

E-NEWS

EDITOR'S NOTE – April 2024

The E-News is the monthly newsletter of CUHMA, the primary outlet to share news/announcements, upcoming events, abstracts of recent publications, job postings, professional perspectives, and images of relevant professional scenes. Submission of applicable content is welcome. New issues are released on the last business day of each month. Past issues are available at <https://cuhma.ca>. Direct correspondence to info@cuhma.ca.

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UPCOMING EVENTS

CUHMA Virtual Annual Scientific Meeting

This one-day online conference will be held Saturday, April 27. Registration fees are \$100 (regular member), \$75 (affiliate member), and \$200 (non-member). Visit: <https://cuhma.ca/cgi/page.cgi/annual-scientific-meeting.html>.

Ponza Rebreather Conference

The eighth iteration of the Ponza Rebreather Conference will be held May 8-12, 2024 on the island of Ponza, Italy (south of Rome and west of Naples in the Tyrrhenian Sea). Each day will include lectures and boat dives organized by the Ponza Diving Center. Visit: www.ponzadiving.com or info@ponzadiving.com.

UMC Level 2 Advanced Diving Medicine Course

Undersea Medicine Canada is offering a CSA Z275 Level 2 'Advanced Course in Diving Medicine: Diagnosis and Treatment.' This 6-day course will be held May 20-25, 2024 at the Atlantic Commercial Diving Centre in Summerside, PEI. Augmenting classroom instruction and case-based learning, site visits will allow observation of commercial diver training, diving, and hyperbaric chamber operations. A CSA Z275.2-15 Level 1 course or equivalent training is a prerequisite for this 45-h program. Find more information at <https://underseamedicine.ca> or contact Dr. Debbie Pestell at drdebl@ns.sympatico.ca or 902-225-8214.

UHMS Annual Scientific Meeting 2024

The annual scientific meeting of the Undersea and Hyperbaric Medical Association will be held June 12-15, 2024 in French Quarter of New Orleans. Visit: <https://www.uhms.org/education/annual-scientific-meeting/asm-registration.html#read-bio>.

EUBS Annual Scientific Meeting 2024

The 48th annual scientific meeting of the European Underwater and Baromedical Society will be held September 16-20 in the port city of Brest, France. The abstract submission deadline is April 16th. Visit: <https://eubs2024.sciencesconf.org>

RECENT PUBLICATIONS

Harris RJ, Challen CJ, Mitchell SJ. The first deep rebreather dive using hydrogen: case report. Diving Hyperb Med. 2024;54(1):69-72. doi: 10.28920/dhm54.1.65-68.

Bounce diving with rapid descents to very deep depths may provoke the high-pressure neurological syndrome (HPNS). The strategy of including small fractions of nitrogen in the respired gas to produce an anti-HPNS narcotic effect increases the gas density which may exceed recommended guidelines. In 2020 the 'Wetmules' dive team explored the Pearse Resurgence cave (New Zealand) to 245 m breathing trimix (approximately 4% oxygen, 91% helium and 5% nitrogen). Despite the presence of nitrogen, one diver experienced HPNS tremors beyond 200 m. The use of hydrogen (a light yet slightly narcotic gas) has been suggested as a solution to this problem but there are concerns, including the potential for ignition and explosion of hydrogen-containing gases, and accelerated heat loss. In February 2023 a single dive to 230 m was conducted in the Pearse Resurgence to experience hydrogen as a breathing gas in a deep bounce dive. Using an electronic closed-circuit rebreather, helihydrox (approximately 3% oxygen, 59% helium and 38% hydrogen) was breathed between 200 and 230 m. This was associated with amelioration of HPNS symptoms in the vulnerable diver and no obvious adverse effects. The use of hydrogen is a potential means of progressing deeper with effective HPNS amelioration while maintaining respired gas density within advised guidelines.

Imbert JP, Matity L, Massimelli JY, Bryson P. Review of saturation decompression procedures used in commercial diving. *Diving Hyperb Med.* 2024;54(1):23-38. doi: 10.28920/dhm54.1.23-38.

Introduction: This is a review of commercial heliox saturation decompression procedures. The scope does not include compression, storage depth or bell excursion dive procedures. The objectives are to: identify the sources of the procedures; trace their evolution; describe the current practice; and detect relevant trends. Methods: Eleven international commercial diving companies provided their diving manuals for review under a confidentiality agreement. Results: Modern commercial diving saturation procedures are derived from a small number of original procedures (United States Navy, Comex, and NORSOK). In the absence of relevant scientific studies since the late 80's, the companies have empirically adapted these procedures according to their needs and experience. Such adaptation has caused differences in decompression rates shallower than 60 msw, decompression rest stops and the decision to decompress linearly or stepwise. Nevertheless, the decompression procedures present a remarkable homogeneity in chamber PO₂ and daily decompression rates when deeper than 60 msw. The companies have also developed common rules of good practice; no final decompression should start with an initial ascending excursion; a minimum hold is required before starting a final decompression after an excursion dive. Recommendation is made for the divers to exercise during decompression. Conclusions: We observed a trend towards harmonisation within the companies that enforce international procedures, and, between companies through cooperation inside the committees of the industry associations.

Kangal KO, Mirasoglu B. Hyperbaric oxygen treatment for infants: retrospective analysis of 54 patients treated in two tertiary care centres. *Diving Hyperb Med.* 2024;54(1):9-15. doi: 10.28920/dhm54.1.9-15.

Introduction: We aimed to analyse the outcomes of hyperbaric oxygen treatment (HBOT) and describe difficulties encountered in infants, a rare patient population in this therapeutic intervention, with limited scientific reports. Methods: This was a retrospective analysis of patients 12 months old or younger who underwent HBOT in two different institutions. Demographic data, clinical presentation, HBOT indication, chamber type, oxygen delivery method, total number of treatments, outcome and complications were extracted from clinical records. Results: There were 54 infants in our study. The patients' median age was 3.5 (range 0-12) months. The major HBOT indication was acute carbon monoxide intoxication (n=32). A total of 275 HBOT treatments were administered, mostly performed in multiplace chambers (n=196, 71%). Only one patient (2%) required mechanical ventilation. Acute signs were fully resolved in the most

patients (n=40, 74%). No complications related to HBOT were reported. Conclusions: This study suggests that HBOT may be a safe and effective treatment for infants. Paediatricians should consider HBOT when indicated in infants even for the preterm age group.

Kondo N, Suzuki S. Preventive hyperbaric oxygen therapy for asymptomatic left ventricular air during CT-guided lung needle biopsy. *Cureus.* 2024 Mar 6;16(3):e55665. doi: 10.7759/cureus.55665. eCollection 2024 Mar.

Lung needle biopsy can cause air to enter the vessels due to the traffic between the vessels and the trachea. Hyperbaric oxygen therapy (HBOT) according to the U.S. Navy Treatment Table (USNTT) 6 or 6A protocol is used for arterial gas embolism (AGE). However, no treatment or HBOT protocol for asymptomatic intra-arterial air has been established. Here we report two cases of asymptomatic intra-arterial air during lung needle biopsy that were preventively treated with HBOT according to the USNTT 5 protocol. In case 1, a 72-year-old man with malignant lymphoma in remission underwent computed tomography (CT)-guided lung needle biopsy of a nodule in his right lung. During the biopsy, the patient developed a cough, followed by chest pain and dyspnea. Chest CT revealed a right pneumothorax and air in the left ventricle and aorta. The patient did not present with symptoms suggestive of AGE. After thoracic drainage, 4.5 hours after onset, the patient underwent HBOT according to the USNTT 5 protocol. After one session in the hyperbaric chamber, follow-up whole-body CT showed disappearance of intravascular air. In case 2, a 69-year-old man with chronic obstructive pulmonary disease underwent CT-guided lung needle biopsy of a nodule in his right lung. Post-examination CT showed intravascular air in the aorta, pulmonary artery and vein, and left ventricle. However, the patient had no symptoms. One hour after onset, the patient underwent HBOT according to the USNTT 5 protocol. A whole-body CT the next day confirmed the disappearance of intravascular air. Both patients were discharged without sequelae. HBOT is an effective treatment to flush out intra-arterial air and inhibit the expression of adhesion molecules. Asymptomatic intra-arterial air may be adequately treated with HBOT according to a short protocol such as USNTT 5.

Nobuhiro N, Heng P, Naoyuki H. The interaction of breath holding and muscle mechanoreflex on cardiovascular responses in breath-hold divers and non-breath-hold divers. *Eur J Appl Physiol.* 2024 Mar 5. doi: 10.1007/s00421-024-05431-4. Online ahead of print.

Cardiovascular responses to diving are characterized by two opposing responses: tachycardia resulting from exercise and bradycardia resulting from the apnea. The convergence of bradycardia and tachycardia may determine the cardiovascular responses to diving. The

purpose of this study was to investigate the interaction of breath holding and muscle mechanoreflex on cardiovascular responses in breath-hold divers (BHDs) and non-BHDs. We compared the cardiovascular responses to combined apnea and the mechanoreflex in BHDs and non-BHDs. All participants undertook three trials-apnea, passive leg cycling (PLC), and combined trials-for 30 s after rest. Cardiovascular variables were measured continuously. Nine BHD (male:female, 4:5; [mean±SD] age, 35±6 years; height, 168.6±4.6 cm; body mass, 58.4±5.9 kg) and eight non-BHD (male:female, 4:4; [mean±SD] age, 35±7 years; height, 163.9±9.1 cm; body mass, 55.6±7.2 kg) participants were included. Compared to the resting baseline, heart rate (HR) and cardiac output (CO) significantly decreased during the combined trial in the BHD group, while they significantly increased during the combined trials in the non-BHD group ($P<0.05$). Changes in the HR and CO were significantly lower in the BHD group than in the non-BHD group in the combined trial ($P<0.05$). These results suggest that bradycardia with apnea in BHDs is prioritized over tachycardia with the mechanoreflex, whereas that in non-BHDs is not. This finding implies that diving training changes the interaction between apnea and the mechanoreflex in cardiovascular control.

Oley MH, Oley MC, Kepel BJ, Faruk M, Wagiu AMJ, Sukarno I, Tulong MT, Sukarno V. Hyperbaric oxygen therapy for diabetic foot ulcers based on Wagner grading: a systematic review and meta-analysis. *Plast Reconstr Surg Glob Open.* 2024 Mar 25;12(3):e5692. doi: 10.1097/GOX.0000000000005692. eCollection 2024 Mar.

Background: Diabetic foot ulcers (DFUs) are common complications of uncontrolled diabetes mellitus that can result in infection and amputation of the lower extremities. This study compared the benefits and risks of hyperbaric oxygen therapy with those of other DFU treatments, based on the Wagner grading system. Methods: Systematic searches for randomly controlled trials using hyperbaric oxygen therapy for DFUs were performed using PubMed, the Cochrane Library, and Embase. Data regarding demographics, wound healing, minor and major amputations, operative debridement, nonhealing wounds, and adverse effects were analyzed based on Wagner grades, using RevMan 5.4.1 and Microsoft Excel. Results: Hyperbaric oxygen therapy was significantly superior to other treatments for wound healing rates 8 or more weeks after the final treatment (RR=2.39; 1.87-3.05; $P<0.00001$) minor/distal amputations (RR=0.58; 0.43-0.80; $P<0.007$), and major/proximal amputations (RR=0.31; 0.18-0.52; $P<0.00001$) for the 14 studies analyzed. In addition, this therapy increased the rate of complete wound healing for Wagner grades II (RR = 21.11; 3.05-146.03; $P = 0.002$), III (RR = 19.58; 2.82-135.94, $P = 0.003$), and IV (RR = 17.53; 2.45-125.44; $P = 0.004$); decreased the minor/distal

amputation rate for grade III (RR=0.06; 0.01-0.29; $P=0.0004$) and the major/proximal amputation rate on for grade IV (RR=0.08; 0.03-0.25; $P<0.0001$); and decreased the operative debridement rate for Wagner grade II (RR=0.09; 0.01-0.60; $P=0.01$). Conclusions: Moderate-quality evidence revealed that adjunctive hyperbaric oxygen therapy improved DFU wound healing for Wagner grades II, III, and IV; prevented minor and major amputations for grades III and IV, respectively; and prevented operative debridement in grade II wounds.

Quatre R, Delafosse B, Schmerber S, Soriano E. Decompression sickness of the inner ear and relationship with a patent oval foramen: a study of 61 cases. *Eur Arch Otorhinolaryngol.* 2024 Mar 12. doi: 10.1007/s00405-024-08544-w. Online ahead of print.

Objective: To discuss the link between inner ear decompression sickness and patent foramen ovale. Materials and methods: Monocentric and retrospective study on decompression sickness of the inner ear requiring hyperbaric chamber treatment, from 2014 to 2021. Results: Sixty-one patients of inner ear decompression sickness were included in this study. Twenty-four patients had vestibular injuries, 28 cochlear injuries and 9 cochleo-vestibular injuries. Compression chamber treatment was given, using an oxygen-helium mixture with oxygen partial pressure (PO₂) limited to 2.8 atmosphere absolute (ATA). All vestibular accidents completely recovered without clinical sequelae. For cochlear accident only 10 out of 37 patients (27%) recovered completely. A right-left shunt (patent foramen oval or intra-pulmonary shunt) was found in 31.1% of patients with inner ear decompression sickness ($p>0.05$). Conclusion: The presence of patent foramen oval in patients with inner ear decompression was not statistically significant in our study. Understanding of the pathophysiology of decompression illness and the physiology and anatomy of the labyrinth would suggest a mechanism of supersaturation with degassing in intra-labyrinthine liquids.

Toppen W, Cho NY, Sareh S, Kjellberg A, Medak A, Benharash P, Lindholm P. Contemporary national outcomes of hyperbaric oxygen therapy in necrotizing soft tissue infections. *PLoS One.* 2024 Mar 21;19(3):e0300738. doi: 10.1371/journal.pone.0300738. eCollection 2024.

Background: The role of hyperbaric oxygen therapy (HBOT) in necrotizing soft tissue infections (NSTI) is mainly based on small retrospective studies. A previous study using the 1998-2009 National Inpatient Sample (NIS) found HBOT to be associated with decreased mortality in NSTI. Given the argument of advancements in critical care, we aimed to investigate the continued role of HBOT in NSTI. Methods: The 2012-2020 National Inpatient Sample (NIS) was queried for NSTI admissions who received surgery. 60,481 patients between 2012-2020

were included, 600 (<1%) underwent HBOT. Primary outcome was in-hospital mortality. Secondary outcomes included amputation, hospital length of stay, and costs. A multivariate model was constructed to account for baseline differences in groups. Results: Age, gender, and comorbidities were similar between the two groups. On bivariate comparison, the HBOT group had lower mortality rate (<2% vs 5.9%, $p < 0.001$) and lower amputation rate (11.8% vs 18.3%, $p < 0.001$) however, longer lengths of stay (16.9 days vs 14.6 days, $p < 0.001$) and higher costs (\$54,000 vs \$46,000, $p < 0.001$). After multivariate analysis, HBOT was associated with decreased mortality (adjusted odds ratio (AOR) 0.22, 95% CI 0.09-0.53, $P < 0.001$) and lower risk of amputation (AOR 0.73, 95% CI 0.55-0.96, $P = 0.03$). HBO was associated with longer stays by 1.6 days (95% CI 0.4-2.7 days) and increased costs by \$7,800 (95% CI \$2,200-\$13,300), they also had significantly lower risks of non-home discharges (AOR 0.79, 95%CI 0.65-0.96). Conclusions: After correction for differences, HBOT was associated with decreased mortality, amputations, and non-home discharges in NSTI with the tradeoff of increase to costs and length of stay.

Tsushima R, Mori K, Imaki S. Secondary deterioration in a patient with cerebral and coronary arterial gas embolism after brief symptom resolution: a case report. *Diving Hyperb Med.* 2024;54(1):61-64. doi: 10.28920/dhm54.1.61-64.

Introduction: Hyperbaric oxygen treatment (HBOT) is recommended for arterial gas embolism (AGE) with severe symptoms. However, once symptoms subside, there may be a dilemma to treat or not. Case presentation: A 71-year-old man was noted to have a mass shadow in his left lung, and a transbronchial biopsy was performed with sedation. Flumazenil was intravenously administered at the end of the procedure. However, the patient remained comatose and developed bradycardia, hypotension, and ST-segment elevation in lead II. Although the ST changes spontaneously resolved, the patient had prolonged disorientation. Whole-body computed tomography revealed several black rounded lucencies in the left ventricle and brain, confirming AGE. The patient received oxygen and remained supine. His neurological symptoms gradually improved but worsened again, necessitating HBOT. HBOT was performed seven times, after which neurological symptoms resolved almost completely. Conclusions: AGE can secondarily deteriorate after symptoms have subsided. We recommend that HBOT be performed promptly once severe symptoms appear, even if they resolve spontaneously.

Turner BL, van Ooij PJA, Wingelaar TT, van Hulst RA, Endert EL, Clarijs P, Hoencamp R. Chain of events analysis in diving accidents treated by the Royal Netherlands Navy 1966-2023. *Diving Hyperb Med.* 2024;54(1):39-46. doi: 10.28920/dhm54.1.39-46.

Introduction: Diving injuries are influenced by a multitude of factors. Literature analysing the full chain of events in diving accidents influencing the occurrence of diving injuries is limited. A previously published 'chain of events analysis' (CEA) framework consists of five steps that may sequentially lead to a diving fatality. This study applied four of these steps to predominately non-lethal diving injuries and aims to determine the causes of diving injuries sustained by divers treated by the Diving Medical Centre of the Royal Netherlands Navy. Methods: This retrospective cohort study was performed on diving injuries treated by the Diving Medical Centre between 1966 and 2023. Baseline characteristics and information pertinent to all four steps of the reduced CEA model were extracted and recorded in a database. Results: A total of 288 cases met the inclusion criteria. In 111 cases, all four steps of the CEA model could be applied. Predisposing factors were identified in 261 (90%) cases, triggers in 142 (49%), disabling agents in 195 (68%), and 228 (79%) contained a (possible-) disabling condition. The sustained diving injury led to a fatality in seven cases (2%). The most frequent predisposing factor was health conditions (58%). Exertion (19%), primary diver errors (18%), and faulty equipment (17%) were the most frequently identified triggers. The ascent was the most frequent disabling agent (52%). Conclusions: The CEA framework was found to be a valuable tool in this analysis. Health factors present before diving were identified as the most frequent predisposing factors. Arterial gas emboli were the most lethal injury mechanism.

Wackett J, Devaney B, Chau R, Ho J, King N, Grewal J, Armstrong J, Mitra B. Reported outcome measures in necrotising soft tissue infections: a systematic review. *Diving Hyperb Med.* 2024;54(1):47-56. doi: 10.28920/dhm54.1.47-56.

Introduction: There are inconsistencies in outcome reporting for patients with necrotising soft tissue infections (NSTI). The aim of this study was to evaluate reported outcome measures in NSTI literature that could inform a core outcome set (COS) such as could be used in a study of hyperbaric oxygen in this indication. Methods: A systematic review of all NSTI literature identified from Cochrane, Ovid MEDLINE and Scopus databases as well as grey literature sources OpenGrey and the New York Academy of Medicine databases which met inclusion criteria and were published between 2010 and 2020 was performed. Studies were included if they reported on > 5 cases and presented clinical endpoints, patient related outcomes, or resource utilisation in NSTI patients. Studies did not have to include intervention. Two independent

researchers then extracted reported outcome measures. Similar outcomes were grouped and classified into domains to produce a structured inventory. An attempt was made to identify trends in outcome measures over time and by study design. Results: Three hundred and seventy-five studies were identified and included a total of 311 outcome measures. Forty eight percent (150/311) of outcome measures were reported by two or more studies. The four most frequently reported outcome measures were mortality without time specified, length of hospital stay, amputation performed, and number of debridements, reported in 298 (79.5%), 260 (69.3%), 156 (41.6%) and 151 (40.3%) studies respectively. Mortality outcomes were reported in 23 different ways. Randomised controlled trials (RCTs) were more likely to report 28-day mortality or 90-day mortality. The second most frequent amputation related outcome was level of amputation, reported in 7.5% (28/375) of studies. The most commonly reported patient-centred outcome was the SF-36 which was reported in 1.6% (6/375) of all studies and in 2/10 RCTs. Conclusions: There was wide variance in outcome measures in NSTI studies, further highlighting the need for a COS.

CUHMA-ACMHS is the Canadian voice for the advancement of hyperbaric and diving medicine throughout our country and beyond. Our activities include continuous medical education for physicians, nurses, respiratory therapists and anyone involved in the fields of hyperbaric and diving medicine. We are also promoting dissemination of clinical research, publishing position statements, liaising with related professional associations and government agencies. Our main goal is advocating on behalf of our patients. Our vision is to be the reference for the development and delivery of hyperbaric and diving medicine in Canada and beyond. Our mission is to promote excellence in hyperbaric and diving medicine through leadership in education, promotion of best practices and advocacy for our patients. Our values are excellence, leadership, collaboration, communication, and integrity.

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