WCHM

WOUND CARE AND HYPERBARIC MEDICINE

VOLUME 9, ISSUE 2 — SUMMER 2018

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WOUND CARE AND HYPERBARIC MEDICINE

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UHMS ANNUAL SCIENTIFIC MEETING

Education is key…

The UHMS Annual Scientific Meeting's primary goal is to provide a forum for professional scientific growth and development of the participants to improve knowledge and competence in order to further patient outcome. The meeting provides a basis for exchange of ideas, both scientific and practical, among physicians, researchers and other health care professionals.

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FOR MORE INFORMATION SEE: WWW.UHMS.ORG

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NOTE FROM THE EDITOR

This summer issue of *WCHM* is being published early due to the UHMS 2018 Annual Scientific Meeting in Orlando, Florida, on June 28-30. This meeting creates a forum for professional scientific growth and development of participants to improve knowledge and competence in order to further patient outcomes. It also provides a basis for exchange of ideas, both scientific and practical, among physicians, researchers, and other health professionals. This is an event you don't want to miss!

You will find the following topics in this issue of *WCHM*:

- The Baromedical Nurses Association will be having their annual membership meeting at the UHMS ASM. Refer to their article for more information on this and their other events.
- The fourth edition of the UHMS *Hyperbaric Facility Accreditation Manual* is now available.
- Dr. Marisse Venter in South Africa describes the use of hyperbaric oxygen therapy in plastic and reconstructive surgery. And our Clinic in Focus Section is back featuring the Milpark Hyperbaric Medicine Centre in South Africa.
- Carbon monoxide poisoning is in the news again, this time involving your car and home. Dr. Neil Hampson, an internationally-known expert in the field of carbon monoxide poisoning, offers his analysis on the subject.
- Discussion by Drs. Robyn Bjork and Heather Hettrick of the clinical implications of emerging paradigms integrating the lymphatic and integumentary systems.
- Press release from Smith & Nephew on the new meta-analysis demonstrating the effectiveness of PICO NPWT.
- Dr. Michael Strauss and Lientra Lu return with Part 2 of their three-part series on diving with disabilities, focusing on musculoskeletal disabilities, neuropsychiatric disorders, and respiratory problems.

Please take advantage of authoring an article for *WCHM* where you will reach an audience of thousands of wound care and hyperbaric medicine practitioners. Please submit your articles to info@bestpub.com or call 561.776.6066, ext 4. We also invite you to join our elite group of *WCHM* advertisers to reach your target audience.

See you in Orlando!
Lorraine Fico-White
Managing Editor, *WCHM* Magazine

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Baromedical Nurses Association (BNA) Updates

Information compiled by Laura Josefsen, RN, ACHRN from the BNA Website: hyperbaricnurses.org

The BNA—so many new and great accomplishments this year! The first successful and exciting Annual Hyperbaric Nurses' Day on April 3 was enhanced by Annette Gwilliam (BNA President) starting off the webinar presentations with an impressive history of the BNA, followed by Sue Churchill's excellent presentation of "Calciphylaxsis: A Case Report. Diagnosis and Treatment with Adjunctive Therapies." Great general discussions followed.

One new and very important item! The BNA invites you to be a part of the Annual Membership Meeting on Friday, June 29, 2018 from 3:30-4:30 EST at the UHMS Annual Scientific Meeting (ASM) in Orlando, Florida. If you are unable to attend in person, we will again be holding our meeting as a webinar so everyone will be able to call in, see the agenda and participate in the discussion. We will send out the information with the connection link a couple of weeks before the meeting. Please contact any member of the BNA Board (all contact information is available on the hyperbaric nurses.org website) if you do not receive the information. Discussions will include new items for the year. You may find one that interests you, and this is a great way to become involved. Your ideas and suggestions make a difference.

The Standards of Care Committee has completed the *Guidelines of Nursing Care for the Patient Receiving Hyperbaric Oxygen Therapy (HBO$_2$)*. This dedicated committee has done an outstanding job of bringing the guidelines up to date. These guidelines are available on the website, hyperbaricnurses.org, and **will be available to all HBO$_2$ facilities to assist them to set up appropriate nursing care for their patients.**

The BNA Certification Board has issued the new guidelines for recertification. These guidelines are available on the hyperbaric nurses' website as well as on the NBDHMT (National Board of Diving and Hyperbaric Medical Technology) website at NBDHMT.org. Nursing education toward recertification is offered free to BNA members and for a fee of $15.00 for nonmembers. The webinars are typically offered live as well as available online at a later date.

The BNA will have a presence at all chapter meetings as well as at the UHMS ASM. The dates are as follows:

Gulf Coast Chapter Meeting - August 24-25, 2018

Midwest Chapter Meeting - TBD

Northeast Chapter Meeting - Oct 20-21, 2018

Pacific Chapter Meeting - November 16-18, 2018

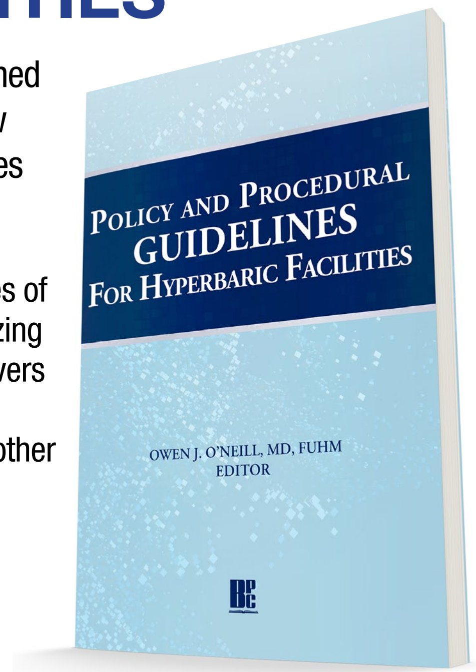
See you at the ASM, chapter meetings, or on the webinars!

About the Author

LAURA JOSEFSEN, RN, ACHRN, has been involved in hyperbaric nursing since 1982. A founding member of the Baromedical Nurses Association (BNA) in 1985, she served as BNA president from 1996 to 1998 and as a board member in several positions throughout the years. She served on the Undersea and Hyperbaric Medical Society (UHMS) Associates Council for six years, with two of those years as Nurse Representative on the UHMS Board of Directors. She has been a member of the UHMS Accreditation Team as a nurse surveyor, served for many years as an executive board member of the National Board of Diving and Hyperbaric Medical Technology and is a previous chairman of the BNA Certification Board. She is a member of the UHMS Associates, former member of Divers Alert Network, and former member of the Hyperbaric Technologists and Nurses Association (HTNA) of Australia. She has numerous publications and is an internationally recognized speaker in the field of hyperbaric medicine. Her passions are quality improvement and education to promote hyperbaric nursing, safety, and optimal standards of care and practice for patients and the community.

POLICY AND PROCEDURAL GUIDELINES FOR HYPERBARIC FACILITIES

Provides needed resource and reference guidelines for new and established hyperbaric facilities, serving as a reference for the development of new hyperbaric policies as well as customizing and enhancing current policies and procedures already in place.



Policy and Procedural Guidelines for Hyperbaric Facilities addresses issues of safety and practice for both the multiplace and monoplace environments. Utilizing regulatory guidelines and standards of practice as its foundation, this book covers governance, administration, emergency procedures, patient care, hyperbaric chamber maintenance, treatment protocols and quality improvement, among other topics. The appendices include sample forms for both Class A multiplace and Class B monoplace chambers.

The guidelines provided in this document will benefit the diverse group of physicians, nurses, tecnicians, and allied health-care personnel in the hyperbaric field as they customize their unit-specific policies and procedures.

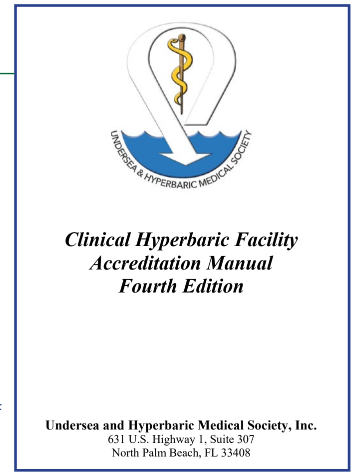
Endorsement from Baromedical Nurses Association (BNA)

The Baromedical Nurses Association endorses **Policy and Procedural Guidelines for Hyperbaric Facilities** as guidelines to enable hyperbaric facilities to develop and/or endorse their unit-specific policies.

The Baromedical Nurses Association (established in 1985) provides a forum for hyperbaric nursing that encompasses quality, safety, teamwork, mentoring, research, education, and nursing guidelines of standards of care for the patient receiving hyperbaric oxygen therapy.

Undersea and Hyperbaric Medical Society

www.uhms.org


Clinical Hyperbaric Facility Accreditation Manual Fourth Edition

Undersea and Hyperbaric Medical Society, Inc.
631 U.S. Highway 1, Suite 307
North Palm Beach, FL 33408

Meet the Challenges Ahead

Fourth Edition of the UHMS Hyperbaric Facility Accreditation Manual *Is Here*

Compiled by Renée Duncan, UHMS Communications Coordinator

www.uhms.org/images/Accreditation-Documents/Fourth_Edition_UHMS_Accreditation_Manual_Final.pdf

INTRODUCTION

In the late 1970s, there were fewer than 30 hyperbaric facilities operational in the United States. Most were either military, commercial or highly specialized research facilities. Today, an estimated 1,350-plus facilities are in operation.

Growth means change. We have seen the primary role of hyperbaric facilities transition from the treatment of diving-related disorders to providing essential primary and adjunctive treatments for multiple medical conditions. Refined research efforts will no doubt validate the continued effectiveness of HBO_2 therapy and perhaps even support new indications for treatment.

In 2001, the Undersea and Hyperbaric Medical Society took on the role of establishing a systematic means of quality assurance for hyperbaric facilities. It continues in this stewardship role with the publication of the *UHMS Clinical Hyperbaric Facility Accreditation Manual, Fourth Edition*, to help address these challenges of hyperbaric medicine in the 21st century.

Facility locations are changing.

From hospital-based centers to non-affiliated outpatient settings, some operations have appropriate medical supervision and others do not. Such gaps demand a formalized set of guidelines for operations.

Certification has become a must.

In the past, minimum recommended staffing/training standards did not exist. Now, they are an essential part of guidelines and recommended practices. Over the past decade, certification in hyperbaric technology and hyperbaric nursing has become a staffing requirement in many programs.

The *UHMS Guidelines for Hyperbaric Facility Operations, Second Edition,* first set these foundational standards of practice for hyperbaric medicine nearly two decades ago. Originally published in January 2000 as the *UHMS Operations Committee Report*, this was the Society's first written guide related to training, responsibility, staffing, safety and quality assurance for hyperbaric facilities – and it laid the groundwork for the UHMS accreditation program. The latest update is at: https://www.bestpub.com/books/hyperbaric-a-undersea-medicine/product/421-uhms-guidelines-for-hyperbaric-facility-operation-2nd-edition/category_pathway-31.html

Challenges lie ahead.

The development of certification for physicians in Undersea and Hyperbaric Medicine reflects a growing recognition of clinical hyperbaric medicine. It also reinforces the need for an institutional accreditation program for facilities like the UHMS Hyperbaric Facility Accreditation Program.

As in any growth process, success has not come without bumps. Our specialty faces challenges now and in the future. Since the UHMS represents a broad constituency base for clinical hyperbaric medicine, the Society remains proactive in helping to ensure that quality is maintained within our specialty.

The work continues.

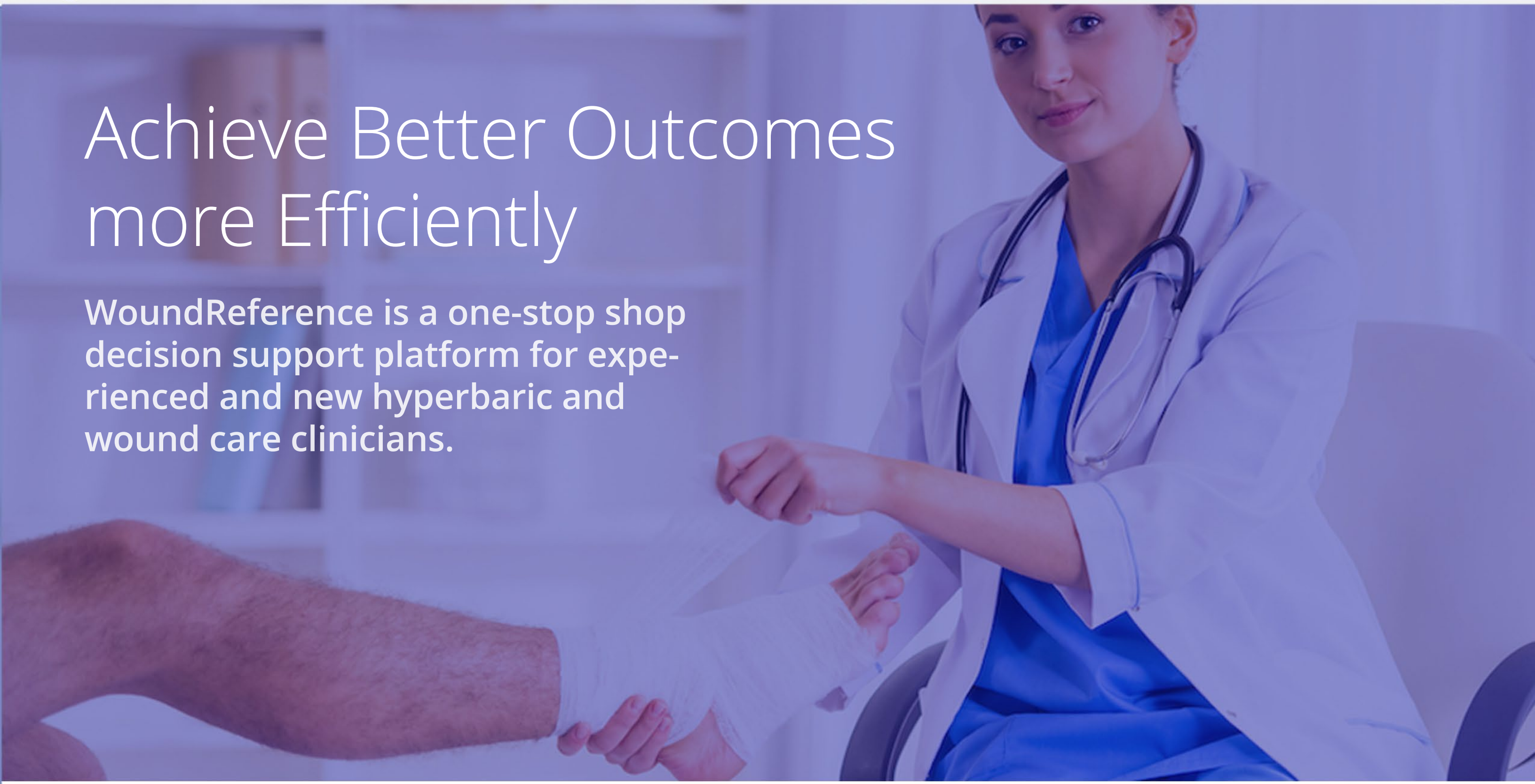
Download your new accreditation manual.* Have your guidelines book on hand. Schedule your facility for an accreditation survey at: https://www.uhms.org/about/accreditation/accreditation-for-hyperbaric-medicine.html

Make sure you're part of the push: Demonstrate your commitment to patient care and facility safety through UHMS accreditation.

If you have questions, contact the UHMS HFA staff: Derall Garrett at derall@uhms.org or Beth Hands at beth@uhms.org T: +210-404-1553 or toll-free at 877-533-8467.

* NOTE: The manual becomes active in August with the launch of its new partner database FileMaker Pro.

WoundReference https://woundreference.com



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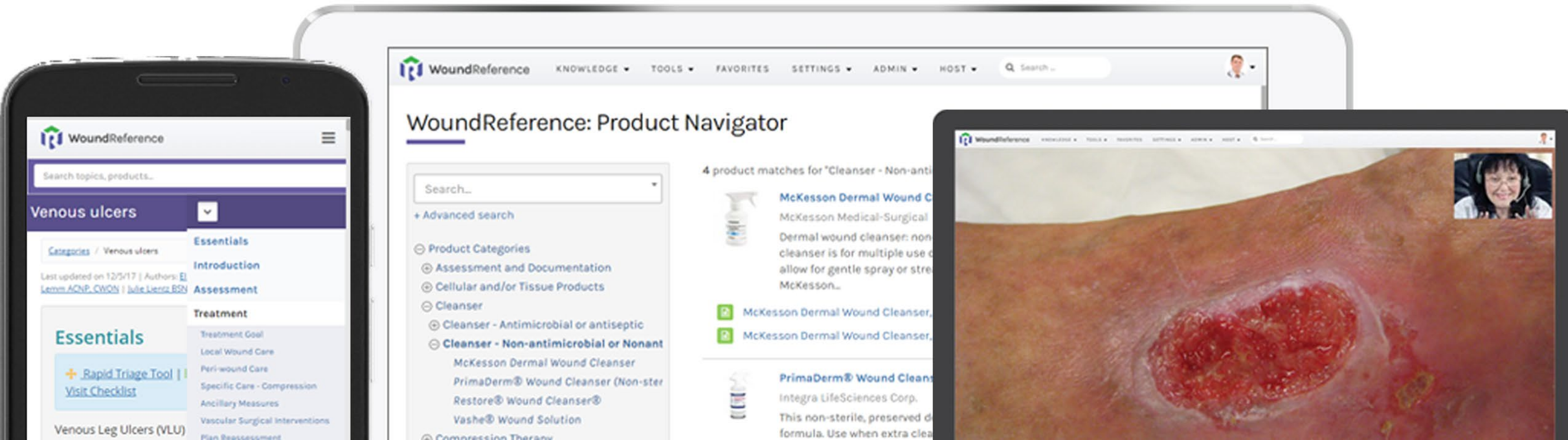


Hyperbaric Oxygen Therapy in Plastic and Reconstructive Surgery

by Dr. Marisse Venter, MBChB(UCT), FCS Plast Surg (CMSA), (WITS)

Ms. Debbie Dias is a breast cancer survivor. She was diagnosed with breast cancer in 2013 at the age of 44. She has a long period of chemotherapy, breast cancer surgery, first-stage breast reconstruction, and radiation therapy. She was extremely brave during a challenging, emotionally loaded time. Our lovely lady recently decided to continue her reconstructive process as a breast cancer survivor.

In order to facilitate second-stage breast reconstruction, we used hyperbaric oxygen therapy. Riedwaan Dass, at Milpark Hyperbaric Medicine Centre, always ensures that patients receive prompt treatment and guides patients during the crucial period before and after surgery where the greatest benefit from hyperbaric oxygen therapy is found.

Clinical studies have shown the benefits of hyperbaric oxygen therapy in the pre- and post-operative periods in breast surgery patients. In breast surgery, skin- and nipple-sparing mastectomies have revolutionized the cosmetic appearance post-cancer surgery. Maintaining blood supply post-skin and nipple-sparing mastectomy remains a significant reconstructive challenge.

Once the inside of the breast has been removed in the mastectomy operation, the breast skin has a thin layer of tiny blood vessels that keeps the outside breast envelope alive. Hyperbaric oxygen therapy works by increasing the oxygen-carrying capacity of the red blood cells within these tiny blood vessels. By maintaining the breast shape, we, as reconstructive surgeons, are able to obtain a far better reconstruction.

Radiation therapy has shown to significantly prolong life expectancy in breast cancer patients. Unfortunately, radiation therapy often causes tight contracted skin and hard lumps in fatty tissue making subsequent reconstruction difficult. We have found that hyperbaric oxygen therapy not only softens the radiated skin but also decreases the size of the fatty lumps. Once again, it is on the basis of the hyperoxygenation that the tissue quality improves much like a sprinkler system for your garden.

Studies have shown the beneficial effects of hyperbaric oxygen therapy to be at various levels in the process of wound healing. It increases the efficacy of white blood cells, kills bacteria, inhibits bacterial toxin formation, reduces swelling, maintains tissue oxygenation in the absence of adequate blood supply, stimulates fibroblast growth, increases collagen formation, promotes rapid growth of blood vessels, and terminates lipid peroxidation. Hyperbaric oxygen therapy helps to preserve ischemic tissue and has a role in radionecrosis.

The unique availability of a hyperbaric unit has enabled us to investigate the use of hyperbaric oxygen therapy in three main areas:

1. Maintaining nipple viability in nipple-sparing mastectomies

Seated: Debbie Dias — Left to right: Denise Hartley (Practice and Patient Coordinator); ChiChi Nakazwe Peterson (Practice and Procedure Coordinator); Dr. Marisse Venter; Sister Sheila Pieterse (Wound Management Expert)

2. Maintaining skin flap viability in skin-sparing mastectomies
3. Improving cosmetic appearance and symptoms associated with radio necrosis.

We evaluated our findings in a clinical control trial utilizing 60 breast cancer patients that have had hyperbaric oxygen therapy post-cancer surgery as the intervention arm of the study. A historical control arm was used for comparison. Descriptive and inferential statistics were used to compare the study findings. Hyperbaric oxygen therapy has statistical value in maintaining tissue viability post-surgery. Hyperbaric oxygen therapy reduces the rate of liponecrosis associated with radiation therapy.

Ms. Dias was one of the patients used in our study. Hyperbaric oxygen therapy has helped us to obtain a far better reconstruction, enabling Ms. Dias to feel feminine, restore her self-confidence, and return to her activities of daily function.

About the Author

Dr. Marisse Venter, MBChB(UCT), Plast Surg (CMSA), (WITS) is a plastic and reconstructive surgeon. She has a special interest in wound healing, breast reconstruction and cosmetic surgery. Her work on the role of adipose derived tissue in wound healing and tissue regeneration has won her numerous national and international awards.

Dr. Venter qualified from the University of Cape Town in 2002. Her specialization encompassed four years of general surgery followed by four years of plastic surgery at the University of the Witwatersrand from where she qualified as a plastic surgeon in 2012. Dr. Venter is registered with the Health Professions Council of South Africa as a plastic and reconstructive surgeon. She is a member of the South African Association of Plastic and Reconstructive Surgeons, The South African Association of Aesthetic Surgeons and The International Association of Aesthetic Surgeons.

Following acting consultancy at the Helen Joseph Hospital, Dr. Venter has been in full-time private practice for the past six years.

Dr. Venter has dedicated her life to helping the plight of her patients, either by managing difficult wounds, reconstruction after breast cancer or general beautification in the most cost-effective manner.

For more information, visit
www.breasthealth.co.za/Dr-Marisse-Venter.html

CLINIC IN FOCUS

Milpark Hyperbaric Medicine Centre

If an accredited facility, how has seeking UHMS accreditation affected your clinic?

In collaboration with the accreditation team, we were guided to see what we do well and what we could do better to improve, providing a safe and effective hyperbaric service. It helped us to resolve our shortcomings.

What are the most common indications treated at your clinic?

- Chronic bone infections
- Compromised skin flaps and grafts
- Crush injuries
- Decompression illness (The bends)
- Problem wounds
- Radiation tissue damage
- Retinal artery occlusion
- Sudden hearing loss

Milpark Hyperbaric Medicine Centre works in collaboration with Netcare Milpark Breast Care Centre to provide treatment for breast care patients pre- and post-surgery, where indicated.

The Centre provides a Fast Recovery Programme for professional athletes who sustain sports injuries on a regular basis and in addition to this, professional rugby players from The Golden Lions Rugby Team, one of South Africa's top teams, have been treated at the Centre since 2010 due to a longstanding contractual relationship with the Golden Lions' medical team.

What is the most memorable treatment success story that has come out of your clinic?

Treating a spinal decompression patient who could not walk when he arrived at the Centre. After completing a TT6 treatment, he could get off the bed and walk with some help. The patient completely resolved his symptoms after a number of HBOT treatments.

Do you work with a management company? If so, which one?

We do not work with a management company and are a 100% private hospital-based hyperbaric centre.

MILPARK HYPERBARIC MEDICINE CENTRE
save a limb • save a life

If you had to pick one thing to attribute your clinic's success to, what would it be?

Setting our goals to be consistent in delivering good service to our patients and referring physicians. Always being available when our service is required in emergencies. We are an emergency-centered facility available 24/7 based at Netcare Milpark Hospital, which has an internationally-renowned Level 1 trauma unit and burns centre.

What is one marketing recommendation that you can make to help clinics increase their patient load?

Patient care is vital when treating patients. Every patient should be treated according to hyperbaric treatment protocols, which in turn will give the results required in patients' care to increase your referral base.

Is there are any additional question you'd like to answer, or any other information about your clinic you'd like to showcase?

As its community outreach programme, Milpark Hyperbaric Medicine Centre runs the Milpark Hyperbaric Foundation, which raises funds to provide hyperbaric oxygen treatment to patients not covered by a medical aid or unable to afford treatment.

Thanks to the generous financial support of private individuals, corporate businesses and companies around the world, funds raised enable the team to provide vital life-saving and limb-saving hyperbaric treatment to patients in need.

We are listed as a GoGetFunding beneficiary (https://gogetfunding.com/hyperbaric-foundation/)

Here is a link to our video, which showcases one of our patients: Milpark Hyperbaric Foundation.mp4 ■

CLINIC DETAILS

Clinic Name: Milpark Hyperbaric Medicine Centre

Location: Netcare Milpark Hospital, Parktown West, Johannesburg, South Africa

Website/phone: www.hyperbaric.co.za
+2711 480 5660

Facebook: Milpark Hyperbaric Medicine Centre

How long in business: 12 years

How many chambers: 3 monoplace chambers

Chamber type(s): Monoplace - Cumulus 3300 (South African designed/manufactured), PAHI 3200 (USA/Taiwan), Sechrist 2800 (USA)

How many physicians/nurses/CHTs: 1 Hyperbaric Medicine Physician; 2 CHTs

Medical director: Dr. Mark Botha, MBChB

Date of UHMS accreditation: The facility is accredited by SAUHMA (Southern Africa Undersea and Hyperbaric Medical Association). Accreditation dates: 2006, 2011 and 2016. The next accreditation date is scheduled for June 13, 2020.

Carbon Monoxide Gets National Exposure

UHMS Past President and CO Expert Dr. Neil Hampson Weighs In

Compiled by Renée Duncan, Communications Coordinator, UHMS

Carbon monoxide poisoning is in the news again. This time it involves your car and your home.

The New York Times recently published an article that described the death of a man who, after parking in his attached garage, simply forgot to turn off the car with his wireless key fob. He died of carbon monoxide poisoning that crept into his home as the car's engine continued to run.*

Dr. Neil B. Hampson echoes the concern raised by the May 13, 2018 article. "Carbon monoxide can pass through drywall, so you don't need an open door or duct from the garage for it to enter your home," he noted. Hampson is a national expert in carbon monoxide poisoning and past president of the Undersea and Hyperbaric Medical Society, a non-profit medical research organization with affiliates worldwide.

"This recent article emphasizes the problem of keyless fobs causing the driver to forget to turn off the car," said Hampson. "Unfortunately, some people just forget to turn off the engine, even with a key." That slip of the mind can be deadly, particularly when your garage is attached to your home, as was the case in the NYT report.

"The keyless issue could be solved with a software revision that turns off the engine automatically after the vehicle idles a set length of time," Hampson said. "This underscores the need for home carbon monoxide alarms in addition to smoke alarms, even if your home is all electric."

In 2010 Dr. Hampson published a paper in the *American Journal of Emergency Medicine*, first drawing medical attention to the problem. In his nationwide study, 175 individuals were poisoned in 59 incidents, with 63 fatalities. The elderly were disproportionately affected: 29% of the individuals poisoned in this fashion were older than 80. Of 17 poisoned individuals over 80, 15 died.

For members of the press and medical community who want more information, Dr. Hampson can be reached for comment through John Peters, Executive Director of the Undersea and Hyperbaric Medical Society, at +561-776-6110 ext. 100. The Undersea and Hyperbaric Medical Society is an important source of scientific and medical information pertaining to hyperbaric medicine. UHMS comprises some 2,500 physicians, scientists, associates and nurses from more than 50 countries in the fields of hyperbaric and dive medicine. ■

* www.nytimes.com/2018/05/13/business/deadly-convenience-keyless-cars-and-their-carbon-monoxide-toll.html?nl=top-xstories&nlid=56973528ries&ref=headline

Emerging Paradigms Integrating the Lymphatic and Integumentary Systems: Clinical Implications

by Robyn Bjork MPT, CLWT, CWS, CLT-LANA
and Heather Hettrick PT, PhD, CWS, CLT-LANA, CLWT

Introduction

Ernest Starling, in the late 1880s, introduced a model of capillary fluid exchange, based on hydrostatic and oncotic pressures (Starling, 1894). It was thought that increased hydrostatic pressure on the arterial side of the blood capillaries forced fluid into the interstitium, while lower hydrostatic pressure, coupled with higher oncotic pressure on the venous side of the blood capillaries, resulted in reabsorption of fluid. Until more recently, this was the prevailing understanding of fluid homeostasis, and formed the basis of wound, edema, and lymphedema education.

More recently, it has been established that the endothelial glycocalyx layer (EGL) controls the movement of proteins and fluid across the blood capillary wall. Despite prevailing principles regarding Starling's Law, it is now understood that there is no reabsorption of fluid back into the venous side of blood capillaries. Rather, there is only diminishing net filtration across the capillary bed, and fluid and blood proteins are removed from tissues via reabsorption through lymphatic capillaries alone. Consequently, a new paradigm that all edemas are on a lymphedema continuum has emerged (Bjork, Hettrick, 2018).

Evidence suggests that areas of lymphatic failure produce regions of integumentary vulnerability subject to inflammation, infection and carcinogenesis, essentially, skin barrier failure (Carlson, 2014). This may be the basis behind most integumentary dysfunction and contribute to the development of various wound pathologies (complicated by underlying disease processes and comorbidities). These combined findings highlight the interconnectedness of the lymphatic and integumentary systems and the need for a more unified clinical approach for the management of patients with chronic wounds and lymphedema.

Structure & Function of the Endothelial Glycocalyx Layer

In 1940, Danielli first introduced the concept of a protein-based lining of all blood vessels that plays a vital role in fluid filtration. And, in 1966, Luft visualized this layer for the first time through electron microscopy. By 2007, the EGL gained recognition as controlling the movement of proteins and fluid across the blood capillary wall. Subsequently, Levick and Michel (2010) mathematically demonstrated that there is no net reabsorption of fluid back into the venous side of the blood capillaries, rather only diminishing net filtration into the interstitium. Then, in 2014, Mortimer and Rockson integrated this new understanding of "no net reabsorption" into their review "New developments in clinical aspects of lymphatic disease", bringing it to the forefront of edema management.

A healthy EGL is approximately 0.5 um thick in the blood capillaries; it is progressively thicker in larger vessels, up to 4.5 um in carotid arteries (Reitsma et al., and Weinbaum, Tarbell, and Damiano, 2007). The EGL is made up of two continuous layers. The base is a slimy layer that coats the endothelial cells of the vessel wall. This slime or gel matrix is made up of chains of glycoproteins and proteoglycans that attach directly into the membranes of the endothelial cells, creating "backbones" (Reitsma et al., and Weinbaum, Tarbell, and Damiano, 2007). These backbones are linked together by a web of glycosaminoglycans that can absorb 10,000 times their weight in water (Biddle, 2013), thus creating a slimy gel layer. This sophisticated layer lines the endothelial cells of blood vessels and is integral in keeping fluid in or out, based on physiologic requirements. Within this base layer are wavy clefts, or channels, with tight junctions that control movement of fluid and protein through the EGL into the interstitium (Weinbaum, Tarbell, and Damiano, 2007). The EGL's essential role is maintaining vascular homeostasis.

The second layer of the EGL is made up of soluble plasma components linked to each other in a direct way or via soluble proteoglycans and/or glycosaminoglycans (Reitsma et al., 2007). This layer is visualized as hair-like projections, extending into the lumen of the blood vessel, organized into a hexagonal matrix with roots that attach to the "backbone" proteins of the gel base layer (Weinbaum, Tarbell, and Damiano, 2007) (Figure 1). Since the "backbone" proteins are tethered into the endothelial cell membranes of the capillary wall, and crosslinked in the gel matrix, blood flow shear forces acting on the hair-like projections mechanically transmit this information into the endothelial cells themselves. The endothelial cells respond to the mechanical signals, such as producing and releasing nitric oxide, which dilates the vessel (Biddle, 2013).

The composite EGL, including soluble proteins and other components that bind to it, has a negative charge that repels red blood cells (RBCs) and platelets so they do not touch the vessel wall. This space between the RBCs and the EGL is called the "exclusion zone" (Reitsma et al., 2007). The EGL is dynamic and can "shed" in response to stimuli, such as during inflammation or disease states. During inflammation, this shedding of the hair-like projections allows more fluid to escape through the EGL. Shedding also exposes adhesion molecules (Reitsma et al., 2007) to which platelets or white blood cells (WBCs) attach. WBCs are squeezed tightest in the blood capillary where they enter the venule and are known to crush the EGL temporarily by 20% (Weinbaum, Tarbell, and Damiano, 2007). It is here that WBCs tether to exposed adhesion molecules and then remain tethered as they roll across the venule wall to exit into the tissues, known as diapedesis.

The EGL is particularly sensitive to ischemia, which can result in rapid shedding as a protective mechanism. A high fat, high cholesterol diet, oxidative low-density lipoproteins, and hyperglycemia also cause shedding of the EGL, and the EGL has been found to be thinner in areas prone to atherosclerosis (Reitsma et al., 2007). The EGL plays an important role in diabetes mellitus, peripheral arterial disease, reperfusion injury, intravenous fluid mismanagement, renal disease, and dialysis (Biddle, 2013). It also has an antithrombotic effect due to "enzyme docking" and plays an important role in reducing oxidative stress (Biddle, 2013). With this, it is important to appreciate the role and implications the EGL has with respect to integumentary dysfunction—inclusive of lymphatic and cutaneous disease.

To summarize, the functional importance of the vascular endothelial glycocalyx layer cannot be overemphasized. (See Figure 1.) Biddle, 2013, eloquently details the EGL's functions as: regulation of vascular permeability, mechanotransducer regulating vascular tone, moderator for leukocyte and platelet adhesion, provides antithrombotic effect in vasculature, repulses red blood cells from the vascular endothelium, and reduces oxidative stress.

No Net Reabsorption Exception

Once the interstitial fluid enters the lymphatic capillary, the lymph is funneled through pre-collectors and into collectors that propel the lymph toward lymph nodes via sequenced contraction of lymphangions coupled with one-way valves. Under normal conditions, ~4L of lymph re-enters the venous system at the venous angles in the neck. However, a sum of ~8L/day of fluid moves out of the blood capillaries and into the tissues (Levick, 2010; Renkin, 1986). The structure and function of the lymph nodes is essential to reconciling this apparent discrepancy.

In 1983, Knox et al. found that ~50% of the fluid portion of lymph is reabsorbed into the venous circulation via the blood capillaries within canine lymph nodes. The same year, Adair and Guyton demonstrated that increasing the venous pressure in canine lymph nodes resulted in movement of fluid back into the node, thereby reducing the concentration of proteins in the efferent lymph vessels. This highlights the role of the lymph nodes and lymphatics in fluid homeostasis, as well as the impact of chronic venous

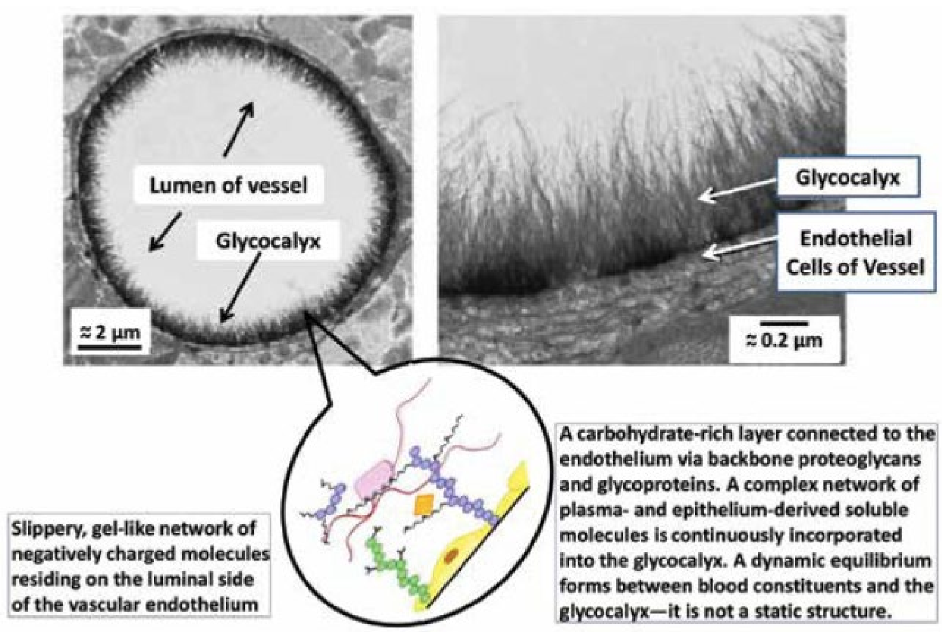


FIGURE 1. Vascular endothelial glycocalyx (Biddle, 2013). This figure is used with permission from the author.

hypertension. Elevated venous pressure not only results in ultrafiltration from the blood capillaries but also slows reabsorption of fluid from the lymph nodes back into the venous circulation. The dense, capsular design of the lymph nodes, their placement in joint areas that are mechanically compressed by movement, and the presumed absence of EGL, all work synergistically to facilitate fluid reabsorption back into the venous system. Conversely, immobility and decreased joint movement through the full range of motion, lymph node removal, or venous hypertension can have a significant impact on fluid retention in the dermis and subcutaneous tissues. Ultimately, this stagnant fluid may lead to fibrosclerosis and deleterious alterations within these tissues.

New Paradigm: All Edemas Are on a Lymphedema Continuum

All edemas are on a lymphedema continuum. Since we now know that all swelling is managed by reabsorption by the lymphatic capillaries alone, the patency of dermal lymphatics and the efficiency of lymphatic drainage are paramount to edema management and wound healing. Interventions to help prevent damage to lymphatic capillaries, and techniques to facilitate lymphatic drainage and lymphangiogenesis need to be considered as part of wound management. As early as 1994 (Scelsi, et al.), damage to dermal lymphatics was observed in skin biopsies from patients affected by chronic venous insufficiency (CVI). In more recent studies using near-infrared fluorescence lymphatic imaging (NIRFLI) technology, baseline imaging showed impaired lymphatic function and bilateral dermal backflow in all subjects with chronic venous insufficiency, even those without ulcer formation (Rasmussen et al., 2016).

As edema progresses to chronic edema, pathophysiological changes occur as a result of localized lymphatic insufficiency or failure. For example, swelling post-orthopedic surgery or traumatic injury or chronic edema surrounding a venous leg ulcer can lead to localized protein accumulation and degradation, resulting in localized inflammation and connective tissue proliferation. According to Foldi, "... stagnating high protein edema develops a pathohistological state of chronic inflammation, with infiltration of the tissue by mononuclear cells, angiogenesis, proliferation of connective tissue, fibrosis and fibrosclerosis . . ." He further goes on to describe how oxidation and degradation of interstitial proteins attracts monocytes (macrophages) that, in turn, ingest proteins and activate fibroblasts and adipocytes. This activation results in connective tissue and adipose proliferation. As such, wounds and impaired cutaneous function are highly associated with inflammation and fibrosis associated with lymphatic dysfunction.

Clinical Diagnosis

In 1976, Robert Stemmer defined a test used for differential diagnosis of lymphedema, which later was corroborated sonographically, macroscopically and microscopically by Brenner, Putz, and Moriggl in 2007. In its original description by Stemmer, "a thickened longitudinal skinfold when pinching the toes is a clinical sign for the early diagnosis of a lymphoedema, and delimits it from a pure venous oedema" (Stemmer, 1976). In the Best Practice for the Management of Lymphoedema (Framework, 2006), the Stemmer test is described as being performed on the second toe or middle finger, attempting to pinch and lift the skin. The test is considered positive for lymphedema when a skin fold cannot be raised, but a negative sign does not exclude lymphedema. In 2007, Brenner, Putz, and Moriggl showed that in individuals with lymphedema and a positive Stemmer sign, both the dermis and subcutaneous tissue of the second toe were thickened and the structure of the dermal layers destroyed, as well as an accumulation of edematous fluid in free spaces within the subcutaneous tissue.

In light of the new paradigm that all edemas are on a lymphedema continuum, co-author Robyn Bjork proposes an expanded version of the Stemmer test. This new test, named the "Bjork Bow Tie Test," can be performed anywhere on the body to assess for inflammation and thickening of the integument that can occur with lymphatic dysfunction, such as around chronic wounds. To perform the test, in one maneuver gently pinch, lift and rotate the skin between the thumb and pointer finger, noting quality of tissue texture and thickness. Healthy skin can be lifted and pinched, should feel slippery between the layers, and produce a "bow tie" of wrinkles when rotated. (See Figures 2 and 3.) Skin that is positive for lymphedema will be thickened, less pliable, less able to be pinched and lifted, more difficult to rotate, and produce limited or no "bow tie" of wrinkles.

FIGURES 2 and 3. Pictured are Bjork Bow Tie Tests performed on different areas of skin with varying thicknesses. Both tests are negative for lymphedema, exemplified by the distinguishing "bow tie" of wrinkles.

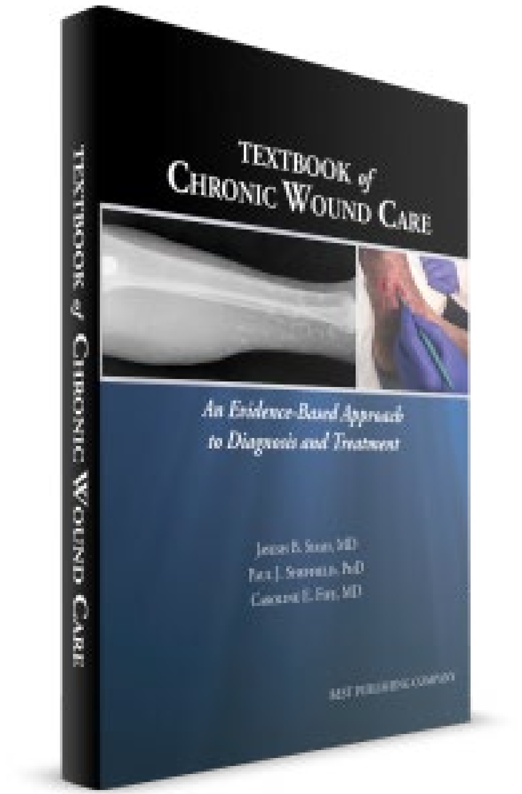
For skin that may be distended from edema and cannot be lifted because of it, still observe for the "bow tie" of wrinkles when performing the technique. Areas of skin should be demarcated on a body map to indicate where the test is positive (+) or negative (-). Even a slightly positive test should be marked as positive (+). The subcutaneous tissue should also be assessed in a similar fashion. A negative test does not exclude lymphedema but means that the dermis and subcutaneous tissues have not yet developed the pathohistological changes described previously.

Relationship Between Lymphatic and Integumentary Systems

It is well established that there is a paucity and lack of standardization with respect to wound and lymphedema education in traditional medical and health professions education. If such education is provided, it is likely segmented and taught in separation rather than in parallel or unison. In 2008, a study by Patel et al. compared wound education in medical school curricula between the United States, Germany and the United Kingdom. The results of this retrospective indicated that the "total hours of required wound education received in the United States was 9.2 hours in the 4 years of medical school. In the United Kingdom, the total time devoted to wound-related issues equaled 4.9 hours over 5 years. In Germany, a total of 9 hours of wound education was provided over 6 years." This study concluded that there is a deficiency with respect to wound education in preparing future physicians to manage wounds.

With respect to lymphedema, the education is even more sparse. A survey study published in 2011 by Vuong, Nguyen and Piller regarding the level of lymphatic education provided in medical schools around the United States, indicated that most programs devoted 30 minutes or less to teaching lymphatic function in the first two years of medical school. Further, nearly 40% of respondents indicated that 1-3 hours of time was devoted to the lymphatic system, while 25% indicated that 15 minutes or less was spent on the topic. The apparent lack of dedicated time in traditional medical education is further compounded by the fact that these two systems are highly interdependent, meaning impairment in one system directly impacts the other.

Carlson describes in his 2014 review article how lymphatic failure produces a cutaneous region susceptible to infection, inflammation and carcinogenesis, which he describes as a locus minoris resistentiae or path of least resistance. He explains in his



TEXTBOOK *of* CHRONIC WOUND CARE

An Evidence-Based Approach for Diagnosis and Treatment

by Jayesh B. Shah, MD,
Paul J. Sheffield, PhD,
and Caroline E. Fife, MD

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About the Book

This textbook is a companion reference book for the *Wound Care Certification Study Guide, 2nd Edition.*

This book belongs in the library of every practitioner who treats chronic wound care patients. It proves to be a valuable text for medical students and all health-care professionals - doctors, podiatrists, physician assistants, nurse practitioners, nurses, physical and oocupational therapists - in various settings. It provides thorough understanding of the evidence-based multipdisciplinary approach for caring for patients with different kinds of wounds.

This textbook provides the best diagnostic and management information for chronic wound care in conjunction with evidence-based clinical pathways illustrated by case studies and more than 350 pictures in addition to up-to-date information for the challenging chronic wound care problems in an easy-to-understand format.

Features

- Chapters are written by more than 50 well-respected leaders in the specialty of wound care.
- Balanced evidence-based multidisciplinary approach to chronic wound care
- Exclusive key concepts in every chapter for a quick review
- Excellent resource for preparation of wound care certification exams with 250 questions and answers
- Chapters specifically focused on wound care in different care settings
- Chapter on telehealth and wound care addressing the future of chronic wound care
- Deep understanding of value-based care in wound care in the United States
- Chapter on healthcare payment reform and the wound care practitioner
- Separate sections on approach to wound care in various countries globally

article how lymphatic failure causes a disruption of adaptive immunity by "decreasing or obstructing immune trafficking by antigen, lymphocytes, macrophages and dendritic/antigen presenting cells (Langerhans cells) to the lymph node crating a cutaneous region of immunosuppression. All these abnormalities create a region of immunosuppression . . . or a condition called lymphatic dermopathy, which is failure of the skin as an immune organ." In essence, lymphatic impairment can lead to integumentary dysfunction and integumentary dysfunction can exacerbate lymphatic dysfunction. For clinicians, it is important to recognize the interdependence these systems have on one another so proper diagnosis and interventions can be delivered.

Conclusion

To summarize, the EGL is the gatekeeper for blood capillary fluid exchange. There is only diminishing net fluid filtration, and no reabsorption across the blood capillaries of the dermis and subcutaneous tissues. All fluid and blood proteins moving into the interstitium must be removed via reabsorption through the lymphatic capillaries alone. Thus, all edemas are on a lymphedema continuum and are at risk of developing chronic inflammation, dermal thickening and connective tissue proliferation. The new, "Bjork Bow Tie Test" can be used to test for these integumentary changes anywhere on the body, including around wounds. Skin that is positive for lymphedema will be thickened, less pliable and produce limited or no "bow tie" of wrinkles.

Assessment of the lymphatics is important in chronic wound management, as impairment in one system indicates impairment in the other with varying levels of complexity and clinical presentation. Improved collaboration is needed between physicians, vascular/vein specialists, wound specialists, lymphedema therapists and other health care professionals, to establish cohesiveness of paradigms and common language. By working more closely together, progress toward effective, multi-disciplinary care, particularly for individuals with lower extremity lymphedemas and chronic wounds, is achievable.

About the Author

ROBYN BJORK, PT, CLWT, CWS, CLT-LANA is the founder and CEO of the International Lymphedema & Wound Training Institute (ILWTI). She is a physical therapist who is an expert in the field of wound care and lymphedema management and has over 20 years experience, spanning outpatient, inpatient, transitional, long-term, home-care and private practice settings.

Bjork is a featured speaker at national and international conferences, such as the Symposium on Advanced Wound Care, European Wound Management Association, Canadian Association of Wound Care, Wild on Wounds, National Lymphedema Network International Conferences, the Lymphatic Education & Research Network's Symposium Series, and numerous regional lymphedema and wound conferences. Bjork has written, produced, and implemented over 155 hours of advanced, accredited curriculum for certifying wound and lymphedema specialists in the United States and abroad (www.ilwti.com). She is co-author on the chapter on lymphedema in *Textbook of Chronic Wound Care: An Evidence-Based Approach to Diagnosis and Treatment* and has authored articles in *Wounds International*, *Pathways* and *Wound Care Advisor.*

Bjork is a Certified Lymphedema and Wound Therapist through the International Lymphedema & Wound Training Institute, a Certified Wound Specialist through the American Board of Wound Management, and a Certified Lymphedema Therapist through the Lymphology Association of North America. She is a proud member of the American Physical Therapy Association, the Lymphology Association of North America, thw Association for the Advancement of Wound Care, the World Alliance of Wound and Lymphedema Care, and the American College of Phlebology.

Bjork is a board member and past secretariat of the World Alliance of Wound and Lymphedema Care. She is an international expert in the morbidity management of podoconiosis and lymphatic filariasis and a chapter author on podoconiosis for a soon-to-be-published global wound and lymphedema management handbook for WAWLC and the World Health Organization. In recognition of her international work, in 2011 Bjork received the Central Florida Humanitarian Award and was featured in the commemorative edition of Space Coast Medicine magazine. She also received a Certificate of Special Congressional Recognition in appreciation of excellence in medicine.

About the Author

HEATHER HETTRICK PT, PHD, CWS, CLT-LANA, CLWT is an associate professor in the Physical Therapy Program at Nova Southeastern University in Ft. Lauderdale, Florida. As a physical therapist, her expertise resides in integumentary dysfunction where she holds three board certifications.

Heather has diverse work experience in academia and the private sector. She is a key opinion leader and is actively involved in numerous professional organizations, conducts research, and publishes, presents and teaches nationally and internationally on integumentary related issues.

Dr. Hettrick is a past president of the American Board of Wound Management and is an active board member of the Association for the Advancement of Wound Care and World Alliance of Wound and Lymphedema Care.

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Press Release from Smith & Nephew:

New Meta-Analysis Demonstrates the Effectiveness of PICO◊ NPWT in Helping to Prevent Surgical Site Complications versus Standard Care

Smith & Nephew (LSE: SN, NYSE: SNN), the global medical technology business, announces the publication of a new meta-analysis of 16 studies that demonstrated the prophylactic application of PICO on surgical site incisions significantly reduced surgical site infections (SSIs), wound dehiscence and length of stay when compared to standard care.

According to the meta-analysis, using PICO with AIRLOCKTM Technology significantly reduced the rate of surgical site complications by 58% and the rate of dehiscence (wound rupturing along a surgical incision) by 26%. PICO treated patients spent half a day less in hospital on average*1.

“This is the first comprehensive meta-analysis that has assessed the benefit of a specific negative pressure wound therapy (NPWT) device on surgical site complications,” said Paolo Di Vincenzo, Senior Vice President Global Marketing, Smith & Nephew.

“It is a significant addition to the growing body of literature supporting PICO as an effective prophylactic treatment option for SSIs and helps provide important insights into optimizing clinical management strategies for preventing SSIs, which are an increasing concern for health-care providers and their patients around the world.”

The meta-analysis evaluated results from 16 peer-reviewed publications (including 10 RCTs) involving 1,863 patients and 2,202 incisions to assess the average effect of PICO Single Use Negative Pressure Wound Therapy System application across a wide variety of surgical indications, on surgical site infection (SSI), dehiscence, or length of hospital stay in comparison to standard of care.

The overall number needed to treat (NNT) to prevent one costly and potentially dangerous and painful SSI was just 14, and this was further reduced to an NNT of 5 for patients, treated with PICO, undergoing colorectal surgery.

Dr. Risal Djohan, Department of Plastic Surgery, Cleveland Clinic, USA, a PICO user, added: “This meta-analysis confirms the benefits and significant role of the PICO system. With the current available and published data, it underlines the importance of adapting the use of this advanced and novel innovation in helping to treat our patients with confidence to lower the potential incidence for surgical complications.”

The PICO Single Use NPWT system is being investigated in a number of further clinical trials worldwide. For more information about this study, please see http://www.smith-nephew.com/strugala/.

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About Smith & Nephew

Smith & Nephew is a global medical technology business dedicated to helping health-care professionals improve peoples’ lives. With leadership positions in Orthopaedic Reconstruction, Advanced Wound Management, Sports Medicine and Trauma & Extremities, Smith & Nephew has approximately 15,000 employees and a presence in more than 100 countries. Annual sales in 2017 were almost $4.8 billion. Smith & Nephew is a member of the FTSE100 (LSE:SN, NYSE:SNN).

For more information about Smith & Nephew, please visit our website www.smith-nephew.com, follow @SmithNephewplc on Twitter or visit SmithNephewplc on Facebook.com

To learn more about what we do to help reduce surgical site complications, please visit www.closertozero.com

Forward-Looking Statements

This document may contain forward-looking statements that may or may not prove accurate. For example, statements regarding expected revenue growth and trading margins, market trends and our product pipeline are forward-looking statements. Phrases such as "aim", "plan", "intend", "anticipate", "well-placed", "believe", "estimate", "expect", "target", "consider" and similar expressions are generally intended to identify forward-looking statements. Forward-looking statements involve known and unknown risks, uncertainties and other important factors that could cause actual results to differ materially from what is expressed or implied by the statements. For Smith & Nephew, these factors include: economic and financial conditions in the markets we serve, especially those affecting health-care providers, payers, and customers; price levels for established and innovative medical devices; developments in medical technology; regulatory approvals, reimbursement decisions, or other government actions; product defects or recalls or other problems with quality management systems or failure to comply with related regulations; litigation relating to patent or other claims; legal compliance risks and related investigative, remedial, or enforcement actions; disruption to our supply chain or operations or those of our suppliers; competition for qualified personnel; strategic actions, including acquisitions and dispositions, our success in performing due diligence, valuing, and integrating acquired businesses; disruption that may result from transactions or other changes we make in our business plans or organization to adapt to market developments; and numerous other matters that affect us or our markets, including those of a political, economic, business, competitive, or reputational nature.

Please refer to the documents that Smith & Nephew has filed with the U.S. Securities and Exchange Commission under the U.S. Securities Exchange Act of 1934, as amended, including Smith & Nephew's most recent annual report on Form 20-F, for a discussion of certain of these factors. Any forward-looking statement is based on information available to Smith & Nephew as of the date of the statement. All written or oral forward-looking statements attributable to Smith & Nephew are qualified by this caution. Smith & Nephew does not undertake any obligation to update or revise any forward-looking statement to reflect any change in circumstances or in Smith & Nephew'sexpectations.

Reference

1. Strugala, V. and Martin, R. Meta-analysis of comparative trials evaluating a prophylactic single-use negative pressure wound therapy system for the prevention of surgical site complications. Surgical Infections (2017). DOI 10.1089/sur.2017.156*Meta-analysisincluded10RCT&6observationalstudies.ReductioninSSI(16studiesincluded): 1839 patients (2154 incisions): PICO 5.2%; control group 12.5%; p<0.0001. Mean reduction in hospital length of stay 0.47 days (8 studies included): p<0.0001.

Mixed surgery

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WoundEvidence

Single paper review

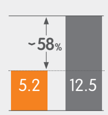
Strugala, V. & Martin, R. (2017)

Meta-analysis of comparative trials evaluating a prophylactic single-use negative pressure wound therapy system for the prevention of surgical site complications

This meta-analysis combines 16 articles, comprised of 10 randomized control trials and 6 observational studies, comparing outcomes for PICO° single-use Negative Pressure Wound Therapy system application to standard of care.

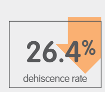
Evidence

- Level I evidence: A meta-analysis
- A weighted analysis of 16 articles involving 1863 patients (2202 incisions)
- The aim of this meta-analysis was to pool results from multiple studies to access the average effect of PICO application across varied surgical indications on surgical site infection (SSI), dehiscence or length of hospital stay in comparison to standard of care



Surgical Site Infection

- Application of PICO reduced rate of SSI by 58% (relative risk 0.43, p<0.0001) compared to standard of care
- Reduced risk of SSI demonstrated by PICO was significant across various surgical specialties including:
  - Orthopaedic (relative risk 0.48, p=0.03)
  - Abdominal (relative risk 0.44, p<0.0001)
  - Colorectal (relative risk 0.29, p=0.0004)
  - Caesarean section (relative risk 0.53, p=0.007)



Dehiscence

- PICO significantly reduced rate of dehiscence by 26.4% (relative risk 0.71, p=0.01) compared to standard of care

Length of stay

- PICO treated patients had significantly less hospital length of stay compared to standard of care (0.47 days p<0.0001)

Diving with Disabilities

Part 2 of 3

Michael B. Strauss, MD, Lientra Q. Lu, BS

This three-part article series on diving with disabilities is an excerpt from the extensive revision in progress of Dr. Michael Strauss and Dr. Igor Aksenov's *Diving Science* textbook

This three-part series is extracted from a chapter in the second edition of *Diving Science* by Michael B. Strauss, MD, et al. which covers special diving types, situations and environments. Part 2 of this series in the current issue of *WCHM* discusses musculoskeletal disabilities, neuropsychiatric disorders, and respiratory problems.

Musculoskeletal Disabilities

Introduction Problems involving the musculoskeletal system are easier to conceptualize as handicaps such as a loss of limb as compared to disabilities such as those imposed by heart disease. The majority of musculoskeletal handicaps with respect to scuba diving consist of three primary problems: loss of limbs, restricted/painful joint motions and loss of function from neurological conditions. How much they interfere with scuba diving needs to be considered on a continuum from almost none to total prevention of the activity. In the majority of scuba divers with disabilities, the dive buddy is a key factor in making the dive safe and enjoyable.

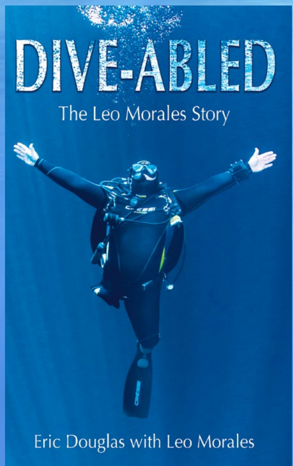
Loss of Limbs Trauma and circulation problems are the two most frequent causes of amputations, and most occur in the lower extremities. Those individuals with loss of limbs from circulation problems usually have other significant comorbidities such as heart disease and diabetes and consequently are not candidates for scuba diving. Conversely, much attention has been given to scuba diving in patients with traumatic amputations. This is largely a consequence of affording wounded warriors from military conflicts the benefits and pleasures of scuba diving.

For single leg amputations, the restrictions for scuba diving are minimal. Usually all that is needed is an adaptive fin-prosthesis device (Figure 5). For above-knee and bilateral amputees, the designs are more complicated, with the most challenges being the attachment of the swimming prosthesis to the remaining limb stump. What can be done in this regard is dependent on the motivation of the amputee and the ingenuity of the prosthetist. While the amputee may be totally independent on land with crutches or even without walking aids, the transition from the land to the water environment is the primary challenge. This is where the buddy diver is essential and adaptive devices for the transition may be needed, such as a ramp or hydraulic lift device for water entries and exits.

Joint, Ligament, Tendon and Muscle Problems Arthritis is a condition where body joints including the spine have deterioration of their articular (joint) cartilage and no longer function as smooth guiding surfaces. The loss of cartilage can progress to bone erosion and collapse of the joint surfaces. With

FIGURE 5. Adaptive Fins for Swimming and Diving

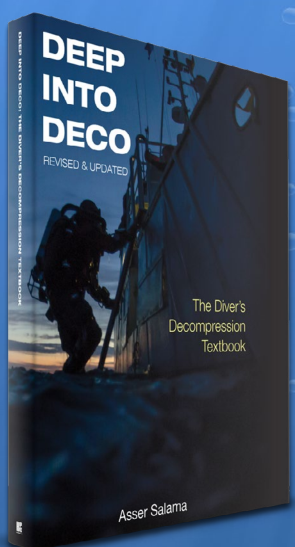
A variety of options exist for swim fins for amputees. Some amputees have a water employable prosthesis for aquatic activities in addition to the prosthesis they use for walking.



DIVE-ABLED: THE LEO MORALES STORY

by Eric Douglas with Leo Morales

If you ask Leo Morales, nothing is impossible if you set your mind to it. And he should know. After he lost his right leg to cancer, Leo struggled with life. But he decided his disability would not define him. When friends suggested scuba diving as part of his physical therapy, he was hooked. He quickly progressed from diver to dive instructor and technical diver. Leo has set two world records as a disabled diver, one for depth and one for distance underwater, and tirelessly travels to share his message that disabilities are only in the mind.



DEEP INTO DECO REVISED AND UPDATED

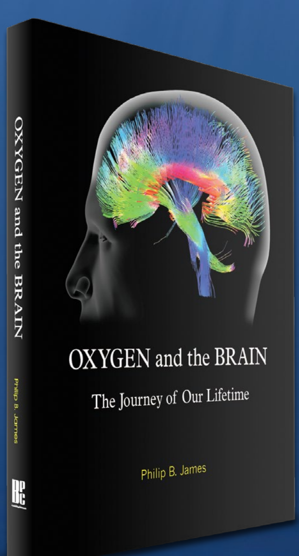
by Asser Salama

This second edition of ***Deep Into Deco*** has been fully updated to reflect the latest research outcomes. Chapter summaries have been added to give a quick overview of each chapter. A new section on nitrogen and helium kinetics has been added as well as a second appendix for calculating the acceleration in post-diving no-fly time associated with breathing surface oxygen.

Deep Into Deco is a comprehensive and well-written reference text that covers various topics of decompression theory. It portrays the latest developments and controversial issues in technical diving in a way that is straightforward, easy to read, understandable and free from technical jargon.

With a writing style that is a mix of strict no-nonsense reporting along with interesting storytelling, ***Deep Into Deco*** includes interviews with accomplished divers, industry professionals, researchers and software developers.

This book is a must read for any diver who wants to understand decompression theory, how it evolved, what it accomplished and where the latest research is headed.



OXYGEN AND THE BRAIN: *The Journey of Our Lifetime*

by Philip B. James, MB, ChB, DIH, PhD, FFOM

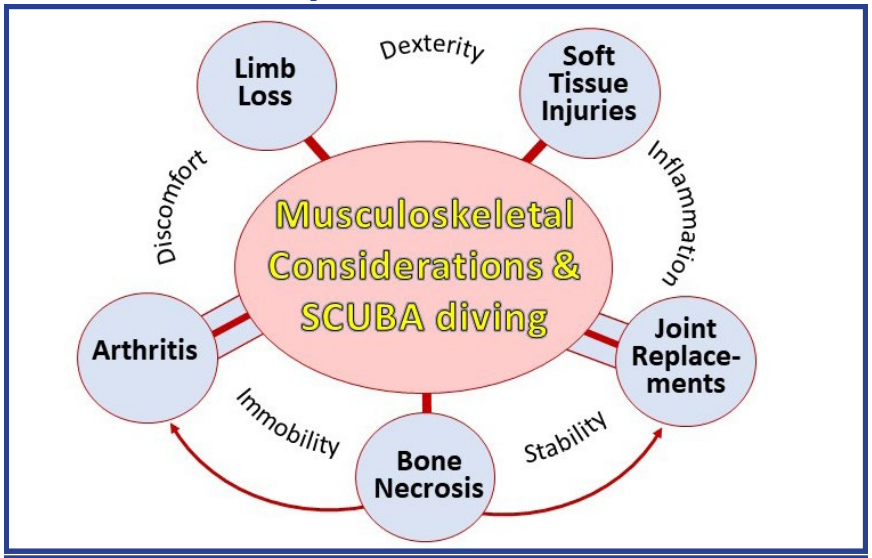
Following the human journey from conception to old age, *Oxygen and the Brain* presents evidence amassed over more than a century that can transform the care of patients with birth injury, head trauma, multiple sclerosis, and stroke and can even reverse decline in old age. There is no more necessary and scientific action than to correct a deficiency of oxygen, especially in the brain, and it is simple to give more.

such, there is marked restriction of the joint's motion and associated pain with movement of the joint. With decreased movement, the joint capsules, ligaments and muscle-tendon units contract and loss of joint motion is the result. Pain and loss of joint motion have consequences for the scuba diver. They include interfering with the donning and removing diving gear—especially exposure suits, entries to and exits from the water, and ability to use the extremities at a capacity necessary to extricate themselves from emergencies, such as negotiating currents or extrication from entanglements. When the above are realized, the scuba diver typically "retires" from this activity for the reason it is too difficult and/or it is "no longer fun or enjoyable."

Although musculoskeletal pain and restricted joint movements for land-based activities may severely curtail activities, the buoyancy effects of water unload joints and need for minimal joint movements for motility make swimming and water aerobics an ideal exercise activity. While these have some relationships to scuba diving, the challenges, as previously mentioned, are donning and removing gear and water entries and exits.

Diving with Joint Replacements
Orthopaedic advancements have greatly expanded the possibilities for those with arthritis problems to dive. These advancements are largely due to the successful outcomes of total joint replacements. Most arthritis problems with respect to scuba diving impose only relative contraindications for scuba diving. Patients with arthritis and/or total joint replacements should not categorically be restricted from scuba diving. There is no data available that patients with total joint replacements have increased incidences of medical problems of diving and, in particular, decompression sickness. Consequently, the decision to scuba dive is primarily a function of the patient's motivation. However, this must be coupled with the joint surgeon's approval that the joint replacement is sufficiently healed, stable and functional enough that scuba diving is OK.

FIGURE 6. Musculoskeletal Handicaps that Have Ramifications for SCUBA Diving



Five conditions encompass almost all the musculoskeletal conditions that can affect divers. When mild-to-moderate they only impose relative or temporary contraindications. For example, bone necrosis can lead to arthritis, which can be mitigated with joint replacements. With adaptive equipment and dive planning, most do not impose absolutive contraindications for SCUBA diving.

Soft Tissue Musculoskeletal Disorders
Other musculoskeletal problems such as shoulder rotator cuff tears, tendinitis, contractures, joint instabilities, knee meniscus tears and low back pain, in general, only impose temporary contraindications for scuba diving, Almost all of these conditions can be mitigated with rest, medications (especially non-steroidal, anti-inflammatory agents), physical therapy and/or surgery. Since conditions just mentioned can interfere with mobility, dive planning and selection of dive sites are important. Conditions to avoid are dive sites where strong currents are present and where water exits require removal of equipment while dangling from a safety line or ladder in turbulent waters.

DIVE SCENARIO While scuba diving in somewhat arduous conditions in a dive that almost exceeded the dive computer's no decompression limits, the diver needed to hang onto a safety line from a boat bobbing in the rough sea to remove his gear.

In the process of doing such, he was repeatedly tugged and twisted while holding onto the safety line with one hand and removing his gear with the other. After climbing aboard with the ladder bouncing up and down, he immediately experienced pain in the shoulder used to hold the safety line.

Decompression sickness (DCS) was suspected, but a shoulder rotator cuff tear (RCT) could not be ruled out.

A trial of hyperbaric oxygen recompression did not resolve the symptoms. The patient was subsequently evaluated and managed for a rotator cuff tear.

COMMENT When decompression sickness is suspected, a trial of hyperbaric oxygen recompression (HBO RC) should always be done. The scenario shows how the history helped to justify DCS as a possible cause of the patient's shoulder complaints.

It is possible that both diagnoses (e.g. DCS and RCT) could have coexisted. With the HBO RC treatment, pain symptoms without moving the shoulder would be expected to resolve. However, pain with shoulder motions and lifting with the extremity would remain and confirm the presence of the RCT.

Bone Necrosis Osteonecrosis (osteo = bone, necrosis = death) is a condition where bone cells die. It has other names such as avascular necrosis, femoral head necrosis (although it can occur in other bones), bone necrosis, diver's bone disease and bone rot. Although the etiology has not been clearly established, it is hypothesized that bubbles form in the blood vessels supplying the bone cells, the cells die from hypoxia and if in a joint area, collapse, cause irregularity of the joint surfaces and result in arthritis. There are reported associations of this condition occurring in saturation divers, divers who do repetitive long, deep dives and those divers who have omitted decompression. However, the incidences are so infrequent as compared to post-traumatic, coagulopathy-related and idiopathic age-related, wear-and-tear arthritis, that the significance of the diving activity can be questioned. However, if osteonecrosis occurs in the relatively young diver, the diving history must be considered.

Osteonecrosis is not a disability unless arthritis and joint collapse occurs. If detected, diving practices should be reviewed and avoidance of diving activities that could further the problem avoided. Consequently, osteonecrosis becomes a relative contraindication for scuba and other compressed gas diving. Hyperbaric oxygen has been reported to prevent progression of femoral head necrosis before it progresses to joint collapse.[12] If a joint replacement is required, commercial diving activities are not recommended. However, as mentioned before, with due considerations, scuba diving with joint replacements should be placed in the relative contraindications category.

Neuropsychiatric Disorders

Spinal Cord Injuries and Peripheral Nerve Problems Neuropsychiatric disorders have two major components, those that affect the brain and those that affect spinal cord/peripheral nervous system. Spinal cord and peripheral nervous system problems mainly concern loss of function. Paraplegic patients who have plateaued in their recovery present relative contraindications for diving. Wounded warriors and other athletic individuals are the major candidates for scuba diving.

Motivation of the paraplegic diver is the key factor in association with a high level of fitness and a nearly ideal body mass index. Next is establishing a dedicated support team. This includes usual and customary scuba

TABLE 5. Mental Conditions and Diving

Condition	Major Problem(s)	Concerns and Recommendations for Diving
Alzheimer's	Similar to developmental delays	If affliction is mild and especially if the patient enjoys the water and had dove before, diving in controlled environments may be beneficial
Anxiety Disorder (less severe than neuroses)	Innate fear of water, drowning, or sharks while able to function well in other situations	As with neuroses diving should not be forced on people with anxiety disorders for aquatic environments
Autism	Lack of communication skills, inability to pay attention, lack of interest	If successfully snorkels, then with close supervision in controlled environments, diving may have therapeutic benefits
Cerebral Palsy	Uncontrolled muscle movements, lack of coordination, spasticity, contractures	Mobility limitations: difficulty handling diving gear, donning and removing it. If mild, planned diving with supervision OK
Developmental Delay/Mental Retardation	Inability to understand or follow instructions. Subject to panicking and doing dangerous things such as "bolting" to the surface breathing or descending to dangerous depths	If moderate to mild impairment, close supervision in controlled environments possibly OK for diving. Better to teach and engage in snorkeling activities
Neuroses	Anxiety, obsessive-compulsive behavior, lack of focus extends to all activities	Spectrum ranging from complete avulsion to diving, sharks, etc. to obsessions with safety, hygiene, contaminants, pollution with behavior that interferes with other divers' enjoyment
Post Traumatic Stress Disorder	Analogous to neuroses	Diving may be a superb diversionary activity with the water environment; supervisions and controlled environments are essential
Psychoses	Depression, mania, paranoia	Suicidal behavior, risky activities, harm to others due to hallucinations, loss of reality, or wanting to harm others. Diving not recommended
Sociopathic Behavior	Drug use, intoxications, deviant behavior	Safety concerns regarding diving; makes the diving experience potentially dangerous for others
Traumatic Brain Injury	Similar to Alzheimer's	Similar recommendations to Alzheimer's

diving training as well as the unique considerations for how to deal with functionless, insensate lower extremity limbs in an environment that provides near neutral buoyancy. The dive buddy and support team need to help with donning and removing diving gear and water entries and exits as well as guiding the handicapped diver through the course of the dive. Of special concern is avoiding the dandling of paralyzed lower extremities onto potential injury-producing marine animals such as barnacles, sea urchins and fire corals.

The third consideration is selection of the "ideal" diving site where minimal cold water exposure gear and weights to establish neutral buoyancy are needed, water entries and exits are easy (such as off of a boat), the water visibility is good, and waves, currents or swells are at a minimum. The dive profiles should be very conservative because the on and offgassing of nitrogen is likely to be much different in extremities that are immobile due to the paralysis. Mixed gas and closed-circuit rebreather scuba diving is not recommended for the paraplegic patient. Not unexpected, it is likely to be very satisfying psychologically for a paralyzed diver to "conquer" the aquatic environment and do things most terrestrial bound people are afraid and/or are unwilling to do. Likewise, for the dive buddy it is a real achievement and a measure of the highest level of scuba diving skills to be able to execute safely the diving activity for the handicapped diver.

Other nerve-related disorders such as carpal tunnel syndromes, tennis elbow, diabetic neuropathy, peripheral neuritis, sciatica, radicular pain, etc., present relative contraindications to diving. Most are remedial with medication and/or surgical management. The physician attending to the patient's problem can usually provide clearance for scuba diving. If in doubt, referral to a diving medicine physician for advice is recommended.

Vision and Other Sensory Organ Impairments or Losses The major considerations are those that deal with hearing, vision and sensation. Much has been written about scuba diving with eye conditions; most are relative or temporary (e.g. after surgical procedures) contraindications for scuba diving.[13] Radial keratotomy and laser refractive surgery (photorefractive keratotomy) impose only temporary contraindications for scuba diving that allow time for healing. The ophthalmologist performing the surgery is expected to provide the clearance as when it is OK to scuba dive after such procedures.

Patients who have surgeries for the above conditions generally have good outcomes. However, convalescence and restoration of full function takes much more time than just the time it takes the incision to heal.

Is back surgery a contraindication for scuba diving? Laminectomies, nerve root decompressions, and fusions are frequently done. While swimming with the neutral buoyancy afforded by the aquatic environment is ideal for rehabilitation, consideration for the "burden" (tanks, weight belt, increased lever arms to the hip and low back musculature imposed by swimming with fins, etc.) of the diving equipment must be considered in making a decision whether to scuba dive or not.

In general, the surgeon and/or the rehab specialist will make the decision whether or not the surgical sites are sound enough to allow scuba diving. If questions arise, the diving physician who is versed in the challenges of the diving environment can provide advice about the feasibility for the patient to scuba dive.

More common considerations are diving with impaired vision, which can usually be managed with corrective lenses. Contact lens use is not a contraindication for scuba diving. Loss of near vision (myopia) is commonly associated with aging. This is somewhat mitigated by the magnification effect of the facemask-water interface, which makes objects appear about a third larger than when visualized in air. Corrective lenses attached to the face mask are a solution to impaired near vision. A more important safety concern is that the loss of near vision makes the reading of dive monitoring equipment difficult and is a reason not to scuba dive without lenses to correct this problem. While blindness is not a contraindication for scuba diving, anecdotal reports exist that legally blind (vision less than 20/200) have done and enjoy scuba diving.[14] Loss of color vision is not a contraindication for scuba diving, except for Naval Special Warfare divers (SEALS) and Explosive and Ordinance Demolition (EOD) divers because of the need to differentiate color-coded wiring for setting-up and deactivating demolitions. While glaucoma is not a contraindication for scuba diving, medications to manage it can affect heart rate and becomes a consideration if cardiac conditions are present.

A concern raised with scuba diving with contact lenses is that if the dive masks flood, the lenses could become dislodged. Trying to replace the lenses in an aquatic environment is a near impossible undertaking. The dislodgment of contact lenses could raise safety concerns about reading monitoring equipment for the save completion of the dive.

Another consideration is bubbles from decompression can develop in the fluid film between the contact lens and the cornea and affect vision. For this reason if contact lenses are used by the scuba diver, they should be of the "soft" variety.

Hearing Impairments Impaired and total loss of hearing are different

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considerations. Age-related decreases in hearing (presbycusis), most noticeable with high frequency sounds, is not a contraindication to scuba diving. However, total deafness in one ear is considered by many to be an absolute contraindication to scuba diving. This is because ear structures are among the most vulnerable of all body structures to barotrauma, and diving presents constant, invariable challenges to these structures. Meniere disease is an absolute contraindication for diving.

The cause of Meniere disease is an excessive accumulation of the fluid (endolymph) filling the inner ear structures thought to be due to the impaired absorption of this fluid.

In this sense, it has many analogies to hydrocephalus, a condition caused by the excessive accumulation of cerebrospinal fluid in the brain. The increased accumulation dilates the ventricles of the brain with resultant pressure atrophy of the brain tissues and enlargement of the cranium if it occurs before the skull bones have fused.

Its symptoms include vertigo nausea, vomiting, tinnitus and hearing loss. The hearing loss tends to fluctuate but worsens with time.

Sensory Losses Sensation has many components such as pain, light touch, two-point discrimination, pressure, stretch/distraction, temperature, and vibration recognition and discrimination. Each has its own sensory organelles for recognition, but the nerve impulses must be transmitted to the brain where they can be interpreted by the sensory cortex. Any perturbation along this transmission and interpretation chain can cause disordered or loss of sensation. While this may seem insignificant since vision is the overwhelming sensory experience during diving, it may have consequences for grasping objects, appreciating marine animal injuries, protecting from cold exposure, and handling safety equipment. Again, dive planning and dive buddies can compensate for diving with rare and unusual sensory nerve problems resulting from diabetes mellitus, trauma, multiple sclerosis, radiculopathies (impingement of nerves leaving the spinal cord), and nerve compression syndromes such as carpal tunnel syndrome.

Psychiatric and Brain Function Disorders Of all the disabilities and handicaps that can confront the scuba diver, these are the most difficult for which to provide concrete recommendations. They encompass a spectrum of disorders in alphabetical order from Alzheimer's disease, to anxiety disorders, to autism, to cerebral palsy, to developmental delay/mental retardation, to neuroses, to post-traumatic stress disorder, to psychoses, to sociopathic behavior, to traumatic brain injury (Table 5). Not to be overlooked in this spectrum is the recognition how scuba diving has benefited those with autism, traumatic brain injury and post-traumatic stress disorder.[15,16]

Scuba diving is an option that appears to have many benefits for the victims of traumatic brain injury and post-traumatic stress disorder as well as other brain function problems. The aquatic environment with its ability to provide almost neutral buoyancy and move about as a bird flying through the air undoubtedly can help sufferers of these problems from the realities and challenges of functioning on land.

Consequently, decisions to scuba dive or not weigh in favor of allowing the patient with psychiatric and brain function disorders to do this activity. However, each patient is a special consideration in itself requiring input from the patient, family members, and the patient's care providers as well as the dive buddy/supervisor.

Scuba diving requires a complement of cognitive skills, coordination abilities, interpretations of sensory input, and integrations of motor (muscle) activity. In making decisions about diving, the most likely factor to interfere with the diving activity and/or make the risks of a problem arising during the dive must be considered the critical variable in making the decision (Table 5). The decision to consider or not recommend scuba diving, consequently, rests on input from a variety of sources as well as the patient's own functional abilities, cognitive skills and desires. Not to be disregarded is a diving physician's role to advise and consent on the diving conditions that would be appropriate for the handicaps in question. The other prerequisites for scuba diving with patients who have mental conditions are diving in a controlled environment with adequate and attentive supervision.

Diving in controlled conditions implies that the diving site is selected for its safety features, accessibility, water visibility, water temperature and weather conditions. Safety features and accessibility include use of fixed diving platforms with safety lines anchored to the bottom, gentle beaches with minimal surf, absence of, or minimal currents.

Water visibility, warm water and good weather conditions are obvious features of diving in a controlled environment and are best achieved by diving in tropical and subtropical waters in lagoons or on the leeward sides of islands or peninsulas.

Respiratory System Problems

Introduction The respiratory system has a multitude of components from the openings of the mouth and nose to the conduits such as pharynx, larynx, trachea, bronchi, bronchioles and terminal bronchioles, to the alveoli where air exchange occurs, to the lining of the lungs (the pleura), to the alveolar

capillaries, to the diaphragm and accessory respiratory muscles, to the rib cage. Each component has conditions that can impose restrictions on divers (Table 6). Two main conditions, asthma and pneumothorax, generate the most questions about making decisions and imposing restrictions on scuba diving. Almost all the other conditions have obvious contraindications for scuba diving or the conditions only impose temporary restrictions as documented in the above-cited table.

The respiratory system is another incredible organ system. Its two main components are the conducting elements and the gas exchange elements. The conducting elements begin with the mouth and nose and continue to the bronchioles. There are 23 divisions or splits of the conducting elements before they reach the alveoli. Not only does the conducting elements provide a conduit, but they also warm and moisturize the inspired air so that it is 100% saturated with moisture and warmed to body temperature before it reaches the alveoli.

All gas exchange (i.e oxygen in and carbon dioxide out, as well as other gases such as nitrogen, carbon dioxide, etc.) occur in the terminal bronchioles (10% of the exchange) and the alveoli 90% of the exchange). There are about 480 million alveoli and if spread out on a flat surface, would cover the area of a tennis court.

Asthma This condition occurs in about five percent of the population and is a leading cause of illness and restriction of activities in childhood and adolescent age groups. It is a disorder that can be chronic or have acute exacerbations characterized by widespread and largely reversible reductions in the caliber of bronchi and bronchioles due in varying degrees of smooth muscle spasm, mucosal edema, and excessive mucus in the lumens of airways.[17] Asthma can impose both absolute and relative contraindications for scuba diving. The main concern with asthma is air retention in the alveoli as a consequence of bronchiole constriction. This interferes both with alveolar filling and alveolar emptying of gas. The consequence of the former is hypoxia and its consequences of inadequate oxygenation of tissues. The consequence of failure to empty is gas retention in the alveoli. This results in carbon dioxide retention plus hypoxia. In the case of a scuba diver, air

TABLE 6. Respiratory System and Its Relevance to Diving

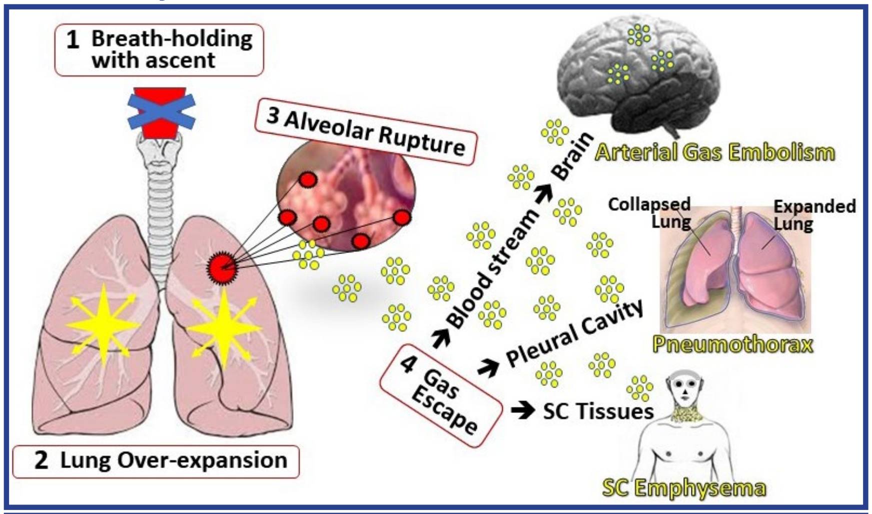
Structure	Function	Medical Problems	Diving Restrictions
		Ingress – Egress	
Mouth & Nose	Gas exchange with outside environments or scuba regulator	Upper respiratory infections, congestion can interfere with middle ear clearing	Temporary
Pharynx	Gas conduct from mouth/nose to respiratory tract	Inflammation tonsillitis; as above regarding middle ear barotrauma	Temporary vs. absolute if chronic & unable to clear ears
		Conduits	
Larynx	Separate alimentary tract from airway tract	As above; tracheotomy for reducing dead space of upper airways	Inflammations temporary; tracheotomy absolute
Trachea	Major conduit from bronchi	Inflammation; respiratory tract infections e.g. tracheitis	Temporary
Bronchi	Two main divisions of the respiratory tree (RT)	Same as above; e.g. bronchitis	Temporary if acute; relative if chronic and associated with coughing & secretions
Bronchioles	Further divisions of RT with 28 in total	Same as above; e.g. bronchiolitis	Same as above
		Ventilation/Gas Exchange	
Terminal Bronchioles	Muscular control of passage to alveoli; account for 10% of gas exchange	Bronchial spasm with restriction of gas passage to alveoli. Partial or complete obstruction from secretions	Relative vs. absolute depending on severity; see Asthma in text
Alveoli	90% of gas exchange (e.g. O_2 in and CO_2 out)	Distention as in chronic obstructive pulmonary disease (COPD), collapse as in atelectasis and/or scaring as in pulmonary fibrosis; pneumothorax	Absolute except pneumothorax (see text)
Alveolar Capillaries	Gas transport to bloodstream before & after exchange at above 2 levels	Ventilation-perfusion inequalities; pulmonary emboli	Absolute; if resolved then relative
		Gas Movement	
Diaphragm	Primary motor/muscle system for moving air in & out of lungs	Paralysis; bowel herniation through diaphragm into chest cavity	Absolute
Accessory Respiratory Muscles	Increase ventilation. Compensate for loss of diaphragm function	Paralysis as in high spinal cord injury	Absolute

retention in the alveoli can result in their rupture during ascent as the gas expands in accordance with Boyle's law. A spectrum of problems collectively termed as extra-alveolar air syndromes can arise from subcutaneous/mediastinal emphysema to pneumothorax to arterial gas embolism.

In the "Diving in Youth" chapter (Chapter 14), the subject of scuba diving in this age group was detailed. The advice is much the same for the adult scuba diver and imposes a relative restriction. Often childhood asthmatics grow out of their asthma attacks, perhaps by enlargement of airways with growth, a less responsive immune system and/or learning to avoid precipitating factors that initiate the asthma attacks. However, another permutation of asthma is the adult onset asthma presentation. If asthma episodes are infrequent and chronic medications are not required, the patient with a history of asthma should be allowed to scuba dive if asymptomatic and not requiring medications to control his or her breathing before, during and after scuba diving activities. Hydration and avoidance of chilling are important considerations in choosing a diving site since cold air can lead to bronchiole spasm and dehydration leading to excessive and/or inspissation (thickening) of the mucus secretions in the respiratory system. This can further interfere with gas exchange and its consequences of hypoxia and alveolar gas retention.

Chronic obstructive pulmonary disease (COPD) has analogies to asthma. However, the condition occurs in older individuals typically with a history of smoking. The disease is characterized by progressive and irreversible damage to the microscopic lung tissue. Because of activity restrictions and often the need for supplemental oxygen, patients with this problem are unlikely candidates for scuba diving. Narrowing of the microscopic airway passages with COPD obstruct gas exchange in the alveoli. This leads to hypoxia and carbon dioxide retention.

FIGURE 7. Extra-alveolar air / Pulmonary Over Pressurization Syndromes



Extra-alveolar air syndromes with SCUBA dive evolve in 3 stages. Once gas escapes from the alveoli, it can move to three sites . Which site becomes the target tissue for the gas bubbles depends on the gradient (explosive gradients are likely to lead to arterial gas embolism), the sites of the alveolar ruptures, and the patient's tissue qualities. If pulmonary blebs rupture, pneumothorax is likely to be the outcome with ascents whether breath-holding or not

KEY: SC = Subcutaneous (which also includes mediastinal presentations)

Another consideration, but almost irrelevant for scuba diving, is that COPD patients can be so decompensated and retain so much carbon dioxide in their tissues that they no longer respond to elevated tissue tensions of this gas and their stimulus to breathe becomes that of low oxygen. Scenarios could be generated where this respiratory adjustment could have consequences for scuba diving with the changes of partial pressures of oxygen (Dalton's law) with ascents and descents.

Pneumothorax This is a condition where gas escapes from the alveoli either spontaneously or after trauma and insinuates itself between the lung pleura (covering membrane) and the lung tissue itself. If leakage is significant, the lung collapses. If the collapsed lung and filling of the pleural space continues unabated, it will compress the unaffected lung leading to the potentially fatal situation of tension pneumothorax. Pneumothoraxes occur rarely in scuba diving with subcutaneous/mediastinal and arterial gas embolism being more frequently reported. Reasons for this are not clear, but probably represent anatomical differences with respect to the anatomy of the interfaces between the air conduits and the surrounding supporting soft tissues such as the lung pleura. Pulmonary blebs also need to be considered as a cause of the spontaneous pneumothorax. The consensus is that if a spontaneous pneumothorax occurs, the patient should not be allowed to scuba dive. The rationale for this is based on the assumption there is a "weak link" in the respiratory system anatomy and the changes of ambient pressure associated with scuba diving make the diver vulnerable to further extra-alveolar air problems. The US Navy has imposed a restriction on submariners and divers that if a spontaneous pneumothorax occurs, the patient can only resume diving and submarine activities if they remain asymptomatic for five years.

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SECOND EDITION

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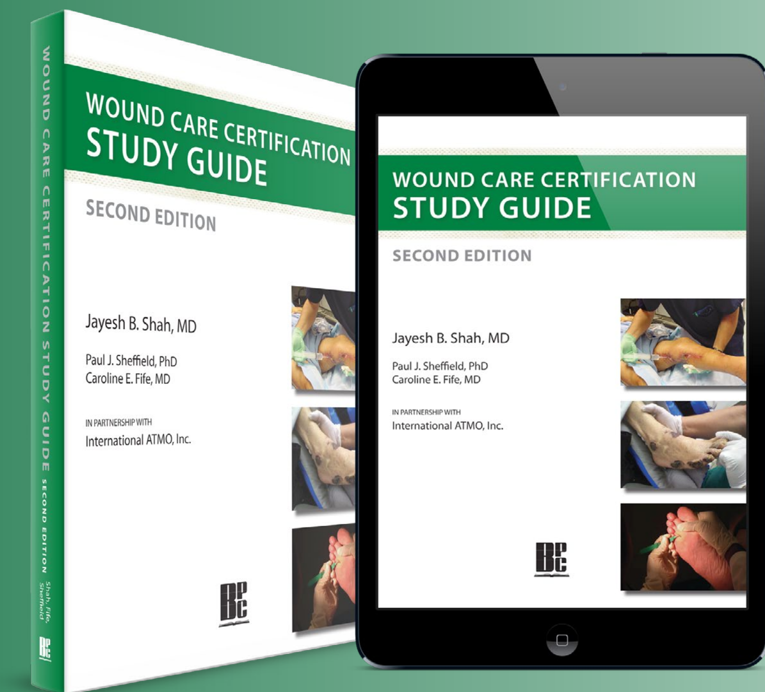

"It was my pleasure to review the second edition of the Wound Care Certification Guide. I found the chapters to be well written and organized, building upon the science of wound healing while including practical clinical applications and sample questions. This text should be useful to all wound care professionals, including the novice and expert alike. It will certainly be an important adjunct for anyone preparing for board examinations."

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As mentioned before, the extra-alveolar air (EAA) syndromes are a spectrum of disorders from subcutaneous/mediastinal emphysema, to pneumothorax, to arterial gas embolism.

Which problem occurs with EAA is speculative. If the bronchial-pleural interfaces are “loose,” it is conceivable that EAA would dissect into the mediastinum and subcutaneous tissues. If the interfaces are “tight” and the alveolar to pleural cavity leak is not explosive, then the EAA could collapse the lung leading to the pneumothorax. If the alveolar rupture is “explosive,” such as an uncontrolled ascent with breath-holding while scuba diving, concomitant rupture of the alveoli and surrounding blood vessels would lead to gas entry into the vessels and arterial gas embolism.

Another cause of pneumothoraxes is pulmonary blebs. With rupture, the gas in them escapes into the pleural space and collapses the lung. Some blebs can be identified on plain chest X-rays and if they occur, make scuba diving unsafe. This is because of changes of ambient pressure with ascent and descent may lead to rupture of the blebs. Definitive diagnosis of pulmonary blebs can be made with computerized tomography. Removal of blebs can be done surgically (blebectomies) with resultant scaring of lung tissue. Scuba diving may be considered after such surgery is successfully completed (see next text box).

The situation is different for the traumatic pneumothorax because of two considerations. First, there is an identifiable cause such as a fractured rib for the lung collapse, and with healing of the traumatic pneumothorax, there is usually a scar tissue formation reaction around the injured lung tissue, so that it is theoretically more resistant to a pneumothorax than the uninvolved lung tissue. For this reason, patients with traumatic pneumothoraxes are allowed to resume scuba diving when healed, asymptomatic and cleared by the physicians attending to the pneumothorax. The time interval from injury to resuming scuba diving is generally about six months.

Subcutaneous and Mediastinal Emphysema These are the least serious of the spectrum of extra-alveolar air syndromes. They are believed to be caused by gas escaping the respiratory tree probable at the alveolar level and moving through the hilum of the lung into the mediastinal and/or subcutaneous tissues rather than remaining in the chest cavity (which would lead to a pneumothorax). Since they are associated with scuba diving, over expansion of the lungs with ascent and rupture of the alveoli is the proposed mechanism. Why presentations vary from mediastinal to subcutaneous locations (as well as not having associated pneumothorax) is not known, but probably reflects individual differences in divers' respiratory system anatomy. Mediastinal emphysema (pneumomediastinum) is characterized by chest pain and labored breathing and is confirmed by chest X-rays. Subcutaneous emphysema symptoms include crepitus (bubbly, sponge-like feeling) of the skin on the neck and lower face from gas dissecting in the subcutaneous tissue planes. The bubbles in this location can also cause changes in the voice, such that the victim sounds like Donald Duck when speaking.

For recurrent spontaneous pneumothoraxes, scarification (pleurodesis) procedures are an option. This procure involves electrocautery or introducing a scarifying agent such as tetracycline into the pleural space (the space between the surrounding lung pleura and the lung tissue itself). This generates adhesions of the pleura to the lung tissue and reduces the changes of a recurrent pneumothorax.

Return to diving after a successful scarification procedure is probably OK. We recommend a trial of compression in a hyperbaric chamber before clearance for scuba diving. During the pressurization, the patient should do some “stress” actions such as forceful increases of abdominal pressure, Valsalva maneuvers, deep breathing, forceful exhalations and hyperventilation. If OK with these actions, it is reasonable to resume scuba diving with the same healing time considerations after scarification, i.e. about six months, as for the traumatic pneumothorax.

Time and reassurance is the accepted “management” for SE/ME. If there is respiratory distress from labored breathing, supplemental oxygen breathing is employed. However, breathing oxygen does not speed the resolution of the gas bubbles in the tissues.

Hyperbaric oxygen (HBO) has been considered as a treatment for SE/ME since pressurization would expect to reduce the bubble size (Boyle's law) and the enriched oxygen environment speed up the offgassing (i.e. wash out) of nitrogen ((Dalton's law). However, this is not an approved indication for HBO, anecdotal information suggests it is not beneficial and ME/SE resolve spontaneously with time.

Subcutaneous and mediastinal emphysema (SE/ME) are self-limiting conditions with spontaneous resolution of the gas with time, usually a week or so. The consensus is that these events do not impose restrictions for future scuba diving. Usually, a detailed history of the dive activity preceding SE/ME can detect breath-holding or unanticipated, rapid ascent portions of the dive. Consequently, the diver should be informed of the probable mechanism of SE/ME and be cautioned to avoid uncontrolled ascents and not to breath-hold during the ascents. If the diver experiences a second occurrence of SE/ME, scuba diving becomes a relative contraindication. In such situations, the diver should be evaluated by a chest medicine physician with imaging studies to rule out lung blebs or other lung pathology before resuming diving. ■

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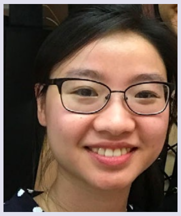
Michael Strauss, M.D., an orthopaedic surgeon, is the retired medical director of the Hyperbaric Medicine Program at Long Beach Memorial Medical Center in Long Beach, California. He continues to be clinically active in the program and focuses his orthopaedic surgical practice on evaluation, management and prevention of challenging wounds. Dr. Strauss is a clinical professor of orthopaedic surgery at the University of California, Irvine, and the orthopaedic consultant for the Prevention-Amputation Veterans Everywhere (PAVE) Problem Wound Clinic at the VA Medical Center in Long Beach. He is well known to readers of *WCHM* from his multiple articles related to wounds and diving medicine published in previous editions of the journal. In addition, he has authored two highly acclaimed texts, *Diving Science* and *MasterMinding Wounds*. Dr. Strauss is actively studying the reliability and validity of the innovative, user-friendly Long Beach Wound Score, for which he already has authored a number of publications.



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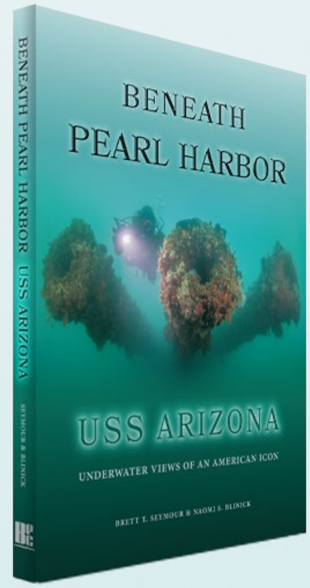

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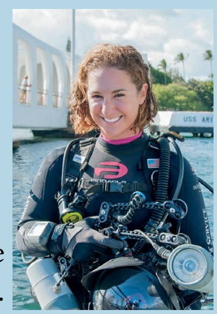
Brett Seymour is the Deputy Chief of the U.S. National Park Service's Submerged Resources Center (SRC).



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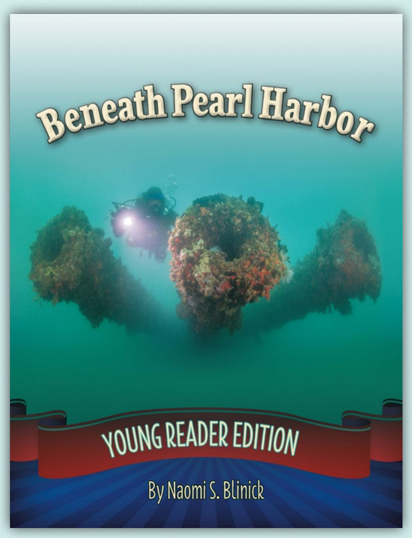

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