# EUBS 2010

# 36th ANNUAL MEETING OF THE EUROPEAN UNDERWATER AND BAROMEDICAL SOCIETY

INTERNATIONAL CONFERENCE
ON DIVING AND HYPERBARIC MEDICINE

**14-18 September 2010**
**Istanbul, TURKEY**

## Abstract and Conference Book

EUBS

European Underwater and Baromedical Society

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EUBS

European Underwater and Baromedical Society

**Dear Colleagues,**

This Abstract and Conference Book of the 36th Annual Meeting of the European Underwater and Baromedical Society you are holding in your hands reflects the broad spectrum of topics and multidiciplinary needs and approaches of diving and hyperbaric medicine. It also reflects the profiles of conference attendants and members of EUBS as academics, medical practioners, technicians, researchers, and members of all related disciplines.

In this book you will find a total of 134 abstracts of scientific presentations and texts of the presentations of invited speakers of this international conference.

It has been a great honour to organize the EUBS 2010. I do thank you for your scientific input on behalf of the Organizing Committee, for it would not be possible to organize such an international conference without your contributions.

We hope the 36th Annual Meeting of EUBS meets your expectations, and you all enjoy it as a scientifically and socially memorable meeting.

**Prof. Maide Çimşit MD, MSc**
**General Secretary, EUBS 2010**

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## EUBS 2010 Scientific Committee

| | |
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| Birol Çotuk | Marmara University, Medical Faculty, Department of Sport Science and Physical Education |

Chronic Wound Council of Istanbul Faculty of Medicine, Istanbul University
(in alphabetical order): Şamil Aktaş, Selçuk Baktıroğlu, Maide Çimşit, Önder Kılıçoğlu, Rıfkiye Küçükoğlu,Halit Özsüt, İlhan Satman, Akın Savaş Toklu, Murat Topalan

# Scientific Program

## September 14, 2010

09:00 - 17:30 Registration
17:30 - 19:00 Welcome Cocktail

## September 15, 2010

### Main Hall, Diamond Meeting Room

09:00 - 09:20 Opening Ceremony

### Scientific Session I

**09:20 - 10:00** **European Code of Good Practice for Hyperbaric Oxygen Therapy** ***Jacek Kot***
***Moderators: Maide Çimşit, Şamil Aktaş***

**10:00 - 10:30** **Coffee Break**

### Scientific Session II

**10:30 - 12:30** **Hyperbaric Medicine; Physiology, Experimental Works and Technical Aspects**
***Moderators: Phil Bryson, Andreas Mollerlokken***

| | | |
|---|---|---|
| 10:30 - 10:42 | EBAss certification scheme for hyperbaric chamber personnel | *Peter Alan Atkey* |
| 10:42 - 10:54 | Technological innovation: medicinal gas and operative procedures in hyperbaric medicine | *Valeria Campanaro* |
| 10:54 - 11:06 | Intensive care patient data management system in the hyperbaric environment | *Peter Kronlund* |
| 11:06 - 11:18 | Protection against biologic agents inside therapeutic hyperbaric chambers: a strategical approach | *Rob Houman* |
| 11:18 - 11:30 | The rating of the patient's satisfaction factors in a clinical hyperbaric center: a 4 years experience | *Rob Houman* |
| 11:30 - 11:42 | Hyperbaric nursing publications: A literature review over the past 10 years | *Damianos Tzavellas* |
| 11:42 - 11:54 | The effects of hyperbaric oxygen therapy on blood-brain barrier permeability in septic conditions | *Sezen Milli Avtan* |
| 11:54 - 12:06 | The effects of the hyperbaric oxygenation during the recovery from the experimental brain injury | *Predrag Brkic* |
| 12:06 - 12:18 | Hyperbaric oxygenation can improve the recovery of motor functions in rats after experimental brain injury | *Predrag Brkic* |
| 12:18 - 12:30 | Incidence of middle ear barotrauma in rats and guinea pigs | *Cem Uzun* |

**12:30 - 14:00** **Lunch**

**13:00 - 13:40** **Lunch Conference**
**Hyperbaric Oxygen Therapy in Eye Diseases** ***Üzeyir Erdem***
***Moderators: Koray Akarçay, Nilüfer Alparslan***

# Scientific Program

## September 15, 2010

### Scientific Session III

**14:00 - 15:30** **Diving Physiology and Diving Technologies**
***Moderators: Alf O. Brubakk. Igor Mekjavic***

| | | |
|---|---|---|
| 14:00 - 14:11 | Detection of cardiac bubbles by means of transthoracic echocardiogram. Analysis of a case on 5th degree E-B and comparison with his fellow worker (3rd degree E-B) | *Jorge Calderon* |
| 14:11 - 14:22 | Automatic analysis for bubble detection on echocardiographic decompression records | *Ismail Burak Parlak* |
| 14:22 - 14:33 | Echographic bubble count: an objective measure of venous gas emboli in diving research | *Peter Germonpre* |
| 14:33 - 14:44 | Effects of FLIRT (First Line Intermittent Recompression Technique) on bubble growth in man - preliminary results - | *Andreas Edmund Koch* |
| 14:44 - 14:55 | Prediction of bubble grades with a simple model; application to an identical repetitive open water dive | *Nico Schellart* |
| 14:55 - 15:06 | Testing and validation of diving computers | *Arne Sieber* |
| 15:06 - 15:17 | Under-Ice scuba regulator performance | *Michael A. Lang* |
| 15:17 - 15:28 | Solid state gas sensors for closed circuit diving systems | *Arne Sieber* |

**15:30 - 16:00** **Coffee Break**

### Scientific Session IV

**16:00 - 17:30** **Hyperbaric Oxygen; Experimental and Clinical Works**
***Moderators: Daniel Mathieu, Halit Özsüt***

| | | |
|---|---|---|
| 16:00 - 16:11 | Evaluation of the interactions between the oxygen labile agent tigecycline and hyperbaric oxygen therapy (HBOT) in an experimental Staphylococcus aureus sepsis model in mice | *Ayşen Kolat* |
| 16:11 - 16:22 | Effect of hyperbaric oxygen therapy on amikacin toxicity | *Cem Uzun* |
| 16:22 - 16:33 | Hyperbaric oxygen assists chronic wound healing through impaired neutrophil recruitment and improved endothelial and neutrophil function | *A. Kendall* |
| 16:33 - 16:44 | Use of hyperbaric oxygen therapy in the treatment of ischemic wounds in Turkey: A multi-center case series of 652 patients | *Mesut Mutluoğlu* |
| 16:44 - 16:55 | Creatine phosphokinase blood test as useful factor in HBOT of diabetic putrified gangrene | *Danica Vujnovic* |
| 16:55 - 17:06 | Treatment of patients with multi-resistant micro-organisms in a multiplace hyperbaric chamber – a case report | *Marga Schweigmann* |
| 17:06 - 17:17 | Long term follow-up results of "HBO and mitomycin-C assisted limbal – minitransplantation" for alkaline corneal burns associated with severe neovascularization | *Üzeyir Erdem* |
| 17:17 - 17:28 | Septic shock and necrotizing fasciitis, at study on predicted and actual mortality through 3 years | *Erik Christian Jansen* |

# Scientific Program

## September 16, 2010

### Main Hall, Diamond Meeting Room

#### ECHM Workshop

| | | |
|---|---|---|
| **08:30 - 10:30** | **Controversial Issues in HBO** | |
| **08:30 - 09:30** | **Aseptic Bone Necrosis** | |
| 08:30 - 08:50 | Introductory Report | *L. Ditri* |
| 08:50 - 09:10 | Short Communications | *J. Desola, J. Von Reumont* |
| 09:10 - 09:30 | General Discussion | |
| **09:30 - 10:30** | **Global Brain Ischemia** | |
| 09:30 - 09:50 | Introductory Report | *B. Ratzenhofer* |
| 09:50 - 10:10 | Short Communications | *D. Mathieu, J. Desola* |
| 10:10 - 10:30 | General Discussion | |
| **10:30 - 11:00** | **Coffee Break** | |

#### ECHM Workshop

| | | |
|---|---|---|
| **11:00 - 12:30** | **Controversial Issues in HBO** | |
| **11:00 - 12:30** | **Autism** | |
| 11:00 - 11:20 | Introductory Report 1: Clinical characteristics, etiopathogenesis & treatment approaches in autism spectrum disorders | *N. Motavalli* |
| 11:20 - 11:40 | Introductory Report Part 2: Current evidence concerning HBO use in autism | *J. Schmutz* |
| 11:40 - 12:10 | Short Communications | |
| 12:10 - 12:30 | General Discussion | |
| **12:30 - 14:00** | **Lunch** | |
| **14:00 - 16:00** | **Meeting of Board of Directors of EBAss** | |
| **16:00 - 18:00** | **General Assembly of EBAss** | |

### Quartz 1 Meeting Room

| | |
|---|---|
| **12:30 - 14:00** | **EDTC Medical Subcommittee meeting** |
| **14:30 - 16:30** | **ECHM Executive Board Meeting** |
| **17:00 - 18:00** | **ECHM Board of Representatives Meeting** |

# Scientific Program

## September 17, 2010

### Main Hall, Diamond Meeting Room

### Scientific Session V

**09:00 - 09:40** **HBOT in Traumatology; Why, When and How?** ***Ian Millar***
***Moderators: Constantino Balestra, Ufuk Talu***

### Scientific Session VI

**09:40 - 10:30** **Hyperbaric Oxygen; Clinical Works**
***Moderators: Peter Knessl, Wilhelm Welslau***

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|---|---|---|
| 09:40 - 09:50 | Use of hyperbaric oxygen therapy in the treatment of central retinal artery occlusion (CRAO) in Turkey: 331 cases | *Aslıcan Çakkalkurt* |
| 09:50 - 10:00 | Traumatic brain injury treated by HBO | *Erik Christian Jansen* |
| 10:00 - 10:10 | Hyperbaric oxygen treatment of unexpected mandibular bone necrosis after orthognathic surgery in a patient with hemifacial microsomia | *Erik Christian Jansen* |
| 10:10 - 10:20 | Femoral condyle osteonecrosis and hyperbaric oxygen therapy. A case presentation and some reflections over its rational therapy | *Jordi Desola* |
| 10:20 - 10:30 | Hyperbaric oxygen therapy as adjuvant therapy in spondylodiscitis | *Moreno Pozza* |

**10:30 - 11:00** **Coffee Break**

### Scientific Session VII

**11:00 - 12:30** **Hyperbaric Oxygen; Clinical Works**
***Moderators: Beatrice Ratzenhofer-Komenda, İlgin Özden***

| | | |
|---|---|---|
| 11:00 - 11:13 | Gas embolism after cardiovascular surgery: Do we need diagnosis confirmation before referring patients for hyperbaric treatment ? | *Daniel Mathieu* |
| 11:13 - 11:26 | Cyanide plus carbon monoxide combined poisoning. Analysis of the role of hyperbaric oxygen based in a review of 62 cases | *Jordi Desola* |
| 11:26 - 11:39 | Assessment of routine hemodynamic parameters and catecholamine demand after HBOT in critically ill patients | *Irem Tezer* |
| 11:39 - 11:52 | Hyperbaric oxygen therapy for hepatic artery thrombosis after combined pediatric liver and kidney transplantation: a case report | *Andrea Brunati* |
| 11:52 - 12:05 | Safe and effective use of hyperbaric oxygen therapy for late hepatic artery thrombosis | *Alessandro Ricchiuti* |
| 12:05 - 12:18 | Treatment of acute ischemic stroke with normobaric, or even hyperbaric oxygen – which strategy provides the first successful preclinical-to-clinical translation? | *Dominik Michalski* |
| 12:18 - 12:30 | Is hyperbaric medicine a cost effective contemporary medical branch or a fad? | *Tomislav Jovanovic* |

**12:30 - 14:00** **Lunch**

# Scientific Program

## September 17, 2010

### Scientific Session VIII

**14:00 - 15:30** **Diving Medicine**

***Moderators: Erika Schagatay, Birol Çotuk***

| | | |
|---|---|---|
| 14:00 - 14:11 | Bubbles after deep breath-hold dives in competition | *Marianne Bjordal Havnes* |
| 14:11 - 14:22 | Pre-dive normobaric oxygen reduces bubble formation scuba divers | *Olivier Castagna* |
| 14:22 - 14:33 | Endurance exercise immediately before sea diving reduces bubble formation in scuba divers | *Olivier Castagna* |
| 14:33 - 14:44 | Mild dehydration per se does not increase the risk of decompression sickness | *Igor B Mekjavic* |
| 14:44 - 14:55 | Comparison between dehydration and hyperthermia on decompression bubble formation | *Mikael Gennser* |
| 14:55 - 15:06 | Vascular gas bubbles indicate decompression risk | *Alf O Brubakk* |
| 15:06 - 15:17 | Diving depths corrected for age and VO2max | *Nico Schellart* |
| 15:17 - 15:28 | Magnetic resonance imaging of the central nervous system in rats following heliox saturation decompression | *Arvid Hope* |

**15:30 - 16:00** **Coffee Break**

### Scientific Session IX

**16:00 - 17:30** **Diving Medicine**

***Moderators: Marco Brauzzi, Şenol Yıldız***

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|---|---|---|
| 16:00 - 16:11 | The profile of Turkish female divers | *Bengüsu Öroğlu* |
| 16:11 - 16:22 | Diving for a large group of recreational divers with Spinal Cord Injury – SCI divers | *Branko Ravnak* |
| 16:22 - 16:33 | Therapeutic scuba diving as a part of rehabilitation for adults with mental and physical disabilities | *Alenka Fidler* |
| 16:33 - 16:44 | Risk factors for running low on gas in Western Australia | *Peter Lee Buzzacott* |
| 16:44 - 16:55 | Web-based system for clinical evaluation of fitness to dive | *Erika Garbella* |
| 16:55 - 17:06 | Medical fitness as a criterion to select "best" commercial divers | *Tamer Ozyigit* |
| 17:06 - 17:17 | A retrospective analysis of and comparison between two diving medical questionnaires | *Catherine Anne Meehan* |
| 17:17 - 17:28 | The effect of inert gas narcosis on critical flicker fusion frequency during a square-profile, 33 msw/110 fsw, 20 minutes air dive | *Pierre Lafère* |

**Quartz 1 Meeting Room**

**11:00 - 15:30** **EUBS Executive Committee Meeting**

# Scientific Program

## September 18, 2010

### Main Hall, Diamond Meeting Room

### Scientific Session X

**09:00 - 10:30** **Diving Medicine; Breath-Hold Diving**
***Moderators: Peter Germonpre, Günalp Uzun***

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|---|---|---|
| 09:00 - 09:11 | Experiment on long duration immersion in thermoneutral water conditions | *Claude Robinet* |
| 09:11 - 09:22 | The effect of acute normobaric hyperoxia on EPO concentration in h ealthy males | *Igor B Mekjavic* |
| 09:22 - 09:33 | Blood lactate after deep dives in 3 disciplines of competitive apnea | *Harald Engan* |
| 09:33 - 09:44 | Effects of warm-up on static apnea performance | *Angelica Lodin Sundström* |
| 09:44 - 09:55 | Eating or fasting before static apnea performance | *Erika Schagatay* |
| 09:55 - 10:06 | Underwater working time in two groups of traditional apneic divers in South East Asia | *Erika Schagatay* |
| 10:06 - 10:17 | Time course of carbon monoxide and nitric oxide pulmonary transfer factor after hypoxic and hyperbaric stress in breath-hold divers | *Erika Garbella* |
| 10:17 - 10:28 | Increased lung “comets” in breath hold divers | *Costantino Balestra* |

**10:30 - 11:00** **Coffee Break**

### Scientific Session XI

**11:00 - 12:30** **Diving Medicine**
***Moderators: Jordi Desola , Akın Savaş Toklu***

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|---|---|---|
| 11:00 - 11:13 | Pre-dive vibration reduces post-dive venous gas emboli: a controlled randomised study | *Peter Germonpre* |
| 11:13 - 11:26 | Decompression sickness (Taravana) in a breath hold diver with delayed-onset reversible focal neurological injury: A case report | *Evangelos Papoutsidakis* |
| 11:26 - 11:39 | Risk factors and clinical outcome in 279 recreational divers with spinal cord decompression sickness | *Jean Eric Blatteau* |
| 11:39 - 11:52 | Inner ear decompression sickness, retrospective analysis of 24 cases | *Mihaela Cristiana Ignatescu* |
| 11:52 - 12:05 | Divers as decompression sickness survivors: exploring their physical exercise involvement and time management | *Yonne Tangelder* |
| 12:05 - 12:18 | Exceeding the limits - estimated tissue pressures among Western Australian recreational divers | *Peter Lee Buzzacott* |
| 12:18 - 12:30 | Pressure modulation of presynaptic Ca2+ currents in frog motor nerve terminals | *Yoram Grossman* |

**12:30 - 14:00** **Lunch**

**13:00 - 13:40** **Lunch Conference**
**Ships Laden With History: Yenikapı Shipwrecks** ***Ufuk Kocabaş***
***Moderator: Rıfkiye Küçükoğlu***

**14:00 - 15:00** **EUBS GENERAL ASSEMBLY**

**15:00 - 15:30** **CLOSING CEREMONY**

# Invited Speakers

# European Code Of Good Practice For Hyperbaric Oxygen Therapy

Jacek Kot
*General Secretary of the European Committee for Hyperbaric Medicine*
*National Center for Hyperbaric Medicine in Gdynia, Medical University of Gdansk, Poland*

The document "European Code of Good Practice for Hyperbaric Oxygen Therapy" (1) was the initiative of the members of the European international group of specialists in hyperbaric medicine who were already cooperating in the project COST Action B14. The COST – European COoperation in the field of Scientific and Technical Research – was the first and is the widest European network for the coordination of nationally funded research activities established in 1971 (2). It coordinates nationally funded research between its 35 Member States in Europe (plus Israel as a "cooperating state") through its cooperation networks (so called COST Actions).

In 1998 the Action B14 entitled "Hyperbaric Oxygen Therapy" has started in Medicine and Health domain of the COST project. Nineteen countries signed the Memorandum of Understanding (Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Israel, Italy, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom) and Professor Daniel Mathieu from Lille, France became the Chairman of the Action. The main objective of the Action was *"to improve the knowledge required for a rational use of hyperbaric oxygen therapy, to a level making it possible to set out specific guidelines for the implementation and development of clinical centres for HBO and to provide scientifically sound recommendations for HBO treatment of various diseases and conditions".*

There were several Working Groups created, including one on Technical Aspects (chaired by Robert Houman from Belgium) which prepared Hazard Identification for HBO and the other Working Group on Safety, started in 2001, chaired initially by Jean-Luis Meliet from France and later by Jacek Kot from Poland, which prepared the European Code of Good Practice for HBO.

In order to prepare the European Code, the Working Group on Safety reviewed all relevant documents choosing one from British Hyperbaric Association "Health and Safety for Therapeutic Hyperbaric Facilities: A Code of Practice" dated 2000 (3) as the most complete document to become a basis for the European Code. This document has been later on rewritten using all available (at those times) national regulations and norms (from UK, France, Germany and Italy). Moreover clinical procedures used at those times in different countries were reviewed and compared with each other to find guidelines to conduct a safe hyperbaric treatment in different settings used in different European countries.

At the same time in Europe, the CEN/BT Task Force 127 was preparing project of the European Norm for "Pressure vessels for human occupancy (PVHO) – Multi-place pressure chambers for hyperbaric therapy – Performance, safety requirements and testing" which nowadays is accepted as EN14931:2006. Both groups, Working Group on Safety and Task Force 127, were cooperating closely to ensure the compatibility of both documents.

As a result a document "European Code of Good Clinical Practice for Hyperbaric Oxygen Therapy" has been approved by all members of the Management Committee of the COST B14 Action and become ready for Public Release since May 2004. After the end of the COST B14 Action (officially in 2005) the European Committee for Hyperbaric Medicine has become the "owner" of the document, so now the European Code can be downloaded freely from the ECHM website (www.echm.org).

COST B14 Action used the European Internet portal, called OXYNET. One of part of the OXYNET is the list of the European HBO facilities which are willing to show themselves in this registry and to cooperate on the European level. The inclusion into this list is based on voluntarily filled questionnaire, so it represents most of those facilities which are interested in international cooperation. At the time of creation of the European Code (2004) there were 182 HBO facilities already registered in the OXYNET including 89 facilities (~50%) installed in countries which had already their national regulations for HBO facilities (UK, France, Germany, Italy) and 42 facilities (~22%) installed in countries which shared their clinical experience in the European Code (Belgium, Spain, Sweden, Finland, Netherlands, Denmark, Austria). This means that kernel of the European Code represents the most widely accepted clinical practice used in Europe.

The European Code is based on law regulations and official standards from countries where hyperbaric medicine has been best developed, with the longest traditions of its use and with greatest experience in its application. Existing national regulations are usually dominant and in such circumstances the European Code is used as international guidelines confirming validity of local regulations sometimes being supportive for national accreditation system specific for hyperbaric facilities (if implemented, like for example in UK). The use of the European Code is also of great importance for other countries, those which do not have yet complete system of national regulations for hyperbaric medicine but would like to start implementation of the hyperbaric services on high level feeling support of those countries which are better experienced.

The example of the country where implementation of the European Code of Good Clinical Practice for Hyperbaric Oxygen Therapy has been very important was Poland. When European Code was under preparation, in Poland there was already a time of conversion from social health care system into the national health fund. There was no national regulation for hyperbaric medicine, but there was a National Center for Hyperbaric Medicine that was delegated to the international cooperation with the COST B14 Action. As a result the European Code has been implemented in the national system to confirm validity of current clinical practice and to define the safe level for other newly created hyperbaric centres. Indeed, having requirement that only those hyperbaric procedures which are conducted according to the European Code, ensured good level of financial reimbursement on the similar level as in other European western countries. And this situation stimulated creation of new HBO centres according to the same guidelines.

Currently the scope of the European Code is the medical hyperbaric facility. Due to inherited risk of treatment in hyperbaric chamber with oxygen or other breathing mixtures of gases, the basic procedure used in any activity of hyperbaric centre is risk analysis, which consist of hazard identifications and measures taken to decrease the risk down to acceptable level. In the European Code there is already included a detailed description of risk analysis procedure with hazard identification specific for medical hyperbaric facility. But such approach should be extended out of medical hyperbaric facilities into the hyperbaric centres with all links to host hospital services, connections with critical care unit, emergency room and other highly sophisticated medical services. Going further, one can even think about the identification of hazards related with hyperbaric medicine per-se, not dealing any more with its specific components, like pressure, oxygen, confined space, which has been already done in the risk analysis for hyperbaric facilities and which can be found in the current version of the European Code. This is true that even the best medical hyperbaric facility with sophisticated hyperbaric system and well trained staff will fail on development of hyperbaric medicine if any of the following hazards occur:

- Lack of recognition of HBO efficacy
- Lack of evidences of HBO safety
- Lack of cooperation with external specialists and other departments
- Presence of different modalities for oxygenation as competition for HBO therapy (eg. local oxygen therapy, inflatable low-pressure monoplace chambers, “mild hyperbaric treatment”, low fraction oxygen supplementation)
- Indications based on experts’ opinion (clinical experience) and not on scientific evidences
- Underestimation of price for hyperbaric treatment.

From the list of those hazards which must be taken into account, two last items will be discussed here in more details: one, concerning indications for hyperbaric medicine and the other one, concerning price of the hyperbaric session.

In the history of hyperbaric medicine, there was a time when hyperbaric medicine was recognized as "the cure in search of a disease". Currently there is time for practicing hyperbaric medicine on a scientific basis and lists of indications are being prepared by world-wide international organisations, like Undersea and Hyperbaric Medical Society (4) or European Committee for Hyperbaric Medicine (5) using Evidence Based Medicine. Those lists are approved in most of countries. But still in Europe there can be found different approaches. For example, as recently published (6), there is already approved new list of indications which differs from other widely used lists (UHMS, ECHM) by adding several indications based on local clinical experience, namely Bell's palsy, open-angle glaucoma, Buerger's and Raynaud's disease and some others. Such approach can have potentially positive effect, as it is source of valuable information not easily being collected in other circumstances. The situation that in at least one of European country there is nationally approved indication for HBO therapy, not accepted in other countries, enables gathering clinically important information which could be used as a basis for later controlled experiments in other countries. But on the other hand, introducing for approval indications based only on experts' opinion or clinical experience can be potentially deleterious for the hyperbaric medicine in general in case when efficiency of hyperbaric treatment will not be confirmed for some of those indications when using Evidence Based Medicine. Such situation occurred in Germany in 90-ties (7), when uncontrolled use of hyperbaric medicine in treatment of tinnitus, after a short boom, led to critical restructuring of nationally approved indications of treatment into the list which is very restrictive and in consequences lead to close some hyperbaric facilities.

The other hazard for implementation or development of hyperbaric medicine in any country is price of a hyperbaric session. In 2009 Dr. Kiyotaka Kohshi from Japan conducted the survey on prices in different countries (including Australia, Canada, France, Germany, Indonesia, Italy, Japan, Malaysia, Poland, Sweden, The Netherlands, UK, and USA). It showed that the price for standard, non-intensive-care sessions varies all over the world from ?18 to ?1680, and for intensive care or emergency sessions from ?65 to ?9000 (personal communication). The most surprising conclusion which came from this survey was that in Japan the price for every HBO session, both standard and emergency, is probably the lowest all over the world. And this price has not changed since 30 years. As admitted by Dr. Kohshi in personal communication, this underestimation of HBO session leads to closure of hyperbaric facilities, including those belonging to medical universities.

Even if differences between prices for hyperbaric session between European countries are not so large as between different world regions, still this is of great importance as currently there is a proposal for a directive of the European Parliament and of the Council on the application of patients' rights in cross-border healthcare (8) which will lead to free exchange of medical services in Europe. This would mean that patients would be free for medical travels all around the Europe expecting at least partial reimbursement. Whether this will become true is questionably and the project is still under heavy debate, but we have to be prepared for such possibility.

Knowing the history of creation of the European Code, its sources of information and its major content, as well as the limitations of the current version and hazards which are specific for hyperbaric medicine per se, there should be a possibility to conduct a SWOT analysis for application of the European Code in any country which is implementing or fixing hyperbaric medicine. This analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in any project.

Strengths of the European Code, defined as "attributes of the person or company (here: a European Code) that are helpful to achieving the objectives (here: implementation of hyperbaric medicine)" include description of safe way

of conducting the hyperbaric session. Keeping strictly with this document and included references allows conducting at least the standard (non-intensive) session in newly created medical hyperbaric facility built in a country where there is no regulation specific for hyperbaric conditions. On the other hand, it can be used as the very first document (of the highest level) in education on hyperbaric medicine, as it leads through all other documents (Directives, Norms, Guidelines and Standards) used in Europe.

Weaknesses of the European Code, defined as "attributes of the person or company (here: a European Code) that are harmful to achieving the objective(s) (here: implementation of hyperbaric medicine)" include too general approach as a reason of accepting different practices in countries which representatives were participating in creation of a document. For example, there is no clear answer where the medical attendant should be in relation to the hyperbaric chamber. There are different modalities concerning attendants of patients under pressure. In different European countries there are many solutions for this: staying all the time under pressure with patients, going under pressure only with the first-time patients and those patients who clearly needs support or even leaving after installation in the hyperbaric chamber intensive care patients who are pharmacologically sedated and relaxed with artificial ventilation assuming detailed monitoring, patient's hemodynamic stability and possibility of medical attendant to fast compression when needed. This strongly depends on experience of the hyperbaric staff, but document like European Code should serve as a guide for non-experienced users, not assuming that a reader is very experienced practitioner. The other potential Weakness of the European Code is the way used for description of use of monoplace chambers. In Europe practice with monoplace chambers is different than for example in United States. In Europe there are countries where monoplace chambers are used in the same departments as multiplace chambers as depending at discretion of personnel, as for example in Sweden; there are countries, where treatment in such chambers is not reimbursed by the health care system (like in Poland) or where monoplace chambers cannot be used, as for example in Italy or France. The only European Norm which concerns hyperbaric chambers (EN14931) is dedicated exclusively to multiplace chambers. So there is no formal regulation concerning manufacturing or installation of monoplace chambers in Europe. Even in the European Code the monoplace chambers are mentioned only in relation with required staff, without any other description, for example of fire safety.

Opportunities for the European Code, defined as "external conditions that are helpful to achieving the objective(s) (here: implementation of hyperbaric medicine)" includes possibility for its usage as international guidelines or as the reference document in countries with lack of national regulations. This was discussed previously.

Treats for the European Code, defined as "external conditions which could do damage to the objective(s) (here: implementation of hyperbaric medicine)", can come from the list of hazards presented previously. From this list underestimated price for hyperbaric session has direct input on operation of the hyperbaric facility especially in developmental phase. The other treat comes from the hazard of lack of scientifically justified list of clinical indications with clear procedure for treating patients with "off-line" indications. We have to remember the situation in Germany, when one of the consequences of central regulation limiting use of HBO for ambulatory patients was significant decrease of treatments leading to closing of hyperbaric facilities.

In conclusion, the European Code of Good Practice for Hyperbaric Oxygen Therapy has been prepared by international cooperation of experts from European countries which had had knowledge and experience in clinical practice of hyperbaric medicine. This document can be used as international guidelines or as a reference document in those countries where there is lack of formal rules. It has some limitations and weaknesses which have been presented in this paper and which should be corrected in the process of updating.

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# Hyperbaric Oxygen Therapy in Eye Diseases

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Hyperbaric oxygen therapy is effective on multiple systemic and ocular diseases by increasing tissue oxygen pressure.

Culton et al. investigated the effect of hyperoxia on chemical injury induced corneal neovascularization in rats. The eyes of rats were exposed to several oxygen concentrations (0, 10, 21, 50, 75 and 100%) for 4 days after injury significant reduction in neovascularization observed only in corneas exposed to 100% oxygen.

Matrix matalloproteinases (MMPs) are a group of proteolytic enzymes which involved in the extracellular matrix remodelling in angiogenesis. Lee et al. found that corneal infiltrating neutrophils express matrix metalloproteinase-9 (MMP-9) and treatment with specific monoclonal antibody reduces the extent of angiogenesis (Lee et al. 2002). HBO reduces neuroinflammation and MMP-9 expression in a rat model of traumatic brain injury (Voladovsky et al. 2006).

Another study (Seta at all.) has demonstrated that CYP4B1 mediated 12-HETrE pathway expression that promotes VEGF mRNA levels in ischemic corneal tissue and increases corneal inflammation and neovascularization. HBOT might be effective for suppression of this pathway and have negative effect of corneal neovascularizations and ischemic trauma induced inflammations by increasing tissue oxygen level and consumption. Increasing epithelial oxygenization with HBO therapy presents anti-angiogenic effect with inhibition of VEGF expression and matrix metalloproteinases. Also has anti-inflammatory effect with inhibition of ICAM-1 expression and reducing PMNL migration

The transparency and avascularity of the cornea and pathophysiologic mechanisms of corneal damage have been reported with previous studies. Many pro and antiangiogenic molecules effects have been revealed in corneal inflammation and neovascularization. To reduce limbal stem cell and basal membrane damage is he aim of conventional therapy.

We have several succesfull studies with HBOT such as ischemic retinopathies, corneal and conjunctival chemical burns, chronic corneal ulcers, skleral necrozis, ischemic optic neuropathies...

Treatment of corneal and conjunctival alkaline burns with HBO therapy is a new approach more effective in acute phase and cost effective in chronic phase than only conventional therapy.

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# Hyperbaric Oxygen in Traumatology

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## *Introduction*

Research on the potential for hyperbaric oxygen in trauma commenced in the 1960's and from the 1970's, hyperbaric oxygen has been promoted as a useful therapy for compartment syndrome, crush injury, acute traumatic ischaemia and acute traumatic brain and spinal cord injury. A series of potentially useful therapeutic mechanisms have been identified and consistently verified in animal models: salvage of critically ischaemic tissue, various anti-infective effects, reduction of oedema and improvements in the rate and quality of healing of bone, tendon, muscle, skin and peripheral nerve. In more recent times, this list of useful actions has been added to with: minimisation of ischaemia-reperfusion injury, favourable modulation of cytokine and inflammatory response to injury, induction of an upregulated anti-oxidant state and pre-conditioning before surgery.

These mechanisms of action would suggest that hyperbaric oxygen could have a significant place in clinical traumatology, and certainly deserves a high profile in trauma research. From the viewpoint of the traumatologist, however, this is clearly not the situation at this time. Only a few trauma research programs include hyperbaric oxygen in their investigations and the number of clinical hyperbaric facilities routinely treating trauma is very small.

The aim of this presentation is not to detail the reasons why hyperbaric oxygen should be of benefit. There are relevant chapters in each of the major hyperbaric medicine textbooks that provide a good introduction. Nor is this a systematic evidence review. Whilst some consensus guidelines and hyperbaric reviews have concluded that there is acceptable evidence for hyperbaric oxygen to be considered "indicated" in at least musculoskeletal trauma, a more appropriate conclusion is drawn by Garcia-Covarrubias et al. who concluded in 2005 that: "Adjunctive HBO is not likely to be harmful in the management of crush injury and acute traumatic ischaemia" and: "Evidence is limited but warrants additional clinical studies….."

This presentation explores issues of potential and practicality, drawing upon clinical experience and impressions of utility from the author's institution and some of those few centres that have a significant proportion of their capacity devoted to treating trauma patients. There is a bias towards reporting on multiplace chamber practices, although some mention will be made of monoplaces, which have advantages in certain areas.

## *Acute Soft Tissue Trauma*

There is little doubt that injured soft tissue responds positively to HBO, with the possible exception of perfectly clean surgical incision repairs and split skin grafting onto ideally vascular wound beds. In all hypoxic tissues, healing will be accelerated and infection risk minimised with many studies suggesting functional quality of the repair may be improved, for instance in peripheral nerve and tendon.

In crushed tissue the consequences of injury can clearly be modulated: hyperbaric oxygen offers the potential to salvage severely crushed or contaminated tissue that would otherwise necrose during the secondary injury phase, or be debrided as either "unviable" or as prophylaxis against infection. Herein lies a significant clinical practice issue, however: If surgical debridement is done rigorously in accordance with recommended surgical practice, there may be no marginal tissue left to salvage. If marginal tissue is left in situ, HBO cannot be guaranteed to prevent infection or necrosis and

some adverse outcomes may thus arise as a consequence of what would otherwise seem to be the admirable aim of preserving tissue. Using HBO is such settings therefore requires a close and cooperative relationship with surgeons. Where debridement can adequately clean a wound and remove doubtful tissue without additional functional or cosmetic deficit, HBO is not indicated. Where the crushed or contaminated tissue involves a critical structure or is adjacent to one, then surgeons can consider minimising their debridement and utilising early HBO.

Both sharp and blunt trauma can create random pattern soft tissue flaps with ischaemic distal areas. As for failing surgical flaps, an increase in tissue salvage can be obtained if HBO is commenced early and provided multiple times per day, at least initially. If the ischaemic area is visible, improvements in colour should be seen in the chamber. If dark or purple ischaemic areas become bright red slowly during a treatment and then remain red for a significant time after depressurisation, this is an indication of static blood and non viable tissue.

With respect to using HBO merely to accelerate healing, there has been little work done in major clinical facilities. Anecdote from sports medicine clinics and observations of skin graft donor sites, abrasions and surgical wounds in trauma patients suggests that the acceleration of soft tissue healing demonstrated in animal models does happen in humans.

### *Reduction of Swelling and Oedema*

In the acute post injury days, HBO will deliver an immediate and very noticeable reduction in soft tissue swelling. In incipient compartment syndrome cases, we have seen forearm circumference shrink by 3cm over a single treatment, having been increasing by 1cm per hour prior. In patients with tight plaster casts, the cast is often loose at the end of a single treatment. As would be expected, the effect seems to be most profound in the in first 6-12 hours post injury but the overall impressions of our surgeons is that a useful acceleration of oedema resolution is gained at any time over the first week or so. For many orthopaedic surgeons in particular, this effect is the one they seek most frequently. For closed fractures with severe swelling, internal fixation is usually delayed until swelling subsides and risk of surgical wound breakdown becomes more normal. Where the patient is held as a hospital inpatient, HBO can reduce length of stay in this setting by bringing forward the time of definitive internal fixation.

### *Compartment Syndrome*

The potential benefits of HBO in compartment syndrome have been well described and investigated in both animal model and human settings. Despite this, the place of HBO for this indication is probably limited. It would be highly risky to routinely offer a trial of HBO in clinically diagnosed compartment syndrome. Where compartment syndrome is well established, there is negligible blood flow at a capillary level and hyper-oxygenation of arterial blood may not provide oxygen delivery to the most needy tissues. The delay inherent in using HBO would almost certainly produce worse outcomes due to increased necrosis following delayed fasciotomy. The potential for HBO therefore lies in three situations: early post fasciotomy use to try to preserve tissue that is ischaemic post re-perfusion, use to reduce oedema and accelerate closure of fasciotomies where there is significant swelling, and perhaps some cases of incipient compartment syndrome. The problem with this latter setting is that the criteria for determining incipient compartment syndrome are unclear. Minor soft tissue crush and swelling is not an indication for HBO and if there is significant suspicion of compartment syndrome, fasciotomy must be undertaken urgently. There are no clear criteria for assessing severity or progress of compartment syndrome, with single time point compartment pressure readings shown to be an unreliable indicator. Some preliminary work with microdialysis, continuous pressure monitoring and tissue pO2 electrodes suggests these might enable monitoring of progression and response to treatment but even if so, there would be significant clinical

challenges in selecting the appropriate site for insertion of the necessary invasive monitoring probes as compartment syndrome severity is often patchy and unevenly distributed.

### *Blast Injury*

Blast injuries represent a major challenge for military and civilian trauma teams. HBO offers the potential to modulate soft tissue injury, reduce infection risk from fragment wounds, treat arterial gas embolism and modulate acute burn injury. Severe blast injury patients are some of the most challenging trauma patients, however, and the logistic requirements of hyperbaric will always limit the practical utility of HBO treatment in the acute setting. Where HBO has been able to be used, the reports have been favourable, but few centres are appropriately equipped and integrated for this. HBO may also be of use for later sequelae of combined blast – burn injury; after delayed evacuation of blast survivors to major centres, unusual patterns of infection are not uncommon, with antibiotic resistant organisms, persistent deep infections and colonisation related skin graft failures. It is our impression that HBO can offer a "turn around" for patients with such complications days or weeks after the blast.

### *Acute Orthopaedic Trauma*

Orthopaedic trauma is common and is responsible for a great deal of hospital resource use as well as personal and social cost of injury. Open fractures with significant soft tissue injury are associated with particularly high rates of complication such as non-union, infection, chronic pain and disability. Complications often require further inpatient care, and in many cases multiple operations and prolonged rehabilitation. Hyperbaric oxygen (HBO) has the potential to reduce the complications of musculoskeletal injury and thus improve outcomes. Although severe open fractures with soft tissue crush injury were the subject of the strongly positive randomised controlled trial of Bouachour et al, HBO has not become a standard of care for such injuries and the HOLLT trial presently underway is aimed at improving the evidence for the role of HBO in this setting.

HBO probably offers benefit in the acute setting primarily by supporting the soft tissues surrounding the fracture. HBO can facilitate retention of soft tissue coverage of bone, optimise muscle healing around fractures and promote angiogenesis in ischaemic tissues. It should reduce infection risk, especially where there is severe contamination or where there are avascular bone fragments or metal fixation in the contaminated field. Where post fixation wound breakdown is a risk, such as in diabetic patients, in crushed skin or in problem locations, such as around the calcaneum, HBO may reduce the risk of post operative wound margin necrosis and delayed infection.

A specific determinant of the value and practicality of HBO in severe open fractures is the surgical practice pattern regarding use of local or free-transfer flaps to close soft tissue deficits. Amongst reconstructive surgeons, one school of thought is that the best results are achieved if soft tissue closure is achieved very early, with some even advocating an "immediate fix and flap" approach in which a flap closure is done at the first surgery, even if this requires micro-vascular free flap techniques. Whilst the literature does suggest poorer outcomes with delayed closure, many take a less urgent approach, with initial debridement and orthopaedic fixation, followed by soft tissue deficit closure several days later, once the patient is more stable, and the flap can be planned and conducted within normal operating hours, especially if a complex and time-consuming free flap will be needed. Many in the orthopaedic community feel that adequate debridement and irrigation and the use of negative pressure wound dressings allow prolongation of the "safe window" of time for definitive fixation and definitive closure. It seems highly likely that HBO will be of benefit in conjunction with this approach. It should reduce risk of infection and improve soft tissue quality, minimising the risk of needing a major flap and improving the condition of the surgical field if one is needed. Like most of the factors in this debate

however, there is limited evidence that any particular approach is better – only fairly clear indications that inadequate debridement and very long delays are associated with poor outcomes.

As mentioned in discussing the anti-oedema effects of HBO, bringing forward the timing of internal fixation may be a useful practical and cost saving function for patients with swelling that is holding them as inpatients. Conversely, most hospitals would not be keen to keep patients admitted purely for HBO if they can be discharged home with temporary splinting or external fixation, to be readmitted some days or weeks later for definitive fixation.

Another area of suggested benefit is that a course of HBO may reduce the risk of osteonecrosis after fixation of osteonecrosis prone fractures such as the scaphoid, head of femur, navicular etc.

Finally, fracture healing is always a relatively slow process, and it would seem likely that some patients, even if not their surgeons, would be keen to utilise HBO for "routine" fractures if it could be confirmed that fracture healing were significantly accelerated, as seems likely based upon multiple animal studies.

***The Problem of Specificity in Orthopaedics***

***The risk of poor outcomes after orthopaedic trauma is extremely variable between different anatomical sites and between specific fracture subtypes at any one location. As a result, subspecialty orthopaedic trauma knowledge is important in estimating management challenges and the potential role of a relatively complex adjunct therapy such as HBO. Whilst the severity of soft tissue injury and the degree of host competence or impairment are important, the hyperbaric physician is likely to be asked whether there is likelihood of benefit in a specific type of fracture at a specific location. This is very difficult for the practitioner with little orthopaedic knowledge. (Hypothetical question to a hyperbaric physician: "We got a remarkably good result from that last patient we sent you with the open Schatzker Grade VI fracture. Do you think there is any role for HBO in a Schatzker Grade IV injury where I've had to do a bone graft and ACL repair?") As the incidence of each individual subtype of fracture is relatively low, it is difficult for any one person or even institution to gain significant numbers upon which to assess the impact of changes in management such as the addition of HBO. This is a problem throughout trauma orthopaedics, with much of the literature consisting of relatively small case series of specific injuries or specific techniques. The more reliable reports on outcomes or the impact of specific management are usually either long duration or multi-centre studies.***

## *HBO Dosing for Musculoskeletal Trauma*

There is no clear evidence to support any particular pressure, duration or dosing schedule of HBO for injured soft tissues and bone. A common usage pattern seems to involve a duration at 2.4 – 2.5 ATA pressure of 70-90 minutes, twice daily for several days in acute, severe injury, and daily subsequently. It is notable however that there is a significant body of positive case experience with using 2.0 ATA and at this pressure oxygen toxicity is a minimal concern and treatments may be better tolerated. Some advocate 2.8 ATA as appropriate for severe injury, and it seems likely that this will provide maximal anti-infective action. Tolerance by acutely injured subjects is worse in our experience and a lower pressure seems a better compromise.

Many animal models have shown benefit at 6-12 weeks following 5-10 days of treatment only and similar durations of treatment seem reasonable in humans. If an acute anti-oedema, anti-reperfusion or infection prophylaxis effect only is needed, this may be able to be achieved with 1-3 sessions.

With respect to bone healing, some animal data suggests different effects depending upon whether twice daily or once daily HBO is used, with the latter possibly offering better results. It is important to note that there may well be significant

differences in tolerance and response to hyperoxia between hypoxia tolerant rodents, hibernating species and higher mammals, including humans. Likewise, data generated from investigations in healthy human volunteers has provided some dose response data (for instance for ischaemia-reperfusion injury modulation) but this will not necessarily translate unchanged into the acute injury setting. Overall, it does seem that soft tissues at least are very tolerant of hyperbaric oxygen across a wide dosing range, with benefit reported by most investigators, regardless of dose used.

### *Acute Neurological Injury*

The established acute management principles for neurological injury are mostly based upon minimising the effects of the secondary injury phenomenon that complicates the initial trauma, particularly over the first 72 hours, via mechanisms that include hypoxia, oedema, inflammation and excito-toxicity. For decades, it has been clear that HBO can reduce intracranial pressure, improve oxygenation and favourably modulate inflammatory changes. It remains far from clear, however, whether this can translate into functional outcome benefits. To complicate matters, there are clear risks of worsening the situation if oxygen toxicity seizures are triggered and a more theoretical risk of exacerbating lipid peroxidation and demyelination if systemic oxidative stress compounds these processes at critical locations in the injured brain or spinal cord. Whilst musculoskeletal tissue seems very tolerant of 1-2 hours of very low or very high oxygen levels, the brain is much less tolerant and a complex and regionally very variable control of blood flow is critical to the brain's normal functioning. When this control is non-homogenously dysfunctional following injury, it is easy to imagine some areas of injured brain being over-oxygenated as a by-product of normalising oxygenation in ischaemic areas, whilst uninjured areas may remain under control.

It is notable that the Chief Investigator of one of the most robust studies of HBO in severe brain injury to date, neurosurgeon Dr Gaylan Rockswold, does not advocate use of HBO for acute brain injury despite his randomised controlled trial demonstrating significantly reduced mortality. It is an important caution that, as with many therapeutic trials in acute brain injury, an improvement in a physiological parameter, or even a reduction in mortality, may be achieved without overall functional outcome improvement, or even with worse outcomes, with the additional survivors having extremely poor neurological function.

Further, it seems likely that HBO, as with most therapeutic interventions studies, would be most beneficial if it could be provided within 3-5 hours of injury – an impractically short time window in real-world clinical practice. Where used later, many promising interventions have proved to be either ineffective, or even adverse, especially during the 6-72 hour secondary injury phase.

Finally, there is an ongoing debate as to what pressure is optimal, with advocates HBO sessions being provided at 1.3 – 1.5 ATA through to 2.8 ATA. Rockswold's most recent work confirms that HBO can be delivered safely to severely brain injured patients who have multi-parameter instrumentation to monitor their injuries and this seems the most appropriate direction for the future as it may enable dose optimisation on an individualised basis. There has recently been a significant increase in animal research finding suggesting potential benefit but pending further clinical trials, caution seems appropriate. This creates a conflict as musculoskeletal injury often co-exists with brain or spinal cord injury. The current practice of the author's institution is to limit the use of HBO in such patients to those with a strong indication for HBO for their musculoskeletal injury, with only mild to moderate CNS injury which is stable at the time of referral.

Specific problems are that some intracranial pressure monitoring systems are incompatible with the hyperbaric environment,

although simple extra-ventricular drains and microdialysis can be easily accommodated. Intra-cranial air is a potential concern for several reasons: although HBO should assist in removing such air, compression of air might in theory stress friable blood clot and predispose to re- bleeding whilst entrainment of additional air from the nasopharynx via a base

of skull fracture could bring with it additional bacteria. These seem unlikely to be major concerns but cannot be discounted at this stage of reported experience.

### *Late Complications of Musculoskeletal Trauma*

HBO can play a part in managing a number of the common late complications of musculoskeletal trauma. Most obviously, skin wounds that are slow to heal will respond as for other chronic problem wounds. Indeed, some hyperbaric centres who report extensive use of HBO for "crush injury" are not describing use in the acute setting, but use of HBO for ischaemic and contaminated problem post trauma wounds. Similarly, some problem wounds occur in tissues repetitively injured by multiple orthopaedic and soft tissue procedures, leaving a "battle scarred" area with poor perfusion which can be readily addressed by an angiogenic course of HBO, as for diabetic or post irradiation wounds.

Patients with complex regional pain syndrome are often difficult to manage and although many cases spontaneously improve over several years, there are some case reports and studies to suggest that there may be some role for HBO in either preventing or treating this condition.

There is no clear role for HBO in delayed or non-union of bone but insufficient study has been done. It seems unlikely that there is any more role for HBO in established traumatic avascular necrosis than there is in advanced avascular necrosis of other aetiologies. The greatest potential would seem to be in prevention or very early use and this is yet to be explored significantly.

### *Post Traumatic Osteitis / Osteomyelitis*

Many hyperbaric authorities list refractory osteomyelitis as an indication for HBO and there are clear synergies between HBO and antibiotics in reducing bacterial counts in infected bone in animal models. An equally important mechanism seems likely to be improved bone turnover, with stimulation of angiogenesis and osteoclast activity, which should in theory help with enabling antibiotics to reach otherwise avascular areas, including microscopic sequestra, areas adjacent to metal fixation and areas protected by biofilm. Clinical studies remain inadequate, however, and are intrinsically difficult given the heterogeneity of bone and implant infection. It is clear that many cases where HBO might have previously been tried can now be addressed by aggressive debridement, enabled by developments in reconstruction using free vascularised tissue transfer, fine wire fixators and distraction osteogenesis.

At The Alfred, much of the utilisation of HBO for bone and implant infection is not in the late, proven refractory stage but earlier, as a coordinated part of the early phases of managing problem cases. This is the setting most clearly supported by animal models and it seems logical to try to prevent infection becoming refractory, rather than wait to see if this eventuates. Situations where HBO may be useful in our opinion include those where it in impossible or undesirable to resect all involved bone surgically, where resistant organisms limit antibiotic choice and where supporting tissues are poorly vascularised. When metal fixation is essential for stability or optimal alignment, HBO can offer the potential to suppress infection and enable the fracture to unite without removal of metal. After this is achieved, the metal can be removed and infection treated as normal, with debridement and antibiotics but without HBO. In cases where fracture fixation is exposed by wound breakdown, we and others have sometimes been able to achieve granulation over the metal, with subsequent wound healing, despite the undoubted contamination of the bone and implant. In cases where implants or a bone segment are removed and temporary fixation or antibiotic impregnated bone cement spacers are used, HBO may improve the speed and/or certainty of eradication of infection, prior to bone grafting or replacement of prosthetic metal.

Finally, there is still clearly a place for a trial of prolonged hyperbaric oxygen therapy in conjunction with multiple, synergistic antibiotics in truly refractory cases where bone resection or implant removal is impossible. The experience of the Karolinska Hospital in eradicating bone and implant infection in neurosurgical cases is a particularly notable example of this.

### *Bone Transport and Lengthening*

A number of animal studies have demonstrated a significant increase in osteogenesis, mineralisation and strength of bone filling defects, including bone undergoing continuous distraction osteogenesis. Although this has not been studied in humans, there may be potential to accelerate distraction, reducing time to restore bone length after shortening is performed to repair traumatic deficits or as part of resections for osteomyelitis or tumour.

### *Late Sequelae of Neurological Injury*

In the United States, a series of major, funded randomised controlled trials are commencing aimed at determining the potential for HBO to improve neurological function after traumatic brain injury. Proponents believe HBO can not only accelerate recovery but also cause permanently non functional but viable penumbral tissue to regain function. Some suggest that neuroplasticity and functional re-mapping can be stimulated. This is an important field and it is an important advance that the evidence for HBO having an effect is being sought by fully funded, multi-centre randomised controlled trials.

### *Chronic Overuse Injuries*

Chronic inflammatory / degenerative overuse injuries such as Achilles tendonosis, plantar fasciitis, lateral epicondylitis, frozen shoulder and many others affect a large proportion of the population at some time. Although not usually included in the spectrum of “traumatology” they usually follow either a single specific injury event or repetitive minor trauma. Some practitioners treating such injuries are understood to have used HBO with good effect, although little has been published. Given that evolving patho-physiological understanding of these conditions suggests a significant degenerative, avascular component in many cases, it is not illogical to expect HBO to have potential. This would be a relatively easy field for good clinical research.

### *Injuries in Athletes*

Athletes frequently suffer musculoskeletal injuries and those competing at an elite level are often in a position to find and pay for treatments that are considered experimental or even speculative, in the hope that their recovery may be accelerated or improved. HBO is understood to have significant use in this sector but unfortunately the experience is not reported in any significant way. It is understood that acute muscle contusion responds well, as would be expected. It may be that there are some advantages to adding HBO to surgical repair but an important caution is that if HBO rapidly reduces pain and swelling, the athlete may be tempted to return to activity before the bone, tendon or muscle repair is sufficient, risking secondary rupture or a lax or failed repair. An area with significant but unexplored potential is athletes with chronic inflammatory or degenerative conditions secondary to overuse. In addition to human athletes receiving HBO, there are a significant number of equine hyperbaric facilities around the world. It would be highly desirable if the experience of such practices could be reported as this may help inform the use of HBO in human trauma patients. Some sports consistently generate many cases of similar injury, such as anterior cruciate ligament rupture or hamstring

injuries. Where one centre sees significant numbers of any one injury, this makes clinical trials much easier to organise.

### *Negative Pressure Wound Dressings*

Negative pressure wound dressings (including the proprietary "VAC" system) are widely used in open trauma wounds. They appear to manage wound exudate well and accelerate the development of granulation tissue. They may minimise infection risk and can reduce oedema. Like HBO, they can be moderately expensive and the formal evidence is limited. There are impressions that the actions of NPW dressings can be augmented by HBO and certainly there are no impediments to using NPW dressings in patients receiving HBO. Where it is desired to continue suction during the HBO session, it is relatively easy to fashion an adapter that enables regulated low pressure suction to be used as a temporary alternative to proprietary intermittent suction pump units.

### *Clinical Lessons Learned at the Alfred*

We have found it relatively easy to deliver HBO to trauma patients on the third and subsequent days after single limb injuries and even after moderate severity multi-trauma, given our large door, multiplace rectangular facility integrated into the acute care hospital building next to intensive care. It is notable that during major overhaul of this facility, the need to use a smaller chamber requiring transfer of patients to a trolley reduced referrals to very low levels, in the setting of an orthopaedic surgical community that was used to HBO being delivered without the patient moving from their normal bed.

In the case of major trauma, especially in the first 48 hours post injury, treatment is often challenging. A number of conscious acute trauma patients have great difficulty tolerating HBO in the early post injury phase, given pain, nausea and anxiety. It is our impression that there is some adverse interaction of HBO with elevated chatecholamines, cytokines and pain, plus the multiple analgesic, anaesthetic, anti-emetic and antibiotic drugs used. Some patients exhibit sweating, anxiety, claustrophobia and general distress that can require treatment to be aborted. It is our impression that young males are most prone to this and a lack of psychological coping skills may contribute, in addition to biochemical mechanisms. Withdrawal from alcohol, nicotine, caffeine and other drugs is often a factor. Low dose clonidine and benzodiazepines seem to offer the best prophylaxis and we recommend routine use of these for initial treatments. We often administer the first doses intravenously in the hyperbaric department to minimise risk of excessive sedation or hypotension following earlier oral administration in the busy environment of the acute trauma ward. Many injured patients have difficulty reading or do not normally read, preferring television, video games, the internet or videos to fill in their time. The availability of these in the chamber can make a major difference to such patients' tolerance of HBO. Preferences for a mask versus a hood as the delivery system for HBO in a multiplace chamber can be very strong in the trauma population. Generally masks seem preferred, especially by the younger and more severely injured patients. This is a problem, however, for those with facial injuries. With cervical collars, significant ingenuity is sometimes required to enable oxygen delivery. The monoplace chamber can be preferable in such cases, although this does, of course, require transfer from the bed and reduces the capacity for nursing support and clinical interventions.

Many trauma patients seem to require high oxygen flows. It is not clear whether this is simply another reflection of anxiety and post injury distress or whether there is a real problem with $CO_2$ elimination. It might well be that hyperoxygenation enables ischaemic tissue to regain aerobic metabolism, resulting in an increase in CO2 production. In support of this hypothesis, there seems to be an association of this "air hunger" with well muscled males and those with larger amounts of injured tissue.

For patients with a time critical indication for HBO, for instance due to severe crush injury or reperfusion syndrome, it

is in many ways easiest to bring the patient to the chamber still anaesthetised and ventilated, provided the facility is suitable equipped and staffed to enable this to be a routine matter. This does incur the need to perform tympanostomy in order to minimise barotrauma incidence. This may be by simple puncture if the patient is to be awoken after the first HBO session. In other cases, micro-tympanostomy systems or insertion of simple IV cannula sections may be used.

During our early experience, several patients experienced an oxygen toxicity seizure and Tramadol was suggested as a possible pre-disposing factor. Tramadol can lower seizure threshold and a we noted that a significant number of patients presenting to neurologists for investigation of a first seizure had recently commenced Tramadol. Despite some intensive care data suggesting that there is no greater association of Tramadol with post traumatic seizure than there is with morphine, we request that Tramadol be avoided for trauma patients referred for HBO and where Tramadol has been administered, we generally utilise lower treatment pressure and/or prophylactic clonidine and benzodiazepine.

On a small number of occasions with patients suffering severely ischaemic muscle recently re-perfused by fasciotomy or vascular repair, early hyperbaric sessions have been complicated by severe pain with changes of oxygenation, both on pressurisation and at the end of treatment.

With respect to continuity of all normal care, acute trauma patients often have high level nursing care requirements, with the need for frequent observations, blood product infusions, wound drain management and the administration of multiple drugs. Given typical hyperbaric oxygen sessions of around two hours total, it is usually inappropriate to suspend such therapies during HBO and adequate staffing, equipment and good communications and medical lock function are important.

Chest injuries including pulmonary contusion and haemo-pneumothorax would be considered contraindications to HBO by many but we have had no adverse events from treating patients with such co-existing injuries. Where intercostal catheter drains are in situ, continuous suction is generally used. For small, stable apical pneumothorax which is undrained, HBO will usually resolve this, as will be the situation for mediastinal air or surgical emphysema.

## *Case Selection and Clinical Oversight*

In much hyperbaric practice, hyperbaric physicians become highly competent at personally assessing whether their patients are likely to respond. In trauma, just as in acute peripheral or skin flap ischaemia, determination of whether HBO is appropriate is much more difficult for those without substantial experience in the outcomes of injury. It is inappropriate to use HBO if tissue is irreversibly doomed. If the tissue will probably recover without assistance, then HBO is clearly not essential, even if there may be some advantages. Whilst the hyperbaric physician needs to evaluate the risks and logistic challenges of treating any patient referred, it is the relevant traumatologist who can best assess the severity of injury, the likely outcomes and the potential value of therapy. It is clear that care needs to be led by trauma, orthopaedic, reconstructive and neuro surgeons, in conjunction with their intensive care colleagues where necessary, ahead of hyperbaric physicians.

## *Barriers to Using Hyperbaric Oxygen*

The trauma patient often has a busy schedule in the early days post injury. In many cases referred, hyperbaric oxygen is a lower priority therapy than many other interventions and yet one which has logistic and time imposts equal to CT or MRI scanning, angiography and visits to the operating theatre. The actual delivery of HBO will be most acceptable to other participants in the patient's care if it can be flexibly scheduled between other interventions, changeable when needed and able to be delivered after hours, including overnight, when other time slots are occupied. This is very difficult and often impractical for busy hyperbaric facilities. As a result, consultative and collegiate relationships are necessary

between not just hyperbaric physicians and referring traumatologists, but between all members of the hyperbaric team and all other participants in the trauma care process.

## *The Optimal Facility for Trauma*

Most hyperbaric chambers are inherently unsuitable for trauma patients. Few acutely injured patients are comfortable transferring from a bed to a trolley or stretcher. Most have encumbrances such as external skeletal fixation, urinary catheters and wound drains. Many institutions use negative pressure wound dressings. It is necessary for the chamber to be fitted with multiple suction outlets to accommodate multiple chest and wound drain suction as well as the necessary oro-pharyngeal and/or tracheal suction capacity. Ongoing intravenous infusions, blood factor replacement, pain control and skin pressure area management must be considered.

The ideal HBO facility, therefore, would allow the patient's normal bed to be taken inside, with comfortable temperature and lighting, minimal noise, the ability to continue all normal nursing care plus audio-visual distraction entertainment for conscious patients. The facility must be within a hospital and should be located close to the trauma wards and operating theatres with the capacity to treat ventilated intensive care or peri-operative patients as well as otherwise healthy victims of a localised but severe injury. Ideally monoplace chambers would be available for those situations where their advantages outweigh their disadvantages for the acutely injured patient, as well as for less severely injured and later stage patients who do not have problems transferring to a stretcher. A hyperbaric facility aiming to optimally serve their hospital's trauma patients will have problems if it is too busy with non emergency work, as ready availability and flexibility is important for acute trauma. Trauma HBO is inherently more expensive per case treated than non emergency HBO practice and the facility needs to have adequate financing, sufficient numbers of experienced staff and flexible rostering arrangements.

## *Evidence Needs and Research Priorities*

Most of the opinion provided in this paper is based upon interpreting clinical experience and published data that falls well short of providing reliable evidence. Although the same could be said of most trauma care practices, the capital cost of hyperbaric facilities and the logistic challenges to taking patients from their trauma wards to the chamber demand a higher standard of evidence before HBO could be considered a candidate for integration into trauma systems on a widespread basis. Randomised controlled human trials are therefore critical to provide sufficient strength of evidence to suggest a need for hyperbaric chambers in trauma centres, or alternatively to prevent inappropriate investment if such facilities do not deliver sufficient benefit. Such studies are difficult, however, as evidenced by the slow progress of the HOLLT study, with limited centres actively participating and enrolments slow, despite wide in principle support initially from many centres. This experience is not unique to HBO research but hyperbaric medicine needs to address it's ability to undertake multi-centre studies as single centre studies will rarely be able to recruit sufficient patients in a reasonable time.

HBO does appear to have significant potential in traumatology, and the experience of the small number of hospitals which are well set up for trauma HBO suggest that HBO can be practically offered, provided there is sufficient physical and human systems integration of hyperbaric medicine into the trauma care system.

There is a growing body of animal study data and this will hopefully expand further if more animal research chambers can be made available to trauma surgery research programs. As with most of hyperbaric medicine, wider collation of case experience via well designed registries would be of significant value.

# Ships Laden With History: Yenikapı Shipwrecks

Ufuk Kocabaş
*Istanbul University Department of Conservation of Marine Archaeological Objects*

Certainly the location of Istanbul at the crossroads of the waterway connecting the Mediterranean and the Black Sea as well as the land route connecting Asia and Europe has contributed greatly to the cultural development and wealth of the city. Due to her location Istanbul has always been, since her early days, a city of higher wealth level where various cultures developed together. Archaeological remains and finds uncovered in the excavations for the subway and Marmaray projects on both the European and Asian sides of Istanbul are of great importance for the cultural history of the world. Particularly the 34 Byzantine shipwrecks uncovered at the Theodosian Harbor known to have been located at Yenikapı is one of the most important discoveries of the recent years.

The shipwrecks uncovered at the Theodosian Harbor, a well-protected commercial harbor, have survived in pretty good condition as they were buried in the silt brought by the Lycus Stream. Their on site recording, dismantling, lifting, conservation, restoration, reconstruction and replica construction have been undertaken by the Istanbul University Department of Conservation of Marine Archaeological Objects .

Excavations still going on have brought to light thousands of archaeological artifacts. Among these artifacts the 34 shipwrecks constitute the largest ancient shipwreck collection of the world and provide us with invaluable information regarding the Byzantine period seafaring, sea trade and shipbuilding technology. The dimensions of the excavation site as well as the widest ancient ship repertory of the world uncovered are considered the most important project of the recent times and have found great reflection both in domestic and international media and public as well as academia.

With the invitation of Istanbul Archaeological Museums (IAM), IU's Department of Restoration and Conservation of Marine Archaeological Objects became one of the teams to conduct archaeological work on the shipwrecks. Our team has undertaken the on site recording and lifting of 24 shipwrecks as well as conservation, restoration and reconstruction work of 28 shipwrecks.

The first stage of our project has been going on since March 2006 with the on site recording, documentation and lifting, a principal rule of archaeology; to date, 21 shipwrecks have been recorded and lifted by our team of 31 experts. Recording and lifting work of the shipwrecks still continue. The second stage of our project covers the 3D drawings of each ship member lifted from the site. Our team implements this stage with the FaroArm device procured by IU's Scientific Projects Unit. Our team is the first one among the Mediterranean countries to use this device for archaeological recording. Studying the ship members via 3D drawings will allow identification of ancient shipbuilding technologies and their presentation of the national and international academia.

The third stage of our project involves the conservation and restoration of the waterlogged wooden members of the shipwrecks implemented by IU's Shipwrecks Conservation and Reconstruction Laboratories. This work will be carried out by Turkish scientists for the first time and the method involves the wooden ship members getting saturated with the synthetic resin polyethylene glycol (PEG). With the completion of this stage the wooden members will be reinforced and will be ready for display at the museum foreseen to be established.

Our work at Yenikapı not only is the first ship archaeology work conducted by Turkish scientists on land but also can be considered the turning point for ship and boat archaeology in Turkey. Utmost care has been paid to make contributions to the scientific literature as well as building up the necessary infrastructure. The first ship conservation and reconstruction laboratory of Turkey has been inaugurated in 2007 at IU Beyazıt campus with the support of the chemical company BASF Turk.

[1] Yenikapı Shipwrecks Project is supported by Istanbul University's Scientific Research Projects (Project No: 2294 & 3907).

In addition to the scientific precision, our project has undertaken the mission of presenting our rich cultural heritage on various international platforms. Our project has been presented at various academic meetings and conferences organized by various universities, institutes and museums in the UK, Germany, France, Denmark, Greece and Spain while our work presented in international scientific and news magazines and international television channels, arousing great interest.

As a result of the efficient presentation of our project in international platform, the International Symposium on Boat and Ship Archaeology (ISBSA), one of the foremost organizations of the field in the world held every three years, will be held in Istanbul, for the first time, on 12-16 October 2009.

In addition to international presentations, nationwide ones were made at universities, symposia and meetings, particularly underlining the richness of our cultural heritage through press and media contributions were made to the development of public awareness for the protection of cultural heritage.

The first volume of our monograph series foreseen to be published since the beginning of our project has come out with the title "Yenikapı Shipwrecks, Volume 1, The 'Old Ships' of the 'New Gate'" in late 2008. Targeting both national and international audience, our book has been published bilingual in Turkish and English presenting the raw data obtained until then, methodology and preliminary evaluations.

Experts and students from abroad join our team for certain periods of time exchanging knowledge and scientific collaboration. In this frame, our work has become a scientific bridge between Istanbul and various other countries across the world, especially the European countries.

Our ultimate goal is to make Istanbul own the largest ancient shipwreck collection in the world. No doubt, this collection to attract numerous Turkish and foreign visitors will contribute to the national economy when displayed in a museum to be founded in the future, adding a new value to the cultural heritage of Turkey.

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**Fig.1_ Yenikapı Excavation site**

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**Fig. 3_ Dismantling of vessel member**

**Fig. 4_ 3D documentation of ship elements**

# Oral Presentations

OP-01

## EBAss CERTIFICATION SCHEME FOR HYPERBARIC CHAMBER PERSONNEL

*Peter Alan Atkey*
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**Introduction:** Following acceptance of the EBAss/ECHM Hyperbaric Resource manual it was evident that there was a requirement for independent certification of Hyperbaric Personnel.

**Method:** EBAss constructed a scheme of examination which, together with training requirements as set out in the above manual would ensure personnel competence. This is particularly important for personnel who look to work in an EU member state other than the one in which they conducted their original hyperbaric training.
We aim to inform the assembled professionals of the methodology and reasons for the new EBAss scheme. The presentation covers the levels of accreditation available, European Certified Hyperbaric Chamber Operator (ECHCO) & European Certified Hyperbaric Registered Nurse (ECHRN) and specific information about how to access the scheme. Also included is information about the examination covering the type of questions used and the resources from which the examination has been produced.

**Discussion:** European Hyperbaric treatment centres will be very well served by this scheme which will ensure that base levels of competence are assured by personnel who have the EBAss certification. When employing personnel who have achieved this level of certification, management can be assured that the individual concerned will have achieved a good level of knowledge which they will be able to bring to bear in their new employment. This will make employment of personnel much more controlled ensuring quality personnel find the best employment possible.

**Keywords:** hyperbaric, chamber, personnel, certification, accreditation, ebass, echm, examination

OP-02

# TECHNOLOGICAL INNOVATION: MEDICINAL GAS AND OPERATIVE PROCEDURES IN HYPERBARIC MEDICINE

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**Introduction:** The necessity to adjust the hyperbaric facilities to a technical development as well as to the safety, has brought new companies and personnel to research new solutions, by refining devices and following new procedures and new behaviours. The sector that was facilitated at most is the one of the utilize of gas in hyperbaric facilities and the gas monitoring.

**Methods:** Due to the introduction and the development of new efficient methods of air generation and filtering, it is now possible to obtain air compressed medicinal and air synthetic medicinal. To obtain air compressed medicinal (Ph.Eur.) the systems for the generation, filtering and control of the air need to be in agreement with the requirement of the European Pharmacopoeia OIL 0,1mg/m3; CO 5ppm; CO2 500ppm; H2O 67ppm; SO2 1ppm; NO/NO2 2ppm. With the mixture of Oxygen (Ph.Eur) and Nitrogen (Ph.Eur), produced following the norms of the European Pharmacopoeia, it is possible to achieve to an air synthetic medicinal:

**Results:** Oxygen and other gases used in hyperbaric medicine must be appropriated to the quality requires of the European Pharmacopoeia and to the requisitions of quantity of En14931. In hyperbaric medicine the continue monitoring of the concentration of the gases in the hyperbaric chamber is compulsory. En14931 defines the principles of displaying and recording the data.

**Conclusions:** A high efficiency and quality of service can be achieved through a contemporaneous updating of the systems technology as well as the knowledge of the personnel in technical and safe procedures. The periodical analysis of the recorded therapeutic data enables the examination and the renew of the procedures now in use, in order to improve them and remove the criticalities. This modus operandi permits to conform with the dispositions indicated in the national guidelines, in the European directives and in European Code Of Good Practice.

**Keywords:** Hyperbaric safety and organization

OP-03

# INTENSIVE CARE PATIENT DATA MANAGEMENT SYSTEM IN THE HYPERBARIC ENVIRONMENT

*Peter Kronlund[1], Daniel Olsson[2], Farhang Naderi[2], Niklas Blomberg[2], Bengt Eriksson[1], Folke Lind[1]*
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*[2]Department of Biomedical engineering, Karolinska University Hospital,Stockholm, Sweden*

**Background :** Karolinska ICU departments use Patient Data Management Systems (PDMS) for on-line continuous registration of physiological data, i.v. drugs etc. This comprehensive digital charting system allows massive data collection while providing a clear view of patient data to facilitate early diagnosis and timely decisions. It also reduces the likelihood of human documentation error and facilitates clinical research.
In the continuous development of providing safe hyperbaric oxygen (HBO) therapy to the critically ill, we have equipped our large four-lock ICU chamber (HAUX 3500) with PDMS to improve quality and safety.

**Methods:** The Ethernetbox transmits data from the patient and equipment to the PDMS server readable from any PDMS configured computer. Because the hyperbaric chamber itself is a CE marked medical device all medical equipment inside must also be approved. This work was therefore done in cooperation with the chamber manufacturer Haux Lifesupport, the PDMS (Clinisoft) provider General Electric Healtcare and the Germanischer Lloyd as notifying body.

**Results :** Installation of a modified 12V supplied Ethernetbox inside the chamber now makes data acquisition easier. Clinisoft PDMS patient data is readable inside and outside the chamber as well as in the ICU. Drugs given during HBO treatment are recorded on-line.

**Conclusions :** HBO treatment of critically ill patients can be done while continuing to send physiological parameters to a central ICU monitoring station for improved clinical care and research.
PDMS improves safety and can advance the development of HBO as an intensive care drug.

**Keywords:** Hyperbaric Oxygen,Intensive Care Monitoring

OP-04

# PROTECTION AGAINST BIOLOGIC AGENTS INSIDE THERAPEUTIC HYPERBARIC CHAMBERS: A STRATEGICAL APPROACH

*Rob Houman, Bart Van Molle*
*Hyperbaric Centre, Military Hospital Queen Astrid, Brussels, Belgium*

**Introduction:** Three types of biological agents can pose a risk of contamination: toxins, allergens and infectious micro-organisms.
Common sources of contamination are patient oronasal secretions, urinary tract infections, surgical wound infections, skin infections, post-discharge infections.
In order to protect patients, personnel and visitors, a protection strategy against biological risks was developed at our hyperbaric Center.

**Method:** This strategy takes into account actions for prevention, reaction, surveillance and reporting.
At the level of "prevention", the following elements are integrated: daily cleansing and disinfection of the seats inside the hyperbaric chamber, hand hygiene, clinical clothes, traceability of seat occupation and (during maintenance) control of the quality of the water from sprinkler, air-conditioning …
On the "reaction" part, the following elements are implemented: inside the hyperbaric chamber there is one dedicated seat for each infected patient; infected and non-infected patients are treated in separate sessions; after every session with infected patients the chamber is disinfected; all medical equipment inside is sterilised; specific measures are taken for MRSA-infected patients waste management is optimised.

A specific training is offered to chamber personnel and is required to wear masks, gloves and gown whenever imposed by the level of risk.
Surveillance of the hyperbaric chamber consists particularly in the systematic follow-up of outlet circuits of patients by laboratory analysis (+ disinfection in case of positive results).
Each action, be it at the level of reaction, surveillance or incident is reported and followed-up.

**Discussion:** By reflecting on and implementing this kind of strategy, we have identified many potential sources of contamination and cross-infection. We are convinced that only the development of this kind of strategy (in close collaboration with the hospital's Clinical Hygiene Department) can help us to control the biological risks in hyperbaric clinical environment and keep contamination levels low and non-threatening.

**Keywords:** Biologic agents inside HBO chambers, contamination HBO chambers

OP-05

# THE RATING OF THE PATIENT'S SATISFACTION FACTORS IN A CLINICAL HYPERBARIC CENTER: A 4 YEARS EXPERIENCE

*Rob Houman*
*Hyperbaric Centre, Military Hospital Queen Astrid, Brussels, Belgium*

**Introduction:** For the record, I have introduced in 2004 the importance of taking into account the patients' satisfaction in the clinical hyperbaric centers. Indeed, a clinical hyperbaric center is a care unit in which "the technical aspect" takes an important space. While every patient is confronted with these restrains, his active participation is necessary for the good progress of the treatment. In order to obtain valid and viable data that can be translated into indicators of the patients' satisfaction and thus improving the care organization, the author has developed in 2006 a satisfaction questionnaire based on four perspectives: environment, communication, personnel, cares.

**Method:** In order to measure the satisfaction aspects, I reported in 2004 about the use of different instruments such like the initial and final satisfaction, the objective and subjective measures, the dissatisfaction and acceptation measures. Continuing on the work of Ware that identifies, in particular, the human relations, the accessibility and commodities, the physical environment and the availability, I held down in addition to that the technical quality of the cares. It consists in an output questionnaire. The objective and subjective measures are taken into account. Moreover, each perspective is subdivided into a number of questions that cover the overall levels of satisfaction and dissatisfaction. All data is treated from an Excel program that takes into account, in its weighting, the different levels of satisfaction/dissatisfaction.

**Discussion:** The questionnaire has already been put into place in four clinical hyperbaric centers in Belgium and in a center in Greece. About 550 answers have been treated so far. In the military hospital queen Astrid, 310 questionnaires have been treated.
Throughout analyzing the given answers, it appeared that the use of the results provides an objective photography of the organization of the taking care of patients in a hyperbaric center.

**Keywords:** Patient's satisfaction, patient's questionnaire, organisation HBO centre

OP-06

# HYPERBARIC NURSING PUBLICATIONS: A LITERATURE REVIEW OVER THE PAST 10 YEARS

*Damianos Tzavellas, Angeliki Chandrinou, Anastasia Argyropoulou, Konstantina Gaitanou, Pavlos Vavasis, Vasileios N. Kalentzos, Georgios Sidiras*
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**Aims:** To provide information about the advances of the hyperbaric nursing specialty through the last decade and highlight areas for research and improvement in the future.

**Methods:** For the purpose of this review, a search of four different electronic databases was performed in order to find publications related to hyperbaric nursing. The databases searched were PUBMED, CINAHL, the COCHRANE library and DORCTIHM. The keywords used in the search criteria were “hyperbaric”, “nursing” and “research”. Additional selection criteria used were year of publication (between January 2000 and May 2009), language (English) and all types of publications. For articles published in journals other than nursing, profession (nurse) was also included in the selection criteria.

**Results:** Seven articles were found that met the search criteria. Three of these were reviews, three were research studies and one was a published guideline for hyperbaric nursing practice. In addition, there was a textbook which is considered the only English textbook for Hyperbaric Nursing.

**Conclusion:** Through the articles analyzed, the characteristics of hyperbaric nurses and the role they can play in a hyperbaric team can be identified and clarified. We can also illustrate trends of interest and areas of improvement and research such as the correlation of Quality of Life and the clinical outcomes of a patient receiving Hyperbaric Oxygen Therapy. It should also be suggested that further reviews should include articles other than English as well as the use of additional search engines to locate other publications.

**Keywords:** hyperbaric,nursing,research

OP-07

# THE EFFECTS OF HYPERBARIC OXYGEN THERAPY ON BLOOD-BRAIN BARRIER PERMEABILITY IN SEPTIC CONDITIONS

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Septic encephalopathy causes an increase in brain microvascular permeability leading to brain edema. Hyperbaric oxygen therapy (HBOT) is known to exert beneficial effects in various pathological conditions including sepsis. In this study, the effects of HBOT on blood brain barrier (BBB) disruption induced by an experimental sepsis model were investigated. Following induction of sepsis by cecal ligation and puncture (CLP), 90 min of 100% oxygen breathing at 2.5 ATA was employed 4 times at 1, 7, 13 and 19 h in Wistar rats. Twenty-four h after CLP and HBOT treatments, 2 tracers with different molecular weights (Evans blue; EB, horseradish peroxidase; HRP) were intravenously administered. In animals treated with CLP or HBOT, the amount of extravasated EB in brain tissue was significantly increased compared to sham-operated controls ($P<0.01$). In these animals a more intense HRP reaction product was also observed macroscopically in cortical and subcortical brain regions in brain sections. In animals treated with CLP plus HBOT, BBB permeability was significantly decreased with respect to animals treated with CLP or HBOT ($P<0.01$). A reduction in intensity of HRP reaction product was also observed in these animals. The intensity of immunostaining for tight junction protein, occluding, was decreased in HBOT and CLP plus HBOT comparing with sham group ($p<0.05$). Glial fibrillary acidic protein immunoreactivity was also decreased in these animals. The results of this study indicate that although HBOT alone causes BBB disruption, it exerts protective effects in functional and structural properties of BBB when applied in the setting of CLP-induced sepsis.

**Keywords:** Sepsis, hyperbaric oxygen, blood-brain barrier

OP-08

# THE EFFECTS OF THE HYPERBARIC OXYGENATION DURING THE RECOVERY FROM THE EXPERIMENTAL BRAIN INJURY

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Cerebral traumatic lesions are one of the most urgent medical states. It has been proposed that hyperbaric oxygenation may have positive effects on the neural survival after the injury.

**Aims:** To investigate the potential neuroprotective effects of HBO after stab cortical injury.

**Methods:** Experiments were conducted on the male Wister rats, 10 weeks old. The first group (n=10) was in ether anesthesia subjected to stab injury of the left sensorimotor cortex (2 mm behind bregma, 2 mm left from the middle line, 2 mm deep). After the wound sanitation, one hour following the surgical procedure, animals were subjected to HBO treatment for 60 minutes (compression/decompression periods lasted 10 minutes), pressure applied 2 - 2.5 ATA. This protocol lasted for 10 days. The second group (n=10) was only subjected to the operation. The third group (n=10) was left intact and served as a control. The fourth group (n=10) was also left intact, but was subjected to same HBO protocol. The posttraumatic processes were evaluated on the brain tissue preparations using the immunohistochemical method (antibodies: GFAP, Vimentin, ED1, SMI31 i SMI32). Our research was approved by the Ethical Committee of the School of Medicine, University of Belgrade (number 3027/2).

**Results:** Reduced expression of GFAP and vimentin after the HBO treatment can be interpreted as a reduction of reactive astrogliosis and the prevention of glial scar formation. Additionally, the macrophage and microglial activities were reduced as well. Weak immunohistochemical reaction to SMI31 and SMI32 after HBO treatment, suggests that HBO was able to attenuate the effects of brain damage by reducing the progression of neural degeneration. HBO by itself had no significant effect on the untreated animals.

**Conclusion:** Our data indicate that HBO therapy can be beneficial in improvement of neurological outcome after traumatic brain injury.

**Keywords:** brain injury, astrogliosis, neural degeneration, hyperbaric oxygenation

OP-09

# HYPERBARIC OXYGENATION CAN IMPROVE THE RECOVERY OF MOTOR FUNCTIONS IN RATS AFTER EXPERIMENTAL BRAIN INJURY

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The reduction of motor ability after brain trauma is one of the most frequent consequences and the biggest obstacle in the recovery of patients.

**Aims:** To investigate if hyperbaric oxygenation can improve the recovery of motor functions in rats after an experimental brain injury.

**Methods:** The experiments were conducted on the male Wister rats, 10 weeks old. Animals were divided in the following groups: Control (C, n =8) intact animals, Control + HBO (CH, n =8) intact animals that were subjected to HBO treatment, Sham control (S, n =8) animals that underwent surgical procedure without damaging the brain tissue, Sham control + HBO (S, n =8), Lesion group (L, n =8) right sensomotor cortex was surgically removed, Lesion + HBO (LH, n =8). HBO protocol: pressure applied 2 - 2.5 ATA, for 60 minutes, once a day for 10 days. Beam walking test and grip strength meter were used to evaluate the recovery of motor functions. Our research was approved by the Ethical Committee of the School of Medicine, University of Belgrade (number 3027/2).

**RESUTS:** The animals from the LH group have achieved significantly better scores ($p<0.05$) in beam walking test compared to the animals from the L group. The recovery of muscle strength of the rear left leg (on the opposite side to the injury) in animals from the LH group compared to the animals from the L group was statistically significantly better ($p<0.05$). The difference in muscle strength between the left and right rear leg of animals from the LH group was significantly lower ($p<0.05$), compared to the animals from the L group.

**Conclusion:** Hyperbaric oxygenation can contribute to the recovery of motor functions after the brain injury.

**Keywords:** brain injury, hyperbaric oxygenation, motor functions

OP-10

# INCIDENCE OF MIDDLE EAR BAROTRAUMA IN RATS AND GUINEA PIGS

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**Objective:** This is a preliminary study on the incidence of middle ear barotrauma in non-anesthetized guinea pigs and rats exposed to hyperbaric air pressure of 3 atmosphere (20 meters = 66 feet) in a rodent chamber.

**Materials-Methods:** We used 8 animals (4 rats and 4 guinea pigs with normal otoscopy). The diving protocol was as follows: Diving to 20 meters (66 feet = 3 atmosphere) in 1 minute, staying there 5 minutes and decompression to 1 atmosphere in 1 minute. After 5 minutes, we repeated the same diving protocol. After the second dive was completed, all animals were anesthetized and otoscopy was performed.

**Results:** Middle ear barotrauma was seen in 6 (75%) ears of the guinea pigs (3 ears with haemorrhagic bullae on pars flaccida, 3 ears with hyperemia on the malleus) and in 6 (75%) ears of the rats (4 ears with hemorrhagic bullae on pars flaccida, 2 ears with hyperemia on the malleus).

**Conclusion:** Otoscopic findings of middle ear barotrauma could be detected in ¾ of the ears in guinea pigs and rats at such a sportive diving simulation protocol described in the present study. This finding may be helpful for estimating the number of animals that are needed for future studies on middle ear barotrauma.

**Keywords:** Middle ear, barotrauma, diving, hyperbaric chamber, rodents, rat, guinea pig, tympanic membrane, otoscopy

OP-11

# DETECTION OF CARDIAC BUBBLES BY MEANS OF TRANSTHORACIC ECHOCARDIOGRAM. ANALYSIS OF A CASE ON 5th DEGREE E-B AND COMPARISON WITH HIS FELLOW WORKER (3rd DEGREE E-B)

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**Aims:** Carelmapu, South of Chile, is the zone in our country with the greatest incidence in Decompression Illness. Daily, hundreds of divers go to work making prolonged and deep divings without respect for the decompression tables. We will study the detection of cardiac bubbles before and after intervention in the diving profile, trying to reduce incidence of Decompression Illness.
Here by we present the stage of cardiac bubbles detection before any intervention.

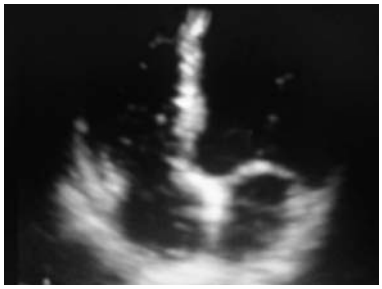
**Methods and Material:** Using Esaote My Lab 30 ® equipment, with 4-1 Mhz transducer, a Cardiologist certified in Echocardiography performed Transthoracic Echocardiogram in 8 divers after their common task. A Neurologist with subaquatic medicine formation, simultaneously evaluated the divers risk factors for Decompression Illness, profile of diving and presence of symptoms of the disease.
The comparative analysis of risk factors was also conduced in the studied divers.

**Results:** 3 divers showed cardiac bubbles. One of them showed a great amount of cardiac bubbles ( 5 th degree E-B), while his fellow diver, with similar diving profile, showed a much smaller amount of cardiac bubbles ( 3 rd degree E-B). The analysis of risk factors did not show greater difference among them.
None diver suffered Decompression Illness symptoms while the study was conducted.

**Conclusions:** The outstanding amount of bubbles found in one of the divers, who reached the greatest possible grade, supports the hypothesis that divers from Carelmapu in Chile, are performing a very unsafe type of diving and because of that, interventions must be done in order to reduce, effectively, the incidence of Decompression Illness. The constitutional risk factors or "tendency to bubbles development", are of enormous importance at the time of predicting what kind of patient will present a great amount of cardiac bubbles after diving and also what kind will suffer Decompression Illness

**Keywords:** bubble detection,echocardiogram, 5th degree EB.

**bubbles 3th grade E-B in echocardiogram**



*This picture shows the echocardiogram of the diving buddy of the first patient.*

**bubbles 5th grade E-B in echocardiogram**

*This picture shows the echcardiogram that the first patiente that evidence a great amount of bubbles.*

OP-12

# AUTOMATIC ANALYSIS FOR BUBBLE DETECTION ON ECHOCADIOGRAPHIC DECOMPRESSION RECORDS

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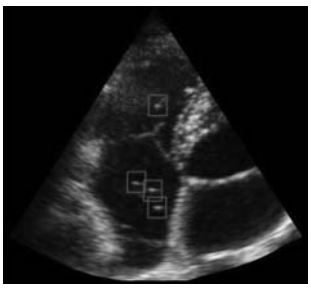
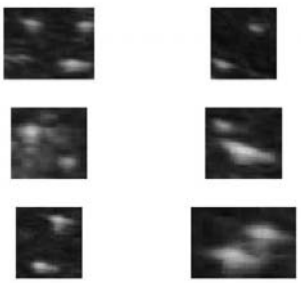
In decompression studies, trans thoracic echocardiography is becoming the conventional routine for bubble detection and counting. Recent studies in undersea medicine focused on the existence of bubbles in cardiac chambers and pulmonary artery. However an automatization for bubble quantification is generally not aimed due to the spatio-temporal challenge of bubble counting. In this study we developped a comparative analysis for automatic bubble evaluation by taking into account all cardiac chambers. Bubble detection is achieved by two different approaches. Firstly, all video records are segmented using Active Contours. Bubbles are quantified by pixel and extent thresholds on segmented areas. Secondly other procedure based on Artificial Neural Networks is performed. In this method we did not need to segment, but only train our artificial network using bubbles with different morphologies. All video frames are convolved with Gabor Wavelet and candidate micro bubbles are localized on video frames. Both approaches are feasible for automatization, we have a detection success of 88% and 92% for primary and secondary approaches respectively. However their advantages and limitations are different. We conclude that automatization is crucial for temporal analysis and the total evaluation in decompression studies. However the computational speed and comparison of Type 1 and 2 errors should be taken into account for objectivity and diagnosis.

**Keywords:** Artificial Neural Networks, Image Segmentation, Trans Thoracic Echocardiography

**Detected micro bubbles on video frame**



**Different morphologies of micro bubbles**



OP-13

# ECHOGRAPHIC BUBBLE COUNT: AN OBJECTIVE MEASURE OF VENOUS GAS EMBOLI IN DIVING RESEARCH

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**Introduction:** Venous Gas Emboli (VGE) are considered an indicator of post-dive decompression stress, and their presence is often used to judge the efficacy of interventions to improve diving safety.
However, counting of VGE is mostly done by acoustic (Spencer and Kissman-Masurel scores) or semi-quantitative echocardiographic methods (Eftedal&Brubakk score). We investigated the intra- and inter-observer variability of a novel technique of "counting bubbles", allowing a more precise VGE evaluation.

**Methods:** Divers were examined with transthoracic echocardiography before, 30 and 90 minutes after a "provocative" dive (square profile, 33mfw, 20minutes, no decompression stops). Four-chamber views with slight rotation were obtained, to visualise the right atrium and apex of the right ventricle. Sequences of 15 heartbeats were recorded onto harddisk for later analysis.
Six investigators were asked to independently analyse the images, counting bubbles in right atrium plus right ventricle in a fixed-frame image (end-diastolic) for 10 consecutive heartbeats. Bubble numbers were averaged to "# bubbles per cycle". In order to improve the evaluation, pre-dive echographic images of the same divers were viewed before bubble counting.
Intra- and inter-observer variability was assessed. A comparison was made with the Eftedal & Brubakk score, attributed by these same observers.

**Results :** This technique has a very good intra- and inter-observer variability. As previously reported, this good reproducibility was also present using the Eftedal&Brubakk score; however, that score is a categorical score with a large "gap" between categories 3 (one bubble per heartbeat) and 4 (at least one bubble per square centimeter). The new technique permits more detailed discrimination between bubble categories relevant to recreational diving safety.

**Conclusion:** The echocardiographic "bubble counting" technique allows an objective and reproducible count of VGE after a dive and may allow a quantitative evaluation of decompression stress. It may also allow for the development of automatic bubble counting algorithms.

**Keywords:** Diving, Venous Gas Emboli, Decompression, Evaluation, Safety

OP-14

# EFFECTS OF FLIRT (FIRST LINE INTERMITTENT RECOMPRESSION TECHNIQUE) ON BUBBLE GROWTH IN MAN - PRELIMINARY RESULTS -

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**Aim:** Recompression during decompression has been shown to result in a reduction in bubble growth both in theory and in animal models. Therefore, the main objective of the current study was to investigate the effects of intermittent decompression on bubble growth in man.

**Methods:** Fifty healty recreational divers were screened for the presence of a persistent foramen ovale and extracardial shunts. Thirty divers without relevant shunts underwent simulated dives in a dry recompression chamber at 5bar (40msw) of ambient pressure in random order. A Buehlmann-based control profile and an experimental profile with intermittent recompression during decompression (FLIRT) were compared. Circulating bubbles in the pulmonary artery were sonographically detected by Doppler mode.

**Results:** Seventeen subjects had successfully underwent both diving profiles until May 2010 without clinical signs of decompression sickness or other incidents. Analysis of the Doppler records of these 17 subjects revealed a considerable reduction in circulating bubbles with the experimental profile compared to the control.

**Conclusions:** Based on the preliminary results of the present study, FLIRT seems to reduce Doppler-sonographic evidence of circulating bubbles. Divers presenting high bubble levels or being at risk for decompression sickness might benefit from FLIRT. Further research is needed to evaluate whether these data are transferable to open water diving.

**Keywords:** Decompression sickness, Decompression incident, DCS, DCI, SCUBA diving

OP-15

# PREDICTION OF BUBBLE GRADES WITH A SIMPLE MODEL; APPLICATION TO AN IDENTICAL REPETITIVE OPEN WATER DIVE

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**Aims:** 1) Developing a simple formalistic model with which bubble grades (BGs) of venous gas embolism (VGE) can be predicted from no-stop square air-dive profiles. 2) Applying this model to an air-dive and an identical, repetitive dive. 3) Comparing the model outcomes with measured BGs of the actually performed dives.

**Methods:** Diving tables indicate that a repetitive dive to the same depth as a first dive should be shortened to obtain the same risk of decompression sickness (rDCS). Without shortening one would expect a higher VGE-grade since VGE and rDCS are (statistically) related. BG data of a previous study (ASEM 2008;79:488-94) of 28 divers who performed 40-min air dives to 20 meters (surface interval 2h30min) were used. VGE-grades were transformed to log bubbles/cm2min to allow parametric statistics.

**Results:** The performance of the model is comparable to that of published, more complicated models. According to DCIEM tables, the second dive has a remaining nitrogen time (RNT) of 8 min. Application of the model to a 48-min dive results in a 0.27 higher logB than that of the 40-min dive, but the measurements showed a 0.14 lower logB of the second dive. Both values are significantly different (P=0.012). With an experimentally validated model (JAP 1992;72:1541-8), which calculates rDCS, a difference of 0.34 log unit was found (yielding P=0.0097).

**Conclusion:** A speculative explanation would be that the divers, who were relatively old and did not perform physical activity for some days before the first dive, were more vulnerable to develop VGE during the first dive. It is also possible that the RBT of 8 min of DCIEM is too high. More research is recommended to investigate the effect of repetition in dependency of profiles and diver characteristics.

**Keywords:** bubble grades, repetitive dive, measurements, model

OP-16

# TESTING AND VALIDATION OF DIVING COMPUTERS

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**Aim/Motivation:** For most diving equipment normatives and regulations exist, describing in detail, how the equipment has to be tested and the test criteria that have to be met, in order to obtain a CE approval, which is required in the European Union. Life supporting equipment, like regulators, are classified as personal protective equipment – in such a case, a notified body is required for CE marking. When it comes to decompression handling, most of today's recreational divers rely on their diving computers. One might assume that for such an important and in our opinion also life supporting equipment a normative exists, however, this is not the case. In the following paper we describe a path to validate a diving computer – mainly addressing the correct implementation of the software.

**Methods:** Normatives were carefully reviewed. EN 13319:2000 (depth gauges and bottom timers) is often used during the CE certification of diving computers, but it does not address decompression.
Validation of a diving computer means proofing that the device meets all specifications in all operating conditions. Evaluation usually starts with testing the correct implementation of decompression code on a PC with a huge amount of test profiles (accelerated testing). Next tests focus on the correct implantation on the final hardware – the diving computer. Once these tests are passed, real time laboratory tests are run using selected and defined diving profiles. After passing lab tests, real test dives in water are carried out.

**Conclusion:** Diving computer validation is a time consuming process. With rising amount of functions, the testing effort rises exponentially. We suggest the development of European Normative addressing diving computers – to introduce standard and harmonized tests mandatory for all manufacturers.

**Keywords:** diving computer, validation, testing, normatives, regulations

OP-17

# UNDER-ICE SCUBA REGULATOR PERFORMANCE

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[2]*US Navy Experimental Diving Unit, USA*

**Introduction:** Single-hose scuba regulators dived in very cold water have a probability of experiencing first- or second-stage malfunction yielding complete occlusion of air flow or massive free flow that rapidly expends a diver's air supply, both conditions referred to as regulator "freeze-up." Principal factors contributing to ice crystallization in the regulator second stage include manufacturer's design, materials, and quality control, exhalant breath of diver, adiabatic gas expansion, mass flow, time, and temperature.

**Materials-Methods:** 17 divers logged a total of 303 dives in -1.86oC sea water under 6-m thick Antarctic fast ice. Dive profiles had an average depth of 38 msw and dive time of 29 min, including a mandatory 3 min safety stop at 6 msw. Seventy-two commercially available, unmodified regulator units (17 models) from 12 different manufacturers underwent standardized pre-dive regulator care and were randomly assigned to divers. Depths and times of onset of second-stage regulator free-flow were recorded.

**Results:** In 303 dives, there were 65 free flows. The free flows were not evenly distributed across the regulator brands. The regulators classified for the purpose of the test as "better" suffered only 16 free-flows out of 170 exposures (9% combined incidence), and the others suffered 49 out of 133 exposures (37% free-flow incidence). Testing on regulator models was aborted when free-flow incidence reached 40% (n=1), and 50% (n=3). Differences between regulator free-flow incidences were tested by the Chi-square test. The pooled incidences for the eight best performing regulators were compared to the nine remaining regulators. The differences between the groupings was significant at $P<0.001$.

**Conclusion:** Regulator freeze-up is a probabilistic event; even the best regulators can fail under polar conditions. Combined laboratory and field-testing, proper pre-dive regulator care, depth-dependent gas density control, breathing rate, and diver experience can influence freeze-up incidence.

**Keywords:** scuba regulators, performance, polar

OP-18

# SOLID STATE GAS SENSORS FOR CLOSED CIRCUIT DIVING SYSTEMS

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*[2]Technical University of Dresden, Sweden*

**Aim:** The present study is a first laboratory evaluation of novel ceramic based solid state micro gas sensors for application in a rebreather.
Up to now in closed circuit rebreathers the partial pressure of O2 is typically measured with wet-chemistry based O2 sensors. Most commonly identified life threatening rebreather failures are
- ppO2 outside of life-sustaining limits
- too high ppCO2
Rebreather manufacturers try to increase safety by using multiple ppO2 sensors together with a "voting logic" or continuous validation [Poseidon]. ppCO2 assessment is addressed either with optical sensors [VR Technology] or indirect via the scrubber temperature [Warkander, US2003074154].
Solid state micro sensors might be a more reliable alternative to state of the art rebreather sensor technology.

**Methods:** Hyperparic O2 test: A small pressure chamber was developed to expose the O2 sensors up to 4 bar ppO2. Gas sensor signals and output of an analog absolute pressure sensor were processed in LabView [National Instruments].

**Rebreather integration:** A commercial rebreather mouthpiece was modified with a sensor support fitted in between the two direction valves. This allows assessment of inhaled and exhaled ppO2 and ppCO2 in real time.

**Results:** The ppO2 sensor was successfully tested from 0..4 bar ppO2. The signal response is not linear, but it can be factory calibrated as it does not change over time. ppO2 and ppCO2 measurement were successfully performed, however, a cross sensitivity for He was observed.

**Conclusion:** The recently developed solid state ppO2 and ppCO2 sensors seem to be suitable for applications in a O2/N2 rebreather. The main advantages are very long lifetime (>5y), high accuracy, mechanical robustness, insensitive to humidity and fast response time (t90~50ms), which allows assessment of ppO2 and ppCO2 in inhaled and exhaled gas. Drawback of that sensor technology is the relatively high power consumption of approximately 1.8W.

**Keywords:** rebreather, oxygen, carbon dioxide, ppO2, ppCO2, sensor

OP-19

# EVALUATION OF THE INTERACTIONS BETWEEN THE OXYGEN LABILE AGENT TIGECYCLINE AND HYPERBARIC OXYGEN THERAPY (HBOT) IN AN EXPERIMENTAL STAPHYLOCOCCUS AUREUS SEPSIS MODEL IN MICE

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Tigecycline is a semi-synthetic derivative of tetracycline antibiotics, which have stability against the tetracycline resistance mechanisms and a broad antibacterial spectrum. The observation of inconsistencies in tigecycline MIC studies showed that tigecycline is oxygen labile in solution.

In this study, we evaluated the interactions between the oxygen labile agent tigecycline and hyperbaric oxygen therapy in an experimental S. aureus sepsis model in mice. Experimental sepsis was obtained with intraperitoneal injection of S. aureus isolate. Inoculum dose was decided as 9,6 x 108 CFU/ml by a fore study. 40 mice were randomized into four groups. Group 1: HBOT (2,4 ATA, 90 min, every 12 hours), Group 2: Tigecycline (25 mg/kg/day, subcutaneously, every 12 hours), Group 3: Control (not receive any therapy), Group 4: HBO + tigecycline (at the same dosages and duration with Group 1 and 2). At the end of seventh day, mice were sacrificed by ether inhalation and autopsies were done. Samples from peritoneum, liver, spleen, kidney, heart and lung were taken for microbiological culture analysis. Histopathological evaluation were also performed in samples from liver, spleen, kidney, heart and lung. Comparison of microbiological results of Group 1 and 3 showed that HBO therapy alone has no significant effect in experimental S. aureus sepsis in mice. When applied with tigecycline, HBOT potentiates the effect of tigecycline. Altough tigecycline is oxygen labile in solution, HBO therapy does not diminish the effects of tigecycline.

**Keywords:** Hyperbaric oxygen; Sepsis; S. aureus; Tigecycline; Oxygen labile

OP-20

# EFFECT OF HYPERBARIC OXYGEN THERAPY ON AMIKACIN TOXICITY*

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**Objective:** To study electrophysiological, ultrastructural and biochemical effects of hyperbaric oxygen therapy (HBO) on amikacin ototoxicity and nephrotoxicity.

**Material-Methods:** Guinea pigs with normal hearing were randomly divided into 4 groups. HBO group received HBO alone (twice a day for 10 days; 60 min 100% oxygen at 2.4 ATA with 10 min compression/decompression. HBO+Amikacin group received the same HBO protocol plus 15mg/kg amikacin intramuscular before each HBO. Amikacin group received only the same amikacin dose. And the control group received neither HBO nor amikacin. Transiently evoked (TEOAE) and distortion product otoacoustic emissions (DPOAE) were measured before/after experiments. Scanning Electron Microscopy (SEM) was used to evaluate cochleas. In addition, kidneys were underwent pathologic and biochemical examination.

**Results:** There was no significant difference at any parameter between the groups before experiments ($p>0.05$). However, after experiments, significant decrease at emission parameters was detected in all groups except the control group. TEOAE's and DPOAE's signal noise ratio (S/N) decreased significantly in the HBO group compared to the Amikacin group ($p<0.05$). There was significant decrease at DPOAEs in the HBO+Amikacin group compared to the Amikacin group, and at 2 KHz'de in the HBO group compared to the one in the HBO+Amikacin group. There was no change at biochemical parameters and also at the histopathologic evaluation regarding nephrotoxicity. SEM revealed significant degeneration at outer hair cell's sterocillia morphology in the HBO group compared to the Amikacin and HBO+Amikacin groups ($p<0.05$).

**Conclusion:** HBO has no protective effect on amikacin ototoxicity, on the contrary, HBO alone did caused ototoxicity. In addition, several other additional factors such as barotrauma and acoustic trauma should also be evaluated in further studies. As nephrotoxicity was not observed at the doses used in this study, effect of HBO on Amikacin nephrotoxicity could not be evaluated.
*This study was supported by Trakya University.

**Keywords:** ototoxicity, nephrotoxicity, aminoglycosides, amikacin, hyperbaric oxygen therapy, otoacoustic emisions, Scanning Electron Microscopy, ear

OP-21

# HYPERBARIC OXYGEN ASSISTS CHRONIC WOUND HEALING THROUGH IMPAIRED NEUTROPHIL RECRUITMENT AND IMPROVED ENDOTHELIAL AND NEUTROPHIL FUNCTION

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**Aims:** Over-recruitment of neutrophils contributes to the prolonged inflammation observed in chronic wounds, which respond to treatment with hyperbaric oxygen (HBO). The effects of HBO on neutrophil-endothelial interactions and functions were investigated using an in vitro chronic wound model.

**Methods:** Human umbilical vein endothelial cells (HUVEC) and neutrophils were incubated with 0.5 μg.ml-1 lipopolysaccharide, 1 ng/ml TNF-□ and 2% O2 for 24 h (an in vitro chronic wound model), then treated with HBO at 2.4ATA for 90 min. Adhesion molecule (AM) expression was measured using ELISA and western blot (HUVEC) or flow cytometry (neutrophils). Neutrophil adhesion to HUVEC was measured at physiological shear-stress. Neutrophil reactive oxygen species (ROS) production was measured. Endothelial mRNA expression of 96 genes in response to HBO was assessed in a dose-response manner at 1ATA, 1.5ATA and 2.4ATA using custom low density arrays.

**Results:** Neutrophil adhesion was impaired by HBO along with reduced endothelial AM expression and impaired neutrophil AM function. Neutrophil H2O2 production was reduced by 20.8±1.8% following HBO. Several genes demonstrated significant HBO-induced reductions in mRNA expression, including the pro-inflammatory AMs CD99, SELP and PECAM1, and the cytokine IL8, as well as the anti-angiogenic ANGPT2 and TIMP2. The pressure-response study revealed a considerable effect of treatment at 1.5 ATA compared with 1ATA or 2.4ATA on expression of numerous genes, including AMs, angiogenic factors and redox proteins.

**Conclusions:** HBO reduces inflammation in chronic wounds by reducing neutrophil recruitment, improving endothelial cell function and reducing neutrophil-mediated tissue damage. This is mediated by altered AM function, altered endothelial mRNA expression and reduced neutrophil-derived ROS production. Gene expression is related to the pressure used for hyperoxic treatment, and could influence changes at the cellular level.

OP-22

# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF ISCHEMIC WOUNDS IN TURKEY: A MULTI-CENTER CASE SERIES OF 652 PATIENTS

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**Aims:** Ischemic wounds are recognized as a significant risk factor for lower extremity amputations. Hyperbaric oxygen therapy (HBOT) has been shown to be an efficient adjunctive modality in the management of ischemic wounds. HBOT is used in Turkey for more than 20 years and The Social Security Organization of Turkey covers HBOT in certain indications including ischemic wounds.

**Methods:** An online questionnaire including demographic and clinical characteristics, history findings, treatment details and outcome results was sent to all HBOT centers in Turkey. Twelve HBOT centers replied and submitted their patient data accordingly. Data were analyzed in SPSS 11.0 for Windows.

**Results:** A total of 652 patients were analyzed. Of these 538 (82.5%) were male and 114 (17.5%) were female. Mean age was 56.36 (± 15.97). For those patients with available data, 28.5% were classified as Fontaine stage I, 12.2% as stage II, 39.1% as stage III and 20.2% were classified as Fontaine stage IV. The most common site of ulceration was the toes (65.7%). 74.9% of the patients had at least one absent pulse in the lower extremity and similarly 47.7% of the patients had at least one lower extremity artery with total obstruction in Doppler ultrasound. Mean number of HBO sessions was 33.05 (±27.80). Overall, the healing and amputation rates were 51.7% and 0%, respectively, for Fontaine stage I and II patients and 36.9% and 15.1%, respectively, for Fontaine stage III and IV patients.

**Conclusions:** Our data has shown that ischemic wounds frequently fail to heal. Higher stages of the Fontaine classification were associated with a progressive gradual increase in amputation rates and with a decrease in healing rates. Adjunctive treatment modalities such as HBO should be considered in the management of selected ischemic wounds to increase the success rates.

**Keywords:** Peripheral artery disease, chronic wound

OP-23

# CREATINE PHOSPHOKINASE BLOOD TEST AS USEFUL FACTOR IN HBOT OF DIABETIC PUTRIFIED GANGRENE

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**Aim:** The clinical view and the treatment protocol (surgery, HBOT, antibiotics and intensive care) of purified gangrenes in diabetic patients are the same in both cases – anaerobic myositis and necrotizing fasciitis. The doctors are in two minds about the following: whether an urgent high amputation or only longitudinal fasciectomia and other smaller surgical procedures should be carried out and how long HBOT should last. The dilemma can be solved by CPK blood test. The different CPK level in the blood shows the presence or absence of muscle damage and the continued observation of CPK in the course of HBO shows the moment when the muscle decay caused by the anaerobes activity stops.

**Material-Method:** This retrospective study of 112 diabetic patients suffering from low extremities putrefied gangrene. The same treatment protocol was applied in all patients. CPK blood test was carried out every day in the period of 7-10 days.

**Results:** Enormously high CPK level was detected in blood of 28 patients and the high amputation was immediately accomplished. Then the massive muscle destruction was observed. CPK level in blood of the other 84 patients was slightly above normal values. The performed longitudinal fasciectomias showed that the infection was localized in soft tissues in the sphere of fascia, while the muscles remained intact. Daily observation of CPK level showed the gradual decrease and it coincided with clinical sings of healing.

**Conclusion:** CPK blood test turned out to be very useful in solving the doctors' dilemma: to keep or to sacrifice the leg. Namely, a lot of urgent high amputation in diabetic patients would be avoided if CPK blood test as a quick diagnostic method were used for differential diagnosis: anaerobic myositis or necrotizing fasciitis.

**Keywords:** Creatine phosphokinase, HBOT, diabetic putrified gangrene

OP-24

# TREATMENT OF PATIENTS WITH MULTI-RESISTANT MICRO-ORGANISMS IN A MULTIPLACE HYPERBARIC CHAMBER – A CASE REPORT

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**Aim:** To test a procedure to treat patients with multi-resistant micro-organisms (MRMO) in a multiplace hyperbaric chamber with minimal risk to other patients.

**Background:** Infections with MRMO are the cause of increased morbidity and mortality and their prevalence is a growing problem worldwide. Hyperbaric centers may expect an increase of these micro-organisms in their patients.

**Methods:** We focused on 1) decreasing the MRMO load in the patient, 2) strict isolation of the patient based on the MRSA-protocol used in Dutch hospitals, 3) additional hygienic measures compatible with the hyperbaric environment, and 4) disinfection.

We tested our procedure in the hyperbaric chamber by means of a simulation patient who was contaminated with "UV-powder", a hardly visible powder that lights up under UV-light.
Also we used our procedure to treat a 58 year old male, carrier of a multi-resistant Staphylococcus aureus (not MRSA), who was referred for HBOT because of a chronic diabetic foot ulcer. He underwent 21 individual treatment sessions with HBO after which the wound showed (hyper)granulation. Swabs from the patient and the hyperbaric chamber were collected regularly.

**Results:** No "UV-powder" was found in the hyperbaric chamber, the facility, or on employees after the test with the simulation patient contaminated with "UV-powder". All cultures from the patient and the hyperbaric chamber remained negative for this MRMO during the treatment period.

**Conclusions:** Decreasing the bacterial load of the patient with a MRMO was successful and even led to temporary decolonization. The extended MRSA-protocol for preventing contamination of the hyperbaric chamber proved to be successful. We have shown that it is possible to treat a carrier of a MRMO in a multiplace hyperbaric chamber with minimal risk to other patients, although a few issues like cost-effectiveness and how to handle in-chamber emergencies need further analysis.

**Keywords:** multi-resistant micro-organisms, MRSA-protocol, multiplace hyperbaric chamber, hyperbaric oxygen therapy

OP-25

# LONG TERM FOLLOW-UP RESULTS OF "HBO AND MITOMYCIN-C ASSISTED LIMBAL – MINITRANSPLANTATION" FOR ALKALINE CORNEAL BURNS ASSOCIATED WITH SEVERE NEOVASCULARIZATION

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**Purpose:** To describe a new treatment method with the support of Hyperbaric Oxygen Therapy and give long term follow-up results for severely neovascularized cornea with total limbal dysfunction by alkaline burn

**Methods:** In 23 eyes (20 cases),scar tissue was removed, surface was smoothed with a diamond burr, and the cornea and corneal limbus exposed to 0.02mg¬/ml MMC for 1 min, and the superior limbus grafted with 4x3 mm size autograft from the fellow eye (18 eyes) or allograft (5 eyes). Patients were underwent to HBO therapy ( 2.4 ATA, %100 oxygen saturation, 1 hour exposure time) for 14 days after surgery to support reepitelization. Topical, steroid (and cyclosporine-A drop for allograft) was applied after reepithelization. Anatomic and histological evaluations were done

**Results:** In all eyes, corneal surface recovered in 14 days and NV regressed in 1 month, the anatomic and histological features maintained during 23.1±4.2 months of mean follow-up. Transient corneal hypotony has seen in 3 cases is main but manageable complication after surgery.

**Conclusions:** MMC and HBO assisted-LMT surgery seems to be one of the best treatment options for severe corneal burns with severe neovascularization

**Keywords:** Hyperbaric Oxygen Therapy, Corneal chemical burns, corneal neovascularization, limbal insufficiency, Mitomycin C, Limbal minitransplantation surgery.

OP-26

# SEPTIC SHOCK AND NECROTIZING FASCIITIS, AT STUDY ON PREDICTED AND ACTUAL MORTALITY THROUGH 3 YEARS

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**Aim:** to identify mortality risk factors in patients with or without septic shock and necrotizing fasciitis.

**Material-Methods:** Our center has served as a national centre for serieous soft tissue infections or necrotizing fasceiitis. Basically the same protocol has been used through the last 12 years. More than 300 patientes have been treating within the protocol. The protocol is surgical diagnosis and rapid transfer to our center. The patient is received in a level 1 trauma centre. At arrival is made decision about priority for intensive care, surgery and hyperbaric oxygen treatment. All elements are employed in the following course of action. We looked into the results from the years 2007, 2008 and 2009. The mortality prediction was made by use of SAPS and APACHE II scoring.

**Results:** 143 patients were admitted. 78 patients had septic shock (54%).
The predicted ICU mortality for all patients was about 32%, the actual ICU value was 10% and the 90 days mortality was 18%. If the patients had concomitant septic shock the predicted value was about 43%, the actual ICU mortality was 16% and the 90 days mortality was 26%.

**Conclusion:** Centralisation and multidisiplinary treatment of a relatively seldom disease seem to provide better survival than anticipated. A concomitant septic shock provides an almost paralel increase in the actual and predicted mortality.

**Keywords:** soft tissue infection, necrotizing fasciitis, hyperbaric oxygen treatment, sepsis, mortality

OP-27

# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF CENTRAL RETINAL ARTERY OCCLUSION (CRAO) IN TURKEY: 331 CASES

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**Aims:** Central retinal artery occlusion (CRAO) is an emergency situation of ophthalmology which can cause permanent loss of vision. CRAO is accepted as an absolute indication for Hyperbaric Oxygen Therapy (HBO) by Turkish Ministry of Health. HBO is used in Turkey for more than 20 years and Social Security Institution of Turkey reimburses HBO in certain indications including CRAO. This study aimed to review the patients with CRAO who treated with HBO in Turkey.

**Methods:** All HBO centers in Turkey were invited to participate in this study. Participating centers were required to fill web-based online form for each patient to collect data regarding; patient characteristics, etiological details, treatments and outcome. Eleven HBO centers agreed to participate in this study.

**Results:** A total of 331 patients (184 male and 147 female) were included. The mean age of patients was 55,2±16,8. Central retinal artery was the most affected vessel (69%) and it was followed by retinal branch arteries (29%). In the etiology, arterial hypertension was the leading cause of occlusion. Before HBO, 12 patients had surgery (anterior chamber paracentesis), 60 patients had been applied ocular massages, and 112 patients had used aspirin and ocular hypotensive drugs. Mean interval time between occlusion and HBO was 61,9 hours (min: 3, max: 720 hrs). After the first HBO treatment, none patient was completely healed, 228 patients (76%) partially healed and 71 patients (24%) were unchanged. The average number of HBO sessions was 12,87±8,11 (min:1, max: 60 sessions). Forty-six (18%) patients were completely healed, 202 patients (66%) were partially healed and 58 patients (19%) were not healed after completing treatments.

**CONCLUSION:** The addition of HBO to standard treatment may increase the rate of healing in patients with CRAO.

Keywords: hyperbaric oxygen, central retinal artery occlusion

OP-28

## TRAUMATIC BRAIN INJURY TREATED BY HBO

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**Aims:** During military operations persons might be hit in the brain by projectiles. In case of survival the person may have serious neurological disability. After intial sugery the further treatment is symptomatic and physical rehabilitation. We wanted to obtain knowledge about the effect of late HBO on traumatic brain injury.

**Methods:** During combat in 2006 the soldier was hit in the mid brain by a small caliber projectile. Fragments of the projectile could not be removed.
After surgery and intensive care the patient was given conventional rehabilitation due to complex neurological deficits. One year ago the patient was given "mild" HBO x 40 at pressures 1,25 – 1,50 ATA. This year the patient was given 30 HBO pressure at 2,0 ATA. PET-scans were performed before and after both series. Neurological assesments were performed before and after the last HBO series.

**Results:** After "mild" HBO the patient observed a slight increase in the gait function. PET-scans were unaltered. After the 2 ATA series the gait function is increased from almost nothing to 40 minutes. The right-sided extremities were a little more forceful. PET-scan showed increased funtional brain tissue.

**Conclusions:** In the present case is found, that HBO at 2,0 ATA increased neurological function and increased functional brain tissue even 4 years after the primary injury. The finding may open a new treatment modality for the traumatic brain injury patient.

**Keywords:** traumatic brain injury, war injury, hbo, PET-scan,

OP-29

# HYPERBARIC OXYGEN TREATMENT OF UNEXPECTED MANDIBULAR BONE NECROSIS AFTER ORTHOGNATHIC SURGERY IN A PATIENT WITH HEMIFACIAL MICROSOMIA

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**Materials-Methods:** A 23-year old female patient was referred to the Hyperbaric Oxygen Unit in Copenhagen University Hospital. The patient had hemifacial microsomia, which is a congenital disorder characterized by underdevelopment of the lower half of one side of the face. The syndrome varies in severity, but the ear and the mandible will always be maldeveloped. Thus the patient underwent orthognathic surgery with the purpose of correcting her dental occlusion and to diminish snoring and facilitate breathing. Immediately after surgery, the healing was normal, but during the following two months, a large dehiscence developed. The occlusion was altered, indicating a dislocation of the osteosynthesis material and mandibular fracture, which was confirmed radiographically. At the subsequent replacement of the osteosynthesis material inserted at the first operation, the lateral part of the mandibular cortex showed comprehensive necrosis, and a large sequestrum was removed. The mandibular bone appeared to have insufficient vascularity. Furthermore, a skin necrosis was present below the incision line. After the surgery for treatment of the osteonecrosis and placement of a reconstruction plate and extraoral submandibular incision was used. 2-3 weeks later a large skin necrosis developed in adjacent to the incision, therefore the patient was referred the the HBO unit. The patient was then treated with 28 hyperbaric oxygen sessions at 24 ATA for 90 minutes each.

**Results:** After HBO treatment, the patient healed completely with no exposed bone or pain. At a surgical intervention more than 1 year later, the osteosynthesis material was still osseointegrated.

**Conclusion:** Although insufficient vascularity and consequent necrosis may not be expected in the mandible of a patient with hemifacial microsomia, attention should be drawn to the fact that also facial vessels may be underdeveloped. Hyperbaric oxygen may be considered as a treatment option in similar cases.

**Keywords:** hyperbaric oxygen treatment, osteonecrosis, hemifascial microsomia

OP-30

# FEMORAL CONDYLE OSTEONECROSIS AND HYPERBARIC OXYGEN THERAPY. A CASE PRESENTATION AND SOME REFLECTIONS OVER ITS RATIONAL THERAPY

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**Background:** Aseptic necrosis of bone is a handicapping diseases of multifactorial origin. Several drug therapies have been tried but no one gave definitive results. Hyperbaric oxygenation has been applied for many years apparently with positive results but no definitive research has been done. We are presenting a case of Postcontusional FCN treated with HBO.

**Case Presentation:** A 62 years old man suffered a mild traffic accident receiving contusions over right knee and ankle. No bone damage was appreciated on XR but a mild knee pain persisted. Magnetic Resonance Scans showed extensive infiltrative image of the whole right femoral condyle. A bone scintygraphy was performed indicating Femoral Osteonecrosis. Therapy with biphosphonates and magnetotherapy were recommended but the patient refused both and consulted to CRIS-UTH. In order to avoid bone collapse, the patient started using crosses and wheel chair. Having consulted the coordinator of the COST B-14 Femoral Head Osteonecrosis controlled study (Dr.L.Ditri) HBO therapy was indicated. The patient received 60 treatments at 2.3/2.5 ata in less than 3 months with an average of 5 treatments per week. MRI scans were performed every 4-5 weeks. A clear improvement of the bone injury was observed after the first month of treatment (22 HBO seasons) that progressed in the following months. A second Scintigraphy, 4 four month after the first one, indicated “resolution of the osteonecrotic process”.

**Conclussion:** HBO applied in a process of Bone Necrosis may induce a valid osteogenetic effect, an enhancement of tissue proliferation, and an effective osteoclastic activity in order to provide a good bone regeneration. This single case can be useful to demonstrate the progressive effect of HBO following a well established protocol and accurate MRI surveillance. An unbiased approx to the treatment of this disease, without interest’s conflict, must recommend HBO as a valid, safe, and inexpensive treatment.

**Keywords:** Femoral bone necrosis, Osteonecrosis, aseptic bone necrosis, postcontusional bone necrosis, necrosisof femoral condyle, Hyperbaric oxygen therapy, HBO

OP-31

# HYPERBARIC OXYGEN THERAPY AS ADJUVANT THERAPY IN SPONDYLODISCITIS

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**Objective:** Spondylodiscitis is generally treated with antibiotics, absolute rest, immobilization and, at times, surgery. This study aims at demonstrating the effectiveness of the hyperbaric oxygen therapy (HBOT) as adjuvant treatment.

**Methods:** From 1st January 1999 up to 1st June 2010, 27 patients diagnosed with spondylodiscitis, arrived at Ravenna Hyperbaric Centre (Italy). Five patients did not start HBOT while the remaining 22 patients, 20 of which were Italian and 2 were foreigners, received daily hyperbaric oxygen therapy at 253 kPa for 90 minutes 5 days a week with an average of 31.4 treatments (range 15-85). The group consisted of 12 men and 10 women with an average age, at the beginning of the treatment, of 52.4 years (range 31-74). 12 patients were diagnosed with post-surgical spondylodiscitis, 3 were diagnosed with tubercular spondylodiscitis and 7 had a different etiology. All the patients underwent a NRM and blood tests with inflammation index at baseline and at the end of treatment as check-up.

**Results:** 22 patients at the end of HBOT, 21 patients out of the 22 treated (95.5%) reported a subjective improvement of perceived pain up to its disappearance. One patient (4.55%) reported unchanged symptoms. 7 patients (31.8%) showed an improvement in inflammation indexes (Erythrocyte sedimentation rate, C-reactive protein and factor I) and 8 patients (36.6%) had an improvement in NRM images, finally 2 patients (9.09%) showed an improvement of both inflammation indexes and NRM. Statistical data are under evaluation.

**Conclusions:** This study demonstrates HBOT effectiveness as adjuvant therapy in spondylodiscitis with an increased success of antibiotic therapy and surgery.

**Keywords:** Spondylodiscitis, HBOT, adjuvant therapy

OP-32

# GAS EMBOLISM AFTER CARDIOVASCULAR SURGERY: DO WE NEED DIAGNOSIS CONFIRMATION BEFORE REFERRING PATIENTS FOR HYPERBARIC TREATMENT ?

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**Background:** Gas embolism (GE) is a potential life threatening complication of cardiovascular surgery. A rapid recognition is necessary to refer patient for an emergency hyperbaric treatment but diagnosis can be difficult to establish. The aim of our study is to assess if clinical manifestations and outcome are different between patients with a confirmed or a suspected diagnosis of gas embolism.

**Methods:** During a 4 year period (2005-2008), all case records of patients with a confirmed or suspected GE diagnosis after cardiac surgery were reviewed. Pre, intra and post operative data, management and outcome were collected. Data were analysed by non parametric tests or Chi-square according to the type of variables in order to evidence differences between groups of patients with confirmed and suspected GE.

**Results:** 32 patients were included in the study. Global incidence of gas embolism in cardiovascular surgery was 0.3 %. Gas embolism diagnosis was confirmed in 11 patients (34 %) and suspected in 21 (66 %). Confirmed and suspected GE did not differ according to initial clinical manifestations except for seizures which were more frequent in the suspected group (18 vs 5, $p < 0.03$). All patients were treated by hyperbaric oxygen and supportive treatment. Outcome both at 10 days and 6 months does not differ according to the group.

**Conclusion:** Clinical presentation and outcome are the same whether GE is confirmed or only suspected. A suspicion of gas embolism is sufficient to start emergency hyperbaric treatment.

**Keywords:** Cardiovascular surgery, gas embolism, hyperbaric oxygen

OP-33

# CYANIDE PLUS CARBON MONOXIDE COMBINED POISONING. ANALYSIS OF THE ROLE OF HYPERBARIC OXYGEN BASED IN A REVIEW OF 62 CASES

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**Background:** Intoxications by Cyanide (CNH) are extremely serious because CNH impairs mitochondrial cellular breathing by a competitive blockage of Nitrous Oxyde. There is no single method to determine CNH in the blood of patients, thus diagnose of Cyanide poisoning (CNHP) is based on the clinical suspicion. Some data suggested formation of CNH when synthetic nitrogen based materials are burn in closed habitats at high temperature. Patients rescued from this kind of fires, presenting very serious condition, systolic hypotension, metabolic acidosis, and evidence of soot surrounding nose and mouth, can be suffering from CNHP (Baud's criteria). Therapy with high doses of Hydroxicobalamin (HCM) has been indicated as an antidote for CNH. We have analyzed our data in search of the prevalence of such intoxication.

**Methods:** Our current series of more than 3300 cases of confirmed Carbon Monoxide has been reviewed. All signs or symptoms required in the Baud's criteria had been previously included in our prospective protocol designed in 1983, thus our research could be efficient and reliable.

**Results:** Sixty-two (62) of our patients accomplished the Baud's criteria, so a joint poisoning by CNH and by CO should be accepted. All patients received at least one HBO treatment during 72 minutes at 303 kPa (3ata), 12 of them (19,3%) through intubation and mechanical ventilation. No one received HCM. Final outcome was satisfactory in 58 cases (93.5%), and 4 patients (6.5%), remained with neurological sequelae. No patient died.

**Conclusions:** A pure CNH intoxication alone is a rare event in clinical practice, but a combined intoxication may be suspected in some cases. HBO proved to be effective in these serious cases. Hydroxicobalamine is not more effective than HBO alone, and it is between 5 and 10 times more expensive than an HBO session. HBO is the best, safe, and inexpensive treatment for CNHP.

**Keywords:** Cyanide, Carbon monoxide, Poisoning, Hydroxicobalamine, Combined intoxication, Antidotes, Hyperbaric oxygen, HBO, CO, CNH

OP-34

# ASSESSMENT OF ROUTINE HEMODYNAMIC PARAMETERS AND CATECHOLAMINE DEMAND AFTER HBOT IN CRITICALLY ILL PATIENTS

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**Introduction:** Treating a critically ill patient in the hyperbaric chamber is still a matter of discussion in ICU tenders posing the risk of transport and exposure to the hyperbaric environment. There is currently a lack of data on the tolerance of HBOT in these patients. This study was designed to evaluate hemodynamic changes and catecholamine demand during and after HBOT to provide data for the design of a larger prospective investigation.

**Methods:** After approval of the Ethics Committee, six mechanically ventilated pts. were included suffering from Fournier`s gangrene (1pt.), COpoisoning (1 pt.), gas gangrene (2pts)., burn injury (1pt.), brain abscess (1 pt.), age 38-86 yr. 4 pts. had catecholamine support (norepinephrine/ dobutamine).
*Inclusion criteria:* No change of catecholamine demand within one hour before transport to the chamber. Catecholamine dosage was adapted in case of change of blood pressure of more than 20% of baseline. No other intervention during the study period.
Systolic (APsys), diastolic (APdia), mean ( MAP) radial arterial blood pressures, heart rates (HR), and catecholamine dosage were recorded at the following measuring points every 10 min: one hour before HBOT (ICU1), during transport to the chamber (Tr1), during the isopression phase, during transport to the ICU (Tr2), and until 1 hr after the session (ICU2).
*Hyperbaric protocol:* 2.2-3.0 ATA, 60-90min. Mean tcPO2 at 2.2 atm abs: 734 mmHg.
Statistics (21 sessions): Wilcoxon Signed Rank Test (2-tailed). P* <0.05.

**RESULTS:** Comparing baseline values (ICU 1) to the other phases, no significant change was found. Catecholamine dosage varied slightly in 2pts and remained stable in 2 pts.

**Conclusion:** Four pts. seemed to benefit from HBOT with resolution of neurological and septic symptoms, 2 pts. developed multi system organ failure. In summary, HBOT was well tolerated but further investigations are required in a larger number of subjects.

**Keywords:** hyperbaric oxygen, ICU patient, hemodynamics

**Table 1: comparison of baseline (ICU 1) to the other phases**

| Phases | APsys (mmHg) | APdia (mmHg) | MAP (mmHg) | HR (bpm) |
|---|---|---|---|---|
| ICU 1 | 125,3 | 60 | 81,5 | 74,8 |
| Tr 1 | 111,3 | 57,5 | 76,5 | 73,5 |
| Isopression | 147,5 | 60,5 | 87,0 | 72,5 |
| Tr 2 | 128,5 | 65,5 | 95 | 74 |
| ICU 2 | 121,0 | 59,3 | 86,3 | 75,8 |

*There was no significant change found in this collective. Catecholamine demand increased slightly in 1 pt., decreased slightly in 1 pt. and remained stable in 2 pts.,Median values. P*<0.05.*

OP-35

# HYPERBARIC OXYGEN THERAPY FOR HEPATIC ARTERY THROMBOSIS AFTER COMBINED PEDIATRIC LIVER AND KIDNEY TRANSPLANTATION: A CASE REPORT

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A case of Hepatic Artery Thrombosis (HAT) after Combined pediatric Liver and Kidney Transplantation (CLKT) treated by Hyperbaric Oxygen (HBO) therapy is reported. The patient was a 2 year and 9-month-old male diagnosed with primary hyperoxaluria type 1 at the age of 4 months. First peritoneal dialysis was started, then Continuous Veno-Venous Hemofiltration (CVVH) dialysis was performed as a treatment of hyperoxaluria. When he was 2 year and 7 month old a CLKT was performed from a 3 year old donor. Immediately after that he developed early renal graft non function treated by CVVH. During the second week post-CLKT, he presented an elevation in liver function test results and Doppler Ultrasound showed no blood flow through the Hepatic Artery (HA). A CT angiography showed HA occlusion at the celiac axis, a small necrotic area in the 3rd liver segment, and a normal biliary tree. No evidence of sepsis was present at that moment. The patient was started on prophylactic antibiotics, ASA, and Low Weight Molecular Heparin (LWMH) to prevent further thrombosis and let the possible process of intrahepatic artery recanalization take place. In addition, he was referred for HBO therapy. He received a total of 28 daily HBO treatments: 13 treatments for 90 minutes at 2.2 Absolute Atmospheres (ATA), and 15 treatments for 90 minutes at 2.5 ATA. HBO therapy was well tolerated. At the end of the first 20 treatments CT angiography showed a normal liver with the presence of some small intrahepatic collateral arteries, without active biliary complications. After HBO therapy the patient is alive and well and his liver function tests are nearly normal. Nevertheless, he needs kidney retransplantation and a future liver retransplantation could be required. In this case HBO offered protection against progression of complication secondary to HAT while the patient is awaiting for retransplantation.

**Keywords:** combined pediatric liver and kidney transplantation, hepatic artery thrombosis, hyperbaric oxygen therapy

OP-36

# SAFE AND EFFECTIVE USE OF HYPERBARIC OXYGEN THERAPY FOR LATE HEPATIC ARTERY THROMBOSIS

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Hepatic artery thrombosis (HAT) occurring after liver transplantation (LT) can lead to septic complications related to bile leak, bilioma, abscess or cholangitis, forcing an immediate or delayed retransplantation.

We described the application of Hyperbaric Oxygen Therapy (HBO) in four cases of late HAT after LT. Median time of HAT after LT was 229 days. Surgical or radiological intervention was not applicable at this time. In one case, intrahepatic arterial blood flow was absent. In other cases, some collateral arterial flow was found at US and at TC scan. In all these patients, HAT was immediately life-threatening because of the development of hepatic abscesses. HBO therapy avoided retransplantation in all these cases: abscesses was totally cleared and intrahepatic arterial blood flow was improved. In our experience HBO therapy was a safe technique and it was effective in reducing the risk of hepatic gangrene in the case of late HAT after liver transplantation.

**Keywords:** Hyperbaric oxygen therapy/Hepatic artery thrombosis/Hepatic gangrene

OP-37

**CHANGED AS PP-65**

OP-38

# TREATMENT OF ACUTE ISCHEMIC STROKE WITH NORMOBARIC, OR EVEN HYPERBARIC OXYGEN – WHICH STRATEGY PROVIDES THE FIRST SUCCESSFUL PRECLINICAL-TO-CLINICAL TRANSLATION?

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**Aims:** Acute ischemic stroke achieves increasing socio-economic relevance in Western countries, and therefore, is an ongoing topic in basic research and drug development. In recent years, normobaric (NBO) and hyperbaric oxygen therapy (HBO) became interesting as treatment options, based on the assumption of an improved oxygen supply to stroke-affected tissue. We therefore reviewed the available literature in this field. Methods. A PubMed/MEDLINE research was performed, using stroke-specific terms combined with HBO and NBO to identify preclinical and clinical reports.

**Results:** Derived from basic research, both NBO and HBO provide mechanisms which lead to beneficial effects after acute ischemic stroke. In preclinical studies, NBO and HBO have shown effectiveness when focusing on functional recovery, mortality, and size of cerebral infarction. However, the direct comparison of NBO and HBO clearly indicates superiority of HBO, but also harmful effects – predominantly associated with increased ambient pressure – must be considered. Despite of numerous promising preclinical studies, no translation into human practice has succeeded until now. A pilot study of NBO in acute ischemic stroke showed a positive trend, but three randomized clinical trials of HBO have failed to reveal superiority. Aside from limitations like small sample sizes with consecutive insufficient power and unfavorable control groups, several open questions exist concerning the optimal time-point, duration and dose of oxygen application. In respect of short- and long-term effects of NBO and HBO, oxygen-affected enzymes like matrix metalloproteinases (MMPs) and transcription factors like hypoxia induced factor (HIF)-1-alpha must be considered because of varying effects in different stroke phases.

**Conclusions:** Further basic research is needed to clarify the interaction between hyperoxia and key factors like MMPs and HIF-1-alpha in different stroke phases. Moreover, sufficiently powered clinical trials are requested to investigate the real potency of NBO and HBO in acute ischemic stroke.

**Keywords:** Acute Ischemic Stroke, HBO, NBO

OP-39

# IS HYPERBARIC MEDICINE A COST EFFECTIVE CONTEMPORARY MEDICAL BRANCH OR A FAD

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It is often said that hyperbaric oxygenation is a very expensive medical therapy. Considering the achievements of pharmacological industry and development of new medical branches such as functional and regenerative medicine, the potentials of molecular oxygen under hyperbaric conditions have not been fulfilled yet.

**Aim:** To reveal the financial benefits of hyperbaric oxygenation in treatment of mass non-infectious diseases.

**Methods:** Comparing the financial costs of the standard medical treatment and the cost of the hyperbaric therapy, by using the data from the statistical year books and the data of the insurance companies in the USA.

**Results:** Costs of the lower limb partial amputation including pre- and post-operative care with therapy are very high, about $ 45.000. Introducing HBO therapy in the first phases of polyneuropathy, the "vicious circle" induced by tissue hypoxia is interrupted in the very beginning. Therapy of 10-15 HBO treatments once a year, eliminates neuropathy and decreases the use of pharmaceuticals, maintains working capability and prolongs the period of possible irreversible changes appearance for a minimum of 10 years. If HBO therapy is included during the period of surgical revascularization, the healing time is significantly shortened, and the potential complications of the reperfusion syndrome is avoided, which does not benefit only the patient. HBO therapy decrease the treatment of the existing irreversible changes (diabetic foot and gangrene) on 30-50 days which is 3-5 times less than the habitual therapy procedure. At last, HBO treatments eliminate the need for an amputation in 60-70% of the cases, or where it became necessary it is postponed for an average period of 15 years.

**Conclusion:** HBO therapy clearly defined and planned in certain time intervals and with very precise dynamic of medical methods, apart from benefiting the patient is significantly cost-effective.

**Keywords:** hyperbaric oxygenation, mass non-infectious diseases

OP-40

# BUBBLES AFTER DEEP BREATH-HOLD DIVES IN COMPETITION

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**Aim:** There are reports of decompression sickness (DCS) among breath-hold divers involved in repetitive apnea diving. However, few studies have measured bubble formation after such dives and we know of no previous studies screening for bubbles after deep competition dives, which was the aim of this study.

**Methods:** Ultrasonic imaging was used to detect bubbles after 118 deep dives during two international apnea competitions. Many divers used 1-4 shallow (<30m) warm-up dives. The probe was directed at the right heart ventricle during 5-10 min starting at 10-20 min after dives of the swimming disciplines constant weight with- (CWT) and without (CNF) fins, and free immersion (FIM) in which the diver pulls down and up along a rope. A questionnaire was completed by 24 divers concerning lifelong experience of symptoms resembling DCS.

**Results:** No bubbles were found in the majority of the dives, which were of depths of up to 90msw, with 16 dives of >70msw. Mean(SD) depths were: 58(18)m for 46 CWT dives, 44(14)m for 31 CNF dives and 56(16)m for 41 FIM dives. Two grade one scores (occasional bubbles) were found, one after a CWT dive to 70msw, the other after a FIM dive to 68msw. The questionnaire revealed that several divers had experienced symptoms including muscle weakness (8/24), numbness or burning (5/12) muscle twitching (2/24), aphasia and impaired short-term memory function (1/24) and urinary incontinence (1/24) after diving.

**Conclusions:** Data suggest that single apnea dives to depths of up to 90 msw involves little risk of developing DCS. However, with greater depths the risk may increase. Logging of a larger number of deeper dives is needed to determine whether nitrogen bubble formation can cause problems after competition breath-hold dives, where world records are now beyond 120 msw. Reported symptoms could suggest earlier incidents of DCS.

**Keywords:** Bubbles, DCS, breath-hold diving, apnea, ultrasonic imaging

OP-41

# PRE-DIVE NORMOBARIC OXYGEN REDUCES BUBBLE FORMATION SCUBA DIVERS

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Pre-breathing is routinely employed as a protective measure to reduce the incidence of altitude decompression sickness in aviators and astronauts, but the effectiveness of normobaric oxygen before hyperbaric exposure has not been well explored. The objective of this study was to evaluate the effect of 30-min normobaric oxygen (02) breathing before diving upon bubble formation in recreational divers. Twenty-one subjects (13 men and 8 women, mean age (SD) 33 ± 8 years) performed random repetitive open-sea dives (surface interval of 100 min) to 30 msw for 30 min with a 6-min stop at 3 msw under four experimental protocols: "air-air" (control), "02-02", "02-air" and "air-02" where "02" corresponds to a dive with oxygen pre-breathing and "air" a dive without oxygen administration. Post-dive venous gas emboli were examined by means of a precordial Doppler ultrasound. The results showed decreased bubble scores in all dives where preoxygenation had taken place ($p < 0.01$). Oxygen pre-breathing before each dive ("02-02" condition) resulted in the highest reduction in bubble scores measured after the second dive compared to the control condition (-66%, $p < 0.05$). The "02-air" and "air-02 "conditions produced fewer circulating bubbles after the second dive than "air-air" condition (-47.3% and -52.2%, respectively, $p < 0.05$) but less bubbles were detected in "air-02 "condition compared to "02-air" ($p < 0.05$). Our findings provide evidence that normobaric oxygen pre-breathing decreases venous gas emboli formation with a prolonged protective effect over time. This procedure could therefore be beneficial for multi-day repetitive diving.

**Keywords:** Keywords Oxygen • Diving • Bubbles • Decompression sickness

**figure 1**

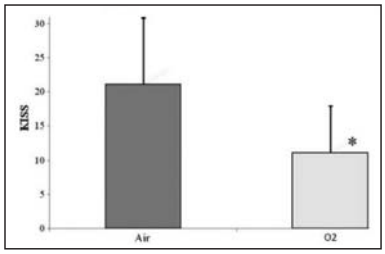


**Fig 1:** Post-dive circulating bubble detection (KISS) for all dives with 02 pre-breathing (white bar) or without (grey bar). Values are expressed as mean ± SD. *Significant difference between conditions, (p<0.01)

**figure 2**

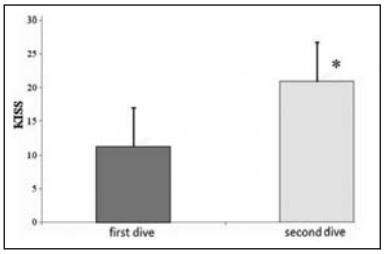


**Fig 2:** Post-dive circulating bubble detection (KISS) for all divers after the first and the second dive, respectively, whatever the experimental condition (with or without 02 pre-breathing before dives). Values are expressed as mean ± SD. *Significant difference between conditions, $p < 0.01$

**figure 3**

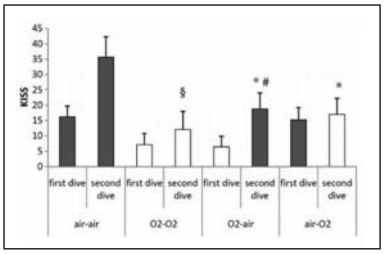


**Fig3:** Post-dive circulating bubble detection (KISS) for all divers after the first and the second dive, respectively, in all experimental conditions. Values are expressed as mean ± SD. *Significant difference between second dive in air-air condition with "air-02" and "02-air" conditions, respectively, $p < 0.05$. § Significant difference between second dive in "02-02" condition with "air-02" and "02-air" conditions, respectively, $p < 0.05$. ÅÚ Significant difference between second dive in "air-02" and "02-air" conditions, $p < 0.05$

OP-42

# ENDURANCE EXERCISE IMMEDIATELY BEFORE SEA DIVING REDUCES BUBBLE FORMATION IN SCUBA DIVERS

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[2]*University of Nice Sophia Antipolis, Laboratory of Human Motricity, France*

Previous studies have observed that a single bout of exercise can reduce the formation of circulating bubbles on decompression, but according to different authors, several hours delay was considered to be necessary between the end of exercise and the beginning of the dive. The objective of this study was to evaluate the effect of a single bout of exercise taken immediately before a dive on bubble formation.
24 trained divers performed open-sea dives to 30 msw depth for 30 min followed by a 3 min stop at 3 msw, under two conditions: 1) a control dive without exercise before (No-Ex), 2) an experimental condition in which subjects performed an exercise before diving (Ex). In Ex condition; 1 hour before immersion, divers ran on the treadmill for 45 min at a speed corresponding to their own ventilatory threshold. Body weight, Total Body Fluid Volume, core temperature and volume of water drunk were measured. Circulating bubbles were graded according to the Spencer scale using a precordial Doppler every 30 min for 90 min after surfacing. A single sub-maximal exercise performed immediately before immersion, significantly reduces bubbles grades ($p<0.001$). This reduction was correlated not only to the sweat dehydration, but also to the volume of water drunk at the end of the exercise. Moderate dehydration seems to be beneficial at the start of the dive whereas restoring the hydration balance should be privileged during decompression. This suggests a biphasic effect of the hydration status on bubble formation.

**Keywords:** Diving, decompression sickness, bubble, exercise, heat, hydration

**figure 1**

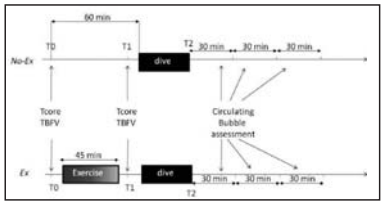


Figure 1: Experimental pritocol in both condition: No-Ex, no exercice before dive; Ex, exercice before dive; T core, core temperature; TBFV, total body fluid volume. T0= 60 minutes before the dive T1= Immediately before the dive T2= Immediately after the dive

**figure 2**

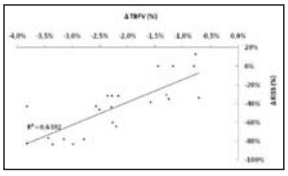

Figure 2: Correlation between bubble reduction, expressed as Δ KISS (%) and total body fluid volume reduction (Δ TBFV) induced by exercise. All data expressed as a percentage.

**figure 3**

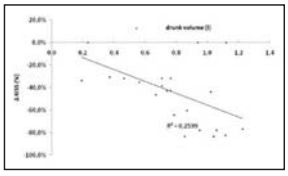

Figure 3: Correlation between the volume of water drunk after exercise (liter) and bubble reduction expressed as Δ KISS (%).

**figure 4**

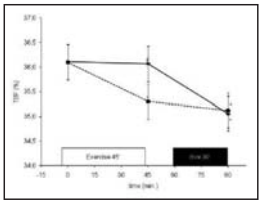

Figure 4: Dehydration level expressed as TBFV (%) between no-exercise condition (solid line) and exercise condition (dash line). TBFV, total body fluid volume. Oral hydration after exercise prevented dehydration induced by diving. *$p<0.05$ from baseline; ÅÚ$p<0.05$ from the corresponding value in exercise condition. Values are mean (SD).

OP-43

# MILD DEHYDRATION PER SE DOES NOT INCREASE THE RISK OF DECOMPRESSION SICKNESS

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**Introduction:** A recent study (Blatteau et al. 2008) has concluded that pre-dive sauna-induced hypovolemia causes a reduction in circulating venous gas emboli (VGE); unfortunately, body temperatures were not measured. Thus, the contribution of body temperature (Mekjavic & Kakitsuba 1989, Gennser et al. 2010), and/or other factors associated with the increase in body temperature to the observed reduction in VGE, was neglected.

**Methods:** To assess whether hypovolemia per se, without any associated elevation in body temperature, enhances the risk of dehydration sickness, seven male subjects participated in two dives to 18msw for 100 min, followed by decompression as per Royal Navy Table 11. On one occasion the subjects were immersed in 40°C water for 45 min, or until their core temperature increased by 1°C. This was followed by three to four 15-min sessions in a sauna (Ta=80-100°C) to maintain sweating and induce a loss of body mass of 2%. Upon completion of the sauna, subjects were immersed in 26°C water to re-establish normal body temperature. Prior to, and upon completion of this pre-dive procedure, a blood sample was obtained to determine haemoglobin concentration, haematocrit, and osmolality. After the dive, precordial Doppler ultrasonic surveillance was used to measure any venous gas emboli that were present. These were graded using the Kisman-Masurel scale. Ocular tear film bubbles were also monitored with a slit-lamp microscope.

**Results:** The dehydration procedure reduced body mass by 2.2+1.1%, and plasma volume by 4.5+8.3%, but the core temperature after the dehydration intervention (36.9+0.3°C) was not significantly different from that observed prior to the dehydration intervention. (36.8+0.3°C). There was no significant difference in either the VGE or tear film bubbles.

**Conclusion:** This study demonstrates that mild dehydration per se does not increase the generation of VGE, and consequently the risk of decompression sickness.

**Keywords:** Venous gas emboli, dehydration, hypovolemia, heat exposure, decompression sickness

OP-44

# COMPARISON BETWEEN DEHYDRATION AND HYPERTHERMIA ON DECOMPRESSION BUBBLE FORMATION

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**Aim:** Blatteau et al (2008) reported a decline in venous gas embolism (VGE) post-decompression after divers were mildly (reduction in body mass: 0.6%) dehydrated in a sauna. Unfortunately, the body temperatures of the divers were not reported. Conversely, Mekjavic et al (2010) did not observe any difference in VGE after allowing dehydrated subjects to attain normothermia before the dive. The present study aimed to differentiate between the effects of hyperthermia and dehydration.

**Methods:** Seven male volunteers performed three chamber dives each to 280 kPa for 100 min with decompression according to RN table 11. Prior to each dive the subjects exercised for two hours in a hot chamber. In one condition the subjects were not allowed to drink or to cool down before the dive (Dehydration Hyperthermia; DH). In a second condition the subjects were cooled until normothermia (Dehydration Normothermia; DN). In the third condition the subjects were given fluid during the exercise to keep the body weight (BW) unchanged but core temperature high (Rehydration Hyperthermia; RH). The subjects remained supine during the dives. After the dives subjects were monitored for VGE for 2 hours, using Doppler ultrasound (KM scale and KISS) and 2-D ultrasound scanner.

**Results:** In RH and DN conditions BW was reduced by an average of 2.3 – 2.4%. A similar fluid volume was ingested during RH. Plasma volume was reduced by 8.7±4.3 % (DH), 13.8±3.3% (DN) and 5.5±11.7% (RH). Rectal temperatures were 38.4±0.6°C, 38.2±0.5°C and 37.2±0.2°C before compression in DH, RH and DN conditions, respectively. Post-decompression there was no difference in maximum KM scores or KISS between conditions.

**Conclusion:** Present results in combination with those of Mekjavic et al (2010) indicate that neither dehydration nor pre-dive hyperthermia or a combination of these factors have an effect on decompression stress after long shallow air dives.

**Keywords:** bubbles, decompression, dehydration, diving, hyperthermia, venous gas emboli

OP-45

# VASCULAR GAS BUBBLES INDICATE DECOMPRESSION RISK

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*[2]University of Split, Croatia*

Vascular gas bubbles indicate decompression risk.

**Aims:** Decompression sickness symptoms (DCS) are rare, therefore of little value for selecting decompression procedures. The present study is based on the assumption that procedures that leads to few vascular bubbles are preferable to procedures that produce many bubbles.

**Methods:** Dives in the range 18-33 msw were performed breathing air. In one series (A, n=12)) dives lasting 60-70 min (18msw), 30-40 min (24 msw) and 15-20 min (33 msw) were performed, either with direct ascent to surface or with a 5 min safety stop at 3 msw.
A different group of 12 divers (B) dived to 24 (30min) and 33 msw (15 min), using decompression procedures suggested by dive computers.

All divers were male.
The outcome of the dives was evaluated using cardiac ultrasound with bubbles graded on a scale 0-5 and the presence of possible clinical symptoms.
The presence of an open Foramen Ovale (PFO) was determined.

**Results:** A total of 72 dives were performed on No-stop procedures (A), 48 dives were performed on the decompression procedures (B). One diver in each group had a PFO.

None of the divers had DCS symptoms. In group A, all divers had considerable venous bubble formation. 8-10/11 diver had Grade 4 bubbles, 4-5/11 had arterial bubbles. In Group B, at 24 msw 3-4/12 divers had Grade 4 venous bubbles while 1/12 had arterial bubbles, at 31 msw 4-5/12 divers had Grade 4 bubbles, while 0-1/12 had arterial bubbles. 5/12 had no venous bubbles.

**Conclusions:** Dives to the No-stop decompression limits produced considerable bubble formation (A). Considerable additional decompression time can reduce, but not eliminate significant bubble formation (B). Arterial bubble formation following symptomless dives is probably quite common and could indicate an increased risk of injury. Considerable improvement in procedures with less bubble formation is needed.

**Keywords:** Venous gas bubbles, arterial gas bubbles, decompression, risk of injury

OP-46

# DIVING DEPTHS CORRECTED FOR AGE AND VO2MAX

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**Aims:** Diving by seniors is becoming increasingly popular. However, above 40 years physiological functions (muscles, heart, lungs) decrease progressively and substantially. This may influence bubble stress and consequently the risk of decompression sickness (rDCS). Models underlying dive tables and algorithms of dive computers (DCs) are generally developed with data of divers <40 years with high VO2max values. Conservatism adjustments of DCs (personal and micro-bubble settings) result in a decrease of no-stop times (NSTs) but never in a limitation of diving depth. It is questionable whether such measures are sufficient for save diving of seniors. Age and VO2max are known to affect rDCS and venous gas embolism (VGE). The study aims to develop a simple, preliminary model which calculates the maximal allowable diving depths and bottom times with given age and VO2max.

**Methods:** From a set of diving tables with known rDCS NSTs for any depth can be calculated. Since VGE grades and rDCS are statistically related a depth-NST-VGE model results. With published VGE, age and VO2max data of a 35-msw air-dive and a similar own dataset of a 20- dive, a simple depth-age-VO2max model is developed which estimates VGE grades.

**Results:** Using the VGE-outcomes of the latter model, NSTs for a given depth can be calculated with the depth-NST-VGE model. In contrast to decompression algorithms of DCs, it was found that older (especially >60 years) or unfit divers should limit diving depths in addition to reducing NSTs.

**Conclusions:** The limitations and reductions found in this preliminary study, with its restricted underlying data sets and various assumptions, are strengthened by the large decrease in cardiac and pulmonary reserves that seriously cuts down the chance on a successful narrow escape. This small study aims to encourage large scale investigations to make elderly diving more save.

**Keywords:** Model, diving depth, age, VO2max, VGE, DCS

OP-47

# MAGNETIC RESONANCE IMAGING OF THE CENTRAL NERVOUS SYSTEM IN RATS FOLLOWING HELIOX SATURATION DECOMPRESSION

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[2]*University of Bergen, Bergen, Norway*
[3]*Norwegian University of Science and Technology, Trondheim, Norway*
[4]*Bergen University College, Bergen, Norway*

**Aims:** For many years it has been discussed whether professional saturation divers are at risk of long-term health effects caused by their diving career and that diving might disturb and impair central nervous system (CNS) functions. The main objective of the present study in rats was to establish an animal model to determine effects of decompression after heliox saturation diving, with and without symptoms of decompression sickness (DCS), on CNS functions assessed by magnetic resonance imaging (MRI).

**Methods:** Female Wistar rats weighing approximately 250 g were trained to walk on a treadmill for later determination of DCS symptoms. The animals were pressurized with heliox to 5 bar with pO2 = 50 kPa at final pressure. After 3 hours at 5 bar linear decompressions at rates of 1 bar/20 s or 1 bar/10 min were performed in the experimental and control series respectively. A 7.0 Tesla small animal MRI scanner was used for detection of possible CNS injuries of the brain and spinal cord. Scanning was performed about two weeks before the dive, two hours after the dive (only spinal cord) and one week after the dive.

**Results:** The heliox dive profile produced neurological symptoms of DCS in about 60% of the animals as monitored in the cage and assessed on the treadmill within the first 20 min after decompression. The T2* brain and spinal cord MRI evaluations did not reveal any visible injuries.

**Conclusions:** Despite massive neurological symptoms no CNS injuries were observed by MRI in these rats. Such injuries have been observed by MRI in several studies on air divers showing a relationship between DCS and CNS lesions. Differences in the volume reduction rate of helium and nitrogen gas phases in CNS after decompression may explain the discrepant findings.

**Keywords:** Diving physiology, saturation, heliox, rats, MRI, DCS, CNS

OP-48

# THE PROFILE OF TURKISH FEMALE DIVERS

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Interest in recreational SCUBA diving has been growing among women in the last decades but research about women and diving is very few if any. Ten years ago we had conducted a study that aimed to establish the characteristics of Turkish female divers but since then not many studies have been done neither locally nor globally. Therefore, we prepared a web based research that intends to reveal the present profile of Turkish female divers and how it changed in ten years. An 80 question- survey that takes about 20 minutes to complete was distributed to mail lists of all diving groups and diving web sites in Turkey. The questions were looking into demographical features of female divers, their diving histories and habits, any possible medical problems related to diving and relations with other divers or buddies of opposite sex. (In addition, there was a part with questions only for trainers. The data was collected in a special database and studied with a statistics program.) A similar survey for male divers was also prepared for comparison and distributed in the same manner.
303 female, 363 male divers completed the survey. The average age of female divers was close to the average in the previous study and less than males' (31, 98±7, 92 years). They were mostly postgraduates. Nine out of ten stated they never took risks. However, the results showed that 41% performed dives that required decompression and half of these people's dives were always deco dives. The average maximum depth was 39, 88±14, 31 meters and one third of all female divers went under 42 meters. The survey also revealed some interesting social findings. One third of female divers and one fifth of male divers met their partners/ spouses by dint of diving. One out of four women, whose partner was a diver before, started diving by influence of their partners.
With this survey we were able to carve out the general profile for Turkish female divers, but still we are missing a broader view of the (female) diver population. So, we hope to spread our survey to be able to shape this.

**Keywords:** scuba diving, woman divers

This work was supported by scientific research projects coordination unit of istanbul university. Project number: 4761.

OP-49

# DIVING FOR A LARGE GROUP OF RECREATIONAL DIVERS WITH SPINAL CORD INJURY – SCI DIVERS

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Because of high potential risk of complications with each additional diver with Spinal Cord Injury - SCI (injury lesions from C6 to L1) in the past, recreational diving for SCI divers referred to one or two individuals with SCI in a large group of able bodied divers.

Systematic data and experience collection over the past eight years have brought us to the point where we can easily operate with 40% of SCI divers in a large group of recreational divers.

Today we can dive inside safety curve with average exposure of 40 minutes for each dive at temperatures between 13ºC and 22ºC to the maximum depth of 40 meters. We can perform two dives per day in almost all conditions.

SCI divers in the group are totally independent and they require minimum assistance which is comparable with assistance for senior divers in commercial dive centers or organized diving tours. Able bodied assistants do not need special training to dive with SCI divers except short introduction which could be made during briefing before diving. When we are organizing the diving expedition for a large group of SCI di vers, all the details related to the personal care of SCI divers, transportation, accommodation, diving vessel, formation of groups and diving locations are carefully planned in advance.

Diving for a large group of SCI divers is significant because we can get great amount of different kind of data at once. We proved that if diving expedition is carefully planned it is no less dangerous than equivalent one for able bodied recreational divers and can also be performed in environments which were traditionally considered as unfavorable to SCI divers.

**Keywords:** recreational diving, SCI divers, able bodied divers, large group, data collection, minimum assistance

**Diving camp Dubrovnik**

**Diving camp Krk**

**Diving camp Monte Argentario**

**Pool practice**

OP-50

# THERAPEUTIC SCUBA DIVING AS A PART OF REHABILITATION FOR ADULTS WITH MENTAL AND PHYSICAL DISABILITIES

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**Aims:** The experimental project 'Diving as a part of rehabilitation' improves the quality of life for adults with mental and physical disabilities, their integration into society and their empowerment through the activities in a swimming pool.

**Method:** The basis of the programme is therapeutic scuba diving in a controlled environment.
The rehabilitation is performed in a group consisting of a physician, a diving instructor and a maximum of four adults with different disabilities (cerebral palsy, Down syndrome, traumatic brain injury, autism, blindness). The programme runs continuously once a week, starting in a swimming pool of 40cm dept and gradually progressing to 130cm. It includes hydrotherapy, social and recreational games and therapeutic scuba diving. Our observation included socialization in the group, reaction in the surroundings and adaptation to the water environment. We closely followed six clients who, with the exception of one, have never been in the swimming pool before.

**Results:** Throughout the follow up we observed their adaptation to water and the progress in social integration for each of them. The individualization of the therapeutic procedure allows us to select a set of methods and techniques in water for a specific pathology. Working with disabled emphasized the importance of honesty for workers included in the programme.

**Conclusion:** Through experience and with the systematic collection of all relevant information, we would like to improve the quality of life for adults with mental and physical disabilities; however, in order to make a reliable conclusion more information is needed.

**Keywords:** therapeutic scuba diving, rehabilitation, hydrotherapy, mental disability, physical disability, socialization.

**Diving as a therapy**

**Diving as a therapy**

**Diving as a therapy**

**Diving as a therapy**

OP-51

# RISK FACTORS FOR RUNNING LOW ON GAS IN WESTERN AUSTRALIA

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[3]*Shenton Park Campus, Curtin University, Perth, Australia*

**Aims:** This aim of this study was to investigate who is most likely to return from a dive low on gas and the associated risk factors for this among certified recreational divers joining organised scuba dives in Western Australia.

**Methods:** Dive and diver information were collected and depth/time loggers attached to each diver. Case dives ending with <50bar in the cylinder were compared with control dives made at the same dive site and time, by divers with >50bar remaining. A conditional logistic regression model identified factors significantly associated with running low on air.

**Results:** Of the 503 divers invited to participate, 321 divers accepted (64%). In total 1032 dive profiles were collected. Depths ranged from one to 45m, water temperatures from 15oC to 29oC and 77% of the dives began with vertical visibility to the bottom or at least 20m depth.

Case dives (n=183) returning with <50bar were compared with 510 control dives ending with >50bar. Some divers appeared to consciously return low on gas, others reported being surprised and ending the dive in panic.

Factors associated with a dive ending low on gas included: younger age, males, higher number of lifetime dives, a longer period since last dive, deeper maximum depth, warmer water, smaller cylinder volume, breathing at a heavier rate and being 16-times more likely at the end of the dive to report surprise at the low remaining level of gas.

**Conclusion:** Dive organisers are recommended to select sites based on the recent experience of the group; when supplying dive cylinders proffer a uniform size; and encourage divers to monitor their remaining gas frequently, relative to the depth of the site. Dive instructors are encouraged to reinforce the importance of these practices during training.

**Keywords:** risk factors, running low on gas, scuba, recreational diving

OP-52

# WEB-BASED SYSTEM FOR CLINICAL EVALUATION OF FITNESS TO DIVE

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**Aims:** To deliver a worldwide suitable, reliable and standardized medical evaluation tool, specifically designed for (sub)aquatic activities, by modern information communication technology.

**Methods:** SIAMS "Sistema Integrato per l'Ambulatorio di Medicina Subacquea" or "Integrated Management of Underwater Medicine Outpatient Clinic" is based on a user-friendly interactive web system. The access is protected by a security firewall and security of information is assured by encrypted data transmission. The system automatically stores biomedical data that can be retrieved any time by connection with the virtually concentrated medical archive. The SIAMS' navigation strategy follows a decision-tree pattern, updated with swimming and underwater medical knowledge, with a series of nested windows and corresponding multiple-choice frames and optional free text fields. Some of the selectable frames lead to a sub-decision tree for further details and/or specific knowledge. SIAMS provides also automatic reports from the available medical devices.

**Results:** SIAMS allows the general practitioner at any remote tourist facility to enter the program and to be guided step-by-step through the decision-tree pattern to an automatic conclusive medical report for fitness to (sub)aquatic activities. Optional free text fields are aimed at summarizing the subject's clinical history, physical examination, testing results and at drawing a conclusive statement. Collected data become available through the network for subsequent health checkups, for survey studies and data analysis.

**Conclusions:** SIAMS contributes to worldwide medical assistance in (sub)aquatic activities and improves general physicians' knowledge about diving/swimming safety. Sharing own repository data with diving accident archives (e.g. of Divers Alert Network), SIAMS can support survey and research studies on diving safety and contribute to the redefinition of underwater medical guidelines. Using telemedicine, SIAMS also appears to be a suitable tool for developing an international evaluation/emergency network and, if necessary, for obtaining a second opinion from a remote consultant.

**Keywords:** underwater, fitness, internet

OP-53

# MEDICAL FITNESS AS A CRITERION TO SELECT "BEST" COMMERCIAL DIVERS

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The selection of the personnel for manned commercial diving operations is a challenging task that requires a detailed assessment of the candidates. Since the offshore and onshore diving activities are contract based, companies should often repeat the selection process. We used multi-criteria decision support tools in order to evaluate the divers by medical fitness for seven different types of generic underwater projects: survey and inspection, cutting, welding, demolition using explosives, lifting and salvage, inshore construction, offshore construction. Considering the complex nature of the decision making process in the existence of multiple criteria, a decision making system is used. The sub-criteria for medical fitness are determined by the three underwater medical specialists. These are 1) age, 2) metabolic equivalent of task (MET) 3) Flicker fusion frequency, 4) psychomotor performance, 5) visual acuity 6) hearing acuity. These sub-criteria are weighted using the Analytic Hierarchy Process in order to obtain the rankings of 16 divers. An alternative sub-criteria set for skills and experience were determined previously by the opinions of two trainers and a senior commercial diving supervisor.

All divers have an up to date medical fitness to dive. In addition to this, the clinical assessments on 6 medical sub criteria were performed. The results of the test are translated into a grading system. The results are different from the evaluation based on professional's opinion. Subsequently, a rank aggregation based selection algorithm is used by combining the results of the medical fitness and skill/experience rank to obtain a hybrid ranking. This methodology simplifies the decision makers' work in selecting the best personnel for occupational underwater projects and reducing the conflicts and confusions that might result from the subjective decisions. The results needs to be applied the real job recruitment with necessary feedback on the outcome in order to evaluate the efficiency.

**Keywords:** Personnel selection, occupational diving, medical fitness criteria, MCDM, AHP.

OP-54

# A RETROSPECTIVE ANALYSIS OF AND COMPARISON BETWEEN TWO DIVING MEDICAL QUESTIONNAIRES

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A retrospective analysis was conducted of the questionnaires completed by 1000 consecutive entry-level scuba diving students attending for a diving medical. The students had filled out two different medical questionnaires required by two different authorities.

Making an assumption that the information found during the face-to-face medical (interview and examination) was correct, a comparison was made between these findings and the answers the candidates made to the questions on each form.

The study aimed to evaluate the prevalence of incorrect answers on either form, inconsistent answers between the two forms, and to identify what further information was found during the interview and examination. A further aim was to measure the prevalence of and reasons for candidates being deemed unsuitable for diving by the process of the interview and examination, after having denied any significant medical history on the recreational scuba training council form (RSTC).

Of the total study group of 1000, 3.7% failed the medical, 9.4% gave inconsistent answers, and 29.9% gave incorrect answers. 63.2% had answered “NO” to all the questions on the RSTC form which is a commonly used self-declaration questionnaire. In some countries, the students in this group would not have been required to go on to have a diving medical examination with a doctor. Of this all “NO” group, 9 went on to be assessed as unsuitable for diving.

Findings with statistical significance:

More likely to give an incorrect answer if you were:
-40 or older
-female

More likely to give an inconsistent answers if you were:
-female
-worked in a medical field

More likely to answer all "NO" on the RSTC form if you were:
-male

If you answered all "NO" on the RSTC form, you were more likely to be subsequently assessed as unsuitable for diving if you were:
-aged 20-29

**Keywords:** diving medical questionnaires, diving medical, RSTC, face-to-face

OP-55

# THE EFFECT OF INERT GAS NARCOSIS ON CRITICAL FLICKER FUSION FREQUENCY DURING A SQUARE-PROFILE, 33 MSW/110 FSW, 20 MINUTES AIR DIVE

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**Introduction:** Despite narcosis have been know since the middle of the 19th century and related to the increase of partial pressure of nitrogen, many aspects of its origins and mechanisms remain uncertain. Narcosis could be explained by the critical volume theory or by binding of the gas with a neurotransmitter receptors. Although providing insights in the basic mechanisms of inert gas narcosis, literature has only produced animal studies. A human study in real dive conditions was thus needed.

**Methods:** 20 divers, selected within strict biometrical criteria, performed a square-profile 33 msw, 20 minutes air dive within no-decompression limits, in a controlled environment (34 msw deep swimming pool). Using a specific water-tight device divers were assessed with the Critical Flicker Fusion Frequency (CFFF). Measurements were made before the dive, underwater when arriving to the bottom and 5 minutes before the ascent, and finally 60 minutes after surfacing. Once the late measurement was made, the diver breathed oxygen for 15 minutes and CFFF was reassessed a final time.

**Results:** There is an increase of CFFF of 4.0±5.1% when arriving to the bottom, followed by a decrease of 6.5±4.3%. This impairment of CFFF persists 60 minutes after surfacing with a decrease of 3.7±8.2%.
After 15 minutes of oxygen breathing compared to the pre-dive value the mean value of CFFF is significantly different and characterized by an increase of 17.9±9.8%.

**Conclusions:** Although these phenomena are excessively complex, this simple study, carried out in real diving condition, with an objective and reproducible measurement makes it possible to draw some CONCLUSIONS: nitrogen narcosis seems well to depend on a gas-protein interaction and that the system is adaptative. Other studies are needed to understand the complexity of the phenomena involved on the variation of the nervous system in the hyperbaric environment.

**Keywords:** Diving, Inert gas narcosis, Critical flicker fusion frequency

OP-56

# EXPERIMENT ON LONG DURATION IMMERSION IN THERMONEUTRAL WATER CONDITIONS

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After the experiment realized in cold water previously presented (EUBS 2006) the «Long duration thermo-neutrality immersion» experiment took place under the scientific management and the coordination of the Institute of Naval Medicine which co-ordinated six civilian and military scientific teams.

**Aims:** During an immersion stay equivalent to long duration seals delivery vehicles missions, (more than six hours) the aim was to study the effects of a thermo-neutrality immersion on physiological great functions and to determine the part coming from either immersion or cold.

**Methods:** Each one of ten well-trained combat swimmers performed a static six hours total body immersion in a temperature regulated swimming pool around 34°C.
An original data collection (blood samples, central and skin temperatures, electrocardiogram, electromyogram) allowed studying the effects of immersion on physiological great functions. All the divers tolerated the experimentation without medical problem.

**Results:** Neuromuscular function was very few impaired. A large loss of water and mineral salts with plasmatic hypovolemia induced a potentially harmful dehydration. Cardiac haemodynamic also confirmed this hypovolemia with a decrease in cardiac preload, stroke volume and cardiac output. Re-hydration with salted and energetic drinks, already recommended after cold immersion is confirmed here. A home made hydration system usable underwater some time before surfacing has been built by our institute to avoid effects of hypotension and loss of operational capacity for the continuation of the mission.

**Conclusions:** Warm water missions, even if divers feel them easier, are physiologically as difficult to endure as cold exposure. There is a need to design fluid replacement protocols to improve the recovery whose delay stays long. Very long immersions (8 to 10 hours) for combat swimmers have to be considered as a hazardous challenge.

**Keywords:** combat swimmers, dehydration, thermo neutrality, immersion, operational capacity.

OP-57

# THE EFFECT OF ACUTE NORMOBARIC HYPEROXIA ON EPO CONCENTRATION IN HEALTHY MALES

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**Aim:** Because it has recently been suggested that a brief exposure to normobaric hyperoxia induces erythropoietin (EPO) release (1, 2), we investigated the effect of a 2-hour normobaric O2 exposure on the plasma concentration of EPO.

**Methods:** Ten healthy males were investigated twice, in a single blinded counterbalanced crossover study protocol, on one occasion they breathed air (NOR) and on the other 100% normobaric O2 (HYPER). Blood samples were collected pre, mid, post-exposure; and thereafter, 3, 5, 8, 24, 32, 48, 72 and 96 hours, and 1 and 2 weeks after the O2/air exposure to determine the EPO concentration.

**Results:** The EPO concentration increased markedly 8 and 32 hours after the NOR exposure (~58% and ~52%, respectively, P <= 0.05) as a consequence of its natural diurnal variation. Conversely, the O2 breathing was followed by a ~36% decrement of EPO 3 hours after the exposure (P <= 0.05). Moreover, the EPO levels were significantly lower in the HYPER than in the NOR condition 3, 5 and 8 hours after the breathing intervention (P <= 0.05). CONCLUSIONS: A short period of normobaric O2 breathing does not increase the EPO concentration in trained healthy males. By contrast, the increased O2 tension suppresses the EPO 3 and 5 hours after the breathing intervention; and subsequently, EPO seemed to resume its circadian rhythm.

**References:**

1. Balestra et al. (2004). Erythropoietin production can be enhanced by normobaric oxygen breathing in healthy humans. Undersea and Hyperbaric Medicine, 31: 53-7.

2. Balestra et al. (2006). Serum erythropoietin levels in healthy humans after a short period of normobaric and hyperbaric oxygen breathing: the "normobaric oxygen paradox". Journal of Applied Physiology, 100: 512-18.

**Keywords:** erythropoiesis, hyperoxia, relative hypoxia, diurnal variation

OP-58

# BLOOD LACTATE AFTER DEEP DIVES IN 3 DISCIPLINES OF COMPETITIVE APNEA

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**Aims:** During apneic diving, selective vasoconstriction and bradycardia conserve oxygen for the most vulnerable organs. Tissues with limited oxygen supply will rely on anaerobic metabolism, causing lactate production. In breathing athletes, lactate produced in underperfused areas may be metabolized in perfused tissues. In apneic divers, lactate will accumulate, with a surge on surfacing reflecting the over-all hypoxic stress. We aimed to determine blood lactate levels in deep competition diving.

**Methods:** Lactate was studied in divers participating in an international deep-diving competition involving the disciplines Constant weight (CWT;n=13) where the diver swims down and up along a line using a monofin, Constant weight without fins (CNF;n=10) involving breaststroke swimming, and Free immersion (FIM;n=10), where the diver pulls down and up on a line using only arms for propulsion. Lactate was measured 34(23) min before and 3 min(42 s) after dives in capillary blood from the finger, via Lactate Scout.

**Results:** Before the dives, mean(SD) lactate was similar between disciplines, at 2.3(0.8) mmol•l-1. Mean post-dive lactate for CWT was 7.6(1.7) mmol•l-1, for CNF it was 8.6(1.9) and for FIM 6.8(1.1), with a difference between CNF and FIM ($p<0.05$). Mean depth for CWT was 58(21)m, for CNF it was 48(13)m and for FIM 60(13)m. Mean dive duration for CWT was 114(34) s, for CNF it was 125(30) s and for FIM 146(30) s, with a difference between CWT and FIM ($p<0.05$).

**Conclusions:** Lactate levels were higher than those reported from non-competition dives. Lactate was highest in CNF, involving whole body work, high in CWT with lower body work, but lowest in FIM involving only arm work, despite FIM dives having the longest durations and greatest depths. Limiting work to small muscle groups may be a fruitful strategy for reaching great depths by avoiding accumulation of hypoxia related factors that may inhibit muscle function.

**Keywords:** Hypoxia, breath-hold, anaerobic, performance, upper body work

OP-59

# EFFECTS OF WARM-UP ON STATIC APNEA PERFORMANCE

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**Aims:** Before a maximum breath-hold attempt, many freedivers use different warm-up techniques, e.g. submaximal apneas. Repeated apneas have been shown to give a short-term training effect, resulting in prolonged breath-hold duration. The aim was to study if apneas are prolonged by warm-up procedures in elite divers and to identify the underlying mechanisms.

**Methods:** Seventeen female and 15 male elite freedivers volunteered during two international competitions. They performed two maximal apneas in the horizontal position on the same day, one preceded by an individually chosen warm-up (WA) and one without warm-up (NW). Apneic duration and time for onset of involuntary breathing movements (IBM) were measured. Heart rate and arterial oxygen saturation (SaO2) were measured via pulse-oxymeter. Spleen diameters were measured in 3 dimensions by ultrasonic imaging for volume calculations.

**Results:** Mean(SD) apneic duration was 4min 34(60)s after WA, which was 36% (1min 13(39)s) longer compared to after NW ($P<0.001$). IBM started at 3min 12(55)s, 48% later after WA ($P<0.001$). SaO2 at apnea termination was 77(12)% after WA and 89(8)% after NW ($P<0.001$). Heart rate reduction indicating the magnitude of the diving response was similar in both conditions (NS). Spleen volume was 19(47)mL smaller during the 2 min period before apnea during WA ($P<0.05$) and tended to be smaller also by the end of the apnea after WA ($P<0.17$).

**Conclusions:** Warmup before a static apnea performance increased apneic duration and delayed onset of IBM. The diving response was not enhanced by WA, in accordance with earlier findings concerning repeated apneas (Schagatay et al 1999). Spleen contraction started earlier during WA, and is a possible candidate for enhancing apneic performance via enhanced hematocrit. In addition, the delay of IBM may result in enhanced comfort, enabling the diver to relax more during the apnea.

**Reference:** Schagatay et al, 1999. Undersea Hyp Med 26:143-149.

**Keywords:** Breath-hold, spleen, diving response, breathing movements, freediving

OP-60

# EATING OR FASTING BEFORE STATIC APNEA PERFORMANCE

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**Aims:** Before static apnea competition many divers fast, which has several effects on physiological function but an unknown net effect. It has been suggested that fasting increases the risk of syncope due to lower RQ. Our aim was to determine the outcome of overnight fast on static apnea performance.

**Methods:** Six female and 7 male divers performed two 2min apneas and one maximal apnea during horizontal rest at 13h (2h 43min) after the last meal in the fasting and 1h 34min (33min) in the eating condition (P<0.001). No hyperventilation or lung overinflation was allowed. Ambient conditions were the same and test order weighted. Apnea duration, onset time for respiratory contractions, lung volume, ETCO2, SaO2 and heart rate were measured.

**Results:** Mean(SD) blood glucose was 5.1(0.4)mmol/L after fasting and 5.9(0.7)mmol/L after eating (P<0.01). During fasting, maximal apnea duration was 4min 41s (43s); 50s (22%) longer than in the eating condition (P<0.001). Time without respiratory contractions was 31s (25%) longer after fasting (P<0.01). Lung volumes were similar in both conditions (NS). Mean nadir SaO2 after 2min apneas during fasting was 95(1)% and in the eating condition 92(2)% (P<0.001). ETCO2 after 2min apnea was lower in the fasting condition (P<0.01). At maximal apnea termination SaO2 and ETCO2 were similar (NS). Heart rate was lower in the fasting condition, with mean HR during 2min apneas at 74(10)bpm, and 80(10)bpm in the eating condition (P<0.01). In maximal apneas, HR was 63(9)bpm during fasting, and 70(10)bpm during eating (P<0.01).

**Conclusions:** Fasting is profitable for static apnea performance in elite divers without enhanced risk of syncope, as they ended apneas at similar SaO2 but after longer time. During fasting, the oxygen conserving effect of the more pronounced diving response and any fasting induced metabolism-limiting mechanisms apparently dominate over effects on oxygen consumption and RQ with fat metabolism.

**Keywords:** Apnea, Metabolism, Performance, Hypoxia

OP-61

# UNDERWATER WORKING TIME IN TWO GROUPS OF TRADITIONAL APNEIC DIVERS IN SOUTH EAST ASIA

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**Aims:** Harvest diving on shallow seabeds has most likely been a major human source of food since ancient times. This natural diving continues in some groups in South East Asia, and their outcome is dependent on the time submerged and the resulting bottom working time. We studied how much of total working time was spent submerged in two groups dependent on diving for a living.

**Methods:** Participants were divers among the Japanese Ama at Hegura island and the Bajau in Davao in Phillipines, studied 2009 - 2010. Diving and surface interval durations were timed for 14 female Ama (mean age 60 yrs) during sea-mollusc collection, and 5 male Bajau divers (mean age 38 yrs) during spearfishing. Average dive time per day was noted. Water was 23C in Japan and 26C in Phillipines. All Ama and one Bajau used wetsuits.

**Results:** In the Ama, mean(SD) dive duration was 38(8)s with surface interval duration of 38(8)s at depths of 5-12m. Diving constituted 50(4)% of the total immersed working time, which was limited to 4h/day by fishing regulations. In the Bajau, dive duration was 28(9)s with surface intervals of 19(8)s at depths of 5-7m, and diving was 60(6)% of the total working time of 2-9h/day. Divers were swimming slowly during most of the dive time and speed of descent and ascent was just below 1m/s.

**Conclusions:** Hegura-Ama results are similar to those reported in 1995 by Mohri et al, stating that they spent the largest portion submerged among all Ama, with approximately 2h/day under water. No previous recordings exist from the Bajau, among which some divers may spend more than 5h/day submerged. We conclude that the natural human diving ability allows efficient sea harvesting at shallow depths and that the main limitation is not total apneic duration but other factors including water temperature.

**Keywords:** Apnea, Ama, Bajau, Working, Interval, Duration

OP-62

# TIME COURSE OF CARBON MONOXIDE AND NITRIC OXIDE PULMONARY TRANSFER FACTOR AFTER HYPOXIC AND HYPERBARIC STRESS IN BREATH-HOLD DIVERS

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**Aim:** To detect physiopathological effects of associated hyperbaric and hypoxic conditions on the alveolar-capillary membrane.

**Methods:** We measured the single-breath diffusing capacity of the lung to carbon monoxide (DLCO) and nitric oxide (DLNO), together with hematocrit (HCT) and haemoglobin concentration (Hb) by venous blood withdrawal and cardiac output by transgiugular ecodoppler, before and at 2, 10 and 25 minutes after a maximal static breath holding at 10 metres depth (mean dive time 4,5 minutes). Test dive was preceded by 10 minutes acclimatisation in water and two warming-up 10 metres dives without static apnoea. The pilot study population consisted of 6 elite divers (5 males, mean age 34±8, non smokers, basal normal lung function).

**Results:** When compared to pre-diving values, DLCO increased at 2 minutes, even if not significantly, in 5 subjects and its mean value significantly ($p<0,002$) decreased below the baseline at 25 minutes. DLNO remained stable at 2 minutes, increased at 10 minutes and decreased at 25 minutes below the baseline. Hb and HCT significantly increased at 2 minutes possibly affecting DLCO values, whereas cardiac output showed a slight but not significant decrease after dive.

**Conclusions:** Being DLCO expression of CO passage through the alveolar-capillary membrane and into plasma/erythrocytes, early but transient DLCO increase after diving may indicate the persistence of blood shift. This hypothesis is supported by the stable trend of DLNO at 2 minutes, being DLNO independent of blood volume and flow and representing the true membrane diffusing capacity due to its very high affinity for Hb. Further DLNO increase at 10 minutes may express VA/Q mismatch secondary to pulmonary capillary blood redistribution. DLNO and DLCO significant decrease at 25 minutes indicates a likely alveolar-capillary distress (interstitial oedema) masked by pulmonary blood shift and its redistribution at early times.

**Keywords:** breath-hold, NO, stress, pulmonary

OP-63

# INCREASED LUNG "COMETS" IN BREATH HOLD DIVERS

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**Introduction:** Episodes of extravascular lung water accumulation may occur in healthy breath-hold divers during breath-hold diving. Several cases of acute pulmonary edema during breath-holding have been reported but the exact nature of this condition is not clear. The purpose of the study was to analyze the ultrasound lung comets (ULCs) variations, which are an ultrasound sign of extra-vascular lung water.

**Methods:** Thirty-five healthy individuals performed breath-hold diving in two different conditions: dynamic surface apnea and depth variable-weight apnea (no-limits). The number of ULCs was evaluated by means of an ultrasound scan of the chest, before and after breath-hold diving. No divers performing lung packing before diving were included into the study since confounding results could appear.

**Results :** The ULC score increased significantly from baseline after dynamic shallow breath-hold diving ($p = 0.0056$) and after depth breath-hold diving as well ($p = 0.0019$). The average increase of ULCs score was similar after depth breath-hold diving and after dynamic shallow breath-hold diving. Thus, we can hypothesize that extravascular lung water accumulation is not primarily due to deep immersion because it occurs during dynamic surface apnea as well. We presume there are two fundamental mechanisms explaining this. First, this may be a consequence of the pooling effect found during the diving response. Secondly, it is possible that the intense involuntary diaphragmatic contractions occurring during the struggle phase of the breath-hold can also produce a blood shift from the pulmonary capillaries to the pulmonary alveoli. Further data gathered in our laboratory confirm this hypothesis since static apneas in shallow water with diaphragmatic contractions show more lung comets than the same total apnea time without diaphragmatic contractions in the same individual (blinded measurements).

**Conclusion:** Depth is not the primary reason for increased lung comets in breath hold divers.

**Keywords:** Diving, apnea, pulmonary effects, adverse effects

OP-64

# PRE-DIVE VIBRATION REDUCES POST-DIVE VENOUS GAS EMBOLI: A CONTROLLED RANDOMISED STUDY

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**Introduction:** It has been previously shown that physical exercise and pharmacological intervention before a dive can potentially reduce post-dive venous gas emboli (VGE). This would likely reduce the risk for decompression sickness (DCS) after the dive, as this risk is proportional to the number of VGE present.

**Methods:** 14 divers, selected within strict biometrical criteria, performed 4 identical dives in a controlled environment, each at least one week apart. Divers were investigated using laboratory tests and bio-impedance, as well as with transthoracic second harmonics echocardiography before and at 30 and 90 minutes after surfacing from a square-profile, 33msw, 20 minute dive. Also, Flow-Mediated Dilation (FMD) was measured, as an indicator of possible arterial endothelial changes. In a random fashion, some of the dives were preceded by a 30 minute whole body vibration session, ending 30 minutes before the dive.
Four-chamber heart views were recorded onto hard disk for later analysis. VGE were counted in the right atrium and ventricle in a fixed frame at end-diastolic (proto-systolic) view, for 10 consecutive frames. The average number of VGE per frame was compared, as described in a previous work.

**Results:** Analysis of the three "control dives" showed no significant difference in post-dive VGE. Pre-dive vibration reduced in a significant way the occurrence of post-dive VGE to 40% of the values for the control dives. Analysis of the 7 divers that had most VGE in the control dives showed a reduction to 7% of initial values. There was no difference in hydration state or other biometric variables that count account for this change. FMD was not significantly altered by vibration.

**Conclusion:** A single pre-dive whole-body vibration session reduces post-dive VGE. A mechanical hypothesis is most likely, although indirect endothelial or lymphatic effects can not be ruled out.

**Keywords:** Diving, venous gas emboli, preconditioning, vibration

OP-65

# DECOMPRESSION SICKNESS (TARAVANA) IN A BREATH HOLD DIVER WITH DELAYED-ONSET REVERSIBLE FOCAL NEUROLOGICAL INJURY: A CASE REPORT

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**Background:** The so called Taravanna´s Syndrome is widely known from its first description in 1947. Neurological symptoms, thought to be caused by blood bubble formation, have been occasionally reported in the literature. Herein, we report a case with delayed onset and reversible focal neurological impairment.

**Case Presentation:** While training for a competition, a 43 year-old breath-hold underwater fisher was diving during 4 consecutive hours, at variable depths between 20 30 msw, with 6 immersions per hour. His breath-hold time was ~2 minutes on average, remaining at depth for about 1 minute. Thus, at the end of this interval, the diver had been up to 24 minutes at a depth of 20-30msw. Three hours after, paresthesias and clonical movement in his upper extremities appeared. The diver came to CRIS-UTH 8 hours after the onset of symptoms. He was fully alert and oriented without apparent distress. During his stay the patient complained from “pins and needles” in his right hand fingers. His neurological examination and routine laboratory analysis were both unremarkable. Recompression was applied per Table CX-12 (120 minutes at 220kPa). The patient referred improvement promptly after the first step at depth, and he became asymptomatic at the end of the treatment. Because he wished to continue his breath-hold diving activity, several changes in his usual diving profile were recommended. A year and a half later, the diver continues his recreational underwater fishing without any further symptoms.

**Conclusions:** Repetitive breath-hold diving during underwater competitions, with frequent long and deep dives, can produce bubble formation from fast tissues, which usually remain only in blood stage with poor symptomatic expression. These divers are at highest risk during their training periods where no surveillance is followed, and they are difficult to manage because they follow their own habits frequently refusing medical advice.

**Keywords:** Taravana, Breath hold, Diver

OP-66

# RISK FACTORS AND CLINICAL OUTCOME IN 279 RECREATIONAL DIVERS WITH SPINAL CORD DECOMPRESSION SICKNESS

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**Objective:** Neurological symptoms are dominant in decompression sickness (DCS) and the most commonly affected area is the spinal cord. We conducted a retrospective and multicentric analysis with the aim to investigate the influence of potential risk factors associated with poor recovery from spinal cord DCS, pointing out different environmental or individual factors that may affect the prognosis.

**Methods:** We included 279 injured recreational divers (42 ± 12 years; 53 women) presenting symptoms of spinal cord DCS from 7 hyperbaric centres in France and Belgium. Diving information, symptom latency after surfacing, time interval between symptom onset and hyperbaric treatment were studied. The initial severity of spinal cord DCS was rated with the Boussuges severity score and the presence of sequelae was evaluated at one month. Initial recompression treatment at 2.8 ATA with 100% oxygen breathing or deeper recompression up to 4 or 6 ATA with nitrogen or helium-oxygen breathing mixture were also recorded.

**Results:** Of the 279 injured divers, 26% had incomplete resolution of neurological symptoms after 1 month. The multivariate analysis revealed that significant variables associated with a poor outcome were: age >= 42 [OR, 1.04 (1 – 1.07)], depth >= 39 meters [OR, 1.04 (1 – 1.07)], bladder dysfunction [OR, 3.8 (1.3 – 11.15)], persistence or worsening of clinical symptoms before recompression [OR, 2.07 (1.23 – 3.48)] and a Boussuges severity score > 7 [OR, 1.16 (1.03 – 1.31)]. However, the time to recompression and the choice of initial hyperbaric procedure did not significantly influence recovery after statistical adjustment.

**Conclusion:** The main finding of this study is that initial clinical presentation of spinal cord DCS provides relevant information about the clinical outcome at discharge. We proposed a new simple score for this initial clinical evaluation that may be useful in predicting spinal cord DCS with incomplete recovery.

**Keywords:** diving decompression sickness hyperbaric spinal cord

**spinal cord DCS score**

| Spinal cord DCS score | | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| Age ≥ 42 | *no* | X | | | | | | |
| | *yes* | | X | | | | | |
| Back pain | *no* | X | | | | | | |
| | *yes* | | X | | | | | |
| Clinical course before recompression | *better* | X | | | | | | |
| | *stable* | | | | X | | | |
| | *worse* | | | | | | X | |
| Objective sensory deficit | *no* | X | | | | | | |
| | *yes* | | | | | X | | |
| Motor impairment | *none* | X | | | | | | |
| | *paresis* | | | | | X | | |
| | *paraplegia* | | | | | | X | |
| Bladder dysfunction | *no* | X | | | | | | |
| | *yes* | | | | | | | X |

*Parameters used in the new scoring system and their numerical weightings for spinal cord DCS, based on the Boussuges score and the present analysis. The analysis of area under the ROC curve (0.88 ± 0.02; 95% CI, 0.84-0.93; p < 0.0001) showed that this score can accurately predict the divers with residual deficit. Patients with scores greater than 8 predict more severe sequelae than scores of 8 or less, with 87% positive predictive value and 74% negative predictive value.*

OP-67

# INNER EAR DECOMPRESSION SICKNESS, RETROSPECTIVE ANALYSIS OF 24 CASES

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**Background:** DECOMPRESSION SICKNESS (DCS) is caused by formation and growth of bubbles from excess dissolved gas in body tissues following reduction in ambient pressure. Inner ear decompression sickness (IEDCS) is a complex disorder involving the vestibulocochlear apparatus whose pathophysiology remains incompletely understood.

**Patients And Methods:** Clinical audit data of 24 divers diagnosed with IEDCS are presented. The divers included had symptoms of nausea, vomiting and dizziness within max 2 hours from surfacing. The clinical examination included a positive Romberg and Unterberger test.

There were 23 males and 1 female treated, age was ranging from 31-60 years, mean 44. 11 patients had isolated IEDCS the others had associated symptoms.

There were 15 divers using air (62.5%), 5 using nitrox (21%), 3 using trimix (12.5%) and one rebreather. In 16 patients a USN TT6 was used as primary treatment and in 7 patients a Comex 30 was used. There was no difference in the speed of recovery or number of treatments needed between the two tables. All but one patient were advised to have a PFO check, which was positive in 20 patients (87%).

**Discussion:** It has been previously shown that after a dive the inner ear remains supersaturated with inert gas for longer than brain tissues and the window of opportunity for growth of small vascular bubbles distributing to the labyrinthine artery territory is longer. So bubbles shunted through a PFO would grow when introduced to a tissue already supersaturated with inert gas explaining symptoms of isolated IEDCS1.

**Conclusion:** Our study confirms the correlation between IEDCS and presence of a significant PFO. In our series only 46% of patients had an isolated IEDCS. It also shows that IEDCS is responding slowly to treatment irrespective of the initial table used. The recovery is thought to be mainly a central compensation process.

**Keywords:** inner ear decompression sickness, PFO, gas supersaturation

OP-68

# DIVERS AS DECOMPRESSION SICKNESS SURVIVORS: EXPLORING THEIR PHYSICAL EXERCISE INVOLVEMENT AND TIME MANAGEMENT

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It is significant for a diver to have sufficient strength and aerobic capacity reserves to cope with the exceptional demands of diving in the underwater environment. Physical exercise can reduce the risk of vascular bubbles formation, which in turn, may cause decompression sickness among divers. Therefore, it is important for divers to adopt an active lifestyle. However, little is known about motives for and against physical exercise among divers. In order to design successful exercise involvement interventions for divers, more knowledge on this topic is needed. The purpose of this project is to explore divers exercise behaviour. Time management can be a problem among divers that may result in less exercise involvement. Even divers with the intention to exercise may need scheduling skills to actually carry out these intentions. Scheduling efficacy, the capability of managing one's schedule, can strongly influence exercise behaviour. Plans of action that specify when, where and how a certain behaviour is enacted, also referred to as implementation intentions, can in turn affect scheduling efficacy. In the current project, the following questions are investigated within the field of health psychology. Which factors influence exercise behaviour among professional divers? Is it possible to increase divers exercise involvement by manipulating scheduling skills by the formation of implementation intentions in an experimental setting?

**Keywords:** divers, exercise, time management, implementation intentions

OP-69

# EXCEEDING THE LIMITS - ESTIMATED TISSUE PRESSURES AMONG WESTERN AUSTRALIAN RECREATIONAL DIVERS

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**Aims:** In Western Australia (WA) between 40 and 60 divers suffer decompression sickness (DCS) per year, many after exceeding accepted safe time and depth limits. The aim of this study was to measure the prevalence of exceeding M-values among certified recreational divers in Western Australia (WA) and to identify potential risk factors for future investigation.

**Methods:** Divers on organised recreational SCUBA dives wore depth time loggers. Dives exceeding the Diving Science and Technology gas-content limits (M-values), determined by depth-time dive profiles, were matched to control dives made at the same dive site at the same time during which no M-values were exceeded. Potential risk factors for exceeding an M-value were evaluated using a conditional logistic regression model.

**Results:** A total of 1,032 organised recreational dives were recorded. Case dives were more likely made by females (OR 5.63, 95% CI 1.86, 17.03), diving deeper than other divers in the water at the same time (OR 10.45, 95% CI 3.02, 36.12). They were also made by divers less likely to have previously dived as deep (OR 14.49, 95% CI 3.11, 66.67).

**Conclusion:** In addition to one in 27 organised recreational dives exceeding an M-value, it is possible that displayed decompression obligations were omitted and that more divers exceeded the no-stop limits displayed by their personal dive computers. We recommend dive organisers in WA encourage recreational dive groups to watch their displayed remaining no-stop time and to dive within the limits of their training and experience.

**Keywords:** M-values, decompression, recreational diving, risk factors

OP-70

# PRESSURE MODULATION OF PRESYNAPTIC Ca2+ CURRENTS IN FROG MOTOR NERVE TERMINALS

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**Aims:** Presynaptic Ca2+-dependent mechanisms are implicated in hyperbaric pressure depression of evoked synaptic transmission. Therefore, we studied for the first time pressure effects on presynaptic Ca2+ currents in an intact nerve tissue.

**Methods:** Ca2+ currents in frog myelinated neuromuscular nerve terminals were recorded at the nodes under the nerve perineurial sheath using a loose macropatch clamp technique. Blocking postsynaptic acetylcholine receptors and inhibition of K+ currents revealed the Ca2+ currents that were evoked by nerve stimulation or direct nodal depolarization. The preparation was constantly perfused with fresh physiological solution introduced to the chamber by a pressure pump and was compressed by helium up to 6.9 MPa. Currents analysis was assisted by a computer compartmental model simulations, using NEURON computing platform.

**Results:** Application of selective blockers of voltage-dependent Ca2+ channels revealed two types of Ca2+ currents: an early fast phase (possibly via N type Ca2+ channels), and a late slow and long lasting phase (possibly via L type Ca2+ channels). High pressure reduced by 80% and 40% the amplitude of the slow and the fast Ca2+ currents respectively. Pressure also moderately diminished the Na+ action current. The computer simulations of the nodal currents verified the validity of the recording methods and explained the terminal and nodal time- and pressure-dependent changes of the ionic currents.

**Conclusions:** The differential reduction of the presynaptic Ca2+ and Na+ currents are probably the major causes of pressure depression of synaptic release that is associated with High Pressure Neurological Syndrome.

Acknowledgements: Supported by USA ONR grants no. N00014-91-J-1908 (early phase) and no. N00014-10-1-0163 (recent phase).

**Keywords:** Hyperbaric pressure, Deep diving, HPNS mechanisms, High pressure biology, Synaptic transmission, calcium currents, Calcium Channels

# Poster Presentations

PP-01

# PLASMINOGEN ACTIVATOR INHIBITOR PROTEIN IS A BIOMARKER OF DECOMPRESSION STRESS IN RATS

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**Aims:** To determine whether the presence of intravascular gas bubbles after diving alters the concentration of plasminogen activator inhibitor (PAI-1) protein in blood plasma.

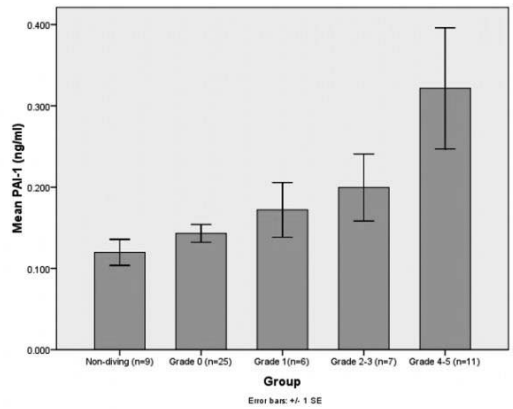
**Methods:** Fifty-six female Sprague-Dawley rats were compressed to 700 kPa breathing air for 50 minutes followed by a 50 kPa min-1 linear decompression to surface. Gas bubble grade in the pulmonary artery was measured by Doppler ultrasound at discrete time points for the first hour after decompression. Blood samples were collected from the abdominal aorta, and total PAI-1 protein in plasma from all surviving animals and 9 additional non-diving controls was measured by ELISA with a polyclonal rabbit anti-rat PAI-1 antibody. The animals were divided into groups according to bubble grade at 60 minutes and multiple comparison analysis between groups was done by ANOVA with Bonferroni corrections using the SPSS analytical software.

**Results:** There was a significant rise in the level of PAI-1 protein in plasma at high bubble grades, grade 4-5, compared to animals with no detectable bubbles, grade 0 (p=0.002) or untreated controls (p=0.006). Differences between groups with lower bubble grades were not statistically significant, but a trend of increasing PAI-1 with increasing bubble grade is apparent.

**Conclusions:** Elevation of PAI-1 is involved in early response to hypoxia, and the presence of high amounts of PAI-1 is used as a biomarker for risk in several diseases. Functionally, PAI-1 is a major physiological inhibitor of blood clot degradation and has been shown to act cardioprotectively, possibly by guarding the integrity of the cardiac vascular barrier. Our results show that increasing amounts of gas bubbles in vascular tissues after decompression correlate with increased concentration of PAI-1 in blood plasma, indicating the triggering of a hypoxic response by the presence of gas bubbles.

**Keywords:** biomarker, rats, hyperbaric air, decompression, intravascular gas bubbles, Doppler ultrasound, plasminogen activator inhibitor (PAI-1), plasma, hypoxia

**Concentration of PAI-1 versus bubble grade**




*Concentration of PAI-1 total protein in blood plasma versus gas bubble grade in the pulmonary artery one hour after decompression.*

PP-02

# HYPERBARIC OXYGEN PREBREATHING DOES NOT REDUCE VASCULAR BUBBLE FORMATION IN DECOMPRESSED RATS

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**Aims:** Investigate the effects of hyperbaric oxygen prebreathing, HBO, on vascular bubble formation in rats exposed to a simulated dive in a hyperbaric chamber.

**Methods:** Thirty-six female Sprague Dawley rats, 282g±13SD, were divided into three groups, 12 in each. Group I: HBO followed by 45 min recovery and dive. Group II: HBO followed 180 min recovery and dive. Group III: Control dive. An HBO profile, 303 kPa for 38 min, previously shown to reduce DCS risk was used, followed by 303 kPa air for 7 min to renitrogenate tissues. After normobaric recovery the rats were exposed to 700 kPa breathing air for 50 min reaching tissue saturation, and decompressed linearly at 50 kPa·min-1. Vascular bubbles were recorded in the pulmonary artery at 15, 30 and 60 min using Doppler ultrasound.

**Results:** Hyperbaric oxygen prebreathing did not decrease the amount of detectable vascular bubbles or increase survival in rats after decompression from hyperbaric exposure. Max bubbles•cm2, gr I: 4.1±4.6SD, gr II: 4.4±4.9SD, gr III: 3.9±4.7SD. Average bubbles•cm2, gr I: 3.5±4.3SD, gr II: 4.0±4.8SD, gr III: 2.9±3.6SD. Mortality rate, gr I: 25%, gr II: 33%, gr III: 17%.

**Conclusions:** This study has for the first time investigated the effects of HBO prebreathing on vascular bubble formation in rats after decompression from hyperbaric exposure. An HBO exposure previously shown to reduce DCS risk did not reduce the volume of detectable vascular bubbles, thus this experiment may indicate that HBO reduces the risk of DCS due to an increased tolerance to vascular gas bubbles. A different explanation may be that a preexisting microbubble population eliminated by HBO has fully recovered before decompression. Further investigations are needed to fully understand the findings in this study.

**Keywords:** hyperbaric oxygen, prebreathing, bubbles, decompression sickness, rat

PP-03

# HIGH SUSCEPTIBILITY TO DECOMPRESSION SICKNESS IN TREK-1-DEFICIENT MICE

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Death and nervous disorders may occur after an organism is saturated with inert gases and then decompressed in a provocative protocol. Sur-saturation in nitrogen partial pressure involves bubbles genesis in vascular pathway, which may induce decompression sickness (DCS). Bubbles alter the vascular endothelium and active the platelet aggregation. Platelet Activation Factor (PAF) plays a crucial role in thrombogenesis and, it is also known to modulate the TREK-1 channel activity. TREK-1 is involved in neuroprotection process by setting the neuronal resting membrane potential (Franks and Honoré, 2004). Moreover, PAF and other polyunsaturated fatty acids have been identified as openers of the TREK-1 channel (Maingret et al., 2000). Actually, these knockout mice have already been described to be sensitive to brain and spinal cord ischemia (Heurteaux et al., 2004). On this basis, we hypothesized that TREK-1-deficient mice could be more sensitive to decompression sickness.

274 C57Bl6 mice were submitted to the decompression protocol, from 90 msw: 143 had a wild type (WD), 88 were knockout (KO) and 43 were heterozygote. In TREK-1+/+ mice, 53.1% showed no DCS symptoms, 27.3% failed the grip-test and 19.6% died in the 6.0±3.0min following the decompression. In survivors, platelet consumption averaged 8.4±31.5%. In TREK-1-/+ mice, 32.6% showed no DCS symptoms, 48.8% failed the grip-test and 18.6% died in the 9.5±6.8min following the decompression. The average in platelet consumption reached 13.5±17.4%. In TREK-1-/- mice, 26.1% showed no DCS symptoms, 42.0% failed the grip-test and 31.8% died in the 9.7±5.2min following the decompression. The averaged consumption in platelet was 13.3±28.1%.

TREK-1-/- mice had a lower threshold of resistance to the decompression protocol, while platelet consumption was equivalent to WT mice. We conclude that the TREK-1 potassium channel could play a key role in the neuroprotection process activated after a provocative dive occurred.

**Keywords:** decompression sickness, TREK-1, mice, platelet, knockout, inert gas

PP-04

# ULTRASOUND DETECTION OF LIVER GAS EMBOLISM IN THE RAT MODEL OF RAPID DECOMPRESSION

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In a previous study we were able to document, by gross anatomy and histology, gas bubble formation in the splanchnic circulation and liver embolism in the rat model of rapid decompression.

**Aim:** To investigate the ability of 2D ultrasound to detect the occurrence of liver gas embolism and to describe its time course in the rat model, as prerequisite for its putative diagnostic use in human decompression sickness.

**Methods:** Seventeen female rats aged 6-8 months, 274±47g body weight, were decompressed in 12 min after 42 min compression at 7 ATA. Eight surviving animals were anesthetized and the liver imaged by ultrasounds at 20 min intervals up to 2 hours following decompression. At 24 hours, animals were sacrificed and liver inspected by gross anatomy and histology. Blood samples for markers of liver dysfunction were obtained basally and before sacrifice.

**Results:** As judged by ultrasound imaging of the inferior vena cava, apparent onset of bubble formation in the lower systemic venous circulation occurred between 20 and 120 min following decompression. Post-processing analysis of echo liver images showed significant enhancement of signal from 60 to 120 min. Liver edema was evident at gross examination as well as perilobular cell swelling, vacuolization or hydropic degeneration at histology. Compared to basal, enzymatic markers of liver damage (AST, ALT, GGT) increased significantly.

**Conclusion:** Post-decompression gas liver embolism can be detected by 2D ultrasound imaging in the rat model. Post-diving ultrasound liver examination might be an easy way to check the occurrence of liver gas embolism in human subjects undergoing decompression.

**Keywords:** Decompression sickness, Gas embolism, Diving, Liver dysfunction, Hyperbaric chamber, Animal model

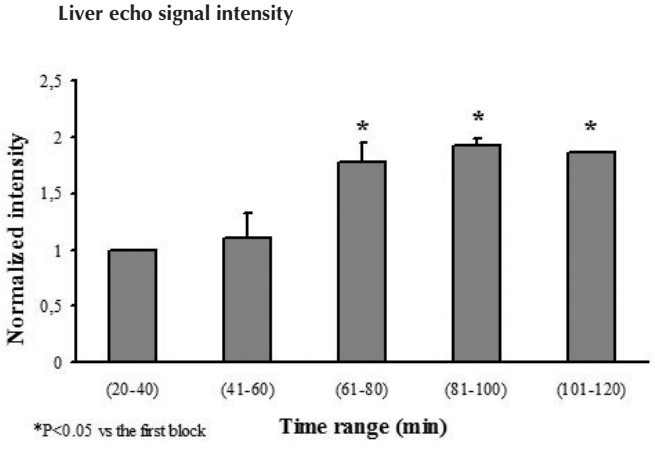


*Figure: echo signal intensity within comparable liver regions of interest, over 2 hour period following simulated dive. Values from different animals within a time range of 20 minutes were averaged (n=8). Data are normalized to values of the first block.*

PP-05

# NITRIC OXIDE SYNTHASE IN HUMAN ENDOTHELIAL CELLS EXPOSED TO SIMULATED DIVING AFTER HEAT STRESS

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**Aim:** Decompression sickness (DCS) may result from damage to the endothelium caused by gas bubbles formed during decompression. Previous work has indicated a relation to the production of nitric oxide (NO) by nitric oxide synthase (NOS), while heat stress or physical exercise has been shown to confer protection against DCS, accompanied by increased production of heat shock protein (HSP). The aim of the present study was to simulate this treatment in human endothelial cells and investigate the biochemical mechanisms involved, including the enzyme activity of NOS.

**Methods:** Human endothelial cells were exposed to heat stress (45 ˚C, 1 h) 24 hours prior to a simulated dive corresponding to 250 msw. After a rapid decompression cells were harvested for analysis of NOS activity, NOS and HSP protein content. NOS activity was determined using a radioassay, and protein amounts were determined by ELISA.

**Results:** The results demonstrated that a dive alone had no significant effects on the enzyme. In contrast, a heat stress reduced the NOS activity approximately 50 %, while a subsequent dive did not seem to change the heat-induced reduction of NOS activity. Increasing the pO2 to 40 kPa during the dive did not affect the enzyme activity, while heat stress alone or in combination with a dive resulted in a similar reduction in NOS as was observed with 20 kPa O2. Preliminary results indicated a similar pattern for the NOS protein content as for the enzyme activity.

**Conclusions:** Our cell model indicated that NOS is not significantly altered from control level neither due to diving per se, or an elevated partial pressure of pO2. In contrast, heat stress alone as well as heat stress followed by a dive reduced the NOS activity markedly. Further experiments elucidating the role of HSPs in this context are in progress.

**Keywords:** Endothelial cells, Diving, Decompression, Nitric oxide synthase, Heat stress

PP-06

# DIRECT COMPARISON OF AUDIO DOPPLER ULTRASOUND SCORES AND 2D ULTRASOUND IMAGES OF PRE-CORDIAL VENOUS GAS EMBOLI

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**Aims:** The amount of venous gas emboli (VGE) in the body following decompression can give an indication of decompression stress, and therefore a level of risk of DCS. Ultrasonic methods are used to detect VGE, the most common being pre-cordial Doppler Ultrasound to grade VGE in the heart. 2D ultrasound imaging is increasing in use as the cost of portable scanning units has reduced. This study aims to contrast and compare visual 2D data with audio grades, providing a greater understanding of the relative VGE load.

**Methods:** Doppler operators are trained to listen to and grade VGE, usually on the Kisman Masurel or Spencer scales. In 2D scanning of the heart VGE are relatively obvious and are commonly graded using the Eftedal and Brubakk system. In the present study, Doppler and 2D data were collected from subjects over 2h following hyperbaric chamber dives. To gain a better idea of how these data relate, a range of Doppler scores and their corresponding 2D images were observed and analysed.

**Results:** From the Doppler scores and associated images, it was possible to note how the KM Doppler and the Eftedal and Brubakk 2D scale reflect each other. In general the two methods corresponded well. At a number of time points, bubbles were detectable by Doppler ultrasound, but could not be seen using the 2D method and vice versa; this might be due to sensitivity of the measurements, or slightly different measurement times catching the onset of, or flurries of VGE.

**Conclusions:** Observing both KM Doppler scores and 2D ultrasound images alongside one another allows the possibility of understanding how they correspond and also highlights the vagaries and limitations of each method. The non-linearity of the data is also highlighted by the comparison.

**Keywords:** Doppler, 2d ultrasound, VGE, DCS

PP-07

# CARDIAC ALTERATIONS INDUCED BY A FISH-CATCHING DIVING COMPETITION

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**Aims:** Cardiac changes induced by repeated breath hold-diving were investigated after a fish-catching diving competition.

**Methods:** Eleven healthy subjects carried out repeated breath hold dives at a mean maximal depth of 20 +/- 2.7 msw (66 +/- 9 fsw) during 5 hours.

**Results:** One hour after the competition, the body mass loss was -1.7 +/- 0.5 kg. Most of the breath hold divers suffered from cold and although the core temperature remained normal, a decrease in cutaneous temperature was recorded in the extremities. Systolic blood pressure was reduced in both upper and lower limbs. Heart rate was unchanged, but left ventricular (LV) stroke volume was reduced leading to a decrease in cardiac output (-20%). Left atrial and LV diameters were significantly decreased. LV filling was assessed on a trans-mitral profile. An increase in the contribution of the atrial contraction to LV filling was observed. Right cavity diameters were increased. The cardiac autonomic alterations were in favour of sympathetic hyperactivity.

**Conclusions:** After a fish-catching diving competition in cold water, alterations suggesting dehydration, contraction in plasma volume and sympathetic hyperactivity were observed. Furthermore, enlargements of right cavities were in favour of right ventricular strains; Repeated apnea and swimming in cold water may account for these alterations.

**Keywords:** Diving, Apnea, Immersion, Cold exposure, Ultrasonography, Doppler, Cardiac function

PP-08

# EFFECT OF COMBINED NORMOBARIC OXYGEN BREATHING AND PERFLUOROCARBON EMULSION TREATMENT ON TNF-α LEVELS DURING DECOMPRESSION SICKNESS IN RATS

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**Aims:** Perfluorocarbon (PFC) have been shown to improve survival and bubble disappearance rate in rats with decompression sickness (DCS). The PFC effect may be explained by an increased oxygen and nitrogen transport capacity of blood. However, during DCS intravascular gas bubbles cause the activation of inflammatory parameters such as cytokines. Limited data exsist on the effects of PFC on pro-inflammatory cytokines during DCS. Accordingly, the purpose of the experiment was to study the TNF-α response in rats with DCS during combined 100% oxygen breathing and PFC infusion.

**Methods:** Anesthetized female Wistar rats weighing 250-300g underwent intervention with implantation of a carotid catheter, tracheotomy and opening of abdominal cavity for bubble studies (see previous published data; JAP. 107: 1857–1863, 2009), and then exposed to 385 kPa for 60 min during air breathing and decompressed to 101.3 kPa over 7½ min in three stages. At 101.3 kPa, rats either continued air breathing, switched to oxygen breathing or switched to combined oxygen breathing with PFC infusion. Five blood samples of 300 µl were taken for TNF-α measurements, 1) just before compression, then 2) 30 min, 3) 90 min, 4) 150 min and 5) 190 min after decompression. Samples were centrifuged and the serum stored in a freezer at -80°C until analysis. A rat TNF alpha ELISA kit from Thermo Scientific were used.

**Results:** Combined 100% oxygen breathing and PFC infusion did neither increase nor lover the concentration of TNF-α in rats with DCS when compared to oxygen breathing alone. Accordingly, no adverse effects of PFC infusion were observed.

**Conclusion:** The result does not give rise to reservations regarding use of PFC when observing levels of TNF-α in rats with DCS. PFC infusion may be a valuable adjunct therapy during first-aid treatment of DCS at normobaric conditions.

**Keywords:** cytokines, inflammation, bubbles, PFC, DCS,

PP-09

# POST-DIVING UKTRASOUND DETECTION OF LIVER GAS EMBOLISM IN SCUBA DIVERS

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**Aim:** To define, in the rat model of rapid decompression, the time course of liver gas embolism according to 2D ultrasound imaging and to scrutinize by this technique the occurrence of liver embolism in scuba divers.

**Methods:** Animal model. Following 42 min compression at 7 ATA and decompression in 12 min, 8 animals were anesthetized and the liver imaged by ultrasounds at 20 min intervals up to 120 min following decompression. Blood samples for markers of liver dysfunction were obtained basally and at 24 hours. Scuba divers. We studied 12 healthy elite divers basally and at 15 min intervals up to 60 min following a 30 min SCUBA dive at 30 msw depth. Ultrasound images were analyzed by MIPAV software. Mean and SD of the signal within standardized regions of interest were evaluated. Blood markers of liver dysfunction were also obtained basally and 24 hours after diving.

**Results:** Animal study. Apparent onset of bubble formation in the systemic circulation (inferior vena cava) occurred between 20 and 120 min following decompression. A significant enhancement of echo signal was recorded from 60 to 120 min. Compared to basal, enzymatic markers of liver damage (AST, ALT, GGT) increased significantly. Scuba divers. Analysis of 11/12 divers' images (one was excluded for technical reasons) showed significant echo intensity increase at 15 min in 5 divers, at 30 min in 9, and at 45 and 60 min in all. Conversely humoral markers of liver function did not significantly change relatively to basal.

**Conclusion:** Two-D ultrasound liver imaging allowed detection of gas embolism in the rat and its time course. Its application to scuba divers revealed liver gas accumulation in all subjects in absence of any humoral evidence of liver dysfunction or symptom. The clinical meaning of our finding remains to be investigated.

**Keywords:** scuba, divers, liver, embolism

PP-10

# HEART RATE VARIABILITY DURING APNEIC UNDERWATER SWIMMING

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**Objective:** Heart rate (HR) is continuously subject to inherent fluctuations (heart rate variability, HRV), especially to those caused by the respiratory rhythm. High frequency oscillations (>0.15 Hz, HF) are thought to reflect parasympathetic effectors, whereas low frequency oscillations (<0.15 Hz, LF) can result from sympathetic and baroreflex influences. In this study we aimed to elucidate how apnoea and apneic exercise would modify these oscillations of heart rate.

**Methods:** 6 healthy experienced divers performed two runs of apnoea swimming with different intensities on the surface, in 5 and 10 m depth (6 runs in total). HR and swimming speed were monitored with a programmable data logger system designed for under water applications. The task for the subject was to swim as long as possible in apnoea with a constant speed. The speed in the second trial in each depth should be higher than the first. Before and after the apneic swim the divers were instructed to breath at exactly 0.15 Hz.

**Results:** Intra- and inter-individual varying HR and HRV response patterns were observed. HR increase with LF oscillations (pattern LFi), HR decrease with HF oscillations (pattern HFd), and a mixed pattern (transition from LFi to HFd) could be distinguished. Change of swimming velocity could produce a pattern change in the individual diver.

**Conclusion:** During apneic exercise both HR and HRV reflect the physiological conflict between “exercise-tachycardia” and “apnea-bradycardia”. Parasympathetic influences may produce a fast fluctuating HR decrease, whereas sympathetic and baroreflex contributions (increase of arterial blood pressure) result in a slow oscillating HR increase. We suggest that breathing at 0.15 Hz (border frequency between LF and HF) before the apneic exercise facilitated the emergence of different HRV response patterns.

**Keywords:** apnea, exercise, HRV

PP-11

# HEART RATE RESPONSE PATTERNS TO INTERMITTENT APNEIC EXERCISE

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**Objective:** In this study we investigated the effects of apneas on the heart rate response during intermittent exercise while increasing power output.

**Methods:** 8 elite male underwater hockey players performed five dry apneas while exercising on a bicycle ergometer. Power output was increased from 25 W to 175 W for each apneic exercise section which lasted 45 s. Recovery between the apneic exercises lasted two minutes. The athletes were connected to a spiroergometer (ZANR) and heart rate was collected on a beat to beat basis by telemetric device (Polar S810iR).

**Results:** Two basic response patterns for heart rate were observed during apneic exercise. Either a monotonic heart rate decrease developed during the entire exercise, or a heart rate increase in the beginning changed to a bradycardia towards the end of the exercise (biphasic response pattern). The increase of power output elevated heart rate during the entire exercise and prolonged the tachycardia, but did not affect the basic response pattern. Individual differences between the athletes were related mainly to the power output. Heart rate was increased during the first minute of the recovery period and returned to baseline levels in the second minute. This post-exercise increase in heart rate was correlated positively with power output.

**Discussion:** During apneic exercise the physiological conflict between “exercise-tachycardia” and “apnea-bradycardia” is predominantly solved in favor of the oxygen conserving heart rate decrease. But increase of power output counteracts this mechanism by an individually varying degree. As we investigated only moderate exercise intensities for these highly trained athletes, a further study with exercise intensities above the anaerobic threshold may further detail the heart rate response to intermittent apneic exercise.

**Keywords:** exercise, apnea, heart rate response, underwater hockey

PP-12

# ACCIDENTS AND INCIDENTS DURING SCUBA-DIVING EVENTS IN CHILDREN

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**Aim:** Scuba diving has become a popular recreational activity among children and adolescents. However, compared with data in adults, there is scarce information available only with regard to both possible and actual complications of scuba diving.

**Methods:** Any complications that could be observed in 44 boys and girls aged 8 to 15 years while participating in pediatric scuba-diving camps (max. dive depth 8m) were documented and analysed.

**Results:** In 7 children there were mild barotraumas of the nasopharyngeal cavities and middle ears subsequent to pressure equalization issues which necessitated premature termination of the scuba dive. One child suffered from more severe middle ear barotraumas during diving. This child also had an attention deficit hyperactivity disorder (ADHD). Analysis revealed that children who suffered from barotraumas were significantly younger than those who did not.

**Discussion:** Barotrauma of the middle ear seems to be a frequent complication in scuba diving children. Younger children appear to be more likely affected. Hyperkinetic disorders may be a risk factor for pediatric diving injuries.

**Conclusion:** Proper ENT evaluation must be a crucial component of pediatric fitness to dive medical assessment. Careful observation of possible equalization issues by adult dive buddies could help to prevent these injuries. ADHD should be considered a contraindication to scuba diving.

**Keywords:** Barotrauma, ADHD, haematotympanon, hematotympanon, SCUBA diving

PP-13

# EFFECTS OF SCUBA-DIVING ON HEART RATE AND RHYTHM IN CHILDREN

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**Aim:** SCUBA diving has become a popular recreational activity within the last decades – even in children and adolescents. Therefore, the main aim of this study was to gain data concerning heart rate and rhythm after open water SCUBA dives.

**Methods:** Nine children performed open water SCUBA dives at 8msw of depth lasting 25 minutes in total. During these dives, ECG was recorded by a special under water ECG-device. These records were analyzed afterwards concerning heart rate and arrhythmias.

**Results:** After an initial increase in heart rate (HR) before the dive (+23±7%) a decline compared to heart rate at rest was detected during the dive (-6 ± 11%). Compared to pre-dive heart rate, heart rate declined by -24±8% (range -36%; -15%) during the dive. In some children a further decline in heart rate was observed within the last minutes of the dive. Some anthropometric descriptors were associated with a higher decline in heart rate. Furthermore singular supraventricular and ventricular extrasystoles were observed in some children.

**Conclusions:** Immersion as well as facial and skin cooling presumably account for the initial decline in heart rate. A further drop in heart rate within the last minutes of the dive might be related to mild hypothermia. The single supraventricular and ventricular extrasystoles observed are not expected to be clinically relevant. During pediatric scuba dives, no grave arrhythmias could be detected.

**Keywords:** Bradycardia, extrasystoles, premature beats, ecg

PP-14

# EFFECTS OF INTERMITTENT HYPERBARIC EXPOSURE ON ANAEROBIC PERFORMANCE OF RECREATIONAL ATHLETES

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**Aims:** Hyperbaric Oxygen (HBO) exposure has been used for increasing anaerobic performance. The results from previous studies have been conflicted. Wingate anaerobic power tests (WAnT) is perhaps the most popular assessment for peak anaerobic power, anaerobic fatigue and total anaerobic capacity. The purpose of this study was to evaluate the effectiveness of hyperbaric exposure on anaerobic performance of recreational athletes by WAnT.

**Methods:** Six recreational athletes participated in this study aged 29.6±3.6 years, weighted 73.8±17.8kg and heighten 176.2±6.2 cm. Participants underwent clinical and instrumental diagnosis excluding any cardio-respiratory problems. Peak power (PP), mean power (MP) and power drop (PD) were measured by using 30-sec WAnT pre and post HBO exposure. Participants received either a 1-hour HBO exposure inspiring 100 % O2 at 2 ATA (Atmospheres absolute pressure) before WAnT.

**Results:** No significant differences (p> or = 0.05) were observed in pre and post HBO exposure PP, MP and PD parameters as determined by Wingate Anaerobic Test.

**Conclusion:** Acute HBO exposure appears to have no significant effect on anaerobic performance. It is necessary to confirm these results by using with control group studies.

**Keywords:** Hyperbaric oxygen, Wingate anaerobic power tests, Recreational Athletes

PP-15

# DYNAMIC CHANGES IN CARDIOVASCULAR FUNCTION DURING DIVING AND DECOMPRESSION AT DIFFERENT CORE TEMPERATURES

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**Background:** Changes in temperature may affect gas uptake and elimination due to altered perfusion and cardiac performance and it is believed that cold decompression increases DCS risk. To improve predictions of the outcome of diving, continuous recordings of hemodynamic changes at different temperatures are needed.

**Aims:** 1) to continuously investigate left ventricular functional variables at depth, during decompression and post dive and 2) to investigate the possible effect a realistic drop in core temperature from 37 to 35ºC during decompression and early post dive will have on bubble production and DCS risk.

**Methods:** Twenty-seven anesthetised rats were monitored with a Millar pressure-volume catheter in the left ventricle and the femoral artery. Rats were assigned to 3 groups; 1) normothermic controls, 2) dry hyberbaric dive at constant core temperature (37ºC) and 3) dry hyperbaric dive with a decrease of core temperature from 37 to 35ºC during decompression and the early post dive period. Rats exposed to a dive were compressed to 600 kPa, maintained for 45 min breathing air, and decompressed linearly to the surface at a rate of 50 kPa min-1. Immediately after surfacing, right ventricle and pulmonary artery were insonated for bubble detection using ultrasound.

**Results:** In rats exposed to the dive several cardiovascular variables changed significantly during compression: decreased respiration frequency, increased mean arterial pressure, pulse pressure, stroke volume, cardiac output, LV end-systolic volume, LV end-systolic pressure, LV dp/dt max, and total peripheral resistance. The changes were reduced during decompression and reached baseline values post dive. Core temperature did not have a significant effect on hemodynamics, bubble production and survival.

**Conclusion:** These data indicate that a cold decompression (35ºC) did not have a significant impact on bubble production and DCS risk and that cardiovascular changes are transient.

**Keywords:** Diving, cardiovascular changes, temperature

PP-16

# THROMBOPHILIC FACTORS AND NEUROLOGICAL DECOMPRESSION SICKNESS IN RECREATIONAL DIVERS

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**Introduction:** Inherited or acquired thrombophilic factors contribute to the development of venous or arterial thrombotic events. At present, preliminary results have suggested that injured divers may have mild hyperhomocysteinemia as potential risk factor for unexplained decompression sickness (DCS). We aimed to determine the interaction between thrombophilic factors and neurological DCS development in recreational divers.

**Material and methods:** Sixty one injured divers (56M, 5F, 45 ± 9 years) and 61 age- and sex-matched healthy divers (57M, 4F, 42.5 ± 6 years) without previous history of DCS were retrospectively examined. From blood samples, C reactive protein, fibrinogen, platelet count, antithrombin, protein C activity, protein S activity, factor VIIIc, activated protein-C resistance, IgG anticardiolipin antibodies, lupus anticoagulant and homocysteinemia were investigated.

**Results:** Mean laboratory values were comparable in both groups. The only statistical difference in the prevalences of thrombophilic factors between the 2 populations was the presence of a higher proportion of hyperhomocysteinemia in DCS divers compared to healthy controls (18.6% vs. 4.9%, p = 0.048, respectively; OR 4.4 [1.1-17.8]). Six injured divers had a history of previous DCS but none of them displayed thrombophilic disorders.

**Conclusion:** Our findings confirm that neurological DCS in recreational divers are associated with an increased level of homocysteinemia without significant alterations of other thrombophilic factors. The evidence that thrombophilia constitute a triggering circumstance for DCS recurrence remains doubtful.

**Keywords:** diving, decompression sickness, thrombophilia, homocysteinemia

PP-17

# VARIATIONS IN SPIROMETRY AND DIFFUSING CAPACITY AFTER 5 YEARS OF MILITARY OXYGEN DIVING

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**Objectives:** Regular diving for a long period can result into changes of lung function as was demonstrated in populations of compressed air or saturation divers. About oxygen divers few articles have been written regarding this long-term effect. Especially changes in diffusing capacity for carbon monoxide (DLco) as a long-term effect due to oxygen diving have scarcely been pub-lished. This has raised the question why this parameter is often mentioned as a more sensitive indicator for pulmonary oxygen toxicity than solely spirometry. Aim of this study was to investigate variations in spirometry and diffusing capacity after 5 years of diving as a military oxygen diver.

**Methods:** For this retrospective study we followed a cohort of 47 healthy, military oxygen divers (at baseline: 31.8 ± 6.9 yrs, 184.2 ± 6.4 cm, 85.11 ± 7.37 kg, 5.9 ± 5.2 pack years) who visited our centre for their annual assessments. We measured spirometry (forced expiratory lung volumes and force expiratory flows) and diffusing capacity at baseline and after a follow up period of 5 years. Spirometry and diffusing capacity were measured using the Vmax Encore (Cardinal Health, Houten, the Netherlands) according to the ATS/ERS guidelines.

**Results:** At baseline both spirometry and diffusing capacity were within normal limits. After 5 years we found a statistical significant increase of VC, FEV1, PEF, FEF25, DLco, Va and Kco. At the same time there was a significant decrease of the Tiffeneau index. However, all these values stayed within normal limits. See table 1.

**Conclusion:** In contrast to earlier publications, diffusing capacity in our population increased after 5 years of oxygen diving. However, as both spirometry and diffusing capacity values stayed within normal limits, five years of oxygen diving under our operational procedures did not lead to negative long-term health effects and is therefore safe.

**Keywords:** long-term health effect, diffusing capacity, spirometry, oxygen diving

**Table 1: spirometry and diffusing capacity before and after 5 years of oxygen diving.**

| | Pre (% of Ref ± SD) | Post (% of Ref ± SD) |
|---|---|---|
| VC | 108 (10) | 119 (12)* |
| FEV1 | 106 (10) | 113 (11)* |
| FEV1/SVC | 78 (6) | 75 (5)* |
| PEF | 108 (16) | 118 (16)* |
| FEF25 | 101 (22) | 107 (22)* |
| FEF50 | 88 (21) | 93 (21) |
| FEF75 | 77 (23) | 73 (18) |
| DLco | 99 (12) | 105 (15)* |
| Kco (Dlco/Va) | 83 (18) | 100 (16)* |
| Va | 99 (11) | 106 (11)* |

*N=47. *= P< 0.05*

**WITHDRAWN**

PP-19

# MRI IN SPINAL CORD DECOMPRESSION ILLNESS. A CASE REPORT

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**Aims:** To present a case report and neuroimaging of a patient with spinal decompression and commitment.

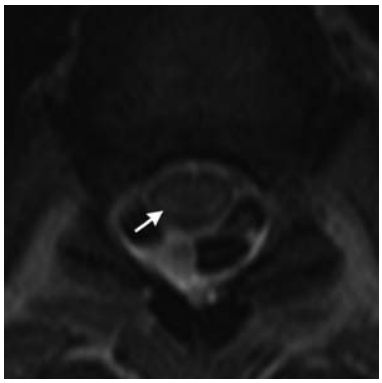
**Methods: Case:** A 42 year old healthy male, with 20 years diving expertise, who presented dysbaric accident after diving to 35 meters for about three hours, showing marked tetraparesis after emerging. He received emergency hyperbaric treatment (Table 6 USN) plus two extensions to 18 meters. Lidocaine infusion was administered for three days and standard hyperbaric oxygen therapy sessions (HBO). Initial neurological assessments showed tetraparesis, with upper limbs M4+ and lower limbs M4-, but neither clear sensory cervical level or proprioceptive defect. Neuropathic pain began in the dorsal region and lower extremities, and carbamazepine was prescribed. Two months later and 40 sessions of hyperbaric oxygen therapy (HBO), brachial paresis was completely recovered, but paraparesis and dorsal sensory level still remains. Because persistence of neuropathic spinal pain at 6 months, a full spinal Magnetic resonance imaging (MRI) at 1.5T was performed.

**Results:** MRI showed diffuse hyperintense lesions appeared at ventral and lateral cords of dorsal spinal cord, between the levels D1 and D7, without swelling or reinforcement after gadolinium injection. Those findings were compatible with a diagnosis of spinal cord decompression sickness with arterial infarction pattern. There were no cervical spinal cord injuries or posterior cord lesions.

**Conclusions:** decompression sickness with spinal neurological involvement may occur after sudden ascents from deep dives. We report a patient with severe myelopathy and quadriparesis, which improved after 40 sessions of hyperbaric therapy and 4 months, recovering self-care but with neuropathic pain. Spinal cord MRI showed ventral and lateral white matter lesions at dorsal levels, consistent with clinical findings and literature reports of spinal decompression sickness. Clinical diagnosis (dorsal spinal cord decompression illnees of arterial pattern) was confirmed by MRI findings.

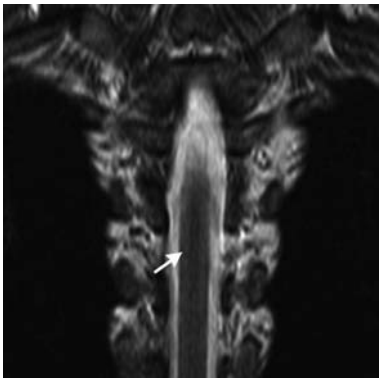
**Keywords:** MRI, spinal cord, decompression illness. ventro-lateral cords of spinal cord. Neurophatic pain.

**MRI in spinal cord decompression illness.**



*MRI 6 months after the accident. Axial T2-weighted spin-echo image at dorsal level. Diffuse high-signal lesion of the ventral and lateral cords (arrow), consistents with spinal decompression sickness.*

**MRI in spinal cord decompression illness. Sagital view.**



*Diffuse high-signal lesion of the ventral and lateral cords (arrow), consistents with spinal decompression sickness*

PP-20

## HEALTH STATUS OF DAN MEMBERS

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**Aims:** The population of recreational divers in the USA is aging. Health status and how it may affect diving activity is not known. The purpose of this study was to establish the prevalence of selected chronic conditions and risk factors among DAN members, and their access to health care and use of preventive health care services.

**Methods:** The DAN Membership Health Survey was composed of the Behavioral Risk Factor Surveillance System questionnaire and Dive Survey 2000. Access to the questionnaire web page was sent by email to 3500 DAN members selected blindly from the membership list. The survey was completely anonymous and there was no way of tracking answers back to respondents. The health conditions, risk factors and use of health care preventive services for DAN members were compared with the general US population.

**Results:** Twenty-five percent of solicited members completed the survey. Sixty-four percent of respondents were older than 44 years versus 52 percent of the US population. More DAN members had college educations (70.6% vs. 33.5%) and higher incomes than the US average.

The health status of DAN members appears better than US population norms. The prevalence of cardiovascular diseases (history of myocardial infarction 1.6% vs. 3.6%; CHD 3.5% vs. 7.6%), diabetes (4% vs. 8%), asthma (3% vs. 8%), disability (11% vs. 18%), smoking (14% vs. 18%) and insufficient physical activity (45% vs. 49%) was less in DAN members. Hypertension (29% vs. 29%) and overweight (BMI >=25, 67% vs. 63%) were similar in both populations. Use of preventive healthcare services was more common amongst DAN members.

**Conclusions:** DAN members are older, healthier and wealthier than the general population. The load of risk factors appears similar to the general population but more DAN members have access to healthcare and use preventive services.

PP-21

# THE PSYCHOLOGICAL IMPACT OF ACCIDENTS ON RECREATIONAL DIVERS

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The aim of this study was to assess the frequency, intensity and duration of post- trauma symptoms in victims of recreational diving accidents. A prospective cohort study was carried out in divers presenting to the Orkney Hyperbaric Unit after recreational diving accidents. Pre-morbid psychological functioning was assessed using the General Health Questionnaire (GHQ12), trauma symptoms were measured using the Revised Impact of Events Scale (ES-R). Responses were compared with two naturalistic control groups, the buddy partner of each victim and an uninvolved diver from the same diveboat, There were no premorbid differences between groups but victims showed more trauma symptoms, more intensely and for longer than controls. The conclusion was that some diving accidents have a significant and prolonged psychological impact on victims with potential relevance to future diver safety, diver training and health care.

**Keywords:** Recreational diving accidents. Psychological impact.

PP-22

# ATYPISM OF DECOMPRESSION IN A HYPERBARIC CHAMBER

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**Aims:** To find the optimal decompression after a simulated descent to 80 meters in a hyperbaric chamber without air conditioning.

**Methods:** 15 descents into the 80 m/10 min were performed with 71 sport divers (including 10 women). The average age of participants was 38 years (SD 12). Air-filled cylindrical chamber of 10 cubic meters was used. Breathing of oxygen from mask (from 18 m) was used during decompression. At first, decompression profile was performed according to the U.S. Navy Tables. Later on it was gradually changed in order to reduce the saturation of nitrogen due to the occurrence of mild decompression sickness.

**Results:** Lymphatic form of decompression sickness was developed in three persons, cutis marmorata in three persons and symptoms of pruritus or rush were very frequent at the end of the dive.
Recompression treatment was performed in three cases, others breathed normobaric oxygen. Decompression problems led to a shift of the first decompression stop from 15 m to 39 m and an extension of the stay at lower depths with oxygen from 46 min to 56 min. The optimized decompression profile was developed and is free of decompression problems. The decompression sickness was probably caused by large temperature differences in comparison with the real dive. Air inside the chamber was heated to about 45° C during a rapid descent, whereas it was rapidly cooled to about 20° C during the ascent. These changes probably notably affect blood circulation in skin - vasodilatation and vasoconstriction.

**Conclusions:** Thermal influences in hyperbaric chamber are contributing to higher nitrogen saturation of the skin during the descent and stay at the depth and vice versa to lower desaturation during the ascent. Simulated dives in hyperbaric chambers to higher depths should be realized according to the optimized procedure.

**Keywords:** Hyperbaric chamber, simulated dive, decompression sickness, air temperature

PP-23

# OXYGEN PARTIAL PRESSURES IN CLOSED-CIRCUIT OXYGEN DIVING

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**Background:** A growing number of amateur and professional divers prefer closed circuit oxygen rebreathing systems (oCCR). Beside the advantages of an oCCR this diving technique bears on one hand the risk of an oxygen seizure, particular when the pO2 exceeds 1,6bar (NOAA-guideline). On the other hand there might be a risk of hypoxia due to a high pN2 inside the breathing bag, if the purging procedures are not sufficient with N2 still inside the dead space of the device or washed out of the tissues during diving.
It was the aim of the study to measure the pO2 inside the device and the correlation between pO2 and the different purging procedures given by the manufacturers in an oCCR under operational open-water conditions.

**Method:** 24 dives were conducted with an LAR V (Dräger, Germany) with a minimum dive time of 60 min. between 4-7m depths, 14 dives according to the German Navy purging procedures (group a), 10 dives with only one purging procedure before descent (group b).
The pO2 in the breathing bag was continuously measured (every 4sec.) with an oxygen sensor (Analytical industries, USA), attached to the device via p-connector (VR3 diving computer).

**Results:** In group (a) pO2 never exceeded 1.5bar, resulting in a mean O2-concentration of 81.0±9.7% and a calculated depth of 9.65m to reach 1.6bar pO2.
In group (b) maximum pO2 reached 1.4bar, mean O2-concentration was 75.33±5.38%. The calculated depth to reach 1.6bar pO2 was 9.95m.
In no dive any critical low pO2-values were observed.

**Conclusion:** Inside the given diving limits (4-7m depth) and with both tested purging procedures no critical hyperoxic or hypoxic pO2-values were observed, the O2-concentrations lay considerably below 100%, and pO2 never exceeded the NOAA value of 1.6bar.
The results may help to contribute to the definition of safety limits for oCCR-diving in future.

**Keywords:** oxygen, rebreather, partial pressure

PP-24

# POST-TRAINING EAR INJURIES AMONG WESTERN AUSTRALIAN RECREATIONAL DIVERS

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**Aims:** To measure the prevalence of self-reported ear trauma among certified recreational divers in Western Australia (WA) and to identify potential risk factors for future investigation.

**Methods:** Dive centres in WA posted a four-page questionnaire to 1,974 entry-level scuba course graduates. Participants (n=499, 25%) returned questionnaires anonymously in reply-paid envelopes. Of 499 responses, 396 (79%) had dived during the previous year and had complete data for number of lifetime dives, time since initial certification, deepest dive during the previous year, maximum number of ascents to the surface in one day, decongestion medication use and ear injury history during the previous year. Variables were fitted to a logistic regression model and non-significant variables ($p>0.05$) were eliminated by backwards elimination.

**Results:** Males (n=298, 75%) were a mean age of 31.7 years and females (n=95, 25%) a mean of 29.7 years. Median time since certification was 1.2 years (range 0.0-38.8 years). Mean maximum depth reached during the previous year was 23.1m (SD 8.8m, range 2-62m). Thirty-eight divers (10%) reported an ear injury within the previous year. Twenty-five divers reported taking decongestant medication within one hour of diving. Fitting the variables to a logistic regression model, the main risk factors for suffering ear trauma were maximum depth reached during the previous year (OR per 5m 1.24, 95% CI 1.03, 1.50, p=0.022) and taking decongestant medication within one hour of diving (OR 4.48, 95% CI 1.68, 12.05, p=0.001).

**Conclusions:** The relationship between maximum depth reached and decongestant use requires further investigation. The finding that decongestant use was significantly associated with ear trauma was converse to previous published findings.

**Keywords:** Decongestant, ear injury, survey, recreational diving

PP-25

# FRENCH OXYGEN DECOMPRESSION TABLES MAY PREVENT DYSBARIC OSTEONECROSIS IN COMPRESSED AIR TUNNELLING BELOW 3.45BAR

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Dysbaric osteonecrosis (DON) comprises necrotic lesions in the fatty marrow-containing shafts of the long bones as well as the ball and socket joints. The fundamental causes are still in question and the illness remains a significant health hazard. The technique of breathing pure oxygen as French Oxygen Decompression Tables has been applied in two compressed air tunnelling projects in Hong Kong during the past few years. As results, two groups of compressed air workers had undergone at least two sets of medical examination with full long bone X-ray examinations. Ninety-seven (n=97) and seventy-six (n=76) of these workers been followed over five to seven years respectively. The author do not found any cases of dysbaric osteonecrosis during this follow-up period. Such a finding may suggest that French Oxygen Decompression Table not only reduce bubbles load and decompression illness, it may also prevent disabling dysbaric osteonecrosis especially when compressed air tunnelling using Tunnel Boring Machine (TBM) with shorter compressed air exposure and swallow working depth within 3.45bar.

**Keywords:** French Oxygen Decompression Table, Dysbaric osteonecrosis,

PP-26

# APNEA DIVE COMPUTER

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**Aims:** Development of a wrist-worn apnea dive computer, which measures SO2, heart rate, plethysmogram, depth and water temperature.

**Introduction:** Up to now only few data is available about SO2 during apnea dives. These data derive from laboratory experiments. No data are available from field studies, as no instruments are available. To fill this gap, an apnea dive computer was developed.

**Methods:** The device consists of a microprocessor, a temperature / pressure sensor and a matrix display. SO2, plethysmogram and heart rate is provided by a reflective pulseoximeter probe. The pletysmogram is sampled with a frequency of 75Hz. All data are stored on an internal memory. The computer was validated against a transmissive pulsoximeter [ChipOx, Weinmann Medical Technology] in dry conditions and in warm shallow water to avoid vasoconstriction. All test dives were approved by the local ethical committee.

**Results:** A first prototype was build up and successfully tested. The unit was evaluated during static and dynamic apnea dives. The athletes SO2 dropped to values as low as 55%. During dynamic apnea (pool distance diving with fins) an accident occurred, where one volunteer lost consciousness. The analysis of the recorded data shows a massive drop of SO2 (from 98% to 45% SO2) 30s - 90s after the start of the dive until the blackout occurred. The heart rate dropped from 110 down to 70 beats per minute.

**Conclusion:** A prototype of a wrist-worn apnea dive computer was developed. During several test dives SO2, plethysmogram and heart beat data were successfully recorded. We envisage that this computer might be an interesting tool for further physiological investigations of apnea divers for training.

**Keywords:** diving, breathhold diving, transcutaneous oximetry, hypoxia, diving research, physiology

**Prototype**

*The prototype wrist mounted apnea diving computer*

PP-27

# POSTURAL STABILITY MEASUREMENTS AS AN INDICATOR OF CO-INTOXICATION AND DECOMPRESSION INJURY

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**Aims:** The neurological status of patients with carbon monoxide intoxication or decompression injuries may be time consuming and difficult to reproduce through the series of hyperbaric sessions. Therefore we introduced the clinical use of a measurement of postural stability, - a Quantitative Romberg's test..

**Methods:** During the test the person is standing on a horizontal platform, a force plate CATSYS 2000 ( Danish Product Development, Denmark). The size is approximately 30 x 50 cm. In each corner is situated a force transducer measuring the vertical load. By vectorial addition of the output from each transducer the center of pressure is fund throughout the test. The patients are asked to stand for 60 seconds on the platform. Firstly the patient is tested with her og his eyes open, - then a short interlude and the test is made again, this time with closed eyes. The patients are not supposed to talk. A helper is ready to catch the patient, if the patient tends to fall. The set of test is performed before and after each HBO-session if possible. The reading is the vectorial mean value during each test. The lack of influence on the test by HBO is given previously (1).

**Results:** The readings may be up to 6 times the normal value in case of CO-intoxication or diving accidents. The improvement of the postural stability serve as a guide in the therapy..

**Conclusions:** The test for postural stability or the quantitative Romberg's test is simple to use and serves as a guideline in the treatment of patients with neurological symptoms related to the standing position.

**Ref:**

1. Tvede MF, Jansen T, Jansen EC: Postural stability before and after hyperbaric oxygen treatment. Acta Neurol Scand. 2005 Dec;112(6):414-6.

**Keywords:** carbon monoxide intoxication, decompression injury, postural stability, Romberg's test, hyperbaric oxygen treatment

PP-28

# TWO YEAR RESULTS OF EVALUATION COMMITTEE FOR THE NEED FOR HYPERBARIC OXYGEN THERAPY

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**Aims:** The purpose of this study is to present the two year results of evaluation committee constituted in our department for the need for hyperbaric oxygen therapy (HBOT).

**Methods:** HBOT is the medical use of 100% oxygen at a level higher than atmospheric pressure. Our hyperbaric chamber's maximum pressure capacity is 6 ATA (165 feet, 50 m below sea level) and maximum patient capacity is 2 patients lying or 4 patients sitting position. Our main purpose is to provide emergency treatment for the flying personnel with decompression sickness that may occur during the hypobaric chamber training or real flight. We also provide treatment for the patients with the approved indications by The Ministry of Health of Turkey. We have constituted an evaluation committee for the need for HBOT in our department in April 2008 to evaluate the patients in a multidisciplinary approach. There are six specialists in this committee; aerospace medicine specialist, orthopedist, plastic surgeon, dermatologist, infectious diseases specialist, and internal medicine specialist. Medical records of patients applied to the committee from April 2008 to June 2010 for the treatment were evaluated.

**Results:** Committee held 63 meetings in 2 years. There were 190 patients evaluated in the committee. 101 patients were decided to take HBOT, but 80 of them came to take HBOT, the other did not come. It was seen that number of patients who took the HBOT were decreased (n: 232 in 2007, n: 156 in 2008, n: 121 in 2009) after the constitution of the committee.

**Conclusion:** The patients who need HBOT especially for the problem wounds require a multidisciplinary approach, because the treatment and rehabilitation concern many specialists and require a long treatment period. We recommend to determine the patients who actually in need of HBOT by a committee, which is very important for multidisciplinary approach.

**Keywords:** Hyperbaric Oxygen Therapy, Evaluation Committee

PP-29

## 18 YEARS EXPERIENCE OF HYPERBARIC OXYGEN THERAPY

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**Aim:** The purpose of this study is to demonstrate the types and prevalence of indications of hyperbaric oxygen therapy (HBOT) carried out in our department.

**Methods:** HBOT is the medical use of 100% oxygen at a level higher than atmospheric pressure. Our hyperbaric chamber's maximum pressure capacity is 6 ATA (165 feet, 50 m below sea level) and maximum patient capacity is 2 patients lying or 4 patients sitting position. We provide treatment for the patients with the approved indications by The Ministry of Health of Turkey. Medical records of patients who were treated in our chamber between the years 1992-2009 were evaluated.

**Results:** In 18 years period (1992–2009), there were 1388 patients treated with HBOT. During this period, patients with carbon monoxide poisoning (n: 496, 35.73%), diabetic foot wounds (n: 249, 17.93%), chronic osteomyelitis (n: 213, 15.34%), peripheral vascular diseases (n: 137, 9.87%), necrotizing soft tissue infections (n: 95, 6.84%), crush injuries (n: 40, 2.88%), sudden hearing loss (n: 56, 4.03%), and other diseases (n: 102, 7.34%) treated in hyperbaric chamber. It was observed that carbon monoxide poisoning is the most common indication treated with HBOT. The number of patients increased clearly between 2003 and 2008. In April 2008, we have constituted an evaluation committee for the need for HBOT in our department in order to evaluate the patients in a multidisciplinary approach. After this date, it was seen that number of patients who took the HBOT were decreased (n: 232 in 2007, n: 156 in 2008, n: 121 in 2009).

**Conclusion:** Our main purpose is to provide emergency treatment for the flying personnel with decompression sickness that may occur during the hypobaric chamber training or real flight. However we also provide HBOT for the patients from a large area, thus serving and supporting public health.

**Keywords:** Hyperbaric Oxygen Therapy

PP-30

# HYPERBARIC OXYGEN FOR TREATMENT OF PERIPHERAL ARTERIAL DISEASE ''BUERGER, RAYNOUD'S SYNDROME ETC'': RESULTS OF THREE CASES

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**Purpose:** To report three cases of digital ischemia where diffusion of oxygen and perfusion in hands improved after hyperbaric oxygen (HBO) therapy.

**Methods:** Three patients complained of pain and ischemic digital ulcerations in distal parts of fingers of their hands. Evaluation of the subclavian, axillary, brachial, radial and ulnar arteries showed no abnormality. The patients received medical drugs for treatment of peripheral arterial disease and HBO therapy. The patients underwent courses of 30 or 40 HBO sessions at 2.4 ATA for 90 min %100 oxygen in multiplace chamber.

**Results:** HBOT arrested progression of complaints and patients experienced some improvement in their symptoms.

**Conclusion:** HBO therapy improves vascular perfusion in patients with limb ischemia. When vascular reconstruction is impossible, the induced neovascularity with HBOT may provide relief for patient with small and diffuse artery disease. Combined use of medical treatment and hyperbaric oxygen therapy may be safe and effective for ischemic limb patologies such as Buerger's disease and Raynaud's syndrome in order to increase limb salvage.

**Keywords:** Buerger's disease, hyperbaric oxygen treatment, peripheral arterial disease

PP-31

# TREATING POSTOPERATIVE WOUND INFECTION AFTER ABDOMINAL SURGERY WITH HYPERBARIC OXYGEN THERAPY

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Postoperative wound infection is a major problem in the operative area and it may make any illness more severe which can be resulted in a poor outcome. Without appropriate treatment, there is a substantial risk of the tissue destruction, spreading infection systemically, and possibly high risk of mortality. A study of three patients with postoperative wound infection and the use of HBOT to improve wound healing is presented. Our patients were admitted with complication of wound healing following abdominal surgery. They have associated complications, such as wound dehiscence, incisional hernias, abscesses. All patients were given antimicrobial agents according to their antibiograms. Incisions of wounds were opened for drainage and wound dressing. Only one of patients received vacuum-assisted closure treatment in addition to HBOT. These 3 patients eventually received hyperbaric oxygen treatment for a total of 20, 25, 50 days. Following HBOT, the condition of the surgical wound improved dramatically.

A setback in recovery such as ischemic heart disease, diabetis mellitus, Behçet disease decreased oxygen diffusion to the tissues and allowed the infection to arise. The combination of HBOT with effective infection control, wound care and VAC accelerates the wound healing. The results of these patients showed that HBOT has the potential to be a cost-effective way to enhance the wound healing and it decreases mortality in patients with Diabetes mellitus, Behçet disease and ischemic heart disease.

**Keywords:** Hyperbaric oxygen, wound healing, postoperative infection

PP-32

# EFFICACY OF EARLY HYPERBARIC OXYGEN THERAPY IN ACUTE ACOUSTIC TRAUMA AFTER GUNSHOT NOISE

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**Background:** Acute acoustic trauma (AAT) is relatively common after exposure to intense gunfire noise. Gunshot impulses consist of a combination of energies from acoustic and pressure waves at high intensities, resulting in rupture of the organ of Corti, its separation from the basilar membrane and fracture and displacement of hair cell stereocilia. Hyperbaric oxygen therapy (HBOT) may improve hearing loss and/or reduce the intensity of tinnitus.

**Patients and Methods:** This randomized study consisted of 52 young male soldiers, aged between 18 and 28 years (mean 22.74 years, SD 2,87 years) suffering from AAT after gunshot noise. According to the time of onset of treatment with HBOT, the patients were divided into three groups: (1) group A (20 patients) in which the treatment began within the first 2 days after the AAT, (2) group B (17 patients) in which the treatment started in more than third day and less than 7 days after the AAT and (3) group C (15 patients) in which the treatment began after a week. The treatment consisted of HBOT and steroid (methylprednisolone amp 40 mg IV, three times/day and then decreased over ten days). Each HBOT session consisted of 100% oxygen inhalation at 2.5 absolute atmospheres (ATA) pressure (10-15 minutes compression on air, 70 minutes of oxygen breathing, 10 minutes of decompression on air) once a day for ten consecutive days.

**Results:** One month after the treatment onset, 36 (69%) patients of all the groups showed hearing improvement (complete-partial recovery) in the pure tone audiometry. The greater number of patients who showed complete recovery after AAT was noted in group A (65%) compared to group B (23.5%) and C (13.3%).

**Conclusion:** The immediate onset of treatment with HBOT after an AAT may lead to better recovery than if started 2 days after the acoustic traumatic event.

**Keywords:** hyprbaric oxygen, acoustic trauma, gunshot noise

PP-33

# HYPERBARIC OXYGEN THERAPY IN SENSORINEURAL SUDDEN HEARING LOSS CASES UNRESPONSIVE TO MEDICAL TREATMENT

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**Aims:** Evaluation of the efficacy of adjunctive hyperbaric oxygen therapy (HBOT) in the treatment of sensorineural sudden hearing loss (SSHL) unresponsive to medical treatment.

**Methods:** This retrospective study included 46 cases medically treated for SSHL, with no or minor hearing gain, and referred to the hyperbaric center for adjuctive HBOT. Only the cases that HBOT was initiated within two months of the diagnosis of SSHL were included in the study. Demographic data, patterns of hearing loss, accompanying symptoms and the time between diagnosis and initiation of HBOT were designed as the variants to be compared. All patients received 20 sessions of HBOT in a multiplace chamber twice daily at 2.5 ATA for 90 minutes. Odiometric examinations were made before and after the 10th and 20th sessions of HBOT.

**Results:** The mean age of the patients (26 male, 20 female) was 41.9±14.3. All patients previously received medical treatment, mainly steroids and vasoactive drugs. The mean time spent between diagnosis and the initiation of HBOT was 13.5±14.8 days. No significant difference was noted in hearing gain regarding various variables of age, gender, and the initiation time of HBOT. 17 patients complained from vertigo. Hearing gain was signicantly less in these patients at 4096 frequency (p=0.037). Regarding the hearing gain there were no significant difference among the SSHL patterns, except the two patients with “cookie bite” pattern, which hearing gain was better comparing to the other patterns. All frequency levels revealed significant recovery with the addition of HBOT to the preinitiated medical treatment protocols (p= 0.0001).

**Conclusion:** We suggest, within the limitations of this retrospective study, that HBOT should be considered in the treatment of sensorineural sudden hearing loss as an adjunctive therapy.

**Keywords:** Hyperbaric oxygen therapy, sudden hearing loss, sensorineural hearing loss

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# HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF ACUTE SEVERE CHEMICAL INJURY OF THE CORNEA AND THE CONJUNCTIVA

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**Purpose:** To present the effectiveness of hyperbaric oxygen therapy (HBO) in the treatment of severe chemical corneal injury, and in the prevention of its long-term complications in the cornea and the external ocular surfaces.

**Material-Methods:** Twenty-nine eyes of 23 patients presented to our hospital within 2 days after severe chemical injury were included in the study. Patients were underwent to HBO therapy ( 2.4 ATA, %100 oxygen saturation, 1 hour exposure time) for 14 days after presentation to the hospital. Doxycycline, 20mg/day for 14 days, and prednisolone, 1 mg/kg/day in tapering doses for 21 days, were co-administered. Structural and functional integrity of the ocular surface were evaluated by serial photographs in the early period and, and clinical and laboratory testing in the late period.

**Results:** Mean follow up was 19±7.9 months (range 7 to 30 months). Re-epithelization is completed within 3 weeks of the therapy in 28 eyes (96.5%). HBO therapy was stopped in a case complicating severe wide scleral necrosis in the inferior fornix to allow neovascular membrane formation to close wounds. One eye developed small neovascular membrane in the inferior fornix. No structural and functional abnormalities including recurrent corneal erosions, dry eye, or symblapharon formation were noted in 27 eyes.

**Conclusions:** With these outstanding results, use of HBO with doxcycline and prednisolone together seems to be a novel and promising treatment option in the cases with acute severe chemical injury.

**Keywords:** Hyperbaric oxygen therapy, acute corneal chemical burns, corneal and limbal neovascularization

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# HYPERBARIC OXYGEN THERAPY FOR CORNEAL NEOVASCULARIZATION SECONDARY TO HERPES SIMPLEX KERATITIS: A CASE REPORT

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**Aims:** Cornea is normally an avascular tissue and corneal neovascularization reduces visual acuity by disturbing corneal transparency. Local oxygen therapy is used in the treatment of corneal neovascularization. Herein, we described a patient who had developed corneal neovascularization secondary to herpes simplex keratitis and recovered successfully with hyperbaric oxygen therapy.

**Methods:** A 20 years old male patient admitted to ophthalmology department for blurred vision on his left eye. Ophthalmologic examination revealed deep and superficial corneal neovascularization and central corneal ulcer. He was previously diagnosed as disciform herpes simplex keratitis. Visual acuity was 20/400 in the affected eye. Topical steroid therapy was not considered due to the risk of side effects. Hyperbaric oxygen therapy was started after getting informed consent from the patient. Patient was examined daily and corneal photographs were taken as needed.

**Results:** Central corneal neovascularization increased but peripheral neovascularization and corneal ulcer regressed in the first week of hyperbaric treatment. In the second week, both corneal neovascularisation and ulcer regressed markedly. The patient received a total of 20 hyperbaric treatments in four weeks. Patient's visual acuity improved to 20/40. No adverse event related to hyperbaric oxygen therapy was observed.

**Conclusions:** This report suggests that hyperbaric oxygen therapy may be used in the treatment of corneal neovascularization in selected patients.

**Keywords:** hyperbaric oxygenation, HBO, eye

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# FOURNIER'S GANGRENE: A RETROSPECTIVE ANALYSIS OF 21 CASES TREATED WITH HYPERBARIC OXYGEN

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**Introduction:** Fournier's gangrene (FG), is a highly mortal disease characterized by aerobe and anaerobe polymicrobial infectious presentation which is necrotizing in nature and beginning to appear in genital or perianal region and moving aggressively up to abdominal wall. Although it is rarely seen, high mortality rate is the most frightening part of this disease. Early diagnosis, sufficient debridement, appropriate antibiotherapy, correction of predisposing factors, appropriate care, nutrition and Hyperbaric Oxygen (HBO) are recommended for treatment.

**Method:** In our study, 21 patients diagnosed with FG and who were begun to treat appealing from various hospitals between April 2003 and May 2010 were analyzed retrospectively.

In our clinic, HBO treatment as 2 sessions a day in the first 2 or 3 days and once a day in subsequent days as 150 minutes/ session under 2,5 ATA is applied to the patients. Daily dressings are done twice a day as wet dressings.

**Discussion:** Mortality rate is 4,76 % in our study which is not having a control group. The case that died was after one session of HBO therapy. Reasons of low mortality rate include both early medical and surgical intervention and HBO treatment, and well control of predisposing factors such as DM. The decrease of this rate can be possible by a multidisciplinary approach.

**Conclusion:** Factors enabling low mortality rates of our cases with Fournier's gangrene we detected in our clinic unlike many reports include early diagnosis of the disease, taking chronical diseases under control urgently, application of wide-spectrum antibiotherapy, performing debridement just in time and in sufficient manner, providing nutrition support, addition of HBO therapy into the treatment, easily-reachable HBO therapy centers and multidisciplinary approach.

**Keywords:** Fournier's Gangrene, Hyperbaric Oxygen Treatment, Necrotizing Fasciitis

**Picture 1: Before HBO Treatment**

**Picture 2: 12th session**

**Picture 3: 19th session**

**Picture 4: 23rd session (last picture)**

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# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF VENOUS STASIS ULCERS IN TURKEY

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**Aims:** Venous stasis ulcers (VSU) frequently fail to heal and lead chronic wounds. Hyperbaric oxygen therapy (HBOT) is used in the treatment of chronic wounds. HBOT is used in Turkey for more than 20 years and Social Security Organization of Turkey covers HBOT in certain indications including VSU. This study aimed to review the patients with VSU who treated with HBOT in Turkey.

**Methods:** All HBOT centers in Turkey were invited to participate in this study. Participating centers were required to fill an online form for each patient to collect data regarding; patient characteristics, wound characteristics, treatments and outcome. Fourteen HBOT centers agreed to participate in this study.

**Results:** A total of 165 patients (126 male and 40 female) were included. The mean age of patients was 48.77 ± 16.55. In the etiology, 7 patients had trauma, 15 had deep vein, 20 patients had a long-term standing. The wound size was 0 to 5 cm in 44 patients, 5 to 10 cm in 32 patients, and larger than 10 cm in 26 patients. There was no record the other patients wound size and etiology. Doppler ultrasonography revealed venous occlusion in 16 patients and regurgitation in 52 patients. Before HBOT, 21 patients had surgery, 35 patients had used varicose bandage, 4 had used inelastic bandage, 17 had used multi-layer bandage. During the HBOT 85 patients had used compression with different type of bandage. 117 had used vasodilators and synthetic veno-active drugs. The average number of HBOT sessions was 37.27±18.11 treatments. Seventy-nine (47.8%) patients were completely healed, 68 (41.2%) were partially healed and 18 (11%) patients did not heal.

**Conclusions:** The addition of HBOT to standard treatment may increase the rate of healing in patients with VSU. However, randomized controlled studies are needed on this issue.

**Keywords:** Venous stasis ulsers, hyperbaric oxygen therapy

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# A MULTICENTER RETROSPECTIVE STUDY: USE OF HYPERBARIC OXYGEN THERAPY FOR SUDDEN HEARING LOSS IN TURKEY

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**Aims:** Sudden hearing loss (SHL) is common and effect the quality of life. Hyperbaric oxygen therapy (HBOT) is suggested in recovering hearing loss. HBOT is widely used in SHL cases in Turkey and the Social Health Organization covers the cost. This study aimed to review the SHL patients treated with adjunctive HBOT in Turkey.

**Methods:** An online questionnaire including patient characteristics, causative factors, clinical history, symptoms and findings, medical and HBOT details, and outcomes were sent to all HBOT centers in Turkey. 15 of the 21 HBOT centers replied accordingly and submitted data.

**Results:** Data from 1027 ears (536 male, 491 female) were analyzed. 81 patients had bilateral hearing loss. Mean age was 43.9. Hearing loss patterns were mostly flat type (32.1%), followed by descending (31.0%) and ascending (20.1%) types. There were 36 cookie bite (Figure 1). There was a history of previous upper respiratory system infection in 191 cases, and vascular pathology in 119. 11 cases were presented with autoimmune disease, and 579 were classified as idiopathic SHL (Figure 2). There were no data for cosymptoms in 298 cases. For the rest, tinnitus and vertigo were the main cosymptoms, in 592 and 220 cases respectively. These two symptoms were present together in 138 patients. 27 cases presented instability, and 2 nistagmus (Figure 3). Medical treatment started in the first 24 hours of the diagnosis of SHL in 338 cases, in the first 48 hours in 432, and in the first week in 796 (Figure 4). The main medication was combination of steroids, vasoactive agents and vitamins. Vasoactive agents were used in 465 cases, steroids in 589. The duration between the diagnosis of SHL and the start of HBOT was absent in 51 cases. 303 cases received HBOT within the first 48 hours, and 570 within the first week of diagnosis (Figure 5). In 171, medication and HBOT were started on the same day. 89 cases were treated in a monoplace chamber at 2.0 ATA for one hour, and the rest in a multiplace chamber at 2.4 ATA for 120 minutes (Figure 6). Numbers of daily sessions were absent in 27 cases. 582 cases were treated once a day, in 419 HBOT started as twice a day and followed once a day (Figure 7). The mean value of total number of treatments was 14.0 (range 1-60). Most of the cases (670) received less than 20 sessions of HBOT. In 178 ears HBOT was extended beyond 20 sessions. Audiometric evaluations were done before the start of HBOT, and frequently after the 10th and 20th sessions. Due to absence of data or poor reporting only 656 cases were included in evaluation of hearing gain. There were no benefits in 131 ears (19.9%). 15.1% of the cases improved 5-10 dB, a gain of 21-40 dB was observed in 21.3%, and above 40 dB in 18.6%. 19.5% of reported subjects showed a moderate improvement of 11-20 dB (Figure 8).

**Conclusion:** According to the data provided we suggest that addition of HBOT to conventional therapies improves the outcome of SHL. It is advisable to apply HBOT as early as possible following the diagnosis of SHL.

**Keywords:** Hearing loss, idiopathic sudden hearing loss, sensorineural hearing loss, tinnitus

PP-39

# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF AVASCULAR NECROSIS OF FEMORAL HEAD IN TURKEY

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**Aims:** Avascular necrosis of femoral head (ANFH) is an important cause of disability in young and active people. Hyperbaric oxygen therapy (HBOT) is suggested to reduce bone marrow edema and increase bone formation in avascular necrosis. HBOT is used in Turkey for more than 20 years and Social Security Organization of Turkey covers HBOT in certain indications. ANFH, however, is not among these covered indications. This study aimed to review the ANFH patients treated with HBOT in Turkey.

**Methods:** An online questionnaire including patient characteristics, history, treatment details and outcome was sent to HBOT centers in Turkey. Nine of the 21 HBOT centers (42%) replied accordingly and submitted their patient data. Data were analyzed in SPSS 11.0 for windows.

**Results:** Data from 37 patients (24 male and 13 female) were analyzed. Mean age of the patients were 37,1 ± 11,4 years (range: 17-68 years). Twenty-three patients (62%) had unilateral lesion and 14 patients (35%) had lesions involving both hips. HBOT started in the first 3 months after the diagnosis of ANFH in 23 (64%) patients. Forty-two (87%) of 51 lesions were in Steinberg 1-2 stages. Mean number of HBOT sessions were 40 ± 21 (range: 7-92). Seven patients (19%) received surgery including drilling, core decompression, and bone grafting. Clinical improvement was observed in 27 patients (75%). No improvement was observed in 6 patients (16%). Three patients (9%) eventually required total hip replacement surgery.

**Conclusions:** Since ANFB is not covered by Social Security Organization of Turkey, the number of patients receiving HBOT for ANFB was limited. Our results suggest that patients with early stage ANFB may benefit from HBOT. A randomized controlled trial is needed to better evaluate the role of HBOT (if any) in the treatment of ANFB.

**Keywords:** aseptic bone necrosis, hyperbaric oxygenation, case series

PP-40

# THE USE OF ELECTROENCEPHALOGRAPHIC (EEG) MONITORING OF ANAESTHETIZED, INTENSIVE CARE PATIENTS DURING HYPERBARIC OXYGEN TREATMENT (HBO)

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**Aims:** HBO is used in the treatment of necrotising soft tissue infections and carbon monoxide poisoning. Often these patients require endotracheal intubation, respirator support and continuous sedation. However, oxygen toxicity (OTOX) of the central nervous system may be a complication in these patients and OTOX is difficult to monitor due to sedation. Reports have shown that non-convulsive status epilepticus occur in 8% of comatose patients without signs of seizure activity. Accordingly, the purpose of the present study was to measure EEG during HBO treatments in sedated patients and evaluate whether or not signs of seizures could be detected.

**Methods:** Patients undergoing HBO treatment were equipped with 3 recording electrodes placed at the forehead, left side of forehead and left retro auricular on the mastoid. The electrodes were cable-connected to the CSM M3 Cerebral State Monitor®, from which EEG's were transmitted wirelessly to a desktop computer, placed outside the chamber, using the CSM Neuro Screen® software for the continuous EEG recording. EEG's and Cerebral State Index (CSI = Level of consciousness used for assessment of sedation and/or depth of anaesthesia) could be analysed in real-time or at a later stage.

**Results:** We monitored 17 patients given a total of 44 HBO treatments (treatment pressure 2.4 to 2.8 ATA) for 90 minutes while sedated, intubated and ventilated on a Siaretron 1000ä CE marked respirator. We were unable to detect any signs of neither short lasting or prolonged signs of seizure activities comparable to status epilepticus in the EEG recordings. When changes did occur, these were related to reductions in anaesthetic depth with a simultaneous increase in CSI levels.

**Conclusions:** We were not able to demonstrate any EEG related adverse effects of HBO treatments in the sedated, intubated and ventilated patients. We believe EEG monitoring will increase patient safety.

**Keywords:** treatment safety, status epilepticus, oxygen toxicity, brain

PP-41

# AN EPIDEMIC OUTBREAK OF CARBON MONOXIDE POISONING AFTER A SNOW STORM COLLAPSING POWER SUPPLY

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**Introduction:** On the eight of March of 2010 a strong snow storm collapsed power supply in the province of Girona (Spain) affecting about 250.000 persons. The electrical power was re-established partially after 48 h and almost completely after five days. The weather in these days was very cold (about 0-5 ºC). Our aim is to describe a carbon monoxide poisoning epidemic outbreak attended at Hospital de Palamós in those days.

**Methods:** Ninety-one patients were consecutively admitted at Hospital de Palamós emergency room between March 9th and March 13th presenting symptoms of carbon monoxide poisoning. Most of them were members of the same family or living at the same home. All of them were discharged alive after receiving treatment. A woman aged 41 was found dead when emergency medical team arrived at her home and other two older people were taken to the hospital. We registered data about origin of intoxication, clinical presentation, treatments administered and discharge. All of them were followed up after 1 month.

**Results:** Ninety-one people between 6 months and 88 years old were attended, 46 were women. CO-haemoglobin level was below 10% in 39 people (43%), between 10-20% in 39 (43%) and above 20% in 13 people (14%). 25 persons (28%) presented transitory loss of conscious and/or other neurological major signs. 16 persons (14%) presented thoracic pain and /or an abnormal ECG or elevation of troponin serum level.

The intoxication was caused by charcoal brazier use in 67% of people, electric generator use in 31% of people and 2 people after a domestic fire.

**Conclusions:** We discuss how this outbreak was managed from clinical and epidemiological point of view. A similar situation has been described previously after Katrina disaster in EEUU and we discuss lessons learned for similar situations in the future.

**Keywords:** carbon monoxide poisoning, epidemic outbreak

PP-42

# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF CARBON MONOXIDE POISONING IN TURKEY: A MULTI-CENTER CASE SERIES OF 1067 PATIENTS

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**Aims:** Carbon monoxide (CO) poisoning is one of the most common cause of toxicological morbidity and mortality worldwide. Hyperbaric oxygen treatment (HBOT) has been shown to have several beneficial effects in CO poisoning. HBOT is used in Turkey for more than 20 years and The Social Security Organization of Turkey covers HBOT in certain indications including CO poisoning. This study aimed to review CO poisoning casualties treated with HBOT in Turkey.

**Methods:** An online questionnaire including patient characteristics, history findings, treatment details and outcome results was sent to all HBOT centers in Turkey. Fourteen HBOT centers replied and submitted their patient data accordingly. Data were analyzed in SPSS 11.0 for Windows.

**Results:** A total of 1067 patients were analyzed. Of these 432 (40.5%) were male and 635 (59.5%) were female. Mean age was 31.9 (± 19.12). The most common cause of CO exposure was stoves (42.6%) and the second most common was water heaters (32.3%). Analyses for several parameters were undertaken for patients with available data and included following statistics: 481 (90.8%) patients had a history of unconsciousness and 49 (9.2%) did not. Twenty three (6.1%) patients were entubated at the time of HBOT. Mean carboxyhemoglobin (CoHb) level was 34.1 (± 12.95). 218 (57.1%) patients received HBOT in the first 6 hours of CO exposure, 137 (35.9%) received between 6 and 24 hours of exposure and 26 (6.8%) received HBOT beyond 24 hours of exposure. Overall 694 (93.4%) patients healed without sequelae, 44 (5.9%) patients showed several motor and neuropsychiatric sequelae and 5 (0.7%) patients eventually died.

**Conclusions:** CO poisoning is a common cause of morbidity and mortality worldwide as well as in Turkey. Early treatment with HBO in selected patients showed efficiency on the outcome of patients.

**Keywords:** Hyperbaric Oxygen Therapy, Carbon monoxide

PP-43

# MITOCHONDRIAL DAMAGE IN ACUTE CARBON MONOXIDE POISONING: THE EFFECT OF OXYGEN TREATMENT

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**Background:** Acute carbon monoxide (CO) poisoning (ACOP) symptoms are attributed to hypoxia due to carboxihemoglobin (COHb). However, CO also inhibits mitochondrial complex IV (mtCIV), responsible of energy supply and oxidative stress production. Since COHb rapidly decreases after oxygen (normobaric -NBO- or hyperbaric -HBO-) treatment, mtCIV and oxidative stress could be more sensitive markers of ACOP severity, treatment efficacy and sequel predictive markers.

**Methods:** 58 ACOP subjects were distributed as: a) severe (n=33, COHb>20% and/or clinical symptoms), randomly treated with 1 or 2 HBO sessions (SHBO1, n=20, and SHBO2, n=13), and b) moderate (n=25, COHb:10-20%), randomly treated with NBO (MNBO, n=11) or 1 HBO session (MHBO, n=14). Controls (n=30) were non-smoker blood donors. Clinical manifestations, COHb, mtCIV activity, mitochondrial mass and peripheral blood mononuclear cells' lipid peroxidation were analysed before and immediately after-treatment, and 24 hours, 1 month and 3 months after it.

**Results:** Before and immediately after-treatment mtCIV was decreased in ACOP compared to controls ($p<0.001$), independently to intoxication severity and COHb. Time-course mtCIV recovery was significant for ACOP on HBO (SHBO1 $p<0.001$, SHBO2 $p<0.005$ and MHBO $p<0.05$), but not in MNBO. Oxidative stress was not increased at baseline, but in severe ACOP, oxygen treatment raised it for 24 hours ($p<0.01$). All treatments normalised COHb and acute neurological symptoms except in two ACOP patients (both suffering late neurological sequels), which clinical manifestations correlated low mtCIV activities and increased oxidative stress.

**Conclusions:** Low mtCIV activity and maintained oxidative stress characterise ACOP. In severe ACOP 1 HBO session is effective enough restoring mtCIV activity and more effective than NBO in moderate ACOP. mtCIV could be a good marker of ACOP recovery, treatment efficacy and sequel development, but would not be a useful poisoning severity marker because is equally inhibited in all ACOP subjects. Clinical implications of these results remain to be established.

**Keywords:** carbon monoxide poisoning, mitochrondial damage, oxygen treatment, hyperbaric oxygen therapy

PP-44

# HYPERBARIC OXYGEN THERAPY FOR LATE RECTAL RADIATION TOXICITY. RESULTS OF A CLINICAL AND QUALITY OF LIFE STUDY

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**Background:** Late rectal toxicity after radiotherapy (RT) for prostate cancer have several therapeutic options including hyperbaric oxygen therapy (HBO). In order to define efficacy of HBO, we conducted a cohort study on patients having late rectal toxicity. We present results of clinical evolution and Quality of Live (QOL).

**Patients and Methods:** From june 2006 to june 2008, 257 patients were treated with RT for prostate cancer, 18 patients diagnosed of late rectal toxicity not responding to local treatments were considered for HBO, 14 patients were diagnosed during the study and 4 were added off period. Evolution, radiation doses and rectal toxicity were recorded. QOL was measured before and after the HBO treatment and every 6 months. Toxicity and clinical evolution were assessed using SOMA-LENT and CTCv3 scales and QOL by SF-36 test.

**Results:** All patients had at least grade 2 on CTCv3 and grade 3 by SOMA-LENT before HBO. At the end of HBO,14 patients remained symptoms free (grade 0) and 4 had grade 1 in CTCv3. The SOMA-LENT results were 1 or inferior in all cases. At the end of HBO, QOL measurements (SF36 test) showed also a significant improvement on physical, social and emotional scales. After 6 months benefit was maintained in all cases.

**Conclusion:** For late rectal toxicity after RT, HBO have a significant improvement in QOL and clinical parameters. This group of patients is rather small but results very promising. Further studies are needed in order to confirm our findings.

**Keywords:** Late rectal radiation toxicity, Quality of life, OHB

PP-45

# HYPERBARIC OXYGEN THERAPY FOR THE TREATMENT OF RADIATION PROCTITIS: A CASE REPORT

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**Introduction:** The acute and late side effects of radiation proctitis were recorded in clinical trials. The treatment of side effects improves the quality of life in cancer patients. The aim of this study was to present a case report of a patient with side effects after radiation therapy and discuss the role of hyperbaric oxygen treatment.

**CASE PRESENTATION:** We report the case of a 42-year-old man who presented with a two-month history of tenesmus, abdominal pain, loss of sphincter control and wound healing problem in perianal region. He was diagnosed with adenocarcinoma in the rectum and low anterior resection was performed for surgical care. The patient developed radiation-induced proctitis after he was treated with chemotherapy and radiation therapy. Patient received hyperbaric oxygen treatment 30 times at 2.4 ATA during two months. HBOT reduced the severity of symptoms due to radiation that improved the quality of life of the patient.

**Conclusions:** Although HBOT is widely applied, its mechanism of action is still poorly understood, discussions on the subject are ongoing, and controversy exists in the literature about its clinical use. Our findings were similiar to studies in literature that showed HBOT reduced side effect and improved oxygen perfusion after radiation therapy. The adjunctive hyperbaric oxygen therapy is an effective treatment option for healing impairment in previously irradiated tissues. Reducing the side effect with HBOT will also improve cure rate in cancer patients.

**Keywords:** Hyperbaric oxygen, proctitis, radiation therapy

PP-46

# RETROSPECTIVE ANALYSIS OF 3086 DIABETIC FOOT CASES TREATED WITH HYPERBARIC OXYGEN IN TURKEY

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**Aims:** Diabetic foot ulcers (DFU) are a common and important complication of diabetes and can result limb amputations. Hyperbaric oxygen therapy (HBO) has been suggested to improve oxygen supply to wounds and therefore improve their healing. DFU is accepted as an absolute indication for Hyperbaric Oxygen Therapy by Turkish Ministry of Health. HBO is used in Turkey for more than 20 years and Social Security Institution of Turkey reimburses HBO in certain indications including DFU.

**Methods:** This study aimed to review the patients with DFU who treated with HBO in Turkey. All HBO centers in Turkey were invited to participate in this study. Participating centers were required to fill web-based online form for each patient to collect data regarding; patient and wounds characteristics, etiological details, treatments and outcome. Thirteen of the 21 HBO centers replied accordingly and submitted patient data.

**Results:** A total of 3086 patients (2112 male and 974 female) were included. The mean age of patients was 60,7±10,8. The vast majority of the patients were with type 2 diabetes (97%). The main factors associated with DFU were neuropathy (83%), arterial hypertension (46%) and retinopathy (39%). Distribution of the patients according to Wagner's and University of Texas Classifications are shown on Table 1. The patients received wound care, antibiotherapy and VAC therapy in addition to HBO. The HBO protocols which applied to the patients were as follows: 90 minutes at 2 ATA (3,4%) and 60 (5,6%), 90 (34,3%) and 120 (56,7%) minutes at 2,4 ATA. The average number of HBO sessions was 35,3±21,9. Outcomes of the treatments were summarized in Table 2.

**Conclusion:** The addition of HBO to conventional treatments may increases the rate of healing and prevents high rate of amputations in patients with DFU.

**Keywords:** diabetic foot ulcers, chronic wounds, hyperbaric oxygen

**Tablo-1**

Table 1. The distribution of the patients according to classification systems

| WAGNER GRADE | | | | | | UNIVERSITY of TEXAS SCALE | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | A | B | C | D |
| 0,13% | 2,55% | 21,56% | 39,98% | 31,08% | 4,7% | 2,27% | 50,26% | 6,23% | 41,24% |

**Tablo-2**

Table 2. Outcomes of the treatment

| RESULT | PERCENTAGE |
|---|---|
| Complete healing | 39,4% |
| Partially healing | 31,3% |
| Minor amputations | 11,9% |
| Below knee amputations | 2,9% |
| Upper knee amputations | 0,6% |
| Unchanged | 13,2% |
| Worsening | 0,3% |
| Exitus (unrelated to HBO) | 0,4% |

PP-47

# USE OF HYPERBARIC OXYGEN AS ADJUNCT THERAPY IN THE HEAD AND NECK RADIONECROSIS: CASE REPORT

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One of the most feared complications of radiation therapy for head and neck cancer is radionecrosis. It is painful and debilitating, and sometimes requires extensive surgery and even segmental bone resection. Moreover, the etiology of this complication and its management remain controversial. Morbidity and mortality are serious, and treatment outcomes are often unsatisfactory. Hyperbaric oxygen therapy (HBOT) for radiation-damaged tissue was introduced in the early 1970's and is included in indication list of two important scientific committees, Undersea and Hyperbaric Medical Society (UHMS) and European Committee for Hyperbaric Medicine (ECHM). This management increases oxygen supply in hypoxic tissue thus inducing fibroblastic proliferation and capillary formation. With daily elevation of oxygen tension in hypoxic, hypocellular, and hypovascular bone and soft tissue near regions of functioning capillaries, fibroblast proliferation, collagen synthesis, and angiogenesis proceed. The killing ability of leukocytes is enhanced with the elevation of tissue oxygen tensions. Preoperative HBOT prepares a vascular, noninfected wound to enable the surgeon to successfully debride and later reconstruct such entities. Unplanned but required surgery in previously irradiated tissue has an increased risk of complications. Adjunctive HBOT is indicated postoperatively in this clinical setting. In this study we report the result of hyperbaric oxygen therapy in a case who had a wide tissue necrosis, resulted from radiation therapy of the head and neck region and involving left parotid region, the mandible, the subcutaneous soft tissue and the skin. The large ulceration over the left parotid region was positive for staphylococcus, streptococcus species and anaerobes, and histology revealed subcutaneous necrosis and non-specific inflammation with no evidence of malignancy. The lesion required multiple minor debridements and a latissimus dorsi myocutaneous flap for reconstruction. This case report emphasizes the importance of latissimus dorsi myocutaneous flap and shows the undeniable value of preoperative HBOT in cases with radionecrosis.

**Keywords:** hyperbaric, oxygen, radionecrosis, head, neck

PP-48

# ADJUVANT HBO THERAPY IN A PATIENT WITH LIFE-THREATENING INTRACRANIAL ABSCESS

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**Patient history:** The 64-year-old patient was admitted to the stroke unit due to acute mastoiditis, septic venous sinus thrombosis and formation of multiple intracranial abscesses. His clinical condition deteriorated: He had CPR, artificial ventilation, tracheotomy, and catecholamine support. SAPS II score: 73.
**NMRI:** Abscess formation in the cerebellum, right caudal brain hemisphere, and in the right tentorium. Partial destruction of C1. Concomitant soft tissue infection of the neck. Surgical intervention: mastoidectomy, ventricular drainage and drainage of the abscesses.

Bacteriologic **FINDINGS:** Streptococcus viridians (mastoid), Staphylococci and Corynebacteria (ear). Subsequent antibiotic treatment with Carbopenem, Metronidazol, Fosfomycin, Linezolid.
Basic neurologic status: Signs of tetraplegia: total paralysis of the upper limbs, occasional movement of the toes. Opening of the eyes on calling without fixation. GCS 6. The patient underwent 31 HBO sessions at 2.2-2.5 ATA / 90 min.
In the course of the treatment a gradual improvement of the neurologic condition was observed. He moved spontaneously all his limbs, communicated with his eyes and started to speak. Until session 8, IL-6 declined from 95.3 to 55.6 pg/mL. During session 10 he made first attempts to swallow, afterwards no catecholamine support. Controls after sessions 19 and 29 showed a regression of the cerebellar abscess and major resolution of the perifocal edema.
After 25 sessions the patient was dismissed from the ICU at a GCS of 14. He developed dysarthria and moderate muscular force in his limbs. GCS after 31 sessions developed to 15.
After the last HBO session, he was able to sit, read and started walking.
According to literature, the average number of sessions is 13 and the mortality rate is 20 percent in brain abscess patients.
In conclusion, HBO therapy is a valuable adjunct in the treatment of brain abscess.

**Keywords:** brain abscess, hyperbaric oxygen treatment.

PP-49

# CLOSTRIDIAL GAS GANGRENE OF THE LIVER - A CASE FOR HBO?

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We report the case of a 40 years old female patient having had liver transplantation in February 2010 due to cryptogenic liver-cirrhosis. Redo-operation was necessary because of dehiscence of the biliodigestive anastomosis. She was discharged with wound dehiscence at the subcostal arch, in otherwise good health. During further uneventful course the wound did not heal completely, she suddenly experienced diarrhoea and was admitted to the hospital in June 2010. Within one day she developed respiratory insufficiency, and a dramatic increase of bilirubin, transaminases, leucocytes and CRP. The CT-scan showed subtotal necrosis of the liver with gas replacing most of the hepatic parenchyma but with patent hepatic vessels.

Under the tentative diagnosis of peracute transplant rejection the patient was immediately enrolled for hepatectomy and re-transplantation at the Highly-Urgent level. During redo-laparotomy the typical smell suggested the diagnosis of clostridial gas-gangrene that was verified microbiologically. During hepatectomy the patient developed cardiac arrest. An attempt to re-establish the circulation with the help of extracorporeal-circulation showed only temporary success. It was not possible to discontinue the circulatory support and the patient died during surgery, 29 hours after admission to the hospital. The HBO-treatment scheduled after the operation could not be carried out. The microbiological specimens showed Clostridium perfringens in the superficial wound at the costal arch and in the liver, alongside with Klebsiella oxytoca and E. coli. The pathologic specimen of the liver revealed subtotal necrosis with gas formation and chronic cholestasis.

This case of hepatic clostridial gas gangrene was the 10th one to be reported in the literature. All patients had liver transplantation in their history and only half of them survived after either re-transplantation or conservative, antibiotic therapy. HBO might increase the survival rate of this rare condition, but the circumstances do not seem to allow for a transport into hyperbaric facilities.

**Keywords:** Gas Gangrene, Clostridium perfringens, HBO, liver transplantation,

PP-50

# USE OF HYPERBARIC OXYGEN THERAPY IN THE TREATMENT OF CHRONIC REFRACTORY OSTEOMYELITIS IN TURKEY

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Chronic refractory osteomyelitis is one of the 17 Hyperbaric Oxygen Treatment (HBOT) indications approved by Turkish Health Ministry. The cost of adjunctive HBOT treatment in osteomyelitis is reimbursed by Social Security Institution. HBOT has beneficial effects in osteomyelitis by increasing leukocyte oxidative killing and synergistic effect with certain antibiotics. In this study the cases with osteomyelitis and received HBOT were evaluated. An electronic questionnaire was filled by participating centers for each case, to collect data including characteristics, history, laboratory tests treatment details and outcome. The data of a total of 350 cases treated in ten different hyperbaric centers was evaluated. The cases with diabetic food were excluded from the study. The mean age of 94 female and 256 male cases was 42.23. Etiologic factor was trauma in 39,4 % of the cases and 14,2 % of cases had history of surgical intervention. There were foreign bodies in 56 cases (16 %). The other predisposing factors were diabetes mellitus, malignancy and sequels of poliomyelitis. A predisposing factor was not reported in 105 cases (%30). S. Aureous was isolated in the bacteriological culture of 93 cases (70,4 % of the culture results). Bacteriological culture result was not reported in 219 cases. A total of 531 surgical interventions were included in the management of the disease in 203 cases. The mean CRP level was 11,68 mg/l which was decreased to 5.65 mg/l after the average of 42.2 HBOT sessions. The average ESR level was decreased to 33.13 mm/h from 54,8 mm/h. The average treatment day was 59.5 days. The signs of osteomyelitis were evident in x-rays of all of the cases. The localization of the disease was in lower extremities in 90 % of the cases. At the end of treatment complete healing and partial healing were achieved in 144 cases and 134 cases respectively. Control examination could be done in only 49 cases (14 %) including 12 cases with recurrences. Chronic refractory osteomyelitis is known as HBOT indication by orthopedists in Turkey. Although HBOT treatment seemed beneficial in our cases, long term follow up is needed to evaluate the effect of HBOT in osteomyelitis since the recurrence rate is high in chronic osteomyelitis.

**Keywords:** hyperbaric oxygen, osteomyelitis, refracter osteomyelitis

PP-51

# THE EFFECT OF HIPERBARIC OXYGEN THERAPY IN PATIENTS WITH TONGUE NECROSIS AFTER EMBOLIZATION OF AN ARTERIOVENOUS MALFORMATION(AVM)

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**Aims:** The AVM is rarely seen in population and endovascular embolization is one of the treatment modalities of AVM. One of the rare complication of embolization is distal end necrosis. We evaluate the effect of HBO treatment in a patient with tongue and nose necrosis after embolization of AVM.

**Method:** A 13 years old, female patient with an AVM in neck and head was diagnosed with angiography and right superior lingual artery, right facial artery embolization at the same time. After embolization the patient had got dizziness, tongue and nose necrosis, aglutition and disability of tongue movements. The day after the embolization, the patient has sent to our clinic. We decided to performe HBOT, in aggrement with ear-nose-throat specialist.

**Results:** During the HBOT treatments the patient was treated with steroids(dexametazone) and antibiotics(amoxicilline clavunate) also. After an 12 treatments for 2 hours at 2.5 ATA on %100 oxygen with HBOT, the patients aglutition and disability of tongue movements was recover and the tongue and neck necrosis get an significant improvement.

**Conclusion:** We think that HBOT therapy is an useful treatment especially in case of acute necrosis after embolization. Also HBO therapy should start as soon as possible in such cases.

**Keywords:** Hyperbaric Oxygen, Arteriovenous malformation, Acute tongue necrosis

PP-52

# HYPERBARIC OXYGEN THERAPY FOR MALIGNANT OTITIS EXTERNA

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**Background:** Malignant otitis externa (MOE) is an invasive infection of the external ear and skull base. Mainly immune-compromised individuals, particularly those who have diabetes, are affected. Urgent treatment is required. In addition to high-dose antibiotics various case reports describe the adjuvant use of hyperbaric oxygen treatment for both bacterial and fungal malignant otitisexterna. The efficacy of this treatment was recently evaluated in a systematic review, stating that more data are needed in order to draw a conclusion. We present our experience with hyperbaric oxygen therapy (HBOT), aiming to contribute more data on the way to finally reach a consensus on the use of adjuvant HBOT for this potentially life-threatening condition.

**Patients and Methods:** Clinical audit data of 5 elderly, diabetic patients with MOE are presented. These patients were referred to our centre between 2007 and 2010. The diagnosis was confirmed by CT and MRI scans. All were treated with up to 30 sessions of adjuvant HBOT over a six week period in addition to high-dose antibiotic treatment. Monitoring was clinical along with C-Reactive Protein (CRP) assay.

**Results:** Adjuvant HBOT was beneficial in 3 patients (60% and 67% taking into account both successful HBOTs of the patient who had a relapse in the contralateral temporal bone after 9 months: 1A, 1B) with no clinical response in one case of MOE in whom HBOT had to be aborted due to general medical conditions and in another case with other general medical problems. A beneficial response was defined by a significant improvement of symptoms (pain, discharge, cranial nerve palsies) as well as normalisation of inflammatory markers post-treatment, which was also the case in patient 4 although CRP remained unchanged.

**Conclusion:** : Adjuvant HBOT should be considered in patients with MOE for Stage I and II disease in addition to the currently used treatment protocol.

**Keywords:** malignant otitis, hyperbaric oxygen

**CRP pre and post HBOT**

**MOE patients treated with HBOT**

| No | AGE | DM | MOE stage | Cranial nerve palsies |
|---|---|---|---|---|
| 1A | 80 | Y | II | L 9th,10th |
| 1B | 80 | Y | II | R 9th, 10th, 12th |
| 2 | 83 | Y | II | L 7th, 12th |
| 3 | 60 | Y | II | R 7th |
| 4 | 70 | Y | II | R 7th |
| 5 | 69 | Y | II | R 9th, 10th |

PP-53

# PULMONARY BAROTRAUMA WITH BILATERAL PNEUMOTHORAX RELATED TO HYPERBARIC OXYGEN TREATMENT - A CASE REPORT

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**Aims:** A purpose of this work is to demonstrate a life threatening complication- pulmonary barotrauma with bilateral pneumotorax (PNO) immediately after non-complicated session of HBOT.

**Methods-Results:** 45-years old female with severe carbon monoxide poisoning (comatose, GCS 3) was reffered immediately to HBOT in our treatment center. Initial level of carbonylhemoglobin was 27.8%. First two sessions of HBOT 2.5 ATA with attendance both physician and nurse inside of chamber with arteficial lung ventilation were provided without any complication. Another HBOT sessions also coursed without significant problems (HBOT 2 ATA, spontaneous breathing, normal capnometry levels, normal blood pressure). 20 minutes after 6th HBOT rapid development of subcutaneous emphysema of the face, chest, upper extremities with dyspnoe, decrease of blood saturation, bilateral weakening of lung auscultation, bradycardia and picture of pulseless electrical activity occured. CPR was started immediately. Wide needles were immediately introduced to the 2nd intercostal spaces of both thoracic cavities. Large amount of air escaped from the right side, followed by immediate restoration of normal sinusal rhythm, qrs complexes and blood pressure as well. Urgent drainage of right chest cavity were peformed. X-ray examination revealed also significant PNO of the left chest cavity with collapsed lung wing followed by implementation of chest drain. Further HBOT treatment were stopped, patient were translated back to the primary hospital and died one month later for pulmonary infection and sepsis.

**Conclusion:** Pulmonary barotrauma with bilateral PNO (unilateral tension) is a rare complication during HBOT. It is urgent life threatening complication and demands quick and effective treatment. In our case report we did not find any reason for occuring this complication (relatively healthy person, spontaneous ventilation, no chest trauma, no punction for veinou access).

**Keywords:** pulmonary barotrauma, pneumothorax, hyperbaric oxygen treatment

PP-54

# CASE REPORT: SEIZURE ASSOCIATED WITH LEVOFLOXACIN IN THE HYPERBARIC CHAMBER

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We present a case of a patient who developed seizures shortly after initiating treatment with levofloxacin and hyperbaric oxygen treatment.

**Case Summary:** 38-year-old woman had an orthopedic operation and soft tissue infection and bone infection. She had no neurological disease. Levofloxacin was prescribed by her orthopedist. We started hyperbaric oxygen treatment at 2.5 ATA, 120 min/per session. After receiving seven doses of oral levofloxacin and 5 sessions HBO treatment, the patient experienced a seizure in the hyperbaric chamber. Seizure stopped by itself. She had transferred by ambulance to the hospital. Her neurological examination, brain MRI and EEG were normal.

**DISCUSSION:** Quinolone antibiotics vary in their ability to induce seizures, with levofloxacin possibly having the least potential. The patient had no history of a previous seizure disorder. Electrolyte imbalances are common with previous reports of fluoroquinolone-induced seizures.

**Conclusion:** Clinicians are exhorted to pay close attention when initiating levofloxacin therapy with HBO treatment in patients taking medications with epileptogenic properties. Some seizures in the hyperbaric chamber may be related quinolone antibiotics.

**Keywords:** Levofloxacin, Quinolone, Seizure, Hyperbaric Oxygen Treatment, Oxygen Toxicity

PP-55

# FATAL HEMORRHAGE DURING HYPERBARIC OXYGEN THERAPY DUE TO CAROTID ARROSION - CASE REPORT

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A 64 years old man was diagnosed with squamous cell carcinoma of hypopharynx. As risk factors alcohol- and nicotine abuse were detected. He underwent primary radiochemotherapy, followed by laryngectomy with neck dissection complicated by pharyngocutaneus fistula. Due to radiochemotherapy the wound healing in the surgical setting was not sufficient, the defect was covered with radial flap in addition to a revision of the fistula. A deep vein thrombosis was complicating the clinical condition, the patient was treated with heparin. Because of the necrotizing radial flap reconstruction of pharynx and hypopharynx was necessary. Along with surgical therapy hyperbaric oxygen therapy was initiated. After a detailed education and examination the patient underwent two preoperative sessions of 100 % medical oxygen inhalation at 2.4 atmospheres absolute for 90 minutes once a day. Then a latissimus dorsi flap was inserted after removing the necrotizing neck tissue. After this surgical intervention the patient continued hyperbaric oxygen therapy without any problems. Wound healing was very pleasing, there were no necrotizing areas. During the 12th session after the second airbreak - the patient was monitored with hemodynamometry and electrocardiogram and furthermore attended by a staff member - bloody secretion was drained over the tracheostomy by suction pump. Concurrently a massive hemorrhage occurred via a small wound dehiscence on the right neck. The patient lost about two liters of blood within five minutes. An emergency decompression was performed, the chain of survival was immediately organized. The patient was resuscitated in cooperation with the requested rescue team. Unfortunately the patient died of hemorrhagic shock in consequence of the carotid arrosion bleeding. This is a severe complication after radiochemotherapy in progredient neck tumors. Patients must be screened for potential complications like this, an efficient emergency management is absolutely necessary.

**Keywords:** hemorrhage, carotid arrosion, hyperbaric oxygen therapy, wound healing, hypopharynx carcinoma.

PP-56

# PARADOXICAL PAIN DURING HYPERBARIC TREATMENT AFTER MUSCULOSKELETAL DECOMPRESSION SICKNESS AND RELATION WITH SUBSEQUENT DYSBARIC OSTENECROSIS

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**Introduction:** There is little information about the prevalence of dysbaric ostenonecrosis (DON) and its relationship to decompression sickness (DCS). Therefore, we undertook a study to determine the potential risk factors associated with the development of DON after musculoskeletal DCS in recreational divers.

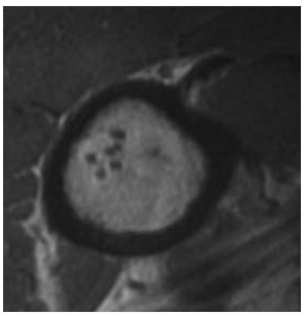
**Methods:** Between 2004 and 2009 we performed an observational, retrospective study of recreational divers treated for musculoskeletal DCS in three hyperbaric centers in the south of France using magnetic resonance imaging (MRI) following hyperbaric treatment.

**Results:** Twenty five (7.4%) musculoskeletal DCS cases were identified amongst 337 diving accidents treated during this period. Average age was 39 years with a mean body mass index of 25 kg.m-2. Joint pains were located in the shoulder area (80%), mainly in experienced male divers after performing repetitive long, deep air dives with adequate decompression using dive computers. Seven injured divers (28%) had initial lesions compatible with ischemic necrosis. Increasing pain during hyperbaric treatment appeared to be the main independent factor associated with DON occurrence ($p < 0,001$).

**Conclusion:** Our preliminary findings show that an increasing pain during hyperbaric treatment of musculoskeletal DCS should alert the physician of a greater risk of developing a DON, thus requiring an early MRI exam. Further investigations with a larger sample size of DCS divers are needed to find additional predictors of ischemic bone necrosis, particularly age >40 years and time interval before recompression >6hours.

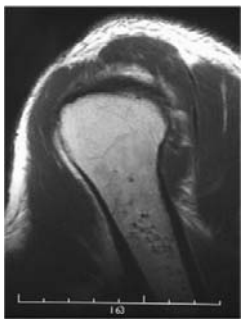
**Keywords:** Diving, Decompression sickness, Dysbaric Osteonecrosis, Magnetic Resonance Imaging, Limb Bend

**MRI examination 24 hrs following DCS**



*humeral shaft micronodular lacunae (T1) evocative of Intramedullar bullae*

**MRI examination 24 hrs following DCS**



*humeral shaft micronodular lacunae (T1) evocative of Intramedullar bullae*

**Table of Results**

| Variables (n=25) | MRI + | MRI - | univariate analysis p | univariate analysis OR (CI 95%) | multivariate analysis p | multivariate analysis OR (CI 95%) |
|---|---|---|---|---|---|---|
| **Age** | | | 0,07 | 9,4 (0,9-95,9) | 0,9 | 1,1 (0,9-0,13) |
| ≤ 40 | 1 | 11 | | | | |
| > 40 | 6 | 7 | | | | |
| **BMI (kg.m$^{-2}$)** | | | 1 | 2 (0,2-15,6) | | |
| ≤ 27 | | 5 | 15 | | | |
| > 27 | | 2 | 3 | | | |
| **History of DCS** | | | 0,59 | 2 (0,2-15,6) | | |
| Yes | 2 | 3 | | | | |
| No | 5 | 15 | | | | |
| **Dive Time (min)** | | | 0,17 | 5 (0,7-33,7) | 0,8 | 1,2 (0,9-1,1) |
| ≤ 40 | 2 | 12 | | | | |
| > 40 | 5 | 6 | | | | |
| **Depth (msw)** | | | 1 | 0,9 (0,1-5,5) | | |
| ≤ 45 | 4 | 10 | | | | |
| > 45 | 3 | 8 | | | | |
| **Repetitive Dive** | | | 1 | 0,8 (0,1-4,9) | | |
| Yes | 3 | 9 | | | | |
| No | 4 | 9 | | | | |
| **Delay to onset of symptoms (min)** | | | 0,66 | 2,1 (0,3-12,3) | | |
| ≤ 30 | 3 | 11 | | | | |
| > 30 | 4 | 7 | | | | |
| **Delay to treatment (hours)** | | | 0,03 | 12 (1,1-123,6) | 0,56 | 1,1 (0,9-1,2) |
| ≤ 6 | 1 | 12 | | | | |
| > 6 | 6 | 6 | | | | |
| **Paradoxical Pain** | | | < 0,001 | infinite | < 0,001 | infinite |
| Yes | 7 | 1 | | | | |
| No | 0 | 17 | | | | |

*Analysis of MRI outcome in divers with musculoskeletal DCS according to diving data, clinical characteristics and time to recompression. MRI + indicates the presence of dysbaric osteonecrosis lesions; OR (95% CI) - odds ratio and 95% confidence intervals*

PP-57

# INSIDE ATTENDANT PRACTICES IN HYPERBARIC OXYGEN THERAPY CENTERS IN TURKEY

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**Aims:** A medical personal accompanying patients inside a multiplace hyperbaric chamber is called as inside attendant. Decompression sickness has been reported in inside attendants. This study aimed to determine the prevalence of decompression sickness in inside attendants and preventive measures taken to reduce the risk of decompression sickness in inside attendants in Turkey.

**Methods:** Hyperbaric oxygen therapy centers in Turkey were asked to participate in this study. A questionnaire was sent via e-mail. Thirteen of 21 centers (61%) responded to our questionnaire.

**Results:** Two incidents of decompression sickness were identified in 55852 hyperbaric treatments. The prevalence of decompression sickness was calculated as 0,0036%. Most common complication in inside attendants was middle ear barotrauma. Terminal oxygen breathing, attendant rotation, setting daily limits for number of dives were among the most commonly used preventive measures against decompression sickness.

**Conclusions:** Decompression sickness is rare in inside attendants. Preventive measures are affective to reduce the risk of decompression sickness in inside attendants.

**Keywords:** inside tender, complication, dysbarism

PP-58

# THE EFFECT OF HYPERBARIC OXYGEN THERAPY FOR NERVE HEALING IN ACUTE MEDULLA SPINALIS LESIONS EXPERIMENTAL STUDY ON RATS

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**Objective:** In this study, the effect of HBO therapy on acute-phase healing in experimental spinal cord injury was addressed via the comparison of HBO's effectiveness with preoperative, postoperative or preoperative and postoperative administration.

**Materıal-Method:** 48 male Sprague-Dawley rats were divided into eight groups. The spinal cord injury was applied with an aneurysm clip placed at the T9-11 level. Preoperative HBO therapy groups received HBO for five days (One a day at 2.8 ATA); The postoperative HBO groups received HBO therapy for 7 days.Preoperative and postoperative HBO groups received HBOT for 5 days preoperatively; then they were operated on the 6th day and continued to receive HBOT for another 7 days. Biochemical results of spinal cord samples and functional healing of rats were compared.

**Results:** When Sci and PreopSci were compared, a significant increase was detected in NOS and NO levels, while the comparison of Sci and PostopSci revealed a significant decrease in SOD levels and a significant increase in NOS and NO levels. When Sci and PrepostSci were compared, a significant decrease was detected at SOD and GPx levels. The comparison of PreopOIH and PostopSci indicated a significant decrease in SOD levels, while the same significant decrease in SOD levels was observed in the comparison of PreopSci and PrepostSci. The comparison of PostopSci and PrepostSci indicated a significant decrease in GPx levels. In terms of functional healing, which was evaluated on the basis of BBB scoring, significant improvement was detected in PostopSci and PrepostSci, when compared to the Sci group. In catalase levels, however, no significant difference was detected in any of the groups.

**Conclusion:** As a result, HBO therapy was found to be beneficial for thoracic spinal nerve damage in terms of biochemical parameters and functional healing.

**Keywords:** Hyperbaric oxygen therapy, rat, spinal cord injury, superoxide dismutase, catalase.

**Pictute-1**

*Barotech Ltd. DB1(2009) Research- Development Pressure Chamber*

PP-59

# THE EFFECT OF HYPERBARIC OXYGEN THERAPY ON TENDON HEALING IN ACHILLES TENDON RUPTURES (EXPERIMENTAL STUDY ON RATS)

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**Objective:** This article aims to investigate the effects of the hyperbaric oxygen treatment on early tendon healing in the treatment of Achilles tendon ruptures, a condition of increased incidence in recent years.

**Methods:** 56 male Wistar Albino rats were randomized and divided into two groups. Intratendinous bethametazone was administered preoperatively for degeneration to 28 rats, while isotonic saline injection was administered to the remaining 28 rats. The Achilles tendons of all rats were sutured following tenotomy. 14 rats were taken from each of the groups with and without the corticosteroid administration and combined in a group on which hyperbaric oxygen therapy was subsequently applied. From the 1st postoperative day, the rats in both groups were given hyperbaric oxygen therapy for 70 minutes per day for ten days in a total of 20 fractions under 2.4 ATA (atmosphere absolute) pressure. (Barotech Ltd. DB1-2009 Research- Development Pressure Chamber).
On the 11th day postoperatively, the Achilles tendons were removed and histopathologically studied.

**Results:** Upon the histopathological study of the tendons, the amount of fibrosis was established to be significantly higher in the hyperbaric oxygen therapy group than in the group without the hyperbaric oxygen therapy. In the groups with steroid administration, on the other hand, the amount of inflammation and vascularisation were found to be significantly higher than in the no-steroid group.

**Conclusion:** Hyperbaric oxygen therapy creates a histologically positive effect on early healing in the healing process of the Achilles tendon.

**Keywords:** Hyperbaric Oxygen, Achilles Tendon.

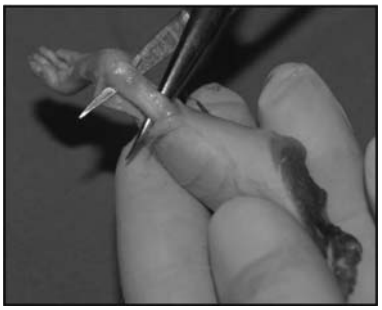
**Picture-1**

*The right Achilles tendon*

**Picture-2**

*Barotech Ltd. DB1(2009)*
*Research- Development Pressure Chamber*

**Picture-3**



*The lower right extremities of the rats were disarticulated from the hip joint to explore the Achilles tendons. The Achilles tendons of all rats were observed to have healed.*
*None presented any findings of infection.*

PP-60

# EVALUATION OF THE OXIDATIVE EFFECT OF REPETITIVE HYPERBARIC OXYGEN CESSATION ON DIFFERENT BRAIN REGIONS OF RATS

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*[2]Department of Underwater and Hyperbaric Medicine, Gülhane Military Medical Academy, Haydarpaşa Teaching Hospital, Istanbul, Turkey.*
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**Aims:** Hyperbaric oxygen (HBO) exposure is known to affect the oxidative as well as antioxidant systems of living organisms. In the literature, there is evidence that at least a single HBO exposure can trigger oxidative stress. The oxidative effect of HBO was reported to be positively correlated with the exposure time and duration of the treatment. There are also reports about an adaptive mechanism which protects against further oxidative damage when HBO therapy was continued for a longer period. Since HBO is an important therapeutic approach with live saving properties in several conditions, we aimed to enlighten the relation of HBO with oxidative/antioxidant systems when administered in a prolonged and repetitive manner.

**Methods:** Sixty Sprague-Dawley rats were divided into 6 study (n=8 for each) and 1 unexposed control (n=12) group. The rats in the study groups were exposed to daily 90-min HBO sessions at 2.8 ATA for 5, 10, 15, 20, 30 and 40 days. One day after the last HBO session, the animals were sacrificed and their whole brain tissue was harvested, and then dissected into its three different regions as the outer grey matter (cortex), the inner white matter and cerebellum. The degree of lipid peroxidation and protein oxidation for the evaluation of oxidative stress and the activities of superoxide dismutase and glutathione peroxidase for reflecting the antioxidant status were measured in these tissues.

**Results:** All measured variables in all tissues resulted in comparable levels. There was no significance among any of the study groups or in comparison with the control group.

**Conclusion:** These results provide evidence for the safety of HBO treatments, even when administered for longer periods.

**Keywords:** Hyperbaric oxygen, oxidative stress, antioxidant enzymes

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# EFFECT OF HYPERBARIC OXYGEN THERAPY (HBOT) COMBINED WITH MICROFRACTURE TECHNIQUE ON HEALING OF FULL THICKNESS CARTILAGE LESIONS

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**Purpose:** To analyze the effect of HBOT alone and combined with microfracture technique on healing of full thickness cartilage lesions.

**Materials-Methods:** 44 adult rats were randomly divided into 6 groups. (A,B,C,D,E,F) In groups A,B,C and D; full thickness cartilage defect was made on the femoral sulcus of both knees after bilateral medial parapatellar arthrotomy. On left knees lesions were microfractured, right knees had no further procedure. In groups E and F; on the left knees, intact cartilage on femoral sulcus was microfractured, right knees were left unoperated. Animals in groups A,C and E received HBOT once a day, 6 days in a week postoperatively at 2.4 ATA for 60 minutes. Animals in groups A,B,E,F were sacrified after 2 weeks for pathological evaluation whereas animals in groups C and D were sacrified after 4 weeks. After H&E staining, specimens were blindly evaluated. A semiquantitative scale was used for evaluation of cartilage repair. Criterias used in this scale were microfracture tunnel healing, synovial thickness over the lesion, synovial coverage over the lesion, cartilage metaplasia in synovial tissue and bone maturation in subchondral tissue. Total and individual scores regarding the criterias were compared between groups. Mann–Whitney test was used for statistical analysis.

**Results:** Total scores were significantly better in all HBOT groups. (Figure1, $p<0.05$) Microfracture tunnel healing was significantly better in all HBOT groups. (Figure 2, $p<0.05$) Synovial thickness was significantly better in HBOT groups sacrified after 2 weeks whereas 4 week specimens had no significant difference. (Figure 3, $p<0.05$) Synovial coverage showed no significant difference. Unoperated knees showed no synovial migration. Cartilage metaplasia was significantly better in all HBOT groups. (Figure 4, $p<0.05$) Bone maturation was significantly better in HBOT groups sacrified after 4 weeks whereas 2 week specimens had no significant difference. (Figure 5, $p<0.05$)

**Conclusion:** HBOT combined with microfracture tecnique is an effective method that accelarates healing process in full-thickness cartilage lesions.

**Keywords:** Cartilage lesion, healing, microfracture, hyperbaric oxygen therapy, synovium

**figure 1**

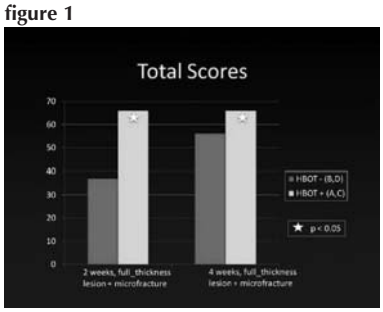
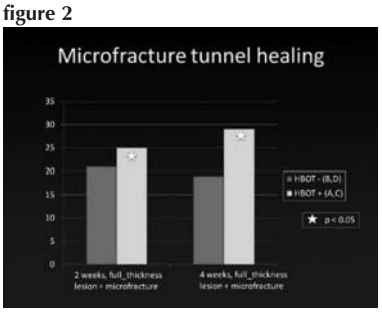



**figure 2**

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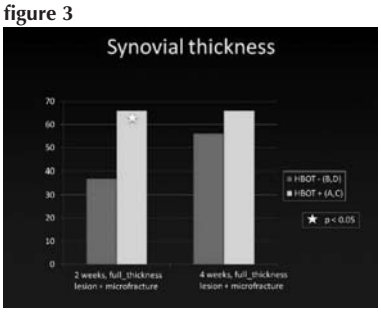


**figure 4**

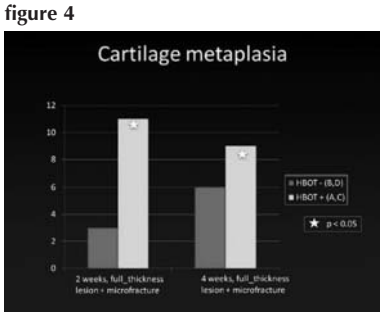


**figure 5**

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# USING A WOUND HEALING ANALYZING TOOL IN HYPERBARIC WOUND CARE

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In three multi-place hyperbaric chambers the Institute for Hyperbaric Medicine in The Netherlands treats a lot of chronic wound patients. Radiation-induced ulcers and diabetic foot ulcers make up about 50% of our total patient population. To determine possible benefit from hyperbaric oxygen therapy a transcutaneous oxygen measurement is performed first. During hyperbaric treatment wound care is carried out in close cooperation with different specialists. Our experience however, is that follow-up of chronic wounds can still be a difficult and subjective process. Therefore, since a year we use a digital program as an extra tool to assess progression in wound healing in our patients.
This program is a so-called wound healing analyzing tool. It automatically calculates the total surface area of a wound and the composing surfaces of granular tissue, fibrin, and necrosis using a digital picture. In order to load a proper wound photograph into the program strict rules have to be followed when taking a picture of a wound. In the program a patient file is created. All relevant information can be saved in this file, like localization of the wound, patient details, type of wound dressing, etc. Subsequently, in the loaded wound picture the borders of the wound have to be designated by hand using a computer mouse, which can be difficult and requires some practice. Best is to always have the same person carrying out this task. Wound size is calculated according to a calibration square photographed together with the wound. The program then produces a sheet with the exact specification in numbers. By repeating these measurements at constant time points wound healing can be recorded adequately. These data can then be used to support decisions on when to progress to a next step in wound treatment.

**Keywords:** wound healing, analyzing, digital tool

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# HYPERBARIC OXYGEN THERAPY AND MELATONIN CO-ADMINISTRATION IN GENTAMICIN INDUCED NEPHROTOXICITY

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**Aims:** This study is designed to determinate hyperbaric oxygen therapy and melatonin co-administration effects on nephrotoxicity caused by gentamicin. It has been known that reactive oxygen species play a role in gentamicin nephrotoxicity. Melatonin prevents from gentamicin nephrotoxicity by scavenging reactive oxygen species.

**Methods:** Wistar albino rats were administered gentamicin (80 mg/kg/day) intraperitoneally and were divided into two treatment groups; Melatonin (20 mg/kg/day, intraperitoneally) and melatonin+HBOT. 10 sessions of HBOT in a pressure chamber once daily, at 2.4 ATA for 60 minutes. Blood urine nitrogen (BUN) and creatinin levels determined for kidney function evaluation and tissue Malondialdehyde (MDA) levels determined for lipid peroxydation evaluation.

**Results:** Blood BUN, creatinin and tissue MDA levels were elevated and tubular necrosis was observed by gentamicine nephrotoxicity. Gentamicin and HBOT co-administration did not change the MDA level, probably HBOT didn't cause additional oxidative stress. Melatonin administration protected from gentamycin nephrotoxicity. This effect appeared via lipid peroxydation inhibition. Melatonin and HBOT co-administration caused healing in tubular necrosis, proved by pathological examination.

**Conclusion:** During gentamicin antibiotherapy, main protective factors are close monitorisation of kidney functions, hidration and avoidance of other nephrotoxic drugs. Antioxydant supplements are frequenty used in HBOT process. Melatonin can be considered an alternative antioxydant in gentamicin and HBOT co-administration.

**Keywords:** hyperbaric oxygen therapy, gentamicin nephrotoxicity, melatonin

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# THE EFFECTS OF HYPERBARIC OXYGEN TREATMENT ON HYPOXIA INDUCIBLE FACTOR-1α, INDUCIBLE NITRIC OXIDE SYNTHASE AND VASCULAR ENDOTHELIAL GROWTH FACTOR LEVELS WITH DIABETIC FOOT PATIENTS

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AIMS: The aim of this study is to investigate the healing effects of HBOT with diabetic foot patients by means of HIF-1α, iNOS and VEGF. So that we aimed to clarify physiological basis of HBOT on chronic wound healing.

**Methods:** 20 patients with Wagner stage 2,3 and 4 diabetic foot are included in this study. Chronic obstructive lung disease, severe congestive heart failure, end-stage renal failure and anemia with Hb<9 mg/dl which cause systemic hypoxia were excluded from the study.
After cleaning the wounds, granulation tissue was taken from the wound-dermis border by curretage. Samples were stored at -82°C until the laboratory studies were performed. These procedures were done before the first and after the tenth HBO treatment. 120 minute-treatment sessions are applied to the patients at 2,5 ATA. Following RNA isolation, real time PCR was applied by using Syber green dye. Results were evaluated by measuring the fluorescence values which the samples took and by calculating percentage ratios.

**Results:** Before the first and after the tenth treatment mean PCR values are given respectively: VEGF 6026,30 (± 1838,08), 5949,30 (± 2313,13); iNOS 5479,95 (± 1580,30), 5448,40 (± 1467,29); HIF1-α 5502,85 (± 2314,11), 5023,35 (± 1337,00). The increase in HIF1-α has a meaningful correlation with increases in iNOS and VEGF ($p<0.05$). VEGF, iNOS and HIF1-α levels in patients, who had major or minor amputations, went up; while all parameters in patients, who recovered, indicated a decline ($p>0.05$).

**Conclusions:** Our research showed that HBOT decreased HIF-1α, iNOS and VEGF levels in diabetic foot wounds that recovered. We concluded that HBOT inhibits prolonged hypoxic stimulus and decreases both the levels of the mentioned parameters and the negative effects of prolonged and intense expressions of these parameters on wound healing.

**Keywords:** Diabetic Foot, Hyperbaric Oxygen, Hypoxia Inducible Factor, Wound Healing

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# THE EFFECT OF HYPERBARIC OXYGEN THERAPY AND DENERVATION ON FRACTURE HEALING

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**Introduction:** The purpose of this study was to evaluate the effect of hyperbaric oxygen therapy on healing of denervated and normally innervated bone fracture.

**Materials-Methods:** The study included 32 Wistar albino rats. Rats in 1.group were performed femoral fracture with intramedullary fixation and HBO treatment, 2. group (control group) were performed femoral fracture and intramedullary fixation, rats in the 3. group were performed femoral fracture with intramedullary fixation, nervus ischiadicus resection and HBO treatment. 4.groups include rats were performed femoral fracture with intramedullary fixation,and nervus ischiadicus resection. On the 28. day the animals were sacrified and radiological and biomechanical evaluations are obtained.

**Results:** Callus area in the nerve resection group was significantly lower than the normally innervated groups and it was higher in HBO treatment group when compared with control group ($p<0,05$). Callus strength was reduced in nerve injury groups compared with normally innervated groups and higher in HBO treatment groups than without HBO treatment groups ($p<0,05$).

**Discussion:** HBO treatment may effect on fracture healing by radiologic and biomechanical evaluation but its effect is limited with nerve injury.

**Keywords:** Fracture healing, denervation, hyperbaric oxygen therapy

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