2,35**±3,13
Phase 4	**871**±186,5	**73,2**±41,7	**48,3**±46,6	**34,2**±33,0	**96,4**±51,6	**3761,4**±2692,4	**73,6**±14,8	**52,8**±14,7	**3,72**±2,71

Table 1

***Fast Fourier Transformation**

P-03 QUANTIFYING THE RISK OF ACUTE NEURONAL INJURY AFTER A "YO-YO" DIVE IN SWINE BY HISTOPATHOLOGIC EVALUATION OF THE SPINAL CORD

Dror Ofir[1], Yehuda Arieli[1], Michael Mullokandov[1], Ben Aviner[1], Alexander Liboff [2], Yoav Yanir[1]

[1] Israel Naval Medical Institute, Haifa, and [2] the Dept. of Pathology, Western Galilee Hospital, Nahariya

Background:

Previous studies conducted at the INMI using a rat model demonstrated that compared with the square dive profile, "yo-yo" diving lowers the probability of decompression illness (DCI). DCI was evaluated in previous experiments based on symptoms and assessment of motor function. We decided to quantify the risk of "yo-yo" diving further using histopathologic evaluation in a swine model.

Methods:

Twenty-two Large White swine (~22 kg, male and female) were used in the experiment. Animals underwent one of three dive protocols (square, two peeps, or four peeps) to a depth of 5 ATA. Five hours after decompression, the animals were sacrificed and 4 cm of the spinal cord was taken from the lumbar area. Spinal cords were fixated in formaldehyde (4%). The tissues were dehydrated, cleared, and infiltrated with embedding material, after which they were embedded in paraffin. The paraffin-embedded tissues were cut into 4-μm slices. Tissues were then stained with hematoxylin and eosin for histopathologic evaluation. A certified histopathology expert, blinded to the experimental protocol, evaluated the slides for the presence of edema and acute neural injury ("red neurons").

Results:

Neural cell injury ("red neurons") was found in the anterior horn of the spinal cord in each of the three experimental groups (see Table 1). Cellular edema was also found in all three groups (in 1-2 animals per group).

Table 1. Summary of histopathologic evaluation

	Square dive (%)	Sham (%)#	Two peeps (%)	Four peeps (%)
Edema	2/7 (29)	0/1 (0)	2/6 (33)	2/7 (29)
Red neurons	4/7 (57)	0/1 (0)	4/6 (66)	4/7 (57)#

#

Summary and Conclusions:

No difference was found between the three experimental groups (square dive, two peeps, and four peeps) regarding the number of animals with edema or red neurons in the spinal cord. Future quantitative evaluation of the prevalence of red neurons in the different groups will help us gain a better understanding of the risk of neural injury for each of the dive protocols.#

P-04 DO ENVIRONMENTAL CONDITIONS CONTRIBUTE TO NARCOSIS ONSET AND SYMPTOM SEVERITY?

C. Balestra[1,4], P. Germonpré[1,5], W. Hemelryck[1,4], G. Cochard[3], A. Henckes[3], P. Lafère[1,2,3]

[1] DAN Europe Research Division
[2] ORPHY, UFR Sciences et techniques, Université de Bretagne Occidentale, Brest, France
[3] Unité de soins hyperbares, CHRU de la Cavale Blanche, Brest, France
[4] Environmental & Occupational Physiology Laboratory, Haute Ecole Paul Henri Spaak, Brussels, Belgium
[5] Centre for Hyperbaric Oxygen Therapy, Military Hospital "Queen Astrid", Brussels, Belgium

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Introduction:

Although many factors potentially associated with the onset and severity of inert gas narcosis (IGN) have been suggested, the available evidence is not particularly strong. Using objective criteria we assessed cognitive impairment associated with IGN under various environmental diving conditions.

Methods:

Forty volunteers meeting strict biometrical criteria (male, age 30–40 years, BMI 20–23, non-smoker) performed a no-decompression dive to a depth of 33 meters for 20 min either in a dry chamber (n=8), a pool (n=20) or the open sea (n=12). They were assessed by critical flicker fusion frequency (CFFF) measurement before the dive, upon arriving at depth, after 15 min at depth, upon re-surfacing and 30 min post-dive.

Results:

Compared to the pre-dive value the mean value of each measure was significantly different. An increase of CFFF to 105.0 ± 0.7 % when arriving at the bottom was followed 15 min later by a decrease to 94 ± 0.6 %. This impairment of CFFF persisted when surfacing and 30 min post-dive, being still decreased to 96.4 ± 0.7 % and 96.2 ± 0.7 % respectively compared with the pre-dive CFFF. Intragroup comparison failed to identify any significant difference between diving environments.

Conclusion:

This study presents evidence that, when objectively measured, nitrogen narcosis may not be influenced by external factors other than pressure and breathing gas. It also confirms previous findings that narcosis persists even after surfacing.

Key Words:

Inert gas narcosis, Critical Flicker Fusion Frequency, Environmental factors

P-05 ARTERIAL BUBBLES FOLLOWING TRIMIX DIVES

[1]S. Lesley Blogg and [2]Mikael Gennser.

1) SLB Consulting, Winton, Cumbria, UK
2) Environmental Physiology, School of Technology and Health, Royal Institute of Technology KTH, Stockholm, Sweden.

Introduction

Recently Ljubkovic et al (Ljubkovic, Marinovic et al. 2010) reported a high number of arterial bubbles accompanying high venous bubble loads in seven divers using open circuit trimix apparatus, while Brubakk et al (Brubakk, Peterson et al. 1986) found arterial bubbles in 10 of 12 excursions from heliox and trimix saturation dives. Apart from these observations there remains a paucity of data on the incidence of arterial bubbles after trimix diving.

Methodology

Two hundred and fifty-one trimix dives of varying profiles, between 20 m to 100 m depth, were made over two studies using military divers. The first was designed to compile new tables for use with the IS-MIX SCRB (118 dives from 36 divers), carried out in a wet-pot chamber. The second followed divers while they participated in an open water CCRB course (133 dives from seven divers). The evolution of gas emboli post-dive was investigated using 2D ultrasound to assess the level of decompression stress.

Results

Arterial bubbles were seen in only three of 43 divers (7%), and in a total of five of the 251 dives made (1.99%); three occurrences were in the same diver. The maximum resting venous EB bubble grade accompanying the arterial bubbles ranged from a grade 1 to 4 and the time for which the arterial bubbles persisted ranged from 15 to 135 minutes post-dive.

Discussion

In comparison to recent trimix studies, the occurrence of arterial bubbles is very low; given that one third of the population has a patent *foramen ovale*, it might have been expected that around 14 of the divers would exhibit arterial bubbles as dives of up to 100 m depth were made. The conservatism of the decompression and the general dive profile are likely much more influential over the outcome of the dive than the dive gas alone.

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P-06 HYPERBARIC OXYGEN THERAPY IN CARBON MONOXIDE POISONING: FIRST YEAR OF ACTIVITY OF HYPERBARIC CENTER OF NIGUARDA HOSPITAL

M. Brauzzi[1], G.F. Panzavolta[1], F. Garuti[1]
[1]Hyperbaric Unit Niguarda Hospital Milano Italy

Introduction.

Hyperbaric oxygen (HBO) therapy is effective for the treatment of carbon monoxide (CO) poisoning. Our hospital started this activity in 2013 and is now a referral center in northern Italy for this injury. We review HBO therapy for CO poisoning during the first year in our Hyperbaric Center.

Methods.

Records of CO intoxicated patients who received HBO in their treatment between February 2013 to January 2014 were reviewed. Collated parameters were age, sex, nationality, circumstances of intoxication, CO source, clinical and analytical data.

Results.

During the period examined we treated a total of 103 people, (61 males and 42 females). Average age was 31 years for males (1-75 yr) and 24 years for females (1-6 yr). Circumstances of intoxication were classified as a domestic accident (75%), other non-work accident (10%); workplace (2%), fire (1%) and unknown (14%). The main CO source were embers (28%); water heaters (23%) or internal combustion engines (16%). Intoxication severity was classified according to the guidelines of Società Italiana di Medicina Subacquea ed Iperbarica (Italian Society of Underwater and Hyperbaric Medicine) in four categories: - very severe: 40%, severe: 11%, moderate: 30%, mild severity: 19%. The most common symptoms were headache (50%), syncope (24%) and/or dizziness (17%). Electrocardiograms were performed for 86 patients (83%) of which 24 (28%) showed alterations. Creatine kinase level was elevated in 41% of blood tests, Troponins I and T were elevated in 42% of tests. The mean carboxyhemoglobin previous to HBO therapy was 19.1% (34.2% -4.5%) and after treatment was 2.46 % (0.2% - 6.9%).

Conclusions.

Our data contribute to estimating the epidemiology of CO poisoning in northern Italy. Also, we show how effective a newly established treatment centre for CO poisoning can be within one year of commencing treatment.

P-07 A NEW MODEL OF HEAD-UP DISPLAY DIVE COMPUTER ADDRESSING SAFETY-CRITICAL RATE OF ASCENT AND RETURNING GAS PRESSURE: A PILOT TRIAL

Peter Buzzacott, Andreas Schuster, Amir Gerges, Walter Hemelryck, Kate Lambrechts, Dennis Madden, Virginie Papadopoulou, Yurii Tkachenko, Aleksandra Mazur, Frauke Tillmans, Miroslav Rozloznik, Qiong Wang, Andreas Mollerlokken, François Guerrero and Arne Sieber.

Introduction:

Head up displays (HUD) are beneficial in diving situations when the diver uses both hands for an activity, e.g. photography, scientific work, operating a diver propulsion vehicle (DPV) or during diver training such as controlled emergency ascent practice. They also remove the need for a diver to locate a submersible pressure gauge or to remember to look at a personal dive computer when ascending, if one is worn. A new model of HUD, one that can be retrospectively fitted to a recreational diver's regulator hose outside the mask lens, has been developed. This study reports on the field-testing of the HUD.

Methods:

A pilot study of 93 open circuit recreational dives was conducted over one week in Croatia, to assess the HUD-user interface. An internet-based electronic survey was developed and completed twice after 16 dives.

Results:

The HUD displayed both remaining gas pressure and a column graph indicating ascent-rate. Mean maximum depth was 23 m and mean total dive time 38 mins. 34 dives (37%) were made with the HUD and 59 made with traditional submersible pressure gauges. During one dive with a DPV the diver rapidly lost gas while being towed through the water. There was good test-retest agreement (kappa score=0.9) between repeated surveys.

Discussion:

The HUD was relatively easy to attach and required no prior familiarity with the user manual. No dive ended with less than 50 bar but at this pressure the screen flashes. Once divers became familiar with the HUD then the ascent rate warning was more readily observed. These warning features have the potential to reduce the likelihood of either running low on gas or ascending rapidly, both of which are risk factors for diving injury.

Keywords:

Ascent, Computers – diving, injury prevention, low air, recreational diving, risk factors

P-08 A RAT MODEL OF CHRONIC ALCOHOL CONSUMPTION AND RISK OF DECOMPRESSION SICKNESS

Peter Buzzacott, Qiong Wang, Kate Lambrechts, Aleksandra Mazur, Michael Theron, François Guerrero

Université de Bretagne Occidentale, Laboratoire Optimisation des Régulations Physiologiques (ORPhy), UFR Sciences et Techniques, 6 avenue Le Gorgeu, CS 93837, 29200 Brest Cedex 3, France.
E-mail: peter.buzzacott@uwa.edu.au

Introduction:

Alcohol consumption prior to diving may be equally prevalent among divers and non-divers, and among DCS / non-DCS divers. This study investigated if chronic alcohol consumption affected susceptibility to DCS.

Methods:

For 28-29 days the treatment group of male rats (n=15) were each given 50 mL of water per day containing 12 mL/L of ethanol. Control rats (n=15) had water *ad libitum*. The rats were then exposed to a hyperbaric protocol known to produce DCS in reliable proportions.[1] They were then observed for one hour. Thirty control rats from a previous experiment raised the control-to-treatment ratio to 3:1. The cumulative probability p of DCS outcome j (noDCS, DCS or Dead) is:

$$Ln\left(\frac{p_j}{1-p_j}\right) = \underline{\alpha} + \beta_1 Alcohol + \beta_2 Weight$$

where $\underline{\alpha} = [\alpha_1, \alpha_2]$ intercepts. For k+1 states, the probability of the i^{th} observation being in state j is

Results:

Rats in the treatment group weighed a mean 378g over the treatment period and consumed a mean 1.3 mL/kg of alcohol per day.
Distribution of DCS did not differ between control groups (p=0.76) so they were combined.
Weight was not different between the combined control group and the alcohol group (p=0.34).
Comparing the treatment group with the combined control group neither weight (p=0.23) nor alcohol consumption (p=0.69) were associated with DCS.

Discussion:

Rats in our treatment group consumed the equivalent of an 80 kg man drinking more than 2 L of 5% beer per day, about three times the recommended daily limit. A limitation is that both groups consumed alcohol throughout sexual maturation and studies using older animals or females may yield conflicting results.
Though acute alcohol consumption ameliorates signs of HPNS in rats,[2] experimental DCS in rabbits[3] and/or improves recompression treatment in humans,[4] we report that chronic alcohol consumption was neither prophylactic nor deleterious for DCS in young, male rats.

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P-09 DIVERS PERCEIVE WATER TEMPERATURE DIFFERENCES <1°C, EVEN AFTER EXTENDED IMMERSION

Peter Buzzacott,[1,2] Georgi Popov,[3] Frauke Tillmans [4]

[1]Optimisation des Régulations Physiologiques (ORPhy), Université de Bretagne Occidental, Brest, France.
[2]School of Sports Science, Exercise and Health, The University to Western Australia, Crawley, Australia.
[3]Mares, Rapallo, Italy
[4] Haute Ecole Paul Henri Spaak, Brussels, Belgium.
E-mail: peter.buzzacott@uwa.edu.au

Introduction:

The author (PB) dived a flooded coal-mine with shafts entering underwater vertical cliffs at 15-30m depth. After an hour of diving, at a shaft at 18m, he 'felt' the rock overhead was warmer than the surrounding water.

Methods:

The diver returned with five Sensus data-loggers (ReefNet, Canada) to record water temperature at resolution of 0.01°C and accuracy of +/- 0.8°C. The loggers were lowered to 6m for 1 hour to equilibrate. Temperature data was recorded every ten seconds and compared from 3600 to 3900 seconds (n=31 per logger) from initial immersion. Standard deviation between loggers was 0.08°C. The loggers were swum across the lake and taken to the underwater cliffs. Two loggers were inserted into the shaft to a distance of 3m, near the roof. Two loggers were hung in front of the shaft, 1m apart. The 5th logger measured the water temperature against the rock above the shaft. The divers again felt a temperature difference. The loggers were left for 3.5 hours to equilibrate and retrieved after 3.8 hours. Temperature data were downloaded for between 210-215 mins, post placement.

Results:

SD ranged from 0-0.01°C within loggers. Mean temperature in the lake was 13.15°C, above the shaft 13.45°C and inside 13.96°C. As the inter-logger variation was 0.08°C during the pre-dive measurement, this difference in temperature between inside and outside (0.81°C) equates to 10.SD therefore water against the roof of the shaft was significantly warmer than outside ($p<0.01$).

Discussion:

These results suggest a perceptive diver has the potential to rapidly detect water temperature differences <1°C. Moving two popular models of dive computer from 13.5°C to 14.5°C water determined that the time to register half a degree of temperature difference took 2:00 and 2:36 minutes respectively. A diver, therefore, has finer capacity to detect subtle water temperature differences than popular dive computers, even after extended immersion.

Keywords:

Case report, dive computers, thermal sensitivity, mine diving.

P-10 ENHANCING HUMAN PERFORMANCE IN THE WATER: ONR'S UNDERSEA MEDICINE PROGRAM

William R. D'Angelo (1), Robert S. Bolia (2)
(1) Office of Naval Research, (2) Office of Naval Research Global

The Office of Naval Research (ONR) Undersea Medicine (UM) program exists because humans were not made to operate under water. To address this, either human physiology has to be enhanced or technology solutions have to be provided. If not, operational limitations are set which can affect mission success. With the goal providing improved undersea capabilities, ONR has funded UM research from the early 1950s until the present day. Throughout, the program has enjoyed close ties to Navy divers, who face occupational safety and industrial hygiene challenges; special warfare operators, who perform high risk missions anytime and anywhere; and submariners, who operate in an unnatural space with diminished sensory input.

The importance of the undersea medicine portfolio was highlighted in the 1960s when the Navy lost two submarines and the SEALAB deep sea habitat experiments were ongoing. While funding levels were much higher at that time, since the 1990s the program has remained a stable part of ONR enterprise. In 2001, a report by the Undersea and Hyperbaric Medical Society clearly articulated the need for sustained, stable research funding and the maintenance of a trained cadre of undersea medical researchers, arguing that without ONR funding the research capability in the US would decline precipitously. As a result, in 2006 Undersea Medicine was declared a "National Naval Responsibility (NNR)," one of only five within the Navy.

The Navy NNR initiative places emphasis on maintaining vigorous science and technology programs in those areas important to maintaining naval superiority. The NNR areas are unique to the Navy and not addressed by research investments from the other Services or the Federal research establishments. Besides supporting research, the NNRs are chartered to support recruitment, education and the critical infrastructure necessary to keep the particular fields healthy. The designation of an NNR guaranteed that undersea and hyperbaric medicine will continue to be a focus of efforts by ONR and the Naval Research Enterprise.

The Undersea Medicine program funds research in diver and submariner health and performance. A special emphasis is placed on understanding the pathology and etiology of decompression illnesses (DCI) and hyperbaric oxygen toxicity. Other areas of interest are nitrogen narcosis; nonrecompressive prevention and treatment of DCI; identifying potential long-term health effects of diving and exposure to the submarine environment; safe diving in cold and/or contaminated water; and improved trauma management in submarine special forces operations.

In addition to funding research at universities and naval laboratories in the United States, the NNR initiatives are chartered to maintain the international infrastructure of both personnel and facilities in the field. The international outreach arm of the US Naval Research Enterprise – ONR Global – uses a variety of funding vehicles to support scientists at foreign institutions and develop international collaborations. ONR Global plays a vital role in conference support, travel funding for visiting scientists, and funding for research projects.

P-11 EFFECT OF MANNITOL INDUCED COLONIC FERMENTATION ON DECOMPRESSION SICKNESS OCCURENCE IN RATS

Sébastien De Maistre, Nicolas Valle, Emmanuel Gempp, Pierre Louge, Jean-Eric Blatteau.

Department of diving and hyperbaric medicine, Ste Anne's military teaching hospital, 83800 Toulon cedex 9, France.

Introduction

Decompression sickness is usually associated with venous gas emboli formation and occasionaly leads to neurological sequelae. Oxidative stress contributes to maintain and amplify the pathophysiological phenomena when bubbles form in the body. We wanted to investigate if hydrogen endogenous production by mannitol colonic fermentation could prevent decompression sickness by reducing oxidative stress in rats.

Materials and methods

On an empty stomach, 81 rats were forced-fed four hours before compression in a hyperbaric chamber. The rats were divided into two groups: one treated with metronidazole (41 rats) for six days before pressurization and one untreated group (40 rats). In each group, half of the rats were force-fed with mannitol (experimental group) and the other half with water (control group). Exhaled carbon dioxide and hydrogen were measured before and after feeding, the latter being a reflection of colonic fermentation. Blood cells tests were performed before and after compression. At the end of decompression, we looked for clinical signs indicative of decompression sickness: labored breathing, motor deficits or moving difficulties, and death.

Results

Without metronidazole pretreatment, a higher incidence of decompression sickness was found in rats forced-fed with mannitol compared with those forced-fed with water (80% , [95% CI 56, 94] versus 40% , [95% CI 19, 64], p = 0.01). In rats forced-fed with mannitol, metronidazole pretreatment significantly reduced the incidence of decompression sickness (33%, [95% CI 15, 57], p = 0,005), while at the same time colonic fermentation was significantly decreased (14ppm, [95% CI -21, 49] versus 118ppm, [95% CI 28, 208], p=0,0001).

Discussion and conclusions

Mannitol ingestion before diving had no beneficial effect in rats with empty stomach. It even promoted the occurrence of decompression sickness when colonic fermentation peak coincided with decompression. More generally, colonic fermentation in rats receiving a normal diet, not stuffed with mannitol, could be a risk factor for decompression sickness.

P-12 POST-DIVING MEASUREMENT OF URINE PARAMETERS OF OXIDATIVE STRESS USING TIME-OF-FLIGHT MASS SPECTROMETRY

T. Demetrowitsch, W. Kähler, J. Manger, A. Koch, K. Schwarz

Christian-Albrechts-University Kiel, Germany
German Naval Medical Institute

Introduction:

For the measuring of markers of oxidative stress in human urine, a number of different analysis and detection techniques have been used. Most studies focus on one or, at most, a few compounds, which are formed within the same metabolomic pathway, for example prostaglandin from the lipid metabolism. This project assessed the feasibility of detecting different biomarkers from different metabolomic pathways within one analysis.

Methods:

Prostaglandines (lipid pathway), oxo-guanosines (DNA pathway) as well as dihydroxylated benzoates (hydroxyl radical markers, DHBs) were detected, identified and quantified. For the detection, a high resolution mass spectrometer (quadrupole time-of-flight system (QToF)) equipped with an electrospray ionization source was used. For the chromatography a UHPLC RP column was used.
The samples were obtained from divers of the German Navy before, soon after and 6h after challenging closed-circuit dives (n=21 dives; duration 60-90min; pO_2 about 1.5 bar).

Results:

The analyses revealed increases in all compounds directly after the dives with return to nearly baseline within 6h. This trend was observed for all divers and dive days. The relative increases directly after diving varied between 100 % and 200 %, depending on the measured compound.

Discussion:

The results for the DHBs are in concordance to a study of Gronov et al. (2005), who also detected a similar trend for diver´s human urine samples [1] and to the study of Kahler et al. (2013) [2]. We conclude that this new QToF method allows the measurement of a number of interesting parameters of oxidative stress with just one preparation.

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P-13 A SCIENTIFIC APPROACH FOR PROPOSING CHEMICAL EXPOSURE LIMITS IN SATURATION DIVING

Rune Djurhuus,

Norwegian Centre for Diving Medicine
Dept. of Occupational Medicine, Haukeland University Hospital
5021 Bergen, Norway

Chemical contamination in the working atmosphere of a saturation diver may represent a greater threat than similar conditions onshore since the diver cannot easily escape the exposure. Health effects with limited impact onshore may have serious consequences for a diver at the sea bottom. In addition, both hyperoxia that is an inevitable part of all diving and the continuous exposure during saturation diving may infer long-term effects of chemicals at lower concentrations than in a normal working environment. At present, divers are protected against chemicals in the breathing atmosphere by standard exposure limits only adjusted for the increased exposure length, i.e. from 8 to 24 hrs a day and from 5 to 7 days a week. The objective of the present study was to indicate a procedure for derivation of occupational exposure limits specific for saturation diving, termed hyperbaric exposure limits (HEL).

Using benzene as an example a procedure is outlined that includes identification of the latest key documents describing toxicology, risk assessments and suggestion for exposure limits at normal conditions. Moreover, the procedure includes extensive literature search with a defined search string and with clearly defined exclusion criteria for the literature retrieved. Hematotoxicity and leukemia were defined as the critical effects, and exposure limits based upon concentration and cumulative exposure data and corresponding risks of leukemia were calculated. For comparison with a normal working schedule onshore the cumulative exposure time expressed as working-years was calculated for a typical saturation diver's career and compared to the cumulative exposure for onshore workers.

Possible interactions of conditions specific for saturation diving, i.e. high pressure, effects of elevated pO_2 and the continuous exposure have been assessed and incorporated in a final suggestion of a HEL for benzene. The procedure should be applicable for chemicals possibly found as contaminants in the divers' breathing atmosphere.

P-14 AUTOMATIC VIDEO ANALYSIS FOR ECHOCARDIOGRAPHIC BUBBLE DETECTION

Ismail Burak Parlak [1], Salih Murat Egi [1,2], Danilo Cialoni [2,3], Massimo Pieri [2], Alessandro Marroni, [2,3]
1. Galatasaray University, Department of Computer Engineering, Istanbul, TURKEY
2. DAN Europe Research Division, Roseto degli Abruzzi, ITALY
3. Phypode Project (Marie Curie ITN) FP7

Introduction:

Air embolism is one of the main threats for Decompression Sickness (DCS). Over last decades, Doppler Ultrasound was considered as the golden standard to measure the quantitative information related to the bubbles. However, this technique was limited due to the technical features and the application areas. On the other hand, Echocardiographic imaging improved embolism studies by adding new features related to DCS. Experimental and clinical studies remark that echocardiography is the most reliable technique to calculate the bubble grade. However, counting and observing bubbles are time consuming and subjective tasks. As the echocardiography provides better spatio-temporal resolution, these tasks become harder in longitudinal studies. For this purpose, we aimed to develop a software; FRAme ANalyzer (FRAMANA) to analyze automatically echocardiographic frames.

Material, Methods:

FRAMANA was developed using Visual Studio 2008 and C# programming language. Graphical User Interface was developed to provide a user friendly tool to analyze apical four chamber view of Trans Thoracic (TTE) Echocardiographic frames. In order to test our procedure and detection algorithms, post decompression TTE videos were acquired. These videos were recorded by a commercially available instrument (Esaote SPA, Florence, Italy). We studied a group of 32 healthy divers (23 men, 9 women); mean age 45.87 ±13.17. All dives were No Decompression Dives, not exceeding 45 minutes total dive time and at depths not deeper than 30 meters.

Results:

In all videos, detected bubbles were located in the left side of the heart. FRAMANA visualized the bubbles in the selected area and offered bubble properties; number, area, average area and densities.

Discussion:

In bubble detection, endocardial boundaries and valves would introduce false alarms due to their similarities with bubble properties. Although TTE offer a complete view of four cardiac chambers, patient movement and probe displacement would reduce drastically image quality for an objective experience.

P-15 SAFETY RULES FOR THE DEVELOPMENT OF A COGNITIVE AUTONOMOUS UNDERWATER BUDDY (CADDY)

S Murat Egi[1,2], Guy Thomas[1], Massimo Pieri[1], Danilo Cialoni[1], Costantino Balestra[1,3], Alessandro Marroni[1]

[1]DAN Europe Research Division; Italy
[2]Galatasaray University, Computer Eng Department, Beşiktaş, Istanbul
[3]Haute Ecole Paul Henri-Spaak, Environmental, Occupational& Ageing Physiology Laboratory

Introduction.

The commercial divers are often monitored by Remotely Operated Vehicles (ROV) to increase safety and efficiency. Their use is strictly regulated. Recreational and scientific divers may also operate in harsh and weakly monitored environments in which the slightest unexpected disturbances can result in catastrophic consequences. The ROV's cannot be used in these cases due to the increased mobility of the SCUBA divers. The aim of the CADDY project is to develop a multi component, highly cognitive autonomous underwater robotic system capable of monitoring, learning, interpreting, and adapting to the diver's behaviour in order to increase the safety and the efficiency of SCUBA diving.

Material, Methods

One must also be careful about the use of robots in the vicinity of the divers since they may impose additional safety measures. So, the CADDY project must include the development of safety rules to be used while diving with Autonomous Underwater Vehicles (AUV)'s as well. During the first period, the existing vehicles that will be adapted for the purposes of the CADDY project are evaluated regarding safety issues.

Results.

The results were published as a safety guideline to be used thought-out the project. It includes a special focus on a number of particular vehicles' maneuvering capabilities as an indicator of whether the vehicles are safe to be used for interaction with divers. The hazards of ancillary equipment such as scaling LASERs and acoustic modems or relocators are addressed as well.

Discussion.

Ten divers gave written informed consent to join the initial experiments with the Diver.Net motion monitoring system, high frequency SONAR imaging and stereo camera. 9 dives were accomplished uneventfully at confined water, with a maximum depth of 5 m and a cumulative dive time of 786 min. The internal safety guideline is aimed to be generalized, as an International Code of Practice for diving with AUV's.

CADDY is a collaborative project funded by the European Community's Seventh Framework Programme FP7-Challenge 2: Cognitive Systems and Robotics - under grant agreement no. 611373

P-16 THE EFFECTS OF HYPERBARIC OXYGEN THERAPY (HBOT) ON BLOOD VISCOSITY AND ERYTHROCYTE AGGREGATION IN DIABETIC PATIENTS

N. Ertan[1], B. Oroglu[2], M. Sinan[1]

1. Istanbul Medical Faculty, Department of Physiology
2. Istanbul Medical Faculty, Underwater and Hyperbaric Medicine Department

Introduction

There are only a few studies about hyperbaric oxygen's effect on hemorheological parameters and their results show an increase in blood viscosity and RBC aggregation both in vivo and in vitro. This would suggest more complications about blood after HBO therapy however; reality is not consistent with study results. Therefore, in this study, the effects of hyperbaric oxygen therapy on blood viscosity and erythrocyte aggregation have been investigated.

Methods

Since they make up an important part of HBO patients, diabetics were chosen as subject at first. 11 diabetic ulcer patients aged between 42 and 82 were included to the study, after their consent. 100% oxygen was applied at 2.4 ATA for two hours in three cycles of 25 minutes of oxygen- 5 minutes air break. Treatments were carried on every weekday usually for six weeks. Blood that was collected before the initial HBO therapy was accepted to be control. Samples were also collected after the initial therapy and twentieth one to be evaluated. Corrected whole blood viscosity was measured using a cone/plate viscometer with a hematocrit of 45%. RBC aggregation was measured using a Myrenne aggregometer in both autologous plasma and dextran70 solution.

Results

Our results showed that there were no significant changes in corrected blood viscosity between the samples collected before and after the first and twentieth HBO treatments. Also RBC aggregation in both autologous plasma and dextran70 solution after the first and twentieth HBO treatments were not significantly different than the control samples.

Discussion

These results were in contrast with the previous experimental studies. The reason of these contradictory results may be caused by experimental method and HBO application differences and/or different reactions of humans and animals. Still, this topic needs further studies to clear such an important effect.

P-17 SENSORS FOR MONİTORİNG OF WOUND HEALİNG

Christian Fabricius

Introduction

Impaired wound healing

Problem wounds fail to heal in response to standard medical and surgical therapy. These wounds are frequently found in patients who have multiple local and systemic factors inhibiting tissue healing.

The role of oxygen

If cells are hypoxic, the oxygen-dependent pathway is severely incapacitated, leading to increasing rates of infection and profound hypoxia inhibits all wound healing processes. Moderate to low oxygen tensions, however, initiates angiogenic growth factor production in vitro and upregulates vascular endothelial growth factor.

Technology presently used to measure oxygen on the skin

The Clark electrodes have numerous drawbacks: consume oxygen, cross sensitive to other gases (CO2, H2S and C2), only allow for single spot measurements, usage is tedious and they cannot be used to measure in a wound.

Materials and Methods

The optical sensor system consists of: a receptor layer, a transducer and a computer that analyses the transducer signal. Their behavior, response time, range and cross reactivity can be tuned and controlled. The optical sensor system has several benefits: easily miniaturized, do not consume oxygen, non-invasive, cheap, do not require a reference electrode, can transmit multiple signals.

Results.

Measurements with optodes :

A. Comparison with Clarke electrode
B. Venous ulcerosis
C. Diabetes non-healing wound
D. Before and after HBOT

Comparison with Clarke electrode (tcpO2) showed the same values: 7,0-7,5 kPa as on skin of healthy subjects. The measurements in wounds showed $< 1\% = < 1$ kPa oxygen and an increase in wound oxygenation after HBOT.

Discussion

Measurement with optodes is an inexpensive and easy method to measure pO2. They are easy to use, cheap and comfortable for the patient and the can be used in a hyperbaric chamber and, most importantly, they allow for measurements in the wounds.

P-18 THE USE OF REMOTELY OPERATED VENTILATION TO THE INTUBATED PATIENT DURING HYPERBARIC SESSIONS

Martin Forchhammer and Ole Hyldegaard

The Hyperbaric Unit, Section 4092, Department of Anaesthesia, Centre of Head and Orthopaedics, University Hospital of Copenhagen, Rigshospitalet, Denmark

Background

In order to optimize treatment capacity and operational safety in an HBOT setting with more than 300 intensive care HBOT sessions yearly, a system was constructed allowing a mechanical ventilator to be operated inside- as well from the outside of the pressurized chamber environment.

Methods

The *MAQUET SERVO-i*™ is a mobile respirator capable of delivering advanced respirator settings. The respirator is operating on a 12V power supply converted from 230V AC power connection. An external UPS power supply may be used in case of power failure. The respirator is mounted onto a gurney for in hospital transport. A touch screen is showing vital parameters. The medical engineers at Rigshospitalet constructed a switch, which once activated, transfers the respirator settings and adjustment controls to an identical screen mounted on the outside of the pressure chamber. Accordingly, the respirator can be operated by the medical staff from the outside of the chamber. A similar setting is constructed for infusion pumps (mrk. Braun™) regulating inotropic- and sedative medicine.

Result

The respirator system was implemented in January 2014. As of today the respirator has clocked more than 50 hours of operations used on ICU patients breathing 100% in 90 minutes at 2.8 atm.abs. No adverse events have been registered.

Discussion and conclusion

Applying HBOT to intensive care patients requires frequent adjustments on ventilation procedures as well as on inotropic support and sedation. If several patients are in the need of the therapy, capacity- and staffing problems may arise unless staff exposure to the hyperbaric pressure environment is reduced to a necessary minimum[1]. The current setting allows for advanced mechanical ventilator adjustments and immediate regulation of inotropic- and sedative medication from the outside of the pressure chamber environment, thereby reducing the total hyperbaric exposure time for the medical staff. The concept of this operational procedure has been used since 1998 with no serious adverse events registered[1].

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P-19 EYE-LID REFLEX, A POSSIBLE INDICATOR FOR N2 NARCOSIS?

Urška Gajšek[1,2], Andreas Schuster[3,5], Sebastian Reif[3], Arne Sieber[3,4]

[1]Universtiy Clinical Center Maribor, Slovenia, [2]University of Ljubljana, Medical Faculty, Institute of Physiology, Ljubljana, Slovenia, [3]Seabear Diving Technology, Graz, Austria, [4]Chalmers University of Technology, Gothenburg, Sweden, [5]ACREO AB, Gothenburg, Sweden
Contact: urska.gajsek@gmail.com, arne.sieber@seabear-diving.com

Introduction:

Nitrogen Narcosis in diving is a reversible alteration in consciousness and is caused by the narcotic effect of N2 at high partial pressures. Different methods are used to assess the level of narcosis, among those simple reaction tests and more complex tests where the diver has to solve mathematical equations. Another method is the critical flicker fusion frequency test, however it is not clear if there is a direct relation to N2 narcosis at all. All these approaches are active methods, where the diver has to do a certain task. This work investigates the feasibility of N2 narcosis assessment based on measuring the time delay between a stimulus and a reflex.

Method:

A set up was designed to trigger the eye-lid closure reflex with a short air blast directed onto the eye. 4 ways were tried to detect the eye lid closure. A high speed video cameras (240 frames per second), a micro-accelerometer attached to the lower eye lid, EMG and a infrared light beam detector, where the eye was illuminated with infrared light (820 nm) and the reflected light was received with a photodiode. A digital oscilloscope was used to measure time delays and amplitude of the reflex, lid closure as well as opening. Nitrogen narcosis was simulated with a Normoxic mixture of 40, 30 and 25% N2O.

Results:

There was only a minimal not significant delay of the olygosynaptic eye- lid closure reflex. The amplitude of the reflex signal decreased with increasing N2O fraction. The eye lid opening was significantly delayed and prolonged with 30 and 40% N2O but not with 25%. .

Conclusion:

While the olygosynaptic eye- lid closure reflex is unsuitable to assess N2 narcosis the polysynaptic eye-opening reflex of the contralateral eye may have the potential for a passive assessment of N2 narcosis.

Acknowledgment:

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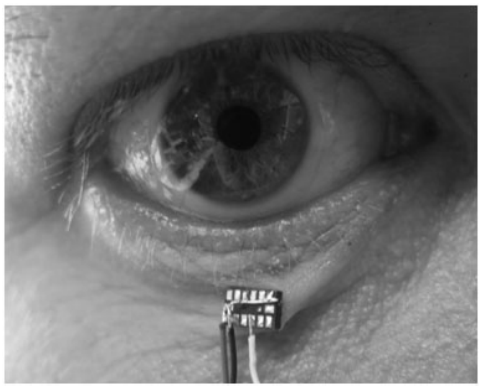

Figure 1: Detecting the eye-lid-closure with a micro –accelerometer

Keywords:

N2 narcosis, diving, SCUBA, inert gas narcosis

P-20 SPINAL CANAL STENOSIS, RIGHT-TO-LEFT SHUNTS AND SPINAL CORD DECOMPRESSION SICKNESS IN SCUBA DIVERS

Emmanuel Gempp, Pierre Louge, Sébastien De Maistre, Michel Hugon.

Department of diving and hyperbaric medicine, Ste Anne's military teaching hospital, 83800 Toulon cedex 9, France.

Introduction

Large right-to-left shunt (RLS) and spinal canal stenosis resulting from vertebral degenerative changes are thought to be potential risk factors for the development of spinal cord decompression sickness (DCS) in scuba divers. We aimed to examine whether these 2 conditions could influence the neurological outcome. We also evaluated the frequency of RLS in DCS patients according to the presence or not of spinal cord compression.

Methods

Sixty-eight non-consecutive divers (48 ± 10 yrs, 57 males) suffering from spinal cord DCS examined by cervico-thoracic MRI and tested for RLS with contrast transcranial Doppler between 2010 and 2013 were retrospectively selected for the study. The extent of spinal canal narrowing was analyzed on T2-weighted sagittal images using a 3 levels grading system validated for cervical spondylolic myelopathy. The size of RLS was classified as hemodynamically relevant if present at rest or after straining maneuver with important passage of micro-bubbles (> 20). The recovery status was assessed at 3 months post-injury.

Results

The presence of large RLS was found in 37/68 (54%) patients while 24/68 (35%) exhibited a significant canal stenosis with spinal cord deformity (grade 2 and 3), mainly on the cervical level (87%). There was no association between RLS and incomplete recovery ($p = 0.47$, χ_2 test), as well as we found no relation between spinal cord compression and the severity of the myelopathy ($p = 0.9$, χ_2 test). Our data revealed a greater frequency of RLS in patients without compressive disorders compared to those with grade 2-3 stenosis (66% vs. 33%, $p = 0.009$, Z test for proportions).

Conclusion

Our findings suggest that spinal cord injury in DCS could be due to 2 distinct pathophysiological mechanisms, i.e. paradoxical venous gas embolism across large RLS and mechanical factors impairing spinal cord vascularisation. RLS and spinal canal stenosis did not appear as predictors of a worse outcome in the present work.

P-21 VENOUS BUBBLE LOAD AFTER TRIMIX DIVES USING ELECTRONIC CLOSED CIRCUIT REBREATHERS

M. Gennser[1] and S.L. Blogg[2]

1) Environmental Physiology, School of Technology and Health, Royal Institute of Technology KTH, Stockholm, Sweden.
2) SLB Consulting, Winton, Cumbria, UK

Introduction:

The use of trimix gas (O_2, N_2, and He) allows for deep bounce dives (1). Although this technique is gaining increasing popularity among ”tech divers”, the few reported measurements on this type of diving indicate that it produces a high bubble load post-dive (Ljubkovic et al 2010). This study was carried out to investigate the venous bubble load after deep rebreather dives using trimix gas.

Methods:

Six military divers and one instructor took part in a training course using closed circuit rebreathers with electronically controlled oxygen levels (eCCR). The dives were carried out using trimix breathing gas to depths between 20 – 100 m. In most cases the oxygen level was kept constant at 1.3 atm. The decompressions were calculated using the VPM-algorithm. The post-dive venous bubble load of the divers was assessed with precordial audio Doppler ultrasound using the Kisman-Masurel (KM) grading scale.

Results:

A total of 133 dives from the seven divers were monitored. No bubble grade higher than a KM III was observed after any dive. After repeated dives to 70 m, the median bubble grade was KM II (n = 11). The deepest dive (100 m / 15 min, n = 6) also resulted in a moderate post-dive bubble load, with KM grades ranging from 0 - III.

Conclusion:

In this study, deep trimix dives using eCCR units with ascents calculated using the VPM-B bubble model algorithm produced low venous gas bubble loads.

Ref: Ljubkovic et al. J.Appl. Physiol. 109(6): 1670-1674.

P-22 EFFECTIVENESS OF DILUENT FLUSH PROCEDURES IN A DIVING RE-BREATHER

Gilbert M. J.[1]
[1]QinetiQ Ltd, UK

Objectives

UK Royal Navy divers perform a diluent flush procedure with their electronic re-breather (known as CDLSE) if a high partial pressure of oxygen (PO_2) exists. However, some data suggested that this procedure may not be effective at reducing high PO_2. An experiment to investigate the effectiveness of the diluent flush procedure was developed in order to quantify its effectiveness.

Methods

The study was approved by the UK Ministry of Defence Research Ethics Committee and conducted in accordance with the Declaration of Helsinki. Using CDLSE, 10 RN divers each dived to 20 m in the RN Submarine Escape Training Tank. A valve allowed the oxygen supply to be turned on and off by a standby diver. Data were monitored using a connection to the CDLSE electronics and divers were observed using underwater cameras. The standby turned the oxygen off once a steady PO_2 was achieved. The diver then carried out a standard flush procedure comprising:

- exhale
- crush counter-lungs
- inject diluent gas for 2 s
- repeat
- oxygen on

This was repeated twice more with ‘crush and exhale’ only and ‘diluent injection’ only procedures.

Results

The mean effectiveness of a pair of flushes was 68.4 %. The ‘crush and exhale’ only procedure was ineffective. The ‘diluent injection’ only procedure was as effective as the standard flush (69.0 %). The duration of diluent injection varied from 1.4 to 3.8 s (mean 2.2 s). The estimated diluent flow rate ranged from 83 to 455 l/min ATPD.

Conclusions

- The current procedure is effective;
- the crush and exhale phase does not contribute to the effectiveness;
- two flushes is the optimum compromise between effectiveness and amount of gas used;
- most variation was due to the degree of diluent purge button depression;
- standardising the diluent flow rate might be useful;
- these findings may be relevant to similar re-breathers.

QINETIQ/TEG/MAR/PUB1400409
QINETIQ/14/01234

P-23 DIVE INJURIES AND DIVING RELATED DISORDERS - EXPERIENCES OVER A PERIOD OF 15 YEARS FROM A HYPERBARIC CHAMBER POINT OF VIEW

A. Glowania [1 2], D.. Böhmer [2], M. Kemmerer [2], F. Kemmerer [2], D. Michaelis [2]

[1] ORL-Department, Hietzing Hospital, Vienna / Austria
[2] Center for Diving & Hyperbaric Medicine, Wiesbaden / Germany

Introduction:

The number of scuba divers has increased since the nineties of the last century enormously. Contemporaneous the number of diving related disorders and dive injuries rised too. As a result Diving & Hyperbaric Medicine Centers are asked for consultation and definite decision how to proceed. We want to report on our experiences of 15 years in this field.

Material & Methods:

We performed a retrospective analysis of all scuba divers who presented to the Center of Diving & Hyperbaric Medicine, Wiesbaden, in between 1999 and 2013 for further consultation after an acute incident after scuba diving. For a closer analysis they were grouped in three categories: Group A consists of patients suffering from DCS 1 / DCS 2 or CAGE who needed further treatment under hyperbaric conditions. Group B contains patients with other diving related disorders who needed different forms of specific treatment. All other scuba divers were summarized in Group C and includes those where a connection between acute symptoms and diving could be excluded.
Personal data and information's concerning the circumstances of the previous dive and diving behaviour were obtained.

Results:

113 scuba divers presented to our Hyperbaric Medicine facility in that period of time. Most of them had to be treated because of acute symptoms in connection to DCS / AGE with hyperbaric oxygen in the chamber. In some cases other treatments were initiated or a relationship of symptoms to dive behaviour could be excluded.

Discussion:

Our scuba divers showed a broad spectrum of different symptoms and disorders. Profound knowledge was and is necessary to pick out those for the adequate therapy.
For this reason we need specific Diving & Hyperbaric Medicine centers who are able to cover the acute hyperbaric treatment on one hand and different diagnostic areas, especially those in the ORL-region, on the other hand.

P-24 CARBON MONOXIDE POISONING TREATMENT IN A CLINICAL HYPERBARIC CENTER – A CASE SERIES ANALYSIS.

Francisco Guerreiro[1, 2], Rui Ganilha[1], António Anão[1]

[1] Subaquatic and Hyperbaric Medicine Center – Portuguese Navy - Lisbon - Portugal
[2] Naval Research Center - CINAV - Portuguese Navy - Portugal

Introduction:

Carbon monoxide (CO) poisoning remains a relevant public health problem. In order to quantify its dimension in our clinical activity spectrum, AA analyse the profile of carbon monoxide poisoning cases, namely epidemiological data, origin of patients referral, clinical symptoms, Carboxyhemoglobin (COHb) tax, therapeutic tables and clinical evolution.

Material and Methods:

AA made a retrospective analysis of 566 carbon monoxide poisoning cases treated in this hyperbaric centre between September 2008 and March 2014. Statistical treatment of data was performed using the mean and standard deviation.

Results:

Majority of the patients were women (62,1%). Average age was 29,61 ± 19,27 years. 536 patients (94,7%) came from Lisbon region hospitals and 30 from distant hospitals. 98% were treated during first 12 hours after rescue. Among most frequent causes of CO poisoning were water heaters (352), and charcoal heaters braziers (104). 8 domestic fires and 6 suicide attempts were reported. 263 patients (46,5%) had Carboxyhemoglobin (COHb) tax between 10-20 and 218 patients (38,5%) had tax among 20-40%. Five were ventilated patients. Clinical findings showed that 81,4% of the patients presented multiple symptoms, mainly persistent headaches and neurologic symptoms (34,1% reported loss of consciousness). Most patients presented no symptoms after first treatment. Only 3 patients were send to our service to perform more Hyperbaric Oxygen Therapy treatments (HBOT) after initial therapeutic session. Most cases (97,2%) occurred in autumn and winter seasons. CO poisoning represents 85% of all emergency treatments performed in our Centre.

Discussion:

CO poisoning is the most important cause of emergency treatments in our service. In a vast majority of patients, a single HBOT was effective for resolution of symptoms. The dimension of this problem justifies more studies concerning the real importance of HBOT in the CO poisoning treatment.

Keywords:

Carbon monoxide poisoning, Carboxyhemoglobin, Hyperbaric Oxygen Therapy.

P-25 DELAYED BLOOD BRAIN BARRIER DISRUPTION AFTER SHALLOW WATER DIVING: CASE PRESENTATION AND DISCUSSION

Hadanny A[1,2], Tal S[2,3], Fishlev G[1,2], Efrati S[1,2,4,5]

[1]The institute of Hyperbaric Medicine, Assaf Harofeh Medical Center, Zerifin, Israel
[2]Sackler School of Medicine, Tel-Aviv University, 69978 Tel-Aviv, Israel.
[3]Imaging Division, Assaf Harofeh Medical Center, Zerifin, Israel
[4]Research and Development Unit, Assaf Harofeh Medical Center, 70300 Zerifin, Israel.
[5]Sagol School of Neuroscience, Tel-Aviv University, 69978 Tel-Aviv, Israel.

Background:

An experienced, healthy, 22-year-old male diving instructor experienced headaches and left side numbness starting 24 hours after after diving at 6 meters for 25 minutes with no decompression violations. When symptoms accrued he was admitted to the nearest ER from where he was discharged after normal neurological examination and normal brain contrast induced CT scan.

Methods:

The diver was admitted to our emergency room (ER) (Assaf-Harofeh medical center, Israel) due to headaches and left side numbness, 3 days after surfacing, when his symptoms worsened. At his arrival the neurological evaluation revealed left arm and left leg hypoesthesia. Brain MRI scan with FLAIR post Gadolinium injection sequence revealed significant diffuse meningeal enhancement indicating significant blood-brain-barrier (BBB) disruption (Figure-1A and 1D). #

Results:

The patient was treated with four daily Hyperbaric Oxygen Therapy (HBOT) sessions of 2ATA, 100% oxygen for 90 minutes, resulting in significant clinical improvement even though some level of headache continued. A follow-up MRI revealed partial improvement in meningeal enhancement (Figure 1B and 1E). The patient continued with 10 additional daily HBOT sessions ending with complete relief of symptoms. A 2nd follow up MRI, demonstrated complete resolution of the BBB disruption with normal FLAIR sequence (Figure 1C and 1F).

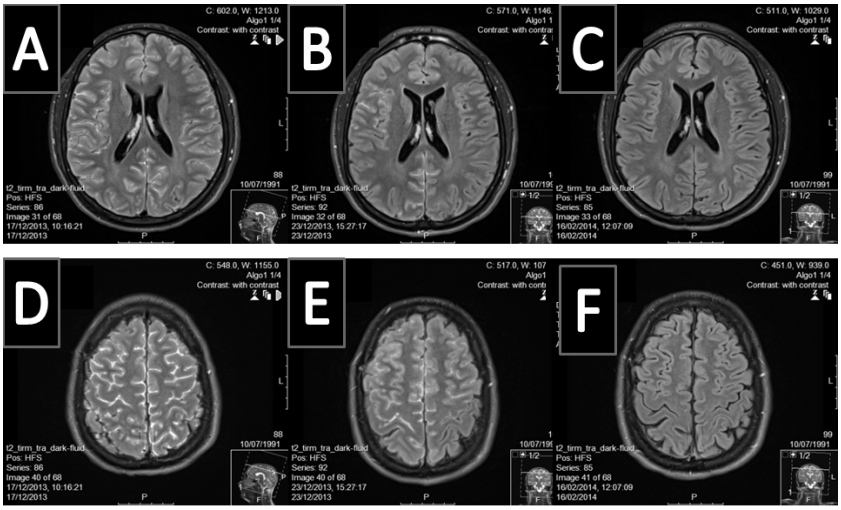

Figure-1: FLAIR post gadolinium images on presenation (A,D) show massive diffuse hyperintensity in CSF spaces which represent enhancement of the meninges. Notice no focal lesions, gray matter or white matter changes observed. One week later after 4 HBOT sessions (B,E) images show decreased enhancement of the meninges. One month after presentation and total of 14 HBOT sessions, the images (C,F) show normal brain MRI.

An echocardiogram evaluation revealed a Patent Foramen Ovale.

Discussion:

The case represents atypical shallow water decompression sickness (DCS) culminating in significant BBB damage with unique MRI imaging, delayed onset of symptoms, and effective HBOT treatment.

P-26 NON HEALING WOUNDS CAUSED BY BROWN RECLUSE SPIDER BITES – APPLICATION OF HYPERBARIC OXYGEN THERAPY

A. Hadanny, G. Fishlev, Y. Bechor, S. Efrati

The institute of Hyperbaric Medicine, Assaf Harofeh Medical Center, Zerifin, Israel. Sackler School of Medicine, Tel-Aviv University Israel.

Introduction:

Bites by Loxosceles species spiders (brown spiders) can cause necrotic ulcerations of various sizes and dimensions. The usual care after bites includes analgesics, ice, compression, elevation, anti-histamines and surgical debridement. In some of the cases significant necrotic ulceration may develop due to phospholipase D and hyaluronidase enzymes secreted by the spiders' venom. Moreover, the venom may trigger a complex inflammatory response including complement activation, release of pro inflammatory cytokines and platelets aggregation which further enhances the dermonecrosis.

The use of hyperbaric oxygen therapy (HBOT) for brown spider bites has been previously suggested; however the data so far is relatively scarce. There are only 2 case series describing the beneficial effect of HBOT when initiated 2-6 days after the bite. Unfortunately, in the daily clinical practice, the diagnosis of spider bite related ulcer can be delayed and since in most cases it involves relatively healthy young population, a long time may elapse before HBOT is considered. The use of HBOT during the late non healing phase, weeks-months after the bite, has not been described yet.

Methods:

Analysis of 3 patients with non healing wounds caused brown spider bites, treated at the institute of Hyperbaric Medicine, Assaf Harofeh Medical Center, Israel. Patients were presented 1-3 months after failure of other "conventional" therapies including topical dressings, antibiotics, or corticosteroids. Patients were treated with once daily HBOT, 90 minutes exposure to 100% oxygen at 2 ATA.

Results:

All patients were reported to be previously healthy without any chronic disease. Their ages were 30, 42 and 73years respectively. All three patients were treated once daily for 13, 17 and 31 sessions respectively. The ulcers of all 3 patients healed and there was no need for additional surgical intervention. The HBOT was proved to be safe and no significant side effects were reported in any of the patients.

Conclusions:

Brown spiders vascular injury and its related ischemic injury may culminate in chronic non-healing complicated ulcers even in a relatively young healthy population. If and when it occur, HBOT should be consider as valuable therapeutically tool.

P-27 ANALYSIS OF 605 COMMERCIAL DIVING DCS LOGS: SYMPTOM CLUSTERS STUDY

JP Imbert[1], Tamer Ozyigit[2], Murat Egi[2], Costantino Balestra[3]
1 Divetech, 1543 ch des Vignasses, 06410 Biot, France
2 Galatasaray University, Computer Engineering Department, Ciragan Cad. 36 Ortakoy 34349 Istanbul Turkey
3 Environmental & Occupational (Integrative), Physiology Laboratory / Haute École PH Spaak, 91, Av. C. Schaller 1160 Auderghem, Brussels, Belgium

Introduction

A project was launched by Technip (a leading commercial diving company) to assess the nature of DCS among commercial divers in bounce diving (to the exclusion of saturation diving). The goal was to 1) identify the groups of symptoms associated to the various types of DCS, 2) determine the most important symptoms in each group.

Method

605 decompression sickness incident logs related to commercial diving were stored into a database and anonymized. The logs covered dives using air and heliox, surface supplied and bell bounce diving with bottom depths ranging from 12 to 120 msw. Ascent was performed using in-water, surface-D and bell TUP decompression.
Two Step Cluster Analysis using Squared Euclidian Distances as the measure of similarity was applied to these data. The analysis was performed based on two and three clusters and the percentages of symptoms in each cluster are listed. The symptoms were clustered using Ward's Method according to their occurrence patterns in DCI cases to analyse the similarly between the patient group characteristics and sign and symptom clusters.

Results

Both for two and three patient clusters, the first cluster is formed by pain in or around a joint only. For three clusters, the second cluster consists of predominantly vestibular symptoms and the third cluster is formed by neurological symptoms. The grouping of signs and symptoms is consistent with distribution of the dominant signs and symptoms into patient clusters.

Discussion

We conclude that cluster analysis is a suitable method for classifying DCI manifestations independent of clinical judgment.
The characteristic sign and symptoms for different groups of DCI patients provide a non-biased statistical point of view to clinically useful DCI subclasses on which there is little scientific consensus.
Although clustering techniques cannot substitute expert knowledge and experience in differential diagnosis, they provide an objective point of view to DCS classification.

Project supported by Citeph (France).

P-28 EIGHT YEARS HYPERBARIC INTENSIVE CARE EXPERIENCE WITH THE ARGUS 600 SERIES SYRINGE PUMP

Peter Kronlund[1], Daniel Olsson[2], Michael Nekludov[1], Folke Lind[1]

[1]Hyperbaric Medicine, Department of Anaesthesia, Surgical Services and Intensive Care, Karolinska University Hospital
[2]Department of Clinical Engineering, Karolinska University Hospital, Sweden

Introduction

The Argus 600 syringe pump is a non hyperbaric CE approved device, that have been used in the Karolinska Hyperbaric facility since mid 2006. The volume of treatments is well over 2000 to Jan 2014. The intended use was to perform ICU treatments drug therapy regardless of the impossibility to use the standard ICU pump of the clinic.

Material & Methods

A trace record of preventive maintenance and negative events in digital form by the Karolinska Bimedical Engineering unit make it possible to monitor the history of every single device.The energy output for the pump is NiMH(NickelMetalHybrid)cell with 8 hrs@5ml/hr.
All treatments are performed on battery supply.

Results

From the Biomedical engineering department we can look at preventive maintenance records; that displays battery changes and software updates.
When looking at battery total time we can simplify it to 2000 treatments times 2hrs resulting in 4000hrs of treatment time.

Discussion

From the clinicians' point of view, the pump is considered to be reliable in use, even in treatment of highly circulatory unstable patients in septic shock. The main problem reported was "translation " from mg/kg/time to ml/ hour of volume setting and deviation from bolus programming method used in the rest of the clinic. The accuracy of volume delivery was affected to some degree by the changes in ambient pressure inside the chamber, which necessitated adjustments in the pump settings during the compression phase.
Therefore we do look forward to see the new Argus syringe pump certified for HBO service and including ICU software programme introduced on the market.

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P-29 FIRST TESTING PROCEDURES FOR DIALYSING PROCEDURE DURING HBO TREATMENT

Peter Kronlund[1], Daniel Olsson[2], Bella Kajtazi[2], Magnus Andersson[2], Michael Nekludov[1], Folke Lind[1]

[1]Hyperbaric Medicine, Department of Anaesthesia, Surgical Services and Intensive Care, Karolinska University Hospital
[2]Department of Clinical Engineering, Karolinska University Hospital, Sweden

Introduction

In order to keep continous CVVHD (Continous Veno-Veno Hemo Dialysis) during the Hbo treatment there is a clinical advantage to not interrupt the dialysis procedure. The CVVHD is a standard programme in critical patient care.

Material & Methods

The Gambro Prismaflex is the standard device in the ICU unit. The intended use is to be continued in 12V auxillary power supply. During transport from and to ICU the battery power is used. During transport the weight of fluid system is deactivated
This development work includes risk analysis, risk assessment and documentation to fulfill a certification procedure.

Results

So far there has been no problems with the different fluid interfaces over the membrane.One point to observe is the fluid-gas shifting level in the bubble trap system
Especially during the decompression phase. One other source could be the reference pressure sensor. For the moment further testing procedures of this device is in the schedule

Discussion

Since the aim for the Karolinska HBO department is to adapt itself to the highest level of ICU treatment, there is a need to try and meet these standards,and create a good relationship with producers of medical technical device. This will result in modern critically ill treatment brought int the hyperbaric environment
From the clinicians' point of view treatment of highly circulatory unstable patients in septic shock the introduction of the CVVHD programme provides further progress in patient rehabilitation

References

EC Directive 93/42 Medical device directory (medical treatment chambers)
EC Directive 97/23 Pressure equipment directive
EN 14931Pressure vessels for human occupancy (PVHO)

P-30 MULTIDISCIPLINARY PROCESS OF DIAGNOSIS AND TREATMENT OF THE RIGHT LEFT SHUNT

P. Longobardi**, P. Limoni *, P. Lega**

* Neurosurgeon, NeuroSonologist – Bologna (I); ** Centro Iperbarico Ravenna (I)
Author address: Pasquale Longobardi, Centro iperbarico, via Augusto Torre 3, 48124 Ravenna. Tel. 0544-500152, email: segreteria@iperbaricoravenna.it

Introduction:

The Hyperbaric Center of Ravenna has developed a process to evaluate the right left shunt, including PFO, based on the evaluation of three parameters: Transcranial Doppler with bubble counts; arterial blood gas analysis during high flow oxygen breathing; transcutaneous oximetry.

Material:

From May 2011 to May 2014 181 procedures were performed to search for right left shunt. 22 procedures for staff that assists patients in HBOT; 12 as a control after PFO closure; 6 for recurrent ischemic cerebral or headache. This analysis refers to 166 cases (where all data were available), 109 males and 57 females. 26% (44 patients) had suffered an episode of neurological DCI; 24% (n=40) cutaneous DCI; 16% (n=26) both types of DCI; 34% (n=56) no DCI (the process was administered to verify diagnosis made elsewhere).

The need for transesophageal echocardiography is evaluated by a cardiologist. If this technique shows no PFO, (or if the PFO size is inconsistent with other available information), then pulmonary angiography is required to rule out extracardiac shunts.

The decision on PFO closure depends on an analysis of six risk factors: previous stroke or neurological DCI; multiple ischemic lesions in cerebral MRI; genetic risk factors for thrombophilia (factor II, V, homocysteine); atrial septal aneurysm (transthoracic echocardiography); large right left shunt (baseline transcranial Doppler); PFO diameter $\geq$ 4 mm (transesophageal echocardiography) .

Results:

40 patients (24%) had no shunt; 126 (76%) had a shunt. The follow-up was annual.

Conclusion:

The assessment of three parameters allows you to accurately assess the severity of the right left shunt. In the event that the shunt is mild, closure is not required and rules of good practice to avoid triggering bubbles in decompression are proposed. In the case of PFO closure, the fitness evaluation to resume diving is scheduled six months after surgery.

P-31 RIGHT-TO-LEFT SHUNTS AND DECOMPRESSION SICKNESS IN SCUBA DIVERS: A RETROSPECTIVE CONTROLLED STUDY OF 634 CASES TREATED AT A SINGLE INSTITUTION.

Pierre Louge, Emmanuel Gempp, Sébastien De Maistre, Michel Hugon.

Department of diving and hyperbaric medicine, Ste Anne's military teaching hospital, 83800 Toulon Cedex 9, France.

Introduction

Right-to-left shunt (RLS) is a risk factor for neurological decompression sickness (DCS). The aims of this study were 1) to evaluate the relationship between this condition and the different clinical features of DCS and 2) to determine if the detection of RLS is beneficial for primary DCS prevention

Methods

Six hundred thirty four patients out of 722 referred for DCS and 259 asymptomatic divers, serving as controls, were enrolled between 1998 and 2013. Type of DCS was based on clinical examination and laboratory investigations. RLS were assessed by contrast transcranial Doppler ultrasonography (TCD) at rest or after straining manoeuvre with classification: No RLS (< 5 bubbles), Minor RLS (> 5 bubbles < 20), Large RLS (> 20 bubbles).

Results

Prevalence of RLS in the control group was 31% (21% with large RLS) and control divers were younger than DCS patients (34.7 +/- 9.0 vs. 43.6 +/- 11.3, $p < 0.0001$).
We found a close relationship between any neurological DCS and the presence of large RLS (OR 5.2, 95% CI 3.6-7.4; $p < 0.0001$) including: spinal cord DCS (OR 2.8, 95% CI 1.9-4.1), cerebral DCS (OR 3.9, 95% CI 2.4-6.5) and inner ear DCS (OR 10.4, 95% CI 6.7-16.0). There was also a significant association between cutaneous DCS and large RLS (OR 9.6, 95% CI 3.3-28.2, $p <0.0001$). Inner ear DCS and cerebral DCS were associated with minor RLS (OR 4.7, 95% CI 2.4-9.2 and OR 4.4, 95% CI 2.2-9.0, respectively; $p < 0.0001$), but not spinal cord DCS ($p = 0.8$).
The diagnostic accuracy of TCD for predicting DCS occurrence or ruling out this event through the presence of RLS was found to be low indicating that this method as screening tool is questionable (Table 1).

Conclusion

This study confirms that RLS is a risk factor for the development of neurological and cutaneous DCS. The eviction of divers carrying this anatomical predisposition in primary prevention could have an impact on reducing the number of DCS but the reliability in clinical practice appears limited.

	Large RLS	No/Minor RLS	OR	IC	Se	Sp	LR-	LR+	p
Control Group	55	204							
Spinal Cord DCS	110	145	2.8	1.9-4.1	67 %	58 %	0.6	1.6	<0.0001
Cerebral DCS	50	47	3.9	2.4-6.5	48 %	81 %	0.6	2.5	<0.0001
Inner Ear DCS	148	53	10.4	6.7-16.0	73 %	79 %	0.3	3.5	<0.0001
Ambiguous DCS	9	38	1.1	0.5-2.5	86 %	16 %	0.9	0.9	NS
Cutaneous DCS	13	5	9.6	3.3-28.2	16 %	97 %	0.9	8.0	<0.0001
MS DCS	3	13	1.2	0.3-4.2	94 %	6 %	1.0	0.9	NS

RLS = Right to Left Shunt; Se = sensitivity; Sp = specificity; LR = Likelihood Ratio; MS = Musculo-skeletal

Table 1: Distribution of right-to-left shunts across types of neurological decompression sickness

P-32 HBO IN THE TREATMENT OF NEUROLOGICAL SEQUELAE OF DCI IN BREATH-HOLD DIVERS (TARAVANA) – CASE REPORT

B.Markuš, J.Milošević, T.Jovanović
Centre for Hyperbaric Medicine, Belgrade, Serbia

Introduction:

Taravana is a form of DCI which occurs in breath-hold divers who are exposed to large number of dives, in short time periods, in depths of 30 - 40 meters. Usual symptoms are dizziness, nausea, fatigue, paralysis and death. Early diagnosis and proper recompression therapy are important, considering that the consequences of inadequate or omitted treatment can be serious.

Method:

U.J., male, 30 years of age, checked in to the local hospital, because of problems he had after surfacing, which consisted of headache, exhaustion, slow motion and poor concentration. In 5 hours, he had between 50 - 80 dives, with maximal depth of 50m. On MSCT of brain, 3 ischemic lesions, were diagnosed. During the preparation for the recompression treatment, epileptic seizure occurred and as a result recompression treatment was not performed. The patient was treated with symptomatic and antiepileptic therapy.
Patient contacted the Center for hyperbaric medicine-Belgrade, after well over a month and HBO was performed for the treatment of ischemic brain lesions symptoms. Two series of HBO on 2.0 ATA, 70 minutes, 40 treatments over a 4 month period were performed. Antiepileptic therapy was also applied.

Results:

HBO treatment resulted in coordination improvement and regression of headache and vertigo. Problems with poor concentration are still present. During the HBO therapy seizures did not reappear.

Conclusion:

Considering the serious nature of neurological type of DCI, as well as the possible consequences, it is necessary to include recompression therapy and HBO. In patients with epileptic symptoms, the use of HBO with correct premedication is recommended. Breath-hold diving as a growing sport activity presents a risk factor for the occurrence of taravana.

P-33 HYPERBARIC OXYGEN TREATMENT IN RADIATION INDUCED PROCTITIS: REVIEW OF A SINGLE CENTER EXPERIENCE

Tânia Meira[1], Cátia Magro[1], António Anão[1], Francisco Guerreiro [1,2]

[1] Subaquatic and Hyperbaric Medicine Center – Portuguese Navy - Lisbon - Portugal
[2] Naval Research Center - CINAV - Portuguese Navy - Portugal

Introduction:

Gastroenterological disorders after pelvic radiotherapy (RT) are developed in 5% to 20% of patients. Radiation-induced proctitis widely affects patients' quality of life and is one of main disorders after pelvic RT. Compared with demanding and difficult treatments, Hyperbaric Oxygen Therapy (HBOT) could prove a safe and effective alternative. Our aim was to analyze the efficacy of HBOT for the treatment of radiation-induced proctitis and the influence of some external variables.

Material and Methods:

Retrospective review of clinical records of all patients with radiation-induced proctitis, undergoing HBOT treatment in our Centre, between January 2010 and December 2013. Patients received 100% oxygen for 90 minutes at 2.5 atmospheres (ATA), 5 days per week. All patients had persistent symptoms for at least 6 months, after ending RT.

Results:

Thirty patients, 73% men, with mean age of 66 years (range, 39-80) were included in the study. They had each been treated with radiation therapy for prostate (n=20), cervix/uterus (n=7), rectal (n=2) and bladder (n=1). Mean period of time between radiotherapy and observation at the Centre was 32 months. Previous endoscopic therapy with argon plasma coagulation was performed in 90% (n=27). 50% needed blood transfusions previously to HBOT. Mean number of treatments was 62, with a mean therapy period of 5.8 months.
73.3% were asymptomatic after HBOT at 6 months follow-up. 20% (n=6) had a colonoscopy after HBOT, showing a reduction of lesions. No HBOT side effects were verified.

Discussion:

HBOT has proven to be an effective therapy for radiation-induced proctitis, amending the damaged tissues, reducing correlated bleeding and improving patients' quality of life. Results are similar to other clinical trials, but further studies with larger samples are recommended.

Keywords:

Hyperbaric Oxygen Therapy, proctitis, radiation

P-34 INCIDENCE OF SIDE EFFECTS DURING HYPERBARIC TREATMENT – RETROSPECTIVE ANALYSIS OF 37,022 TREATMENT SESSIONS

O. Meir, Y. Bechor, G. Fishlev, J. Bergan, M. Friedman, S. Efrati
Assaf-Harofeh Medical Center, Israel

Background:
Hyperbaric oxygen (HBO) serves as primary or adjunctive therapy for a diverse range of medical conditions. The therapy is generally safe and well tolerated. Most side effects are mild and reversible, although severe consequences can occur in rare cases. The aim of this study was to evaluate the incidence of side effects and complications in diverse population cohort treated treatment at the hyperbaric institute of "Assaf Harofeh Medical Center" Israel.

Methods:
Retrospective analysis of 37,022 elective or emergency hyperbaric oxygen treatments administrated to 1380 patients during 3-yr period (2011-2013). Data was collected from the patient files and included all recorded patient complains and phisician diagnoses of possible side effects.

Results:
From a total of 1380 patients, 243 (17.6%) reported side effects. Ear pain was the most common complain (11.1%), from whom 95% were diagnosed with barotitis. Other less frequent side effects included: shortness of breath (1%), hypoglycemia (0.6%), sinus squeeze (0.57%), chest pain (0.5%), and claustrophobia (0.3%). Only two patients (0.14%) developed seizures during the treatment. The first patient, had history of extensive stroke, and the second patient, was treated with Table 6A due to an air embolism. Only 14 patients (1%) had to terminate their treatment due to side effect.

Conclusions:
Hyperbaric oxygen therapy is safe and severe complications rarely occur. Since barotitis was the most common complication, and since it can be prevented in most cases, patients should be well educated before the first HBOT session and should be repeatedly reminded during the course of their treatment.

P-35 THE CLINICAL EXAMPLES OF SUCCESSFUL APLICATION OF HBO IN THE TREATMENT OF SOFT TISSUE INFECTIONS

J.Milošević, B.Markuš, T.Jovanović
Centre for Hyperbaric Medicine, Belgrade, Serbia

Keywords:
Soft tissue infection, Diabetes mellitus, HBO.

Introduction:

Soft tissue infections are commonly caused by mixed aerobic and anaerobic bacteria. They usually occur in patients suffering from diabetes mellitus, vascular insufficiency, immunocompromised and traumatic patients or after surgical procedures.
Since anaerobic infections are life threatening, the timely introduction of HBO treatment as the therapy of choice, along side surgical and antibiotic therapy is important in order to reduce the morbidity and mortality.
The aim of this study was to show the effects of HBO in the treatment of soft tissue infections.

Method:

In December of 2013, 7 patients with severe soft tissue infections, were admitted in the Center for hyperbaric medicine, Belgrade. The infections were of different etiology – diabetes mellitus, complication after hernioplasty, complication after injection of narcotics, flegmona of perianal region.
The infections were located in the different body areas.
HBO treatment was introduced, alongside existing pharmacotherapy and daily wound care.
Treatment protocol included 100% oxygen at 2.8 ATA, 90 minute, 5 exposures every 8 hours, followed by 2.5 ATA, 70 minute daily, 15-30 exposures totally.

Results:

After completion of HBO therapy, the infection was eliminated in all the patients. In 3 patients the wound completely closed, and in 4 other together with the infection elimination the wound was greatly reduced, but they needed additional treatment for next 2 months.

Conclusion

Serious nature of soft tissue infections demands early introduction of HBO, together with aggressive treatment protocols, without delay. Considering the complexity it is necessary to have a multidisciplinary approach to treatment. Clinical example from our practice show the importance of HBO in the treatment of soft tissue infections regardless of location or etiology.

P-36 A 24 YEAR EXPERIENCE OF A UNIVERSITY HYPERBARIC MEDICINE CENTER

M. Cimsit, B. Oroglu, A. Cakkalkurt, S. Aktas, AS Toklu

Department of Underwater and Hyperbaric Medicine of Istanbul Medical Faculty is the oldest and well developed hyperbaric center in Turkey serving for more than two decades. This study aims to present our center which we think is a unique model and share our experience of 24 years.

The center:

Underwater and Hyperbaric medicine was first started as a part of Medical Ecology and Hydroclimatology in Istanbul Medical Faculty in 1984. Five years later it became a separate department and was recognized as a specialty where residents are trained for three years. Initially, patients were treated in a small multiplace chamber that served for eight years. In 2001, the clinic was moved to its own building but worked with only two monoplace chambers until 2008, in which a new multiplace chamber was installed. The center now serves in a separate four-floor building with in-patient (21 beds) and out-patient departments, a multiplace chamber and a physiotherapy unit.

Organization:

Currently, apart from the academic staff, ten residents, six nurses, one chamber operator and one physiotherapist are working as the medical staff at the center. Patients who either apply themselves or are referred by other departments are first evaluated by residents and specialists. For the ones that hyperbaric oxygen therapy is indicated, a lung x-ray is always seen before treatment. Treatment protocols are in line with ECHM and UHMS recommendations. HBO is usually applied at 2.4 ATA and the duration is two hours. All sessions, including emergency calls, are attended by a resident or a nurse in the chamber. This way, patients are closely monitored for any sign of complication during session.

Experience:

Since 1990 to the end of 2013, 2473 patients were treated in our chambers and the total number of treatments was 63136. For all the years the leading indication was diabetic foot, with 591 patients and 20731 sessions. No severe blood loss anemia and brain abscess were treated and anoxic encephalopathy was the rarest condition in 24 years. Decompression sickness cases make only the 4.97 % of our patients and only 1.5 % of our sessions. Carbonmonoxide intoxicities tended to decrease in time where as sudden hearing loss increased and idiopathic aseptic necrosis treatments almost exploded in the last five years. The most common side effect was middle ear barotrauma as expected with a total of 32 cases and not a single oxygen toxicity or lung barotrauma were seen. The barotraumas incidence was almost same for monoplace and multiplace chambers.

P-37 DIETARY NITRATE REDUCES OXYGEN COST FOR DYNAMIC APNEA

Alexander Patrician and Erika Schagatay
Dept of Health Sciences, Mid Sweden University, Östersund, Sweden.

Introduction:

Dietary nitrate has been shown to reduce oxygen cost in a variety of situations, although in sports involving apnea results have been conflicting. Nitrate supplementation was found to increase saturation after static apnea (Engan et al 2012) – but was reported to have the contrary effect by Schiffer et al (2012), while they reported no effect on simulated dynamic apnea (DYN).

Methods:

We studied the effect of dietary nitrate on post-dive arterial oxygen saturation (SaO_2) after DYN. Fourteen experienced male apneic divers with mean (SD) age 33(11) years volunteered. They performed 2 x 75 m DYN in a pool with 4.5 min recovery between dives, one day after ingesting 70 ml of organic beetroot juice (nitrate content 5.000 mmol), another day after ingesting placebo juice with the nitrate removed (nitrate content 0.003 mmol). Juices were ingested 2.5 h before the tests at a randomized, blinded order. SaO_2 was measured via finger pulse oximetry. For 11 subjects, mean values from their two dives in each condition were used, and in three subjects with incomplete data in some dives, data from the completed dive and the corresponding dive from the other condition was used.

Results:

Nitrate ingestion resulted in higher SaO_2 at 20 s after the dives (86.3$\pm$10.6%) compared to placebo (79.4$\pm$10.2; $P<0.01$). Nadir values were 83.1(11.1) after beetroot ingestion and 77.4 (11.1) for the placebo trial ($P<0.05$).

Discussion:

Our result suggests an oxygen conserving effect of nitrate, which is contrary to the "no effect" reported by Schiffer (2012), but in line with the effect on static apnea found by Engan (2012). The data by Schiffer reveals a tendency for an effect, not reaching statistical significance in their small sample (n=10). An oxygen conserving effect by dietary nitrate, as suggested by our study, could have important applications in competition apnea and other diving.

P-38 BLOOD GLUCOSE REAL TIME MONITORING AND RECORDING DURING SCUBA DIVING: CASE REPORT

Massimo Pieri [1,2], Danilo Cialoni[1,3], Salih Murat Egi[2,4], and Alessandro Marroni [1,2,3]

1 DAN Europe Research Division, Roseto degli Abruzzi, Italy
2 Caddy Project: Cognitive Autonomous Diving Buddy (FP7 Marie Curie, grant no. 611373)
3 Phypode Project: physiopathology of decompression (FP7 Marie Curie, grant no. 264816)
4 Galatasaray University, Department of Computer Engineering, Istanbul, TURKEY
E-mail: dcialoni@daneurope.org

Introduction:

Type 1 Diabetes Mellitus (DM) was traditionally considered a contraindication to scuba diving for the risk of complications such as sudden hypoglycaemia.
Even if this is currently being reconsidered, there are still many doubts about diving and diabetes mainly because of the impossibility to check Blood Glucose values during diving.
To prevent worsening of hypoglycaemia and to correctly interpret hypoglycaemia-like symptoms whilst diving, diabetic divers could benefit from real- time Blood Glucose (BG) monitoring during their dives.
The scope of this work is developing a continuous BG monitoring system using a real time monitor during diving.

Materials and Methods

A Female diver, N.B. (Female, 29 yo, weight 53 Kg, height 1.57 mt) was monitored every 5 minutes on every dive, by a dedicated subcutaneous glucose monitor (Dexcom G4) hosted in a waterproof case (Dive system Furyo diving computer) and the BG level was shown on the Furyo's display, allowing the diver to continuously check her BG. Data were recorded every 5 minutes during dives and also during 1 hour before and 1 hour after the dive.

Results

With our prototype system for continuous BG monitoring we have had the opportunity to continuously check the BG value during all the time of diving. 26 dives were recorded; no statistical difference between BG recorded every 5 minutes pre, during and post dives could be found (P Value= 0,2113). However occasional hypoglycaemia was observed (< 70mg/dl).

Discussion

Our data show that even if scuba diving does not imply significant risks of hypoglycaemia the possibility of occasional hypoglycaemia exists. A real time BG monitoring system that Diabetic Divers can use while diving can significantly improve their diving safety.

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P-39 MECHANICAL VENTILATION IN THE HYPERBARIC CENTERS : EUROPEAN SURVEY

Pignel R., N. Rey , A Lyazidi , P Avrillon, M Pellegrini, R. Cordioli , JC Richard

Most hyperbaric centers are required to handle emergencies. They must be able to provide mechanical ventilation and monitoring during the sessions of hyperbaric oxygenation, regardless of the recompression table used (high pressure, use of helium) .
The purpose of this study is to identify practices of mechanical ventilation in a hyperbaric environment.

Method

We used the site Oxynet (www.oxynet.org). A survey was developed in English and sent to 181 hyperbaric centers. We conducted three reminders by email.

Results

Forty hyperbaric centers responded, representing 22 % of European centers, from 13 different countries. A strong majority (92%) centers provide hyperbaric emergencies. Only 70 % (28 /40) take care of ventilated patients and 42% treat children with an age or weight limit.
The first restrictions on the realization of mechanical ventilation are the lack of specific device and lack of monitoring system.
There are 57 ventilators across 28 centers. We found 19 Servo 900, 15 Siare 1000, 9 Oxylog and only 5 Servo -i HB.
The majority of centers modify the ventilation settings during compression except users of Servo -i- HB

Conclusion

Too few hyperbaric centers support ventilated patients due to lack of reliable high pressure device and accepting helium.

P-40 INVESTIGATING THE COGNITIVE FUNCTION OF TRAINED FREE-DIVERS WITH A PSYCHOMETRIC TEST IN THE MARES ICON NET READY DIVE COMPUTER – A FEASIBILITY STUDY

G Popov[1], C Balestra[2, 3], P Lafère[3, 4, 5], V Papadopoulou[2, 6], M Rozloznik[2], F Tillmans[2, 7], W Hemelryck[2, 8] and G Distefano[1]

1 Mares, S.p.A., Rapallo, Italy; 2 Haute Ecole Paul-Henri Spaak, Environmental, Occupational & Ageing Physiology Laboratory, Brussels, Belgium; 3 DAN Europe Research Division; 4 ORPHY, UFR Sciences et techniques, Université de Bretagne Occidentale, Brest, France; 5 Unité de soins hyperbares, CHRU de la Cavale Blanche, Brest, France; 6 Department of Bioengineering, Imperial College London, London, UK; 7 Ulm University Clinic, Dept. Anesthesiology, Ulm, Germany; 8 Centre of Hyperbaric Oxygen Therapy, Military Hospital "Queen Astrid", Brussels, Belgium. Contact: g.popov@mares.com

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Introduction:

The aim was to test the implementation of the psychometric test in the Mares Icon dive computer for real use underwater for scientific purposes. As a first feasibility study, we looked at investigating potential differences in cognitive function of trained free-divers during breath hold on the surface and immersed in 1m depth.

Methods:

Thirteen free-divers, eight male and five female (mean age 41.85 ± 8.9 years), body composition (BMI 24.42 ± 3.66), were tested with the math processing ("math-proc") psychometric test from Psychology Experiment Building Language (PEBL) implemented in Mares Icon dive computer. The experiment consisted of three runs: one run on the surface with normal breathing for base-line and two randomly assigned runs, one during static apnea out of water in supine position and another during static apnea at 1m depth (24°C). Number of correct and time-out responses were analyzed. Matched statistical comparison between the three tests was done with ANOVA followed by Tukey post hoc test.

Results:

It proved possible to run underwater tests on the Icon dive computer and retrieve all information without losses. Some subjects reported difficulty reading the small letters underwater and were thus excluded (originally 13 people, only 8 kept). No significant differences were found in number of correct answers or number of "time-out (over 4 seconds)" between the test taken while breath-holding immersed, breath-holding out of the water or no breath-holding out of the water.

Discussion:

The eight subjects recruited for this study are all trained breath-hold divers who can comfortably breath-hold for well over 3 min. The duration of the math-proc test was 1 min 20 sec on average (20 trials) so this was well-within the comfort zone of breath-holding for our free-divers, which could explain why no significant differences were observed. However, to be conclusive, we would need the detailed trial by trial responses as well as exact time to complete for the math-proc test which is not stored in the current Icon implementation.

Conclusion:

We conclude that it is in principle possible to use the Mares Icon dive computer math-proc test for underwater studies and recommend the following improvements on future implementations: bigger letter display during the test, as well as storing the exact time to complete and trial information.

P-41 PREARRANGEMENTS FOR ICU PATIENTS UNDERGOING HBO THERAPY

A. Preininger

In the past, the treatment of an ICU patient under hyperbaric condition was a very stressful time for tenders and technicians.
The goal was to minimize the effort under pressure and to reduce the time of preparation.
We developed a standardized form for all Intensive Care Units at our hospital to prepare the patient for emergency treatment or repeated treatment.
All details are documented in this form by the nursing staff.

The form has 5 sections.

The first section covers paracentesis, x-ray and the depth of tube.
Performing a thoracic drainage is easier at ICU.
For reducing time to start HBO, the cuff could be filled with water at the ward.
The second section is about all organizational steps. Identification (Patient), laboratory tests, special deseases or allergies.
The third section is about medical devices, e.g.: pacemaker, hearing aid device or feeding tube and indwelling catheter.
The fourth section covers sedation, ventilation and the catecholamines. All medication has to be present bedside, when the patient is leaving the ICU. Depending on the estimated dive/therapy and transportation time the medication has to be prepared in syringes for the whole time.
Also the infusion systems must be compatible for hyperbaric atmosphere.
The fifth section is about special intensiv care bedsystems. At our hyperbaric chamber patient don´t need to change bed for HBO.
And some special points,e.g. material for fixing the patients arms. And also that any form of aromatherapy is permitted two or three hours before the treatment.
The standardized form is for four dives and accompanies the patient each time he/she left the ICU for HBO.

Conclusion:

For nursing staff it is now much more easier to prepare the patient faster and tenders are not forced to recheck every detail before diving, they relay now on a check of the standardized form

P-42 CARBON MONOXIDE (CO) PRODUCED BY WOODEN PELLETS?

(1) Richard Pyrek, (2) Dr.med. Birger Freier, (3) Thomas Kutschker

1. Richard Pyrek Inspektionsrauchfangkehrer Berufsfeuerwehr Stadt Wien Schießstattgasse 359 A-2013 Göllersdorf
2. Dr.med. Birger Freier Facharzt Anästhesie und Notfallmedizin Ärztlicher Leiter Rettungsdienst der Stadt Offenbach am Main Rhönstraße 10 D-63071 Offenbach am Main
3. Thomas Kutschker Master of Desaster Feuerwehr Offenbach am Main Rhönstraße 10 D-63071 Offenbach am Main

Introduction

Depending on the production and storage of wood Pellets are able to produce Carbon Monoxide.

Material, Methods

In an Experiment, we measured the development of CO, CO_2, O_2 and Ex-Gas simultaneously in four identical volumes of 15 Liters. Each containment was filled with 12 KG of wood Pellets. The four looked containers where separated in two and settled in two different room climate. Even the continues measuring of room humidity and Temperature at the same time took place. The measuring of development of CO, CO_2, O_2 and Ex-gas was taken after a timetable every second day after 48 h at the same time.
A fifth Container with the Volume of 100 Liter was even filled with 12 KG wood Pellets unmotionaless for the Period at 20 C° the interest is, if a larger air cushion has an influence of the different Gas concentration

Results

Wood Pellets produce CO under define conditions even in limited amounts.
Even the pressure of the pellets, a process of rising temperature during the storage without any air circulation are reason for the increasing CO development.

Discussion

It is important to invest more in the protection of employers however even for private persons because not even a larger amount of wood pellets could increase life threatened CO concentrations especially in normal area of a flat or in-house.

P-43 CARDIOVASCULAR RESPONSE TO MILD NORMOBARIC AND HYPERBARIC HYPEROXIA IN RAT: A PILOT STUDY

M. Rozloznik[1, 4], L. Molcan[2], P. Svitok[2], M. Mach[3], C. Balestra[1, 5], M. Zeman[2]

[1] Environmental, Occupational & Ageing Physiology Laboratory, Haute Ecole Paul-Henri Spaak, Brussels, Belgium; [2] Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia; [3] Institute of Experimental Pharmacology & Toxicology, Slovak Academy of Science, Bratislava, Slovakia; [4]DNB consult, s.r.o., Kezmarok, Slovakia; [5] DAN Europe Research Division

Introduction:

Hyperoxic exposure has significant effects on the cardiovascular system, including bradycardia, hypertension, vasoconstriction and endothelial dysfunction. However, the role of ambient pressure and pO_2 during hyperbaric hyperoxia in cardiovascular adjustment is still not clear.

Methods:

The expression of hyperoxic bradycardia during normobaric and hyperbaric hyperoxia were investigated radio-telemetrically in un-anesthetized rats. Five Wistar rats five weeks old, weighted 352 ± 19 g and kept on a 12:12-hour light/dark cycle were exposed for 30 minutes to mild hyperbaric hyperoxia (ppO_2 63 kPa, p_{abs} 300 kPa) and normobaric hyperoxia (ppO_2 67 kPa, p_{abs} 100 kPa). Heart rate, heart rate variability and spontaneous baroreflex activity were calculated from aortal pulse waves and corrected for locomotor activity.

Results:

Hyperbaric and normobaric hyperoxic exposure led to development of significant hyperoxic bradycardia ($p \leq 0.001$; $p \leq 0.01$ respectively), what was not observed when animals were exposed to normobaric normoxia in the same experimental setting. Changes in the heart rate were not accompanied significant changes of heart rate variability, spontaneous baroreflex activity, body core temperature or locomotor activity.

Conclusions:

This study showed feasibility of telemetric measurement during hyperbaric exposure. In addition, our data suggests that mild hyperoxia plays a relevant role in cardiac regulatory mechanisms, however more experiments are needed to fully understand underlying mechanisms.

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FRP/2007-2013/ under REA grant agreement n° 264816, VEGA 1/0686/12, 2/0107/12 and NOREG.

P-44 COPING WITH AN UNDERWATER LIFE-THREATENING EVENT DURING SCUBA DIVING: A CASE STUDY

M. Rozloznik[1, 6], K. Stebelova[2], V. Papadopoulou[1, 3], F. Tillmans[1], Y.Tkachenko[4], W.Hemelryck[1], M. Zeman[2], R. Pudil[5], C. Balestra[1, 7]

[1] Environmental, Occupational & Ageing Physiology Laboratory, Haute Ecole Paul-Henri Spaak, Brussels, Belgium; [2] Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia; [3] Department of Bioengineering, Imperial College London, London, UK; [4] National Center for Hyperbaric Medicine in Gdynia, Medical University of Gdansk, Poland; [5] 1st Department of Internal Medicine – Cardioangiology, Medical Faculty, Charles University, Hradec Kralove, Czech Republic; [6]DNB consult, s.r.o., Kezmarok, Slovakia; [7] DAN Europe Research Division

Introduction:

SCUBA diving is considered as a relatively safe sport activity (1). However, diving beyond recreational limits (e.g. technical, cave diving) may expose human beings to extreme psychological and physiological stress. Such a stress reaction can be further elevated during an emergency event. Here the physiological response to accidental out of gas emergency event is presented.

Case Study:

A 39-years old diver performed a dive to 70m on TMX (10/54). After 16 min of bottom time he experienced an accidental out of gas situation, commenced buddy breathing and aborted the dive with accelerated decompression procedure on EAN 50 and pure oxygen respectively. After the dive he was DCS symptom/signs free and no visible vascular bubbles were present in the blood stream as confirmed by transthoracic echocardiography and automatized bubble counting software (2, 3). Analysis of the critical flicker fusion frequency and math-processing cognitive PEBL test showed no difference between pre-dive, dive and post-dive values. Salivary cortisol levels measured 15, 60and 120 min after the dive were respectively 14-, 16- and 2-fold increased compared to pre-dive values. Similarly, urinary cortisol levels corrected for creatinine excretion determined 15, 60 and 120 min after the dive showed the14-, 18- and 14-fold increase compared to pre-dive values, respectively. Urinary aldosterone showed no increase 15 min after the dive compared to pre-dive values. The diver also showed minimal dehydration 15 min after the dive as assessed by specific urine gravity.

Discussion:

To our knowledge this is the first case study where some physiological parameters could be measured during an accidental life-threatening underwater event. This rare case shows that extreme hypothalamic-pituitary-adrenal axis stress response was not accompanied with noticeable alteration in arousal state and/or simple cognitive function test, thus allowing a trained diver to manage such an emergency event.

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FRP/2007-2013/ under REA grant agreement n° 264816.

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P-45 SATURATION DIVING – PROJECT HYDRONAUT.

Sazel, M.[1], Bohacek, P.[2],
[1]Institute of Aviation Medicine, Prague, Czech Republic (sazel@ulz.cz)
[2] Hydronaut - Space Research Center, n.g.o., Czech Republic

Introduction:

In the nineteen-sixties Czechoslovakia was the first landlocked country working on saturation habitats. In 1967 the dive (in Project Permon) was 102 hours in 25 m freshwater depth. Project Hydronaut, connecting saturation diving with the simulation of a space stay, was published at the International Astronautical Congress (Sanda 2010). The Hydronaut Underwater Research Laboratory and Training Station (H3) will be used as a ground-based space analog research facility. Equipped for long-duration stays, H3 allows a simulated space mission. It can be used for physiological and compatibility testing of a crew and developing/testing of new procedures and equipment. The environment below the water‘s surface and the possibility of a long-duration stay provide ideal conditions for basic research in psychology.

Methods:

Health and psychological status of five divers was evaluated in detail last year.

Results:

Three of them have been chosen to stay seven days in the habitat. The residential module will be probably finished this year. A limit of the stay of “hydronauts” at depth is connected with the risk of cumulative oxygen toxicity therefore the maximal depth during air breathing should be 20 m. Maximum change of depth during exits is recommended at about 10 m with regard to dissolved gases in tissue. The final ascent H3 will take 35 hours with twelve decompression stops, gradually by steps of 1.5 m.

Discussion:

The aim of Project Hydronaut will be to research the influence of stress during an extended stay in a close, isolated and dangerous environment. The main ambition of Project Hydronaut is to contribute to preparation for European space flights.

Sanda, M.: Project Hydronaut 1. In: Abstr. 61st Int. Astronaut. Congr., Prague 2010, pap. 8315.

P-46 AIR CONSUMPTION DURING THE DESCENT OF OPEN WATER DIVES; A PRELIMINARY STUDY

Nico A.M. Schellart,[1,2] Hans van Dam[2] and Jean Claude Le Péchon[3].

[1]Biomedical Engineering and Physics, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands;
[2]Foundation for Diving Research (SDR), Amsterdam, The Netherlands;
[3]JCLP Hyperbarie, Paris, France.

Introduction/Aims

The descent and minutes after reaching maximal diving depth (MDD) are critical parts of a dive. Gas filled cavities should be pressure-equalized, especially the lung. Descending is mentally more stressful than staying at depth. With less experienced recreational divers, this may cause extra ventilation. Experienced divers may also ventilate extra to prevent hypercapnia and N_2-narcosis. The aims of this preliminary study, novel in diving-physics and physiology, are firstly to develop an exact method of calculating air consumption and, secondly, to examine whether the descent of recreational, nearly effortless air-dives demands extra ventilation (corrected for lung volume equilibration).

Methods

Five divers with varied experience made an open sea descent (23 msw/min) to 34 msw and then stayed at 13-8 msw. Every four seconds, tank pressure, water temperature and heart rate (HR) were measured with the UWATEC Galileo dive computer. Gross air consumption in ambient pressure (aL/min) was calculated from tank pressure, water temperature with adiabatic correction with a given half time of the heat transport between gas in the tank and the water. Nett consumption was found after correcting for lung volume equilibration and for the effect of central pooling in the lung tissue.

Results

During descent, the extra ventilation of 3.7 aL/min (range 0-14 aL/min) compared with at 13-8 msw depth (15-20 aL/min) suggests that it is experience-dependent. During the dive, (following the initial descent), heart rate decreased: $HR_{descent} > HR_{MDD} > HR_{10\text{-}15}$ ($P < 0.01$).

Conclusions

During the descent heart rate is elevated and there seems to be subject-dependent extra ventilation. More research with standardized profiles and more subjects are needed to unravel air consumption and heart rate during descent.

Keywords:

Lung, ventilation, descent, adiabatic, temperature, heart rate

P-47 HOW TO ASSESS AUTONOMIC BALANCE DURING SCUBA DIVING?

Zenske A.[1], Schipke J.D. [2], Kähler W. [3], Koch A. [3], Oellrich K. [3], Krüll M. [4]
1Klinikum Landshut, Landshut
2University Hospital Düsseldorf, Research Group Experim. Surgery, Düsseldorf
3German Naval Medical Institute, Maritime Medicine, Kronshagen
4Medical Institute Berlin-Marathon, Berlin

Background:

The effects of diving on the autonomous nervous system (ANS) are often studied in the hyperbaric chamber, where posture, temperature, diving response and blood shift cannot adequately be mimicked.

Aim:

To assess changes in the ANS during SCUBA diving by using a waterproof, pressure-resistant Holter monitoring system.

Volunteers and Methods:

25 divers (~40ys) performed either air or Nitrox40 open water dives (max. 25m and 40min). Before, during and after diving an electrocardiogram was recorded with a three-channel portable Holter monitor inserted into a custom-made aluminium cylinder. Three leads (ca. 1.5 m) with push buttons were attached to adhesive electrodes, which in turn, were attached to the chest wall of each volunteer (subclavicular right, subclavicular left and position V6) before dressing for the dive. For later ECG analyses, conventional software was employed to assess heart rate (HR) and heart rate variability (HRV).

Results:

Intense physical activity associated with donning and doffing the dive gear, and by entering / leaving the water affected the signal quality due to motion artefacts. During diving the proportion of regular beats was ≥80%, warranting reasonable HRV measures.

Discussion:

A developed system is presented to asses HR plus HRV while diving in the open water. Signal quality during the dive is secured, provided the electrodes are firmly attached and none detach during preparation for the dive. The external monitor-containing cylinder does not impede the dive, as it can be worn on a belt inside a dry suit or in a BCD pocket outside a wet suit.

Conclusion:

The analysis of HRV (whether by time or frequency domain) offers a non-invasive method to evaluate changes in the autonomous nervous drive. As HRV permits differentiating between parasympathetic and sympathetic drive, it seems useful to better understand how a diver processes different stimuli during the dive.

P-48 DEVELOPMENT OF A MINIATURIZED DEPTH-LOGGER TO RECORD DIVE PROFILES OF UNDERWATER RUGBY PLAYERS

Andreas Schuster[1,2], Dominik Bachmaier[3], Arne Sieber[1,2,4]

1 SEABEAR Diving Technology, Graz, Austria
2 ACREO AB, Gothenburg, Sweden
3 Technical University, Graz, Austria
4 Chalmers University of Technology, Gothenburg, Sweden
Contact: andreas.schuster@seabear-diving.com

Introduction:

In Underwater Rugby (UWR) two teams try to place a negatively buoyant ball in the opponent's goal, which is a metal bucket at the bottom of a swimming pool. The pools UWR is played in are 3.5m – 5m deep. The players wear swimsuits (blue or white), a cap with earmuffs, fins, a diving mask, and a snorkel. Any other equipment like watches or a dive computer is not permitted.
To our knowledge no one has ever systematically studied dive patterns of UWR players – in particular dive times, depth and surface intervals. Therefore, we aimed to develop a device that is small enough to fit into one of the earmuffs of an athlete and that is able to record the ambient pressure the player is exposed to. This would allow the collection of dive profiles of UWR-players.

Methods:

Main components of the developed device are a microcontroller (ATXmega 192A3, Atmel) and a pressure sensor (MS5803-14BA, measurement specialties). They are soldered onto a small circuit board that also has four contacts that implement a user interface. The board and a lithium ion battery are molded into a water proof resin.
A graphical user interface (GUI) was programmed in LabWindows (National Instruments). It can be used to obtain the recorded pressure data, write these data into log files, and it graphically represents the pressure and temperature profiles. In addition it calculates the total dive time and the duration of the longest dive.

Results:

One prototype was assembled. The current consumption is 2.5mA in active mode and <5µA in sleep mode. The capacity of the battery is 50mAh. Max recording time is 180min.
The dive profile of one UWR-player was recorded during practice. Within 90 minutes this athlete performed 113 dives which lasted 13.45 ± 5.77 seconds (mean ± standard deviation).

Conclusion:

The depth-logger is able to record dive profiles of UWR-players.

Acknowledgment:

The work was funded by the EU-FP7-Marie Curie ITN PHYPODE

Keywords:

Underwater rugby, apnea, breath-hold diving, dive profile, depth logger, data logger

P-49 DUAL WAVELENGTH CO2 SENSOR FOR THE USE IN A REBREATHER

Andreas Schuster[1,2], Arne Sieber[1,2,3]
1 SEABEAR Diving Technology, Graz, Austria
2 ACREO AB, Gothenburg, Sweden
3 Chalmers University of Technology, Gothenburg, Sweden
Contact: andreas.schuster@seabear-diving.com

Introduction:

The increase of the CO_2 partial pressure inside the breathing loop is one major issue in rebreather diving which has led to fatalities. This may be caused by malfunction, exhaustion or bypass of the CO_2-scrubber. Two different ways of scrubber monitoring are implemented in some rebreathers – one is based on measuring the temperature of the scrubber to predict the remaining scrubber lifetime and the other methods uses a single wavelength infrared (IR) CO_2-sensor. Single wavelength CO_2-sensors are failure prone, as any change in the light path (condensation, etc.) leads to false readings.

Methods:

A dual wavelength CO_2-sensor was designed with one optical window at 4,25µm (CO_2 measurement channel) and one at 4µm (reference channel). A path length of 5cm was chosen to achieve an optimized sensitivity from 0.0001 bar to 0.02 bar pCO_2. The sensor signals are processed with an 8 bit microcontroller. The protocol for characterization of the sensor in a pressure chamber included generating a vacuum, flushing the chamber with a calibration gas, and then increasing the chamber pressure up to 8 bar with N_2 to maintain the pCO_2 constant.

Results:

Three prototypes were assembled. Characterization was done with calibration gases in a hyperbaric chamber. Especially between 0 bar and 4 bar, the pressure broadening of the IR absorption peaks leads to a decreased sensor reading. The characteristic Lambert-Beer-Law that normally describes the relationship between the sensor signal and the pCO_2 cannot be applied. Instead a look-up-table has been implemented to determine the pCO_2 as function signal of the CO_2 channel, the reference channel and the ambient pressure. Introducing a reference channel makes the setup insensitive to changes in the power supply or in the absorption that is not caused by CO_2. Next to chamber trials several dives were carried out in the Mediterranean Sea as well as in an indoor pool

Conclusion:

The dual wavelength CO_2 sensor is capable of measuring the pCO2 in the breathing loop of a rebreather.

Acknowledgment:

The work was co-funded by the Marie Curie ITN PHYPODE and the Austrian FFG.

Keywords:

Rebreather, CO_2 sensor, NDIR CO_2 sensor, Scrubber monitoring

P-50 INVOLUNTARY BREATHING MOVEMENTS ASSESSMENT IN BREATH-HOLD DIVING

Andreas Schuster[1,2], Dennis Madden[3], Zeljko Dujic[3], Arne Sieber[1,2,4]

1 SEABEAR Diving Technology, Graz, Austria
2 ACREO AB, Gothenburg, Sweden
3 University of Split, School of Medicine, Split, Croatia
4 Chalmers University of Technology, Gothenburg, Sweden
Contact: andreas.schuster@seabear-diving.com

Introduction:

During an apnea dive the transition from the easy-going phase into the so-called struggle phase is marked by the onset of involuntary breathing movements (IBMs).
To detect theses IBMs different methods have been applied. These include a pneumatic repiratory belt [1, 2], electrode catheter electromyography (EMG) in the oesophagus [3], and magnetometer coils [4].

Methods:

As an alternative to previously used methods to detect IBMs the idea was to develop an accelerometer based system to detect small twitches of the rib cage that are caused by diaphragm contractions. The accelerometer is connected to a PC via a 10m long cable.
Validation of the device was carried out in a calm bay in the Mediterranean Sea. An apnea diver performed static apnea. Each time the diver felt an IBM, he pressed the button of a waterproof packed computer mouse. After the dive it was checked if the mouse clicks correlated with characteristic signal changes of the accelerometer.

Results:

One prototype was built. Its main components are an accelerometer (LSM303DHL, STMicroelectronics) and a microcontroller (ATXmega192A3, Atmel). The microcontroller reads the accelerometer data with a frequency of 200Hz and transmits this data to a laptop via 10m long cable. A LabWindows (National Instruments) GUI records the data from the prototype as well as the mouse clicks. The IBMs could be identified in the form of the accelerometer signal and corresponded to the mouse clicks.

Conclusion:

IBMs can be detected with an accelerometer.

Acknowledgment:

This work was co-funded by the EU FP7 Marie Curie ITN PHYPODE.

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Keywords:

Breath-hold diving, involuntary breathing movement, digital diver, accelerometer, IBM

P-51 DIGITAL DIVER – DATA COLLECTION AND EVALUATION WITH A TABLET PC

Sebastian Reif[1], Andreas Schuster[1,3], Urška Gajšek[4,5], Andreas Mollerlokken[6], Arne Sieber[1,2]

[1]Seabear Diving Technology, Graz, Austria, [2]Chalmers University of Technology, Gothenburg, Sweden, [3]ACREO AB, Gothenburg, Sweden, [4]Universtiy Clinical Center Maribor, Slovenia, [5]University of Ljubljana, Medical Faculty, Institute of Physiology, Ljubljana, Slovenia, [6]Department of Circulation and Medical Imaging, Faculty of Medicine, Norwegian University of Science and Technology, Trondheim, Norway

Contact: arne.sieber@seabear-diving.com

Introduction:

Research on diving physiology and development of novel individualized physiological decompression algorithms requires first collection of physiological data on divers during a dive. There are 2 main problems so far – first, the type of sensors that can be used in an aquatic environment, and second, how the data are collected. Till now, specialized ad-hoc instrumentation [1] was developed, but this is costly. One group proposed to use an Android phone as basis for the data collection, however Android is difficult to program, so far no solutions were proposed how the device could be operated underwater in terms of input capabilities. In spring 2014 an ESF funded meeting about scientific diving was carried out in Crete. One finding was that a standardized platform, like a tablet PC could be a very useful tool for underwater research. There exists a housing for an I-Pad, but I-Pads are difficult to program and only Wifi can be used as digital input interface.

Method:

One Windows 8 operated Tablet PC was chosen as platform. A housing was designed and a 4-wire-touchscreen filled with silicon oil was placed in front [2]. The signals of the touchscreen are processed with a Human Interface Device controller. A digital pressure sensor was implemented as well. As programming language National Instruments Labview is proposed. It is an industrial standard, is very simple to learn in few days, and C code can be integrated as well.

Results:

The housing was designed for a maximum depth of 50m. The touch-panel is fully operatable also under water and under pressure. Many input interfaces are available – serial port, bluetooth, Wifi as well as low frequency data transmission like used to read out tank pressure transmitters. Bluetooth and Wifi are 2.5Ghz based, therefore the transmission range in salt water is very limited to only a few cm.

Conclusion:

A tablet PC can be an economic and powerful tool for data collection on divers. A special touchscreen was developed which allows using the tablet even underwater.

The work was co-funded by the EU-MC-ITN PHYPODE.

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Keywords:

Digital diver, data collection, tablet pc, touchscreen

P-52 OPTICAL PO2 SENSOR FOR REBREATHER DIVING

Arne Sieber[1,3], Andreas Schuster[1,2], Peter Enoksson[3]
[1]SEABEAR Diving Technology, Graz, Austria; [2]ACREO AB, Gothenburg, Sweden, [3]CHALMERS University of Technology, Gothenburg, Sweden
Contact: arne.sieber@seabear-diving.com

Introduction:

In rebreathers galvanic O2 sensors are used for pO2 measurement and pO2 control. Those sensors fail frequently and as consequence the breathing gas may be hyper- or hypoxic. An alternative to traditional galvanic pO2 sensors are fluorescent pO2 sensors, typically referred to pO2 optodes, which are up to now dominantly used for measurement of traces of O2.

Methods:

Miniaturized fluorescent sensors were designed. A small electronic read out board comprises a low cost microcontroller, optical components, a blue LED, a pin photo diode, temperature sensors as well as a heater and all analog components to process the sensor signal.
The pO2 optodes were tested and characterized in the hyperbaric chamber with air as well with TRIMIX 21/35. In the follow the artificial aging was carried out to estimate the life of the optodes.

Results:

4 optodes were assembled. A mathematical model was developed to enable an effective and precise temperature compensation of the optode signal. A 3 point calibration was carried out with O2, air and NX60. The optodes were able to measure in a measurement range from 0.1 to 1.6 bar pO2. There was no cross interference with He observed. The artificial aging test revealed that one can expect a lifetime of the pO2 optodes of >1000 diving hours assuming a sample rate of 1Hz. In fact, over 1000h of diving the output signal did not drop more than 10% from the initial signal. Different to galvanic pO2 sensors the optodes were insensitive to humidity, in fact they withstand even storage in high humidity condensing environment.

Conclusion:

A pO2 optode was developed which has the potential to replace traditional galvanic pO2 sensors. They are much smaller and more robust. In comparison to galvanic sensors, which need to be replaced in regular intervals (12-18 months) optodes have a long lifetime, as they only get consumed

Acknowledgment:

This work was co funded by the EU FP7 Marie Curie ITN Phypode as well as the Austrian FFG.

Keywords:

pO2 sensors, pO2 control, rebreather, oxygen sensing, optodes, fluorescence sensors

P-53 HYPERBARIC OXYGEN THERAPY FOR TOXIC EPIDERMAL NECROLYSIS: A CASE REPORT

Selin Gamze Sümen[1], Sezer Yakupoğlu[2], Tuna Gümüş[1], Hakan Acar[3], Nur Benzonana[4]

[1.]Dr. Lütfi Kırdar Kartal Training and Research Hospital, Department of Underwater and Hyperbaric Medicine, Istanbul, Turkey
[2.]Dr. Lütfi Kırdar Kartal Training and Research Hospital, Burn Intensive Care Unit, Istanbul Turkey
[3.]Dr. Lütfi Kırdar Kartal Training and Research Hospital, Burn Unit, Istanbul Turkey
[4.]Dr. Lütfi Kırdar Kartal Training and Research Hospital, Infectious Disease and Clinical Microbiology, Istanbul Turkey

Introduction:

Toxic epidermal necrolysis (TEN), is a potentially life-threatening mucocutaneous disease largely due to administration of a drug or occasionally infections, and is characterized by acute necrosis of the epidermis. There is no definitive consensus about the treatment of toxic epidermal necrolysis. We report Hyperbaric oxygen therapy (HBOT) administered to a patient who developed TEN while using ciprofloxacin for urinary tract infection.

Material and Methods:

A 60 year-old woman was diagnosed with multiple myeloma 3 months ago. Ciprofloxacin was added to her medical treatment because of urinary tract infection. She experienced malaise, pain with maculopapular and bullous eruptions in the whole body on the 3rd day of ciprofloxacin treatment. Physical examination revealed positive Nikolsky sign. SCORTEN value was calculated as 5 and mortality rate was estimated as 90%. The standard treatment included, intravenous immunoglobulin, pain control with analgesics, wound care, nutrition and fluid support and, anti-infective therapy if needed. HBOT was added to her medical treatment on the 2nd day of admission to Burn Intensive Care Unit.

Results:

After patient underwent 5 sessions of HBOT at 2.4 ATA, epidermal detachment was noted to stop within first day and reepithelialisation rapidly occurred. The patient was discharged from the burn unit after 14 days of hospital stay.

Discussion:

High clinical doubt, early diagnosis, and initiation of treatment in the Intensive Care Unit is essential. In this case report we suggest that HBO therapy might be beneficial, and safe. Shorter length of stay for the patient might be explained by early diagnosis and faster recovery. Although other treatment recommendations in TEN are widely used, HBO treatment in addition to standard therapies may enable to shorten hospital stays and reduce both morbidity and mortality.

Keywords:

Toxic epidermal necrolysis, adverse event, hyperbaric oxygen therapy

P-54 HYPERBARIC OXYGEN THERAPY COULD CHANGE LIFE OF A PATIENT WITH LONG-TERM CONSEQUENCES OF CO POISONING?

Selin Gamze Sümen[1], Canan Bolcu Emir[2], Tuna Gümüş[1]

1. Dr. Lütfi Kırdar Kartal Training and Research Hospital, Underwater and Hyperbaric Medicine Department, İstanbul Turkey
2. Okmeydanı Training and Research Hospital Neurology Department, İstanbul Turkey

Case Report

64 year old female patient who was previously diagnosed as dementia and on medication was admitted to the hospital with symptoms of late neurological sequelae of CO intoxication. The diagnosis was made by a combination of the previous history of exposure, clinical presentation, and laboratory testing.

After having been discharged from the hospital 3 weeks ago, patient developed neurologic symptoms. She was advised to visit hyperbaric oxygen treatment center in our hospital in order to be diagnosed correctly and treated with hyperbaric oxygen treatment. Firstly, patient was evaluated by neurology department and diagnosed as recurrence of symptoms in dementia. After taking into consideration her previous history of CO intoxication, the results of MR and EEG were revaluated and diagnosed as delayed neuropsychiatric sequelae of intoxication. She was admitted to hyperbaric oxygen treatment unit. Videotapes of the patient were also used for storing physical examination results before and after treatments. After 30 treatment sessions, an overall healing of the symptoms was observed. The therapy had no side effects, and the patient tolerated the protocol very well.

Discussion

In this case report, we present the results of hyperbaric oxygen (HBO) therapy in a 64-year-old Turkish woman who had been firstly diagnosed with late symptoms of dementia which was resistant to other therapies then revised as late sequale of CO intoxication.
Development of delayed neuropsychiatric sequelae, including dementia, psychosis, parkinsonism, chorea and incontinence are the feared long-term consequences of CO poisoning. Delayed neurologic sequelae of CO poisoning should be well recognized by other clinicians such as neurologists and psychiatrists. Although response to different treatment modalities varies with individual patients, patient selection for HBO treatment should be done carefully.

O-36 UNDERWATER MONITORING OF DIVER'S RESPIRATION AND REGULATOR PERFORMANCE BY INTERMEDIATE PRESSURE

S. Murat Egi[1], Corentin Altepe[2], Tamer Ozyigit[1]

[1]Galatasaray University, Computer Engineering Department, Ciragan Cad. 36 Ortakoy 34349 Istanbul – Turkey

[2]Bogazici Underwater Research Center, Yavuzturk Sk. 32/1 Altiyol 34716 Istanbul - Turkey

Introduction

This study is about a system for monitoring the breathing cycles of divers and the functioning of regulators underwater. The system warns the diver and other divers around in case of long time cessation of respiration and if the regulator's intermediate pressure is out of predefined limits, enabling immediate intervention to regulator and breathing problems.

Method

The system is equipped with pressure sensors, colored LEDs, buzzer, microprocessor piezo switch and VLF transmitter. It can be mounted by low pressure hoses or directly to first stage regulator and can sense the alterations of the intermediate pressure, the maximum and minimum values of the intermediate pressure and the depth. In case of cessation of respiration by durations defined by the user or if the intermediate pressure of the first stage regulator is out of its maximum and minimum limits defined by the user, the system triggers different levels of alarms to warn the diver itself or other divers around.

Results

The breathing cycles and the regulator performance are sensed very accurately underwater and at surface. All data including dive profile, is logged and can be transferred to PC or mobile devices to be analyzed after dive. The low and high level alarms are effective to enable immediate intervention in case of breathing and regulator problems. The system can send data wirelessly to dive computers during dive so that the values measured by the sensors are displayed numerically and graphically and the visual and vocal alarms are shown by dive computer.

Discussion

Breathing and regulator related problem is hard to be noticed underwater. Major benefits of the system are rapid realization of respiration/regulator problems and ease of locating an unconscious or deceased diver. Additionally, using this system, the decompression algorithms of dive computers can be ameliorated taking into account the breathing rate of diver.

O-37 DELAYED RECOMPRESSION FOR DECOMPRESSION SICKNESS

A. Hadanny, G.Fishlev, Y. Bechor, J. Bergan, M. Friedman, A.Maliar, S. Efrati

The Institute of Hyperbaric Medicine, Assaf Harofeh Medical Center, Zerifin, Israel. Sackler School of Medicine, Tel-Aviv University Israel.

Introduction

Most cases of decompression sickness (DCS) occur soon after surfacing, where 98% within 24 hours. Recompression using hyperbaric chamber should be administrated as soon as feasible in order to decrease bubble size and avoid further tissue injury. However the time beyond which hyperbaric treatment is non effective is unclear.
The aim of the study was to evaluate the clinical results of patients who received delayed recompression treatment, more than 48h after surfacing. The treatment results were compared to the data of divers treated early after surfacing at the same hyperbaric institute.

Methods

From January 2000 to February 2014, 65 divers had delayed treatment (>48h) for DCS in the institute of Hyperbaric Medicine, Assaf Harofeh Medical Center, Israel. Data was collected from medical records and was compared to data of 139 patients treated less than 48h after surfacing.

Results

The mean age of the divers was 32±9 years, 81% were males, and the average maximal dive depth was 28±7 meters. Complete recovery was achieved in 75% of the divers, partial recovery in 19% and no improvement after recompression treatments in 6%. In analysis of 139 divers recompressed less than 48h after surfacing, similar results of 78% complete recovery, 15% partial recovery and 6% no recovery were noticed.
In the delayed recompression group, there was a positive correlation between the time to recompression and the clinical outcome ($p=0.027$). Interestingly, older age correlated with prolonged lag time between surfacing and presentation of DCS symptoms.

Conclusions

Late recompression for DCS, more than 48 hours after surfacing, has clinical value and when applied can achieved complete recovery in 75% of the divers. Time to treatment should be shortened if possible even after 48 hours.

O-38 ANALYSIS OF 605 COMMERCIAL DIVING DCS LOGS: TRENDS AND UNDERLYING MECHANISMS

JP Imbert[1], Murat Egi[2], Tamer Ozyigit[2], Costantino Balestra[3]

1) Divetech, 1543 ch des Vignasses, 06410 Biot, France
2) Galatasaray University, Computer Engineering Department, Ciragan Cad. 36 Ortakoy 34349 Istanbul Turkey
3) Environmental & Occupational (Integrative), Physiology Laboratory / Haute École PH Spaak, 91, Av. C. Schaller 1160 Auderghem, Brussels, Belgium

Introduction

A project was launched by Technip (a leading commercial diving company) to assess the nature of DCS among commercial divers in bounce diving (to the exclusion of saturation diving). The goal was to 1) characterize the commercial diver population and diving methods, 2) determine the groups of symptoms associated to the various types of DCS, 3) identify underlying mechanisms driving the onset of the DCS symptoms.

Material, methods

605 decompression sickness incident logs related to commercial diving were stored into a database and anonymized. The logs covered dives using air and heliox, surface supplied and bell bounce diving with bottom depths ranging from 12 to 120 msw. Ascent was performed using in-water, surface-D and bell TUP decompression.

Results

The database permitted mapping of the symptoms reported over dive exposures; bottom mixes and decompression methods.
The analysis of symptoms indicates that commercial divers are essentially subjected to “pain only symptoms as opposed to recreational divers. However, surface decompression significantly increases the risk of type II symptoms.

Discussion

The analysis of delays between the beginning of the decompression and the onset of first symptoms seems to indicate two possible underlying mechanisms; one related to venous bubbles and associated to type I DCS; a second related to arterial bubbles and associated to cerebral and/or vestibular symptoms. Medullar symptoms could be the result of the sequential action or superposition of the two mechanisms.

Project supported by Citeph (France).

O-39 INNER EAR BAROTRAUMA & INNER EAR DECOMPRESSION SICKNESS - HOW TO DIAGNOSE & TO TREAT?

Andreas Glowania

ORL-Department, Lainz Hospital, Vienna / Austria & Center for Diving & Hyperbaric Medicine, Wiesbaden / Germany

Introduction:

As diving has gained popularity, the number of diving related disorders and dive injuries has risen too. More than 70% of these medical problems are related to the Head and Neck-region. Inner ear barotrauma (IEBT) and inner ear decompression sickness (IEDCS) are rare and involve the danger of permanent inner ear damage but are still, even for the ORL - specialist, difficult to diagnose.

Material & Methods:

Founding on an actual literature search and own experience from treating dive accidents at the Center for Diving & Hyperbaric Medicine, Wiesbaden / Germany, data concerning pathophysiologic mechanisms and symptoms were collected. A workflow for diagnosis and optimal treatment of patients suffering from IEBT or IEDCS was arranged.

Results:

No common consent exists concerning therapy in IEBT. Conservative therapeutic options range from decongestants and analgetics up to rheologics and corticosteroids. In case of a persistent vertigo and / or an unilateral hearing loss a tympanotomy is recommended and should be performed to exclude a round window membrane fistula.
On the other hand IEDCS should be treated with HBO without delay, though a correct differential diagnosis can be difficult.
Therefore every scuba diver complaining about symptoms like vertigo, tinnitus and / or hearing loss should be presented to an ORL-specialist immediately for investigation and specific diagnostic (e.g. audiometry) - especially if the diagnosis remains unclarified.

Discussion:

IEBT and IEDCS are difficult to distinguish diseases in scuba divers. Because of the popularity of scuba dives every Diving and / or Hyperbaric physician should be informed in diagnosing and treating those patients.

O-40 EFFECTS OF INSPIRED CO_2 AND BREATHING RESISTANCE WHILE BREATHING OXYGEN

Dan E. Warkander, Barbara E. Shykoff

Navy Experimental Diving Unit
321 Bullfinch Rd
Panama City, FL 32407, USA

Introduction

European diving standards allow inspired CO_2 ($P_{in}CO_2$) of up to 2 kPa (20 mbar). We measured in-water effects of that $P_{in}CO_2$ in O_2 and with resistance like that of breathing apparatus.

Methods

At 3 m depth, 16 subject exercised on a cycle ergometer at 85% peak O_2 uptake, breathing PO_2 = 130 kPa with $P_{in}CO_2$ of 0 or 2 kPa. Work of breathing was 1,0 (R1) or 1,8 (R2) J/l at 62,5 l/min, substantially below European limits. End-tidal CO_2 ($PetCO_2$) and inspired minute ventilation ($\dot{V}_I$) were measured. Tests stopped when the subject could not continue, after 60 minutes, or if $PetCO_2$ reached 8,7 kPa (65 mm Hg).

Results

Table 1. Mean values of $\dot{V}_I$ and $P_{et}CO_2$ for combinations of R and $P_{in}CO_2$

mean (sd)	**R1**		**R2**	
$P_{in}CO_2$	**$\dot{V}_I$ (l/min)**	**$P_{et}CO_2$ (kPa)**	**$\dot{V}_I$ (l/min)**	**$P_{et}CO_2$ (kPa)**
0 kPa	66,5 (9,4)	5,7 (0,9)	61,6 (11,3) *	5,7 (0,9)
2 kPa	78,4 (17,5) *	7,0 (0,8) *	69,9 (15,0)	7,1 (0,7) *

* different from R1, 0 kPa, $p<0.05$, paired t-test with Bonferroni correction

Respiratory responses varied greatly among divers. For example, one usually maintained $\dot{V}_I$ but let $PetCO_2$ increase, and one varied $\dot{V}_I$ to maintain $PetCO_2$.
With R1 and $P_{in}CO_2$ =2 kPa, six subjects maintained $PetCO_2$ above 8 kPa (60 mm Hg), a value excessive for diving, and one was stopped at 8,7 kPa. With R2 and $P_{in}CO_2$ =2 kPa, seven subjects maintained $PetCO_2$ above 8 kPa and three subjects were stopped at 8,7 kPa.
Various subjects reported nausea, anxiety, dizziness, headache, and inability to remember instructions. One surfaced suddenly. One was not himself after surfacing. Others reported no problems.

Discussion

With heavy work, PO_2 = 130 kPa, $P_{in}CO_2$ = 2 kPa is potentially dangerous with even modest breathing resistance.

O-41 NITROX: EFFECTS ON AUTONOMOUS NERVOUS SYSTEM IN SCUBA DIVERS

Zenske A.[1], Schipke J.D. [2], Kähler W. [3], Koch A. [3], Oellrich K. [3], and Krüll M. [4]
1Klinikum Landshut, Landshut
2University Hospital Düsseldorf, Research Group Experim Surgery, Düsseldorf
3German Naval Medical Institute, Maritime Medicine, Kronshagen
4Medical Institute Berlin-Marathon, Berlin

Background:

Oxygen-enriched air (Nitrox) is frequently used by recreational divers, but the effects of these breathing gases on the autonomous nervous system (ANS) in the aqueous environment remain unsettled.

Aim:

We studied the effects of breathing gas on the ANS of SCUBA divers. Measures of heart rate variability (HRV) and gas consumption were assessed during diving.

Methods:

25 divers (~40ys) performed two open water dives each: one with air and another with Nitrox40 (max. 25m and 40min). The divers were equipped with a 3-lead ECG. In parallel, gas consumption was assessed. Standard software was used for analysing ECG recordings (5-min intervals) for HRV measures. Comparison between data at the start and end of diving was made using Wilcoxon signed rank test.

Results:

Diving with either air or Nitrox40 was associated with a decreased heart rate (10% and 13%; $p<0.05$). Two measures of the parasympathetic drive (pNN50 and RMSSD) were increased at the end of dive (pNN50: 91 vs 131% and RMSSD: 33 vs 50%; both $p<0.05$). One geometrical HRV measure (=triangular index) also exhibited an increased vagal tone (33 vs 18%, n.s.). In line, the high frequency power component (HF: vagal tone) increased during the dive (71 vs 139%; $p<0.05$). In addition, autonomic balance (LF/HF) was decreased (22 vs 34%; n.s). Gas consumption in the Nx40 group was less than in the air group (9%).

Discussion:

Autonomic balance changed in favour of the parasympathicus, compared with resting conditions. All HRV variables assessed speak for an increasing vagal tone during open water dives, thus reducing heart rate and, in parallel, gas consumption. The more marked responses in HRV in the Nitrox40 group could be related to hyperoxia. Hyperoxia during the dive is beneficial with respect to the ANS, as it helps normalizing autonomic balance, and hence, reducing unnecessary stress.

40th EUBS Annual Scientific Meeting – Wiesbaden 2014

Hyperbaric Oxygen & Stem Cells

Stephen R. Thom, M.D., Ph.D.
Dept. of Emergency Medicine
University of Maryland School of Medicine
Baltimore, MD

WHAT'S A STEM CELL?

Pluripotent stem/progenitor cells = capability to differentiate into cells from any of the three germinal layers.

Found in bone marrow (& elsewhere) of adults.

Cells exhibit properties similar to embryonic stem cells.

Hold promise for treating degenerative and inherited disorders.

Jiang, *et al.* Nature 418:41, 2002; Rafii, J. Clin. Invest. 105: 17, 2000

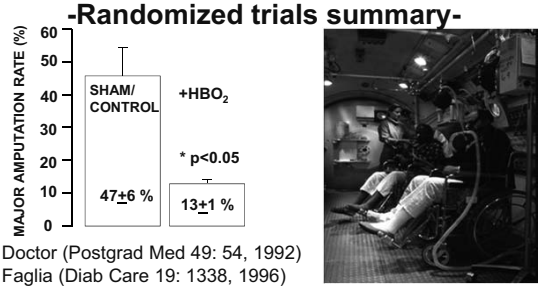
Wounds heal by two separate processes:

Angiogenesis = resident endothelial cells adjacent to wounds proliferate, migrate, and remodel into neovessels.

Vasculogenesis = *de novo* process occurring when stem/progenitor cells lodge at wound site and give rise to replacement vascular network.

Notion of EPC (endothelial progenitor cell) introduced by Asahara in 1999

DIABETIC WOUND HEALING & HBO_2 -Randomized trials summary-



Doctor (Postgrad Med 49: 54, 1992)
Faglia (Diab Care 19: 1338, 1996)
Abidia (U Hyperb Med 28: 64, 2001)
Kalani (J Diab & Complications 16: 153, 2002)
Duzgun (J Foot & Ankle S. 47: 545, 2008)
*Londahl (Diab Care 33: 998, 2010 – 52 vs 29% healed)

… HBO_2 in wound healing: EVIDENCE PROVIDES SUPPORT BUT…

Citation	Control-AMPUTATION	HBO_2-AMPUTATION	Control-HEALED	HBO_2-HEALED	
Doctor, 1992	7/15	2/15			3.0 ata O_2
Faglia, 1996	11/33	3/35			2.5 ata O_2
Duzgun, 2008	37/48	4/44	0/48	27/44	2.5 ata O_2
Abidia, 2003			1/8	5/8	2.4 ata O_2
Londahl, 2010			12/42	25/48	2.5 ata O_2
Ma, 2013			3/18	8/18	2.5 ata O_2

If we understood mechanisms, better insight into how/when to use HBO_2

Effects of HBO_2 based on controlled oxidative stress.

HBO_2

Reactive O_2 species (ROS)

Reactive Nitrogen species (RNS)

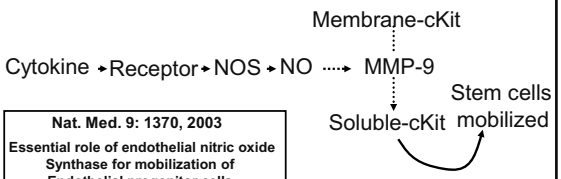
ENDOTHELIUM-ISCHEMIA/ REPERFUSION

INFECTION/ INFLAMMATION

WOUND HEALING

IMMEDIATE → **LATE**

ONE MECHANISM FOR STEM CELL MOBILIZATION INVOLVES NITRIC OXIDE SYNTHESIS.



Nat. Med. 9: 1370, 2003

Essential role of endothelial nitric oxide Synthase for mobilization of Endothelial progenitor cells.

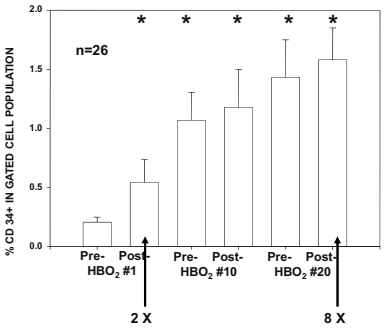
A. Aicher, C.H. Heeschen, C. Mildner-Rihm, C. Urbich, C. Ihling, K.Technau-Ihlng, A.M. Zeiher & S.Dimmler
University of Frankfurt

HBO_2 ELEVATES NO SYNTHESIS

J. Neurobiology 51: 85, 2002
AJP-Heart 284: H1230, 2003
(Cabigas Cardiovasc Res 72: 143, 2006)

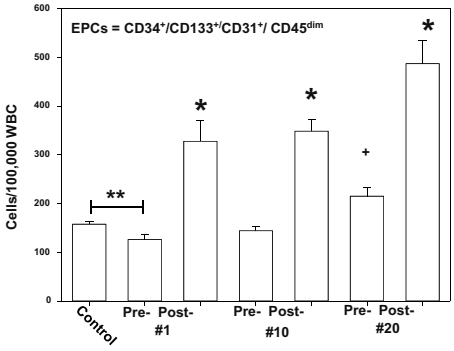
HUMAN STEM CELL MOBILIZATION BY HBO_2

Am. J. Physiology 290: H1378, 2006



- PATIENTS PREVIOUSLY EXPOSED TO RADIATION -

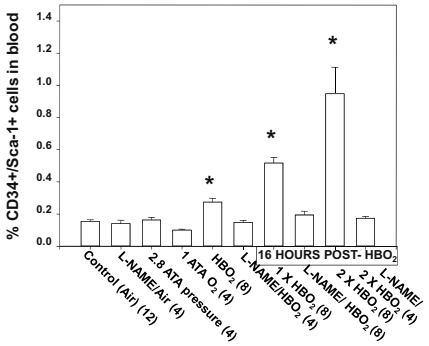
DIABETIC PATIENTS (n=25)



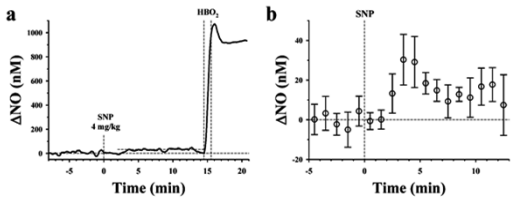
Thom et al. Wound Repair & Regen. 19:149, 2011

MOUSE STEM CELL MOBILIZATION BY HBO_2

Thom et al. Am. J. Physiology 290: H1378, 2006



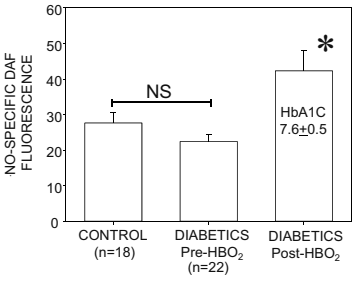
·NO DONOR CANNOT SUBSTITUTE FOR HBO_2



Nitroprusside (4 mg/kg IP) reduces BP by 25% for 1 hour

Nitroprusside (8 mg/kg IP) is ~ ¾ of LD_{50}

HBO_2 ENHANCES ATP-DEPENDENT eNOS ACTIVATION



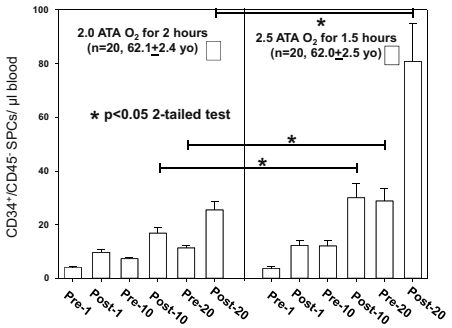
Thom, et al. Wound Repair & Regeneration 19: 149-161, 2011

Also supported by *Gurdol, et al. Physiol Res 59: 423, 2009*

OXYGEN PRESSURE MATTERS FOR SPCS MOBILIZATION

20 consecutive patients, tx for radionecrosis prophylaxis

Stem Cell Research 12: 638, 2014



Stem cells, Wound Healing and Hyperbaric Oxygen Therapy

There is more to the story than just numbers …..

ARE MOBILIZED CELLS FUNCTIONAL *in vivo*?

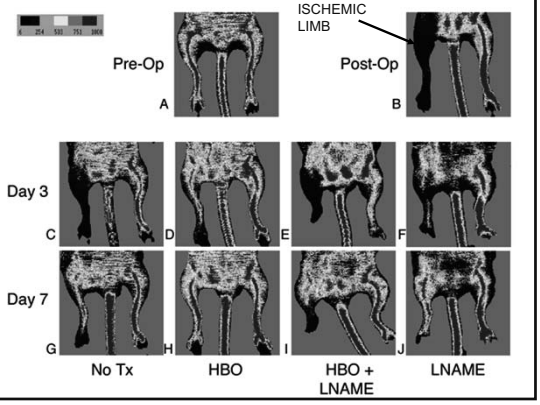
CHIMERIC MOUSE MODEL – SO WE CAN TRACK SPCs

Ischemic wounds heal faster due to mobilized progenitor cells released from bone marrow by HBO_2.
Goldstein, *et al*. *Stem cells* 24:2309, 2006

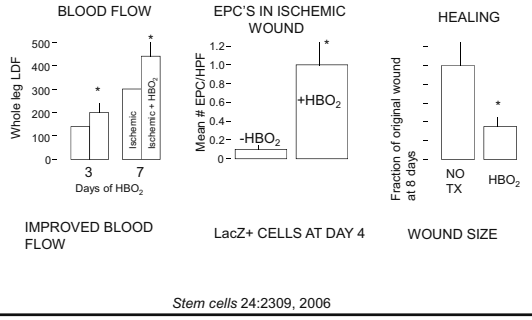
Diabetic wound heal faster due to HBO_2-induced progenitor cell mobilization and homing still better if SDF-1α placed in wounds.
Gallagher, *et al. J. Clin. Invest.* 117: 1249, 2007.

LASER DOPPLER FLOW

Stem cells 24:2309, 2006

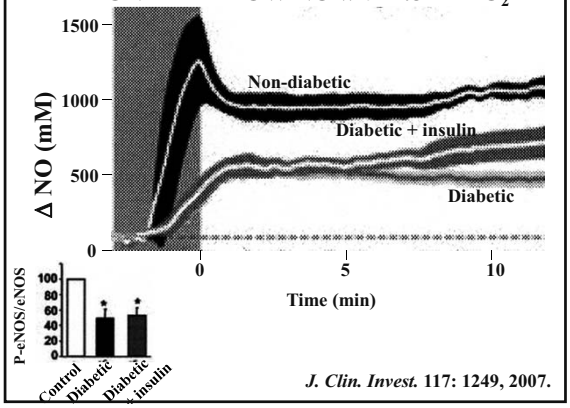


HBO_2 HASTENS EXPERIMENTAL WOUND HEALING



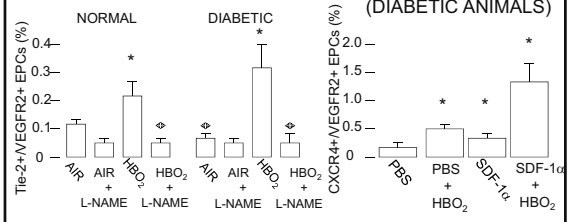
Stem cells 24:2309, 2006

BONE MARROW NO with 2.8 ATA O_2



***J. Clin. Invest.* 117: 1249, 2007.**

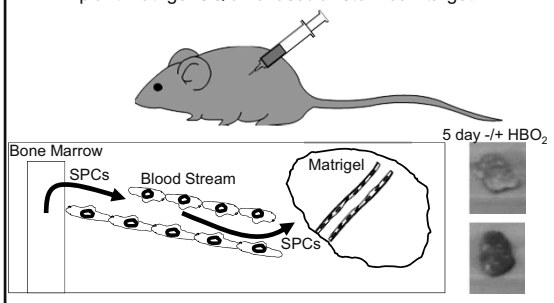
Diabetic impairments in NO-mediated endothelial progenitor cell mobilization and homing are reversed by hyperoxia and SDF-1α. Gallagher, et al. *J. Clin. Invest.* 24: 2309, 2006.



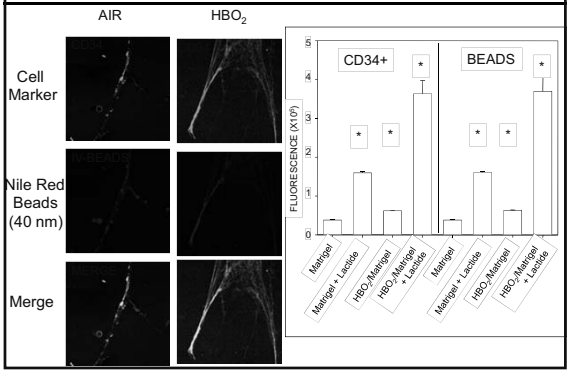
Stem cell mobilization and vasculogenesis stimulated by lactate and oxygen.

Mol. Cell. Biol. 28: 6248, 2008; J Appl Physiol 106: 711, 2009

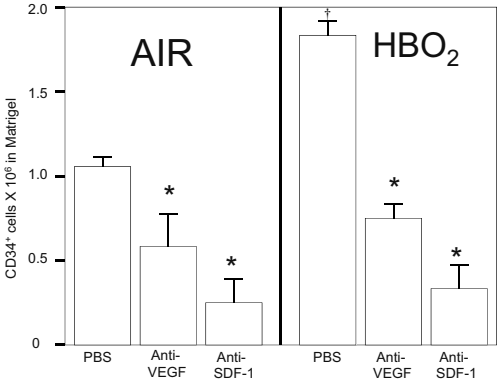
Implant Matrigel SQ an avascular stem cell 'target'



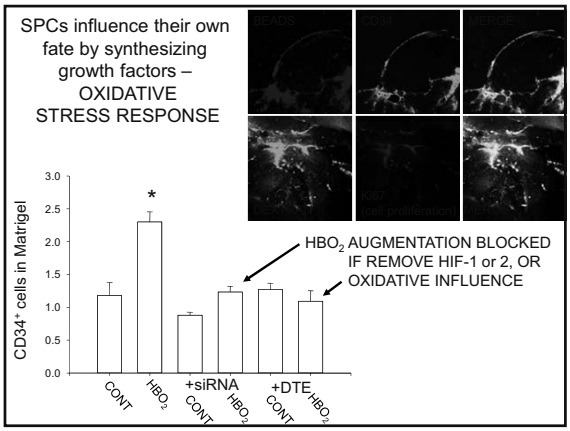
VASCULAR CHANNELS IN MATRIGEL
J Appl Physiol 106: 711, 2009



SPCs influence their own fate by synthesizing growth factors

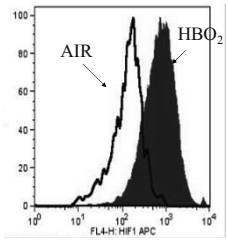


SPCs influence their own fate by synthesizing growth factors – OXIDATIVE STRESS RESPONSE



ROS

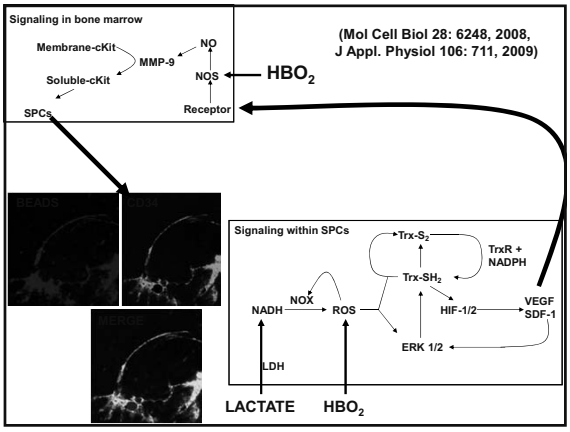
ANTIOXIDANT RESPONSE/ THIOREDOXIN SYS'SIS (Trx can serve as a transcription factor)



MORE HIF'S

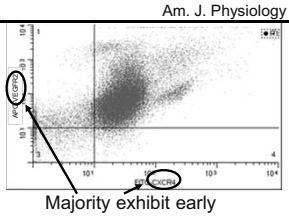
IMPROVED SPCs FUNCTION

Mol. Cell. Biol. 28: 6248, 2008; J Appl Physiol 106: 711, 2009



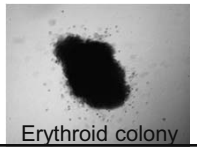
Cultured CD34+ Human Stem Cells

Am. J. Physiology 290: H1378, 2006



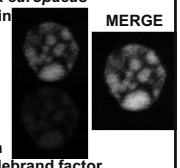
~ 10 % EXHIBIT VASCULAR ENDOTHELIAL CELL MARKERS

Majority exhibit early progeny markers



Ulex europaeus lectin

MERGE

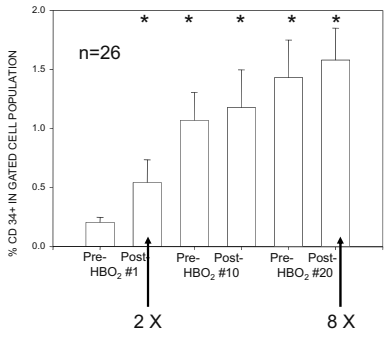


Von Willebrand factor

WITH EXTENDED CULTURE, SOME CELLS DIFFERENTIATE INTO BONE MARROW HEMATOPOIETIC CELLS

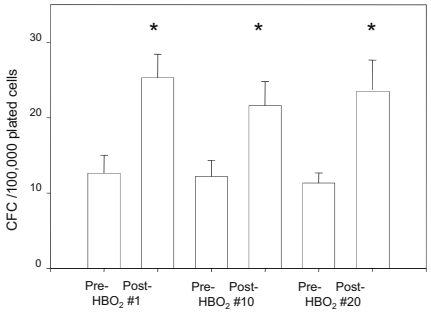
HUMAN STEM CELL MOBILIZATION BY HBO_2

Am. J. Physiology 290: H1378, 2006



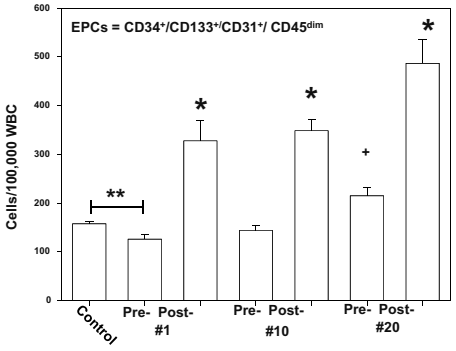
- PATIENTS PREVIOUSLY EXPOSED TO RADIATION -

STEM CELL GROWTH POTENTIAL *ex vivo* AUGMENTED IN HBO_2 GROUP



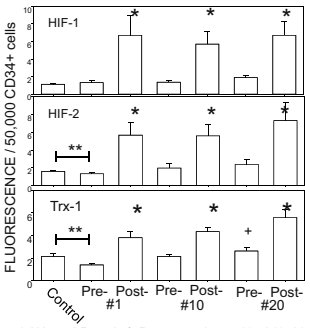
Am. J. Physiology 290: H1378, 2006

DIABETIC PATIENTS (n=25)



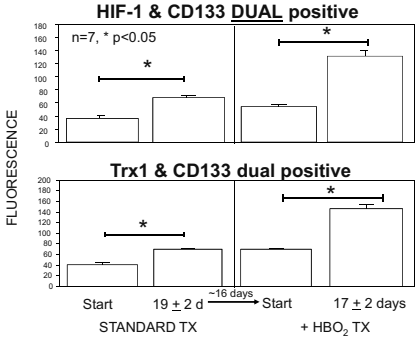
Thom et al. Wound Repair & Regen. 19:149, 2011

HBO_2 INCREASES # CIRCULATING SPCs AND THERE IS INCREASED HIFs & THIOREDOXIN



Thom, et al. Wound Repair & Regeneration – 19: 149-161, 2011

DIABETIC WOUND CELLS

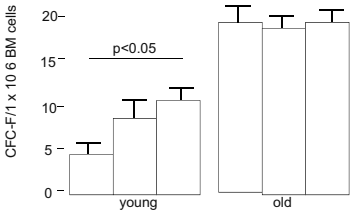


Thom, et al. Wound Repair & Regeneration – 19: 149-161, 2011

Age-dependent response of murine female bone marrow cells to hyperbaric oxygen
C.R. Gomez et al Biogerontology (2012) 13:287–297

Bone marrow colony-forming unit fibroblasts, a measure of mesenchymal stromal cells (MSCs), doubled in young (2 months) but not old mice receiving HBO_2

Air-only, 1.0, or 2.8 ATA O_2 for 90 min daily for 5 days



CONCLUSION

BY INITIATING OXIDATIVE STRESS, HBO_2 STIMULATES NEOVASCULARIZATION

1. Improved tissue oxygen gradients expected to trigger Better macrophage recruitment.
2. Increased wound growth factor synthesis (esp. VEGF).
3. HBO_2 stimulates vasculogenic stem cell mobilization from bone marrow
4. HBO_2 improves SPCs-linked growth functions (e.g. HIF's).
5. Anti-bacterial effects.

QUESTIONS?

O-42 MEASUREMENT OF COGNITIVE PERFORMANCE AND FATIGUE FOLLOWING 0.4MPA DRY CHAMBER DIVES BREATHING AIR OR ENRICHED AIR NITROX.

P. Germonpré[1,3], C. Balestra[1,2], W. Hemelryck[1,2], M. Rozloznik[2], P. Lafère[1,4,5]

[1] DAN Europe Research Division
[2] Environmental, Occupational & Ageing Laboratory, Haute Ecole Paul-Henri Spaak, Brussels, Belgium
[3] Centre for Hyperbaric Oxygen Therapy, Military Hospital "Queen Astrid", Brussels, Belgium
[4] ORPHY, UFR Sciences et Techniques, Université de Bretagne Occidentale, Brest, France
[5] Unité de Soins Hyperbares, CHRU de la Cavale Blanche, Brest, France

This study is part of the Phypode Project, financed by the European Union under a Marie Curie Initial Training Network Program FRP/2007-2013/ under REA grant agreement n° 264816.

Introduction:
Several beneficial properties are attributed to the use of enriched air nitrox (EANx) as a breathing gas in diving. However, strong evidence to support these claims is lacking. This double-blinded, randomized controlled trial tested the hypothesis that the use of EANx could measurably reduce fatigue and improve cognitive performance following a simulated dry chamber dive at moderate depth.

Methods:
Eight male volunteers (aged 30–40 years, BMI 20–23, non-smokers) performed two simulated dives in a hyperbaric chamber breathing either air or EANx (40% oxygen, 60% nitrogen) in randomized order for 20 minutes at 0.4MPa (30msw). Cognitive brain functions were assessed using a computerized battery of tests and fatigue was assessed with a visual analogue scale (VAS). Measurements were taken before the dive, upon arrival at 0.4MPa, after 15 min at depth, upon surfacing and at 30 min post-dive.

Results:
Divers were not able to reliably identify the breathing gas used. Compared with air, behavioral assessments showed a significantly better performance while breathing EANx. Compared to pre-dive values, for both gases there was an initial improvement, as a significant decrease in time-to-complete in both Math-Processing and Trail-Making tests was observed upon arrival at depth. Then, the EANx measurements showed a gradual return to baseline (but not below), whereas the air dives showed further performance degradation continuing post-dive. The Time-Wall (spatio-temporal) test inaccuracy was constant ($p=0.0639$). However air dives were characterized by more late responses, especially during the ascent and post-dive phases ($p<0.0001$), suggesting late dive/post-dive impairment. VAS showed a trend toward increased perceived fatigue, significantly higher after the air dives compared to EANx dives ($p<0.001$).

Conclusion:
EANx protects (at least partially) against objectively-measured decreased neuro-cognitive performance induced by inert gas narcosis. As success or failure is influenced not only by one's objective abilities but also by subjective judgment (self-assessment of fatigue, hence confidence in one's capabilities), it seems that EANx could be a better choice in situations where accurate judgment or actions are essential.

Keywords:
Air, enriched air nitrox, diving, brain performance, fatigue, chamber dive

O-43 EARLY DETECTION OF NITROGEN-INDUCED COGNITIVE IMPAIRMENT WHILE DIVING USING THE CRITICAL FLICKER FUSION FREQUENCY

P. Lafère[1,2,3], P. Germonpré[1,5] , W. Hemelryck[1,4], F. Guerrero[2], C. Balestra[1,4]

[1] DAN Europe Research Division
[2] ORPHY, UFR Sciences et techniques, Université de Bretagne Occidentale, Brest, France
[3] Unité de soins hyperbares, CHRU de la Cavale Blanche, Brest, France
[4] Environmental & Occupational Physiology Laboratory, Haute Ecole Paul Henri Spaak, Brussels, Belgium
[5] Centre for Hyperbaric Oxygen Therapy, Military Hospital "Queen Astrid", Brussels, Belgium

This study is part of the Phypode Project, financed by the European Union under a Marie Curie Initial Training Network Program FRP/2007-2013/ under REA grant agreement n° 264816.

Introduction

Cognitive impairment continues to be a significant threat to safety and operation at depth. Non-invasive, reliable, easy to implement underwater neurocognitive performance testing is desirable to identify presymptomatic cognitive impairment offering divers at depth a tool to quantify their performance and safety. Critical flicker fusion frequency (CFFF) could address this need.

Methods

The cognitive performance of 8 subjects was assessed subjectively, by behavioural computer-based testing (Math-Processing Task, Trail-Making Task, and Perceptual Vigilance Task) and by CFFF. Performance of the subjects was measured while in a hyperbaric chamber breathing air or enriched air nitrox 40% (EANx) for 20 minutes at 0.4 MPa, each diver being his own control. Measurements were taken on arrival at depth, just before return to the surface, and 30 minutes post-dive.

Results

Compared to the pre-dive value, diving both on air and EANx is characterized by an increase of CFFF (Air: 104± 2.54 % ± 9.8 %; EANx: 112.7± 7.13 %) and a significant decrease in time to complete in both Math-Processing (Air: 91.84± 2.54 %; EANx: 86.36± 10.51 %) and Trail-making (Air: 68.99± 10.01 %; EANx: 71.95± 28.62 %), on arrival at 0,4MPa. Then, both "time to complete" and CFFF follow the same evolution: for EANx by a gradual return to the baseline and for air by significant post-dive performance degradation (CFFF: 94.82 ± 4.6 % & 96.37 ± 3.54 %, Math-Processing 106.55± 19.31% & 107.4±32.11% Trail-Making: 102.9± 21.41% & 108.1±30.84%, $p<0.0001$)
The magnitude of CFFF change and time to completion of both tests were inversely correlated in both breathing conditions: Air (Pearson r of -0,90 (MathProc) and -0,86 (PTrail), $P < 0.0001$) and EANx (Pearson r of -0,91 (both), $P < 0.0001$).
The perceptual vigilance task did not show a difference between air and EANx ($P > 0.4$).

Conclusion

The CFFF test provides an assessment of cognitive function that is similar to some tests from PEBL, but requires a less complicated set up and could be used under various environmental conditions including diving.

Keywords:
Diving, inert gas narcosis, brain performance, critical flicker fusion frequency

O-44 EARLY-STAGE BRAIN ACTIVATION DURING HYPERBARIC EXPOSURE IS OXYGEN-RELATED

P. Lafère[1,2,3], P. Germonpré[1,5], W. Hemelryck[1,4],V. Papadopoulou[4,6], C. Balestra[1,4]

[1] DAN Europe Research Division
[2] ORPHY, UFR Sciences et techniques, Université de Bretagne Occidentale, Brest, France
[3] Unité de soins hyperbares, CHRU de la Cavale Blanche, Brest, France
[4] Environmental & Occupational Physiology Laboratory, Haute Ecole Paul Henri Spaak, Brussels, Belgium
[5] Centre for Hyperbaric Oxygen Therapy, Military Hospital "Queen Astrid", Brussels, Belgium
[6] Department of Bioengineering, Imperial College London, London, UK

This study is part of the Phypode Project, financed by the European Union under a Marie Curie Initial Training Network Program FRP/2007-2013/ under REA grant agreement n° 264816.

Introduction

Depth while diving is associated with progressive deterioration of brain performance due to inert gas narcosis. It has been demonstrated by both critical flicker fusion frequency and behavioral computer-based testing that this impairment is preceded by a performance improvement while arriving at depth. At 0.4MPa, divers breathing air actually breathe a gas with a partial pressure of oxygen, almost equivalent to breathing pure oxygen at surface, which facilitates nerve conduction. This double blinded, randomized controlled trial was designed to demonstrate the implication of oxygen in brain performance improvement following a simulated dry chamber dive at 0.4MPa.

Methods

Eight volunteers (male, age 30–40 years, BMI 20–23, non smoker) performed two simulated dives in a hyperbaric chamber breathing air or enriched air nitrox 40% (EANx) for 20 minutes at 0.4 MPa (n=8). Divers were assessed by continuous recording of brain near infrared spectroscopy (NIRS). We measured values of oxy-hemoglobin (HbO2), deoxy-hemoglobin (HHb), total-hemoglobin (THb) and total oxygenation index (TOI) in the prefrontal cortex. Blood pressure and heart rhythm were also recorded.

Results

Arrival at 0.4MPa was associated with increased HbO2 and decreased HHb especially with EANx (HbO2: 2619 ± 590%, $p<0.0001$; HHb: -550 ± 253%, $p<0.05$). This pattern was also present with air (HbO2: 354 ± 154 %; HHb:-836 ± 225%) however only the HHb decrease was significant in air ($p<0.001$). The difference between the two gases was significant, EANx producing a far more important effect than air ($p<0.05$). We did not observe any changes in TOI or hemodynamic parameters.

Conclusion

Since changes were not related to measured hemodynamic variables, HbO2 and HHb values indicate the significant activation in the prefrontal cortex is oxygen-dependent. However, to determine whether this activation is the result of a more oxygen-rich breathing gas or a more nitrogen-free mixture needs more research.

Keywords:

Air, enriched air nitrox, diving, brain performance, chamber dive, NIRS

O-45 EFFECTS OF VALSALVA MANOEUVRE AND THE 'CO_2 OFF-EFFECT' ON CEREBRAL BLOOD FLOW.

Fiona Seddon, Julian Thacker, Karen Jurd, Geoffrey Loveman

QinetiQ, Maritime Life Support, Haslar Marine Technology Park. Haslar Rd. Gosport. Hampshire. UK. PO12 2AG.

Introduction:

Previous research has shown that a rapid drop in inhaled carbon dioxide partial pressure reduces cerebral blood flow and may induce faintness – the 'CO_2 off-effect'. The aims of this study were to investigate the effects of performing Valsalva manoeuvres while experiencing the 'CO_2 off-effect', and whether symptoms occur that are sufficient to jeopardise submarine tower escape.

Methods:

Twenty male volunteers mean (SD) age 34.7 (8.5) years each completed three Tests. The first Test was to perform Valsalva manoeuvres breathing air. The second and third Tests involved breathing a high CO_2 mix (5% CO_2/16% O_2/79% N_2) for 1 h prior to switching to breathe O_2 and performing Valsalva manoeuvres, or switching to breathe air for 1 min then O_2 and performing Valsalva manoeuvres. Blood pressure, cerebral blood flow velocity, electrocardiogram, and respiration were monitored throughout. A subjective questionnaire was administered at intervals to monitor symptom type and severity.

Results:

Symptoms whilst breathing high CO_2 included breathlessness and headache. Following the switch from high CO_2, some subjects reported symptoms of faintness, headache and nausea. Cerebral blood flow dropped by 34% when switching from breathing high CO_2 to O_2; by 35% when switching to air and by a further 14% after performing the Valsalva manoeuvres. The drop in cerebral blood flow for the subjects that reported faintness following the switch was greater than that in the subjects who did not, but this difference was not significant. Transient faintness or headache may occur in the escape tower during pressurisation, but this should be short-lived and not incapacitating.

Keywords

Hypercapnia, Valsalva, cerebral blood flow, Transcranial Doppler, physiology, submarine.

O-46 HYPEROXIA-ACTIVATED BAROREFLEX IS POTENTIAL CONTRIBUTOR TO BENEFITS OF HBO TREATMENT

Demchenko IT, Piantadosi CA.

Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC, USA

Introduction.

The cardiovascular system initially responds to HBO_2 with vasoconstriction, bradycardia and reduced cardiac output. We have found that these physiological responses are coordinated through the HBO_2-activated arterial baroreflex. Here we tested experimentally whether the hyperoxia-activated arterial baroreflex can contribute to the beneficial effects of HBO_2 treatment.

Methods.

Rats were exposed to HBO_2 at 2.5-6 ATA while cardiovascular and bioelectrical variables were measured continuously. Baroreflexes in HBO_2 were evaluated in intact animals, after baroreceptor deafferentation, vagotomy, and electrical stimulation of aortic depressor or vagus nerve.

Results.

Our main findings are: (i) HBO_2 triggers the baroreflex by increasing blood pressure from arterial vasoconstriction. The major contributor to hyperoxic vasoconstriction is reduced vascular NO bioavailability due to its inactivation by intense production of superoxide. (ii) Vasoconstriction-mediated hypertension activates arterial baroreflexes leading to bradycardia and decreased cardiac output, which partially reverses the hypertension. These responses are abolished by deafferentation of the baroreceptors, demonstrating the role of baroreflex afferent pathways. (iii) Moderate levels of HBO_2 ($\leq$ 2.5 ATA) enhance baroreflex function (baroreflex sensitivity index) due withdrawal of sympathetic drive in the autonomic balance. (iii) At 5-6 ATA HBO_2, sympathetic drive rises abnormally, leading to baroreflex impairment and uncontrolled increases in systemic blood pressure. These responses facilitate HBO_2 seizures and are accompanied by cardiac dysfunction and acute pulmonary hypertension. (iv) At 5- 6 ATA HBO_2, activation of baroreflex afferent pathways by electrical stimulation of the aortic depressor or vagus nerves prevents sympathoexcitation, diminishes pulmonary hypertension, improves cardiac function and delays seizures.

Conclusion.

Baroreflexes have two protective functions in HBO_2: they limit cerebral oxygen delivery and restrain brain excitation, prolonging seizure latency. At < 3 ATA HBO_2, the arterial baroreflex sustains depression of sympathetic activity during the entire period of hyperoxia. This baroreflex-derived autonomic response may benefit HBO_2 treatment of patients with sympathetic hyperactivity (e.g. traumatic brain injury, heart failure, hypertension, epilepsy, diabetes).

Supported by the USA Office of Naval Research

O-47 BLOOD GLUCOSE LEVELS IN THE RAT FOLLOWING EXPOSURE TO HYPERBARIC OXYGEN

Mirit Eynan, Michael Mullokandov, Nitzan Krinsky, Adi Biram
Israel Naval Medical Institute, IDF Medical Corps, Haifa, Israel

Background:

There are conflicting findings regarding blood glucose levels (BGL) during exposure to HBO. These contradictory results are probably related to the different pressures at which oxygen was administered.

Objective:

To elucidate the influence of HBO at various pressures on BGL.

Methods:

The study was conducted on 4 groups of Sprague-Dawley rats. Group 1: Exposure to oxygen at 6 ATA until the appearance of convulsions, to determine the animal's baseline latency to central nervous system oxygen toxicity (CNS-OT). These rats were subsequently exposed to HBO at 2, 3, 4, 5 and 6 ATA in sequence, one exposure per week, for 60% of their latency to CNS-OT, calculated for each of these pressures in proportion to the baseline value obtained for 6 ATA. Group 2: Exposure to 6 ATA breathing a gas mixture containing oxygen at a partial pressure similar to that of air, with nitrogen as the diluent gas. Group 3: Animals received 10U/kg insulin to induce hypoglycemia before exposure to HBO at 6 ATA until the appearance of convulsions. Group 4: Animals received 33% glucose in 3 ml saline IP to induce hyperglycemia before exposure to HBO at 6 ATA until the appearance of convulsions. In all groups, blood samples were drawn before and after exposure for measurement of BGL.

Results:

BGL were significantly elevated following exposure to oxygen at 6 ATA until the appearance of convulsions ($P < 0.01$). The HBO pressure had a dose-response effect on BGL. BGL began to rise following exposure to 4 ATA, after which they continued to increase linearly up to 6 ATA ($P < 0.01$). No change was observed in BGL after exposure to 6 ATA breathing a gas mixture containing oxygen at a partial pressure similar to that of air. Hypoglycemia significantly shortened the latency to CNS-OT ($P < 0.05$), whereas hyperglycemia had no effect.

Conclusions:

Exposure to HBO at 4 ATA and above induced elevation of BGL. CNS-OT occurs in rats above 4 ATA oxygen. Blood glucose elevation could therefore serve as a marker for the development of CNS-OT in the rat.

O-48 HYPERBARIC OXYGEN THERAPY AMELIORATES GLUCOSE HOMEOSTASIS IN TYPE 2 DIABETIC PATIENTS

Francisco Guerreiro[1,2], Paulo Vera Cruz[1,2,3], Silvia V. Conde[3], Maria P. Guarino[3,4]

[1] Subaquatic and Hyperbaric Medicine Center - Portuguese Navy - Lisboa – Portugal
[2] Naval Research Center - CINAV - Portuguese Navy - Lisboa – Portugal
[3] CEDOC, NOVA Medical School, NOVA University - Lisboa - Portugal
[4] UIS -Unidade de Investigação em Saúde - Escola Superior de Saúde de Leiria Instituto Politécnico de Leiria, Portugal

Introduction:

Carotid bodies (CB) are arterial chemoreceptors that sense changes in arterial blood O_2, CO_2 and pH levels. When activated, CB respond to induce a fan of cardio-respiratory reflex responses, aimed to normalize the altered blood gases and to regulate blood pressure and cardiac performance via sympathetic nervous system activation. Recently we have found that CB is involved in development of insulin resistance and hypertension in overfed animals through sympathoadrenal over-activation. Knowing that CB activity is abolished by hyperoxia (100% oxygen) the aim of present work was to investigate the effects of Hyperbaric Oxygen Therapy (HBOT) on glucose homeostasis in type 2 diabetic (T2D) patients.

Materials and methods:

Volunteers, recruited at Subaquatic and Hyperbaric Medical Centre of Portuguese Navy, were divided in two groups: T2D patients and controls. Inclusion criteria for T2D are those defined by American Diabetes Association in 2010. All groups were submitted to 20 HBOT sessions. Oral glucose tolerance tests were performed before 1st and in the last HBOT session.

Results:

Sixteen T2D patients (Age: 64 ± 2.6 years; BMI: 26.02 ± 1.07 kgm^{-2}) and 16 controls (Age: 58 ± 3.2 years; BMI: 25.22 ± 1.05 kgm^{-2}) were included. Fasting plasma glucose was 145.6±12.62 mg/dl in T2D patients and 92.06±2.99 mg/dl in controls. In T2D patients before the 1st HBOT session, plasma glucose levels 2 hours post-OGTT were 280.25 ± 22.29 mg/dl. After 20 HOT sessions glycemia values were 119.1 ± 4.80mg/dl at fasting and 185.78 ± 11.70 mg/dl 2 hours post-OGTT. In control group HBOT did not modify either fasting glycemia or post-OGTT glycemia.

Discussion:

Our results showed that HBOT ameliorates glucose tolerance in T2D patients and suggest that HBOT could be used as a therapeutic intervention for the treatment of T2D in selected cases.

Keywords:

Glucose homeostasis, type 2 diabetes, hyperbaric oxygen therapy, carotid body

O-49 MULTIDISCIPLINARY APPROACH FOR THE ENHANCEMENT OF HEALING IN SELECTED PROBLEM WOUNDS.

K. Hoxha[1], P. Baroni[1], E. Bondioli[2], D. Melandri[2], P. Longobardi[1], I. Tomasini[3]

[1]Centro iperbarico Ravenna (I); [2]Burn Centre and Regional Skin Bank, Bufalini Hospital, AUSL Cesena (I); [3] Blood Transfusion Service, S.M. delle Croci Hospital AUSL Ravenna (I)

Contact: k.hoxha@iperbaricoravenna.it

Objectives:

To verify if a multidisciplinary approach allows the enhancement of healing in selected problem wounds better than the benchmarking (for Venous Stasis Ulcers: > 29 % reduction in ulcer area at 4 weeks as an indicator of the total healing in 24 weeks – reference 1)

Methods:

At Hyperbaric Center of Ravenna, in 2013, 398 patients with skin wound were treated for a total of 32,161 Wound Care procedures. The etiology was: traumatic (38%), venous stasis (22), rheumatic (14), mixed vascular insufficiency (14), pressure (7), arterial insufficiency (6). Inclusion criteria: ulcer present for > 6 weeks; size from 5 cm^2 to the whole leg circumference; Falanga score ≥ B2. The wounds were treated with: mechanical ultrasound debridement; homologous platelet gel; HBOT (20 sessions in a multiplace chamber at 254 kPa with a FiO_2 in mask > 0.9, for 90 minutes, 5 days per week); Frequency Rhythmic Electrical Modulation System, 20 sessions, 5 days per week; allograft *(only if necessary)* once every two weeks for three times.
Platelet gel was prepared following a validated method and activated, at clinical use, in 1:1 ratio with gluconate calcium and thrombin on a support of modulating matrix proteases. The final product, so gelled, was topically applied once a week for 4 weeks.
The evaluation was carried out every week (measurement of ulcer area with Visitrak®, transcutaneous oximetry, photography and clinical examination).

Results: The table 1 shows the results at eight weeks from the inclusion

Skin wound	Healed (%)	Improved (%)	Stationary (%)	Drop out (%)
Traumatic	6.2	22.4	10.4	-
Venous	80.5	12.2	4.9	2.4
Rheumatic	72	24	-	4
Mixed (Vascular)	69.2	30.8	-	-
Pressure	57.1	28.6	14.3	-
Ischemic	33.3	-	66.7	-

Most of the wounds healed or improved *(reduced by 72%, Falanga score A2)* after eight weeks from the inclusion. Arterial insufficiency ulcers had less benefit. There were no side effects.

Conclusion:

Our experience suggests clinical efficacy of multidisciplinary approach for the enhancement of healing in selected problem wounds.

Key words:

Hyperbaric Oxygenation, Wound Repair, Platelet Rich Plasma, Platelet gel, Skin Graft

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O-50 HBO PRECONDITIONING: HOW DOES IT AFFECT CNS MITOCHONDRIAL FUNCTION?

Michael Mullokandov [a], Adi Biram [a], Moshe Gavish [b], and Yehuda Arieli [a]

[a] Israel Naval Medical Institute, and [b] Department of Pharmacology, Rappaport Faculty of Medicine, The Technion, Haifa, Israel

Background:

We have previously shown that HBO preconditioning (HBO-Pc) results in increased latency to CNS-oxygen toxicity, associated with alterations in the activity of hippocampal ROS scavenger enzymes. In the present study, we examined the effect of HBO-Pc on isolated mitochondrial function.

Methods:

Male Sprague-Dawley rats were divided into four groups. Rats in the negative control group (Ctl^-) were not exposed at all to HBO. Rats in the control group (Ctl) were exposed to HBO at 6 ATA until the appearance of grand mal convulsions. Two groups of rats were preconditioned to HBO by three 1-hour exposures to oxygen at 2 ATA, one session every other day. At the end of the preconditioning process, one of these groups (Pc+6) was exposed to HBO at 6 ATA. The second group (Pc) was not exposed further to HBO after preconditioning. Samples were extracted from the frontal cortex and hippocampus of the animals in all four groups to evaluate mitochondrial membrane potential using JC-1 dye and to assess ATP production, both under normal conditions and under oxidative stress. Grp75 levels were evaluated by Western blot.

Results:

Both membrane potential and the driving force over the mitochondrial inner membrane in the hippocampus were increased following exposure to HBO at 6 ATA, representing a hyperpolarized state of mitochondrial respiration. The same hyperpolarization was observed in the HBO-Pc group not exposed to HBO at 6 ATA (Pc). In addition, membrane potential in the Pc+6 group was slightly reduced when compared with the Ctl group. ATP production was highest in the cortex of the preconditioned rats; however, following HBO exposure it decreased in the preconditioned rats and increased in the control rats. Similar results were obtained under oxidative stress. No significant change in ATP production was found in the hippocampus in any group. Measurement of the stress-induced chaperone Grp75 showed decreased levels in the hippocampus in the Pc and Pc+6 groups, and in the cortex in the Ctl and Pc+6 groups.

Conclusions:

We observed improvement in mitochondrial function following HBO preconditioning, expressed in increased cortical ATP production, elevated mitochondrial inner membrane potential in the hippocampus, and low mitochondrial Grp75 levels.

Author Index