Wound Care & Hyperbaric Medicine

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Wound Care & Hyperbaric Medicine

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Note from the Publisher

This issue of *Wound Care & Hyperbaric Medicine* represents the official switch from print to eBook. We continue to see significant growth in our web traffic and online audience, so we are responding. I see real value in expanding our reach by providing the publications *WCHM* and *DEPTH* at no cost to our customers while providing our advertising partner's access to our expanding audience.

WCHM's editorial categories will remain the same as listed below.

- Wound Care
- Hyperbaric Medicine
- Undersea Medicine
- Safety
- Reimbursement
- Compliance
- Legal
- Continuing Medical Education
- Quality

As we noted previously, CMS announced significant changes in payment structure for hospitals billing HCPCS codes for advanced skin substitutes and outpatient visit level reporting.

Advanced skin substitutes historically were billed in two stages, one for the product itself in a reimbursement to the facility for the average wholesale price *minus* and two, the application of the product. Advanced skin substitutes like Apligraf and Dermagraft are now bundled where the product itself is paid through an increase in procedure application payment. However, the add-on code (Modifier) does not have an assigned payment so there is no additional payment for more skin substitute application. I can hear the brakes being applied in nearly every wound care program in the nation as they look at the impact this has on their bottom lines.

With regard to visit level reporting, the traditional evaluation and management (99201-205 and 99211-215) HCPCS codes used in wound care programs went from ten codes to one G-code: G0643. The jury is out on what impact if any this will have on hospitals because simply, if the hospital coded and billed every evaluation and management around the mid-level (assuming a bell curve of utilization), there might not be significant impact. I think the question I have is: What is the impact on wound care and hyperbaric medicine turnkey operators who charge their hospital clients on a *per click* basis for patient encounters? What percentage of hospitals will require those operators to return to the table and force renegotiation of their contracts, as this qualifies in my opinion as a "significant" change in the wound care payment system.

Additionally, a group led by Helen Gelly, MD and Caroline Fife, MD, et al. petitioned Novitas Solutions, Inc. at a CAC meeting in PA last month to delay or strike language included in a *draft* LCD requiring UHMS Accreditation and physician board certification through the ABPM or the non-board certification sponsored by the ABWM. This is significant as it is the first MAC to issue such stringent requirements for the provision of hyperbaric medicine. Novitas Solutions, Inc. covers jurisdictions H and J, representing 11 states.

News that is hot-off-the press has Tennessee BCBS adopting the Milliman Care Guidelines, which no longer recognizes osteomyelitis, necrotizing tissue infections, skin flap/graft, ANY delayed radiation tissue damage (osteoradionecrosis, soft-tissue radionecrosis), and crush injuries or compartment syndromes as indications for hyperbaric medicine. This decision has catastrophic consequences. Let us hope that a collective group of experts in the field can come together and influence the decision makers and reverse this absurd policy.

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This issue is packed full of great articles and case studies, again making this the MOST robust publication in the wound care, undersea and hyperbaric medicine fields.

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John S. Peters, FACHE
Publisher, *Wound Care & Hyperbaric Medicine Magazine*

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Wound Care & Hyperbaric Medicine

2014: THE YEAR FOR BIG BILLING CHANGES

By Gretchen Dixon CCS, CPCO, AHIMA Approved ICD-10 CM/PCS Trainer

The New Year is off to a break-neck start with the amount of changes the Department of Health and Human Services (DHHS) with the Centers of Medicare and Medicaid Services (CMS) have issued diagnoses for us starting January 1, 2014. Changes began a few years ago with the implementation of ICD-10-CM for outpatient services in all settings—hospital clinics and emergency departments, ancillary services, and physician practices to name a few, as well as the transition to electronic health records which includes patient portals for individual information. Now with the 2014 CMS issuance of the Hospital Outpatient Prospective Payment System Final Rule on November 27, 2013, we are going to experience even more changes as to how hospitals will be able to bill for outpatient services, especially in the wound care department. This article will try to summarize the major issues affecting hospital outpatient wound clinic services for reporting and billing of services. At the writing of this article the formal Federal Register version was not available; therefore reference page numbers may likely not coincide.

Business Strategies Change Mandated—Hospital Outpatient Clinic Visits Changed

> *This information has been edited to only reflect wound care department or clinic changes, thereby not covering changes associated with the emergency department or critical care services.*

The DHHS with CMS have decided to eliminate the CPT code levels of clinic visits and change the reporting of visit level to a single visit level regardless of the complexity of patient care. This requires use of a single new HCPCS (Healthcare Common Procedure Coding System) code in the Ambulatory Classification Payment (APC) system. According to information in this final rule, CMS states "this single level may result in a larger payment with a strategic goal of payment bundles to encourage hospitals to provide care in the most efficient manner according to specified rules. With this methodology, they believe incentives to provide medically unnecessary services or resources will be removed to achieve a higher level of visit reimbursement."[1] In summary, **by removing the differentiation among the five levels related to intensity of care for each visit, the incentive for hospitals to up-code patient visits will be eliminated.[2] As of January 1, 2014, the only outpatient visit level reportable will be HCPCS code G0643 under APC 0634.**

By eliminating the need for hospitals to develop and apply their own internal guidelines differentiating between the five resource levels for coding clinic visits, along with the need to distinguish between new and established patients, DHHS and CMS feel the administrative burden will be greatly lessened for the outpatient billing and claims arena. **A visit payment of approximately $92.00 regardless of the complexity of care creates business challenges that include assessing all operational activities to determine the most effective and efficient processes while maintaining the high quality level of patient care management.**

[1] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule. P. 668*
[2] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule. P. 669*

Recommendations:

- Perform time studies for patient visits to determine amount of inefficiency
  - Time of appointment arrival
  - Time taken to the exam room
  - Time the nurse entered and completed assessment
  - Time the physician entered and completed evaluation
  - Time the patient care completed and patient left the room
  - Total time to turn over the room (from the time the patient left, room cleaned and set up for next patient, and next patient entered room)
- Document down time
  - Staffing issues—complexity of patient care, leanness for progress
  - Physician tardiness — conducting non-wound care business etc.
  - Is everyone multi-task capable—cross trained?
  - Waiting for supplies / biologicals / ancillary documentation (results)
  - Other discovery
- Review staffing work patterns to ensure efficiency of activities or tasks
  - Review details of each activity to determine the effectiveness and opportunities for improvement
  - Brainstorm with staff
    - Collect all ideas for trials
    - Be open to ideas by thinking outside-of-the-box
- Perform chart documentation time study
  - Is all clinical documentation completed within 1 hour after the patient leaves the clinic?
  - If not why: what are the action blockers
- Review all policies & procedures which affect operational efficiency

The following excerpt from Table 42 provides an overview of the change application with the new HCPCS code G0463.

TABLE 42. (EXCERPT) COMPARISON OF CY 2013 and 2014 CLINIC AND EMERGENCY DEPARTMENT VISIT HCPCS CODES AND APC ASSIGNMENTS

Visit Type	CY 2013		CY 2014	
	HCPCS Code	APC	HCPCS Code	APC
CLINIC VISIT	99201	0604	G0463	0634
	99202	0605		
	99203	0606		
	99204	0607		
	99205	0608		
	99211	0604		
	99212	0605		
	99213	0605		
	99214	0606		
	99215	0607		

Table 1.
Addendum A from the CMS Hospital Outpatient Prospective Payment System 2014 Final Rule

HCPCS Code	Short Descriptor	Status Indicator	APC	Relative Weight	Payment Rate	National Unadjusted Copayment	Minimum Unadjusted Copayment
G0463	Hospital Outpatient Clinic Visit	Q3 =Codes that may be paid through a composite APC	0634	1.2732	$92.53	$37.01	$18.51

Provider Clinical Documentation Granularity Improvement continues

Over this year our articles have continued with the theme of helping you to improve your clinical documentation with incremental tidbits of information. Have you been successful in adding a few of these improvements to your daily method of written communication? Clinical documentation improvement is vital to detailing the reason for the patient's encounter identifying all relevant information in the medical record. It is this information which supports the medical necessity of the patient's care. Our articles will continue to focus on physician clinical documentation specificity or granularity. Why? Week after week performing provider / physician documentation audits, the discovery continues to find documentation which is inaccurate, incomplete, missing, or vague in the medical record. So how can your documentation support diagnoses and /or procedure codes (CPT codes reporting Evaluation Management encounter, procedures) when the information is inaccurate or not there?

Documenters are similar to athletes-football or basketball players because of the number of mental activities which must be accomplished simultaneously. It is these mental activities which may cause distraction from documenting thoroughly and completely. Your documentation only has to provide the facts as well as linking findings, and information to the reason for the test (e.g. lab or imaging) and/or a procedure(s) as well as the encounter. Just listing a problem, medical condition does not adequately demonstrate medical necessity for the visit especially when HPI, ROS and PE are inconclusive with limited information or notations of normal, with a diagnosis is documented.

As a documenter and communicator, you the provider have to be on your game to ensure you are able to gather all of the necessary information to make a medical decision to assist your patient in reaching or maintaining their health goals. Many patients have very complex health concerns and require close monitoring. However, without clear, concise, accurate and factual clinical documentation, it is often difficult to determine the providers thought processes for the treatment of the patient as well as for other healthcare team providers to follow through with your undocumented thoughts.

Practice, practice, and more practice are necessary to ensure our outcomes are as required. A single habit took 90 days to make it a life routine, so chin up, smile on; we can make our documentation meaningful for the continuity of patient care and win the big game.

IMPORTANT TAKE AWAYS

- ✓ Tell a story about the patient's reason for the encounter
- ✓ Document all relevant elements to the reason for the encounter. Don't assume other healthcare team members have the same level of knowledge you have about the patient.
    - o History of onset of the condition & it's presumed cause (injury/ sprain)
        - Location
        - Duration
        - What has been done to address the condition
        - Describe the type and severity of pain
        - Failed therapies
- ✓ Link the identified diagnosis to HPI, ROS, PE and Medical Decision Making process.
- ✓ Only listing a diagnosis even with patient discussion information and/ or treatment information does not support medical necessity.
- ✓ Know your payer's medical policies and document in their terms when possible.

Pay Attention to the Little Details for Big Results

As we move towards ICD-10-CM, the little details you begin to add to your documentation now will ensure your transition to a more transparent process than waiting to the last month before the ICD-10 implementation date and scrambling. Hope to see your documentation telling a story filled with details that is thorough, relevant, and easy to understand.

Have You Heard?

What The Payers Are Saying: Payers (CMS, Blue Cross/ Blue Shield, United Healthcare, Kaiser Permanente to name a few) have been providing seminars on how the current coding system of ICD-9-CM is insufficient to demonstrate medical necessity through selected codes on billing forms. This has created a necessity to place claims on hold until a request for a copy of medical record documentation is received and reviewed. Once the review process is completed, then the determination of either denying the claim or reimbursing the claim is made. However, the ICD-10-CM coding system requires a high level of granularity/specificity or detail in the clinical documentation by all documenters. Once ICD-10-CM is implemented on October 1, 2014 the payers are expecting a drastic reduction in the number of requests for information due to the level of specificity each code entails.

Hearsay: Stay away from unspecified diagnosis and only select them when there is no other options. There has been speculation and volumes of discussion within the industry that unspecified code reimbursement may be significantly reduced up to 75% within the specific code family or denied without and follow-up requested. There are specific coding guidelines issued by CMS with the approval of the Cooperating Parties (American Hospital Association, American Health Information Management Association, Centers for Medicare and Medicaid Services) related to unspecified diagnosis use with ICD-10-CM.

Specific Bundling of Wound Care Services

Bundling of Hospital Services for Resource Efficiency and the Effects on a Wound Care Department

DHHS developed packaging of service policies to support their strategic goal of using larger payment bundles to maximize hospitals' incentives to provide care in the most efficient manner. That is, packaging encourages hospitals to use the most cost-efficient item while meeting the patient's needs rather than using a more expensive item which often resulted in a separate payment for the item. This process is expected to encourage hospitals to establish protocols ensuring furnished services are necessary while scrutinizing services ordered by practitioners to maximize the efficient use of hospital resources. Packaging will affect primarily the ancillary and supportive areas of diagnostic and therapeutic items and services.

The Application of Skin Substitute Procedural Coding Changes

In the past we have reported up to two or more surgical procedure codes depending on the total wound surface area. As of January 1, 2014, this is drastically changing where the add on codes for a wound greater than the specific CPT code description notes is bundled or packaged into the primary surgical CPT code. However, the responsibility of reporting both codes is mandatorywhen appropriate. This is necessary for accurate data to DHHA and CMS for our annual updates to their reimbursement methodologies. Payment adjustments have been now made inclusive for add on CPT codes and supplies. As you review these tables, it will become obvious to first identify the procedure performed and refer to your current CPT manual for the long descriptions.*

You most likely noticed the change in payment rate from 2013 to 2014; however, this is due to the bundling policies of including add-on CPT codes and supplies.

The Reporting of Biologicals—Skin Substitutes

Out of the seven items listed for bundling, the wound care department will be affected under number 2 defined as: drugs and biologicals that function as supplies when used in a surgical procedure.[5] Biologicals include skin substitutes, which are considered a supply in a surgical procedure. Within this final rule for 2014 outpatient services, there is lengthy discussion on the category of skin substitutes where this supply item does not function like human skin grafted to a wound, but is applied to aid in the healing of a wound through various mechanisms of action as they stimulate the host to regenerate lost tissue. The focus is skin substitutes that are applied during a surgical procedure described in the CPT code manual under the heading of "skin replacement surgery" and subheading of "skin substitute grafts" with a CPT code range of 15271 through 15278. In the past, manufactures of skin substitutes, specifically Apligraf and Dermagraft, assumed and have marketed these in the classification of specified covered outpatient drugs (SCODs).

Additionally, although the FDA approves skin substitutes from Apligraf, Dermagraft, and Integra as medical devices through the PMA (Premarket Approval Application) process, CMS notes the FDA regulatory process should not determine outpatient payment policy.

Therefore, CMS categorized skin substitutes as a supply item because they are used in a surgical procedure as part of a surgical repair procedure by reinforcing and aiding in the healing of tissue as having a therapeutic purpose. Skin substitutes are recognized through the assignment of HCPCS codes in the Q4100 series for high cost (at or above $32.00 per sq. cm) or HCPCS C527X series for low cost (below $32.00).[6] However, because CMS recognized the disparity of resource cost from approximately $7.00 to $200.00 per sq. cm, packaged skin substitutes have been divided into two groups denoting either high or low cost. Using claims data from 2012 through July 2013 noted in Addendum B, they weighted the average payment per unit of all skin substitutes; those above $32.00 per sq. cm are classified as in the high cost group and those at or below $32.00 are classified as in the low cost group.[7]

Billing and Reporting High Cost Skin Substitutes

For 2014, continue to report/bill high cost skin substitute products using the existing skin substitute application codes 15271 through 15278 as well as reporting the applicable HCPCS Q-code. Currently, CMS is establishing code edits in their claims processing system requiring these codes to continue being reported with these CPT codes. Refer to Table 3 for a sample of the skin substitute assignment to high and low cost groups.

Refer to Tables 2 and 3 with the following coding example:
Example: A patient with a diabetic foot ulcer located on the top of the right foot with total wound surface of 22 sq. cm (5.5 x 4.0 cm.) had Apligraf applied.

- ➢ Using the below tables 2 and 3 the following codes would be reported:
  - o 15275 with anticipated reimbursement at $1371.19
    - CPT code 15275 – Application of skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet and/or multiple digits, total wound surface area up to 100 sq. cm.; first 25 sq. cm. or

Table 2. Skin Substitute Procedural Coding Changes

HCPCS Code[4]	Short Descriptor*	Status Indicator	APC	Payment Rate 2014	Payment Rate 2013
15271	Skin substitute graft –trunk/arm/leg total wound surface area up to 100 sq. cm: first 25 sq. cm. or less of wound surface area	T	0328	$1371.19	$251.48
15272	Skin substitute graft –trunk/arm/leg add on; each additional 25 sq. cm. wound surface area or part thereof	N			$85.75
15273	Skin substitute graft-trunk/arms/legs: total wound surface area- first 100 sq. cm	T	0329	$2260.46	$393.38
15274	Skin substitute graft-each additional 100 sq.cm. wound surface area	N			$251.48
15275	Skin substitute graft-total wound surface area up to 100 sq. cm. face/neck/hands/feet/digits, total wound surface area up to 100 sq.cm, first 25 sq. cm or less wound surface area	T	0328	$1371.19	$251.48
15276	Skin substitute graft-- face/neck/hands/feet/digits; each additional 25 sq. cm wound surface area, or part thereof	N			$85.75
15277	Skin substitute graft- face/neck/hands/feet/digits; first 100 sq. cm. wound surface area	T	0328	$1371.19	$393.38
15278	Skin substitute graft - face/neck/hands/feet/digits; each additional 100 sq. cm. wound surface area	N			$251.48

Legend:
Status Indicator Key: N = Items & services packaged into APC rate, T = procedures or services, multiple reduction applies

[3] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule, page 302*
[4] *AMA Professional Edition of 2014 CPT Manual*
[5] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule, page 306*

less wound surface area

- o Q4101 Apligraf has been assigned Status Indicator of N meaning there is no separate payment for this supply item

It is very important to consistently report supplies to ensure accurate data for the composite of all claims for future data collections. This information is used by not only CMS but also third-party payers to adjust reimbursement but for tracking the type of procedures and all reportable resources consumed providing patient care.

How to Code to Report Application of Low Cost Skin Substitute Products

CMS has created a set of new HCPCS codes which parallel the current set of skin substitute application CPT codes 15271 – 15278 for the application of low cost skin substitute procedure along with the applicable HCPCS Q-code. Refer to Tables 3 and 4.

Example: A patient with a wound of the right lower abdominal quadrant with total wound surface of 18.5 sq. cm has Oasis applied.

➢ Using the below tables 3 & 4 the following codes would be reported:
  - o C5271 with anticipated reimbursement at $409.41
  - o Q4102 Oasis has been assigned Status Indicator of N meaning there is no separate payment for this supply item

It is very important to consistently report supplies to ensure accurate data for the composite of all claims for future data collections. This information is used by not only CMS to adjust reimbursement but for tracking the type of procedures and all reportable resources consumed providing patient care.

Summarization

Take this article along with a copy of CMS HOPPS final rule and begin to energize your New Year with a focus on operational effectiveness and efficiency while improving your patient's healthcare experience. It is all doable from each team member but requires a strong will and determination to implement these changes while driving away the naysayers.

Table 3.
Current Year 2014 Skin Substitute Assignments of High and Low Cost Groups

Disclaimer: This is a synopsis of the list with the most common types of skin substitutes used in wound care departments. Refer to the Federal Register HOPPS 2014 document.

HCPCS Code	Short Descriptor — Skin Substitute	Status Indicator	Low/High Cost
Q4101	Apligraf	N	High
Q4102	Oasis Wound Matrix	N	Low
Q4103	Oasis Burn Matrix	N	Low
Q4104	Integra BMWD	N	Low
Q4105	Integra DRT	N	Low
Q4106	Dermagraft	N	High
Q4107	Graftjacket	N	High
Q4108	Integra Matrix	N	Low
Q4110	Primatrix	N	High

Legend:
Status Indicator Key: N = Items and services packaged into APC rate

[6] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule, pages 331-332*
[7] *DHHS 2014 Hospital Outpatient Prospective Payment Final Rule, page 334-336*

References:

2014 CMS Hospital Outpatient Prospective Payment System, update website http://www.cms.gov/Medicare/Medicare-Fee-for-Service Payment/HospitalOutpatientPPS/Hospital-Outpatient-Regulations-and-Notices-Items/CMS-1601-FC-.html

Optum 2014 ICD-10-CM The Complete Official Draft Code Set manual

Optum 2014 ICD-10-CM Mappings: Linking ICD-9 to all valid ICD-10-CM Alternatives

AMA Professional Edition CPT 2014 manual

Gretchen Dixon, senior consultant for Hayes Management Consulting, performs audits regarding the outpatient revenue cycle healthcare compliance arena. She has conducted compliance education and audits for outpatient departments and physician services with a focus on wound care department operations for more than seven years. She holds several credentials including an MBA in healthcare management; RN with a practicing license in New York and a 23 multi-state licensure from Virginia; AHIMA approved ICD-10-CM trainer and CCS; and is a certified healthcare compliance officer. As a long-time internal healthcare auditor, she identifies issues through audits of documentation, coding, and billing practices. The outcome of each audit determines the topics of education to be provided to the staff and physicians as she proactively believes education is the key to having complete, accurate, and consistent documentation for accurate reimbursement of billed services. Contact her at gretchendixon@cox.net or 615.210.7476 for more information.

Table 4.
Skin Substitute Application Procedures for Low Cost Skin Substitute Products

HCPCS Code	Short Descriptor — Skin Substitute	Status Indicator	APC / National Payment Rate
C5271	Application of low cost skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm; first 25 sq cm or less wound surface area	T	0327 / $409.41
C5272	Application of low cost skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm; each additional 25 sq cm wound surface area, or part thereof (list separately in addition to code for primary procedure)	N	N/A
C5273	Application of low cost skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm; first 100 sq cm wound surface area, or 1% of body area of infants and children	T	0327[8] / $409.41
C5274	Application of low cost skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm; each additional 100 sq cm wound surface area, or part thereof, or each additional 1% of body area of infants and children, or part thereof (list separately in addition to code for primary procedure)	N	N/A
C5275	Application of low cost skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area up to 100 sq cm; first 25 sq cm or less wound surface area	T	0327 / $409.41
C5276	Application of low cost skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area up to 100 sq cm; each additional 25 sq cm wound surface area, or part thereof (list separately in addition to code for primary procedure)	N	N/A
C5277	Application of low cost skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area greater than or equal to 100 sq cm; first 100 sq cm wound surface area, or 1% of body area of infants and children	T	0327 / $409.41
C5278	Application of low cost skin substitute graft to face, scalp, eyelids, mouth, neck, ears, orbits, genitalia, hands, feet, and/or multiple digits, total wound surface area greater than or equal to 100 sq cm; each additional 100 sq cm wound surface area, or part thereof, or each additional 1% of body area of infants and children, or part thereof (list separately in addition to code for primary procedure)	N	N/A

Legend:
Status Indicator Key: N = Items and services packaged into APC rate, T = procedures or services, multiple reduction applies

[8] *HCPCS code C5273 –there is an APC category discrepancy between table 14 in the Federal Register on page 338. Notes APC 0327 versus Addendum B which notes APC 0328.*


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Wound Care & Hyperbaric Medicine

Stresses in SCUBA and Breath-Hold Diving
Part I: Introduction and Physical Stresses

By Michael B. Strauss MD and Stuart S. Miller MD

Introduction

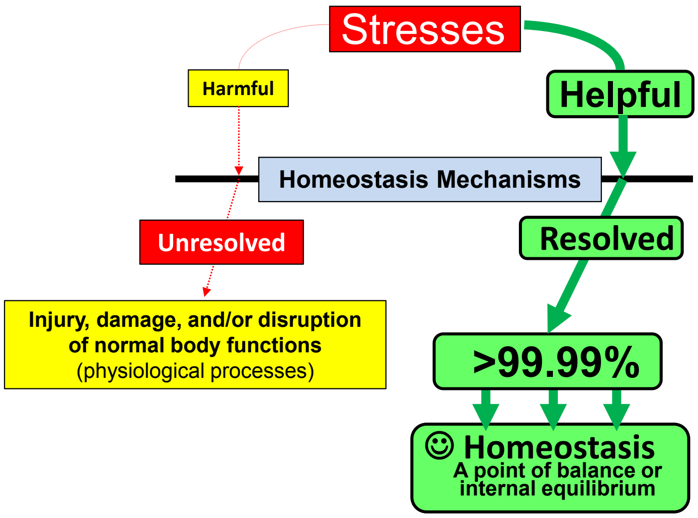
When SCUBA and breath-hold diving are done and done appropriately, divers are usually not aware of the stresses that constantly "bombard" them and are subliminally resolved. Only when the stresses are not resolved completely do diving-related medical problems occur (Figure 1).[1] Stresses associated with SCUBA diving can be divided into three categories; physical, physiological, and psychological (Figure 2). Different phases of SCUBA and breath-hold dives (because of the special challenges associated with each phase) have the propensity for generating specific medical problems.[2] This article discusses the physiology of the stress-response (stimulus-reaction) phenomenon, describes the medical problems that are associated with the physical stresses of diving, and integrates this information with the phases of the dive for which the stresses predominate. Subsequent articles will discuss the physiological and psychological stresses of diving. The goals of this introductory article are to make the SCUBA and breath-hold diver aware of the physical stresses associated with diving and what measures can be done to prevent them from leading to medical problems that will interfere with the dive or result in injury or death to the diver.

The Stress-Response Phenomenon

As mentioned above, when SCUBA and breath-hold diving is done and done appropriately, the divers are usually not aware of stresses that constantly occur and that are subliminally resolved. A few important concepts need to be appreciated with respect to stresses. For every stress that challenges an organism, a response from the organism results. Homeostasis is the goal of the organism's stress/stimulus—response/reaction mechanisms to cope with these challenges. Homeostasis (homeo = similar; stasis = standing still) is an organism's goal to keep all systems running on an "even keel." Perhaps the easiest example to appreciate is the body's regulation of blood sugar. A desirable

> Stimulus to Breathe
>
> The stimulus to breathe is another example of how imperceptible responses to stimuli maintain homeostasis in the body. The stimulus to breathe is initiated by elevation of blood carbon dioxide (CO_2) gas tensions. The elevation occurs because CO_2 is a waste product of metabolism. Receptors in the blood stream detect the elevation and send a stimulus to the respiratory center of the brain to initiate a breathing response (i.e. inhalation and exhalation) to dissipate the CO_2 accumulation in the blood stream through the lungs. To test this stimulus-response homeostatic mechanism, merely hold your breath. As the CO_2 levels in the blood stream increase, there is an increasingly stronger desire to breathe eventually reaching the point that a breath must be taken, the so-called breath-hold break point.
>
> Ondine's curse from mythology recognizes how important the homeostatic mechanism to breathe is and the consequences that result when it is impaired. Ondine was a water nymph who had a mortal lover. He swore to Ondine that "every waking breath would be a testimony of his love" for her. Upon witnessing his adultery, Ondine laid a curse on her unfaithful lover such that if he should fall asleep, he would forget to breathe. Inevitably he fell asleep from sleep deprivation, stopped breathing, and died. This insightful myth shows how important the CO_2 homeostatic mechanism is to breathe (without conscious awareness/brain stem involvement) and is labeled today as the congenital central hypoventilation syndrome. Its pathophysiology is due to brainstem nerve injury and dysfunction.

Figure 1: Stresses, Stress Resolution, and Homeostasis



Legend: The body is constantly subjected to stresses. Most are resolved spontaneously and usually without conscious effort to maintain homeostasis (homeo=constant, stasis=stable i.e. even, normal function).

When stresses are not adequately resolved, harm to the organism can result. The purpose of homeostasis mechanisms is to resolve stresses to maintain normal/orderly function.

homeostasis range (e.g. 60-100 milligrams per deciliter) exists. If food intake occurs, the sugar in the food raises the blood sugar (i.e. the stimulus) and the body responds by insulin secretion from the pancreas to keep the blood sugar in the optimal range. Like most homeostasis mechanisms that occur in the body, the blood sugar responses are imperceptible. Only when totally "out of whack" are the consequences for not maintaining homeostasis manifested. For blood sugars, this may be loss of consciousness from hypoglycemia if blood sugars are too low or diabetic ketoacidosis if too high.

Phases of a Dive and Diving Medical Disorders

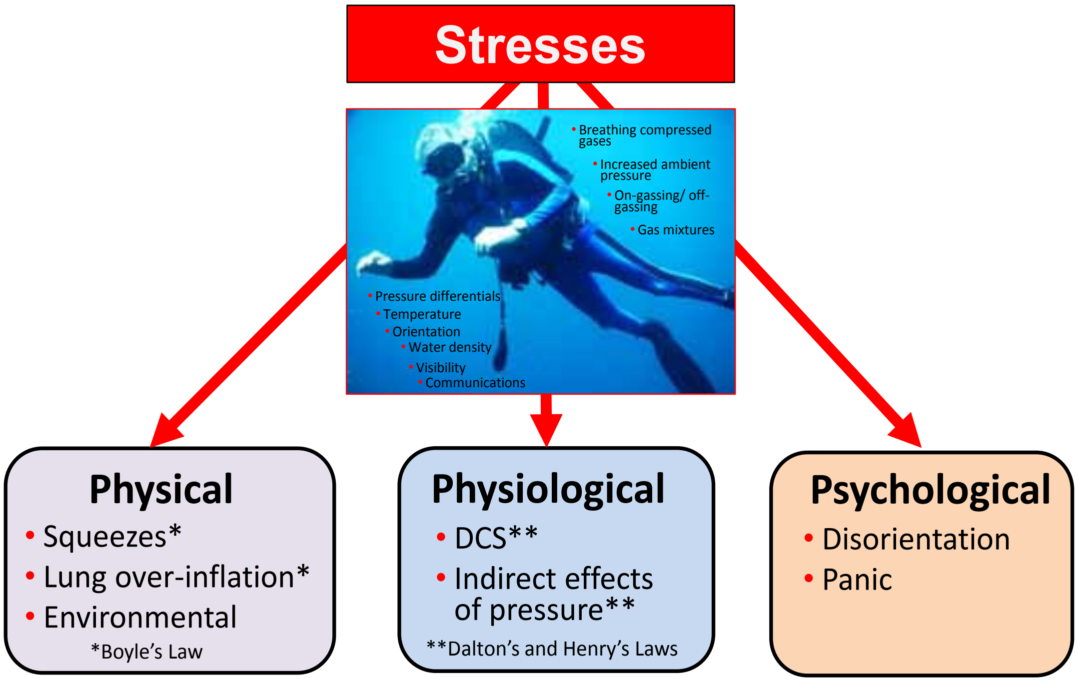
The stress/stimulus—reaction/response phenomena during diving, whether SCUBA or breath-hold, has similarities to land-based activities. However, the water environment imposes stresses that are prone to occur at specific phases of a dive. Diving activity can be divided into four phases which include: 1) Pre-dive/Surface, 2) Descent, 3) Bottom and 4) Ascent/post-dive segments (Figure 3). Each phase of the dive imposes stresses on the diver that in the majority of instances are resolved subconsciously or with minimal conscious effort. Only infrequently are the stresses not adequately resolved and thereby interfere with the diving activity (Figure 1). Fifteen disorders are the predominant ones that occur as a consequence of diving and each is usually associated with one of the four phases of the dive (Figure 3). The exceptions to this are the pre-dive/surface medical disorders that may occur at any of the dive phases, as well as drowning/near-drowning, cardiac arrest, and shock (possibly associated with marine animal injuries, propeller injuries, or trauma such as being hurled onto rocks from wave action). Physical stresses are experienced throughout the four dive phases and relate primarily to pressure related phenomena and environmental challenges.

Dive Scenario: A snorkel diver was found unconscious and in profound shock on the shore line with two large parallel gashes on his right leg. Initially, impressions were that he exsanguinated as a consequence of a shark bite. The victim expired en route to the hospital. A coroner's inquest concluded that the injury was from a boat propeller because of the parallel grouping of the gashes, absence of shark teeth in the wound, and appearance of the wound with no avulsed tissue.

Comment: This scenario illustrates a surface-phase medical problem of diving and how shock can occur with traumatic injuries. Many questions remain unanswered such as: Was the diver diving alone, did the motor boat "hit and run," how did the diver get to shore, and had a tourniquet been used, could his course have been altered?

Shock has many causes such as blood loss, infection, loss of sympathetic nervous system control of blood vessel diameter, heart problems, etc. In this scenario, blood loss was the obvious cause. With a circulation time of about 30 seconds, shock from bleeding from a large vessel such as in the patient's leg can occur in a minute or two and death from exsanguination shortly thereafter.

Figure 2: Types of Stresses in Diving and their Associated Medical Problems



Legend: When diving, three types of stresses must be resolved. This article describes the physical stresses with Boyle's law providing quantification for squeezes and lung overinflation (i.e. extra-alveolar air/ pulmonary over-pressure/air retention) syndromes.

Part I: Physical Stresses of Diving

Pressure-Related Phenomena

Pressure-related phenomena can be attributed to Boyle's law. Boyle's law explains the physics for ear, sinus, and other squeezes (e.g. tooth, mask, and diving suit) as well as arterial gas embolism. With any change in ambient pressure, there is a change of volume of the gas in the confined space. The stresses imposed by changes in ambient pressure are met by pressure equalization techniques such as "clearing" the ears to equilibrate pressure in the middle ear spaces during descents in the water and to breathe in a regular fashion during ascents with SCUBA gear to prevent extra-alveolar air syndromes (arterial gas embolism, pneumothorax, and mediastinal/ subcutaneous emphysema). For the squeezes, stresses (of pressure differentials between the confined gas-filled cavities and the ambient pressure) evoke responses of halting or slowing the descent rate and in this situation the stresses are perceptible. For arterial gas embolism, the stresses are typical imperceptible (as a consequence of breath-holding with uncontrolled ascent) and must be mitigated by training to not breath-hold during ascent. A cardinal principle with respect to pressure differentials is that the body "abhors" pressure differentials (i.e. a vacuum), and if not resolved through homeostatic and/or conscious-associated responses, they will lead to injury.

When considering squeezes, the body consists of three compartments (Figure 4, Table 1).[1] The first of these compartments is the liquid and solid structures of the body such as solid organs, hollow organs filled with fluid (e.g. heart, blood vessels, eyes, bladder), semicircular canals and cochlea of the inner ear, bones, blood, tissue fluids, skin, subcutaneous tissue, and fat. This compartment is not subject to squeezes, but because it transmits the changes of ambient pressure equally and undiminished (in accordance with Pascal's law), no pressure differentials develop (Figure 5). This compartment imposes no limitations on the depth or duration of dives with respect to squeezes.

Boyle's Law

This gas law quantifies volumes changes with changes in ambient pressure and formulated as $V_1 \times P_1 = k$ or $V_1 \times P_1 = V_2 \times P_2$ (where P = pressure, V = volume, k = a constant). In simplistic terms, Boyle's law explains that when pressure is increased (or decreased) on a confined volume of gas, the volume of the gas decreases (or in the situation of decreased pressure increases). For example, if the pressure on gas confined in a flexible enclosure such as a balloon doubles, the volume of the gas decreases by 50% (Figure 5).

Liquid Respiration

Theoretically, if all three body compartments could be converted to liquids and solids, no squeezes—or even gas embolism would occur no matter how deep the dive. This has been experimented with utilizing fluid respirations.[3] The lungs and tracheobronchial tree are filled with fluid such as normal saline or fluorocarbons and the fluid pressurized with oxygen. The oxygen in the fluid (analogous to physical dissolved oxygen in plasma as utilized in hyperbaric oxygen therapy) diffuses through the alveoli in the lungs to be delivered by the blood stream to body tissues to meet their metabolic demands. Two challenges limit the theoretical benefits of fluid respiration. These are elimination of carbon dioxide (CO_2) and the work of "breathing" a fluid. Whereas it is possible to deliver oxygen through this technique, measures to eliminate the one hundred-fold increases in CO_2 between inspired gas (or fluid) and the waste products of metabolism have not been solved. With respect to the work of breathing, it should be appreciated that water is over 700 times denser than air and results in an enormous work of breathing just to move fluid in and out of the lungs.

The science fiction-adventure movie *The Abyss* (1989) utilizes the technique of fluid respiration for one of its epic scenes. For the record, this movie was "truly" an underwater undertaking. Forty percent of the live action took place underwater. The actors themselves shot scenes at 33 feet of sea water (FSW) for periods of less than one hour so decompression (other than standard ascent rates) was not required. On the other hand, the camera crews stayed at depths of 50 FSW for five hour durations and did oxygen breathing during ascent.

The second pressure-volume related compartment is the air-filled, flexible wall cavities such as the lungs and gut. This compartment responds to the stress of increased pressure by decreasing in volume and vice versa with decreases in pressure as expressed by Boyle's law (Figure 4). Ordinarily, this compartment tolerates the compression stresses of diving without problems and merely decreases in volume. An exception to this is the point at which the lungs are compressed to their residual volumes. After this the alveoli assume the characteristics of the rigid-walled, air-filled compartment (as will be discussed in the next paragraph). Whereas compression stresses of this compartment are almost always well tolerated with ordinary SCUBA and breath-holding diving activities, alveoli tolerate overexpansion poorly. When these structures are filled to capacity with a maximal inhalation, further enlargement with decreases in ambient pressure (i.e. ascent) will cause them to rupture. This leads to one or more of the three presentations of extra-alveolar air syndromes, namely subcutaneous/mediastinal emphysema, pneumothorax, or arterial gas embolism (Figure 6). This is an example of a physical stress of diving that must be avoided by not breath-holding during ascent when diving with SCUBA gear because the homeostatic mechanisms of alveolar distention are very limited. That is, the elastic properties of the alveoli do not tolerate overexpansion beyond a few percentage points before they rupture.

Alveoli tolerate over-expansion poorly. Even though this tissue type has some elastic properties, overexpansion, rupture, and gas embolism can theoretically occur with breath-holding after full inspiration from a 3 foot depth. This equates to about a 10% overexpansion of the fully inflated alveoli.

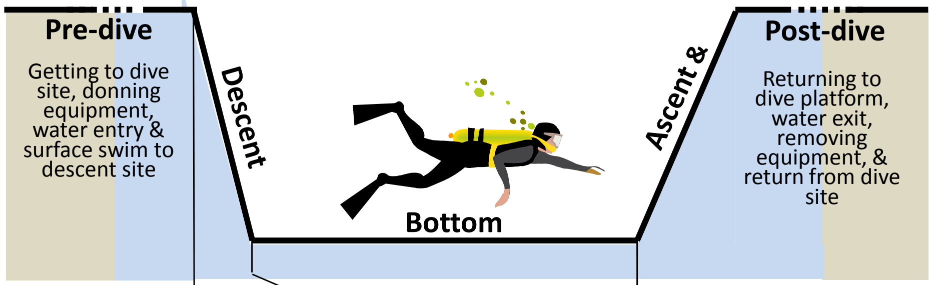
Arterial gas embolism has been observed with breath-holding from an eight foot depth after breathing compressed gas.

Dive Scenario: A couple of kids were playing in a backyard swimming pool. They decided to weight an upside down bucket filled with air so it would sink to the bottom of the pool then breathe air from the bucket in order to stay underwater. Soon the air became stale (from carbon dioxide accumulation) and with one last deep breath, one kid swam to the surface while holding his breath. Immediate loss of consciousness occurred and after rescue and breathing oxygen, consciousness was restored with no apparent brain damage. The presumptive diagnosis was arterial gas embolism from breath holding after breathing the compressed gas in the upside down bucket.

Comment: This scenario illustrates how minimal pressure differentials can lead to alveolar rupture and supports the theoretical estimates from the above text box. It is noteworthy that about 50% of arterial gas embolisms resolve with breathing 100% oxygen on the surface.

The third pressure-volume related compartment is that of rigid-walled, air-filled compartments such as the middle ear spaces, the sinuses, and the face mask. Less typical examples of this compartment included air pockets in carious teeth and wrinkles with air-filled cavities in wet suits. With changes in ambient pressure, pressure differentials arise between the solid, ridged-walled external structures and their gas-filled inner contents. Since a pressure differential is a stress that homeostatic mechanisms attempt to

Figure 3: Phases of the Dive, their Stresses and their Medical Problems

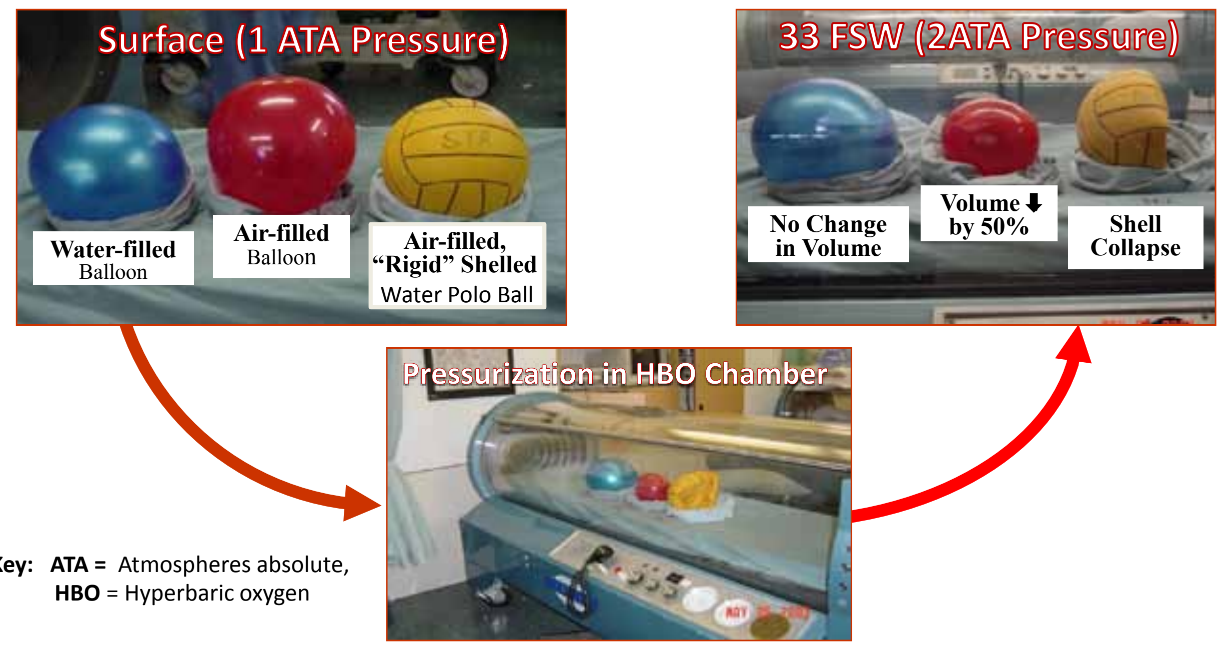


	Pre-dive	Descent	Bottom	Ascent & Post-dive
Major stress categories	Exertional Environmental	Pressure Direct effects of pressure	Physiological Indirect effects of pressure	Physiological (AGE) Physiological (DCS) Exertional
Problems that may occur	Panic Hypothermia Blackout Ear canal infections Injuries from marine animals	Squeezes Ear, sinus, face mask, etc. Thoracic squeeze	Nitrogen narcosis Oxygen toxicity CO_2 toxicity Hypoxia Carbon monoxide poisoning	Extra-alveolar gas problems Subcutaneous emphysema Mediastinal emphysema Pneumothorax Arterial gas embolism Decompression sickness Alternobaric vertigo
Stress prevention / elimination	Dive planning Fitness Equipment	Skill sets Experience	Training Equipment Dive planning	Dive Planning Fitness

Legend: This all-encompassing (an entire synopsis of diving medical problems) figure shows when, why, and what diving problems occur and how to prevent them. All the medical problems listed in the pre-dive column are not exclusive to this phase of the dive, and in contrast to the other disorders, can occur in other phases of the dive. Drowning, cardiac arrest, and shock (from traumatic injuries e.g. boat propellers) can also occur at any phase of the dive.

AGE=arterial gas embolism, **CO_2**= carbon dioxide, **DCS**=decompression sickness.

Figure 4: Effects of Pressure on Water and Air-Filled Balloons and on a "Rigid" Shelled Water Polo Ball



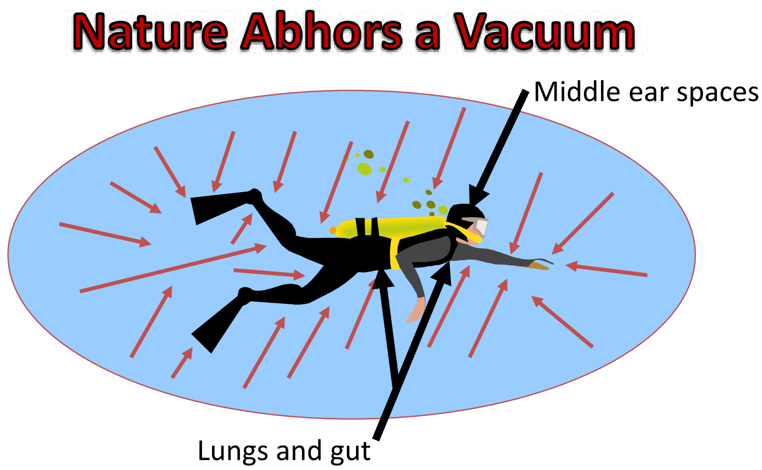
Key: **ATA** = Atmospheres absolute,
HBO = Hyperbaric oxygen

Legend: The above photos illustrate how the three body compartments respond to increased pressure. The water-filled compartment (blue balloon) corresponds to the **liquid-solid structures** of the body (> 90 of the body composition).

The air-filled, flexible walled structures (red balloon)decrease in size with increased pressure and **correspond to the lungs and gut.**

The rigid-walled, air-filled structures (water polo ball) **include the middle ear spaces**. Pressure differentials arise with increased pressure which lead to barotrauma. In these structures bleeding and ear drum perforation occur before collapse (as might happen in a submarine that exceeded crush depth and is demonstrated with the water polo ball).

Figure 5: Pascal's Law and Pressure Related Phenomena in Diving



Legend: Pascal's law states that fluids transmit pressures equally and undiminished in every direction. This has important ramifications for divers. In essence it means divers are "invincible" to the effects of pressure with respect to the body's liquid and solid structures.

The liquid and solid structures in the body subscribe to Pascal's law and transmit ambient pressures equally and undiminished so no pressure differentials develop in these structures with changing depths. Conversely, in air-filled structures, pressure differentials arise with changing depths. Pressure differentials lead to symptoms such as those associated with ear squeezes.

Body structures do not tolerate pressure differentials i.e. "abhor a vacuum" and divers need to initiate techniques such as clearing the ears to prevent pressure differentials in susceptible structures.

resolve, the linings of the cavities begin to swell, which in effect decreases the volume of the cavity. This is usually heralded by pain and is a "warning symptom" that the diver needs to equilibrate pressure in the middle ear spaces, usually an active process such as a Valsalva maneuver or related ear-clearing technique. The swollen lining of these cavities reduces the volume of the cavity and is an automatic, stress-invoked, teleological response to the pressure differential. With increasing pressure differentials, tissue fluids and ultimately blood leak (i.e. diapedesis) through the vessel walls in the lining of the rigid-wall cavities. The endpoint in this continuum of squeeze pathology is rupture of the blood vessels lining the cavity and/or rupture of the tympanic membrane (in the ear squeeze). Once the cavity fills with fluid or the ear drum ruptures, pressure differentials are obliterated and the middle ear cavity responds to pressure as other liquid-solid structures of the body do. It is easy to appreciate at which stages of diving the pressure-related stresses will occur (Figure 3). The squeezes typically occur during the descent phase of diving although reverse ear squeezes can occur during ascent. Conversely, extra-alveolar air syndromes occur during the ascent phase of diving. Knowledge and training are effective prevention measures for these diving medical problems.

Environmental Stresses

Environmental stresses the diver encounters include exposure to cold water, infections of the external ear canal, injuries from marine animals, and the physical

Middle Ear Barotrauma and Hyperbaric Oxygen Therapy

Middle ear barotrauma is a recognized complication of hyperbaric oxygen (HBO) treatments. Because HBO therapy usually requires repetitive treatments, fluid accumulation in the middle ear spaces can make pressure equilibration increasingly difficult with each successive treatment. Much can be done to mitigate ear squeezes associated with HBO therapy including slowing the ascent rate and use of vasoconstrictors and antihistamines (if the patient has allergies). These same techniques are used by divers when they experience difficulty clearing their ears.

A device to equilibrate face-mask pressures and the external ear is purported to prevent ear squeezes. However, little information is known to the authors about its effectiveness and the mechanisms the device utilizes to equilibrate pressures in the middle ear spaces

The HBO patient has the option of insertion of ventilation tubes in the tympanic membranes. They prevent any pressure differentials developing between the ambient pressure and the middle ear spaces. Unfortunately, this is not an option for the diver because water can enter the middle ear space through the ear tubes and lead to infection, vertigo, and fluid retention in the middle ear spaces.

Table 1: Pascal's Law and Pressure Related Phenomena in Diving

Compartment (see Figure 4)	Examples	Effects of Increased Pressure
Liquid-solid 	blood bones, joints, teeth muscles, tendons solid organs skin, fat, connective tissue, nerves	Pressure transmitted equally & undiminished No pressure differentials No depth limitations
 Air-filled, flexible-walled	lungs, gut	Compress as pressures increase (Boyle's law) No pressure differentials
 Air-filled, rigid-walled	middle ear spaces sinus cavities face mask, creases in wet suits	Pressure differentials arise Tissue damage if not equilibrated

Note: See Figure 4 for description of the colored spheres.

characteristics of the aquatic medium itself. All can occur while on the surface of the water (i.e. surface phase of a dive), but also at any of the other phases of the dive. Rarely do the environmental stresses interfere with a dive, but in almost every dive, the diver initiates measures, usually without conscious awareness and/or initiated during the pre-dive planning to mitigate the environmental stresses that could lead to bodily harm.

The Physical Challenges of Cold Water

The specific heat of water is 1000 times greater than air of equal temperatures. This means to warm a volume of water one degree requires 1000 times the heat energy that it would require to warm an equal volume of air one degree. This, coupled with the thermal conductivity of water, which is 25 greater than air, imposes enormous thermal stresses on divers. The LD_{50} (lethal dose i.e. exposure where a 50% death rate occurs) for near-freezing water is about 5 minutes.

Challenges of Cold Water Cold water imposes enormous thermal stresses on the diver. Whereas survival in cold air is measured in days, in cold water of equal temperature it is measured in minutes. The stress of diving in cold water is mitigated by donning exposure suits. They insulate the diver from the thermal conductivity of water and generate a microenvironment that markedly lessens the specific heat challenges of cold water exposure. Many factors in addition to using exposure suits contribute to meeting the cold water stress challenge such as avoiding alcohol ingestion, minimizing swimming movements, slowing breathing rate, etc. (Table 2).

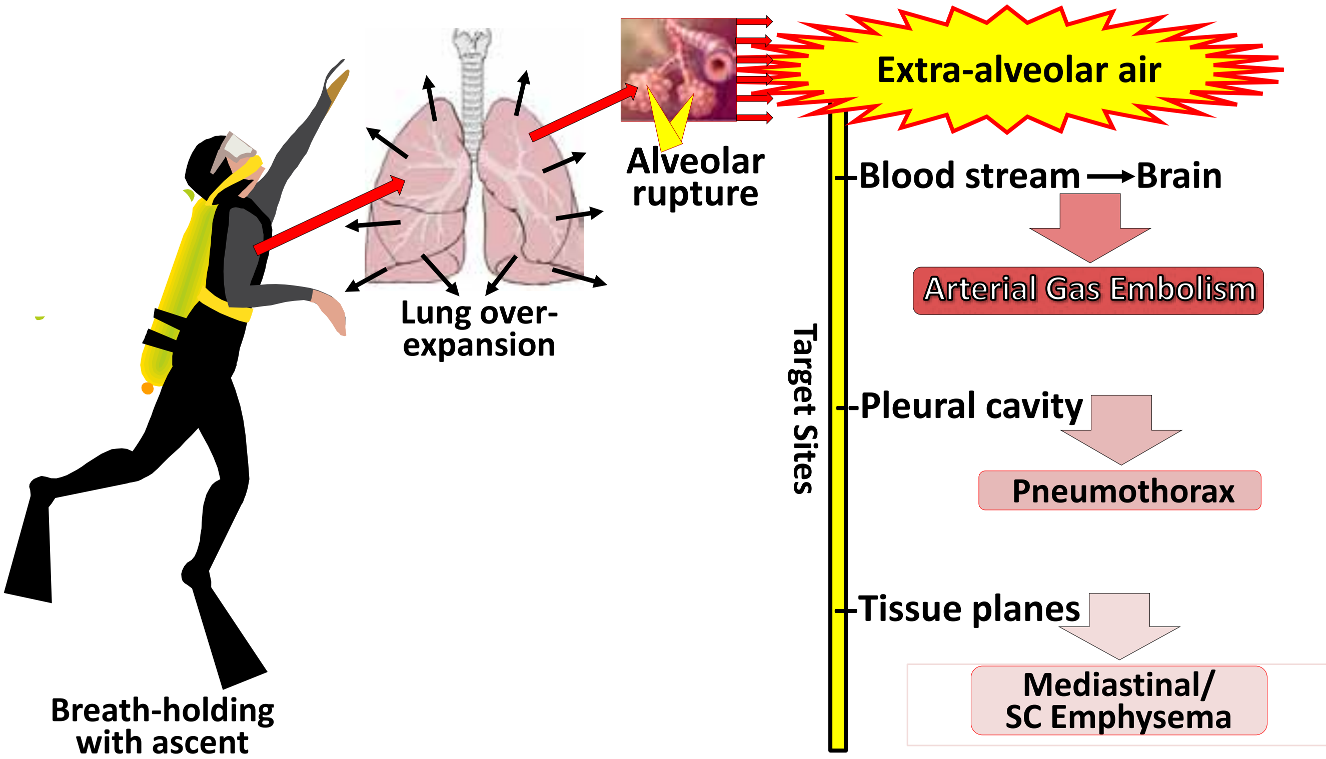
Mitigating the Stresses of Cold Water

It is interesting to note that prior to the era of using exposure suits, the commercial breath-hold diving activities in Japan and Korea (Ama divers) were performed by women. The natural selection of women was based on their increased tolerance to cold water as compared to men. The physiological explanation for this is that women have increased subcutaneous fat which acts as additional insulation from the cold water

It was observed that wet-suited Navy divers who sat nearly motionless in 40°F water for 6 hours in a simulated operational environment hardly dropped their core temperatures. However, their extremity temperatures approached that of the external water temperature as skin temperature measurements moving distally on the extremities were made. Physiology to explain this included heat conservation by minimizing blood flow (and the radiator effect of heat exchange of the extremities) to the almost motionless limbs through vasoconstriction (to reduce blood flow) and countercurrent heat exchange. In countercurrent heat exchange, the cold blood from the extremities (minimal flow secondary to vasoconstriction) allows heat in the blood flowing from the warm core to be transferred to the returning cold blood from the extremities. Conversely, with the heat exchange the blood flowing to the extremities is cold.

Conditioning as well as body habitus can also mitigate the challenges of cold water. A noteworthy example is the feat of Lynn Cox, who swam in freez-

Figure 6: Extra-Alveolar Air/Pulmonary Overpressurization Syndromes



Legend: Alveoli tolerate over-expansion poorly. Even though this tissue type has some elastic properties, overexpansion, rupture, and gas embolism can theoretically occur with breath-holding after full inspiration from a 3 foot depth. This equates to about a 10% alveolar overinflation. **SC** = Subcutaneous

Table 2: Mitigating the Effects of Cold water

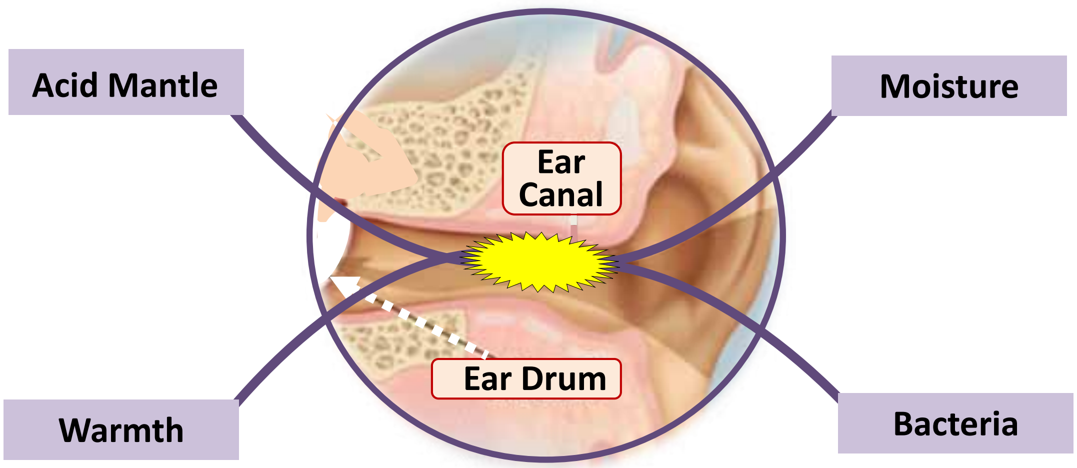
Techniques	Comments
Exposure suits --Lycra --Neoprene --Semi-dry --Dry --External heat sources (hot water, battery, chemical)	Exposure suits insulate the diver from the thermal challenges of cold water. Whereas, the Lycra suit provides 1 or 2 degrees of increased thermal comfort, dry suits and external heat sources allow divers to tolerate sub-freezing water. Chemical and battery heat sources only have a short (1 or 2 hour) duration of action. Hot water suits require tremendous logistical support and are only practical in commercial diving situations.
Monitoring breathing pattern	20% of body heat loss occurs imperceptibly through the lungs with breathing. Inhaled air must be heated to body temperature and fully saturated with moisture before it reaches the alveoli where gas exchange occurs. These two effects are magnified as one descents breathing compressed, dehumidified, ambient temperature gas. Slowing the breathing rate minimizes energy outlay as well as lessens respiratory heat and body fluid losses.
Maximizing propulsion efficiency	Vasoconstriction and counter current heat exchange are mechanisms to conserve heat. The extremities act as radiators to dissipate heat. Of course, this is undesirable in cold water. Alcohol acts as a vasodilator and increases heat loss through the radiator effect of the extremities. These heat conserving mechanisms are augmented by minimizing movements of the extremities while underwater. See text box on "Mitigating the Stresses of Cold Water."

ing Antarctic waters for 25 minutes without any thermal suit protection. Her determination, superb conditioning, and relatively high body mass index (i.e. 29 versus 21-24 for a female of equal height and weight), in addition to being female with a natural protective layer of subcutaneous fat, provide the physiological explanation for these amazing accomplishments.

Swimmer's Ear Ear canal infections (otitis externa, i.e. inflammation of the external portion of the ear) are a second consequence of an environmental stress to which divers (and swimmers) are subject. Normally the external ear canal maintains a healthy, homeostatic environment with four balanced components: Warmth, moisture, acid mantle of the ear canal lining, and bacteria (Figure 7).[4] When the environmental stresses of increased moisture from immersion and/or increased warmth from a tropical environment occur, bacteria proliferate and lead to inflammation and changes in the acid mantle. With progression, discharge (pus) develops in the ear canal. Early symptoms include itching sensations in the canal. This may progress to tenderness of the external ear structures and discharge in the ear canal. Ear canal infections are avoided by augmenting the homeostatic mechanisms that maintain ear canal health such as drying the canal with desiccating agents when moisture accumulates in the ear canal and using weak acid solutions to maintain the acid-base balance. With progression, antibiotic ear drops are used to control the bacteria flora.

Marine Animal Injuries Injuries from marine animals are another category of environmental stresses since diving as well as other aquatic activities subject the participant to encounters with these animals. The stresses imposed on the diver by these encounters can be both physical injury and psychological stress. This latter consideration will be additionally discussed in a subsequent article on psychological stress. While avoidance of encounters with marine animals is a way of eliminating these stresses, such is usually the antithesis of what divers seek. The physical injury marine animals cause can be classified into five injury types (Table 3).[5] The categories include biting injuries, stinging injuries, puncture injuries, poisonous bites, and lacerations. Each imposes specific stresses to the diver/swimmer/bather with resultant disturbances of the normal physiology of the body. For example, a stinging injury injects toxins into the skin. The body's stress response to this insult is the generation of an allergic reaction, usually local, but it can be systemic and life threatening. Much can be said about marine animal injuries, with dedicated chapters and entire books written about this fascinating subject.[6-8]

Figure 7: Maintaining Homeostasis of the External Ear Canal



Legend: Four factors interact to maintain homeostasis in the ear canal. When one or more become out of balance, ear canal problems develop. Increased warmth and moisture will foster the growth of bacteria. Desiccation will dry the canal and disrupt the acid mantle which provides an avenue for bacteria to invade the ear canal lining.

As in all homeostatic mechanisms in the body, too much or too little disrupts homeostasis. The ear responds when the stresses overwhelm the balance between the four factors above . This generates an inflammatory response with itching, pain, swelling and/or discharge.

Table 3: Injuries from Marine Animals

Injury Type	Examples	Pathology	Complications	Management
Bites, avulsions < 1% of Problems	Shark, eels, seals, etc.	**Disruption of tissues**	Bleeding, shock, tissue loss, death	Control bleeding, treat shock, repair tissue injuries
Stings ~ 20% of Problems	Jellyfish, hydra, corals, anemones	**Allergic reactions** Toxins injected with microscopic trigger devices (nematocysts)	Burning itching, welts, Shock, collapse	Inactivate with alcohol or acetic acid "Shave" off residual tentacles
Punctures ~ 20% of Problems	Sea urchins, sting rays, sculpins, cone shells, bristle worms	**Penetrating wounds** Injections of toxins and/or inflammatory proteinaceous debris	Pain, infection, granuloma formation, collapse & death	Soak in "hot" water until pain dissipates Tetanus prophylaxis Treat latent infections
Poison Bites < 1% of Problems	Sea snakes, blue ringed octopus	**Envenomations**	Muscle stiffness, myoglobinuria, respiratory arrest	Resuscitation, life support, antivenins
Miscellaneous ~60% of Problems Cuts, lacerations, rashes (shocks)	Barnacles, corals, parasites, (electric eels & rays)	**Persistent wounds & sores** (shocks)	Indolent wounds, festering sores (Arrests from shock)	Cleanse; debride persistent wounds, antibiotics (Resuscitation if arrest from shock)

Physical characteristics of the aquatic medium is the fourth environmental stress that the diver encounters. Water is approximately 775 times denser than air. This physical fact has both benefits and disadvantages for the diver. An important advantage of water's density is that it provides buoyancy. With proper control, buoyancy allows the diver to hover at any depth without any seeming effort (Figure 8). Exertion stresses arise when buoyancy is not controlled and the diver must expend energy with swimming movements to maintain depth or to ascend. A more serious concern is the total loss of buoyancy control. If too light, uncontrolled ascent may lead to lung overexpansion as discussed previously (Figure 6). If too heavy, uncontrolled descent into the abyss can lead to death. Response measures to mitigate imperfect buoyancy control include monitoring lung volumes and/or using swimming movements, though this is at the cost of increased energy expenditures.

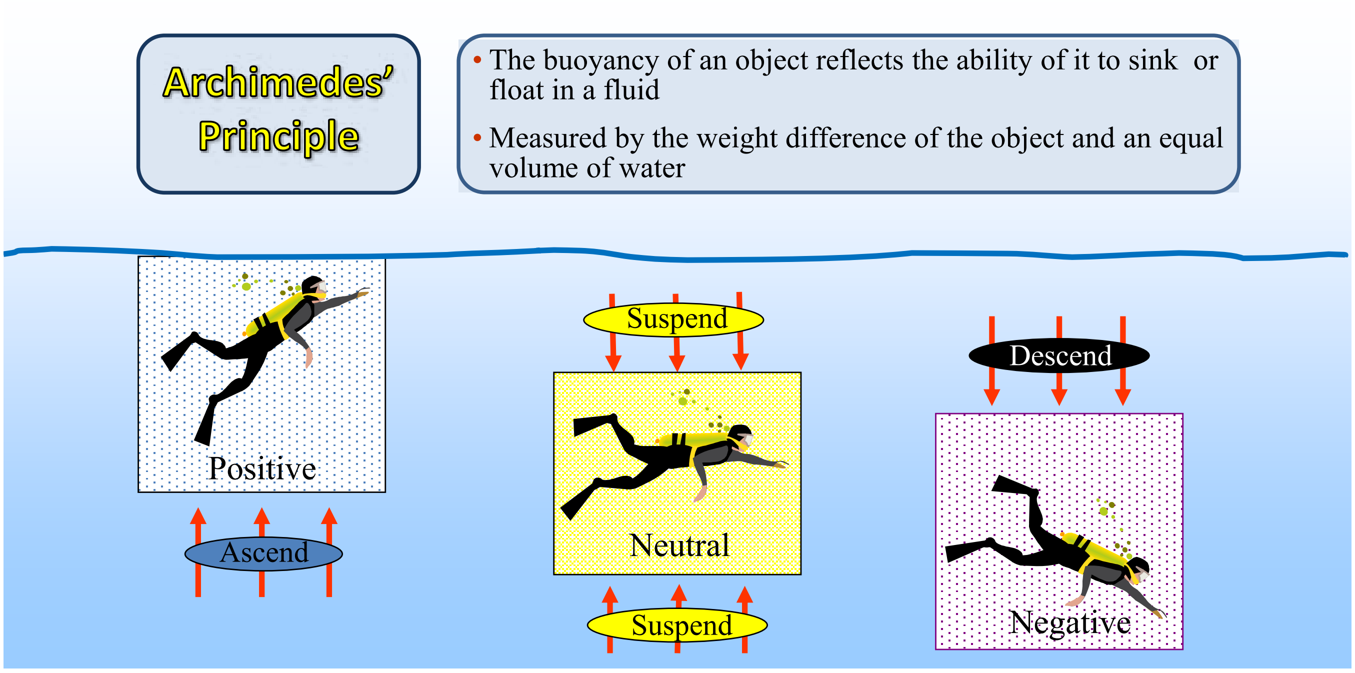
While the density of water provides buoyancy, it also interferes with movement. The reason is the viscosity or "thickness" effect of water, which causes resistance when moving though this medium (Figure 9). This stress is beneficial for the competent swimmer and lessened by the use of swimming fins, but still the ease and speed of moving through water does not approach that of moving through the terrestrial environment. Ramifications of the viscosity of water pose seven other physical challenges which

Dive Scenario: A mildly overweight SCUBA diver wearing a Lycra exposure suit did not think he needed any lead weight for buoyancy control. After a swimming descent with considerable effort, he could not maintain his depth without vigorous swimming efforts. After 20 minutes he had nearly expended the air in his SCUBA tank even though he was only at a 30 foot depth. Somewhat humiliated, he signaled to the dive guide that he was low on air and needed to surface. Meanwhile, his dive companions were able to remain submerged for the better part of the hour—and when they surfaced were concerned that something had gone wrong for the diver.

Comment: Obviously, the diver did not have neutral buoyancy control. The neoprene booties, Lycra suit, air tank, buoyancy compensator, fins, and adipose tissue all added up to giving the diver about 10 pounds of positive buoyancy. With the proper weights this diver was the last out of the water on the second dive.

Not only did the lack of buoyancy control rapidly expend the diver's air supply, but it also put him at risk for an uncontrolled ascent with possible consequences of arterial gas embolism and even decompression sickness (from failure to off gas the super-fast tissue compartments).

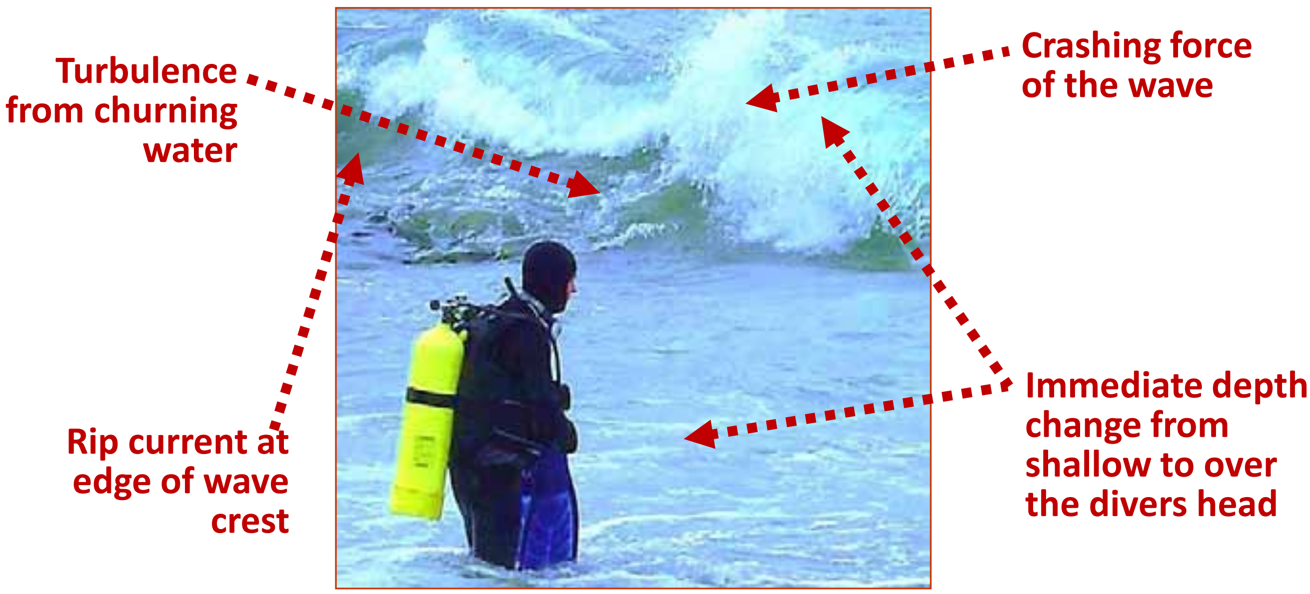
Figure 8: Buoyancy Management for Stress Reduction in Diving



Legend: Buoyancy control is often underappreciated and not fully considered as a stress reducer for divers. Archimedes' principle articulates buoyancy.

By neutralizing buoyancy, the diver does not have to expend energy to maintain position in the water through swimming movements. This reduces exertional stresses. Also, unrealized changes in depth can lead to ear barotrauma and extra-alveolar air syndromes.

Figure 9: Viscosity and Density Challenges of Water for the SCUBA Diver



Legend: A cresting wave can be a great challenge to the inexperienced diver. With water being over 700 times denser than air, even a small wave can cause enormous mechanical forces (see dive scenario).

Awareness of this information and pre-dive briefings can do much to prevent unpleasant experiences while transiting the surf zone.

Table 4: Challenges Related to the Viscosity of Water

Types	Description	Diver Challenges	Management
Current	Continuous flow of water moving in an evident direction	Exhaustion; a mild current of a knot is faster than a SCUBA diver can move through the water	Avoid with pre-dive briefings; swim diagonal to current, "ride" with the current to a safe exit point
Swell	A long often massive and crestless wave usually found beyond the surf zone	Generally not a problem for the diver while underwater Obscures line of sight vision for divers on the surface to see each other & support boats	Use of signaling devices, whistles, sausage tubes to improve visibility while on the surface
Wave	A moving ridge of water as the energy in a swell is transformed due to approaching the shallow bottom of the shore line	As the wave breaks, churning of water generates turbulence and obscures vision	Dive under the cresting wave while leaving the shore; ride with the wave when coming to shore; insure that all dive equipment is securely fastened
Tide	Periodic rising and falling of bodies of water in response to gravitational forces from the moon & sun	Tides can increase swimming efforts to get to and exit from a shore entry dive site	Pre-dive briefings should include tide information; shore dives should be scheduled for low tides
Rip Tide / Current	A strong, usually narrow surface current flowing outward from shore	Exhaustion/panic when trying to swim against the rip tide attempting to return to shore	Swim in a diagonal (or perpendicular) direction until out of the rip tide
Turbulence	Usually small areas of erratic, churning of water where currents mix or waves break	Disorientation, difficulty making swimming progress	Pre-dive briefing to avoid; Try to "ride out" of

include current, swells, waves, surge, tides, rip tides, and turbulence (Table 4). The responses to these stresses are both volitional and reflexive. Buoyancy control and swimming out of the danger zone are awareness actions made to meet these stresses, while increased heart and breathing rate to meet the exertion requirements are unconscious responses. Overwhelming exertion responses from the ramifications of the viscosity of water can lead to fatal outcomes from heart attack or drowning.

Dive Scenario: A petite female diver was making her first open water SCUBA dive entry. While wading out in waist deep water a wave crested over her. This lifted her off the bottom and disrupted the seal on her diving mask, filling it with water. She immediately began to struggle and yelled for help. After the wave passed the dive instructor walked the diver back to the beach. She decided not to continue her SCUBA diving training.

Comment: Although the seemingly innocuous combination of cresting wave and water turbulence frightened her enough to terminate her diving training, it reflects water's density effects and also its ramifications. A briefing before entering the water could have prepared her mentally for the unanticipated event. Had the dive instructor appreciated her timidity regarding the surf zone, he could have provided support by stabilizing and/or supporting her while transitioning through the turbulent area.

Conclusions

Stresses/stimuli and their responses/reactions are inherent to all living organisms. The goal of resolving stresses is homeostasis. Almost all stresses are resolved unconsciously (through physiological mechanisms in the organism), with appropriate conscious efforts or in rare situations with life or death (i.e. fight or flight) responses. With SCUBA and breath-hold diving, the situation is no different in terms of trying to achieve homeostasis. However, the aquatic medium imposes stresses that do not have counterparts on land (e.g. ventilatory with insufficient oxygen availability) or are greatly magnified (e.g. thermal, mobility, etc.). The physical stresses including pressure-related phenomenon and environmental challenges have been described in this first of three articles discussing diving stresses. Subsequent articles will deal with the physiological and psychological stresses of diving. The goal of every diver for every dive is a safe and enjoyable experience. While stress reduction is for the most part presupposed with SCUBA and breath-hold diving, awareness, pre-dive briefings, proper equipment, and conditioning should never be disregarded with these activities (Figure 10).

Figure 10: The Goals for Every Dive

Safe, Enjoyable Stress Reduction

Legend: Stress reduction is one of the essentials for sports diving. Three cardinal requirements are needed to make it is as safe and enjoyable as possible

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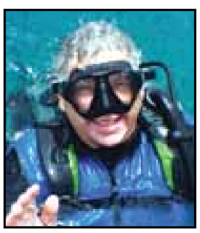

Michael B. Strauss, MD, FACS, AAOS, has had a long-standing and keen interest in diving and diving medicine. His formal training started with Navy Submarine and Diving Salvage Schools. This was followed by tours on a nuclear submarine, with salvage divers in the Philippines &Vietnam and as the undersea medical officer for Underwater Demolition & SEAL Teams in San Diego. Dr. Strauss's special interests in diving include panic & blackout, disordered decompression, the source of pain in decompression sickness, diving stresses (Part 1 in this issue), diving in older age (published in the previous edition of *WCHM*) and mammalian adaptations to diving. As Medical Director of the Long Beach [California] Memorial Medical Center Hyperbaric Medicine Program, he continues active in diving medicine having evaluated and managed nearly 500 diving medical problems, generating over 50 papers & posters on these subjects, conducting yearly worldwide diving-diving medicine programs and authoring *Diving Science*, a well-acclaimed text that describes essential physiology and medicine for divers.

Wound Care & Hyperbaric Medicine

Why Your Smoke/Fire Hood Should Meet the American National Standards for Certification

An advertorial by Ira Gurvitch, President,Elmridge Protection Products, LLC (iEvac® Evacuation Products)

Evacuation from a smoke/fire emergency is crucial especially considering the high level of oxygen in a hyperbaric situation. A smoke/fire hood is the quickest and simplest piece of equipment to use for such an emergency situation. Choosing the proper smoke/ fire hood is extremely important as there are many questionable non-certified products on the market.

Glutted Marketplace

Confusion over smoke/fire hood options is very real. After 9/11, the marketplace was flooded with a number of different products that touted safety during an escape situation. In 2007, responding to a marketplace glut of questionable products, the Consumer Product Safety Commission tested a number of off-the-shelf escape products.[1]

Not one of these products passed the test!

In light of the many sub-standard products on the market, an American National Standard was established. This new National Standard defines both test criteria and approval methods. It contains specific requirements for certification. Certification includes: extensive product testing to meet the rigorous standard, quality audits, follow up inspection programs and annual random product testing.

Certification is achieved through the SEI (Safety Equipment Institute) which tests thousands of safety and protective products. SEI currently certifies all NFPA 1981 self-contained breathing apparatus (SCBA) used in the fire and emergency services. (www.seinet.org)

Currently there is only one product, the iEvac® Smoke/ Fire Hood that has achieved certification to the American National Standard for a smoke/fire escape hood.

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1. *"Evaluation of Consumer personal Protective Equipment: Emergency Escape Masks, October 2007" and "Human Factors Analysis of Consumer Personal Protective Equipment: Emergency Escape Masks, October 2007"*


Undersea & Hyperbaric Medical Society
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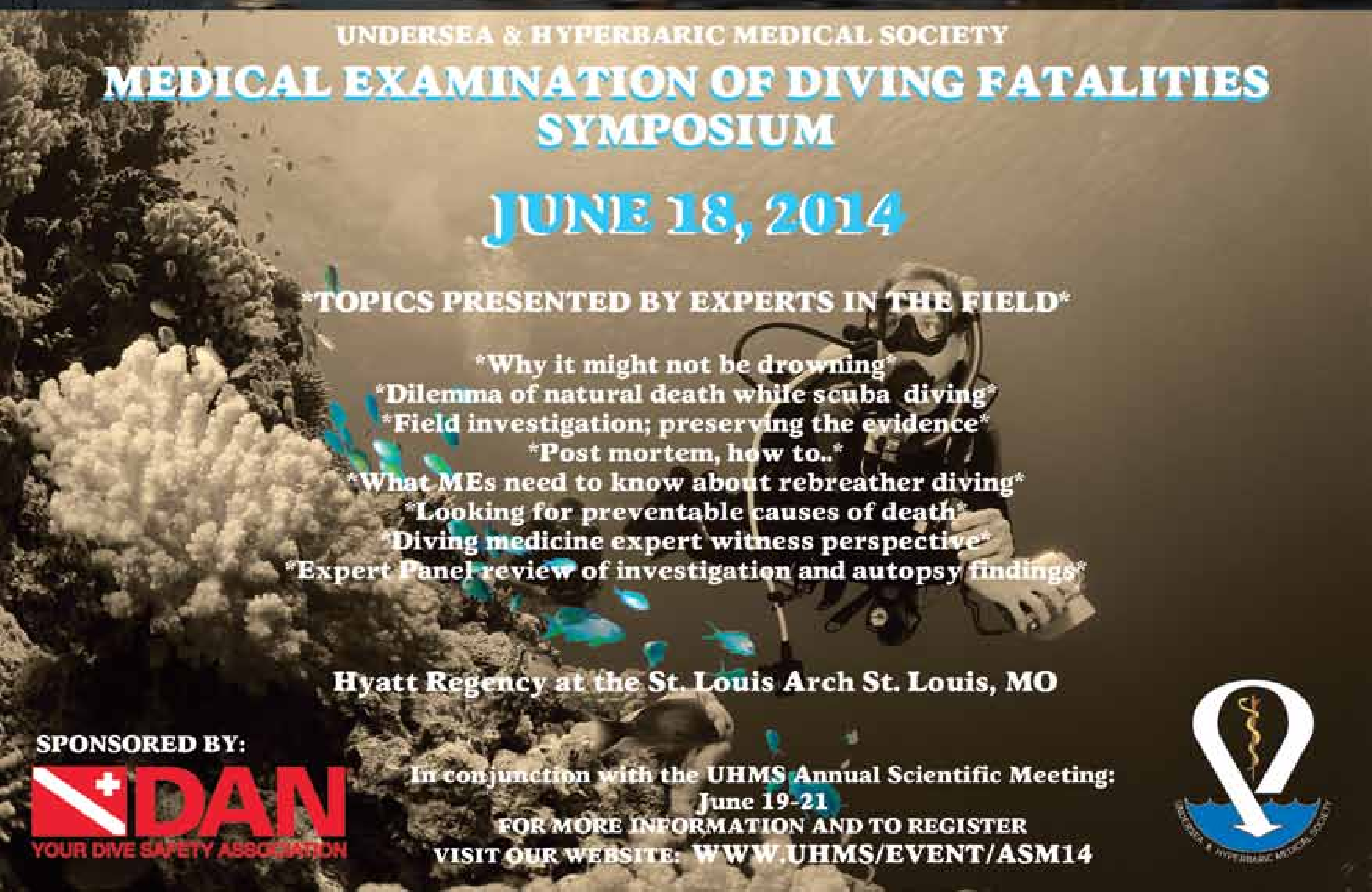
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Field investigation; preserving the evidence
Post mortem, how to..
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Wound Care & Hyperbaric Medicine

Why is a Hyperbaric Facility Maintenance Program Necessary?

By Wound Care Education Partners

The development of a comprehensive maintenance program for a hyperbaric system and its supporting equipment is essential for a safe and cost-effective operation. The chamber and its operational systems, the chamber room, and the equipment used in and around the chamber should be maintained at he highest operational level. This should also include the cleanliness of all elements of the interior and exterior systems.

Components of a Maintenance Program

It is important to understand and comply with applicable codes and standards in order to reduce the potential for:

- ➢ Chamber mishaps and patient/staff injury
- ➢ Costly repair expenses
- ➢ Lost revenue due to unexpected chamber shutdown

The National Fire Protection Association (NFPA) publishes one of the most important standards that apply to hyperbaric facilities. Chapter 14 of the NFPA 99 "covers the recognition of, and protection against, hazards of an electrical, explosive, or implosive nature, as well as fire hazards associated with hyperbaric chambers and associated facilities that are used, or intended to be used, for medical applications and experimental procedures at gauge pressures from 0 kPA to 690 kPA (0 psi to 100 psi)." Section 14.3.1.3.2 of the NFPA 2012 Edition specifies responsibility for administration and maintenance requirements, "each hyperbaric facility shall designate an on-site hyperbaric safety director to be in charge of all hyperbaric equipment and the operational safety requirements..." It continues on to explain that "the safety director shall participate with facility managment personnel and the hyperbaric physician(s) in developing procedures for operation and maintanence of the hyperbaric facility."

The Undersea and Hyperbaric Medical Society (UHMS) Guidelines for Hyperbaric Facility Operations (2004 edition) recommends minimum safety program elements:

- ➢ Documented safety procedures, which must address:
  - o General facility safety
  - o Specific chamber related operational safety procedures such as fire in the chamber and/or the area surrounding the chamber, patient evacuation, contaminated air, equipment failure
  - o How to deal with physiological reactions such as ear pain, sinus pain, oxygen toxicity reactions, claustrophobia
- ➢ Documented recurring in-service training for all full-time and part-time hyperbaric facility staff on selected safety topics. Training sessions shall consist of fire

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drills, mock patient emergencies, simulated equipment failure, contaminated air, updates on codes and standards, etc.

- ➢ Documented preventive maintenance program executed either by local technical personnel or by a third-party maintenance contractor.
- ➢ Documented major maintenance program for specific hyperbaric facility components such as compressors, control components, fire suppression system components, etc (as appropriate).

Chamber mishaps and patient/staff injuries serve as paramount reasons for establishing a comprehensive maintenance program. Catastrophic accidents such as the loss of chamber pressure due to acrylic cylinder or viewport failure, fire due to faulty equipment, or injury due to faulty instrumentation, all serve as reminders that the hyperbaric environment is unforgiving. Even the inadvertent activation of the Fire Suppression System (FSS) in a multiplace system has the potential to injure a patient by possible wound contamination. For this reason alone the FSS tank and headers in a multiplace system should be drained and refilled at least monthly to reduce the amount of contaminants present in the FSS water reserve. Consequently, when setting up a maintenance program many of the activities can be developed to revolve around the prevention of mishaps.

NOTE: *This article focuses on the establishment of a maintenance program. The examples presented within are not meant to serve as an in-depth or detailed account of every maintenance item that may be preformed for a hyperbaric maintenance program.*

References: *This article first appeared on Rx Pad, the blog of Wound Care Education Partners. www.WoundEducationPartners.com/Rx-Pad. Reprinted with permission from Wound Care Education Partners. Workman, Wilbur T. Hyperbaric Facility Safety: A Practical Guide. Flagstaff, AZ: Best Publishing Company 2010. Workman, Wilbur T. UHMS Guidelines for Hyperbaric Facility Operations. Kensington, MD: Undersea and Hyperbaric Medical Society: 2004.*

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Wound Care & Hyperbaric Medicine

Quality Improvement

By Laura Josefsen, RN, ACHRN

Hyperbaric medicine practice follows multiple organizational and accreditation guidelines and standards for overall safety and optimal outcomes. Quality improvement organizations are meeting and working together at the national level in the effort to improve the health care system. These include:

- Agency for Healthcare Research and Quality (AHRQ)
- American Medical Associations Physician Consortium for Performance Improvement (PCPI)
- American Nurses Association (ANA)
- Buying Value
- Centers for Medicare and Medicaid Services (CMS)
- Institute of Medicine (IOM)
- Measure Application Partnership (MAP)
- Measurement Policy Council (MPC)
- National Committee for Quality Assurance (NCQA)
- National Quality Forum (NQF)
- National Quality Strategy (NQS)
- Physician Quality Reporting System (PQRS)
- Public support
- Robert Woods Johnson Foundation (RWJF)
- U.S. Department of Health & Human Services (HHS)

The following is a collective summary of the work these organizations are doing together. The quotes are taken directly from the above organizations.

Focus for This Year

- An unprecedented collaboration between public and private payers leading to the establishment and adoption of a consensus set of core measures
- New progress on reducing the burden of data collection for providers engaged in quality improvement
- Updates to all national tracking measures where data are available

Current Issues

- Patients get effective care about half the time
- There are gaps in coordination of care
- There are still serious preventable medical errors
- Health care costs could be decreased by improving quality and efficiency
- Many quality measures are not yet consistent or widely used
- The quality measures are not yet in place to address most things that matter to patients
    - Measures related to their outcome: How they can function, work, and perform activities in their daily lives
    - Measures of reliable and consistent information on the price and cost of care

The Role of Quality Improvement

- Expanding to create optimal medical, nursing, and technical patient-centered care at the most effective cost
- The relationship with the nursing role to define and increase nursing scope of practice as well as nursing standards of practice

Payment Reforms In the Next Decade 2014-2023

- Shift toward paying for coordinated care that meets each patient's needs
    - Prevention and innovative combinations of treatments based increasingly on patient-specific

characteristics and preferences
  - o Develop and improve performance measures to reflect patient-specific outcomes, experiences, and other key aspects of quality at the person level
  - o Diverse quality improvement initiatives are in progress at all levels of the health care system with the goal of putting quality measures to use

Upcoming Changes for the Future

- ➢ Quality improvement
  - o Associated with diagnosis
- ➢ Health care
  - o Patient education
  - o Staff education
  - o Wellness model
- ➢ Affordable Care Act
  - o Three aims:
    1. Improve the experience of care for individuals
    2. Improving the health of populations
    3. Lowering per capita costs
  - o Six priorities
    1. Safer care by reducing harm caused by delivery of care
    2. Ensuring that each person and family are engaged as partners in their care
    3. Promoting effective communication and coordination of care
    4. Promoting prevention and treatment practices
    5. Working with communities to promote wide use of best practices to enable healthy living
    6. Making care more affordable by developing and spreading new health care delivery models

Opportunities for Improving Health Care Quality

- ➢ Medicare has established quality reporting systems for providers
- ➢ Activity in the development of quality measures
  - o American Medical Association (AMA) Physician Consortium for Performance Improvement
- ➢ National Quality Forum (NQF)
  - o This organization does not develop quality measures
  - o Helps to identify and analyze gaps in areas where measures are needed but do not currently exist
    - • Gaps are identified using the three aims and the six priorities of the National Quality Strategy as a guiding principle.
  - o Makes recommendations on quality measures
    - • Which ones should be adopted in Medicare's payment system for clinicians
    - • Which ones should be eliminated
    - • Which ones needs further development
- ➢ Buying Value initiative
  - o Made up of 19 organizations
  - o October 2012 met with Federal agencies, including CMS and AHRQ, to discuss approach for developing common performance measures for value purchasing among public and private payers and leveraging work by the MAP
  - o February 2013 Buying Value purchasers had an initial core set of ambulatory measures for use by health plans and private purchasers
- ➢ Common Measures now list 35 measures
  - o Twenty are part of Stage 2 Meaningful Use in the Medicare and Medicaid Electronic Health Record Incentive Programs
    - • Use of High Risk Medications in the Elderly (NFQ#0022)
    - • Timely Transmission of Transition Record (NQF# 0648)
    - • Blood Pressure Control (NQF # 0018)
    - • Comprehensive Diabetes Care: HbA1C<8% (NQF # 0575)

Quality Measures

- Designed so they can be implemented from data systems used in the actual delivery of care—this is less costly than retrospective data and also lets us know where the gaps are
- Measure Application Partnership (MAP)/PQR System guidelines
  - o Identify core sets of endorsed outcome measures that are clinically relevant to almost all clinicians, regardless of the specialty
  - o Align measures across multiple programs to reduce administrative burdens and achieve greater impact
  - o Provide a lower-cost pathway for promising but less-developed measures to transition into more widespread use and NQF endorsement
- Payment reforms
  - o Can enable health care providers to get more resources to
    - Set up registries
    - Implement other changes in health care
    - Avoid unnecessary costs
    - Answering patient calls or email to avoid the cost and delay of an office visit
    - Spending more time with the complex patient
    - Monitor patient adherence to medications
    - Monitor patient lifestyle changes
    - Other care management steps that can enable patients to prevent their disease of health risk form progressing
    - Activities that can improve patient care and potentially reduce cost

o Nursing Impact

- Taking time and implementing systems to coordinate care
- Decrease duplicate or inappropriate services
- Don't let organized structure stop the opinions and power of individual voices
- Talk to other specialties
- Liberate your team
- Acknowledge the passion of special interest
- Strengthen partnerships with practice education/change
- Share information

Campaign for Action Summit 2013

- Targets for improvement for each of the remaining national tracking measures
- Private sector champions achieving excellence and sharing best practices in each of the six priority areas
- A spotlight on three strategic opportunities, reflecting the breadth of activity to improve quality infrastructure across the country
- Consensus among public and private payers on quality measurement
- National Quality Forum convened the Measures Application Partnership (MAP)
  - o A consensus based entity composed of over 60 public and private sector organizations representing
    - Consumers, businesses, and purchasers
    - Labor
    - Clinicians
    - Hospitals
    - Federal partners
    - National Quality Strategy
  - o Families of measures
    - Safety
    - Care coordination
    - Cardiovascular conditions
    - Diabetes
- This immediately inspired action from public and private payers across the health care sector
  - o Ensure ongoing harmonization of measures across agencies and programs
    - Hypertension control
    - Smoking cessation
    - Hospital-acquired conditions
    - Care coordination
    - Patient experience of care
    - Depression screening and remission

- o Align measures for current work focus on:
  - HIV/AIDS
  - Obesity
  - Diabetes
- ➢ CMS Opportunities
  - o CMS is pursuing opportunities to align reporting requirements in 2013 for eligible professional practicing in groups

Quality Improvement continues to be an evolving process. Our knowledge and input into this process is encouraged by the above organizations to assist in providing a comprehensive program.

Laura Josefsen, RN, ACHRN is on the UHMS (Undersea and Hyperbaric Medical Society) Board of Directors as the current Nurse Representative on the Associates Council, and has been a member of the UHMS Accreditation Team as a nurse surveyor since its inception. She is a founding member of the (BNA) Baromedical Nurses Association, served as president from 1996-1998, and has been active on the executive board since 1985. She served for many years as an Executive Board Member of the NBDHMT (National Board of Diving and Hyperbaric Medical Technology), and is a previous member of the BNA Certification Board. She is currently on the Board of Directors of the TMAA (Texas Medical Auditors Association). She is a member of the Undersea and Hyperbaric Medical Society Associates, former member of DAN (Diver's Alert Network), and HTNA (Hyperbaric Technologists and Nurses Association) of Australia. She has numerous publications and is an internationally recognized speaker in the field of hyperbaric medicine.

Print This Free Poster for Your Clinic!

Critical Events Occuring During a Dive in the Water and During Hyperbaric Oxygen Treatment

This table serves as a reminder of the factors to consider in preparing patients for and managing them during hyperbaric oxygen treatment.

	Air Breathing Diver in the Water	Oxygen Breathing Patient in Monoplace Chamber
Compression	Absolute pressure increases…the volume of gas containing spaces with flexible boundaries decreases (*Boyle's Law*) 1. Middle ear and sinus barotrauma 2. Mask squeeze 3. Decrease in volume of wet suit, and buoyancy compensator 4. Breathing gas density increases, work of breathing increases 5. Number of gas molecules consumed with each breath increases	Absolute pressure increases…the volume of gas containing spaces with flexible boundaries decreases (*Boyle's Law*) 1. Middle ear and sinus barotrauma 2. Volume of gas containing medical implants or within medical devices decreases, can affect equipment function 3. Breathing gas density increases, work of breathing increases 4. Number of gas molecules consumed with each breath increases
	Partial pressure of gases increases leading to increased gas tensions in blood and tissues…inert gas and oxygen (*Dalton's Law*) 1. Inert gas narcosis 2. Oxygen toxicity 3. Carbon dioxide retention in ambient environment	Partial pressure of gases increases leading to increased gas tensions in blood and tissues…oxygen (*Dalton's Law*) 1. Pharmacophysiologic effects of hyperoxygenation of blood and tissue 2. Oxygen toxicity 3. Carbon dioxide retention in ambient environment
		Pharmacophysiologic effects of hyperoxygenation of blood and tissue 1. Improved oxygen dependent cellular metabolism 2. Antimicrobial effects 3. Protection against ischemia reperfusion injury 4. Tissue regenerative effects (angiogenesis, tissue growth) 5. Anti-inflammatory effects 6. Anti-apoptotic effects 7. Activated stem cell mobilization
	Increased inert gas volume in solution (*Henry's Law*) defined by partial pressure of ambient gas, solubility of gas in water and lipid, gas diffusion	Increased oxygen volume in solution (*Henry's Law*) defined by partial pressure of ambient gas, solubility of gas in water and lipid, gas diffusion
		Ambient temperature increases in the chamber (*Gay-Lussac's Law*)
Decompression	Absolute pressure decreases…the volume of gas containing spaces with flexible boundaries increases (*Boyle's Law*) 1. Middle ear and sinus barotrauma 2. Pulmonary barotrauma, pneumothorax 3. Breathing gas density decreases, work of breathing decreases 4. Number of gas molecules consumed with each breath decreases 5. Any inert gas or oxygen bubbles forming during decompression (phase separation) will increase in size as ambient pressure decreases	Absolute pressure decreases…the volume of gas containing spaces with flexible boundaries increases (*Boyle's Law*) 1. Middle ear and sinus barotrauma 2. Pulmonary barotrauma, pneumothorax 3. Breathing gas density decreases, work of breathing decreases 4. Number of gas molecules consumed with each breath decreases 6. Any inert gas or oxygen bubbles forming during decompression (phase separation) will increase in size as ambient pressure decreases
	Partial pressure of gases decreases leading to decreased gas tensions in blood and tissues…inert gas and oxygen (*Dalton's Law*) 1. Recovery from inert gas narcosis 2. Hypoxia	Partial pressure of gases decreases leading to decreased gas tensions in blood and tissues…inert gas and oxygen (*Dalton's Law*) 1. Blood and tissue oxygen gas tensions decrease but hypoxia cannot occur with normal lungs as patient always breathing 100% oxygen even on return to 1 ATA at surface
	Decreased inert gas volume in solution (*Henry's Law*) defined by partial pressure of ambient gas, solubility of gas in water and lipid, gas diffusion 1. Inert gas decompression sickness	Decreased oxygen gas volume in solution (*Henry's Law*) defined by partial pressure of ambient gas, solubility of gas in water and lipid, gas diffusion 1. Oxygen decompression sickness could occur but would be very short lived due to rapid re-absorption of oxygen as it is metabolically consumed
		Ambient temperature decreases in the chamber (*Gay-Lussac's Law*)

Boyle's Law: At a constant temperature, the volume of a given gas is inversely proportional to the surrounding ambient absolute pressure.

To maintain a neutral lung volume as we descend on scuba, we inhale proportionally more gas molecules per breath.

Dalton's Law: The total pressure exerted by a gas mixture is equal to the sum of the partial pressures of each individual gas.

As we breathe more gas molecules per breath on descent, the potential impact of elevated partial pressures becomes important. Nitrogen narcosis is the result of elevated nitrogen partial pressures.

Henry's Law: At a constant temperature, the amount of a given gas that dissolves into a liquid is directly proportional to the partial pressure of that gas above the liquid. In physiological terms, this gas pressure exists within our lungs relative to the gas pressure within our blood.

The greater the gas pressure within our lungs, the more gas will dissolve into our blood and body tissues. This is the basis of decompression sickness.

Wound Care & Hyperbaric Medicine

Ask the Experts: What is the Current Perspective Regarding Supervision of Hyperbaric Dives by Nurse Practitioners?

From The Wound Care Education Partners blog, *Rx Pad*

Question: "I would be interested in the current perspective regarding supervision of hyperbaric dives by Nurse Practitioners.

1. Is it safe?
2. What preparation for supervision is appropriate?
3. How many centers across the nation are using NPs?
4. What are the pros and cons to having an NP supervise dives?

Other policy or procedure recommendations for NP supervision of dives."

Question from Carol, BSN, RN and student of Wound Care Education Partners.

Our Experts Offer the Following Answers:

Question 1. Is it safe?

Answer. It is safe with appropriate preparation. As with other disciplines within medicine that utilize nurse practitioners and physician assistants, the provision of safe care is a function of proper training and sufficient supervision. The UHMS and NBDHMT consider mid-level practitioners qualified to safely supervise HBOT so long as those criteria are met (see position statements below).

Question 2. What preparation for supervision is appropriate?

Answer. The UHMS (Undersea and Hyperbaric Medical Society) position statement:

The Non-Physician provider specific recommendations:

a) The UHMS supports the on-site supervision of hyperbaric oxygen therapy by a Nurse Practitioner or Physician Assistant if each of the following conditions is met:

i. The supervising physician meets the UHMS recommendations for physician attendance as per UHMS guidelines.

ii. The supervising physician is immediately available to the Hyperbaric Medicine Department as specified by applicable government regulations.

iii. The Nurse Practitioner or Physician Assistant has obtained appropriate specialty certification through the National Board of Diving and Hyperbaric Medical Technology (NBDHMT) as a Certified Hyperbaric Registered Nurse (CHRN) or Certified Hyperbaric Technologist (CHT), or international equivalent

The NBDHMT position statement:

a) HBO must be directly supervised by a physician (or nurse practitioner/physician assistant where permitted by prevailing credentialing and regulatory standards) who is formally (UHMS or other authoritative body) trained in hyperbaric medicine, involving face to face classroom versus online setting. Such supervision should extend to:

a. Assessment of suitability for HBO therapy
b. Determination of risk-benefit profile
c. Interpretation of any related diagnostic testing
d. Generation of a therapeutic dosing profile
e. Evaluation of subsequent clinical course, and
f. Management of any related side effects and complications

Further, the hyperbaric physician must be on the premises and immediately available to the chamber facility at all times that the chamber(s) is occupied. Immediately available would meet the intent of this Position Statement if the physician could arrive at the chamber facility within five minutes of being summoned and in doing so, would not place in jeopardy any other patient presently under their care. It is the duty of hyperbaric nursing and technical personnel to safely implement ordered therapy and closely monitor patients during their treatments. Should a patient voice complaints or manifest signs suggesting an unanticipated change in status, considered to be hyperbaric related or otherwise, the hyperbaric physician should be immediately notified. Importantly, hyperbaric nursing and technical personnel do not assume any of the physician responsibilities noted above and cannot initiate hyperbaric treatment without patient-specific hyperbaric physician signed medical orders.

Question 3. How many centers across the nation are using NPs?

Answer. At this time, there are only a few.

Question 4. What are the pros and cons to having an NP supervise dives?

Answer. As with many pro/con discussions, the determination of which elements fit into a given category hinges largely on one's perspective. Any substantive answer must acknowledge the parties represented in this discussion, which include: patients, mid-level providers, physicians and administration. Each group will see this topic through a unique lens and there are doubtless opinions that won't be represented here. The points made below are not listed as pro or con for those reasons.

Patient: some may prefer physician level supervision, but there shouldn't be any difference in the actual treatment provided. There are no cost savings to the patient subsequent to having mid-levels supervise HBOT.

Mid-level: enjoyment of engaging in hyperbaric medicine, expanded scope of practice, potential for additional income.

Physician: Potential for reduced work hours and revenue loss due to less time working in HBO, increased requirement for direct supervision of mid-levels and immediate availability. Responsibility for mid-levels requires additional work and liability which are frequently not associated with added compensation.

Administration: Potential for greater scheduling flexibility as more people can supervise treatments; mid-levels are paid less but physician supervision and immediate access may offset these overhead reductions.

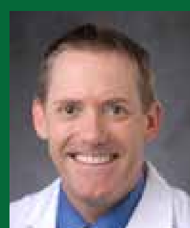
Question 5. Other policy or procedure recommendations for NP supervision of dives.

Answer. One recommendation is to include a Nurse Practitioner job description per NP scope of practice guidelines. In addition to broadening the scope of practice, hyperbaric specific training, experience and competency standards are necessary for credentialing purposes within a healthcare facility. While stand-alone wound care centers may not require that level of documentation, proof of training and experience is part of the UHMS and NBDHMT position statements.

References: Expert answers provided by Laura Josefsen, RN and Nick Bird, MD, MMM

About the Experts

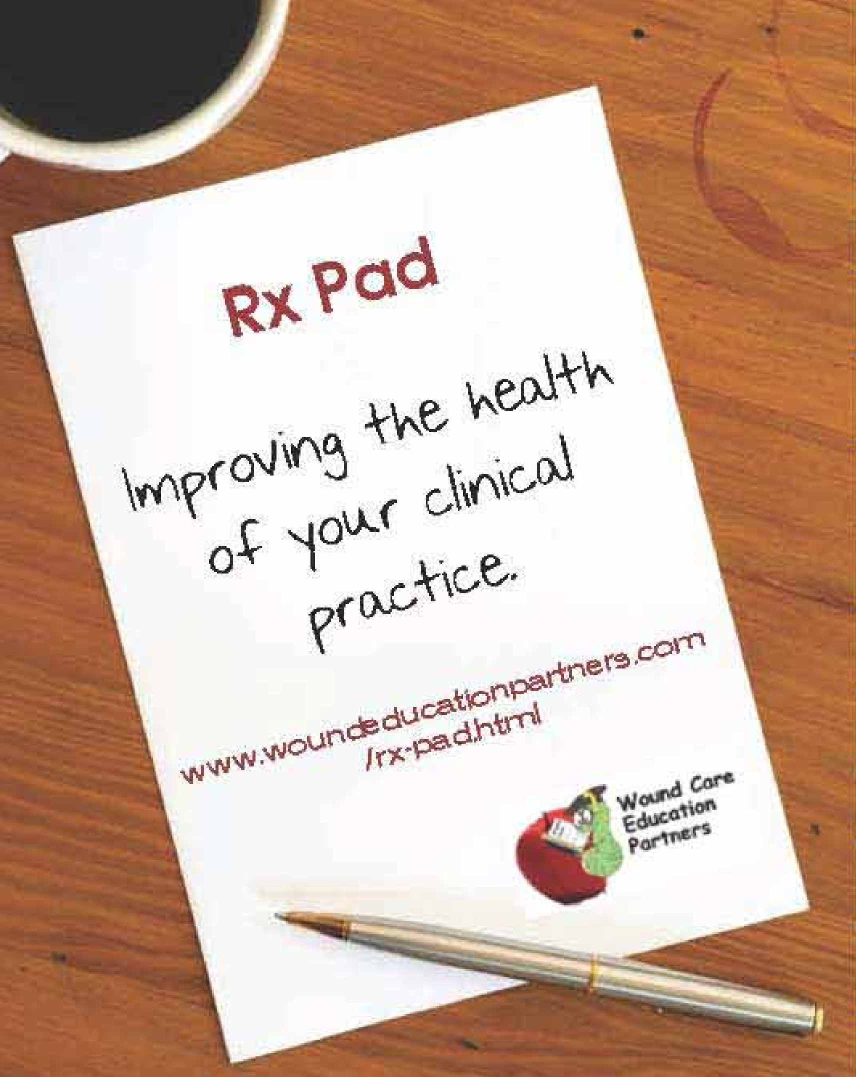
Laura Josefsen, RN, ACHRN is on the UHMS (Undersea and Hyperbaric Medical Society) Board of Directors as the current Nurse Representative on the Associates Council, and has been a member of the UHMS Accreditation Team as a nurse surveyor since its inception. She is a founding member of the (BNA) Baromedical Nurses Association, served as president from 1996-1998, and has been active on the executive board since 1985. She served for many years as an Executive Board Member of the NBDHMT (National Board of Diving and Hyperbaric Medical Technology), and is a previous member of the BNA Certification Board. She is currently on the Board of Directors of the TMAA (Texas Medical Auditors Association). She is a member of the Undersea and Hyperbaric Medical Society Associates, former member of DAN (Diver's Alert Network), and HTNA (Hyperbaric Technologists and Nurses Association) of Australia. She has numerous publications and is an internationally recognized speaker in the field of hyperbaric medicine.



UHM Nick Bird, MD, MMM is a fellowship-trained, board certified hyperbaric physician. He is the past CEO and Chief Medical Officer for Diver's Alert Network (DAN) in Durham, North Carolina. Prior to his position with DAN, he served as the Medical Director of Hyperbaric Medicine at Dixie Regional Medical Center in St. George, Utah. Additionally, Dr. Bird served in the United States Air Force as a flight surgeon and received his initial training and experience in hyperbaric medicine at Travis AFB while working as the Deputy Flight Commander of the hyperbaric /wound center. He was honorably discharged with the rank of Major, but not before serving as the final Commander of the Base Hospital in Jordan during Operation Iraqi Freedom.

Earning his Bachelor of Arts degree from the University of California at Santa Cruz in 1992, Dr. Bird went on to earn a medical degree from the Royal College of Surgeons in Ireland in 1999. He completed a residency in family medicine under the University of Washington and a fellowship in hyperbaric medicine at the University of California at San Diego. In addition to his fellowship training, he attended the US Air Force hyperbaric course, the International ATMO program, and the NOAA Diving Medical Officer course.

Dr. Bird has remained a clinical instructor in hyperbaric medicine and wound care. He is an active member of the UHMS, works as part of the UHMS accreditation team, has authored articles and book chapters in diving medicine, is a member of the UHMS Diving Medicine Committee, and he has both attended and presented at multiple conferences on diving and hyperbaric medicine. Additionally, he was the course director for the DAN DMT course and author of the revised series of DAN educational programs.



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Test your Knowledge of Diving Medicine

1. Arterial gas embolism (AGE) symptoms will typically occur in a DCS case within 48 hours of surfacing.

   A. True
   B. False

2. What are the main stresses of diving?

   A. Physical
   B. Physiological
   C. Psychological
   D. None of the above
   E. All of the above

3. Which body function change is correct as one gets older?

   A. Increased cardiac output; decreased BP
   B. Improved judgment & reasoning ability
   C. Decreased metabolic rate/ weight loss
   D. Decreased ability & decreased time for injury recovery
   E. Decreased ant-post diameter of chest

4. Lungs, blood, brain and heart all equilibrate very quickly to new ambient pressures.

   A. True
   B. False

5. ___% of DCS symptoms will manifest within 48 hours of a dive.

   A. 60
   B. 100
   C. 83
   D. 98
   E. 42

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