【Abstracts】

# THE 4TH CONFERENCE ON DIVING PHYSIOLOGY, TECHNOLOGY AND HYPERBARIC MEDICINE(formerly UJNR)

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SESSION 1-1

## DECOMPRESSION ILLNESS TREATMENT IN KAWASHIMA ORTHPAEDIC HOSPITAL

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INTRODUCTION: There are many professional diving fishermen in the Kyushu area. Most decompression illness (DCI) patients who were treated in Kawashima Orthopaedic Hospital were fishermen. They ignore the decompression table and dive according to their own experience to maximize their yield. As a result, they are prone to a high incidence of DCI. The purpose of this study is to investigate the effect of recompression treatment for DCI.

METHODS: The subject of this investigation was 515 DIC cases which were treated in Kawashima Orthopaedic Hospital from 1981 to 2011. We followed U.S.Navy Treatment Table 5A, 5, 6A and 6 for recompression treatment. In addition to recompression treatment, almost all these cases were treated with infusion therapy and/or rehabilitation.

RESULTS: A symptomatology classification of DCI was as follows: limb bends 390 (75.7%),spinal cord injury 54 (10.5%),Meniere's 24 (4.7%),cerebral injury 22 (4.3%),and chokes 10 (1.9%),and skin bends 3 (0.6%).

Results of treatment were as follows:

| | good | | fair | | failure | | total | |
|---|---|---|---|---|---|---|---|---|
| limb bends | 387 | (99.2%) | 3 | (0.8%) | 0 | (0.0%) | 390 | (100.0%) |
| spinal cord injury | 41 | (75.9%) | 13 | (24.1%) | 0 | (0.0%) | 54 | (100.0%) |
| Meniere's | 18 | (75.0%) | 6 | (25.0%) | 0 | (0.0%) | 24 | (100.0%) |
| cerebral injury | 18 | (81.8%) | 3 | (13.6%) | 1 | (4.6%) | 22 | (100.0%) |
| chokes | 10 | (100.0%) | 0 | (0.0%) | 0 | (0.0%) | 10 | (100.0%) |
| skin bends | 1 | (33.3%) | 2 | (66.7%) | 0 | (0.0%) | 3 | (100.0%) |
| other cases | 9 | (75.0%) | 2 | (16.7%) | 1 | (8.3%) | 12 | (100.0%) |
| total | 484 | (94.0%) | 29 | (5.6%) | 2 | (0.4%) | 515 | (100.0%) |

good: symptom eliminated
fair: symptom clearly improved
failure: symptom not improved much

CONCLUSION: It is important to carry out proper recompression treatment and fluid therapy as soon as possible.

SESSION 1-2

## TREATMENTS OF DYSBARIC OSTEONECROSIS

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It is well known that inappropriate or excessive diving causes dysbaric osteonecrosis (DON). DON of upper femur progresses the collapse of the femoral head and osteoarthritis of the hip joint. When pain and destruction begin, progression is usually relentless and non-surgical methods are usually futile. Operations for DON of the femoral head are divided into three groups. One is adduction (varus) osteotomy, and another is transtrochanteric anterior rotational osteotomy, the other is prosthetic femoral head replacement arthroplasty. Surgical treatment for DON of the femoral head was done for 22 patients with 24 hips from 1986 to 2012 at our hospital. In our series, varus osteotomy was done to four patients, transtrochantric anterior rotational osteotomy was fourteen, and prosthetic femoral head replacement arthroplasty was four. Prosthetic replacement is not indicated as the initial surgical treatment in the young and early middle-aged patients. Osteotomy with the transposition of the weight-bearing portion is often chosen for the patients of DON, because many of these patients are young. However, patient treated with osteotomy needs long hospital stay, and sometimes fails to bone union because of pseudarthrosis. Recently, the patient is forced to shorten the length of hospital stay in Japan for medical cost containment policy. In addition to that, prosthetic replacement develops year by year and survival rate has improved. There is a possibility that prosthetic replacement will be adapted to the younger people instead of osteotomy in the future.

SESSION 1-3

## PATHOPHYSIOLOGY OF DYSBARIC OSTEONECROSIS

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It is known that the incidence rate of dysbaric osteonecrosis (DON) is high among divers. We have continued medical check-ups of divers since 1972. The total number of them is 952 by 2003. There are 442 cases of DON out of 952 divers (46.4%). We found that the occurrence of DON is related to the experience of bends-type decompression illness.

We also conducted some experiments using some kinds of animals to analyze pathophysiology of DON. From these examinations and medical check-ups, we assume the onset factors of DON as follows:

1) Long exposure to high pressure

2) Presence of a lot of adipocyte

3) Rapid decompressing

These conditions could cause DON. In other words, nitrogen dissolves much more in adipocyte, and the blood flow is slower around the adipocyte. The bone marrow cavity is semi-closed space. Therefore, bubbles were generated due to inappropriate decompression. After that the tissue pressure rose, and bone compartment syndrome was induced. As a result, blood flow and nitrogen discharge stopped.

The other important thing is intravascular obstruction. Nitrogen bubbles in the vascular cause blood coagulation. Nitrogen bubbles explode adipocyte, and discharge adipo into bone marrow cavity. As a result, bone marrow vascular was obstructed.

It is important to follow the standard table to avoid decompression illness. If symptom of decompression illness appeared, you should receive the recompression treatment and anticoagulant soon. Additionally, DON may appear to divers who have long experience of diving without decompression illness. Divers should receive a medical check-up regularly.

SESSION 1-4

## CIRCULATORY PHYSIOLOGICAL CHANGE IN SCUBA DIVING - COMPARISON BETWEEN SCUBA DIVING AND DAILY LIVING -

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OBJECT: Scuba Diving(SD) is loved by not only healthy young people but also elderly people and the disabled person as a recreation sport. Although loads, such as underwater high pressure and respiratory restriction, are applied, there are few researches about the influence on the body. Additionally evidences about the influence of SD for elderly people, people with illness and the disabled are very scarce, in order to carry out permission or restriction of SD.

Purpose of this research is to obtain the basic data about changes of the circulatory physiological index, and to know the influence on the body of SD, and to establish the standard of the safety and limit.

METHODS: Subject is 46 years old healthy male diving-instructor as a healthy typical diver.

The portable Holter recorder (FM-800:Fukuda Denshi Co., Ltd., Tokyo, Japan) was put on the body, blood pressure(BP), electrocardiogram and oxygen saturation(SpO2) were measured for 24 hours, including two SDs performed by wearing special dry suit for waterproofing. Each SD performed for about 40 minutes by the boat entry in the sea of Kume Island, Okinawa Japan. Data during SD and following usual life were compared

RESULTS: Maximal heart rate(HR) 144bpm was recorded soon after second SD, minimal HR 67 while sleeping. Average HR during SD was 107. Six single paroxysmal supra-ventricular contractions were observed, 3 during SD and 3 in usual living.

Maximal BP 219/106 (systolic / diastolic) was seen during SD, minimal BP 104/56 appeared in usual living. The average BP was 222/89 about first SD, 135/97 second SD, 120/85 in the daytime and 113/81 while night sleeping.

The range of SpO2 during two SDs was 90-99(average 97.2), during usual living 83-98, maximal SpO2 99 was seen only during SD, the minimal 83 during usual living.

DISCUSSION: Although some reports about HR and electrocardiogram in SD are found, neither SpO2 nor especially BP in SD is seen. The purpose of this study is, first of all, to obtain the data about them. Measuring BP underwater is very difficult, but it has become possible to obtain it by this method at last.

Although it seems that the value of BP becomes higher than usual living, more data accumulation and considerations are necessary.

SESSION 1-5

## A CONSIDERATION OF HYPOXIC STATE FOR THOSE WHO ENGAGED IN HYPERBARIC OXYGEN THERAPY

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Every creature on the Earth breathes the air for its existence, that is, the Oxygen is inevitable for the Lives on the Earth. However, its concentration in the air has not been constant throughout the terrestrial history, but has been fluctuating. When its concentration was rich in the air, the Big Bang of the evolution of the lives was found in the fossils of the Cambrian period. On the other hand, when its concentration became poor all of a sudden, many a creature died away, and some of the so-called great extinctions are said to be caused by this condition, especially massive extinction of Permian-Triassic border. Only some privileged creatures could manage to survive through the adverse condition by the help of the mechanism to cope with this oxygen deficient environment. If not so , they must also have been swept away from the Earth history. And this mechanism was provided by the factor, now known as the Hypoxia Inducible Factor.

A tiny life in the land water, you may find a kind of Plankton, named Water-Flee. This creature has peculiar nature, when it is exposed to oxygen poor environment, its color turned into thick red, because its hemoglobin synthesis promoted by HIF. And this mechanism is the very proof of the survival of the lives from oxygen deficiency.

We, being engaged in the Hyperbaric Oxygen Therapy, no need to say, must have knowledge of the oxygen rich state, but also of the oxygen poor state, for the whole understanding of the oxygen utilizing mechanism of all the terrestrial lives. We review the history of the fluctuation of the oxygen concentration and its effects on the lives, so that we may come to better understanding of oxygen behavior in the human body, both in its poor and rich environment.

**SESSION 1-6**

## HBOT OF CARBON MONOXIDE POISONING IN BUENOS AIRES, ARGENTINA ANALYSIS OF 2101 CONSECUTIVE CASES AND 16 CASES OF DELAYED NEUROLOGIC SYNDROME

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INTRODUCTION: Carbon monoxide (CO) poisoning continues to be a significant public health issue. There is no agreement among the medical community about the specific indication and efficacy of HBO in the treatment of this condition. In Argentina CO is an accepted indication for HBOT. We present our experience in the HBOT of CO poisoning during recent years.

MATERIALS & METHODS: Clinical and demographic data and clinical outcomes of 2,101 victims of unintentional acute CO-poisoning treated in hyperbaric chambers in Buenos Aires from 1998 to 2011 are analyzed. Treatment goals included resolution of symptoms persisting after surface oxygen therapy and normalization of carboxyhemoglobin (COHb). Besides, 16 patients with neurologic complications (NC) of CO poisoning received HBOT included in the treatment scheme. Clinical correlation with imaging studies was conducted.

RESULTS: 2030 patients (94%) showed resolution of symptoms, notably persistent headaches and normalization of COHb after one HBO session at 2.8 ATA for 90 minutes. 63 patients presenting with more severe symptoms, received from 2 to 10 sessions with complete to partial improvement. Eight severely affected patients did not respond to HBOT. The main indication of HBOT was history of loss of consciousness, neurological symptoms and persistent headaches. 59% of patients had COHb levels from 20 to 39%. Rabdomyolisis confirmed by CPK test was observed in 21 patients (from 332 registered data). 95% of patients were treated during the first 12 hours after rescue, but 18 patients still symptomatic after 24 hours of NBO, showed symptom resolution with HBOT. Nine patients with NC demonstrated complete resolution of symptoms; others showed partial recovery or no effect. Two patients with definite neuro-psychiatric symptomatology after CO poisoning refused HBOT, their clinical picture remained unchanged.

The correlation of symptomatology with neuroimaging was poor, but MRI with DWI and with spectroscopy reflected clinical changes better than other techniques.

The highest incidence of CO poisoning was observed in June, July and August (winter) (73%) with moderate incidence in May and September (19%). The majority of patients were treated during the night and pre-dawn hours. The socio-economic level of CO victims was heterogeneous; that correlates with the general sources of poisoning: charcoal briquettes, water heaters, furnaces or gas-powered boilers.

CONCLUSION:

• A single HBOT was effective for resolution of symptoms in the vast majority of acute CO poisoned victims. A significant number of patients with more severe symptoms demonstrate improvement after continued HBOT.

・The use of HBOT seems to be beneficial for patients with neurologic complications after CO poisoning. The lack of a meaningful control group is recognized. There is a need for further research to define efficacy and optimal protocol for HBOT in neuro-psychiatric complications after CO poisoning.

Carbon monoxide poisoning, carboxyhemoglobin, neurologic complication after CO poisoning, HBOT in CO-poisoning.

SESSION 2-1

## CIRCULATING INTRAVASCULAR BUBBLES AND JAPANESE AMA DIVERS

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In the 1960s, neurological diving accidents were initially described in professional breath-hold (BH) pearl divers in the South Pacific as "Taravana" diving syndrome by Cross. The development after repetitive BH diving was thought to be extremely rare. However, similar cases have been reported in other BH divers including the Japanese Ama divers. A survey for 173 Ama divers showed 12 divers experienced neurological stroke-like symptoms during and after BH diving; 11 of 29 assisted divers and only one of 144 unassisted. Nowadays the neurological events have been known as decompression illness (DCI) caused by repetitive BH diving, and the incidence is not as low as one would like to think. Repetitive deep BH diving leads to nitrogen (N2) accumulation in blood and tissues, which will probably cause neurological DCI. In compressed air diving, there is a strong correlation between high level of venous bubbles and risk of DCI. While a large number of venous bubbles can be found in such diving, neurological DCI is not popular because the lungs constitute a complete filter for venous bubbles. However, neurological DCI occasionally happens in repetitive BH diving despite the difficulty of detecting intravascular bubbles.

The aim of our study was to detect circulating intravascular bubbles following repetitive BH diving in the local area where neurological DCI often occurred among Ama divers. Participants were twelve male partially assisted Ama divers (descent using weights). The equipment (AQUALAB system) used continuous-wave doppler with a frequency of 5 MHz, and the Doppler probe was placed in the precordial site, with the ultrasonic wave being directed into the pulmonary infundibulum. We recorded intravascular bubbles immediately after continuous diving for 3-4 hours, and the recordings were made on numerical tracks to be graded in a blind manner by two experienced investigators, according to the Spencer Doppler code.

All Ama divers used 20-kg weights. Dive depths and numbers were 8~20 meters and 75~131 times. Mean descending, bottom and ascending times, and surface interval were 9±2 sec, 38±8 sec, 16±3 sec and 63±12sec, respectively. We detected intravascular bubbles (Spencer's grade I) on an Ama diver whose mean surface interval was only 35 sec. Four Ama divers had experienced neurological disorders that were all transient and recovered completely. MRI of their brains showed multiple cerebral infarcts.

Intravascular bubbles are formed after repetitive BH diving with short surface intervals and probably cause neurological DCI in Ama divers. The most plausible mechanism of brain involvement is N2 bubbles retained or trapped in the pulmonary arteries and which are liable to pass through the lungs during BH diving and expand during each ascent and gather in the cerebral arteries.

SESSION 2-2

## LOW LEVELS OF MANGANESE SUPEROXIDE DISMUTASE ACTIVITY AND ELEVATED LEVELS OF TELOMERASE ACTIVITY IN MALIGNANT PHEOCHROMOCYTOMA

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BACKGROUND: Malignant pheochromocytoma is a life-threatening disease. Reliable foresight of harmful behavior on the justification of histopathology is occasionally difficult. While, extracts from neuroblastoma appeared to possess reduced superoxide dismutase(SOD) activities (1). Similar results were also obtained in benign pheochromocytoma tissuesue in our previous study (2). We analyzed SOD and telomerase activities in malignant pheochormocytoma with special reference to assess their

utility as prognostic markers.
METHODS: Specimens for superoxide dismutase were determined according to Oyanagui method (3) slightly modified by us (2). Telomerase activity of the identical tissue was done as previously described method (4). Sixteen benign pheochormocytomas, 3 malignant pheochromocytomas and 16 normal adrenal mdullae obtained from patients with renal cancer were analyzed in this study.
RESULTS: CuZn-SOD activities in normal adrenal medulla, benign pheochromocytoma and malignant pheochormocytoma were identical. Remarkably low level of Mn-SOD activity was observed in malignant pheochromocytom. Reduced Mn-SOD activity was also noted in benign pheochromocytoma, in lesser extent. No telomerase activity was detected in benign pheochromocytoma. By contrast, all of the 3 malignant pheochromocytomas had elevated telomerase activity.
CONCLUSIONS: Low level of Mn-SOD activity and the expression of telomerase activity suggest the malignant behavior of the component cells. Such expression appears to be used for the malignant pheochromocytomas.
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**SESSION 2-3**

## 5200M HIGH ALTITUDE 50M HELIUM-OXYGEN DIVING EXPERIMENT

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The simulated helium-oxygen dive experiment was conducted at the high altitude of 3000, 4000 and 5200 meters. The main purpose of this experiment is to calculate and verify the high altitude diving decompression program. The high & low pressure chamber-complex was used, and 4 professional divers participated in this experiment. The divers were stayed at the altitude of 3000, 4000 and 5200 meters for 2 days respectively. Totally 24 person-times of dives to the depths of 30-50 meters were operated; they stayed under the water for 60 min with helium-oxygen mixture gases. During the experiment, we studied the pressurization procedure, decompression table, medical and equipment support and physiological functions of the divers. The results indicate that, although the relative pressure differences between the surface and underwater was larger at high altitude than at sea level, the appropriate prolongation of the compression time was able to prevent the difficulty in pressure regulation for the divers to avoid the injury of middle ear. Four tables of the decompression procedures for different altitude were calculated with pressure corrections method using underwater stage stops. There were no signs and symptoms of decompression sickness and bubbles in the body of divers.
The physiological functions were recorded on divers at high altitudes and during diving time including central nerve system (event related potential (ERP), alpha attenuation coefficient (AAC)), autonomic nerve system (heart rate variability (HRV)) and circulation functions (cardiac output, stroke volume, blood pressure). The results indicated that compared with the values at sea level (50 m) in high altitude area the P300 latency was prolonged significantly after exposure to hypobaric-hypoxic conditions for 2 days with no significant change in amplitude. The divers AAC decreased, and their sleepiness and fatigue increased significantly at 3000, 4000 and 5200m. During the hyperbaric diving the AAC and subjective evaluation returned to the baseline value. The result of HRV indicated that acute hypoxia induced a decrease of TP, LF, LF/HF, reduce in parasympathetic and increase in sympathetic tone, which tended to be reversed with hyperbaric exposure. Diving had favorable effects on the cardiovascular response to high-altitude exposure and its control by the autonomic nervous system. At the same time, the divers symptoms of hypoxia were also relived. With strict organization, thoughtful and detailed medical security, precise and accurate equipment operation, this experiment was a great success. These results of the diving test indicate that our high altitude exposure procedure, diving compression and decompression table is effective and safe, and it could be extensively used for underwater construction and special military training in high altitude area.

**SESSION 2-4**

## THE EFFECT OF HIGH ALTITUDE DIVING ON HUMAN EEG AND SUBJECTIVE EVALUATION

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This study examined the effects of the high altitude and it's diving on spontaneous electroencephalographic activity of alpha attenuation coefficient (AAC) and subjective evaluation under exposure to 3000, 4000, 5200m and diving condition to 30 or 50m for 60min. Four professional divers participated in this experiment. They gave a written informed consent to the study, which was approved by the ethical committee of the hospital, for the volunteer informed written consent was also obtained. All the subjects were healthy and active, with an unremarkable previous history, and normal clinical examination. Each subject underwent the physiological and psychological examinations in a semi sitting at rest, and at a moderated level of exercise by using a cycle ergometer (cardiopulmonary exercise test, CPET), at sea level in Beijing (50m above sea level), and after arrival on the simulated high altitudes of 3,000,4000and 5200m. 4 divers participants (n=4) were asked to (a) sit quietly for 15-min adaptation, (b) carry out exercise bouts of 600Kgm/min on a cycle ergometer for 6 mins, and (c) sit quietly for a 5-min recovery period. The EEGs and subjective evaluation were carried out during the sea level, 3000,4000 and 5200m and diving condition. The experiments were conducted in a hypobaric-hyperbaric chamber controlled at a temperature of 25°C and a relative humidity of 50-60%. In our study, AAC (Alpha attenuation coefficient) was used as indices of central nervous system activity, and EEG was recorded by monopolar lead from the Fz, Cz and Pz locations according to the international 10/20 system, using a Ag/AgCl electrode and the left earlobe as a non-linked electrode reference. A digital multi-purpose electroencephalograph was used for amplification with a time constant 0.3 second and an upper cutoff frequency of 30Hz. For AAC, 1 minute eyes-closed resting and 1 minute eyes-open resting were repeated three times reciprocally, and EEG were digitized, on-line (sampling frequency 500Hz). Subjective performance sleepiness, mental fatigue was recorded before and after exercise immediately under each high altitude and diving exposure was carried out by 10-grade evaluation from 0 to 10.

The results of EEG recording at Pz showed that AAC was more decreased at high altitude than at sea lever and the speeds of recovery at Fz, Cz, and Pz were slower during the 5200m. The changes in AAC were most remarkable at Pz. after exercise. The level of sleepiness at the high altitude was significantly higher than those at the sea level and diving condition ($P<0.05$). All levels of fatigue showed a significant interaction between high altitude and exercise. These results suggest that during the condition of diving exposure the fatigue was more decrease than at high altitudes. It indicated more comfortable and advantageous to physical exercise and that the diving condition is beneficial for rest and fatigue recovery after work than at hypoxic exposure.

Conclusions: Our results suggest that at high altitude the human arousal and congnitive level of brain decreased but the sleepiness and fatigue increased. During the hyperbaric exposure AAC and subjective evaluation returned to the baseline value.

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**SESSION 2-5**

## HISTORY OF EVA SIMULATION TANK (WETS) AT JAXA TSUKUBA SPACE CENTER

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The Japanese module (Kibo/JEM, Japanese Experimental Module), and also other modules, of the International Space Station (ISS) was designed with ExtraVehicular Activities (EVA, space walk) as necessary procedure for activation and repair. Thus, its design verification incorporated water tank EVA simulation to validate astronaut hardware interface and procedures.

The simulation pool, the WETS (Weightless Environment Test System) was located at JAXA (Japan Aerospace Exploration Agency) Tsukuba Space Center, Tsukuba, Japan. It's construction generally followed the concept of the Neutral Buoyancy Simulator (NBS) at NASA Marshall Space Center (MSFC).

JAXA WETS pool had a depth of 10.5 m, with a circular plan shape with a diameter of 16 m. It allowed part mockup of JEM components to be submerged.

Besides two astronauts in NASA EMU space suites, a large group of SCUBA divers participated in diving operations. To accommodate NASA diving activity requirements, a multiplace hyperbaric chamber was installed on WETS pool deck.

There was no barotrauma case in EMU suite subjects. We observed two cases with suspected DCS which were presented at 1998 UHMS Seattle. Following discussion at the conference, one of the two cases was diagnosed to be alternobaric vertigo in ascent phase.

After the WETS water tank removal in spring 2012, there is no EVA simulation plan at JAXA. Keeping the diving operation experience is the theme to follow.

**SESSION 2-6**

## HOW DO WE THINK ABOUT THE PHYSICAL FITNESS TO DIVE AFTER THE TOF RADICAL OPERATION?

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SUMMARY: A forty four year old female recreational diver who underwent complete repair of a Tetralogy of Fallot (TOF) at the age of 5 years old asked us to evaluate her physical fitness to dive with the TOF restoration and to assess her cardiovascular condition as an adult, long after her original surgery. Since her surgery at age 5, she has been asymptomatic with no limitations to activity, and has remained healthy.

Surgical repair of the TOF provided complete reduction of the pulmonary infundibular stenosis, correction of the overriding aorta, and closure of the ventricular septal defect (VSD). Published reports of complete correction of TOF indicate that patients return to full activity without limitations, and surgical results have been in general good. It is not surprising that individuals with complete repair of TOF would undertake recreational diving as it is an interesting and enjoyable sport.

In this patient, cardiac status after complete correction of the TOF was evaluated with chest CT scan, echocardiogram, 24 hour Holter ECG and Exercise Tolerance Test. These studies indicated that the aortic valve functions normally, she has mild mitral regurgitation and moderate tricuspid regurgitation. Right and left ventricles function normally, some areas of hypokinesis are noted in the right ventricle likely related to the corrective surgery for TOF, no right to left or left to right shunts were seen.

Holter monitor shows very low frequency of premature atrial beats which are not considered to be abnormal. Her exercise stress test to 8 mets demonstrated exercise tolerance found in most other recreational divers. These data showed results as good as or better than many diver candidates with other cardiovascular diseases who are judged to be safe for recreational scuba diving.

Echocardiography did not demonstrate any impairment of cardiac function or anatomic abnormalities. She did not have pulmonic stenosis, pulmonary hypertension aortic or pulmonic regurgitation. Her tricuspid regurgitation was moderate and did not result in any impairment of right ventricular function or impairment of physical capacity. This patient had already been diving for sixteen years without incident at the time she appeared for evaluation of her cardiac status.

CONCLUSION: Patients with complex congenital heart disease who undergo corrective surgery and are shown to have good exercise tolerance, normal cardiac function and absence of serious arrhythmias are safe for recreational diving. This patient is an excellent example of the ability of these patients who undergo complete surgical correction to return to a normal life that can include recreational scuba diving. Periodic evaluation using echocardiography, exercise testing and Holter monitoring are adequate to determine fitness for diving in such patients.

**SESSION 3-1**

## MALIGNANT BRAIN TUMOR TREATMENTS USING HYPERBARIC OXYGEN

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Over the past 50 years hyperbaric oxygen therapy ($HBO_2$) has been used in a wide variety of medical conditions; this therapy increases the oxygen supply to hypoxic tissues independent of hemoglobin. $HBO_2$ is used for the enhancement of radiosensitivity in the treatment of some cancers including malignant gliomas of the brain. The presence of hypoxic tumor cells is widely regarded as one of the major reasons for failure to control malignant tumors with radiotherapy and/or chemotherapy.

Since molecular oxygen has long been recognized as one of the most powerful modifiers of cellular radiation sensitivity, $HBO_2$ has been used in combination with radiotherapy to treat malignant tumors. A recent meta-analysis in cancers of the head and neck shows that hypoxic modification improved tumor control and mortality and that $HBO_2$ resulted in greater benefit compared with other forms. A clinical trial of malignant gliomas treated with radiation during $HBO_2$ appeared to confer survival benefit for patients. However, this method in which each irradiation was administered into a pressure chamber was hazardous and complex. In this context, irradiation after $HBO_2$, a new treatment regimen which has been performed at several institutes, shows the therapeutic feasibility for malignant gliomas. Recently, a long-term treatment result in 57 patients with malignant gliomas shows a possible advantage to adding $HBO_2$ compared with historical controls.

Hypoxic tumor cells have low growth fractions leading to relative resistance to chemotherapy. $HBO_2$ has been shown to potentiate the cytotoxic effects of some chemotherapeutic agents in experimental models; however, in the English literature there are no reports suggesting improvement of chemotherapy with $HBO_2$ in cancer patients. A non-randomized clinical trial shows a significant advantage in survival for relapsed malignant gliomas using carboplatin chemotherapy with $HBO_2$. This

adjunct treatment is to expose to one session of $HBO_2$ after administration of carboplatin. Furthermore $HBO_2$ is applied for the treatment and/or prevention of radiation-induced brain injury after stereotactic radiosurgery. A clinical study evaluating the prophylactic effect of $HBO_2$ shows a lower rate of radiation injury at 1 year. We reviewed the literature to evaluate the manner in which $HBO_2$ contributes to the fields of treatments for malignant brain tumors.

SESSION 3-2

## INCREASE OF MUSCLE REGENERATION BY HYPERBARIC OXYGEN TREATMENT IN A RAT MODEL OF SKELETAL MUSCLE INJURY.

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OBJECTIVE: Hyperbaric oxygen (HBO) treatment is an increasingly popular treatment for athletes suffering from muscle injury. However, the mechanism of HBO treatment has yet to be defined. In this study, we investigated whether HBO treatment promoted muscle regeneration, modulated regulatory factor expression, and accelerate healing from muscle injury by using a rat model of skeletal muscle injury model.

METHODS: Muscle injury was induced by injection of cardiotoxin (CTX) into bilateral tibialis anterior muscles. Rats were divided into two subgroups with HBO or without HBO treatment (NT). Rats in the HBO group were placed in the animal chamber with 100% of oxygen under 2.5 ATA for 2 h/day for 10 times in two weeks. Muscle samples were taken at day 0, 1, 3, 5, 8 and 15 after CTX injection. We performed measurements of muscle weight, muscle contractile force, quantitative mRNA expression analyses of muscle differentiation regulatory factors and histological analyses.

RESULTS: The size of regenerative muscle fibers was significantly increased in the HBO group compared to the NT groups at 5, 8 and15d after CTX injection. The muscle contractile force of the HBO group was significantly higher than the NT group at 8d after CTX injection. The expressions of MyoD, Myogenin and IGF-1 mRNA were significantly increased in the HBO group at 3 and 5d after CTX injection, but the expression of other factors was not significantly different between the groups.

CONCLUSION: HBO treatment increased the size and the contractile function of regenerating muscle fibers, and expression of MyoD, Myogenin and IGF-1 after myotoxic injury. These results suggest that HBO treatment accelerates healing from muscle injury by promoted differentiation of myoblast.

SESSION 3-3

## LEGAL ASPECTS OF OXYGEN IN DIVING ACTIVITIES IN JAPAN

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Although oxygen is well appreciated in the world as a key gas in promoting diving activities, its use is under strict regulations in Japan. For examples, current Pharmaceutical Affairs Law restricts the distribution of oxygen only to the approved wholesalers. Dive companies are not allowed to purchase oxygen. Ordinance on Industrial Safety and Health and the Ordinance on Safety and Health of Work under High Pressure forbid the use of oxygen for divers underwater. As these regulations and restrictions tend to impede smooth practice and progress of diving, broad interpretations of the regulations are employed and official circular notices are sometimes issued to help solve the problems. Despite these efforts, there are still many problems related. Legal aspects on the use of oxygen in diving so far will be discussed for further reexaminations of the regulations underway.

SESSION 3-4

## INDUCIBLE FACTORS OF DECOMPRESSION SICKNESS OF LEISURE DIVERS -A STUDY ABOUT DIFFERENCES OF DIVING AREA-

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PURPOSE: We had already studied about inducible factors of decompression sickness from the view of physical condition, environment and behaviors before, during and after diving, compared between divers with the sick and without the sick. However, it is well known that diving styles are quite different depending on diving area. Here, we will present inducible factors of decompression sickness with reanalyzing diving styles and with increasing sample number.

SUBJECTS/METHODS: Decompression-sickness group (DS) assigned 232 patients, who diagnosed as decompression sickness by Tokyo Medical and Dental University Hospital, and control group (C) included 398 healthy divers. All volunteers were asked 35 questions about personal profiles, conditions on the diving day, diving deepness and numbers of diving, and other diving

profiles. The answers were statistically analyzed about relationship on the decompression sickness. Statistical analyzes were performed between groups by Wicoxon rank sum test. Moreover, odds ratios were available for evaluation of the risk.

RESULTS/DISCUSSION: Diving area were mainly following three points: Izu, Okinawa and other countries. Diving styles showed different among in diving area. Common style in Izu area was day trip or 1-night stay with 2 dives a day. However, in Okinawa and other countries area, stay periods were likely longer and numbers of diving larger than in Izu. Here, we focused on Izu area (DS: n = 67, C: n = 377), where number of volunteers was highest in our collecting data. Similar tendencies showed with the results in our previous study (limited number and all sampled area), except that odds ratio of "did you dive three or more today?" became nearly value with other risk factors. This results suggest inducible factors might be confliction on risk factors such as longer diving over decomposition time, suddenly coming to the surface and dehydration. Results analyzed in Okinawa and other countries area also showed similar directions: DS had dived with the risky diving way, like to dive deeper compared with C.

SESSION 3-5

## DELAYED DYSBARIC SYMPTOMS AND HBOT IN RECREATIONAL DIVERS

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INTRODUCTION: Five cases of decompression sickness are reviewed in which recompression treatment was delayed for 12 hours or longer after the onset of dysbaric symptoms. Two patients had pain only. The other two patients had more serious decompression sickness with numbness, limb pains and weakness, nausea/vomiting; one patient had decompression sickness of internal ear.

MATERIALS & METHODS REVIEW OF CASES: One patient received HBOT (Table 5 US NAVY) and then continued 9 treatments at 2.0 ATA for 60 min. till symptoms disappearance. Three patients received 6-10 HBOT sessions at 2.0ATA 60 min. each, and the fifth normobaric oxygen (1 hour per day) during 1 month

A 56 years old male patient (history of seminoma and successful surgery in 2001) consulted after 3 weeks of diving with rapid decompression. Referred pain in the right elbow, which appeared in 48 hours after the immersion with relief in certain position.

A 35 years old male patient (history of fracture of the left shoulder treated with internal fixation conserved till the moment, and open angle glaucoma), moderate obesity. The dive was realized 4 months ago in cold water, and after 2 hours post surfacing began with thorax pain, pain in both upper limbs, which was changing in intensity. The specific treatment was denied at the clinic near the site of diving. The patient continued with numbness, limb pains and weakness. In 2 weeks appeared hypersensitivity in the right leg. In 3 weeks cramps in lower limbs. Continues with symptoms.

A 42 years old male patient consults after 12 days post diving for pain in the nape, and strong pain in the lower limbs, headaches, nausea/vomiting, weakness, and fatigue. After surfacing suffered nausea/vomiting, weakness, but hasn't sought for medical aid referring the symptoms to neuropathy. Then the symptoms alleviated but returned 6 days later.

A 33 years old male patient received one HBO session (Table 5) because of decompression sickness type I 6 days after diving at the place near the diving location. Suffered thorax pain, pain in the left arm, vomiting, transpiration, difficulty in concentration, anxiety, and distress. The symptoms returned some days after the HBOT. Consulted us 8 days later, (14 days after dive).

A 59 years old male patient. Four months ago suffered pain in the left ear and tinnitus during diving realizing Valsalva maneuver. Denies laberintic symptoms. Otolaryngologist diagnosed acute otitis media. In 3 weeks hypoacusia was diagnosed with loss of audition progressively from 500 Hz till 8000 Hz. Treated with steroids. MRI ruled out internal ear trauma.

RESULTS: Four patients recovered either completely (1.3.4) or substantially (2) associated with treatment, although it was not a standard recompression protocols. One patient (5) continued without improvement.

Conclusion: Late treatment of decompression sickness seems to be beneficial, but long delays may present lack of response or result less successful. Although some hyperbaric facilities are located far away from recreational diving sites, hyperbaric staff should be ready for hyperbaric treatments for diving pathology.

SESSION 3-6

## TREATMENT OF DECOMPRESSION ILLNESS USING A MONOPLACE CHAMBER

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Although the best and basic approach to the treatment of decompression illness is prompt recompression on oxygen in a multiplace recompression chamber, limited locations

of medical facilities equipped with multiplace chamber in Japan may lead to considerable delay of treatment. Also high altitude exposure over 1000m during evacuation is unavoidable in some cases. To improve this unfavorable situation, the use of monoplace chamber equipped in more than 500 hospitals/clinics in wide area of Japan should be encouraged to pursue. Problems and feasibility of the treatment using monoplace chamber will be discussed.

SESSION 4-1

## "TEARS OF THE MOON" — THE CREATION OF SOUTH SEA PEARLS.

**Robert M Wong**
**The former Director of dept. of Hyperbaric Medicine, Fremantle Hospital, Diving medical consultant to the Australian Pearl Producers**

This paper gives an historical perspective of the evolution of diving technique and its problems, with subsequent modifications to make diving safe and a brief account on the technique of creation of cultured pearls.
Commercial pearl fishing (collection of mother of pearl shells) began in Broome, a township north-west of Western Australia, towards the end of the 19th Century. Compressed air diving gave rise to a high prevalence of Decompression Sickness. The diving technique was developed by trial and error without any scientific verification. With the introduction of the technique of cultured pearls after World War II, the industry flourished after the decline in the 1950s. This paper gives a bird's eye view of the creation of cultured pearls, and the evolutionary process of the dive profiles, from the original "trial and error" to the use of scientific techniques available.

SESSION 4-2

## BROOME—MODIFICATION OF PEARL DIVING PROFILES FOR SAFER DECOMPRESSION

**Ronald Y. Nishi**

The pearl divers of Broome in Australia carry out multiple repetitive dives at depths between 11 and 23 metres of seawater (msw) with 20 min surface intervals between individual dives for about 12 hours a day for eight consecutive days. For example, at 21 msw, nine 40-minute bottom time dives could be carried out every 20 minutes. Developed empirically over the years by trial and error, these dives had a high incidence of decompression sickness (DCS). In 1990, owing to regulatory pressures, modifications (suggested and implemented by the divers) were made to the multiple dive profiles to try to make them safer. These profiles were tested in a dry hyperbaric chamber by monitoring the divers for venous gas emboli (VGE) with a Doppler ultrasonic bubble detector and were found to cause high levels of VGE and DCS. The DCIEM™ air decompression model was used to analyze the complete sequence of repetitive dives and to modify the decompression requirements to provide adequate decompression while maintaining the same bottom time and frequency of diving used in the past. These modified tables were tested in the hyperbaric chamber and at sea and further modifications made with additional oxygen at the decompression stops until the dives were deemed to be acceptable. A "probabilistic bubble evolution" model was also used to assess the risk of DCS and to "fine-tune" the profiles. Since the modified dive profiles have been in use, the incidence of DCS has been extremely low.

SESSION 4-3

## PROPOSAL OF AMENDMENTS TO THE RULES FOR STANDARD DECOMPRESSION TABLE

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From 2004 to 2007, basic research to clarify the amendments of decompression table standard listed in the Safety and Health Regulations has been implemented as a project Research Occupational Safety and Health. Current decompression table was revised before 50 years.
There are several challenges of standard decompression table, the following points are noted especially.

① In a large depth and long hours of work, the current decompression table has a high incidence of decompression sickness.
② Calculation process of decompression table is unclear.
③ Table 2 Maximum depth is displayed until 90m has not been used much.
④ Oxygen and mixed gas breathing matters to prevent decompression sickness, has not been established.

For this reason, we have established a procedure for calculating the decompression table that employs a new decompression theory, to standardize the breathing gas mixed with oxygen, taking into account safety and efficiency. Furthermore, in the performance of the caisson, we investigated the incidence of decompression sickness due to the presence or absence of oxygen breathing and depth. Then, analyze the results, we reflected on the calculation process as a "safety factor". Thus, and performance, we have created the fusion theory a safer decompression table. However, there is no data for diving and its performance is not reflected.
Ministry of Health, Labour and Welfare has held "Safety and Health Regulations Review Committee amendment". However the adoption of this plan is uncertain. This decompression table is defined as a rule the penalties are

imposed on businesses if you do not follow it. Therefore, we must determine the decompression table to achieve both safety and commercial viability.
Although it is very difficult, the amendment decompression table shall provide users with most value.

SESSION 4-4

## THE DESIGN OF A THERAPEUTIC HYPERBARIC FACILITY FOR EMERGENCIES

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Summary: The acceptance of hyperbaric oxygen ($HBO_2$) as a legitimate drug for certain indications has led to the expansion of therapeutic hyperbaric centers worldwide with a huge variety of designs depending on local resources and the specialty and interest of the $HBO_2$ director and local surroundings. This diversity of structure of hyperbaric centers also holds true for Europe, also within each separate European country.
Treatment with $HBO_2$ requires a hyperbaric chamber with appropriate medical equipment and supervision of properly trained medical staff so that oxygen can be breathed safely at pressure by the patient. These requirements can best be fulfilled in a hospital based $HBO_2$ facility. Stand-alone out-patient $HBO_2$ and wound care facilities can be run professionally but should not in general be the basic facility for emergencies.
$HBO_2$ treatment centers with personnel and equipment for treating critically ill patients on a 24-hour basis should be regionalized to major trauma centers to keep up quality and cost effectiveness. Well functioning helicopter and other emergency transportation services are necessary. Time to treatment is crucial for acute indications for $HBO_2$ e.g. cerebral arterial gas embolism in a comatose diver after free ascent or the anesthetized patient not waking up after open heart surgery; the burn victim with inhalation injuries and CO & cyanide intoxication or the streptococcal “toxic shock” septic patient with necrotizing fasciitis. In general, the earlier these patients with potentially life-threatening conditions are treated, the better the outcome.
Monoplace and/ or multiplace chambers can generally both safely be used as HBO delivery tools but should be operated and maintained according to international guidelines and regulations. Acrylic monoplace chambers pressurized with oxygen provides cost-efficient, individualized and patient friendly delivery of $HBO_2$, especially for awake spontaneously breathing children. Monoplace chambers are also used for mechanically ventilated ICU patients in USA and other parts of the world but not in Europe. The multiplace chamber is ideally suited for $HBO_2$ therapy of the critically ill ventilator-dependent patient with failing vital functions. The larger air compressed multiplace chamber allows appropriate ICU equipment to be used and continuous "hands-on" intensive care by an accompanying physician and/or nurse. Close proximity to ICU is strongly recommended. An Intensive Care Hyperbaric Chamber System should preferably enable $HBO_2$ therapy without having to change the patient’s bed, monitoring, ventilator, infusion pumps or interrupt continuous renal replacement therapy. The chamber treatment rooms should resemble conventional modern intensive-care or trauma rooms. A rectangular chamber is recommended with easy to clean surfaces, washbasins and flexible air control ventilation system to provide good hygiene and infection control and a functional work environment for the staff.

Multidisciplinary guidelines should be established within the hospital for the correct use of HBO as a therapeutic drug. The $HBO_2$ facility should be incorporated into the hospital organization via educational efforts supported by the hospital administration. The quality of hyperbaric medicine practiced should be advanced by clinical research and development.

SESSION 4-5

## PREVALENCE OF SUDDEN CARDIAC DEATH RISK FACTORS IN SCUBA DIVERS

**Petar J. Denoble**
**Divers Alert Network**

BACKGROUNDS: Sudden cardiac death (SCD) is a major contributor to fatalities in scuba diving. Risk factors for SCD in middle-age and older subjects in general population are a history of cardio vascular diseases (CVD) and common cardiovascular risk factors. However, the prevalence of overt cardiovascular diseases (CVD) and cardiovascular risk factors in recreational divers was not studied. We have conducted a web administered survey to establish these factors among members of DAN.
METHODS: The aim was to establish prevalence of cardiovascular diseases including angina, myocardial infarction, pacemakers, cardiac surgery and stroke, and in addition diabetes Targeted involuntary risk factors were hypercholesterolemia, hypertension and obesity. Life style associated risk factors included current smoking, heavy drinking and lack of vigorous physical activities. We attempted this by an on-line questionnaire administered to the sample of DAN members. The survey comprised the core questionnaire of Behavioral Risk Factor Surveillance System (BRFSS) and few of its modules addressing SCD risk factors. The survey was adjusted and validated for on-line administration.

RESULTs: Survey was completed by 4876 participants. The mean age was 50.3 years (SD=12.4) years and median age was 52 years. Males represented 74% of participants, while females represented 26%. Prevalence of CVD was 4.6% (n=252). Diabetes was present in 3.6% (n=200), with an overlap of 0.62% (n=34) with CVD. Involuntary risk factors were present in 48.2% (n=2652), and lifestyle associated risk factors for CVD in 23% (n=1263). Simultaneous presence of at least one risk factors from each of the three groups was reported in 1.3% participants (n=71) and from any two groups in 18.2% participants (n=1003). Participants with reported CVD underwent medical control at least once per year in 99% of cases, those with involuntary risk factors in 97% cases, and those with risky lifestyle choices in 93% cases.

DISCUSSION: The prevalence of CVD, factor carrying the greatest risk of SCD, is much smaller among divers than in general population. Divers with CVD seem to use preventive medical services at least once a year and it appears that most have already modified their life style for better. Prevalence of the life style risk factors was less among participants than in general population. This may imply that existing medical filters and awareness among divers have already attenuated risk in these two subgroups making significant additional improvements unlikely. The prevalence of involuntary risk factors in divers was the largest of the three groups of risk factors and similar to prevalence in general population. On their own, in general population these factors increase risk of SCD only slightly but because of the size of population affected they generate most SCD. However, because of high prevalence and low associated risk, any preventive intervention targeting this group would yield little benefits. Furthermore, it is not known if and in what extent diving may affect risk of any of the factors in question. Thus, we need further studies to stratify risks, identify practical targets and proper interventions for prevention of SCD among divers in the future.