Davis Hyperbaric Laboratory
USAF HYPERBARIC NEWSLETTER
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RESEARCH & DEVELOPMENT

BASIC SCIENCE RESEARCH

(*TOO MUCH HAPPENING RIGHT NOW--UPDATE NEXT ISSUE)*

CLINICAL HYPERBARICS

PEDIATRIC CONSIDERATIONS WITH HBO THERAPY

Introduction

Of all the indications for hyperbaric oxygen therapy (HBOT) which apply to adults, many also apply to the pediatric population. While not regular beneficiaries, it is inevitable that at some point pediatric patients will be referred for hyperbaric medicine services. Children are not just small adults but are on a developmental continuum of progressive physiological and anatomical maturation of multiple physical and psychosocial systems. It is therefore important that hyperbaric personnel are knowledgeable about the clinical management considerations and appreciate and are sensitive to the requirements of this age-group. Dose-response data for hyperbaric oxygen has been determined for young, healthy men and extrapolated to include all adults, including women. These same dosage regimens have been used with success in treating a number of pathologic pediatric conditions with favorable response and low morbidity; this suggests that HBOT is appropriate to consider for children.

This article identifies the basis for pediatric indications for HBOT. It outlines important physiologic and developmental aspects to be considered in the clinical management of this age-group with respect to the selection of pediatric patients for common HBO indications and discusses practical points in the preparation of patients for therapy. Pediatric doses of medications useful in HBOT and settings for ventilators and IV's are incorporated in the *Practical Pediatric Points* section.

Pediatric Differences and Risk-Benefit

The hallmark of pediatric clinical practice centers about the pathological process taking place against the backdrop of developmental changes in the growing/maturing host individual. These changes sometimes present obstacles to successful therapy or at times are necessary considerations when determining the life-long effects of the intended therapy upon the individual, e.g. radiation therapy for a parotid gland carcinoma and subsequent radionecrosis of tissue in the treated field. Protecting the pediatric patient's ability to continue to grow and develop one's full life potential is the goal of any therapeutic intervention, however, frequently, a trade-off is accepted of risk of adverse side-effects versus benefit of therapy as the only viable option to progress through treatment and resolution of a pathological process.

Oxygen Toxicity: The outcome of the interaction of oxygen free radicals and the body's defenses against them can result in disease states which are most noted in the CNS, pulmonary, and to a lesser extent, ocular systems. The oxygen chemically held by hemoglobin is stable with respect to radical production, however, the oxygen physically forced into solution in the hyperbaric environment is free to interact to form superoxides leading to loss of essential protein function(enzymes), cellular damage(lipid peroxidation), tissue damage, and ultimately organ system dysfunction/failure. For example, there is a positive correlation between the reduction of brain GABA levels and the

time to seizure onset. To protect human beings, superoxide dismutase, catalase, peroxidases are the primary enzymatic defense in the antioxidant system. These are assisted by molecular scavengers and compartmentalization of highly reactive energy transfers within cells. This antioxidant system is active in both adults and pediatric populations with certain limitations affecting pertinent body systems which are highlighted below:

CNS

- Observational experience reporting of 100 children who had no adverse effects on HBO
- Problem in reporting early symptoms in pre-verbal population
- >3 yr up to adult, CNS is "mature", i.e., normal risk

Pulmonary

- Alveolar type 1 cell lysis, type 2 proliferation
    - normobaric O2 leads to loss of surfactant
- Late effect of interstitial fibrosis
- Protective antioxidant mechanisms: catalase, dismutase
- After newborn period, antioxidant system as good as adult
- Pre-term (<36 wks) system deficient with cascade of effects:
    - loss of surfantant leads to alveolar collapse, inc FIO2/mech vent needs
    - inc inflammation leads to proliferation of scarring, dec # alveoli

Ocular

- Retinopathy of prematurity risk dissipates by 40 wks adjusted gestation
- Effect of alternating hypoxia/hyperoxia
- Proliferation of retinal vessels invading vitreous

Barotrauma: Potential sites of non-pulmonary involvement include the middle ear, paranasal sinuses, external ear, inner ear, teeth, GI tract, and equipment taken into the chamber. This is a result of the indirect relationship of pressure and volume(Boyle's law). Prevention and management concerns regarding middle ear barotrauma is covered in *Practical Pediatric Points* section. Pulmonary overpressurization directly causing pneumothorax, or in association with lung disease, either active(obstructive and/or restrictive disease, e.g. bronchopulmonary dysplasia in a premature infant, asthma in a child) or latent(congenital cyst) can indirectly lead to air gas embolism. A patent R to L shunt(foramen ovale or ductus arteriosus) can also contribute to air gas embolism. It should be remembered that oxygen is a potent stimulus for closure of a patent ductus arteriosus; in an infant who still has congenital heart disease, this might be the only means of providing oxygenated blood to the infant, contraindicating HBOT. There is no real substitute for a thorough review of history to include the post-partum period when considering HBO for infants and young children. A complete physical examination to follow the history is paramount. The requirement of a quality screening chest radiograph to rule out any congenital cardio-pulmonary problems prior to instituting HBOTis also prudent practice. Other assessments and diagnostic procedures or tests may be indicated based on the above baseline evaluation.

Clinical Indications and Treatment

Dose-response data have been elucidated for HBO to show efficacy of application of pressure and hyperoxia to achieve supernormal partial pressures of tissue oxygen. This is what really drives the decision to use HBO--pressure and hyperoxia. There has been no basic science research or experimentation in pediatric dosing so recommendations for treatment are limited to experiential reports. Below are a sample of indications and the treatment schedule used by some pediatric institutions.

Carbon Monoxide poisoning: The child or infant in the car or home environment poisoned by CO, will often be the first one to present with symptoms. Within a cluster of affected family members, the level of carboxyhemoglobin found in the youngest pediatric patient will generally be lower than the rest of the family. This may be explained by the greater minute ventilation rate of the child compared to an adult. The child would onload CO faster and clear faster based on this principle. It should be noted that the fetus lags mother in onloading and has delayed clearance of CO. Children frequently present with vomiting and irritability. Treatment regimen is the same as for adults except for a lower threshold for initiating HBO in pediatric patients as they (especially pre-verbal ones) may be more difficult to assess in some areas, e.g. history and neuropsychiatric testing.

Air Gas Embolism: Overinflation of the lungs during resuscitation or from breath-holding from a submerged car, violent trauma, or the use of diagnostic and therapeutic intravascular catheters may all be cause for the introduction of air bubbles into the arterial tree leading to the classic neurologic presentation of AGE. Treatment is as for adults.

Decompression Sickness: With US diver training extending to minors under supervision of adult trained divers, it is possible for DCS to develop. It may

also be caused by an exposure to altitude, e.g. rapid decompression in a pressurized craft or an excursion in an unpressurized aircraft. The presentation is like that in adults and should be treated in like manner.

Acute Traumatic Ischemias/Injuries: Crush injuries, compartment syndrome, traumatic amputations with replantation, threatened flaps from reconstructive surgery, and Brown Recluse spider bites all represent pediatric surgical situations which may require use of adjunctive HBO. Lowering the threshold for implementation of therapy is an important consideration to maximize the potential for preservation of tissue/function. Begin HBOT with TID and change to BID, then daily if needed; the individual depth can be modified from 3 to 2.5 ATA and duration of session lessened with each O2 period decreased to 15 minutes.

Necrotizing Infections and Chronic Refractory Osteomyelitis: Dirty contaminated wounds complicated by ischemia leading to necrotizing infections including gas gangrene, can occur in the pediatric population. A high index of suspicion and early intervention is vital to salvage of viable tissue in this aggressively destructive disease. The timeliness of early intervention regarding the "chronicity and refractoriness" of osteomyelitis is another important consideration in the lifelong quality of life of pediatric patients. The increased correlation of pulmonary and CNS oxygen toxicity in the case of HBO-treated gas gangrene (up to 15 % in adults) alludes to the toxic manifestation of this disease. The maturity of the pulmonary system and CNS must also be weighed when deciding the therapeutic schedule for children. Initially, TID treatments are considered in necrotizing infections for the first few days then followed by BID and later daily; sparse literature suggests the prudence of decreasing the oxygen intervals to 15 minutes in children and possibly shortening the duration of each HBO session. No comment or rationale is given for this plan other than the reference of increased oxygen toxicity found in treating gas gangrene patients with HBO. Osteomyelitis calls for daily HBO similar to adults.

Radiation Tissue Injury: Irregardless of advanced radiotherapy techniques, the long-term results of therapy still include the complications of progressive fibrosis, decreased vascularity, and loss of epithelial function leading to necrosis, ulceration and fistula formation, the chronic radiation wound. The pediatric population carries a life-long residual of such therapy, therefore the prophylactic and therapeutic application of HBO to obviate the late effects of ionizing radiation is paramount. In a small study, ten patients who underwent radiation therapy as children were referred for HBOT. Six received prophylaxis and four were treated after having either sequestrectomy for osteoradionecrosis or soft tissue radionecrosis. The ages at HBOT ranged from 3.5 to 26 yrs with the interval between radiation exposure and HBOT ranging from 2 mos to 11 years. In all but one patient the outcome was excellent; the one patient treated for a 7th cranial nerve palsy (vasculitis) had unsustained improvement. The final assessment was that HBO for children with radiation-related bone and soft-tissue complications was safe, efficacious, and had few adverse effects.

Thermal Burns: Substantial literature exists to support the use of HBO in thermal injuries which acts to reduce edema, decrease healing time and aid in clearing infections. Of 70,000 burn center admissions per year, there are 12,000 deaths with the extremes of the age spectrum being more vulnerable than the average adult population. One hyperbaric center suggests treating children with the same schedule as adults who receive TID treatments at 2 ATA for 90 minutes for the first 24 hours then BID thereafter.

Problem Wounds: Pediatric patients are the victims of violent trauma at home and on the highways or have congenital diseases or tumors or other diseases which require surgical intervention. In the course of surgical therapy they may have poor results (threatened flap), complications(wound infection), contributing host factors(diabetes mellitus or malnutrition) or staged procedures requiring multiple procedures, and in any case develop non-healing or poorly healing, hypoxic wounds. The benefits of HBO can work for pediatric patients as it does for adults and be applied at the same dosage regimes.

Practical Pediatric Points

Anxiety

- Anxiety is #1, the 1-2 combo is:
    - novelty-driven and
    - removal of the one constant in life, mom or dad
- Appeal to logic—Not!
- Solution to commotion is **Distraction**
- Toys, safe for HBO use, TV, kid videos, HBO puppets, reading books
- Familiarization with pre-HBO "play" in the chamber area and buddy up with caregiver
- Sedation: IV preferred for better titration, Morphine 0.05-0.1 mg/kg or benzodiazepine(Versed) see dosing schedule for specific age-group of patient. Must monitor patient continuously.
- Avoid antihistamines and chloral hydrate for variable response

Parents

- Can be best ally versus biggest show-stopper
- Parent anxiety best managed by education, education , education

- Generally advised to keep patient outside the chamber(don't need another patient)

Staff

- Remember the inside observer is stuck with the kid; how well prepared is that person?
- Solution is education, hands-on equipment know-how, inservice refreshers and having a plan in place

Restraints

- For procedures: Ventilators, NG tubes, Foleys, ET/NT, chest tubes, monoplace use
- Papoose boards must have velcro removed so figure out something else for straps/wraps
- Paralytic(Pavulon: 0.1 mg/kg prn) and sedation(see above)—helpful control, more safe but require constant monitoring

Temperature Management

- Kids have greater surface area to body mass—results in increase radiation of heat, smaller/younger the patient the more the effect
- If they're using Kcals to heat then sacrifice wound healing

Fluid Management

- Shock: crystalloid volume expansion= 20 cc/kg; hemorrhage=packed cells 10cc/kg, FFP/Platelets 10-20cc/kg
- Maintenance: D5 0.2NS with 20 meq/L K acetate
    - over age 1 yr: rate 50cc/hr during dive
    - under age 1 yr: calculate 4cc/kg/hr

Airway Management and O2 Administration

- Comatose pt: nasal tracheal intubation preferred
    - what passes through nares passes by the cords
    - 3-mo=4.0, 6-yr=6.0, 10-yr=7.0
- Tracheal hygiene while in chamber is with Deleed trap
- Infants are nose-breathers—keep 'em clear
- Monoplace: no problem if conscious; if not:
    - Sechrist has volume irregularity problem for kids<5yrs old, therefore use Gregory CPAP bag with IO in chamber with patient
    - Sechrist settings: starting pressure 20-30 cm, I/E ratio 1:2, Flow volume sets tidal volume + I/E; 10 cc/kg tidal volume, rate 14 for adolescent, rate 36 for toddler. CAUTION USE IN <5YR OLD CHILDREN
- Multiplace: Oxford-Penlon-1989; Siemens Servo 900C, adults on volume-control, kids on pressure-control
- If using head box watch for O2 leaks and monitor FIO2 inside box—need flow of 50-60 lpm
- Duke head tent or Sea-Long hood good to use

Middle Ear Barotrauma

- Eustachian tubes hypoplastic till age 8
- Valsalva can be learned/performed at age >5 yrs if child is not too ill
    - must obsrve movement of TM—not practical
- Bottle-sucking=modified Frenzel + very slow descent in monoplace--maybe get by
- Crying baby is a ventilating baby=myth
- Gum-chewing might be an idea for some older ages
- Myringotomy +/- tubes--the way to go for age<6 yrs

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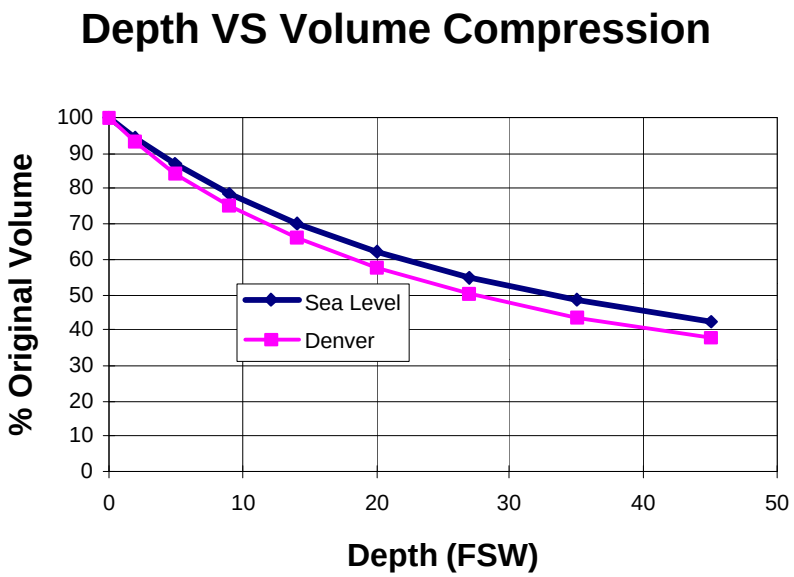
A SMOOTH RIDE

So there I was in Panama City Florida communing with squids. During the multiple discourses with with Davey Jones we learned that pressure was the most important environmental variable. Although this seemed rather ostentatious, upon reflection one quickly realizes that in effect, pressure controls the way in which clouds move throughout the firmament, upon which land the sun falls, and even the where's and why-fors of rainfall. Applied to the hyperbaricists realm we find the old adage "pressure is the most important environmental variable" again holds true. Consider the most common form of adverse effect upon our patients during their treatment profile in the chamber. Since every dive involves a descent and an ascent, during which we pass from 14.7 PSI to 34.7 PSI, with of course, a return to sea level some two hours later, we put our patients through some significant changes. These changes were admirally predicted by Sir Robert Boyle when he formulated his law relating pressure and volume. We know for a constant temperature if you double the pressure you will halve the volume. In a more mathematical formulation we would say that for a constant temperature T, $P_1V_1=P_2V_2$. Now this is where the tricky parts begins! Most of our hyperbaric chambers are designed to provide a constant rate of descent towards the target depth in terms of feet per minute. Where the chambers are programmed to go from sea level to 45 Feet of Sea Water (FSW) in five minutes we are in essence instructing the system to perform a constant rate descent at 9 feet per minute. Thus in the first minute we descend from sea level to 9 FSW. In the second minute we descend from 9 to 18 FSW. This scenario continues until during the fifth minute we descend the last 9 feet from 36 to 45 FSW. Let's examine the physics of these steps to gain a better understanding of the physiological processes which are simultaneously occurring.

During the first minute of transition we pass from sea level or pressure of 14.7 pounds per square inch to a pressure equivalent of nine FSW at depth. If we consider our middle ear to have a volume of 100 at sea level by proceeding to nine few sea water depth in one minute that volume using Boyle's law will be compressed from 100 to 78.6. This volume change may be determined by using the equation V = V0*(P0/(P0+.44545D)) where D equals the equivalent depth in FSW and V0 is our original 100%. This equation predicts that by the time we reach our target depth of 45 feet, the volume will have been compressed from 100 to 42.3. It is the relative volume change of 57.7 units which we wish to spread equally over our total descent time in order to enhance patient comfort. The equation in its general form will allow us to draw a curve for the equivalent rate of volume change with time as we descend from the surface to our target of 45 few sea water. As applied to our current example the zero was chosen to be 100 percent and P0 is equal to the atmospheric pressure at sea level or 14.7 pounds per square inch we may easily change this equation if you find yourself performing a dive in say Denver Colorado when the atmospheric pressure at 5200 feet is significantly less than 14.7 PSI. Looking up the estimated value for pressure in Denver at 5200 feet we find that it would nominally be 625.5 Torr or 12.1 PSI. The curves generated by these two equations can be seen in the graph shown below for Denver and sea level.



The graph demonstrates something we all know from having participated in many chamber descents with our patients: the effects related to pressure change occur most rapidly during the first several feet of the descent and then taper off during the latter portion. In an attempt to straighten things out I reasoned that a more comfortable descent and ascent profile would be one in which the rate of volume change with time was constant. To produce this we would need to adjust the depth rate of descent with time throughout our descent profile. More specifically we need to make our descent slower at the beginning of the dive and faster toward the end. At Brooks Air Force Base we were fortunate enough to have a computer controlled chamber in which we can have up to 20 segments per dive profile. Previously we had been using two segments to control the descent, taking us from sea level to 15 FSW in the first two minutes and then from 15 feet to 45 feet in the remaining three minutes for a total descent time of five minutes. Not infrequently many of our patients would have ear or sinus blocks during the first two to three minutes of descent time. Using our current descent profile this would be expected since the largest relative volume change occurs during these first several minutes.

In deciding how to configure a standard descent and ascent profile that would minimize the risks on descent for those with mild ear or sinus problems and reduce the risk of air trapping in those having potential obstructive or restrictive lung defects, we decided to use a seven minute total time for every descent and a 10 minute total time for every ascent. In the past we had multiple descent and ascent profiles attempting to optimize our days dive profile in consideration of every mix of patient we could have in the chamber. This led to chamber operator confusion and frequent ear and sinus problems. We attempted to used a five-minute ascent if there were no known lung problems within our patient population on a particular dive; however if we had a patient with a history of asthma, COPD, or emphysema we would use a 15 minute ascent profile. In examining the 15 minute ascent I found we had programmed a single segment linear ascent over 15 minutes from 45 feet to the surface. This meant we were ascending three feet per minute throughout the entire profile. The most rapid rate of volume change would occur during the last minute of ascent during which time we would ascend from three feet to the surface, going through 8.3 units of volume change. I reasoned that if my 10 minute profile did not exceed this final rate of volume change, then it

should be just as safe as the old 15 minute ascent. I shall examine the final ascent profile later on in this paper to see if it meets that criteria.

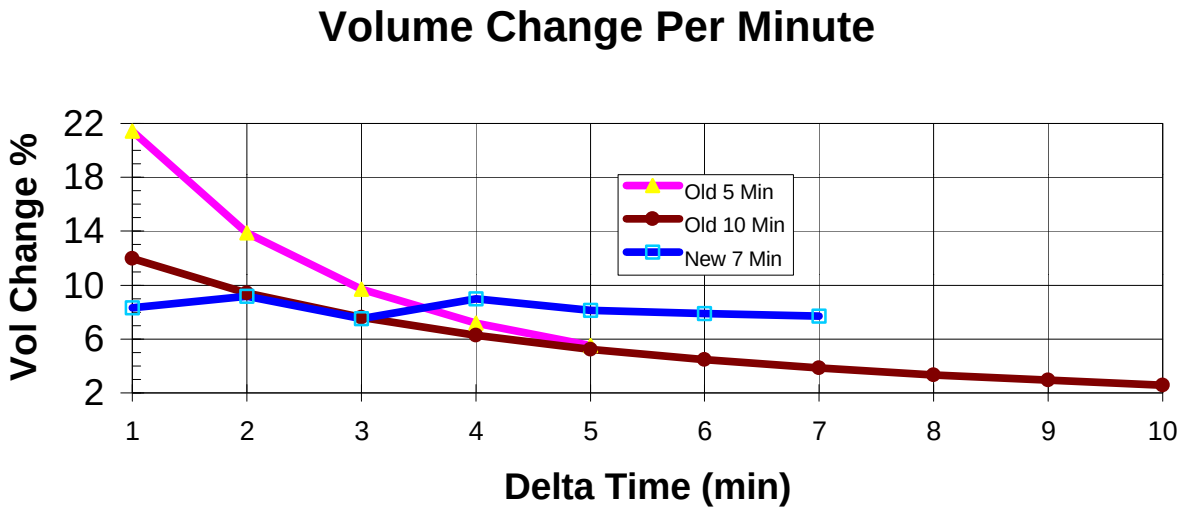
To create our smooth descent and ascent profiles, I broke the descent into seven segments, each of which would take us a part of the way from the surface to 45 feet. Each segment would be completed in one minute. In order to determine how many feet of depth we should pass through in each segment I took the total volume change of 57.7 units and divided it by 7 to get the number of volume change units that should occur during each minute of the descent. This produced a target of 8.24 units of volume change per minute. I built a spreadsheet to make working with the numbers a bit easier. Since our dive controller would only permit the entry of time and depth in integer format and would not accept fractional feet or minutes (aesthetically displeasing, but functional) our boundary values were forced to be a bit more granular then I would have liked. This necessitated some segments volume change being upwards of 9.5 units of volume change while other segments only accumulated 7.4 units. This variation was unavoidable given the constraints of our controller system. One should note that this variation is much less than the variation experienced during our original profile in which the first one minute of descent produced a 7.5 ft. change equivalent to 18.5 units of volume change and the last minute of descent from 35 to 45 feet produced only 6.2 units of volume change. For the 10 minute ascent I had a choice of using 10 segments of one minute each or five segments of two minutes each. In the interests of time and simplicity we chose the latter for our model. The spreadsheets detailing the seven minute descent and the 10 minute ascent (using two min-

ABOVE:
DESCENT PROFILE (7 Minutes)

Period	Start Depth	End Depth	Start Press	End Press	Delta P	Start Vol	End Vol	Delta Vol Calc	Delta Vol Target
1	0	3	1.00	1.09	0.09	100.00	91.67	8.33	8.24
2	3	7	1.09	1.21	0.12	91.67	82.50	9.17	8.24
3	7	11	1.21	1.33	0.12	82.50	75.00	7.50	8.24
4	11	17	1.33	1.52	0.18	75.00	66.00	9.00	8.24
5	17	24	1.52	1.73	0.21	66.00	57.89	8.11	8.24
6	24	33	1.73	2.00	0.27	57.89	50.00	7.89	8.24
7	33	45	2.00	2.36	0.36	50.00	42.31	7.69	8.24

BELOW:
ASCENT PROFILE (2 min per period = 10 min)

Period	Start Depth	End Depth	Start Press	End Press	Delta P	Start Vol	End Vol	Delta Vol Calc	Delta Vol Target
1	45	29	2.36	1.88	-0.48	42.31	53.23	-10.92	-11.54
2	29	18	1.88	1.55	-0.33	53.23	64.71	-11.48	-11.54
3	18	10	1.55	1.30	-0.24	64.71	76.75	-12.04	-11.54
4	10	4	1.30	1.12	-0.18	76.75	89.19	-12.45	-11.54
5	4	0	1.12	1.00	-0.12	89.19	100.01	-10.81	-11.54



utes per segment) are shown above.

To see why this profile enhances patient comfort, one need only examine a chart of the amount of "volume change" that occurs per minute of descent. The more consistent this is, the less variability will be experienced. Also, the smaller the magnitude of the volume change, the more time a patient will have to adjust to the descent and therefore, the less likely to experience an ear or sinus block. On the previous page, I compare linear 5 and 10 minure descents to 45 FSW with the new "smooth ride" profile. You can see that the new profile is more consistent over the entire descent, and the maximum volume change per minute is the lowest, even when comparing it to a 10 minute "linear" descent.

We have been using this "smooth ride profile" on every treatment dive since May 1998. Subjectively our patients noticed the difference and felt the new profile was more comfortable than the old. Although sufficient time has not yet passed for us to compare objective measures of the frequency of adverse chamber reactions on descent between the old profile and the new profile, my expectation is the number of ear and sinus blocks will be greatly decreased using the new smooth ride profile. In addition, having a single profile for descent and ascent with no reason for profile modification based on patient mix, has made the chamber controllers job less confusing. As promised, the comparison of terminal ascent rates: the old 15 minute rate was 3 feet per minute over the final minute for 8.3 volume units. The smooth ride ascent target was 5.8 volume units per minute (11.54 in 2 min) - 30% more conservative than the old profile. I predict that soon, all hyperbaric chambers will control their ascent and descent using a constant volume rate of change instead of the current constant depth rate of change mechanisms. Enhanced patient comfort and overall satisfaction are bound to be the end result.

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CASE REPORTS

A 16 year old lady presented with a two week history of left cheek wound that had not healed. The wound dated from a warm day of sun-bathing. On this warm day in mid-winter the young lady proffered a blanket from the closet only to feel a mild itching shortly after laying down. Later the area enlarged and became reddened. Within two days there was central darkening and pain. This was followed by drainage, crusting, swelling, drainage cycles. There was no further change in the lesion over the ensuing two weeks.

The young lady had no other pertinent medical or surgical history.

Exam was remarkable for a 1.0 cm x 1.5 cm lesion with a centrally crusted violaceous depression. This area was surrounded by a 1-2 cm margin of erythematous induration.

It was felt that this wound was the result of a "possible" brown recluse spider bite. Plastic Surgery felt surgery would be cosmetically damaging. Consultation was requested of Hyperbaric Medicine.

Evaluation agreed with Plastic Surgery's assessment. Although the lesion was two weeks old, it was felt a short trial of HBO would be helpful. After five (5) treatments, there was significant improvement. Wound closure was seen in Wound Check Clinic within 10 days.

Commentary: Although necrotic arachnidism does not appear on the UHMS list of approved indications, there is certainly data to support its treatment with HBO. The brown spider (*Loxosceles*) is one of three spider genera known to cause necrotic skin lesions in the United States. The other two are *Tegenaria* and *Chiracanthium* (hobo spider and yellow sac spider, respectively). Overall, the most common source of necrotic arachnidism is the US is *Loxosceles reclusa* or the "brown recluse spider."

This spider has three pairs of eyes (most spiders have four pairs) and a unique dorsally placed "violin" on its cephalothorax. "Violin spider" and "fiddleback spider" are nicknames based on this characteristic marking. These timid spiders prefer warm, dry, dark places that are undisturbed. In urban settings closets, attics, and garages are commonly inhabited. These nocturnal hunters are rarely seen in daylight and when disturbed are usually seen rapidly retreating.

When threatened, the brown recluse spider will bite. The venom injected by its fangs contains 8-9 proteins. Included in this mix are nuclease, hydrolase, collagenase, protease, and esterase. However, the two most active components are hyaluronidase and sphingomyelinase D. Hyaluronidase acts as a "spreading factor" carrying sphingomyelinase D wherever gravity draws them. Although hyaluronidase is over 99% of the venom, it is sphingomyelinase D that causes the damage.

Sphingomyelinase D attacks cell membranes (ie, RBC, endothelial cell). This damage leads to the release of arachadonic acid, prostaglandins, thromboxanes, and leukotrienes which cause severe localized vasospasm. In addition, there is significant leukocyte chemotaxis. Endothelial E-selectin is up-regulated accompanied by an overly excessive leukocyte adherence. Leukocytes degranulate amplifying the progressive in-

jury. When this exuberant leukocyte infiltration is experimentally inhibited, the necrotic result is mitigated.

Despite an estimated 90% of bites going unnoticed, the remainder certainly garner intense attention. Within 10 minutes there is local pruritis, pain, and swelling. Sometime over the next 8 hours, an indurated, erythematous papule will appear. This gradually transforms into the typical "red, white, and blue" or "halo" lesion. Centrally placed is a darkly violaceous region (vaso-occlusive cyanosis). Around it is an irregularly shaped pale "halo" (vasospasm). This, in turn, is surrounded by a variable degree of erythema (inflammation). After 48 hours central necrosis occurs with eschar formation. In fact, the necrotic process can actually penetrate into the subcutaneous fat. Rarely, it can extend to fascia or muscle. Generally, healing occurs over the ensuing 6 months producing a large ugly scar.

Prompt treatment can potentially avoid the nasty consequences of the brown recluse bite. There are several well accepted general measures. Tetanus prophylaxis and pain relief are obvious. Rest and elevation to reduce the hyaluronidase-mediated gravity effect are important. Of greater import is the application of ice. It does not prevent necrosis, but it does reduce the activity of sphingomyelinase D. Incidentally, systemic symptoms, though rare, are seen; here, supportive care is the key.

Other treatment modalities are controversial. Early surgery, initially advocated, was shown to be ineffective. Recent studies give little support for steroid dosing whether it be intralesional, intradermal, or systemic. Dapsone (used to treat leprosy) depresses leukocyte function suggesting benefit. However, animal and human data are conflicting. In addition, Vanderbilt University has reported success with an antivenom. Unfortunately, the antivenom is not commercially available.

And, finally, HBO has its advocates. It was first suggested in 1986 by Svendsen. This was based on 15 successfully treated cases. He suggested venom inactivation as a potential mechanism. Since then, animal trials have evenly split. Two showed benefit and two showed no benefit. In 1995, Caniglia and Kendall examined 90 patients treated with HBO. All were treated within 72 hours using 2 ATA for 90 minutes twice daily. They averaged 7 treatments per patient. Only four patients required surgery or suffered a severe scar. This strongly suggests a clinical benefit that can not be ignored.

How might HBO work? It is clear from the work of Maynor et al (1997) and Merchant et al (1997) that HBO does not directly affect sphingomyelinase D. However, we do know that HBO will block leukocyte-endothelial adhesion. Sphingomyelinase D action results in an exuberant leukocyte infiltration into the bite site. Years ago Smith et al noted this same profound leukocyte accumulation. Using an animal model he was able to interrupt this phenomenon by inhibiting leukocyte function. The outcome was a marked diminution in lesion necrosis. This suggested a leukocyte mediated amplification of tissue damage. Perhaps HBO inhibits the leukocyte adhesion thus blocking bite site infiltration and mitigating leukocyte-mediated injury amplification. Needless to say, further investigations are needed.

In conclusion, the brown recluse spider bite is a common cause of necrotic arachnidism. Sphingomyelinase D is the active ingredient in the venom. Untreated, prolonged pain and severe scarring are likely. Treatment includes tetanus prophylaxis, rest, elevation, and ice. Although controversial, dapsone and HBO have advocates and should be seriously considered in severe cases.

WPB

LITERATURE REVIEW

The Valsalva Manoeuvre: A Critical Review. David Taylor

SPUMS Journal. 26(1): 8-13, 1996.

Abstract: The Valsalva manoeuvre is commonly used in diving to equalise middle ear pressures during descent. A forceful expiration with the nostrils and mouth held shut results in an increased nasopharyngeal pressure and opening of the Eustachian tubes. The correctly performed manoeuvre is easily taught, effective and usually without complications.

When performed incorrectly, prolonged periods of raised intrathoracic pressure may lead to decreased venous return, decreased arterial pressure and increased pressures within the superior and inferior vena cavae. An intact autonomic nervous system will initiate compensatory cardiovascular reflexes. The manoeuvre has clinical and research uses which rely on induced physiological changes and the initiation of reflex responses. The physiology and clinical uses of the manoeuvre are discussed.

The inappropriate use of the manoeuvre has been associated with significant morbidity. This includes pulmonary and aural barotrauma, hyper- and hypotension, cardiac arrhythmias, arterial and venous haemorrhage, gastric reflux and stress incontinence. The complications of the manoeuvre are discussed.

Commentary: This review is an excellent discussion of the Valsalva Maneuver which was first described by Anton Maria Valsalva in 1704. Forced expiration

against a closed glottis or pinched nose is the essence of the maneuver. Dr. Valsalva recommended this for the treatment of "discharging ears." The maneuver would force air into the Eustachian tube driving pus from the middle ear through a ruptured tympanic membrane. Thus, chronic suppurative otitis media might be cured.

Dr. David Taylor describes the many uses and complications associated with the Valsalva maneuver. Clinically, sympathetic and parasympathetic nervous system dysfunction can be tested with it. Atrial septal defects and patent foreman ovale can be investigated with it. And, paroxysmal supraventricular tachycardia can be treated with it. Furthermore, rare as they may be, complications are seen with the Valsalva maneuver. These include syncope, hemorrhagic retinopathy, inner ear barotrauma, and pulmonary barotrauma.

Perhaps most fascinating, however, is his discussion of the complex physiology that accompanies the simple Valsalva maneuver. Dr. Taylor describes in detail the four phased physiologic response. Phase I is characterized by increased intrathoracic and intraabdominal pressure. This compresses the aorta and increases peripheral resistance. While the maneuver is sustained (about 7 seconds) Phase II begins. The increased intrathoracic pressures cause diminished venous return with its consequent decreased cardiac output. The resultant drop in blood pressure is detected by the carotid baroreceptors. Via a complex neural pathway, the vagus nerve parasympathetic fibers are inhibited and sympathetic fibers are stimulated. Reflex tachycardia and peripheral vasoconstriction ensue. Phase III follows cessation of the maneuver. External aortic pressure falls. This promotes Phase IV (overshoot phase) where the large capacitance veins (superior and inferior vena cavae) resume unobstructed flow into the heart. Cardiac output increases to handle this transient elevated venous return. However, this is pumped into a constricted peripheral arterial tree. Again, the carotid baroreceptors detect the blood pressure change. This time it is elevated. The result is a reflex bradycardia. Syncope is a known consequence. Shortly thereafter, equilibrium returns.

Briefly, this paper is a short, detailed review and deserves reading. The physiology alone is worth the effort.

WPB

HYPERBARIC TRAINING AND EDUCATION

LECTURES

The Staff/Fellow Conferences at Davis Hyperbaric Laboratory are alive and extremely well. We have had the pleasure and privilege to host numerous formal lectures/discussions. All of them have been CME accredited by the Office of the USAF Surgeon General. Each has been videotaped to facilitate continuing proficiency training in Hyperbaric Medicine.

WPB

HBO LECTURE/SAFETY VIDEOS

The Davis Hyperbaric Laboratory Video Library, has had a growth spurt! The monthly Staff/Fellow Lecture Series held at Brooks AFB, is now being videotaped.

Lectures by scientists, foreign visitors, nurses, technical experts and physicians are available, and can be borrowed. All you have to do is ask! Plans are in the works to have these filmed lectures accredited for CHT, CME, and nursing.

To borrow a film---

Call: DSN: 240-3281
COM: (210) 535-3281
Write: DET 1, HSC/AOH
2509 Kennedy Circle, Suite 309
Brooks AFB, TX 78235-5304
E-mail: dolores.larkin@platinum.brooks.af.mil.

Capt Barbara Susen
Chief, Clinical Education & Equipment Development

A Partial Listing

Long Term Health Effects of Diving
Aircraft Mishap Investigation---Australian Style
Fire Review/Operational Safety (2 hours)
Pharmacology of HBO & Biochemistry of Healing
Monoplace Protocols
Crush Injury/Compartment Syndrome
The Historical Basis and Use of TcPO2 (2 hours)
Basic Science and HBO
Cardiopulmonary Effects of Pressure
Osteomyelitis and HBO
HBO---Delivery and Extraction in Human Tissues
Diabetes Mellitus and ABI
Wound Healing and Oral-Maxillofacial Surgery
Croatia Experience with HBO (4 hours)
Nicaraguan Indigenous Diving Experiences (2 hours)
Brown Recluse Spider Bites
Carbon Monoxide Poisoning
Nitrogen Narcosis
HBO and Frostbite
Altitude DCS---Current Concepts
Women's Health in Hyperbaric/Hypobaric Arenas
Environmental Medicine---The Russian Experience
Forensic Aspects of Diving Accidents

WPB

HYPERBARIC NURSING COURSE

The Hyperbaric Nursing Course has been revised. The course is 7 weeks long, it requires the 1 week HTHCO course as pre-requisite, and four weeks OJT on the job site. The focus of the course changed from book learning and demonstrations, to hands on in the chamber. A total of eleven scheduled dives are now in the course plan; more emphasis has been placed on the specialized nursing skills needed in the hyperbaric environment. The nurses' critical care backgrounds are put to the test during the training dives with drips, ventilators and critical management.

The course continues as before, listed in the AFCAT 36-2223, as a TDY to school at BAFB, enroute to the new base. The number of nursing contact hours has not yet been determined. Questions? Call, Capt Barbara Susen COM: (210) 536-3281, DSN: 240-3281 or E-mail: barbara.susen@platinum.brooks.af.mil.

Capt Barbara Susen
Chief, Clinical Education & Equipment Development

ENLISTED HYPERBARICS

There is a Clinical Hyperbaric Training Course for Technicians (B3AZY4X0X1-005) tentatively scheduled for April 1998. This three-week course is mandatory for 4NOX1s and 4MOX1s who are stationed at or have an assignment to a clinical hyperbaric treatment facility. Let us know ASAP if you have individuals who require training. Our POC for the course is TSgt Robert Johnston; he can be contacted at DSN: 240-3281.

Clinical Hyperbaric Medicine is losing physicians, nurses and technicians from all three clinical treatment facilities within the next year due to separations, retirements and PCS. We are looking for a few folks who are interested in broadening their horizons and would like a challenging job in the exciting field of Clinical Hyperbaric Medicine. If you're up to the challenge, contact one of the POC's listed:

Brooks AFB, Texas: MSgt Dave Pridgen or SMS John Kettinger at DSN: 240-3281.

Wright-Patterson AFB, Ohio: MSgt Hector Chavez at DSN: 787-8603

Travis AFB, California: MSgt John Gorum at DSN: 799-3988

MSgt David Pridgen
Manager, Hyperbaric Medicine (DHL)

FELLOWSHIP TRAINING FOR PHYSICIANS

The USAF School of Aerospace Medicine trains two physicians annually in a Clinical Hyperbaric Medicine Fellowship at the Davis Hyperbaric Laboratory. The primary emphasis of the program is clinical (i.e., wound care and adjunctive use of hyperbaric oxygen for wound healing). However, fellows also treat decompression sickness (DCS) cases that are referred from the mid-south and are consultants for USAF operational DCS cases occurring worldwide. The USAF has been treating aviator's DCS in hyperbaric chambers since 1959.

In 1974 the Surgeon General established a hyperbaric center (later named the Davis Hyperbaric Laboratory) at Brooks AFB to direct the development of operational and clinical hyperbaric medicine throughout the Air Force. Davis Hyperbaric Laboratory is the lead agent for all DoD Clinical Hyperbaric Medicine programs.

The physician fellowship was established in 1978. It was the first Clinical Hyperbaric Medicine Fellowship in the United States, and remains the only military hyperbaric fellowship.

In the year of training, fellows learn the latest techniques in the management of chronic nonhealing wounds. In addition, they learn the nuances of the other thirteen accepted indications for hyperbaric oxygen therapy. Included in that list is the operationally relevant altitude-induced DCS. Fellows become singularly qualified in dealing with this malady. The current program achieves an exceptionally broad-based experience with multiple outside rotations (i.e., diving medicine, monoplace chamber operations, international conference attendance).

Fellows actively participate in hyperbaric medicine education by teaching classes to physicians, nurses, and technicians at the School of Aerospace Medicine. Opportunities for basic science and clinical research are available and encouraged.

Fellowship training incurs a two-year pay-back commitment. At the completion of training, fellowship trained physicians are assigned to one of the USAF's clinical hyperbaric medicine facilities located at Brooks AFB, Travis AFB, or Wright-Patterson AFB.

Physicians interested in fellowship training should contact **Lt Col Robert Bertoldo**, Director, Hyperbaric Medicine Fellowship, Davis Hyperbaric Laboratory, Brooks AFB at **DSN 240-3281**.

WPB

Fellow Profiles

Dr. Hector Ramirez earned his medical degree at the University of Autonoma Guadalajara and completed Fifth Pathway program at the U of Puerto Rico Medical School. He finished dual Internships, Transitional, at U of Thomas Jefferson, Philadelphia and Internal Medicine at Keesler USAF Medical Center, Biloxi, MS. From there he completed a Family Practice residency at Andrews AFB, MD and is a Diplomate of the American Board of Family Practice. He was commissioned November, 1984 and carries the current grade of Lt Colonel. He has been the past clinic chief of the Clinical Medicine at Randolph AFB, TX

He and his wife, Mariceli, are the parents of three sons, Armando, Gabriel, and Ivan.

We welcome this highly qualified physician to the realm of Hyperbaric Medicine. He is certain to make many contributions to the field during the upcoming years.

WPB

MEDICAL SUPPLEMENTAL TEAM MEMBERS

There have been a lot of Supplemental Dive team members, both MC and NC trained. We always need more!!! The HTHCO course has now been reduced to 4 days, being offered only four or five times a year. Class slots need to be requested from your MAJCOM by your training action officer. The AFCAT has full prerequisite information. Plan now for the future.

The function and services our supplemental divers perform for their specific clinical HBO units are so important. They enhance our staff by knowledge, energy and numbers. I know you join me in thanking them for their willingness to volunteer their time to our units.

Capt Barbara Susen
Chief, Clinical Education & Equipment Development

PARALLEL UNIVERSES

US NAVY

Clinical Hyperbaric Medicine

James Chimiak, who is the Head of the Navy Operational Medicine Institute's Hyperbaric Medicine Division, was recently selected to co-chair a joint papers session on the cross-over day of the AsMA and UHMS annual meetings. He will represent the Aerospace Medical Association. Dr. Chimiak is a Fellowship trained Hyperbaricist (Duke University), in addition to being an active Flight Surgeon.

Diving Medicine Training for Uniformed Physicians, Physician Assistants, and Physiologists

The Naval Diving and Salvage Training Center (NDSTC), Panama City, Florida offers five graduate level diving medicine courses for interested DoD physicians, PA's, and physiologists. Quotas for training slots are offered based on operational need and order of application. This training is required for Navy Undersea Medical Officers and Navy residents in Aerospace Medicine and highly encouraged for all Flight Surgeons, Army Special Operations Medical Officers, and Aviation Physiologists.

The Recognition and Treatment of Diving Casualties courses (R & T) are 10 days long. Graduates receive 63 hours of CME credit and are certified to initiate hyperbaric treatment of dysbaric illnesses, to review diving duty physical exams, and to serve as inside tenders during recompression therapy. This course provides training necessary to safely and effectively perform as a medical advisor for diving operations. Students learn each job as part of the chamber team during diving accident scenarios and do several chamber dives, the deepest being 165 FSW. Applicants must have a current diving physical exam. There are no extra physical fitness requirements.

The Diving Medical Officer courses (DMO), a pipeline course for Navy Undersea Medical Officers, are 9 weeks in length. The course consists of one week of diving physics, 2 weeks of diving medicine which is almost identical to the R & T course, 5 weeks of dive training, and a final week of advanced diving medicine topics. Unlike the R & T students, DMO students must complete the rigors of Navy diver training which include daily strenuous physical training, one stressful week of SCUBA confidence training and certification dives to 190 FSW. DMO's become *bona fide* Navy divers qualified in open-circuit SCUBA and all Navy surface supplied rigs. They get a closed-circuit SCUBA familiarization which culminates in pool dives with the Draeger LAR-V. In addition to a current diving physical, applicants must pass a diver physical readiness test and a 1000 yard timed surface swim with fins. Graduates receive 95 hours of CME credits.

NDSTC, a tenant command on the Naval Coastal Systems Station, is considered to be one of the best diver training facilities in the world. These courses provide uniformed medical providers excellent continuing medical education opportunities and current, professional instruction in diving medicine. The are **no**

course costs. Government messing and berthing are available. For more information and the 1998 course dates, contact **LT Jackson**, at DSN **436-5216/5** or COMM (904) 235-5216/5.

WPB

US ARMY

The Army has decided to close the chamber complex at Ft. Rucker, Alabama. However, this was not the end of Army Hyperbaric Medicine. LTC Daniel Fitzpatrick, one of the Army's few fellowship trained hyperbaricists, moved to Eisenhower Regional Hospital on Ft. Gordon, Georgia. There, he began a Hyperbaric Medicine program. To accomplish this task, Davis Hyperbaric Laboratory loaned their Sechrist monoplace unit to the Army. Presently, there is talk of establishing a multiplace chamber there.

The Army's Institute of Surgical Research (ISR a.k.a. Burn Unit) has shown a new interest in Hyperbaric Medicine. Colonel Cleon Goodwin, Commander, has been discussing the possible use of HBO for his patients with the staff of Davis Hyperbaric Laboratory. Needless to say, this is an exciting future.

WPB

NASA

In April of this year, NASA held a two day workshop chaired by Dr. Mike Gernhardt. The sole purpose of this workshop was to carefully examine NASA'a risk assessment and contingency plans for Decompression Sickness (DCS) during Extravehicular Activity (EVA). With the construction of the International Space Station (ISS) looming in the very near future, it is clear that there will be an increased risk of DCS. After literally months of intense work assessing all data available pertaining to EVA related DCS, a program of research and an approach to dealing with DCS was generated. Dr. Gernhardt then organized the workshop with an independent oversight committee chaired by Dr. Chris Lambertson. The committee members included individuals from academia, the commercial diving world, the US Navy, and the USAF. This committee reviewed the data presented, the risk assessment, and the contingency plans for EVA related DCS. A short report followed: in short, the committee felt Dr. Gernhardt's program to be appropriate and well thought out. Over the next 5 years the research program will mature and the contingency plans will face the ultimate test.

WPB

PERSONALS

USAF Hyperbaric Medicine is losing a number of valuable individuals:

Colonel (S) William (Doggie Bone) Butler will be leaving DHL to matriculate to the Residency in Aerospace Medicine. He will pursue a Masters Degree in Tropical Medicine and Hygiene at the Uniformed Services University for Health Sciences, Bethesda, MD. Following that, he will return to Brooks AFB for the remainder of his training. He vows to remain active in Hyperbaric Medicine.

Although it is tough for us to lose such quality people, we wish them great luck in their new endeavors and look forward to their return to Hyperbaric Medicine.

And, speaking of folks in Hyperbarics:

Lt Col (Dr) Bob Todaro, staff hyperbaricist at Travis, will command the Aerospace Medicine flight at Travis, beginning late summer. Congrats, Bob.

Lt Col Charles, physiologist and deputy commander at Travis HBO, left for a staff job at the Pentagon Annex in late January.

Major Skarbans left Travis HBO to be a flight commander at the clinic in Grand Forks. Congrats!

Captain Charlene Sylvestre has successfully completed the Hyperbaric Nursing Course in March/April. Her presentation, "HBO and the Hot MI", was a *tour de force*. She will take Major Skarban's position at Travis AFB.

Captain Cheryl Athearn arrived at W-P to join the hyperbaric team from Andrews AFB, MD as a PTO.

Captain Perry Carlson completed hyperbaric training at DHL and is now heading up HBO nursing at W-P.

Captain Dale Gray moved from Yakota to do HBO Nursing course at DHL where he wowed us with his expertise in nutrition and HBO, then off to join HBO at W-P.

SSgt Oliver Kahlor left Travis physio and was selected for OTS and will join the AWACS as 2Lt Kahlor.

SSgt Anna Parker left Travis physio and is joining the unit at Langley.

A1C Scott McKinney moved from the altitude chamber at W-P to work Chamber Maintenance/Supply and **SSgt Jeff Walton** swapped places with him moving from HBO to the Altitude Chamber, W-P.

SMSgt David Pridgen recently was promoted. This was a richly deserved reward for a hard-working operations technician and unit supervisor. Rumor has it that this promotion will necessitate a transfer (perhaps Kadena AB).

MSgt Virginia Yeaton recently was promoted. This was a richly deserved reward for a hard-working medical technician. It is rumored that she is actively pursuing an assignment in her heart's home, Alaska.

TSgt Robert Johnston recently came to DHL from Kelly AFB. His background includes IDT training. He is a welcome addition to DHL.

SSgt Terry Lucas comes to DHL after an illustrious tour with the School of Aerospace Medicine. His teaching prowess is greatly appreciated.

SSgt Richhh Madrid come to DHL after a remarkable tour with Wilford Hall Medical Center. His work with the Transplant Team was stellar. He is certainly a welcome contributor to DHL.

USAF Hyperbaric Medicine is also suffering through the upheavals of retirement.

TSgt Geno Sekinger, who is an operations physiology technician at Davis Hyperbaric Laboratory, is planning to retire by summer's end. He's been a long-timer here and a steady helmsman of hyperbarics; he'll be greatly missed.

TSgt Rich Welch, who is an operations physiology technician at Davis Hyperbaric Laboratory, is retiring this summer. His tenure at DHL has been an asset; his absence we'll miss very much.

Congratulations to these friends on their retirements. We wish them the best in their civilian pursuits. We look forward to future visits at any variety of conferences.

WPB

EDITOR'S NOTES

This newsletter is a bunch of work; however, it is a load of fun! I am sincerely grateful to all who contributed to its final face.

Comments and suggestions are welcome! Articles, case reports, informational letters, etc. are welcome!

Please send it all to:

USAF Hyperbaric Newsletter
DET 1, HSC/AOH
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Brooks AFB, Texas 78235-5119

Lt Col William P. Butler, Editor

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