Acute Traumatic Injuries

& Hyperbaric Oxygen Therapy

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Summary

Registered nurses adopt the role of life-long learners when they enter the field of nursing. To stay abreast of the latest technological advances in research, nurses must search for new knowledge and use evidence to define their practices; positive patient outcomes and elevating the profession of nursing are the desired results.

Evidence-based practice (EBP) is a paradigm that involves a methodological approach. Nurses must first take an active role in defining problems or issues in their clinical area and develop an answerable question. The clinical question also serves a role in determining the research design, theoretical perspective, and the appropriate tools to analyze the relevant data. The choice of diagnostics or treatments, the effects of treatments or care, the likely outcomes of a disease or condition, or the etiology of the illness may serve as generalized roots of clinical questions. The clinical question “In acute traumatic injuries (ATIs) treated with Hyperbaric Oxygen Therapy (HBOT) as compared to not using HBOT, what are the benefits of immediate treatment?” will guide the process of EBP.

The literature review helps nurses evaluate what is currently known about the topic, identify gaps in knowledge, and provides a basis for inquiry to formulate additional questions. A literature search using several databases was completed to acquire the evidence regarding HBOT practice as an adjunct or initial treatment of ATIs. The evidence was critically appraised for its research design, theoretical framework, and data sampling methods, validity and usefulness in clinical practice. The evidence and data was translated into practice that can be adopted to improve patient outcomes. The possible consequences of failing to incorporate best practices were examined. Finally, strategies for disseminating the evidence, and communication methods were discussed.

ACUTE TRAUMATIC INJURIES & HYPERBARIC OXYGEN THERAPY

BACKGROUND

The first documented use of Hyperbaric Oxygen Therapy (HBOT) dates back to 1662 and it was used to treat various diseases (Gill & Bell, 2004). HBOT is the definitive treatment for decompression illness (DCI) in scuba divers and has had successful results in treating various non-diving conditions.

Description of the Condition

Trauma, a sudden injury or wound caused by an external force (Trauma, 2015) is one of the leading causes of death of persons aged from 1 to 45 years of age (Peek-Asa, Zwerling, & Stallones, 2004). Delayed onset muscle soreness (DOMS) is a syndrome of pain, stiffness, and swelling in muscles several days after the initial insult. Traditional methods of treating ATIs and DOMS varies and can include rest, ice, elevation, splinting, massage, medications, physical therapy, stretching, surgery, and rehabilitation. An increasingly utilized non-traditional therapy for treating ATIs includes hyperbaric oxygen therapy (HBOT). This treatment has facilitated accelerated healing, earlier recoveries, and improved the prognosis of many disorders and injuries. However, HBOT in ATIs has gained criticism amongst providers as a primary and adjunct treatment modality.

Description of the Intervention

The Undersea and Hyperbaric Medical Society (UHMS) defines HBOT as a treatment that involves placing the patient in a specialized and enclosed chamber; the patient breathes in 100% oxygen under pressures greater than sea level (one atmosphere absolute, (ATA); it's use is limited to 3 ATA oxygen or the pressure placed on the body at 99' below the sea. This procedure increases the amount of oxygen dissolved in the blood and oxygen tension in the tissues. The specific effects of HBOT include (Kindwall & Whelan, 2008):

- Reduction of blood Flow in hyperoxic tissues
- No reduction of blood flow in hypoxic tissues
- Increase in healing of hypoxic wounds
- Reduction of carbon monoxide toxicity
- Improvement of bone repair
- Suppression of autoimmune responses
- Effects on blood cells
- Decrease in lipid peroxidation
- Improvement of tissue salvage in burns
- Improvement of viability in tissue flaps
- Improvement of tissue salvage in ischemia-reperfusion injury
- Improvement of nerve cell regeneration
- Formation of free radicals
- Decrease in surfactant production
- Oxygen toxicity
- Production of visual disturbances

Feasibility of the Intervention

First utilized as the definitive treatment for decompression sickness in scuba divers, HBOT has had successful results in treating various non-diving conditions and diseases through relieving tissue hypoxia, edema, and pain, improve elasticity of red blood cells and reducing platelet aggregation (Kindwall & Whelan, 2008). In recent years, HBOT has been used by professional athletes, (Effective Therapy for Sports Injury Recovery, 2011) to allow accelerated healing and obtain pre-injury status faster, and alleviate pain.

Costs Considerations of the Intervention

Economic factors should be considered when contemplating HBOT (Babul & Rhodes, 2010). Medicare and insurance companies recognize and reimburse HBOT for the following medical conditions: air or gas embolisms, anemia, carbon monoxide and cyanide poisoning, gas gangrene, chronic osteomyelitis, decompression sickness, radiation injury, aerobic and anaerobic infections, crush injuries, skin grafts and flaps, and diabetic and ischemic ulcers (Hyperbaric Oxygen Therapy, 2006). Off-label indications of HBOT include autism, cerebral palsy, Lyme disease, migraines, Multiple Sclerosis, near drowning, recovery from plastic surgery procedures, sports injuries, stroke, and traumatic brain injuries and may not be reimbursed by Medicare or insurance companies (FAQ, 2014).

The Role of the Hyperbaric Nurse

The specialty of hyperbaric nursing has evolved since the 1950s. Nurses provide care for patients in the altered environment of the hyperbaric chambers, through education, experience, and professional licensure (Certified Hyperbaric Nurse (CHRN), 2015). CHRNs have a multi-functional role, clinician, educator, and researcher. The goals of CHRNs are to provide safe, cost-effective, and quality patient care according to established standards of practice. The CHRN is often the primary provider in HBOT chamber rooms and facilitates the delivery of this treatment method. Nursing practice in this specialty area often includes activities within the medical domain (Kindwall & Whelan, 2008, p. 235).

OBJECTIVES

The primary purpose of this paper was to review the current literature and build additional knowledge about HBOT and its use in ATIs. The secondary purpose was examining the knowledge gained, critically appraise the literature, and apply the results of the primary purpose into evidence-based practice.

Evidence-Based Practice (EBP)

The Institute of Medicine (IOM) defines EBP as having three distinct factors: (1) best research evidence, (2) best clinical experience, and (3) consistency with patient values (Clinical Question Anatomy, 2012). The first step in EBP is to convert information needs into clinical questions (Polit & Beck, 2012, p. 36).

Barriers of EBP

The top three barriers to EBP identified in the literature includes the lack of time to search for and read research articles, the inability to understand statistical terms, and insufficient understanding of research terms used in articles. Effectively applying EBP requires the RN to identify gaps, formulate questions, conduct a literature search, evaluate validity, implement findings, and involve the patient (Majid, et al., 2011, p. 230).

Several resources are available to RNs who have difficulty understanding research terms represented in clinical trials and studies. A website called Understanding Research (Lythgoe, 2015) and instructional tools to understand difficult terminology (Johnson, Reineck, Daigle-Bjerke, Goupil, & Captain, 1995) are available resources. Additionally, the website Flying Start NHS (2015) provides a comprehensive electronic resource aimed at professionals who want to stay on track with their learning goals and defines strategies to overcome the barriers of EBP.

CRITICAL APPRAISAL

Critical appraisal is an essential part of EBP and consists of five steps; (1) Formulating questions into a format where you can interrogate the literature and find the answer using the PICOT tool, (2) Conduct a literature search to find the evidence, (3) Critically appraise the evidence, (4) Integrating the evidence, and (5) Implementing the evidence and evaluating outcomes (Polit & Beck, 2012, pp. 36-41).

Anatomy of Clinical Questions

The mnemonic PICOT helps researchers recall the four areas of clinical question formulation (Clinical Question Anatomy, 2012). Breaking up the question into its relevant parts allows the researcher to search for answers efficiently and effectively (Polit & Beck, 2012, p. 36).

- **P** Patient, population or problem
- **I** Intervention, Prognostic Factor, or Exposure
- **C** Comparison (if there is one)
- **O** Outcome
- **T** Time element

Clinical Question

In acute traumatic injuries (P) treated with HBOT (I) as compared to not using HBOT (C), what are the benefits (O) of immediate (T) treatment?

Search Methods

Terms

Search terms identify information in order to research a question. In general, nouns, noun phrases, and verbs found in the research question are utilized to construct database searches. Searching databases for research studies using search terms is a process and takes time. Trying different combinations of key words, synonyms, alternate spellings and associated words are considered "trial and error." Often the priority of search terms utilized will determine which research articles will be provided. Key words utilized to perform the literature search of the previously mentioned research questions are included in *Figure A*.

Literature Search

Database	Term(s)	Results	Relevant Articles
Cochrane Database of Systematic Reviews	Hyperbaric	27	7
Database of Abstracts and Reviews of Effects (DARE)	Hyperbaric	37	5
CINAHL Plus with Full Text	Hyperbaric	1,994	
	Hyperbaric and acute	161	
	Hyperbaric and acute and injury	40	16
MEDLINE with Full Text	Hyperbaric	15,043	
	Hyperbaric and acute	1,474	
	Hyperbaric and acute and injury	284	
	Hyperbaric and acute and injury and trauma	29	22
PsychINFO	Hyperbaric	71	
	Hyperbaric and acute	13	3
Evidence Updates	Hyperbaric	47	13
Joanna Briggs Institute EBP Database	Hyperbaric	25	7

Figure A

Electronic searches were utilized in gathering the literature from several different databases within the Walden Library (Searching for Evidence - Health Sciences & Nursing:

Where to Search, 2015). *Filtered databases* included the Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews and Effects (DARE), and Google Scholar. *Unfiltered databases* included CINAHL Plus with Full Text, Medline with Full Text, SUMsearch. *Guidelines and Summaries* included Evidence Updates, FPIN Cis and PURLS (MoSpace), the Joanna Briggs Institute EBP Database, and National Guideline Clearinghouse..

LITERATURE REVIEW

Data Collection

This literature review consisted of ten manuscripts relating to the use of HBOT in ATIs. The titles of all the studies were representative of the research conducted. All Systematic Reviews (SRs): Eskes 2013; Villanueva 2009; Bennett 2010, 2012a, 2012b, 2012c; Randomized Controlled Trials (RCTs): Bouachour 1996, Wolf 2012; Retrospective Studies (RSs): D'Agostino Dias 2008, Rogatsky 2007 contained abstracts that clearly summarized the main features of the manuscript and prominently stated objectives and hypothesized the importance of the studies. Cited references ranged across all the levels of the evidence hierarchy (Polit & Beck, p. 28) and dates of publication ranged from 1961 to 2011; Level II evidence was most prevalent and within the previous 10 years. SRs are not required to have Institutional Board Review (IRB) approval (Sullivan, 2011); the remaining four manuscripts all received IRB approval on the study protocol for human experimentation according to guidelines published in the Belmont Report (U.S. Department of Health & Human Services, 1979).

Systematic Reviews

<u>Comparison I:</u>

HBOT for treating acute surgical and traumatic wounds (Eskes, Vermeulen, Lucas, & Ubbink, 2013).

Four RCTs met inclusion criteria that involved 229 participants. Two independent variables (IVs) included HBOT only, and HBOT as an adjunct treatment; the dependent variables (DVs) included wound healing, and survival rates of the grafts/flaps; controlled variable (CV) represented no HBOT. Perrins 1967 studied burns which required skin grafts and reported increased survival rates of the grafts with use of HBOT. Vishwanath 2011 reported no significance in graft survival rates with HBOT. Bouachour 1996 reported a significant increase in wound healing and less necrotic tissue in crush injuries upon using HBOT. Xie 2007 reported no significance in graft survival rates using HBOT as compared to use of dexamethasone or heparin without HBOT as an adjunctive therapy. The SR authors concluded there was a lack of high-quality RCT evidence to support claims on the benefits of HBOT on wound healing. See Table 1.

Comparison II:

HBOT for thermal burns (Villanueva, Bennett, Wasiak, & Lehm, 2009).

Two RCTs met inclusion criteria which involved 141 participants. The IV was HBOT; DVs included acute fluid requirements, healing times, number of additional surgeries, lengths of stay (LOS), and adverse effects of HBOT; CV was no HBOT. Brannen 1997 reported no significant results in HBOT in thermal burns as compared to sham. Hart 1974 reported conflicting results; decreased healing times, fluid requirements and increased survival rates of skin grafts of the burn victims. The SR authors concluded there is no sufficient evidence to support or disclaim HBOT as a method to manage thermal burns. See Table 2.

Comparison III:

HBOT for delayed onset muscle soreness and closed soft tissue injury (Bennett, Best, Babul-Wellar, & Taunton, 2010).

Nine RCTs met inclusion criteria which included 219 participants. The IV was HBOT; DVs included healing times, functional outcome scores (FOS), pain, and swelling; CV was no HBOT. Two of those nine trials focused on HBOT versus sham in closed soft tissue injuries. Borromeo 1997 focused on ankle sprains; Soolsma 1996 studied medial collateral ligament (MCL) injuries. Neither trial produced evidence to support or disclaim HBOT as an adjunct therapy. The remaining seven trials examined the effects of HBOT on DOMS following eccentric exercise. Four of those studied HBOT effects on quadriceps muscles; two studied elbow flexors; one studied gastrocnemius. The SR authors concluded there was some evidence that HBOT may increase interim pain, however, there was not sufficient evidence to support HBOT use on soft tissue injuries or DOMS. See Table 3.

<u>Comparison IV:</u>

HBOT for promoting fracture healing and treating fracture non-union (Bennett, Stanford, & Turner, 2012).

No RCTs met inclusion criteria and the authors recommended further research in the area of HBOT for promoting fracture healing and non-union. See Table 4.

<u>Comparison V:</u>

HBOT for the adjunctive treatment of traumatic brain injury (Bennett, Trytko, & Jonker, 2012).

Seven RCTs met inclusion criteria and consisted of 571 participants. The IV was HBOT; DVs included FOS, mortality, activity of daily living (ADL), intracranial pressure (ICP) measurements, Glasgow Coma Scores (GCS), adverse effects, and costs; CV was no HBOT. The SR authors concluded HBOT may reduce the risk of death and improved GCS by a mean of 2.68 (which was difficult to interpret given an increase of GCS from three to six is negligible); there is little evidence survivors have a good outcome and quality of life given the extent of their TBIs. See Table 5.

Comparison VI:

Recompression and adjunctive therapy for decompression illness (Bennett, Lehm, Mitchell, & Wasiak, 2012).

Two RCTs met inclusion criteria and included 268 participants. Bennett 2003 compared HBOT and administration of a nonsteroidal anti-inflammatory drug (NSAID) to HBOT only. Drewry 1994 used Heliox (mixture of helium and oxygen) instead of 100% oxygen during recompression. The SR authors concluded HBOT is the first line treatment of DCI and there are no RCTs withholding HBOT for patient safety and ethical issues. The data showed a decrease in the number of recompression sessions needed in both RCTs, however, neither IV improved the recovery times or outcomes in DCI. See Table 6.

Randomized Controlled Trials

Comparison I:

Hyperbaric Oxygen Therapy in the Management of Crush Injuries: A Randomized Double-Blind Placebo-Controlled Clinical Trial (Bouachour, Cronier, Gouello, Toulemonde, Talha & Alquier, 1996).

Statement of Purpose

HBOT has been advocated to treat extremity trauma and associated surgeries because of the physiology effects of increased tissue oxygenation and infection prevention. This is the first RCT to examine the effects of HBOT on crush injuries.

Methods

A double-blinded randomized controlled clinical trial was approved by the Institutional Review Board of the University Hospital of Angers in France. Thirty six participants were enrolled in the study (HBOT group, n=18; placebo group, n=18); all patients received the standard treatments according to crush injury protocol; anticoagulants, antibiotics, and wound dressings. HBOT treatments included 100% oxygen, 2.5 ATA, 90 minute sessions, twice daily, for six consecutive days. DVs included complete healing times, the number of additional surgeries required, LOS, and number of wound dressings.

Results

Complete healing was achieved in 17 of the crush injuries with HBOT; 10 patients with sham. Additional surgeries were required in only one of the patients with HBOT; six in the sham group.   Wound healing in patients greater than 40 years old occurred in seven patients with HBOT; only three with sham.

Conclusion

Although there were no significant differences in LOS or number of wound dressing required, data revealed that HBOT was effective in the improvement of wound healing, reduction of additional surgeries, and is a useful adjunct therapy in patients greater than 40 years old with crush injuries. See Table 7.

<u>Comparison II:</u>

Hyperbaric side effects in a traumatic brain injury randomized clinical trial (Wolf, Prye, Michaelson, Brower, Profenna, & Boneta, 2012).

Statement of Purpose

The primary purpose of this study was conducted to determine if HBOT would benefit veterans with mild TBIs as an alternative treatment. The secondary purpose was to produce independent and reliable data on the frequency and severity of encountered side effects of HBOT. The Undersea and Hyperbaric Medical Society was used a resource in the identification and definition of the most commonly experienced side effects relating to HBOT.

Methods

A double-blinded randomized controlled clinical trial was approved by the Wilford Hall Medical Center Institutional Review Board in August 2007. Neurologists identified 50 veterans with TBI and cognitive deficits; 48 males and 2 females who were diagnosed with a TBI at least six years prior to initiation of the study. The veterans were randomly entered into one of two groups; the control group received a 90 minute treatment breathing air (21% oxygen) at 1.3 ATA; the treatment group also received a 90 minute exposure with 100% oxygen at 2.4 ATA. Each group consisted of 24 males and one female; ages ranged from 20 to 51 years old. A total of 30 exposures were represented by a cycle of 5 days on and one day off. The research crew consisted of the crew chief, chamber operator, inside attendant and a medical monitor. Medical monitors assessed the veterans prior to and immediately after each treatment session. The HBOT chamber operators noted any complaints or concerns of the veterans on the treatment log while the veteran was in the chamber. The chamber operators and inside attendants were privy to pressurization and obviously knew which group the veteran was in. Non-disclosure agreements were signed by all members.

Results

Ear block (barotrauma) was defined as a difficulty of pressurizing the middle ears during descent and required pressurization to be discontinued momentarily; prevalence in the HBOT group was 5.91% compared to the control group (1.09%). Sinus block or squeezes were only reported in the HBOT group; confinement anxiety appeared equally in both groups with two occurrences each. Headaches (0.61%); nausea (0.2%); numbness, heartburn, musculoskeletal chest pain, latex allergy and hypertension were all equally occurring events at 0.7%.

Conclusion

The authors concluded the mild side effects of HBOT have demonstrated it was a safe treatment at high pressures on mild TBIs. Furthermore, this data could be utilized in risk/benefit calculations during the decision making process of utilizing HBOT in the treatment of various other diseases in the TBI patients. See Table 8.

Retrospective Studies

Comparison I:

Hyperbaric oxygen therapy: types of injury and number of sessions: a review of 1506 cases (D'Agostino Dias, Fontes, Poggetti, &Birolini, 2008)

Statement of Purpose

HBOT has been used as an adjunctive treatment for many conditions; experimental and clinical studies have proved that HBOT increases healing times, preserves tissues, and saves lives. Controversies and inconsistencies remain concerning the clinical application of HBOT; further research is needed. When examining the effectiveness of HBOT, the number of treatment sessions should be taken in consideration. The purpose of this study was to determine the minimum number of treatment sessions sufficient to treat acute and chronic injuries effectively.

Methods

This retrospective study reviewed 1730 cases utilizing chart reviews and examined the types of injuries of participants and the number of sessions utilized in HBOT. Only cases where the hypothesized effective treatment sessions (acute, n=5; chronic, n=10) were included in the data analysis (n=1506). Acute (n=1014) and chronic (n=492) injuries were distinguished and cross referenced with recovery times and against the number of HBOT sessions received.

Results

The authors reported effective therapy should consist of 15 consecutive HBOT sessions for acute injuries and 30 consecutive sessions of HBOT for chronic injuries as an established baseline to guide treatment. Prospective studies would validate the findings and may determine the number of baseline treatment sessions needed for other injuries. See Table 9.

<u>Comparison II:</u>

The life-saving effect of hyperbaric oxygenation during early-phase severe blunt chest injuries. (Rogatsky & Mayevsky, 2007)

Statement of Purpose

Severe BCIs initiate cardiopulmonary dysfunction and leads to a significant decrease in oxygen transportation to vital organs and is associated with poor outcomes. Mortality increases with the severity of the BCI, especially when TBIs are concurrent. Given that HBOT is the most powerful anti-hypoxic treatment available, the role of HBOT in severe BCIs has not been thoroughly examined.

Methods

A retrospective study examined the early intervention effects of HBOT on severe blunt chest injuries treated in an ICU of Moscow's Scientific Research Institute for Emergency Medicine. DVs included mortality rate and hemodynamic values: cardiac index (CI), stroke volume index (SVI), partial pressure of oxygen in arterial blood (PaO2), and PaO2/FiO2: the ratio of the partial pressure of oxygen in atrial blood to fractional inspired oxygen which indicates the severity of hypoxemia. Group A (n=4) were surviving victims who were treated by conventional therapies. Group B (n=14) were non-surviving victims who died shortly after being treated by conventional therapies. Group C (n=4) were surviving victims who were treated with HBOT in addition to conventional therapies; sessions consisted of 100% oxygen, 1.6-2.0 ATA, 40-60 minutes daily for 4-15 consecutive days.

Results

The authors concluded there was a significant reduction in mortality as Groups A, B, and C was compared. HBOT should be the first-line treatment and initiated as soon as possible within the first 24 hours of the initial trauma in efforts to decrease mortality rates in this population. See Table 10.

CONCLUSION

Summary

The SRs have not identified sufficient evidence to support or disclaim the effectiveness of HBOT on ATIs. There were too few RCTs available without bias, randomization, and additional subsets included in the studies.

Quality of Evidence

The review of the literature was relevant; the majority of articles were published within the last 10 years with specific information cited. Physiological assessment data, clinical instrumentation, and structured interviews and questionnaires were used to objectively describe the data obtained and side effects reported. The research designs, variables of interest, population, and settings were clearly stated; quantitative methods were appropriately utilized in each paper. Statistical analyses deciphered the findings and were illustrated in figures, tables, and graphs. The authors' qualifications and extent of knowledge and/or expertise in the prospective clinical areas were not provided by the majority of the contributors.

Implications for Research

Additional high-quality and larger RCTs are needed to provide sufficient data analysis to discern HBOT's role as an adjunct therapy for ATIs. There is also a lack of studies regarding the long-term effects or on quality of life from the use of HBOT. Appropriate sample sizes, selection of target patients, blinding of outcome assessors and measures, and careful interpretation of any adverse effects should be evaluated. Ranges of ATA, treatment times, and number of consecutive sessions should be cross-referenced in all possible scenarios. Cost benefits should be examined, especially in using HBOT within emergency departments in community hospitals versus Level I Trauma medical centers.

Implications for Practice

There is insufficient evidence to support the routine use of HBOT as an adjunct treatment in ATIs despite some evidence of improved wound healing in crush injuries (Eskes, Vermeulen, Lucas, & Ubbink, 2013), (Bouachour, Cronier, Gouello, Toulemonde, Talha, & Alquier, 1996) and decreased mean healing times in burns (Villanueva, Bennett, Wasiak, & Lehm, 2009). There was some evidence of increased pain in DOMS (Bennett, Best, Babul-Wellar, & Taunton, 2010) and use of HBOT cannot be justified in this case.

HBOT may reduce the risk of death and increase GCS scores (Bennett, Trytko, & Jonker, Hyperbaric oxygen therapy for the adjunctive treatment of traumatic brain injury (Review), 2012); however, it cannot be justified for use in patients with severe TBIs to increase the quality of life. In treating patients with mild TBIs, HBOT was found to produce very few mild side effects (Wolf, Prye, Michaelson, Brower, Profenna, & Boneta, 2012); this knowledge could be used in risk/benefit calculations with additional injuries.

HBOT continues to be the definitive treatment in DCI despite no evidence to support this practice (Bennett, Lehm, Mitchell, & Wasiak, 2012). Although there was evidence to support decreased recompression times with HBOT and NSAIDs or alternative recompression with Heliox; benefits may be purely economic and should be considered in new clinical trials examining the use of different breathing gasses and pressure gradients. Prospective studies may govern the HBOT profiles; there was some evidence to indicate a baseline of 15 HBOT sessions in acute injuries and 30 HBOT sessions in chronic injuries (D'Agostino Dias, Fontes, Poggetti, & Birolini, 2008). HBOT should be highly considered as a first-line therapy in patients with severe BCIs when it can be provided immediately after injury; retrospective case reviews revealed it reduced mortality significantly (Rogatsky & Mayevsky, 2007).

A statistical knowledge deficit prohibited substantiated analysis of the data provided in the manuscripts examined. These findings are preliminary, based on the premise of gaining additional knowledge concerning literature reviews prior to revision of this document.

HYPERBARIC NURSING

Hyperbaric Nurses (HNs) practice in a highly specialized area that is physically, emotionally and environmentally challenging. Nurses provide care for patients in an altered and potentially volatile environment and are the primary clinicians delivering HBOT. HNs are trained in chamber operation, the theory and application of gas laws, chamber safety, and patient assessment in the HBOT environment. Certification is obtained through the Baromedical Nurses Certification Board after 480 hours of hands-on delivery of HBOT in their facility (Broussard, 2004). Certified HBOT physicians are usually present only during initial compression and decompression periods. Nurses accompany patients in either a multi-chamber (HNs breath air at pressurized rates) or a mono-chamber (HNs breathe 100% oxygen). The occupational risks of being exposed to these high pressures of air, and especially oxygen, include arterial gas embolism, Decompression Illness (DCI), and barotrauma (Kindwall & Whelan, 2008).

The primary goal of HNs is to provide safe, cost-effective, and quality patient care according to established standards of practice and strict safety protocols. The prevalence of DCI among HNs as an occupational hazard is relatively small. On occasion, HNs have developed

DCI and there has been one documented death resulting from HBOT occupational exposure (Uzun, Mutluoglu, Ay, & Yildiz, 2011). The safety of patients is dependent upon the safety of the provider delivering the care. Implementation of and strict adherence to HBOT treatment session protocols should be enforced to protect the HNs and their patients.

HBOT is recommended for a variety of medical conditions with varying evidence and has been the definitive treatment for DCI and air embolism (Gill & Bell, 2004). The benefits of HBOT can be classified into four generalized categories (Broussard, 2004):

1. Mechanical effects; reducing air bubble size
2. Bacteriostatic effects; treating necrotizing infections and osteomyelitis
3. Treatment of poisoning; displacing carbon monoxide from hemoglobin
4. Treatment of hypoxia: enhancing tissue oxygenation and healing

The two most common adverse effects of HBOT include middle ear barotrauma-the inability to equalize pressure in sinus cavities, and claustrophobia. Measures to decrease these adverse events seen in approximately one percent of patients include aborting the dive to prevent injury to the ears and sinuses, and reassuring patients with education through orientation of the process. Reporting HBOT outcomes through an international database would provide evidence of efficacy as an adjunct treatment in conditions not recognized by third-party payers (Broussard, 2004).

DISSEMINATION OF FINDINGS

It is necessary to establish a growth development plan to meet treatment and financial goals for HBOT, given the limited knowledge and acceptance of HBOT as an adjunct treatment modality. Increasing awareness of HBOT and its potential uses, identifying potential candidates who would benefit from HBOT through referrals can increase the patient volume thus determining the cost effectiveness of implementing or upgrading an existing HBOT service.

HBOT is expensive and not logistically available to many facilities offering emergency treatment (Gill & Bell, 2004). Hyperbaric medicine marketing is essential to managing, projecting the financial feasibility, and growing the clinical practice of HBOT. The primary targets of HBOT education include referring medical specialists: orthopedic, oral-maxillofacial, radiation oncology, plastic surgery, infectious disease and emergency trauma physicians and surgeons; nurses; emergency medical services personnel; divers; athletic organizations; third-party payers and the general public.

Hyperbaric medicine experts may be called in to provide a kick-off campaign to introduce the concept of HBOT as an adjunct to medical and surgical treatment. A media approach can create public awareness of existing and future treatment centers and educate the public on the benefits of HBOT. Printed brochures aimed at referring specialists and consumers can enhance education and resources that provide a growth development tool. Training and education through new-hire orientation can create awareness and acceptance of HBOT, and possibly serve to recruit potential nurses and physicians as adjunct hyperbaric department staff. Group presentations are cost-effective and constructed for each targeted group. All of the methods described creates awareness and educates targeted groups about HBOT and would help establish a growth development plan to facilitate policies and procedures in facilities new to HBOT.

Advancing Research and Clinical Practice through Collaboration (ARCC) Model

The ARCC model was designed to guide organizational change towards the EBP paradigm. Mentors serve as the primary strategy to facilitate change through educating and engaging nurses in the EBP process. Nurses need to train in other topics than change theories:

leadership roles and expectations, engagement strategies, mentorship, and debate to affect organizational change. In addition to mentors, several other strategies are utilized to institute an EBP paradigm: development of champions, provision of resources, journal clubs, and nursing rounds (Barnsteiner, Reeder, Palma, Preston, & Walton, 2010). "Successful impleentation occurs when there is appropriate interaction between the evidence being used in decision making, the context in which the evidence is being used, and how the implementation is being facilitated (Fineout-Overholt, Williamson, Kent, & Hutchinson, 2010)."

CONCLUSION

Effectively applying EBP requires the RN to identify gaps, formulate questions, conduct a literature search, evaluate validity, implement findings, and involve the patient (Majid, et al., 2011, p. 230). EBP care leads to clinical and financial benefits to organizations (Steurer, 2010). Organizational change continues to be a primary barrier for promoting EBP, and nurses can opt to take the lead in changing the culture on small scales within their units, through the ARCC model. Disseminating the knowledge into practice and evaluating the outcomes of EPB implementation can be presented to the administration and upper management through the visual representation of metrics provided by the nursing researchers. There are several different approaches available to nurses for implementing organizational change; existing models and programs have been proven successful and should serve as a foundation to build upon. Given the limited level of knowledge and acceptance of HBOT within the nursing, medical and public communities, it is essential to create a growth development and marketing plan through education.

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Eskes, A., Vermeulen, H., Lucas, C., & Ubbink, D. (2013). Hyperbaric oxygen therapy for treating acute surgical and traumatic wounds (Review). *The Cochrane Collaboration*(12), 1-27.	Type of Study: RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, acute surgical wounds, acute traumatic wounds Independent Variable: HBOT only, HBOT with standard treatment Dependent Variables: Wound healing, Adverse effects, Survival of flap/graft, Mortality, Pain, QOL, Patient Satisfaction, ADL, TcpO2, Amputations, LOS, Costs Controlled Variable: No HBOT	Four trials (n=229 participants): ▪ Perrins 1967 (n=48, burns with grafts) reported a significant increase in graft survival with HBOT. ▪ Vishwanath 2011 (n=10, free flap surgery) reported no significance in graft survival with HBOT. ▪ Bouachour 1996 (n=36, crush injuries) reported significant increase of wounds healed and significantly less tissue necrosis. ▪ Xie 2007 (n=135, flap grafting) reported no significance in graft survival with HBOT as compared to use of dexamethasone or heparin. There is lack of high-quality RCT evidence on use of HBOT for wound healing.	Level I

Table 1

Citation	Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Villanueva, E., Bennett, M., Wasiak, J., & Lehm, J. (2009). Hyperbaric oxygen therapy for thermal burns (Review). *The Cochrane Collaboration*(2), 1-13.	Type of Study: RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, thermal burns Independent Variable: HBOT Dependent Variables: Acute fluid requirement, Healing time, Number of surgeries, Length of stay, Adverse effects of HBOT Controlled Variable: No HBOT	Two trials (n=141 participants): ▪ Brannen 1997 (n=125 acute burns), reported no significant results in HBOT compared to sham. ▪ Hart 1974 (n=16 thermal burns 10-50% BSA), reported healing times decreased with HBOT (mean: 19.7 days v. 43.8 days); fluid requirements decreased with HBOT (mean: 2.2ml/Kg v. 3.4 ml/Kg); graft survival rate was increased with HBOT (mean: 100% of 3/3 v. 50% of 1/2). There is no sufficient evidence to support or disclaim HBOT in management of burns.	Level I

Table 2

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Bennett, M., Best, T., Babul-Wellar, S., & Taunton, J. (2010). Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury (Review). *The Cochrane Collaboration*(6), 1-40.	Type of Study: RCTs Quasi-RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, DOMS, soft tissue injury Independent Variable: HBOT Dependent Variables: Healing times, Functional Assessment Scores, Pain and Swelling Controlled Variable: No HBOT	Nine trials (n=219 participants) Two trials compared HBOT to sham in closed soft tissue injury: ▪ Borromeo 1997 (n=32, acute ankle sprain) ▪ Soolsma 1996 (n=19, MCL injury) No sufficient evidence to support or disclaim use of HBOT. Seven trials examined effects of HBOT on DOMS following eccentric exercise. ▪ Babul 2003 (n=16, quadriceps) ▪ Germain 2003 (n=16,quadriceps) ▪ Harrison 2001 (n=21, elbow flexors) ▪ Mekjavic 2000 (n=24,elbow flexors) ▪ Staples 1999a (n=49, quadriceps) ▪ Staples 1999b (n=30,quadriceps) ▪ Webster 2002 (n=12, gastrocnemius) Some evidence that HBOT may increase interim pain. No significance to support HBOT.	Level I

Table 3

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Bennett, M., Stanford, R., & Turner, R. (2012). Hyperbaric oxygen therapy for promoting fracture healing and treating fracture non-union (Review). *The Cochrane Collaboration*(11), 1-18.	Type of Study: RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, fractures Independent Variable: HBOT Dependent Variables: Bony union, Healing time of bony union, Pain, Functional Outcome Score, Malunion or Cosmetic deformity, Complications and Adverse events Controlled Variable: No HBOT	No trials met the inclusion criteria for review. The systematic review failed to locate any clinical evidence to support or disclaim HBOT in fractures.	Level I

Table 4

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Bennett, M., Trytko, B., & Jonker, B. (2012). Hyperbaric oxygen therapy for the adjunctive treatment of traumatic brain injury (Review). *The Cochrane Collaboration*(12), 1-42.	Type of Study: RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, TBI Independent Variable: HBOT Dependent Variables: Functional Outcome Score, Mortality, ADL, ICP, GCS, Adverse effects, Costs Controlled Variable: No HBOT	Seven trials (n=571 participants) ▪ Artru 1976 (n=60) ▪ Holbach 1974 (n=99) ▪ Mao 2010 (n=60) ▪ Ren 2001a (n=55) ▪ Rockswold 1992 (n=84) ▪ Rockswold 2010 (n=26) ▪ Xie 2007 (n=60) HBOT may reduce the risk of death and improve GCS; there is little evidence survivors have a good outcome and quality of life.	Level I

Table 5

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Bennett, M., Lehm, J., Mitchell, S., & Wasiak, J. (2012). Recompression and adjunctive therapy for decompression illness (Review). *The Cochrane Collaboration*(5), 1-27.	Type of Study: RCTs Design Type: Systematic Review Framework/Theory: Conceptual	Not disclosed	Concepts: HBOT, Recompression, DCI Independent Variables: HBOT with adjuvant therapies Recompression with Heliox Dependent Variable: Mortality, Severe functional disability, Complete recovery, Functional Outcome Scale, Number of Recompression sessions, Time to complete recovery, time to return to diving, ADL, QOL, Adverse events Controlled Variable: HBOT	Two trials (n=268 participants) Bennett 2003 (n=180) ▪ HBOT with NSAID Drewry 1994 (n=88) ▪ Heliox HBOT is the first line treatment of decompression illness (DCI) despite no RCTs existing for its use. ▪ HBOT with NSAID ▪ Heliox instead of HBOT The data showed a decrease in the number of recompression sessions needed using either treatment. Neither treatment improved the recovery time or outcome of DCI.	Level I

Table 6

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Bouachour, G., Cronier, P., Gouello, J., Toulemonde, J., Talha, A., & Alquier, P. (1996). Hyperbaric Oxygen Therapy in the Management of Crush Injuries: A Randomized Double-Blind Placebo-Controlled Clincial Trial. *Journal of Trauma-Injury Infection & Critical Care, 41*(2), 333-339.	Type of Study: Experimental Design Type: RCT Framework/Theory: Theoretical	University Hospital of Angers; Angers, Fance	Concepts: HBOT, Crush Injuries Independent Variable: HBOT: ▪ 100% O2 ▪ 2.5 ATA ▪ 90 min ▪ BID ▪ Six days Dependent Variables: Complete healing time, BPI, Additional surgery, LOS, Number of wound dressings Controlled Variable: No HBOT	36 participants: HBOT n=18; placebo n=18 Complete healing ▪ 17 patients HBOT ▪ 10 patients sham Surgery ▪ 1 patient HBOT ▪ 6 patients sham Wound healing (age >40 yo) ▪ 7 patients HBOT ▪ 3 patients sham No significant differences in lengths of stay or number of wound dressings. Data revealed that HBOT is effective in the improvement of wound healing and reducing the need for additional surgeries. HBOT is a useful adjunct in management of crush injuries of persons > 40 years old.	Level II

Table 7

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
Wolf, G., Prye, J., Michaelson, R., Brower, G., Profenna, L., & Boneta, O. (2012). Hyperbaric side effects in a traumatic brain injury randomized clinical trial. *Undersea & Hyperbaric Medicine, 39*(6), 1075-1082.	Type of Study: Experimental Design Type: RCT Framework/Theory: Theoretical	Wilford Hall Medical Center; Lackland AFB; San Antonio, TX	Concepts: HBOT, TBI Independent Variable: HBOT: ▪ 100% O2 ▪ 2.4 ATA ▪ 90 minutes ▪ 30 sessions Dependent Variables: Side Effects Controlled Variable: No HBOT	Data reported slight increases in percentage rate of side effects in HBOT group over sham group: ▪ Ear block 4.82 % ▪ Sinus squeeze 0.27 % ▪ Nausea 0.13 % ▪ Numbness 0.13% ▪ Musculoskeletal chest pain 0.13% Mild side effects of HBOT demonstrated it is a safe treatment at high pressures on mild TBIs. Data could be utilized in risk/benefit decisions.	Level II

Table 8

Citation	Type of Study Design Type Framework/Theory	Setting	Key Concepts/Variables	Findings	Hierarchy of Evidence Level
D'Agostino Dias, M., Fontes, B., Poggetti, R., & Birolini, D. (2008). Hyperbaric oxygen therapy: types of injury and number of sessions: a review of 1506 cases. *Undersea Hyperbaric Medicine, 35*(1), 53-60.	Type of Study: Observational Design Type: Retrospective Framework/Theory:	University of Sao Paulo (1992-2002)	Concepts: HBOT, Acute & Chronic Injuries, Treatment sessions Independent Variable: Number of Treatment Sessions Dependent Variable: Acute Injuries, Chronic Injuries Controlled Variable: HBOT	▪ Acute injuries: 15 consecutive HBOT sessions ▪ Chronic injuries: 30 consecutive HBOT sessions	Level IV

Table 9

Citation	**Type of Study** **Design Type** **Framework/Theory**	**Setting**	**Key Concepts/Variables**	**Findings**	**Hierarchy of Evidence Level**
Rogatsky, G., & Mayevsky, A. (2007). The life-saving effect of hyperbaric oxygenation during early-phase severe blunt chest injuries. *Undersea and Hyperbaric Medicine, 34*(2), 75-81.	Type of Study: Observational Design Type: Retrospective Framework/Theory: Theoretical	ICU of Moscow Scientific Research Institute for Emergency Medicine	Concepts: HBOT, Mortality, Blunt Chest Injury Independent Variable: HBOT Dependent Variable: Mortality Rate, Hemodynamic values: CI, SVI, PaO2, PaO2/FiO2 Controlled Variables: No HBOT, Survivors of BSI, Victims of BSI	▪ HBOT initiation ASAP within 24 hours of initial trauma ▪ HBOT: 1.6 – 2.0 ATA ▪ Session time: 40 – 60 minutes daily ▪ Consecutive sessions (4 – 15) based on response ▪ Significant reduction in mortality.	Level IV

Table 10

REFERENCES

(2015). Retrieved May 30, 2015, from Flying Start NHS: http://www.flyingstart.scot.nhs.uk/

Babul, S., & Rhodes, E. (2010, December). The Role of Hyperbaric Oxygen Therapy in Sports Medicine. *Sports Medicine, 30*(6), 395-403.

Baines, C., & Sykes, P. (2014, December 1). Professional capability within the Australian hyperbaric nursing workforce. *Australian Journal of Advanced Nursing, 32*(2), 6-13.

Barnsteiner, J., Reeder, V., Palma, W., Preston, A., & Walton, M. (2010, July/September). Promoting Evidence-Based Practice and Translational Research. *Nursing Administration Quarterly, 34*(3), 217-225.

Bennett, M., Best, T., Babul-Wellar, S., & Taunton, J. (2010). Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury (Review). *The Cochrane Collaboration*(6), 1-40.

Bennett, M., Lehm, J., Mitchell, S., & Wasiak, J. (2012). Recompression and adjunctive therapy for decompression illness (Review). *The Cochrane Collaboration*(5), 1-27.

Bennett, M., Stanford, R., & Turner, R. (2012). Hyperbaric oxygen therapy for promoting fracture healing and treating fracture non-union (Review). *The Cochrane Collaboration*(11), 1-18.

Bennett, M., Trytko, B., & Jonker, B. (2012). Hyperbaric oxygen therapy for the adjunctive treatment of traumatic brain injury (Review). *The Cochrane Collaboration*(12), 1-42.

Bouachour, G., Cronier, P., Gouello, J., Toulemonde, J., Talha, A., & Alquier, P. (1996). Hyperbaric Oxygen Therapy in the Management of Crush Injuries: A Randomized Double-Blind Placebo-Controlled Clincial Trial. *Journal of Trauma-Injury Infection & Critical Care, 41*(2), 333-339.

Broussard, C. (2004). Hyperbaric oxygen therapy and wound healing. *Journal of Vascular Nursing, 22*(2), 42-48.

Certified Hyperbaric Nurse (CHRN). (2015). Retrieved June 6, 2015, from Baromedical Nurses Association: http://hyperbaricnurses.org/certification/

Clinical Question Anatomy. (2012). Retrieved May 30, 2015, from Walden Student Center for Success: http://academicguides.waldenu.edu/content.php?pid=183871&sid=2950360

Cooper, D., Van den Broek, C., & Smart, D. (2009, June). Hyperbaric chamber attendant safety II: 14-year health review of multiplace chamber attendents. *Diving and Hyperbaric Medicine, 39*(2).

D'Agostino Dias, M., Fontes, B., Poggetti, R., & Birolini, D. (2008). Hyperbaric oxygen therapy: types of injury and number of sessions: a review of 1506 cases. *Undersea Hyperbaric Medicine, 35*(1), 53-60.

Dukes, S., Bridges, E., & Johantgen, M. (2013, January). Occurrence of Secondary Insults of Traumatic Brain Injury Patients Transported by Critical Care Air Transport Teams From Iraq/Afghanistan: 2003-2006. *Military Medicine*, *178*(1), 11-17.

Effective Therapy for Sports Injury Recovery. (2011). Retrieved June 7, 2015, from Hyperbaric Therapy USA: http://hbtusa.com/athletics/

Eskes, A., Vermeulen, H., Lucas, C., & Ubbink, D. (2013). Hyperbaric oxygen therapy for treating acute surgical and traumatic wounds (Review). *Cochrane Database of Systematic Reviews*(12).

FAQ. (2014). Retrieved June 6, 2015, from Harch Hyperbaric Oxygen Therapy: http://www.hbot.com/faq

Fineout-Overholt, E., Williamson, K., Kent, B., & Hutchinson, A. (2010). Teaching EBP: Strategies for Achieving Sustainable Organizational Change Toward Evidence-Based Practice. *Worldviews on Evidenc-Based Nursing*, *7*(1), 51-53.

Gill, A., & Bell, C. (2004). Hyperbaric oxygen: its uses, mechanisms of action and outcomes. *Quarterly Journal of Medicine*, *97*(7), 385-395.

Harvey Cushing/John Hay Whitney Medical Library. (n.d.). *Pyramid*. Retrieved June 7, 2015, from Evidence-Based Clinical Practice Resources: http://guides.library.yale.edu/content.php?pid=9786&sid=73113

Johnson, J., Reineck, C., Daigle-Bjerke, A., Goupil, N., & Captain, C. (1995). Understanding research articles. A pilot study of critical reading of research publications. *Journal of Nursing Staff Development*, 95-99.

Kindwall, E., & Whelan, H. (2008). *Hyperbaric Medicine Practice* (3 ed.). Flagstaff, AZ: Best Publishing Company.

Lythgoe, A. (2015). Retrieved May 30, 2015, from Understanding Research: http://www.understandingresearch.com/

Majid, S., Foo, S., Luyt, B., Zhang, X., Theng, Y.-L., Chang, Y.-K., et al. (2011, July). Adopting evidence-based practice in clinical decison making: nurses' perceptions, knowledge, and barriers. *Journal of the Medical Library Association*, *99*(3), 229-236.

National Coverage Determination (NCD) for Hyperbaric Oxygen Therapy (20.29), 3. (2006, June 19). Retrieved June 6, 2015, from CMS.gov: http://www.cms.gov/medicare-coverage-database/details/ncd-details.aspx?NCDId=12&ncdver=3&NCAId=37&ver=7&NcaName=Hyperbaric+Oxygen+Therapy+for+Hypoxic+Wounds+and+Diabetic+Wounds+of+the+Lower+Extremities&fromdb=true&IsPopup=y&bc=AAAAAAAAEAgA

Peek-Asa, C., Zwerling, C., & Stallones, L. (2004, October). Acute Traumatic Injuries in Rural Populations. *American Journal of Public Health*, *94*(10), 1689-1683.

Persels, J. (1987). Developing the Hyperbaric Medicine Service. *Journal of Hyperbaric Medicine*, *2*(2), 97-105.

Polit, D., & Beck, C. (2012). *Nursing Research: Generating and Assessing Evidence for Nursing Practice* (9th ed.). Philadelphia, PA: Wolters Kluwer Health/ Lippincott Williams & Wilkins.

Rogatsky, G., & Mayevsky, A. (2007). The life-saving effect of hyperbaric oxygenation during early-phase severe blunt chest injuries. *Undersea and Hyperbaric Medicine, 34*(2), 75-81.

Searching for Evidence - Health Sciences & Nursing: Where to Search. (2015). Retrieved June 6, 2015, from Walden University: http://academicguides.waldenu.edu/healthevidence

Steurer, L. (2010). An Evidence-Based Practice Scholars Program: One Institution's Journey Toward Excellence. *The Journal of Continuing Education in Nursing, 41*(3), 139-143.

Sullivan, G. (2011). Education Research and Human Subject Protection: Crossing the IRB Quagmire. *Journal of Graduate Medical Education, 3*(1), 1-4.

Trauma. (2015). Retrieved June 5, 2015, from Merriam-Webster: http://www.merriam-webster.com/dictionary/trauma

U.S. Department of Health & Human Services. (1979, April 18). *The Belmont Report*. Retrieved June 23, 2015, from HHS.gov: http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.html

Uzun, G., Mutluoglu, M., Ay, H., & Yildiz, S. (2011, June 1). Decompression sickness in hyperbaric nurses: retrospective analysis of 4500 treatments. *Journal of Clinical Nursing*, *20*(11/12), 1784-1787.

Villanueva, E., Bennett, M., Wasiak, J., & Lehm, J. (2009). Hyperbaric oxygen therapy for thermal burns (Review). *The Cochrane Collaboration*(2), 1-13.

Wolf, G., Prye, J., Michaelson, R., Brower, G., Profenna, L., & Boneta, O. (2012). Hyperbaric side effects in a traumatic brain injury randomized clinical trial. *Undersea & Hyperbaric Medicine*, *39*(6), 1075-1082.