CLINICAL HYPERBARIC MEDICINE
Session G
Clinical Hyperbaric Operations

G 1

Environmental cultures of hyperbaric chambers and treatment areas

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WITHDREW

G 2

Rates of myopia in patients receiving hyperbaric oxygen in multiplace chambers by hood or mask

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Introduction / Background: Myopia is a known side effect of hyperbaric oxygen (HBO2). In previous work we found that rates of myopia were similar between patients who were treated in monoplace and multiplace chambers (approximately 30%). Here, we report vision changes by multiplace chamber breathing apparatus.

Materials and Methods: We queried our patient dataset for multiplace patients receiving ≥20 HBO2 sessions with at least two weeks of vision checks by Snellen eye chart. Visual change was defined as myopia (Snellen test worsened to 20/40 or greater) or by loss of ≥2 lines. Patients were categorized by their preferred gas delivery system (hood or face mask). Data presented as mean±1SD (range).

Results: We identified 167 patients treated 1/2015-12/2019 as meeting inclusion criteria. Patients received 37±14 HBO2 treatments and were treated for radiation injury (n=66), compromised flap (n=41), osteomyelitis (n=30), diabetic wound (n=18), and other indications (n=12). All multiplace chamber sessions were delivered at 2.0 ATA, 100 minutes at pressure, with one 10-minute air breathing period. Sixty-eight patients received oxygen by hood, and 99 by mask. Nineteen patients (11%) experienced at least a two-line change by Snellen eye chart, 11 (7%) had decreased visual acuity to 20/40 or worse. In total, 22 patients (13%) had "myopia" by either definition. Fourteen of the patients with myopia received oxygen primarily by hood, and eight by mask. The overall rate of myopia for patients receiving oxygen by hood was 21% and 8% by mask.

Summary / Conclusion: In this retrospective review both hood and mask patients had lower rates of myopia than previously reported, possibly due to different patient inclusion criteria. Myopia was significantly less frequent in the mask group compared to the hood group. This result is consistent with refractive error changes measured in a recent randomized trial (Bennett MH, et al. Diving Hyperb Med. 2019 Dec 20;49(4):245-252).

G 3

Creative staffing solutions for a specialty hyperbaric medicine unit at a trauma center

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Introduction / Background: Hyperbaric Medicine at The University of Maryland Medical Center (UMMC) is one of only 10% of chambers in the United States available for emergencies. This team of specialists is available for consultation and serves Maryland, D.C., Delaware, and parts of Pennsylvania, Virginia and West Virginia. The unit is staffed with a minimum of one physician, three registered nurses (RNs), and two respiratory therapists (RTs) during normal business hours. Outside of normal business hours an on-call team of one physician, one RN, and one RT is available. Due to the high demand on all staff to cover normal business hours and call, a job-sharing program was implemented.

Materials and Methods: Partnerships were created within the nursing and respiratory therapy leadership teams. The hyperbaric RNs cross-trained to UMMC Shock Trauma Critical Care units and the RTs cross-trained to the UMMC Pulmonary Function Lab (PFT). After cross training, each RN worked one week per month in critical care and each RT worked one week per month in PFT.

Results: Additional RN and RT positions were approved as a result of this program. The additional staff reduced on-call requirement from one week per month to one week every five weeks. This job-sharing model also attracted interest from other UMMC critical care RNs and RTs. This increased the interest in becoming a hyperbaric staff member across the hospital.

Summary / Conclusion: Our specialty unit needed a unique approach to train many nurses and therapists to maintain around the clock operations. Our program achieved this and added the benefit of stronger collaborative relationships between the units.

G 4

Update: Incidence of DCS and oxygen toxicity in chamber attendants: A 36-year review of employee hyperbaric exposures

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Introduction / Background: Decompression sickness (DCS) and central nervous system (CNS) oxygen toxicity are recognized as inherent occupational risks for "inside attendants" (IAs) of hyperbaric chambers. At the University of California San Diego (UCSD) Hyperbaric Medicine Center, protocols have been developed to safely mitigate the risk profile while decompressing IAs.

Materials and Methods: The hyperbaric exposures were conducted in a 72-foot Class A multilock chamber. Occupational guidelines as described in departmental policy limits employees to one hyperbaric exposure within a 12-hour period. Individuals exposed to a U.S. Navy Treatment Table 6 (TT-6) are not utilized as IAs for a minimum of 24 hours.

- **Protocol 1:** For a total bottom time (TBT) of less than 80 minutes at 2.4 atmospheres absolute (ATA) or shallower, the U.S. Navy (1955) no-decompression tables were utilized.
- **Protocol 2:** For a TBT between 80 and 119 minutes, IAs breathed oxygen for 15 minutes prior to initiation of ascent.
- **Protocol 3:** For a TBT between 120 and 139 minutes IAs breathed oxygen for 30 minutes prior to ascent.

Results: These protocols have been in use for approximately 36 years and have produced zero cases of DCS or CNS oxygen toxicity. These results, based on almost 31,000 exposures, have an upper limit of risk of DCS and oxygen

toxicity of 0.01471 (95% CI) using UCSD IA decompression Protocol 1; 0.00013 for Protocol 2; and 0.00483 for Protocol 3.

These protocols have collectively been termed the "Newman Protocols" after their inventor, Dr. Tom Newman.

Summary / Conclusion: We conclude that the utilization of these protocols displays an impressive safety record for IAs, and should be adopted as standard operating procedures at other sea-level multiplace treatment chambers.

G 5

Anatomy of a safety pause: examining the continuous evolutions of a vital safety practice

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Introduction / Background: The advent of the safety pause, stop or time out prior to a critical procedure is not a novel concept. Taking cues from surgical safety time-out procedures and the Joint Commission, the Mayo Clinic has adopted this pretreatment process to enhance their safety program since 2007. Currently, the National Fire Protection Association 99 codebook mandates that a pretreatment safety check is performed and documented prior to each hyperbaric treatment. This report aims to provide a perspective of safety pause design and seeks to share these solutions with other programs that may face similar challenges.

Materials and Methods: The author will provide several examples of safety pause evolutions for monoplace and multiplace operations and explore enhanced strategies for successful document integration. Input derived from 12 years of practice experience and periodic safety committee review are examined.

Results: This paper provides the hyperbaric community with guidance in how to construct, review for efficacy, and effectively modify documents to support the pretreatment safety pause. Such a periodically applied process equips hyperbaric programs with tools that promote alignment with NFPA standards and UHMS accreditation guidelines.

Summary / Conclusion: It is important for hyperbaric programs to consider the experience of other institutions during the development of their own safety pause document to meet the unique needs of their practice. Examining this approach may ensure that critical safety components of this process are not missed and adverse events are avoided.

G 6

Hyperbaric oxygen therapy and closed irrigation for osteomyelitis of long bones

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Introduction / Background: Pyogenic osteomyelitis is an inflammatory disease of the bone marrow, cortical bone or periosteum caused by bacterial infection. Up to now it has been very difficult to cure. If not addressed at the initial treatment for infectious arthritis or acute osteomyelitis, infection will spread throughout the bone. Many patients are affected by the recurrence of chronic osteomyelitis. Moreover, an increase in multiple-resistance bacteria, opportunistic infection and traumatic osteomyelitis make it very complex to treat. We have treated many patients with pyogenic osteomyelitis using hyperbaric oxygen (HBO2) therapy and closed irrigation suction therapy. Recently we use "ozone nano-bubble water" in the irrigation. The main feature of the ozone nano-bubble is that it has an excellent antiseptic capability against bacteria and is harmless to the human body.

Materials and Methods: From January 2000 through December 2019, 269 patients with osteomyelitis of the long bones were treated with both antibiotics and HBO2. Debridement of infected granulation tissue, curation of sequestrum, and closed irrigation suction therapy was carried out. After the irrigation therapy, HBO2 is again carried out.

Results: 157 out of 269 cases (58.4%) were improved or healed conservatively, and another 96 cases (35.7%) were treated surgically in addition to having HBO2; 16 cases (5.9%) interrupted treatment without surgical treatment; 91 out of 96 cases (94.8%) treated with irrigation therapy were improved or healed. In total, 248 of 269 cases (92.1%) were successfully treated.

Summary / Conclusion: HBO2 is an effective treatment for pyogenic osteomyelitis; however, HBO2 alone was not sufficient for the case with sequestrum and/or severely infected granulation tissue. The combination of HBO2 and surgical treatment with irrigation is useful in such severe cases.

G 7

Suicide screening in the outpatient hyperbaric medicine setting

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Introduction / Background: In 2016 the Joint Commission issued an advisory recommending suicide risk assessment screening for all inpatient and outpatient settings. We report our experience implementing this recommendation in outpatients receiving hyperbaric oxygen (HBO2) therapy.

Materials and Methods: After review of the available outcome measures, we selected the Columbia-Suicide Severity Rating Scale (C-SSRS). The C-SSRS was administered verbally by the physician or advanced practice provider. To avoid conflict with inpatient safety initiatives we confined our screening to to adult outpatients receiving HBO2. We excluded patients with acute intentional carbon monoxide (CO) poisoning, as they were triaged to inpatient psychiatry after HBO2. We performed a monthly chart audit to assess implementation.

Results: Two months after initiation (April 2017), screening had returned to 0%. At that point we moved the screening from the initial HBO2 consultation to the procedural consent activity occurring with the first HBO2 treatment and bundling the C-SSRS forms with the procedural consents for routine patients. Following that change, we achieved 80-100% compliance for >1 year. We did not include the C-SSRS in the consent bundle for emergent patients because the transition to a new electronic medical record system limited our ability to standardize our care models at that time. In January 2019 we added the C-SSRS to the procedural consent bundle for acute CO poisoning and have consistently achieved our compliance targets since that time.

Of 242 outpatients treated with HBO2 over a 2.5- year period, 184 (76%) were screened for suicide ideation, and one responded in a manner that required triage. The patient was escorted to the emergency department. To the best of our knowledge, none of the patients we screened have completed suicide.

Summary / Conclusion: In this quality improvement initiative we achieved greatest compliance when the C-SSRS forms were bundled with the procedural consents completed at the first HBO2 session.

G 8

Patient preference of monoplace or multiplace hyperbaric chambers and hood/mask oxygen delivery systems

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WITHDREW

G 9

Go/No Go: the impact of a digital risk assessment tool and training on accurate completion of risk assessment process for prohibited items

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Introduction / Background: One of the cornerstones in hyperbaric safety is performing a 'Go/No Go' assessment prior to each treatment or new patient. Some facilities fail to evaluate products and document safety in a hyperbaric environment, per NFPA requirements. We measured the impact of a digital risk assessment tool (dRAT) on completion and documentation of the risk assessment.

Materials and Methods: Two U.S. hospital-based hyperbaric centers participated in this prospective, one-group pre-test/post-test study. Each safety officer (SO) received training on the dRAT and utilized it to perform and document the risk assessment process for 20 commonly seen prohibited items that were selected by the medical director (MD) at each facility. Outcomes were measured by external chart audits and surveys answered by the SOs before and after the intervention.

Results: Risk assessment was performed for 36 unique prohibited items. Material safety data sheet (MSDS) was not found for 23 items (63.9%). For the 13 items with MSDS (31.1%), seven (53.8%) lacked flashpoint information.

For each facility we analyzed 20 consecutive patient records immediately prior to training and eight after (n=56). In total, 463 (48.3%) of 958 treatments prior to training, and 153 (67.4%) of the 227 treatments after training indicated the presence of a prohibited item in the chamber. Among these, our intervention resulted in a statistically significant improvement in the number of treatments with a completed 'prohibited item' form, exceptions log notation signed by both SO/MD, and documented risk assessment (Chi-squared, p0.01 for all variables).

Surveyed SOs rated usability as 5/5 (easy) but still struggled to complete risk assessment for items that lacked complete MSDS information.

Summary / Conclusion: Utilization of the dRAT coupled with training on risk assessment and documentation significantly improved completion rate and documentation of the risk assessment process. Opportunities for continued improvement were identified. Processes were optimized and incorporated into each facility's EMR.

G 10

Operation of HBO2 therapy with monochamber in one tertiary hospital in South Korea

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Introduction / Background: Hyperbaric oxygen (HBO2) therapy has been advocated as a treatment for a wide variety of diseases in the clinical setting. Treatments are carried out according to the UHMS (Undersea and

Hyperbaric Medical Society) or ECHM (European Committee on Hyperbaric Medicine) guidelines, but the frequency of treatments may vary. This paper aims to share our experience of HBO2 therapy with a monoplace chamber.

Materials and Methods: This study is a retrospective observational study; data of patients who received HBO2 therapy during 40 months, from October 2016 to January 2020, were aggregated. Patients were classed according to 15 diseases, including the 14 criteria in UHMS guidelines with an additional class of DNS (delayed neuropsychiatric sequelae). The total number of patients and treatment sessions as well as the average treatment sessions of each classification are described comparatively.

Results: A total number of 383 patient received a total number of 3,317 HBO2 treatment sessions. Treatment for acute carbon monoxide (CO) intoxication, compromised graft and flaps, decompression sickness accounted for the most with 310, 18, 17 patients respectively. The average number of treatment sessions for delayed radiation injury, DNS, refractory OM accounted for the most with 28, 23.2, 14.7 sessions relatively.

Summary / Conclusion: In our HBO2 center acute CO intoxication patients accounted for the most treatments, and the highest average number of treatment sessions was for delayed radiation injury. The prevalence of diseases differs in countries: Hence the treatment on the basis of standard guideline with appropriate equipment and criteria for each center should be carried out.

G 11

Effect of antiplatelet and/or anticoagulation medication on the risk of tympanic barotrauma in hyperbaric oxygen therapy patients and development of a predictive model

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Introduction / Background: Middle ear barotrauma (MEBt) is a common side effect of hyperbaric oxygen (HBO2) therapy and can result in symptoms ranging from pain, hearing loss, tinnitus and otorrhagia. Use of antiplatelets/anticoagulants (AP/AC) has been postulated to increase the risk and severity of MEBt during HBO2 therapy.

Materials and Methods: This was a single-center, retrospective observational cohort study of all patients treated with HBO2 over a four-year period (January 1, 2015 to December 31, 2018) looking at incidence of MEBt and the concurrent use of AP/AC. MEBt was assessed by direct otoscopy of the tympanic membrane post HBO2 and scored using the modified Teed classification. An ordered (ternary) logistic regression model including age, sex, medication use and interactions was weighted by the number of HBO2 treatments completed. The model was optimized through backward elimination with least significant variables and interactions, (identified by joint tests and conforming to the hierarchical principle), removed until all remaining variables were significant at ≤0.05.

Results: We found no evidence to show that AP/AC medication increases the risk of tympanic barotrauma in HBO2 patients. The prevalence of MEBt was higher in female patients than in males (χ^2 P=0.004) and increased with age (χ^2 P=0.048). No MEBt was recorded in patients undergoing HBO2 for decompression sickness or cerebral arterial gas embolism. The predictive model had goodness of fit P>0.05 (the expected outcomes did not significantly differ from the observed outcomes) and the final predictive model is shown in Equation 1.

$$P(MEBt)/[1 - P(MEBt)] = \alpha_i - [0.3421 * Sex(M = 0,\ F = 1)] - [0.0148 * Age(yrs)] \quad \text{(Eq. 1)}$$

Summary / Conclusion: In this retrospective single-center study, AP/AC medication did not affect the risk of MEBt. However, both older age and female sex increased the risk of MEBt, compared with younger patients and males. Previous exposure to equalizing while diving appeared protective. The predictive model, while requiring further validation, may be helpful in assessing the likelihood of MEBt in HBO2 patients.

G 12

The role of hyperbaric oxygen therapy in adenovirus-/cytoxan-induced hemorrhagic cystitis

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Introduction / Background: Viral hemorrhagic cystitis (HC) is not an approved UHMS indication for hyperbaric oxygen (HBO2) therapy. However, adenovirus is detected in approximately 2% of all patients with severe hemorrhagic cystitis after undergoing hematopoietic stem cell transplantation (SCT). Given the number of patients undergoing SCT and the reported effectiveness of HBO2, the hyperbaric physician should be aware of adenovirus-induced HC.

Case Description: A 37-year-old male after autologousstem cell transplant that included high-dose cytoxan conditioning developed severe dysuria and hematuria, with adenovirus viremia.

He was admitted to the hospital. Several trials of antibiotics were ineffective. Cystoscopy noted diffuse erythema, ulceration, necrosis, hemorrhage and extensive degenerative changes. Prednisone, hydromorphone and gabapentin were ineffective. Urine viral studies were positive for adenovirus. Intravessicular cidofovir was initially ineffective. After two months without improvement, HBO2 therapy was started (2.0 ATA /two hours /five-minute air break). Gross hematuria resolved after treatment #16, with gradual waning of pain to resolution after treatment #20. Foley, cidofovir and HBO2 were discontinued after 21 total treatments. Unfortunately, pain and hematuria recurred after two weeks and persists. However, the patient has not required readmission, surgery or blood transfusions. Repeat cystoscopy six months post HBO2 therapy noted no lesions, mucosa slightly pale, some bleeding areas and terminal pinking of urine after distention.

Discussion: Consistent with previous case reports, this patient with multifactorial hemorrhagic cystitis (adenovirus, cytoxan) and severe blood loss anemia responded quickly and definitively to concurrent cidofovir and HBO2 therapy. Despite debilitating presentation, he initially experienced resolution of both pain and hematuria allowing hospital discharge. Although pain and hematuria recurred and continues to be problematic, it is manageable with standard outpatient therapy. This case supports the need for further investigation regarding HBO2 efficacy and protocols for adenovirus and cytoxan-induced hemorrhagic cystitis.

G 13

Carbon monoxide poisoning trend in South Korea 2016-2018

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Introduction / Background: Carbon monoxide (CO) is a colorless, odorless gas that can cause fatal poisoning when exposed in high concentrations even for short periods of time. In the past 20 years suicide from the burning of ignition charcoal, charcoal, and briquettes has been common in Asia. Our study aims to use national emergency department information system (NEDIS) data to describe the epidemiology of CO poisoning in South Korea.

Materials and Methods: We retrospectively analyzed emergency patients with CO poisoning disease codes or hyperbaric oxygen treatment prescription codes in NEDIS from January 2016 to December 2018. The clinical information – including time, mental state, age, gender, type of discharge, Korea triage acuity scale, intentionality – was examined.

Results: A total of 18,802 CO poisonings occurred over three years. The annual number of patients increased from 5,753 in 2016 to 7,152 in 2018 – approximately 23%. The gender distribution was 1:0.69, with more men intoxicated. The major age group was between 20 and 59 years old, accounting for 72% of all patients. From December to February the incidence of patients was relatively high compared to other periods during the winter season. Patients who attempted acute carbon monoxide poisoning as a method of suicide increased from 1,344 in 2016 to 1,962 in 2018 – about 46%. The results of ED examinations for carbon monoxide poisoning patients showed discharge (55.6%), transfer (11.2%), admission (31.2%), death (1.3%) and other (0.6%). 68% of all patients with CO poisoning had no access to hyperbaric oxygen (HBO2) therapy and were transferred to a hospital where HBO2 was available.

Summary / Conclusion: Through this analysis it was found that the number of CO poisoning patients is increasing, especially among those attempting suicide. Hyperbaric oxygen therapy devices are deployed only in some areas necessitating many interhospital transfers to other emergency departments. In the future, it is necessary to improve suicide patient management and the proper allocation ofHBO2 therapy devices.

G 14

Quality review for hypertensive patients receiving HBO2

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Introduction / Background: Therapeutic application of hyperbaric oxygen (HBO2) is accompanied by elevation of blood and tissue oxygenation, vasoconstriction, relative bradycardia, and reduction of glycemia in diabetic patients. We conducted a retrospective review of the records of 50 patients who had received HBO2 therapy at our Wound Center and Hyperbaric Facility at Memorial Hospital in Tampa.

Materials and Methods: The aim of this review was to investigate if hypertensive patients (systolic blood pressure (SBP) >130 mmHg, or diastolic (DBP) >90 mmHg) experienced a greater increase blood pressure after HBO2 treatments than non-hypertensive patients. Heart rate, systolic and diastolic blood pressure, and blood glucose in 50 diabetic patients were measured just before exposure to HBO2 and immediately after multiple treatments during 2018: 30 patients were exposed to 2.0 ATA for various wound care regimens while 20 were treated at 2.5 ATA post radiation injury or other indications, all in monoplace hyperbaric chambers. This quality review generated a recommendation for patient safety. Statistical comparison utilized paired t-tests and ANOVA.

Results: Mean SBP before and after HBO2 was 132.7 (± 23.4 SD) and 139.7 (±33.4) mmHg respectively. Mean DBP before and after HBO2 were 70.4 (±13.0) and 73.6 (±17.5). Mean heart rate before and after was 79.2 (±16.7) and 69.8 (±18.3) beats per minute bpm. Mean Blood glucose levels before and after HBO2 were 192.6 (±74.8) and 159.3 (±69.4) mg/dL respectively. All changes were highly significant.

ANOVA statistical comparison for all patients is reported in the Table. [SEE ATTACHED PDF]

Hypertensive patients after HBO2 did increase systolic pressures significantly more than non-hypertensive patients ($p<.0001$). Diastolic pressures approached significance.

Summary / Conclusion: We recommend that patients with hypertension before HBO2 treatment be carefully evaluated to avoid complications and should be treated with anti-hypertensive treatment before HBO2.

G 15

Joining the hyperbaric oxygen treatment registry consortium coordinated by Dartmouth: Experience of a large academic center

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Introduction / Background: Hyperbaric oxygen (HBO2) therapy has been used to treat various diseases for decades. However, a registry to record treatments, conditions treated, and outcomes has gained momentum only recently. Currently, two registries exist that address separate aspects of HBO2 therapy, one primarily for academic research and another geared toward documentation, outcomes, and quality metrics to insure future reimbursement. Both are not yet widely used but have the potential for general adoption and immense benefit to the field.

Materials/Methods: This case report describes the decisions and processes a large academic center made to join a registry and contribute data to it.

Results: After six months of coordination the University of California, San Diego (UCSD) joined the research-oriented Multicenter Registry for Hyperbaric Oxygen Therapy Consortium on January 1, 2020.

Summary/Conclusions: UCSD, as a member of the Registry Consortium, contributes to data-gathering and research for a multicenter group of hyperbaric centers of various sizes and settings. From proposal to participation, an arduous months-long process was undertaken, significantly facilitated by the Registry founders. Along the way, the methods for Institutional Review Board application and approval were explored and the available, free database (REDCap) for recording data was adopted.

Each new center brings value to the registry. At UCSD a couple of new challenges were encountered. Demographic differences in the patient population highlighted the need for questionnaires in other languages plus the greater incidence of dive-related accidents revealed the need for revisions in data collection parameters. Questionnaires in Spanish were created and more robust situational and clinical information for dive injuries were incorporated. The registry consortium was able to quickly address these issues and integrate solutions to minimize potential data loss. Ultimately, the research-oriented focus of the Registry made a great fit for our academic center, allowing our institution to easily evaluate quality metrics of our department.

G 16

Update on CHYMAERA - the Collaborative Hyperbaric Medicine and Extreme Environment Research Association Network

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Introduction / Background: Diving and hyperbaric medicine (DHM) has a great deal of trouble entering 'mainstream medicine.' Despite the best efforts of great pioneers in the field, we simply do not seem any closer to widespread acceptance from either academic institutions or our professional colleagues. The CHYMAERA Network is a global clinical trials and registry network. The aim is to foster meaningful clinical trials and registries in DHM.

Materials and Methods: CHYMAERA has an overall steering committee and is active in two distinct capacities: those primarily interested in the development of a comprehensive diving and hyperbaric medicine registry and those primarily interested in clinical research. CHYMAERA was first proposed as DAHMNet by the first author in March 2017 and embraced by the developers of two important initiatives developing registries for those having treatment in DHM facilities (Jay Buckey [U.S.] and David Cooper {Australia/NZ]). The organization has become rapidly more complex; the structure, purposes and personnel are available in a handbook available form the first author on application.

Members of CHYMAERA include dedicated researchers who are highly skilled in research methodology and have success in the coordination, conduct and management of randomized controlled trials. CTNs are about accumulating experience and wisdom concerning trialing, as well as empowering younger or inexperienced researchers to develop while assisting in meaningful research that will change practice.

Results: We have several groups active in promoting registries and primary research. Our role in the development of a comprehensive hyperbaric registry is to assist in the coordination of different efforts around the world – particularly in developing compatible platforms and data dictionaries. Active clinical research groups include radiation injury, problem wounds and necrotizing infections.

Summary / Conclusion: The development of high-quality evidence is paramount for DHM to continue to contribute to global health. CHYMAERA is an important avenue with great potential. We actively seek participants in this global initiative.

End Session G