2020

Safety Manual/Monthly Safety Awareness Program

SerenaGroup
building the nation's leading wound care team.

SerenaGroup Hyperbaric Medical Center
2020

Fire Safety Plan

1. Purpose

To provide hyperbaric personnel a predetermined plan in the event of a fire in the hyperbaric area in order to reduce injury and/or catastrophic outcomes.

2. Policy

2.1. In the event of an emergency, the Hyperbaric Medicine Center personnel will be prepared to respond.

2.2. The Safety Director shall be designated by the Program Director / Manager or designee.

NOTE: NFPA 99 Health Care Facilities, 1999 edition, (page 131)

"19-3.1.3.2 A safety director shall be designated in charge of all hyperbaric equipment. The safety director shall work closely with facility management personnel and the hyperbaric physician(s) to establish procedures for safe operation and maintenance of the hyperbaric facility. He or she shall make necessary recommendations for departmental safety policies and procedures. The safety director shall have the authority to restrict or remove any potentially hazardous supply or equipment items from the chamber."

2.3. Each plan shall be collaboratively developed with the hospital fire safety policy in conjunction with NFPA standards.

2.4. There will be no smoking or open flames in the hyperbaric area.

2.5. The area will be kept exceptionally clean and free of fire hazards according to the NGPA for Hyperbaric health care facilities.

2.6. The chamber itself will be kept exceptionally clean of lint and dust particles as these are hazardous when inside the chamber.

2.7. Each hyperbaric patient will be searched and questioned about possession of an ignition source before entering the chamber.

2.8. All items listed in the chamber safety policy will not be allowed in the chamber.

3. Scope

Applies to all Hyperbaric Medicine Center staff and patients.

4. Responsibility

It is the responsibility of the Safety Director for the center to implement and ensure that fire safety practices are followed within the department.

5. Procedure

5.1 The Program Director/Manager shall obtain the hospital fire safety plan.

5.2 A comprehensive plan will be developed and incorporated into the overall emergency plan for the center. It shall include the following at a minimum:

5.4.1 Signage locations

5.4.2 Extinguishing (sprinklers, smoke detectors, fire extinguishers, etc.) methods, equipment and location.

5.4.3 R.A.C.E. protocol or similar standard guideline for response in the event.

5.4.4 Emergency phone numbers-who to contact, when and where.

5.4.5 Oxygen leak testing-frequency and procedure.

5.4.6 Electrical equipment-location, preventive maintenance schedule

5.4.7 HBO requirements for fire prevention

5.4.8 Mock drill-frequency

5.4.9 General response to fire-code announcement, door and window handling

5.3All Oxygen-8 Hyperbaric Medicine Centers personnel will be knowledgeable of the fire safety plan and be prepared to proactively prevent fire and in the case of a fire, extinguish it immediately.

5.4 Assure appropriate signage (readable from a distance of 5 feet) in the center prohibiting smoking.

5.4.1 Ensure patients, staff and visitors do not smoke or have any open flames within the center.

5.5 Ensure the patient has changed into 100% cotton clothing prior to the therapy. **CLOTHING DISALLOWED IN THE CHAMBER INCLUDE THE FOLLOWING:**

5.5.1 Underwear (bra, panties, briefs)
5.5.2 Street clothes (even if tag states 100% cotton)

NOTE: These items are potential sources of ignition as well as a place for concealment of lighters or matches.

5.6 Ensure all linens are 100% cotton. This includes pillow cases, blankets, and sheets.

5.7 Search all patients prior to initiation of every treatment to secure that no lighters or matches, jewelry etc. are being placed in the oxygen enriched environment. (Wedding bands may be taped if patient refuses to remove).

5.8 Cleanse or allow the patient to cleanse off the following petroleum based products:

- Make-up
- Hair spray
- Nail polish
- Perfume
- After shave lotion
- Oil-based creams/ointments (petroleum jelly), or cover wound or skin area with 100% cotton linen.

5.9 Allow only the items necessary for patient care during therapy such as:

- NG tubes (vented)
- External fixation devices covered with cotton towels

- Wound Dressings
- Soft contacts
- Foley catheters, auto vented
- Other drains or catheters, vented
- Monitoring leads and cables compatible with the chamber such as pass through lines for EKG or TCOM monitoring
- Intrinsically safe transducers

NOTE: Cover all dressings with 100% cotton linens.

NOTE: If patient has a post-op skin graft and physician does not want the dressing removed, cover existing dressing with 100% damp cotton towel. NEVER expose a wound covered with an ointment in the chamber.

5.10 Disallow the following items in the chamber:

- External pacemakers
- Holter monitors
- External TENS or similar product
- External insulin pump

5.11 Turn off the main oxygen supply to the chambers at the end of each day to ensure no
leakage of oxygen into the room.

5.12 Analyze the oxygen concentration in the room around the gaskets of the chamber and various sites in the room to ensure no leakage of oxygen is occurring, according to policy.

5.13 Sign off on the pretreatment checklist before every HBO therapy.

5.14 **FIRE OUTSIDE OF CHAMBER AREA BUT INSIDE THE BUIDLING**

5.14.1 Follow hospital fire plan

5.15 **FIRE IN THE HYPERBARIC UNIT BUT OUSIDE OF THE CHAMBER**

5.15.1 Pull fire alarm and activate hospital fire plan informing of location of the fire

5.15.2 Notify patients of need for rapid decompression.

5.15.3 "Emergency vent" the chambers and remove patients from chambers.

5.15.4 Turn off oxygen.

5.15.5 Assist in the evacuation of the area per hosptial evacuation plan

5.16 **FIRE INSIDE OF THE HYPERBARIC CHAMBER**

5.16.1 Notify other staff members to pull fire alarm and activate hospital fire plan informing of location of the fire

5.16.2 "Emergency vent" the chambers and remove patients from chambers.

5.16.3 Have patient breathe from the air break mask during emergency ventilation.

5.16.4 Turn off oxygen.

5.16.5 Prepare to extinguish fire.

5.16.6 Assist in the evacuation of the area per hosptial evacuation plan

Emergency Preparedness

1. Purpose

To establish an Emergency Preparedness plan specific for the hyperbaric center.

2. Policy

2.1. To provide optimal patient care and support in the event of an emergency such as fire, flood, hurricane, ice storm, earthquake, tornado, etc.

2.2. All patients will be oriented in alternative care options

2.3. All staff will be oriented and updated to the emergency preparedness plan with safety as a primary focus

2.4. The Hyperbaric Medicine Center Emergency Preparedness plan compliments the hospital's plan; it does not supersede the hospital emergency preparedness plan.

3. Scope and Responsibility

Applies to all members of the Hyperbaric Medicine Center.

4. Procedure

4.1. Should it become necessary to remove patients from the chambers, the following actions should be taken:

4.1.1. Explain to the patients why they are being decompressed.

4.1.2. Decompress chambers at a normal rate. **DO NOT EMERGENCY VENT THE CHAMBERS**.

4.1.3. Provide alternative care information to the patient on admission that instructs the patient on the plan for care in the event of a natural disaster.

4.1.4. Once chambers are empty and all of the patients have exited the center, secure the chambers in the following manner:

4.1.4.1. Close the doors on the chambers
4.1.4.2. Switch off both the Oxygen and Air supply to the chambers at the wall source.
4.1.4.3. Disconnect the transformer from the electrical outlet at the wall. The will interrupt the supply power to the battery charger.
4.1.4.4. Cover the chambers with the cloth chamber cover.

2020 Safety Program Schedule

Call in Number: See monthly email

Patient adherence

Overview: When patients experience chronic or acute episodes such as a limb threatening wound, many treatment options require patients to immediately make lifestyle changes in order to address the root cause of their illness. For a diabetic patient, managing sugar levels along with 30 HBOT treatments can significantly impact their quality of life, while a radiation protasis patient may need to commit to 60 to 70 treatments to fully heal, again impacting their quality of life.

Getting patients to adhere to a lifestyle change or a recurring treatment can be quite challenging for many centers. Part of the challenge comes from how these changes are communicated and the value patients may see by complying with their treatment protocols.

Achieving patient buy-in can be easier when there is a focus on education, training, and staff development at your facility. If there is no in-depth conversation about why or how a negative consequence occurs, a patient is more likely to give up or not stick with their regiment this directly correlates to understanding what matters to the patient and not just what is the matter with them.

Ultimately, patient compliance can be easier to achieve when you focus on patient buy-in and make it part of the culture at your wound center. When approaching this concept with your own team, ask yourself why patients should care about making proactive and purposeful changes, and ask yourself how you can make patient education as easy as possible.

Procedure: Ten strategies you can utilize to improve patient adherence:

1. Keep up to date on various wellness programs available to your patients
2. Have frequent follow up conversations with patients to monitor progress and provide educational opportunities
3. Make sure they are appropriately educated during and after their treatment
4. Take advantage of educational opportunities for yourself, patients feel safer and are more likely to internalize recommendations when there is an expert at the wheel.
5. Have an open and honest discussion with your patient to make sure that they truly understand the importance of limb salvage and the roll daily HBOT treatments plays in faster closure of their wound.
6. Say please and thank you, none of us like to feel as if we are being ordered around by those who are providing a service to use, manners matter.
7. I have long believed that laughter is the best medicine. Keep it lite, this does not mean act the fool or being inappropriate but rather be social. Keep in mind that your patients are investing an enormous amount of time and money to receive their treatment. Engage them in everyday social subjects such as TV, movies or books. Find that common interest and exploit it. Make it as an enjoyable as possible. Encourage them along the way, share your success stories of other patients you've had that have the same condition they have. Show them that you care about them and this is why you do what you do.
8. As you know in most cases this is a centennial event in your patient's life. Use your time to educate them as to the importance of their treatment. I am not proposing to that you be preachy, scolding or graphic, in fact I believe that to be counterproductive but rather at the appropriate time help them to see the seriousness of their ulcer and the positive results of receiving their daily treatment and adherence the plan of care that their doctor has designed

for them. Provide them with the information they need to make a fully informed decision to not show.

9. Follow up on missed appointments. A phone call on the same day may bring them back sooner, try and be creative in ways to help them make it, sometimes it just a matter of swapping time with another patient. It also shows that they are important to you as well as the importance that they come each day and that you are concerned with their wellbeing.
10. When scheduling their time slot take into account their needs. Do they have other previous appointments? Do they work? Do they babysit grandkids that they need to see off to school or be home when they get home? Do they use transportation that has limited time availability? This can be a difficult task but becoming an expert scheduler goes with the territory.

Reference:

https://www.uspharmacist.com/article/patient-compliance-and-health-behavior-models
The challenge of patient adherence
Leslie R Martin,1 Summer L Williams,2 Kelly B Haskard,2 and M Robin DiMatteo2
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2503662

Date:_____

Name:_____

Post-Test
Patient Adherence

1. Your daily treatment schedule should be ridge and .and it is the patients reasonably to “make it work”

   (circle) True False

2. Have an _____ and _____ discussion with your patient to make sure that they truly _____ importance of limb salvage and the roll daily HBOT treatments plays in faster closure of their wound.

3. Achieving patient buy-in can be easier when there is a focus on _____, _____, and _____ _____ at your facility..

4. It is a good practice to keep up to date on various wellness programs available to your patients?

   (circle) True False

5. Name two local rescores that your patients may benefit from.

   _____
   _____

6. It is best if only one person in your center provides patient education?

   (circle) True False

Patient education and why it is important

Overview:

Patients and health consumers nowadays fall into two extremes. There's the information junkie, armed with a bunch of articles and studies found online, not to mention the well-meaning advice they get from friends and relatives about their medical condition. But who's to say if the self-diagnosis they did online was correct? Was the source of their information even reliable?

Then there's the little informed, possibly, devil-may-care patient with zero information —and possibly zero interest — about his/her health and medical records. Until something happens.

Despite the difference between patients, it's clear that patient education should be viewed as an important part of providing quality health care.

After all, there's more to patient education than understanding the prescription, or cause of an illness.

Educating patients can help them manage diseases, or prevent them from occurring in the first place. For instance, by informing a rather unhealthy family about the drastic repercussions of processed and sugary foods, you can help save them from obesity.

Inform them how difficult it is to live obese, and the host of medical problems they'll have to deal with once there. Many patients report that they would've tried harder to maintain a healthy weight, if they were fully aware its unwanted effects.

Researchers from Ohio found that one to two physical therapy sessions before a total hip or knee replacement reduced the need for postoperative care by 29% after reviewing 4,733 Medicare cases.

Of course, people assumed that the cause for improvement is the physical therapy sessions. But two sessions are not enough to trigger that much improvement. The reason for the

development was that the physical therapy sessions helped surgery patients understand the procedure and recovery process before going under the knife.

The therapy sessions helped them feel in control of the situation, instead of feeling scared and vulnerable.

What happens if a patient doesn't follow their prescription? For the common cold, they're just not going to get better anytime soon. But what if a patient has a chronic condition that requires rigid maintenance, such as hypertension or diabetes?

Patients with illnesses requiring multiple medications, lifestyle modifications, and constant monitoring (i.e. blood pressure, glucose level), need more help on the education front.

In most cases, it's not enough to explain all this verbally. The healthcare provider will need to provide educational aids, such as pamphlets and online resources, to ensure compliance and help them accept the diagnosis.

A Gallup study showed the relation between patient preparedness before a surgery and patient satisfaction with the results. When a patient 'strongly agreed' about knowing what to expect after surgery, 72% are more likely to be satisfied with the surgery results.

The study also shows that reports of problems or complications following an operation dropped to 8% if the patient knew what to expect

Procedure:

Document all teaching.

The following is some information you should share with your patients, remembering that is our opportunity to help them prevent a reoccurrence of their ulcer.

HBOT Frequently Asked Questions

What is Hyperbaric Oxygen Therapy?

Hyperbaric oxygen therapy (HBOT) is a medical treatment which enhances the body's natural healing process by inhalation of 100% oxygen in a total body chamber, where atmospheric pressure is increased and controlled. It is used for a wide variety of treatments usually as a part of an overall medical care plan.

How long are the treatments?

You will be placed in one of our chambers for a period of 120 minutes each day. This does not include the time you need to arrive at the facility, change into appropriate clothing and upon completion of your treatment change back into your clothing. A typical Hyperbaric treatment will take two and a half hours from arrival to departure.

How many treatments are required?

The number of treatments and duration of each treatment will be determined by the physician. This is based on your diagnosis and your response to treatment. Typical patients require 30-40 visits daily Monday through Friday with the exception of holidays and weekends.

Is Hyperbaric Oxygen Therapy safe?

Yes. Hyperbaric Oxygen Therapy is prescribed by a physician and you are always under medical supervision while in our chamber. You are monitored by a specially trained Hyperbaric Technologist who is in the treatment room at all times and a specially trained hyperbaric physician is always available.

Are there any side effects?

The most common side effect is barotrauma to the ears and sinuses caused by the change in pressure. To minimize this risk patients learn techniques to promote adequate clearing of the ears during compression or in cases when patients have problems with pressure equalization, tubes may be inserted into the ears. In most cases patient may experience ‘popping and or cracking ‘ at night after there first 2-3 treatments, this will subside and is nothing to be concerned with. Occasionally some patients may experience changes in their vision during their treatment period. These

changes are usually minor and temporary. A rare side effect is oxygen toxicity which is caused by administration of too much oxygen.

How should patients prepare for their hyperbaric treatments? Patients should arrive for their treatments 15 minutes prior to their scheduled treatment time. Only clean cotton clothing provided by the center is allowed into the hyperbaric chamber. No cosmetics, perfumes, hair products, deodorants, wigs, under clothing, eyeglass's or jewelry are allowed into the chamber. Patients are also advised not to drink carbonated beverages or alcohol for four hours prior to their treatment. Additionally, patients should give up smoking and nicotine products while receiving hyperbaric treatments as they interfere with the body's ability to transport oxygen. Patents with diabetes get hypoglycemia (low blood sugar) when their bodies don't have enough sugar to use as energy. Each person may have different symptoms. Please help to recognize yours as your blood glucose can drop by an unpredictable amount during your treatment. We will check your glucose level before and after each treatment. We will not treat you if it is below 120, however a high level will delay wound healing, so we will work with you to help control you blood glucose levels.

Diabetes and Diet

A diabetes diet simply means eating the healthiest foods in moderate amounts and sticking to regular mealtimes.

A diabetes diet is a healthy-eating plan that's naturally rich in nutrients and low in fat and calories. Key elements are fruits, vegetables and whole grains. In fact, a diabetes diet is the best eating plan for most everyone.

Purpose

If you have diabetes, your doctor will likely recommend that you see a dietitian to help you develop a healthy eating plan. The plan helps you control your blood sugar (glucose), manage your weight and control risk factors for heart disease, such as high blood pressure and high blood fats.

When you eat excess calories and fat, your body responds by creating an undesirable rise in blood glucose. If blood glucose isn't kept in check, it can lead to serious problems, such as a dangerously high blood glucose level (hyperglycemia) and long-term complications, such as nerve, kidney and heart damage.

You can help keep your blood glucose level in a safe range by making healthy food choices and tracking your eating habits.

For most people with type 2 diabetes, weight loss also can make it easier to control blood glucose and offers a host of other health benefits. If you need to lose weight, a diabetes diet provides a well-organized, nutritious way to reach your goal safely.

Diet details

A diabetes diet is based on eating three meals a day at regular times. This helps your body better use the insulin it produces or gets through a medication.

A registered dietitian can help you put together a diet based on your health goals, tastes and lifestyle. He or she can also talk with you about how to improve your eating habits, for example, by choosing portion sizes that suit the needs for your size and level of activity.

Recommended foods

Make your calories count with these nutritious foods:

- **Healthy carbohydrates.** During digestion, sugars (simple carbohydrates) and starches (complex carbohydrates) break down into blood glucose. Focus on the healthiest carbohydrates, such as fruits, vegetables, whole grains, legumes (beans, peas and lentils) and low-fat dairy products.
- **Fiber-rich foods.** Dietary fiber includes all parts of plant foods that your body can't digest or absorb. Fiber moderates how your body digests and helps control blood sugar levels. Foods high in fiber include vegetables, fruits, nuts, legumes (beans, peas and lentils), whole-wheat flour and wheat bran.
- **Heart-healthy fish. Eat heart-healthy fish at least twice a week.** Fish can be a good alternative to high-fat meats. For example, cod, tuna and halibut have less total fat, saturated fat

and cholesterol than do meat and poultry. Fish such as salmon, mackerel, tuna, sardines and bluefish are rich in omega-3 fatty acids, which promote heart health by lowering blood fats called triglycerides.

Avoid fried fish and fish with high levels of mercury, such as tilefish, swordfish and king mackerel.

- **"Good" fats.** Foods containing monounsaturated and polyunsaturated fats can help lower your cholesterol levels. These include avocados, almonds, pecans, walnuts, olives, and canola, olive and peanut oils. But don't overdo it, as all fats are high in calories.

Foods to avoid

Diabetes increases your risk of heart disease and stroke by accelerating the development of clogged and hardened arteries. Foods containing the following can work against your goal of a heart-healthy diet.

- **Saturated fats.** High-fat dairy products and animal proteins such as beef, hot dogs, sausage and bacon contain saturated fats.
- **Trans fats.** These types of fats are found in processed snacks, baked goods, shortening and stick margarines. Avoid these items.
- **Cholesterol.** Sources of cholesterol include high-fat dairy products and high-fat animal proteins, egg yolks, liver, and other organ meats. Aim for no more than 200 milligrams (mg) of cholesterol a day.
- **Sodium.** Aim for less than 2,300 mg of sodium a day. However, if you also have hypertension, you should aim for less than 1,500 mg of sodium a day.

Putting it all together: Creating a plan

A few different approaches to creating a diabetes diet are available to help you keep your blood glucose level within a normal range. With a dietitian's help, you may find one or a combination of the following methods works for you:

- **The plate method.** The American Diabetes Association offers a simple seven-step method of meal planning. In essence, it focuses on eating more vegetables. When preparing your plate, fill one-half of it with nonstarchy vegetables, such as spinach, carrots and tomatoes. Fill one-quarter with a protein, such as tuna or lean pork. Fill the last quarter with a whole-grain item or starchy food. Add a serving of fruit or dairy and a drink of water or unsweetened tea or coffee.
- **Counting carbohydrates.** Because carbohydrates break down into glucose, they have the greatest impact on your blood glucose level. To help control your blood sugar, eat about the same amount of carbohydrates each day, at regular intervals, especially if you take diabetes medications or insulin.

  A dietitian can teach you how to measure food portions and become an educated reader of food labels, paying special attention to serving size and carbohydrate content. If you're taking insulin, he or she can teach you how to count the amount of carbohydrates in each meal or snack and adjust your insulin dose accordingly.

- **The exchange lists system.** A dietitian may recommend using food exchange lists to help you plan meals and snacks. The lists are organized by categories, such as carbohydrates, protein sources and fats.

  One serving in a category is called a "choice." A food choice has about the same amount of carbohydrates, protein, fat and calories — and the same effect on your blood glucose — as a serving of every other food in that same category. So, for example, you could choose to eat half of a large ear of corn or 1/3 cup of cooked pasta for one starch choice.

- **Glycemic index.** Some people who have diabetes use the glycemic index to select foods, especially carbohydrates. This method ranks carbohydrate-containing foods based on their effect on blood glucose levels. Talk with your dietitian about whether this method might work for you.

A sample menu

When planning meals, take into account your size and activity level. The following menu is tailored for someone who needs 1,200 to 1,600 calories a day.

- **Breakfast.** Whole-wheat bread (1 medium slice) with 2 teaspoons jelly, 1/2 cup shredded wheat cereal with a cup of 1 percent low-fat milk, a piece of fruit, coffee
- **Lunch.** Cheese and veggie pita, medium apple with 2 tablespoons almond butter, water
- **Dinner.** Salmon, 1 1/2 teaspoons vegetable oil, small baked potato, 1/2 cup carrots, side salad (1 1/2 cups spinach, 1/2 of a tomato, 1/4 cup chopped bell pepper, 2 teaspoons olive oil, 1 1/2 teaspoons red wine vinegar), unsweetened iced tea
- **Snack.** 2 1/2 cups popcorn or an orange with 1/2 cup 1 percent low-fat cottage cheese

Results

Embracing your healthy-eating plan is the best way to keep your blood glucose level under control and prevent diabetes complications. And if you need to lose weight, you can tailor it to your specific goals.

Aside from managing your diabetes, a diabetes diet offers other benefits, too. Because a diabetes diet recommends generous amounts of fruits, vegetables and fiber, following it is likely to reduce your risk of cardiovascular diseases and certain types of cancer. And consuming low-fat dairy products can reduce your risk of low bone mass in the future.

Risks

If you have diabetes, it's important that you partner with your doctor and dietitian to create an eating plan that works for you. Use healthy foods, portion control and scheduling to manage your blood glucose level. If you stray from your prescribed diet, you run the risk of fluctuating blood sugar levels and more-serious complications.

What is a Diabetic Foot Ulcer?

A diabetic foot ulcer is an open sore or wound that occurs in approximately 15 percent of patients with diabetes and is commonly located on the bottom of the foot. Of those who develop a foot ulcer, 6 percent will be hospitalized due to infection or other ulcer-related complication.

Diabetes is the leading cause of non-traumatic lower extremity amputations in the United States, and approximately 14-24 percent of patients with diabetes who develop a foot ulcer will require an amputation. Foot ulceration precedes 85 percent of diabetes-related amputations. Research has shown, however, that development of a foot ulcer is preventable.

Causes

Anyone who has diabetes can develop a foot ulcer. Native Americans, African Americans, Hispanics, and older men are more likely to develop ulcers. People who use insulin are at higher risk of developing a foot ulcer, as are patients with diabetes-related kidney, eye, and heart disease. Being overweight and using alcohol and tobacco also play a role in the development of foot ulcers.

Ulcers form due to a combination of factors, such as lack of feeling in the foot, poor circulation, foot deformities, irritation (such as friction or pressure), and trauma, as well as duration of diabetes. Patients who have diabetes for many years can develop neuropathy, a reduced or complete lack of ability to feel pain in the feet due to nerve damage caused by elevated blood glucose levels over time. The nerve damage often can occur without pain, and one may not even be aware of the problem. Your podiatrist can test feet for neuropathy with a simple, painless tool called a monofilament.

Vascular disease can complicate a foot ulcer, reducing the body's ability to heal and increasing the risk for an infection. Elevations in blood glucose can reduce the body's ability to fight off a potential infection and also slow healing.

Prevention

The best way to treat a diabetic foot ulcer is to prevent its development in the first place. Recommended guidelines include seeing a podiatrist on a regular basis. Your podiatrist can determine if you are at high risk for developing a foot ulcer and implement strategies for prevention.

You are at high risk if you have or do the following:

- Neuropathy
- Poor circulation
- A foot deformity (e.g., bunion, hammer toe)
- Wear inappropriate shoes
- Uncontrolled blood sugar
- History of a previous foot ulceration

Reducing additional risk factors, such as smoking, drinking alcohol, high cholesterol, and elevated blood glucose, are important in prevention and treatment of a diabetic foot ulcer.

Wearing the appropriate shoes and socks will go a long way in reducing risks. Your podiatrist can provide guidance in selecting the proper shoes.

Learning how to check your feet is crucial so that you can find a potential problem as early as possible. Inspect your feet every day—especially the sole and between the toes—for cuts, bruises, cracks, blisters, redness, ulcers, and any sign of abnormality. Each time you visit a health-care provider, remove your shoes and socks so your feet can be examined. Any problems that are discovered should be reported to your podiatrist as soon as possible; no matter how simple they may seem to you.

The key to successful wound healing is regular medical care to ensure the following “gold standard” of care:

- Lowering blood sugar
- Appropriate debridement of wounds
- Treating any infection
- Reducing friction and pressure
- Restoring adequate blood flow

Reference:

Clinical Procedures in Emergency Medicine, 3rd Edition, Ed Roberts & Hedges, W.B. Saunders. Hyperbaric Medicine Practices, 2nd Edition 1995, Eric P. Kindwall, M.D. ,
UCAOA Corporate Support Partners *(CSP) program. Thank you to* Patient Direct*, a Diamond CSP.,*
https://www.mayoclinic.org/diseases-conditions/diabetes/in-depth/diabetes-diet/art-20044295?pg=1*,*
http://www.apma.org/Learn/FootHealth.cfm?ItemNumber=981.

Date: _____

Name:_____

Post Test
Patient education and why it is important

1. Educating patients can help them _____ diseases, or _____ them from occurring in the first place

2. A Gallup study showed that patient preparedness before a surgery resulted higher patient satisfaction scores. (circle) True False

3. Diabetes increases your risk of heart disease and stroke by accelerating the development of clogged and hardened arteries. (circle) True False

4. Your Patient asks you to suggest a healthy meal for her your best reply is:
    a. Hot Dogs, French fries and a soda?
    b. Fried chicken, rice and beans?
    c. Salmon, 1 1/2 teaspoons vegetable oil, small baked potato, 1/2 cup carrots, side salad?
    d. Fast food such as a Big Mac and fries?

5. Patients with Neuropathy:
    a. Have difficulty performing task as they are mentally challenged?
    b. Have a lost of sensation in the lower extremities, often resulting in their ulcer?
    c. No blood flow to there feet?

6. Bonus: Foot ulceration precedes ____ percent of diabetes-related amputations.

Physician supervision and meaningful contact.

Overview: Supervision of HBOT (From LCD for HBO Novitas Solutions, Inc,)

Appropriate supervision is a requirement for Medicare coverage. The Office of the Inspector General (OIG) links the quality of care to the physical presence of the physician (Qualified Hyperbaric Health Care Professional) during the entire treatment for the purpose of managing the patient's overall care, as identified in the October 2000 report, 'Hyperbaric Oxygen Therapy, Its Use and Appropriateness.' The capacity of a hyperbaric facility to care for a patient is determined by the training and experience of the supervising physician the professional staff and the nurses and hyperbaric technicians in addition to the equipment available (e.g., ventilator support for critical patients, resuscitation and intervention capacity and intensive care beds available on the facility). Thus, requirements for physician credentialing at any practice setting should be developed in conjunction with the policies and capabilities of the facility in consideration of the acuity level of patients to be treated, the diagnoses managed and the type of chamber being utilized. Hyperbaric credentialing requirements should be commensurate with the level of care and scope of practice of the individual clinical settings. For the purpose of this LCD, "Immediately available" shall mean present in the HBO chamber area and available to assist in five minutes or less.

Direct Physician Supervision

HBO therapy rendered within a hospital outpatient department is considered furnished **"incident to"** a physician's services and requires physician supervision. For payment purposes, **"direct supervision"** per 42 CFR 410.27(f), in a hospital lout patient setting, means the physician must be present and on the premise of the location

and immediately available to furnish assistance and direction throughout the performance of the procedure. It does not mean that the physician must be present in the room when the procedure is performed. ((42 CFR 410.27(f)(emphasis added)) The physician supervision requirement is presumed to be met when services are performed on the hospital premises (i.e., certified as part of the hospital and part of the hospital campus). Immediately available shall mean at a maximum of five minutes from the chamber. However, for patient safety purposes (thus reasonable and necessary) in all instances, the physician must be personally present during the ascent and descent portions of each treatment and a trained emergency response team must be available throughout the treatment for emergent clinical care and process to transfer the patient within the facility or to another facility for required critical care services as necessary. In a physician office setting or off-campus provider-based setting, direct Physician Supervision is achieved only when a physician is present in the office/suite and immediately available during the entire hyperbaric treatment session. The physician's personal presence is required during the ascent and descent portions of the hyperbaric treatment. Direct supervision means the physician must be present in the office suite and immediately available to furnish assistance and direction throughout the performance of the procedure. ((42 CFR 410.26(a)(2) and 410.32(b)(3)(11))

Incident To" Service

Hyperbaric Oxygen (HBO) Therapy performed in a hospital outpatient department is an "incident to" service and requires physician supervision Requirement presumed to be met when services are performed on the hospital premises In all locations, it is recommended that a physician be present during ascent and descent portions of the HBO treatment. Meaning is a ambiguous term is in the CMS manual for all incident to procedures with no definition provided.

Meaningful Contact

The SerenaGroup™ interpretation of “meaningful contact” as required by CMS and other payers:

Pretreatment (before tx. #1):

- Assessment of suitability for HBO therapy
- Determination of risk-benefit profile
- Interpretation of related diagnostic testing
- Generation of a therapeutic dosing profile
- Point of Service documentation

Procedure:

Pretreatment (min. each tx.)

- Auscultate heart
- Assess Lungs
- Exam tympanic membranes
- Assess blood glucose level
- Document finding.

Post treatment:

- Evaluation of subsequent clinical course
- Determination of patient discharge status
- Management of any related side effects and complications
- Point of Service documentation

References: LCD for HBO Novitas Solutions, Inc, CMS Manual, Serenagroup 2020 Policy and Procedure manual

Date:_____

Name:_____

Post-Test
Physician Supervision and Meaning contact

1. There is no official definition for the term Meaning Contact.
   (circle) True False

2. In all settings the physician is required to be in the room for **ascent and descent portions of the HBO treatment?**
   (circle) True False

3. The physician called and said that he was leaving home and you can proceed with the treatment, Can you?
   (circle) True False

4. When on the hospital premises (i.e., certified as part of the hospital and part of the hospital campus). Immediately available shall mean at a maximum of __ minutes from the chamber.

5. If you are in a off-campus provider-based setting, direct Physician Supervision is achieved only when a physician is present in the office/suite for ascent and descent.
   (circle) True False

6. List two things that are recommended the physician should do before and/or after each treatment.
   _____ and
   _____.

Bonus question;
In your own words define “Incident to”.

_____
_____
_____

Discussing Smoking and wound healing

Introduction:

As each of you know, each day that we have a patient in our chamber room we have a unique opportunity to provide important information concerning their wound. It is our duty to provide with accurate and timely information that may not be obvious to all. One area that may fall into this category would be the link between wound healing and smoking. The following material can provide you with talking points to share with you smoking patients.

(From **Advanced Tissue** Website)

Smoking is often admonished by healthcare professionals for its ability to cause serious diseases, but puffing on a cigarette does more than just increase your risk for developing cancer and emphysema – it can also decelerate your body's natural **wound healing** process. According to the American Orthopedic Foot & Ankle Society, smokers face a steeper uphill battle than their non-smoking counterparts when it comes to recovering from injuries or surgeries, a process that can already be arduous depending on the severity of the wound. Read on to discover three key ways a smoking habit can get in the way of a successful medical recovery.

1. Smoking prevents wounds from receiving enough oxygen

Few elements are as crucial to the healing process as oxygen. After being inhaled, oxygen travels through the blood stream to the wound, where it becomes essential in the biological battle to fight infection, regenerate tissue and return to health.

Smoking, however, holds the body back from being able to win this battle. The chemicals found in cigarettes – and cigarette smoke – can cause respiratory and cardiovascular problems, both of which can reduce the amount of oxygen that tissue is able to receive, explained

the National Health Service. Cigarettes also cause users to inhale carbon monoxide, which connects to red blood cells and prevents adequate amounts of oxygen from passing through the bloodstream.

2. Smoking raises blood sugar levels

Heightened blood sugar levels have numerous medical consequences, one of which is a deceleration of the wound healing process. According to Wound Care Centers, high blood sugar, which can be caused by smoking, creates arterial stiffness and narrows the blood vessels.

An elevated blood sugar level can also make red bloods cells cluster together. Cell clumps are often unable to pass through capillaries, which can result in a lack of sufficient blood flow to **healing wounds**.

3. Smoking can cause patients to experience increased pain

Wound healing can be achy for anyone, but normal pain levels can be greatly exacerbated in patients with smoking habits. The American Orthopedic Foot & Ankle Society noted that cigarette-related chemicals have been shown to negatively impact the way bodies understand “pain signals.” Smoking can also aggravate inflammation, which can boost pain and add to the difficulties of the healing process.

Effects of smoking on cost and duration of hyperbaric oxygen therapy for diabetic patients with non-healing wounds.

Abstract

During this study to determine the effects of smoking on diabetic patients undergoing hyperbaric oxygen therapy (HBO2T) for nonhealing wounds, one physician visited five hyperbaric facilities and reviewed records on 1,006 patients who had received HBO2T for diabetic wounds. Smoking history was documented on 469 patients, while 180 patients had complete information on number of HBO2Ts, outcome, age, duration of diabetes, transcutaneous oxygen baseline in air at ambient conditions, Wagner score of the worst wound, smoking history, and intensity of treatment. These factors were statistically significant predictors of treatment

outcome using multiple regression modeling. No difference was found between smokers with less than 10 pack years of cumulative history and nonsmokers. After that point there was a significant increase in the number of HBO2Ts needed to produce at least some healing in smokers vs. patients who had never smoked. The average patient with a greater than 10 pack-year smoking history* who benefited from treatment was estimated to need between 8 and 14 more HBO2Ts. This translates into an added treatment cost of $4,000 to $7,000 for the average patient who has smoked, and an estimated $22-37 million annually for the United States.

Procedure:

Discuss the effects of smoking and wound healing with your patients. Document your discussions in the teaching record portion of his/her chart.

This discussion should not be judgmental, but rather educational and factual, avoid such things as remarking on smell, remember you may be giving them information no one has given them before. Your goal should to help support them toward quitting. The attach study preformed by *Otto GH[1], Buyukcakir C, Fife CE,* should help when discussing the real life effects on HBO as well as the advantages of quitting

References: **https://www.advancedtissue.com/smoking-negatively-impacts-wound-healing/,** Effects of smoking on cost and duration of hyperbaric oxygen therapy for diabetic patients with non-healing wounds. Otto GH[1], Buyukcakir C, Fife CE.

*It is calculated by multiplying the number of packs of cigarettes smoked per day by the number of years the person has smoked. For example, 1 pack-year is equal to smoking 20 cigarettes (1 pack) per day for 1 year, or 40 cigarettes per day for half a year, and so on.

Date:_____

Name:_____

Post Test
Discussing Smoking and wound healing

1. Smoking has no effect on wound, this is just a myth the doctor tells to get people to stop smoking. (circle) True False

2. One study shows that there is little difference if the patient has only been smoking __ pack per day for less then ___ years, what should we counsel our patient about this?_____ _____.

3. When patients are being treated in the Hyperbaric Chamber they receive so much oxygen that it overcomes the effects of smoking. (circle) True False

4. How will smoking effect a diabetics blood sugar ? _____, will this effect wound healing? _____-

5. How will effect pain levels? _____, Why? _____>

6. Bonus: Please propose some ways you could approach your Patients about smoking?

_____

_____

Discussion: Should we treat smokers with HBOT?

_____

_____

_____

Pneumothorax Under Pressure

Overview: A pneumothorax in the chamber is extremely serious. Symptoms suggesting pneumothorax include sudden shortness of breath, stabbing chest pain, tracheal shift, asymmetric chest movement, and increased respiratory distress during decompression. If a pneumothorax is suspected, a 14-16 gauge needle should be readily available prior to decompression. Upon exiting the chamber, additional findings may be present on physical exam. These include asymmetric breath sounds, hypotension and tachycardia. Perform an immediate needle decompression if the patient appears to have a "tension" pneumothorax as evidenced by significant tachycardia, hypotension, or respiratory distress. Decompression is performed by inserting a 14 or 16 gauge needle over the top of the 2nd rib at the midclavicular line.

Procedure: If patient exhibits any of the above symptoms, do the following:

- Stop decompression
- Notify Hyperbaric Physician
- If it is determined that the patient does have a tension pneumothorax, gather your equipment and staff to immediately insert a 14-16 gauge needle upon opening the chamber door
- Once physician has arrived, bring patient up at a rate of 5 psig or as ordered by the physician
- Following this initial stabilization, make arrangements for appropriate transfer and further management

Reference: Clinical Procedures in Emergency Medicine, 3rd Edition, Ed Roberts & Hedges, W.B. Saunders. Hyperbaric Medicine Practices, 2nd Edition 1995, Eric P. Kindwall, M.D. pp. 291-292

Date: _____

Name: _____

Post Test
Pneumothorax

1. Patients may experience the following symptoms during decompression _____ and _____.

2. During the decompression the pneumothorax expands.

   (circle) True False

3. A a pneumothorax in the Hyperbaric Chamber is not in serious condition.

   (circle) True False

4. The patient may exhibit signs of cyanosis in the chamber.
   (circle) True False

5. Patients with any kind of pulmonary lesions on x-ray should have a _____ descent rate.

Seizures in the Hyperbaric Chamber

Introduction: Oxygen toxicity occurs in approximately 1.3 times in 10,000 exposures. Pre-treatment assessment is one of the major tools in preventing oxygen toxicity. Air breaks can be used to decrease the potential for oxygen toxicity in patients that are on high doses of steroids, narcotics (narcotics decreases the respiratory drive that can lead to increased oxygen levels) or febrile. The room environment plays a role decreasing the chance of a seizure by eliminating fluorescent lighting in the chamber room.

Signs/Symptoms: Patients may exhibit one or more of the symptoms, however the seizure may happen without warning. Careful monitoring of your patient at all times is essential. Signs of oxygen toxicity begin with: sweating, nausea, vomiting, apprehension, shortness of breath, tunnel vision, tinnitus and muscle twitching.

Other Considerations: Seizures may also be caused by hypoglycemia, high doses of steroids, hyperthermia, and chemical/alcohol abuse.

Procedure: If patient is observed or complains of any of the above symptoms have the patient breathe off their air break system, this will lower their oxygen level. Notify the Hyperbaric Physician supervising the treatment. Continue air breathing for 5-10 minutes until patient states they feel better. Discontinue patient's treatment and decompress the patient at a normal rate. ***If patient is a Diabetic immediately check blood sugar, episode could be hypoglycemia.*** Prior to the next treatment incorporate an air break in the patient's treatment protocol. If patient has a seizure it will consist of a tonic phase where the patient may hold their breath. ***Never decompress at this phase.*** When the patient begins a jerking motion this is the clonic phase. Patient should be observed for breathing, chamber can be decompressed at a

rate tolerated by patient. Patient should have a complete assessment done post treatment. The Hyperbaric Physician will determine the course of action for the patient.

References: Hyperbaric Nursing. 2002, Larson-Lohr., Norvell, pp. 143-144 pp. 250-251; Hyperbaric Medicine Practices, 2nd Edition 1995, Eric P. Kindwall, M.D. pp. 80, pp. 290-291

Date:_____

Name:_____

Post Test
Seizures in the Hyperbaric Chamber

1. Patients will always exhibit one or more signs/symptoms prior to having a seizure in the chamber. (circle) True False

2. The seizure will consist of two phases: _____ and _____ .

3. You can only decompress the patient during the clonic phase. (circle) True False

4. _____is the major tool used to help you prevent oxygen toxicity.

5. During your pre-treatment assessment what at some of the factors that would determine if the patient should get an air break incorporated in the their treatment protocol. _____, _____, _____.

Medication Precautions in hyperbaric

Overview: **NOTE:** The issue of drug interaction with HBOT is a complicated and conversional one that can only be navigated by your physician. However as with other things of this nature it is important that all member of your clinical team. When researching this subject, I came across a great deal of inaccurate or outdated information. After a review of 5 abstracts that all came to the same conclusion, that more research is needed, I decided that the best way I can provide guidance was to include the following abstract in its entirety. I realized that this will take a bit of time to read over carefully but I encourage you to do so as it will give you at lest a basic understanding of this issue and what to consider when preparing for a new patient in your center. Please feel free to share with your center's physician.

An Appraisal of Potential Drug Interactions Regarding Hyperbaric Oxygen Therapy and Frequently Prescribed Medications

Author
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Abstract: Many healthcare providers may overlook or even be unaware of most drug-to-drug interactions. Recognizing the existence of drug interactions with the use of hyperbaric oxygen can empower a clinician with knowledge to avoid dangerous interactions that may result in hazardous, negative patient outcomes. Hyperbaric oxygen therapy (HBOT) can reduce the efficiency of certain drugs or make drug therapy more unpredictable. Methods. This review offers the physician information regarding prescription drug interactions with hyperbaric oxygen therapy. First, mechanisms found in the medical literature of potential drug interactions with the use of hyperbaric oxygen are presented. Second, the 100 most frequently prescribed medications in 2009 are reviewed regarding hyperbaric oxygen. Lastly, a table of these 100 medications and any reported effects of hyperbaric oxygen on each drug are provided. Results. The total number of different medications in this review was 69. Reported drug interactions resulting from the effects of hyperbaric oxygen occurred with 38 of the 69 drugs that were reviewed (55%). Descriptions of the possible effects of hyperbaric oxygen are presented for each reviewed medication. Thirty-one medications of the 69 review drugs (44.9%) did not have any description of the possible effects of hyperbaric oxygen. A few references recommended avoidance of hyperbaric oxygen because co-administration of these drugs

predisposes the patient to oxygen toxicity. Conclusion. Hyperbaric oxygen therapy may interact with medications through pharmacokinetic or pharmacodynamic mechanisms. This review offers the healthcare provider information regarding potential drug interactions. Empowered with this information, clinicians may assist their patients to maximize pharmacologic outcomes by avoiding these reported harmful interactions. Prescription medications are vital to preventing and treating illness as well as assisting in the avoidance of more costly medical complications.1 Use of prescription medications to treat chronic medical conditions is particularly high among older individuals. Almost 40% of older Americans take five or more therapeutic agents monthly.2 Moreover, the most recent data from a sample population survey of United States civilian households reveals that 50% of the population consumes at least one or more prescription drugs per month, while 1 out of 10 Americans use five or more prescription drugs each month.2 Oxygen is a common and widely prescribed therapeutic agent. Given, oxygen possess both biochemical and physiological actions, a distinct range of effective doses, and well-defined adverse effects at high doses, it may be considered a pharmacologic agent.3 Hyperbaric oxygen (HBO) therapy is defined as inhalation of oxygen at increased pressure, for potential therapeutic benefit in a variety of clinical situations.4 Medical literature and current compendia have reported the use of hyperbaric oxygen therapy to treat hypoxic as well as diabetic chronic lower extremity ulcers as an effective adjunctive wound treatment.5–10 Upon reflection of lower extremity ulcer prevalence statistics collectively, as well as prescription use, patterns with the inclusion of hyperbaric oxygen therapy encourage an inference in which overlapping cross-sectional population exists as it pertains to prescription medications and patients with lower extremity wounds being treated with hyperbaric oxygen under pressure. Many healthcare providers may overlook or are unaware of specific potential drug interactions. It is imperative that clinicians be knowledgeable of the existence of pharmacological interactions either beneficial or harmful between a patient's medication regimen and potential outcome effects of hyperbaric oxygen effects. The purpose of this review is to offer clinicians information regarding oxygen drug and physiology effects within the context of HBOT, increased atmospheric pressure, and lower extremity wound care. In order to accomplish this endeavor, specific concepts must be exemplified. An overview describing human pharmacokinetics, observed human physiological effects of hyperbaric oxygenation and pressure will be first offered because achieving this understanding is essential when discussing both pharmacodynamic and pharmacokinetic principles of drug-drug interactions. Secondly, building upon this foundation potential drug and hyperbaric oxygen effects as cited in the medical literature will be offered both as a narrative and as

a graphic table to accentuate these effects. Finally, pharmacological precautions and contraindications as they relate to drug use and hyperbaric oxygen therapy will be offered.

Review of Pharmacology Principles

Clinical healthcare providers should recall that pharmacology is the study of the interaction of chemicals with biological systems. The science of pharmacology encompasses both pharmacokinetics, which is the science that describes the body's action on a medicinal agent, and pharmacodynamics, which is the scientific description of the medicinal agent's action on the body's systems. Pharmacokinetics involves four major body functions: absorption, distribution, metabolism, and excretion. Absorption is the rate at which and extent to which a drug leaves its site of administration. Drug absorption occurs at different sites along the gastrointestinal tract, including the stomach and the small and large intestines. Once absorbed, most drugs bind to plasma proteins that are specific for some aspect or structural feature of the drug. After a drug is absorbed or injected into the blood stream it enters the circulation and is distributed throughout the body. Drug distribution is the process by which a drug reversibly leaves the blood stream and enters the extracellular fluid or the cells of the tissues. Drugs can be distributed into different compartments of the body (ie, blood, plasma, fat, or bone). The term volume- of-distribution is commonly used to describe the extent of drug distribution to tissues relative to the plasma volume. Drug metabolism is a biochemical enzyme-mediated reaction resulting in structural modification to the drug that changes its biological activity and/or water solubility. Drug metabolism occurs as a result of enzymatic reactions on the medications resulting in metabolites that may be active or rendered inactive. Body organs such as the gastrointestinal wall, lungs, and the liver, as well as the blood possess enzymes that metabolize drugs.11–13 Metabolism via the smooth endoplasmic reticulum of the liver is the first step in the elimination of many drugs.11,13 Drug metabolism by the liver occurs through one or both biotransformation reactions classified as either Phase I or Phase II reactions.12 Phase I reactions modify the drug by using oxidation, hydrolysis, and reduction. Oxidation involves the enzymatic addition of oxygen or removal of hydrogen, carried out by mixed function oxidases, often in the liver. Oxidative reactions typically involve a cytochrome P450 monooxygenase, NADPH, and oxygen. These modifying reactions create a more polar and highly water-soluble drug molecule for elimination by the kidney. Phase II reactions modify the drug pharmacologically to an inactive form using conjugation resulting in glucuronides, acetates, and sulfates. This is accomplished by the formation of a covalent linkage between a functional group appearing on the parent drug as a result of

phase I metabolism and endogenously derived glucuronic acid, sulfate, glutathione, amino acids, or acetate.11,14 This new drug metabolite may now be eliminated by the kidney. Some important preventable drug interactions are due to their effects on drug metabolizing enzymes, resulting in either reduced activity of the enzyme or increased activity of the enzyme, referred to as enzyme induction. The major group of enzymes in the liver responsible for metabolizing drugs can be isolated in a sub-cellular fraction termed the “microsomes.” Cytochrome P450 is a superfamily of enzymes bound to the cell membrane that are the terminal oxidases of this oxidation system. “Cytochrome” means colored cells; these enzymes contain iron giving the liver its red color. “P450” comes from the observation that the enzyme absorbs a very characteristic wavelength (450 nm) of ultraviolet light when it is exposed to carbon monoxide. These enzymes are named according to families that are defined by the similarity of their amino acid sequence. The nomenclature of each cytochrome isoenzyme follows some simple rules.15,16 Using CYP3A4 as an example, root of its name is CYP. Its family is noted with the number 3, while its subfamily is represented with the letter A. Its gene is denoted with the last number in the series 4. These P450 iso-enzymes are denoted with the following numbers and letters: “CYP1A2, CYP2A6, CYP2C8, CYP2C9, CYP2C19, CYP2D6, CYP2E1, and CYP3A4.”15–17 More than 50% of currently used medications that are metabolized undergo CYP3A4 metabolism. The CYP3A subfamily is of particular interest because it is responsible for the metabolism of a large number of clinically important drugs in humans.16 The CYP3A4 isozyme accounts for over 25% of hepatic CYP450 content, and is responsible for more than half of all CYP450-mediated drug metabolism. Close to 14% of the adult liver contains a substantial proportion of CYP3A5, but it is proportionally more important in intestinal tissue and is the primary CYP3A enzyme in the kidney 16,17 Metabolism and elimination are responsible either separately or together for drug inactivation. Without these two pharmacokinetic functions, drugs would continuously circulate through the body interacting with various body receptors and interrupting important physiological processes.18 Drugs are either eliminated directly or converted into metabolites that are subsequently excreted. Removal of a drug from the body may occur by a number of routes, the most important being through the kidney into the urine. Other routes of elimination for drugs from the body include sweat, tears, breast milk, or expired air.

Hyperbaric Oxygenation and Pressure on Human Physiology

The hyperbaric environment is associated with physiological changes in the central nervous system, the endocrine system, respiration and hemodynamics.19 Hyperbaric oxygen reduces cerebral edema and improves the function of

neurons damaged by ischemia or hypoxia. Changes in various endocrine organs have been reported under hyperbaric oxygenation. A fall in blood glucose has been observed in volunteers exposed to hyperbaric oxygen. However, there is scant data describing basic experimental studies assessing the effect of hyperbaric oxygen in experimentally induced diabetes mellitus. Patients with diabetes who are given hyperbaric oxygen for other indications should be carefully monitored for changes in blood glucose, as the insulin requirements are usually reduced and the dosage needs to be readjusted. Dreval et al20 devised a calculation method to assess the effects of hyperbaric oxygen in lowering the insulin requirement in these patients. Hyperoxia suppresses the respiratory reactivity to CO2. Hyperbaric oxygen reversibly depresses the hypoxic ventilatory drive by a direct effect on the carotid CO2 chemoreceptors. Hyperbaric oxygen therapy has a limited role in pulmonary disorders. Usually there are no differences between forced vital capacities and maximal expiratory flows before and after hyperbaric oxygen exposure while breathing dry or humidified oxygen.21 In human patients, hyperbaric oxygen defined as 100% oxygen results in a decrease in cardiac output by 10%–20% due to heart rate reduction rather than a reduction in stroke volume.19,21 Animal experiments reveal evidence that hyperbaric and hyperoxic conditions cause changes in cardiac output distribution.19,22,23 Risberg et al23 observational experiments demonstrated that the perfusion of several organs was markedly affected. Arterial liver perfusion was significantly increased while kidney and spleen perfusion were significantly reduced after 75 minutes but not after 15 minutes at 5 bar depth.23 Blood pressure remains essentially unchanged. Blood flow to most organs falls in proportion to the fall of cardiac output except to the right and left ventricle of the heart.21 Vasoconstriction may be viewed as a regulatory mechanism to protect the healthy organs from exposure to excessive pO2. Hyperbaric oxygen improves the elasticity of the red blood cells and reduces platelet aggregation.21 Increases in partial pressure of oxygen in the blood disturbs the reduction of oxyhemoglobin causing an increase in solubility of CO2, thus there is a retention of CO2 leading to a slight rise of H+ ions in the tissues. Hyperbaric oxygenation therapy reduces excess lactate production in hypoxic states.21 The presence of hyperbaric oxygen affects mono-oxygenases pathways, and results in both biochemical and human physiological alterations in metabolic pathways. The biochemical effects of hyperbaric oxygen include cyclo-oxygenase inactivation resulting in decreased production of prostacyclin by hyperoxic tissues.21 Hyperoxia inhibits phenylalanine and tyrosine hydroxylase. Increased oxygen saturation of Tyrosine Hydroxylase leads to increased turnover of catecholamines.21 Both Succinic Dehydrogenase and Cytochrome Oxidase are activated by hyperbaric oxygen. Cytochrome Oxidase is involved in the

cytochrome P450 monooxygenase system. In the vernacular of chemistry, “activated” means to accelerate a reaction. In the setting of biology, “activated” means to convert into biologically active derivatives. When applying both these relative definitions of “activated” to the science of pharmacokinetics specifically drug metabolism in the presence of hyperbaric oxygen, the inference that drug metabolism by the cytochrome P450 monooxygenase system is accelerated is a reasonable deduction, despite the lack of actual clinical evidence gathered from randomized control trials.

Hyperbaric Oxygenation and Pressure Effects on Medications

Oxygen is one of the most widely used pharmacological agents. When oxygen is breathed in concentrations higher than those in the atmospheric air, it is considered to be a drug. Under elevated partial pressure oxygen behaves like any other drug; too little is ineffective and too much will cause harm. It is important for the clinician to realize that oxygen under a hyperbaric pressure environment can interact with other drugs. Either potentiate or reduce the effects of other medications. Medications in a patient’s drug regimen taken for chronic illnesses may either reduce or potentiate the effects of hyperbaric oxygen. Also, many medications (including nonprescription medications) have undesirable side effects that may be modified in a hyperbaric oxygen environment. The distribution of a drug is affected by multiple body composition parameters: plasma volume, body mass index, average blood flow, total body water, plasma proteins, body fat, and cardiac output.18 Both liver blood flow and hepatic enzyme activity influence hepatic clearance of drugs. Because the perfusion of organs responsible for drug absorption or elimination may be altered, pharmacokinetics may also change under hyperbaric conditions.19 No study was found among the available medical compendium describing the influence of hyperbaria or hyperoxia on drug absorption from the gut. However, applying the observation that drug absorption is known to be altered in patients with congestive heart failure, it is plausible to make the assertion that hyperbaric and hyperoxia environments may affect drug absorption due to reduced cardiac output. Liver perfusion is a major determinant of the clearance of drugs that demonstrate a high hepatic extraction rate from the plasma.19,21 Similarly, a reduction of renal perfusion and glomerular filtration may reduce the clearance of drugs eliminated through the kidney,19,21 thus alterations in both liver and kidney blood flow, as well as resulting changes in drug clearance under hyperbaric or hyperoxic conditions, may be expected due to environmentally induced hemodynamic changes.19,21 The efficiency of pharmacological agents is affected by pressure usually manifested as it decreases in activity.24 Drugs that act on cellular membranes include anesthetics, narcotics, and tranquilizers.

These medicines are all affected by an increase in atmospheric pressure changes that result in observed decreased effectness.24 Recalling that the major enzymes involved in drug metabolism are the cytochrome P450 monooxygenases bound to cellular membranes allows for an inference that alterations of atmospheric pressure may interfere with a number of drug metabolism pathways. The generation of oxygen free radicals related to high pO2 values affect the permeability of biological membranes.19,21 Oxygen free radicals are highly reactive, toxic entities that induce lipid peroxidation and may alter both proteins and nucleic acids. Alterations in drug protein-binding rates are associated with quantitative or qualitative changes in proteins. Unfortunately, experimental clinical based evidence is not available on effects of hyperbaria or hyperoxia environmental alterations on the protein-binding rates of drugs. Theoretically, one can infer that drugs displaying a high protein-binding rate should be most affected, demonstrating an altered volume of distribution and altered drug clearance because of the generation of oxygen free radicals. Further, the generation of oxygen free radicals might affect the activity of drug-metabolizing enzymes that affect hepatic clearance of drugs with a capacity-limited hepatic elimination.19 The medical community appreciates that it is impossible to remember all possible drug interactions. Conversely, a physician may apply an understanding of the real and theoretical mechanisms of drug interactions between hyperbaric oxygen, pressure, and drugs to empower themselves to avoid major adverse events caused by drug interactions. Advances in the understanding of the cytochrome monooxygenases system have made it possible to associate specific enzyme activity with the formation of a particular metabolite and, in some cases, to identify the major isoenzyme responsible for total clearance of a drug. Data regarding interactions between medications and hyperbaric oxygen from the scientific literature were identified by searching current compendia using both the electronic source (PubMed), as well as manual searches of bibliographies and reference listings.19,25–67 Figure 1 delineates the search criteria scheme graphically. Three hundred and forty-seven (347) citations were found and evaluated as defined by search limitations and Medical Subject Headings (ie, MeSH terms) for the search dates 1962–2010. These MeSH terms included: “hyperbaric oxygen,” “HBOT,” “drugs,” “the specific pharmacologic agent’s generic name,” “pharmacology,” and “interactions.” One hundred and seventeen (117, 34%) were found to be relevant for this review. Forty-three citations are included in this review. The majority of citations (n = 17) are defined as case reports or case studies by their authors. Observations and data from nine randomized control trials were assessed as well as observations and data from eight animal studies or laboratory experiments as it related specifically identified pharmacological generic names. The remaining

citations were either author reviews or consensus from noted experts of hyperbaric medicine. For this review, observed pharmacokinetic and pharmacodynamic changes resulting from the interaction with hyperbaric oxygen was applied to the 100 most frequently prescribed medications in 2009 (Table 1). There is only a relatively small volume of data concerning observed pharmacokinetic studies regarding intravenous anesthetics and analgesics regarding the hyperbaric oxygen environment. Pentobarbital and merperidine have been investigated and showed no significant differences in half life, volume, and distribution, or plasma clearance at measured 2.8 and 6 atmospheres absolute (ATA).25 Camporesi26 recommends the use of intravenous sedation in the hyperbaric environment describing the use of ketamine and a benzodiazepine, along with a muscle relaxant, because these agents have proven to be very useful for induction and maintenance of anesthesia under hyperbaric conditions. Further, Camporesi26 stresses that while delivering anesthesia under hyperbaric conditions attention to detail is paramount. It should be delivered to be effective at pressure and not with any preconceived formulations.26 Narcotic analgesics generally depress respiration by reducing the reactivity to carbon dioxide in the medullary centers. Theoretically, combining the observed respiratory depressing effects of hyperbaric oxygen and the drug-induced depression observed with narcotic analgesics, the clinician must consider that a potential for an elevation in physiological paCO2 causing vasodilation and the potential for oxygen toxicity does exist when using narcotic analgesia and hyperbaric oxygen therapy. Beubler et al33 report on the practical aspects and the clinical application of oxygen under pressure using both mice and rats. These investigators report the analgesic effect of morphine was observed to be unchanged by the clinical application of oxygen under high pressure.33 Jain25 also reports the action of morphine is unchanged by hyperbaric oxygen. Conversely, central nervous stimulants such as amphetamines or related compounds such as methylphenidate may interact unfavorably with hyperbaric oxygen and may predispose the patient to oxygen toxicity. Rump et al review the influence of hyperbaric hyperoxia on the pharmacokinetics of lidocaine in two healthy men as a crossover trial experiment type at 1 and 2.5 bar.19 Lidocaine was given intravenously and blood samples were serially collected for 75 minutes.19 Lidocaine was measured by using an immunoassay and serum-concentration curves following an open two-compartment model.19 The pharmacokinetics parameters of lidocaine as recognized in the literature affirm its clearance from the body depends on liver plasma flow. Despite the fact that there are alterations in liver perfusion under hyperbaric or hyperoxic conditions, the results of this case study demonstrated that lidocaine disposition was not influenced by hyperbaric oxygen therapy.19

Using this observation these authors conclude that changes in liver perfusion at 2.5 bar breathing 100% O2 does not affect the clearance of drugs eliminated by hepatic plasma flow considered to be perfusion limited.19 The effect of hyperbaric oxygenation in anaerobic infections is well recognized. Oxygen acts as an antibiotic by impairing the bacterial metabolism. Hyperbaric oxygen is most effective in anaerobic infections. The nature of hyperbaric oxygen lends itself to be non-selective covering a broad spectrum of gram positive as well as gram-negative organisms. A state of hypoxia impairs the body's immune system. The process of phagocytosis is impaired by hypoxia and improved with hyperbaric oxygen. Knighton et al28 published research that has demonstrated that breathing 45% oxygen is as effective as ampicillin in controlling certain aerobic bacterial inoculations, by stimulating leukocyte function. Oxygen may enhance the effects of other antimicrobial agents, particularly para-aminobenzoic antagonists, such as sulfonamides. The synergistic effects of combining hyperbaric oxygen at 2.87 ATA with sulfonamides (specifically sulfisoxazole) transforms its sole bacteriostatic action into more of a combined bactericidal mechanism of action.27 Efficacy of certain antibiotics, to include extended spectrum penicillin, aminoglycosides, vancomycin, and clindamycin, have been shown to be enhanced with hyperbaric oxygen without increasing antibiotic toxicity.29 Suggested mechanisms for the synergetic relationship between hyperbaric oxygen and antibiotics is described in one reference.29 First the increased pressure of oxygen in ischemic tissues improve the activity of aminoglycosides, fluoroquinolones, vancomycin, trimethoprim, and some sulfoamides.29 Secondly, inhibition of some reactions involved in bacterial biosynthesis, such as the enhancement of sulfonamide activity and the increased duration of post antibiotic effect of aminoglycosides in Pseudomonas infections.29 Finally, altered Redox potential of the bacteria, combined with an increase in reactive intermediates as in nitrofurantoin that requires a low Redox potential.29 Merritt and Slade30 investigated the influence of hyperbaric oxygen on the pharmacokinetics of single-dose of gentamicin in five healthy men between 28- and 43-years-old in a randomized crossover trial. Gentamicin disposition was studied under normobaric control conditions and under hyperbaric and hyperoxic conditions.30 Gentamicin doses of 1.5 mg/kg of lean body weight were intravenously infused in 100 mL over 30 minutes. Blood samples totaling eleven were serially collected over 300 minutes.30 Gentamicin clearance depends on glomerular filtration rate, which is reflected by creatinine clearance. Despite observations that hyperbaric oxygenation has shown to decrease renal blood flow,21,31 data from this investigation demonstrated that exposure to 2.4 ATA for 90 minutes did not alter gentamicin in a clinical manner.30 Clinical practice does recommend that Mafenide (Sulfamylon®) a

topical antibacterial agent used in burn patients, be removed from all surfaces before they undergo hyperbaric oxygenation therapy.25 Mafenide is classified pharmacologically as a carbonic anhydrase inhibitor. It promotes CO2 retention and vasodilatation when placed in a hyperbaric oxygen environment. Acetazolamide, another carbonic anhydrase inhibitor used to treat moderate to severe metabolic alkalosis as well as glaucoma, epileptic seizures, benign intracranial hypertension (pseudotumor cerebri), altitude sickness, cystinuria, and dural ectasia prevents oxygen-induced vasoconstriction and increases blood flow in the presence of hyperbaric oxygenation. Therefore it may predispose the brain to oxygen toxicity.25 Wood32 used animal studies to demonstrate acetazolamide and 5% CO2 shorten time to onset of convulsions and suggest that increased tissue levels of CO2 play an important role in hyperbaric oxygen toxicity. Bove34 relates the premise that there is a very distinct possibility that patients selected to undergo hyperbaric oxygen therapy will have one or more pharmacological therapeutic agents classified as cardiovascular medications. Moreover, Bove recommends that cardiovascular medications can be continued during hyperbaric oxygen therapy; however, these agents should be reviewed in the context of the presenting current medical condition.34 Further, Jain25 offers the observation that the hypotensive effects of both alpha and beta-blockers, ganglion blockers, and β-adrenomimetics are considerably reduced in the hyperbaric oxygen environment. Other observations include both the direct and indirect “pressor” effects of α-adrenomimetics, as well as the cardiotropic effects of β-adrenoblockers are potentiated.25 Filatov and Reznikov35 related observations in rats suggesting that the action of oxygen is mediated via its direct, but primarily indirect action of as adrenomimetic and beta adreno-blocking effects. Given these observations, Jain25 recommends that these drugs should be given after and not before a scheduled hyperbaric oxygen session. The influence of hyperbaric oxygen and pressure has been extensively studied in propranolol in both animals and humans.36–39 The influence of both beta sympathetic agonists and blocking agents on oxygen at high pressure toxicity was examined in rats by Crittenden and Beckman.36 Rats were exposed oxygen at high pressure (6 ATA) and examined for time to seizures. Pretreated propranolol rats demonstrated a 70% increase in time to seizure, as well as prevention of brain depletion of glycogen prior to seizure.36 Their results suggest a possible role for secondary messengers mediating some of the acute CNS toxic effects of oxygen at high pressure toxicity, because propranolol blocks the beta-receptor influence on adenyl cyclase-simulated second messenger production.36 Torbati37 measured the effect of 1, 2, and 5 mg/kg of propranolol on the neuroelectrophysiological manifestations of CNS oxygen toxicity in conscious rats. The results of this research suggest that the protective effect of

propranolol against the neurological manifestations of oxygen toxicity may be related to propranolol's multiple effects on physiological systems rather than beta adrenergic blocking action alone.37 The positive clinical effect of hyperbaric oxygen therapy has been shown to be accompanied by higher activity of superoxide dimutase in red blood cells.38 This enzyme catalyzes the conversion of superoxide into oxygen and hydrogen peroxide. Oxygen free radicals are normally removed in our bodies by the superoxide dismutase enzyme, which functions as an antioxidant and anti-inflammatory to protect the human body from harm. The combination of propranolol (40 mg) and a 40-minute hyperbaric oxygenation session at 1.5 ATA was studied in 33 men with coronary heart disease.39 These investigators concluded propranolol induced a supplemental reduction in sympathetic activity causing the drug's negative chronotropic and inotropic effects to be potentiated.39,40 Al- Waili et al41 offer salient advice that the use of beta blockers for the management of hypertension should be avoided during hyperbaric oxygen therapy, because their results showed that the use of beta-blockers in 41 patients with hypertension and diabetes mellitus caused a significant elevation of blood pressure while reducing heart rate.41 Other pharmacological agents that may be therapeutically beneficial in cardiovascular or circulatory pathologies that have been studied in combination with hyperbaric oxygen under include: nitroglycerin (depot-glycerol trinitrate), nifedipine, aspirin, pentoxifylline, digoxin, heparin, enoxaparin, and losartan.38–40,42–51 Seriakov et al40 demonstrated while studying 35 patients with ischemic heart disease that a single hyperbaric oxygenation session lasting 40 minutes at a pressure of 1.5 atmosphere had no impact on the degree of hemodynamic effect of depot-glycerol trinitrate. Intravenous nitroglycerin has been administered to animals in an effort to prevent bubble formation during decompression sickness.42 In the animals that received NTG at 0.4 mcg/kg/min for 30 minutes significantly fewer bubbles were detected after decompression and no deaths resulted.42 The indirect hemodynamic effect of nifedipine has been shown to be reduced during a hyperbaric oxygenation session.40 Despite animal studies25 that revealed that salicylate clearance was significantly increased at an atmosphere of 2.8, Seriakov and Feofanova43 concluded that the platelet anti-aggregant activity of aspirin at a daily dose of 125 mg or pentoxifylline dose at 300 mg daily was not altered during 8 to 12 hyperbaric sessions lasting 40 minutes at depths of 1.3–1.6 ATA. A recent case report describing the treatment of retinal artery embolization during carotid angioplasty and carotid artery stenting validates the concurrent use of aspirin, ticlopidine, and hyperbaric oxygen for 1 week without ill effects to the patient.44 Animal research has produced findings suggesting that the effectiveness of cardiac glycosides (Digitalis/Digoxin) was decreased in the presence of 100% hyperbaric oxygen sessions.45 Initial results from animal

experimentation showed that heparin treated animals exposed to hyperbaric oxygen developed pulmonary hemorrhages.46 It was concluded that the heparin-hyperoxic interaction during development of pulmonary and CNS oxygen toxicity may be related to the anticoagulant effect of heparin and hyperoxic-induced pulmonary lesions.46 Quite the opposite results are reported in three recent case reports describing the successful use of either heparin or low-molecular-weight heparin in combination of hyperbaric oxygen without ill effects to patients.47–49 One case report discusses the beneficial effects of systemic heparin and hyperbaric oxygen therapy to prevent liver failure in an infant who underwent an orthotopic liver transplant.46 Another case report presents information regarding successful use of a heparin infusion (1000 units/h) with concurrent hyperbaric oxygen therapy for 9 days to treat a 37-year-old man with frostbite of his right hand. The combination of heparin and hyperbaric oxygen therapy did not produce any adverse effects noted during the combination therapy.48 The last case report describes a 63-year-old Polynesian woman presenting with atypical calciphylaxis attributed to warfarin therapy.49 A therapeutic dose of enoxaparin was substituted for warfarin and the patient underwent forty sessions of hyperbaric oxygen sessions with no adverse effects noted and resolution of cutaneous lesions.49 Animal models have demonstrated that the combination of losartan, an angiotensin II antagonist, and the combination of hyperbaric oxygen therapy increases the drug's efficacy and has significant benefits as it relates to the management of proteinuria.50,51 Human case control investigations have demonstrated hyperbaric oxygen therapy sessions improve metabolic control and reduce insulin requirements in patients with type 2 diabetes mellitus.41,52,53 Al-Waili et al41 revealed hyperbaric oxygen therapy sessions lowered blood glucose levels by 23% ($P < 0.001$). When the basal blood glucose level was between 120 mg/dL–170 mg/dL, it dropped to less than 100 mg/dL in 31/60 (52%) treatment sessions.41 When the basal blood glucose level was less than 120 mg/dL, it dropped to less than 70 mg/dL in 8/34 (23.5%) sessions.41 The combined treatment of intrapancreatic autologous bone marrow stem cells and hyperbaric oxygen in type 2 diabetic patients to determine improvement of islet function and metabolic control was investigated by Estrada et al.52 Significant improvement was seen when comparing base line values and 12-month follow up values of fasting glucose 205.6 ± 5.9 vs. 105.2 ± 14.2 mg/dL and HbA1c 8.8% ± 0.2 vs. 6.0% ± 0.4.49 Karadurmus et al's recent investigation yielded similar gradual reduced results from base line values in fasting blood glucose and HBA1c after hyperbaric oxygen therapy (FBG 152 ± 3.7 mg/dL vs. 113 ± 14 and HBA1c 9.1 ± 1.3 versus 8.0 ± 1.1).53 Given all these results collectively, the dosage of insulin among patients with diabetes during hyperbaric oxygen therapy sessions should be readjusted. One attractive metabolic effect of

hyperbaric oxygen therapy is that it reduces excess lactate production in hypoxic states, as well as during exercise.21 This detail was appealing when evaluating a patient for hyperbaric oxygen therapy whose drug regimen may have included metformin, that is thought to increase the risk of lactic acidosis. Recently, pooled data from 347 comparative trials and cohort studies revealed no cases of fatal or nonfatal lactic acidosis in 70,490 patient years of metformin use.54 These authors found no evidence from prospective comparative trials or from observational cohorts that metformin is associated with an increase risk of lactic acidosis, or increased levels of lactate, compared to other anti-hyperglycemic treatments.54 Finally, despite the lack of actual clinical based evidence, the clinical results observed during hyperbaric oxygen therapy sessions on blood glucose levels among patients with diabetes may be applied to other pharmacologic oral agents with hypoglycemic actions like thiazolidinediones, sulfonylureas, and perhaps sitaglipyin (DPP-4 inhibitor). Two medications that may enhance oxygen toxicity and must be used with caution when electing HBOT, besides acetazolamide, includes thyroid extract and disulfiram (Antabuse®), which is used in alcohol aversion therapy. It may potentiate oxygen toxicity through in-vivo reduction to diethyldithiocarbamate and subsequent inhibition of superoxide dismutase.25 Animal experiments have revealed that those animals given thyroid or thyroid extract under hyperbaric oxygen conditions have an enhanced chance of experiencing oxygen toxicity. The drug induced increase in metabolic rate is thought to predispose the subjects to oxygen-induced convulsions.25 It is not out of the realm of possibility to apply this data to humans and assume that the same adverse outcome could occur.

Potential Interactions

The medications selected for review were the 100 most frequently prescribed (brand and generic names) in 2009 as measured by IMS Health based on $300.3 billion of prescriptions sold.55 A literature review was conducted to identify intrinsic drug interactions with hyperbaric oxygen. The data obtained were primarily qualitative and were based on reports in the current compendium, recent journal articles, and drug package inserts.25–67 Current literature sources were used to resolve conflicting information presented in reference materials. Information and drug interaction observations and recommendations presented in Table 1 are centered on the applied science of pharmacology and physiology, as well as clinical intuitive judgment balancing both aspects of patient benefit verses patient risk. The first limitation is that the majority of drug and hyperbaric oxygen interactions described do not rise to observations seen during high-quality randomized trials with statistically significant difference and a narrow confidence interval. The drug interaction observations seen with concurrent use

of hyperbaric oxygen are either from case series or from expert opinion. Another limitation of the data presented in tertiary literature sources is that the data is based on animal studies that have to be interpreted and then applied to humans. A table was constructed listing 100 medications by either brand name or generic name, followed by the information concerning drug interactions (Table 1). During the review, it was noted duplicates were present owing to listing of medications by both brand name and generic name. Therefore, the actual number of different medications in the review was 69. Reported drug interactions resulting from the effects of hyperbaric oxygen occurred with 38 of the 69 drugs reviewed (55%). Descriptions of the possible effects of hyperbaric oxygen are presented for each reviewed medication. Thirty-one medications of the 69 that were reviewed (44.9%) did not have any description of the possible effects of hyperbaric oxygen. A few references recommended avoidance of hyperbaric oxygen because co-administration of these drugs predisposes the patient to oxygen toxicity. Possible drug interactions and the effects of hyperbaric oxygen on medications that were likely, but not certain to cause a negative interaction because they were only observed in animals or found in similar pharmacological agents or a parent drug, were noted as “probable.”

Conclusion

Drug interactions with hyperbaric oxygen represent an important subject, but there is a lack of overwhelming clinical based evidence describing the effects of hyperbaric oxygen for many of the commonly prescribed medications. Clinicians should perform a careful patient medication history to avoid medications that may be adversely effected by hyperbaric oxygen. Therefore, this review offers the healthcare provider information regarding prescription drug interactions caused by hyperbaric oxygen. Mechanisms found throughout the literature of potential drug interactions caused by hyperbaric oxygen were presented. The 100 most frequently prescribed medications measured by IMS Health for 2009 were reviewed regarding hyperbaric oxygen as cited in the medical literature. The actual number of different medications review was 69. Reported drug interactions resulting from the effects of hyperbaric oxygen occurred with 38 of the 69 drugs reviewed (55%). Descriptions of the possible effects of hyperbaric oxygen were presented for each medication. Thirty-one medications of the 69 review drugs (44.9%) did not have any description of the possible effects of hyperbaric oxygen. Further, experimental research that rises to significant clinical evidence related to pharmacokinetic and pharmacodynamic interactions of commonly prescribed drugs receiving hyperbaric oxygen is recommended. (References see website)

PROCEDURE:

It is **recommended** that patients should NOT have hyperbaric oxygen therapy if they are currently taking or have recently (within 3 months) taken any of the following medications**.***

1. **Doxorubicin (Adriamycin) -** cardiotoxity will occur. Wait until last dose has cleared from blood stream before starting HBO treatment.

2. **Mafenide acetate (Sulfamylon)** - interferes with carbonic anhydrous.

3. **Bleomycin (Blenoxane)** – idiosyncratic (depending on individual) risk of pulmonary toxicity.

4. **Votrient (Pazopanib)** - should wait 3 to 5 days to start HBO for wound healing.

Caution should be given to patients that are currently on or recently taken the following medication.

1. **Cisplatinum** - wound healing may be impaired. May treat in limb salvage or emergency HBO.

2. **Erbitux** - may have HBO for limb salvage and emergency conditions

"Anti-VEGF" medications (e.g. Avastin) - impairs wound healing may receive HBO for limb salvage and emergency conditions.

3. **Disulfram (Antabuse)** - blocks the production of suproxide dismutase, which protects against oxygen toxicity

***As this is a clinical discussion the physician should consider the haft life of the medication in question, likely side effects and the results of a risk benefit analyzes.**

References: 2017 SerenaGroup policy and procedure manual, UHMS ask the expert.
https://www.woundsresearch.com/article/appraisal-potential-drug-interactions-regarding-hyperbaric-oxygen-therapy-and-frequently-pre

Date:_____

Name:_____

Post – Test
Mediation precautions

2. Bleomycin (Blenoxane) – idiosyncratic risk of pulmonary toxicity, Idiosyncratic means? -_____ ___ _____

3. High pressure oxygen is a drug and has different effects on other drugs then normalbaric oxygen.

   (circle) True False

4. List three Chemotherapy medications we should be cautious of and why;
   _____ ,
   _____
   _____.
5. 3 weeks is the recommended time period after these Chemo drugs . (circle) True False

6. What are the two most common negative side effects in HBOT?

   _____ and _____

Static Electricity/Grounding

Overview: When oxygen concentration increases in an atmosphere, the risk of fire increases. Sparks caused by discharges of static electricity have been implicated as ignition sources in fires and explosions. To prevent fires in any environment the 3 legs of the fire triangle must be considered, fuel, ignition source and oxygen. Fire prevention in hyperbaric environments focuses on reducing the amount of available fuel and eliminating the source ignition. The majority of fires in Hyperbarics have been caused by the introduction of an ignition source (hand warmers, cigarette lighters, etc.) Static electricity is a routine part of our lives. We have all experienced a snap or pop of static when you reach for a doorknob, particularly after walking across a carpeted floor. In certain situations a static discharge can lead to disaster. Electrons accumulate on the surfaces of objects (including our body) and can result in significant voltage potentials under certain conditions. These voltages usually flow unnoticed from object to object through conductive pathways. To reduce the potential for sparks, static charges must have conductive pathways to flow through and these are called grounds. Ground examples are: conductive footwear, cables, chains or elevated relative humidity levels (>40-50%) can provide an appropriate path to ground in order to dissipate the accumulated charge. There are specific grounding requirements for Hyperbaric Chambers and occupants defined in the National Fire Prevention Agency Manual (NFPA) Chapter 19, NFPA 99 or Chapter 20, NFPA 02. Requirements state that a grounding system must provide a high impedance conductive pathway in contact with the patient's skin. Grounding straps used in hyperbaric chambers are usually attached to the patient's wrist or to an adhesive ECG monitoring pad. The Hyperbaric environment poses an increased fire hazard primarily due to elevated oxygen concentration. It would be extremely rare to see the discharge of more than a single spark especially if the patient was properly grounded.

Procedure: Daily inspection of your hyperbaric chamber includes the inspection of the grounding wire attached at the rear of your chamber. All patients are required to wear a grounding wrist band or ECG patch before entering the chamber. Grounding Areas: **chamber** (cable is attached to grounding plate upon daily inspection) **patient** (wrist band or ECG patch attached) **gurney** (chain at bottom of gurney making

contact with the floor). To safely treat patients in an increased oxygen environment we must pay close attention to static control by increasing relative humidity and providing adequate conductive pathways as listed above.

References: NFPA 99, Chapter 19 Section 2.7.4, 3.1.5.3, NFPA 03, Chapter 20 Section 20.2.7.4, 20.3.1.5.3.2, Wilbur T. Workman, Hyperbaric Facility Safety: A Practical Guide, Chapter 3, pp 523-533

Date:_____

Name:_____

Post-Test
Static Electricity/Grounding

1. A static spark does not generate enough charge to be dangerous in an oxygen enriched environment. (circle) True False

2. Give two examples grounding used in the HBO department_____ and _____.

3. To decrease static electricity you may need lower your humidity in the chamber room. (circle) True False

4. This_____ grounding area is inspected prior to treating your first patient of the day.

5. The_____ Manual gives you specific grounding requirements.

6. If your patient is grounded it is extremely rare to have a static spark. (circle) True False

7. The human body is capable of producing significant voltage potential under the certain conditions. (circle) True False

8. The majority of fires in HBO chambers have been caused by _____ source.

9. The 3 legs of the fire triangle are:_____, _____ and _____.

10. When the concentration of oxygen is increased so does the risk of fire. (circle) True False

Dressing in Chamber

Background

This is a question that plagues new and inexperienced HBO techs on a daily basis and immediately after the Florida accident some have gone to extremes of removing all medical related dressings and skin barriers prior to HBOT, of course you cannot be too safe right? Well, not really. You do run the risk of making the patient's wounds worse by drying it out and exposing it to the atmosphere.

"Traditional practices of excluding certain types of dressings should be revisited. Vaseline gauze dressings are permitted in the monoplace chamber and have been used for many years without incident. A good practice is simply to cover them during treatment. If a patient with severe psoriasis, for example, requires a lotion or cream with a petroleum base to control the skin eruption, it is counter-productive and harmful to the patient to scrub away all the medicament on a daily basis prior to HBO."**

NFPA 14.3..5.4.3

"The physician or surgeon in charge, with the concurrence of the safety director, shall be permitted to use prohibited items in the chamber that are one of the following"

1. Suture material
2. Alloplastic devices
3. Bacterial barriers
4. Surgical dressings
5. Biological interfaces

Procedure:

When evaluating a dressing for Hyperbaric we must use a logical fact based method that we can then document. It is at all times of the upmost importance that balance the overriding

safety concerns with the need to provide good wound care.
You should then document your decision.

References: **"Hyperbaric Medicine Practice" 2nd edition by Dr. Kindwall (pp. 417).
NFPA 99, 2012 addition chapter 14 SerenaGroup policy and procedure.2020

Date:_____

Name:_____

Post Test
Dressing in chamber

1. Vaseline gauze dressings are permitted in the

   monoplace chamber (circle) True False

2. The first test be place a dressing the chamber is to determine if the patient _____**for an effect wound healing treatment.**

3. The physician or surgeon in charge, with the concurrence of the safety director, shall be permitted to use prohibited items in the chamber that are one of the following: (pick two)

   ._____**,**_____**.**

4. If you are not sure that a product is safe to go into a chamber, if the doctor ordered it then it is ok to go in the chamber with no further investigation needed.

   (circle) True False

5. If a product contains a small amount of a questionable ingredient, such as a petroleum base, a good practice is simply to cover it during treatment.

   (circle) True False

Treating the Dialyzes patient

Background

Hyperbaric oxygen exposure can produce significant hemodynamic changes. An increase in systemic afterload due to hyperoxic vasoconstriction in well perfused tissues can lead to a decrease in left ventricular function and a decrease in ejection fraction in some patients. When this decrease in left ventricular function occurs in the setting of pulmonary arterial vasodilatation due to improved alveolar oxygenation with increased left atrial and left ventricular filling, acute left ventricular dysfunction and pulmonary edema can result. Cases have been reported in patients with a history of pulmonary edema or low left ventricular ejection fractions or in patients with sudden fluid shifts from volume overload. Acute pulmonary edema appears to be more common in monoplace than multiplace treatment settings, perhaps because of the requirement for patients to be in a more supine position in the monoplace chamber rather than the sitting position with legs dependent available in the multiplace chamber.

Procedure

Many patients receiving hyperbaric oxygen treatment have severe peripheral arterial disease or diabetes mellitus. These patients are at increased risk for coronary artery disease and occult left ventricular dysfunction. Have a high index of suspicion for prior episodes which could represent congestive heart failure, especially in patients with renal failure, on dialysis, who may be prone to rapid changes in fluid volume. Obtain an echocardiogram in any patient with a history of congestive heart failure, and when abnormal, refer these patients for evaluation and optimization by a cardiologist. While an absolute safe cutoff for left ventricular ejection fraction cannot be defined, patients with ejection fractions of less than 30% should be considered at very high risk for HBOT induced acute pulmonary edema. Weigh renal failure patients daily before HBOT to determine if excessive fluid retention is present. Monitor these patients observationally closely, and have a low threshold to abort treatment at the first sign of respiratory distress.

Reference: Larson-Lohr V, Norvell H, Josefsen L, Wilcox J et al. Hyperbaric Nursing and Wound Care. Flagstaff, AZ: Best Publishing Company; 2010.

Date:_____

Name:_____

Post-Test
Treating the Dialyzes patient

1. Acute pulmonary edema appears to be more common in monoplace than multiplace treatment settings.

   (circle) True False

2. The may be due to the requirement for patients to be in a more _____position in the monoplace chamber rather than the _____position with legs dependent available in the multiplace chamber**.**

3. You should weigh renal failure patients daily before HBOT to determine if excessive fluid retention is present.

   (circle) True False

4. Hyperbaric oxygen exposure will not produce significant hemodynamic changes.

   (circle) True False

5. Patients who have severe peripheral arterial disease or diabetes mellitus are at_____risk for coronary artery disease.

6. List two special precautions that should be taken with the dialyzes patient. _____**and**_____**.**

Ear Barotrauma

Overview: Barotrauma to the ear is the most common complication of hyperbaric therapy. It is more difficult to inflate the middle ear because the inner ends of the Eustachian tubes have slit like openings. These openings tend to close tighter if not opened actively by swallowing, yawning or doing the Valsalva maneuver.

Procedure: If the patient experiences mild to moderate pain, stop the pressurization and decrease to the point of no pain. Make sure the patient does not try to clear while the chamber is decompressing. Reinforce equalization techniques and continue to pressurize when patient states they have no more discomfort. If patient experiences severe pain and it is not relieved by stopping the pressurization or decompressing, remove patient from the chamber and notify the Hyperbaric Physician.

Ear Exam: Classification system for the degree of ear squeeze is based on the appearance of the ear drum. It was devised by Wallace Teed, a United States Navy Submarine Medical Officer during World War II.

TEED SCALE
TEED 0 - Symptoms with no physical findings
TEED 1 - Erythema or injection around the handle of the malleus
TEED 2 - Erythema or injection of the entire tympanic membrane
TEED 3 - Hemorrhage into the tympanic membrane appearing as bright red patches
TEED 4 - Deep blue/black appearance of the tympanic membrane due to blood filling the middle ear with the possibility of rupture present.
TEED 5 - Perforated ear drum

References: Eric P. Kindwall, Hyperbaric Medicine Practice, Chapter 4 pp. 51
Larson-Lohr, Norvell, Hyperbaric Nursing, pp. 87,127,140

Date:_____

Name:_____

Post-test
Ear Barotrauma

2. What is the most common complication of Hyperbaric Therapy _____.

3. The TEED Scale was developed to assess patients for potential oxygen seizures. (circle) True False

4. Patients should be instructed not to try to equalize during_____.

5. Equalizing techniques include all of the following except: Valsalva, Yawning, Blinking, Swallowing _____.

6. Hemorrage in the tympanic membrane is classified as a TEED 1. (circle) True False

Chamber Inspection

Background

The following is inspection requirements, they apply to both Class A and Class B as appropriate, it is for information to add to your knowledge base.

Procedure

2.3.6.7 INSPECTION OF PRESSURE VESSELS FOR HUMAN OCCUPANCY (PVHO's)

A pressure vessel for human occupancy (PVHO), as defined by ASME PVHO-1 is a pressure vessel that encloses a human being or animal within its pressure boundary while it is subject to internal or external pressure that exceeds a 2 psi differential pressure. PVHO's include, but are not limited to submersibles, diving bells, personal transfer capsules, decompression chambers, recompression chambers, hyperbaric chambers, high altitude chambers and medical hyperbaric oxygenation facilities.

This section provides guidelines for inspection of PVHO's. Due to the many different designs and applications of PVHO's, potential failures of components or safety concerns that are not specifically covered, such as rapid decompression or Fire/sparking issues should be considered.

Operational

1) PVHO's must be constructed in accordance with ASME PVHO-1 and PVHO-2. These codes adopt Section VIII and therefore the vessels should bear a "U" or "U2" ASME stamping.
2) Cast and ductile iron fittings are not allowed.
3) Due to the human occupancy element, a person should be in attendance to monitor the PVHO, when in operation, in the event there is an accident.
4) Because of the human occupancy element, these vessels should have a depressurization rate less than 145 PSI/sec.
5) The installation should be such that there is adequate clearance to inspect it properly. In some applications, such as underground

tunneling, it may be impossible to perform a complete external inspection.

Internal Inspection

1) Where existing openings permit, perform a visual internal inspection of the vessel. Look for any obvious cracks and note areas that are subject to high stress such as welds, welded repairs, head-to-shell transitions, sharp interior corners, and interior surfaces opposite external attachments or supports.

2) The vessel should be free of corrosion, damage, dents, gouges or other damage.All openings leading to external fittings or controls should be free from obstruction.

3) All exhaust inlets should be checked to prevent a chamber occupant from inadvertently blocking the opening.

External Inspection

1) The Inspector should closely examine the external condition of the pressure vessel for corrosion, damage, dents, gouges or other damage.

2) The lower half and the bottom portions of insulated vessels should receive special focus, as condensation or moisture may gravitate down the vessel shell and soak into the insulation, keeping it moist for long periods of time. Penetration locations in the insulation or fireproofing such as saddle supports, sphere support legs, nozzles, or fittings should be examined closely for potential moisture ingress paths. When moisture penetrates the insulation, the insulation may actually work in reverse, holding moisture in the insulation and/or near the vessel shell.

3) Insulated vessels that are run on an intermittent basis or that have been out of service require close scrutiny. In general, a visual inspection of the vessel's insulated surfaces should be conducted once per year.

4) The most common and superior method to inspect for suspected corrosion under insulation (GUI) damage is to completely or partially remove the insulation for visual inspection. The method most commonly utilized to inspect for GUI without insulation removal is by x-ray and isotope radiography (film or digital) or by real time radiography, utilizing imaging scopes and surface profilers. The real time imaging tools will work well if the vessel geometry and insulation thickness allows. Other less common methods to detect GUI include specialized electromagnetic methods (pulsed eddy current and electromagnetic

waves) and long range ultrasonic techniques (guided waves).
5) There are also several methods to detect moisture soaked insulation, which is often the beginning for potential GUI damage. Moisture probe detectors, neutron backscatter, and thermography are tools that can be used for GUI moisture screening.
6) Proper surface treatment (coating) of the vessel external shell and maintaining weather tight external insulation are the keys to prevention of GUI damage.

Inspection of Parts and Appurtenances (piping systems, pressure gage, bottom drain)

1) As stated above, cast iron is not allowed on PVHO's and shall be replaced with parts fabricated with other suitable materials, in accordance with ASME Code Section II,
2) If valves or fittings are in place, check to ensure that these are complete and functional.
3) The Inspector shall note the pressure indicated by the gage and compare it with other gages on the same system. If the pressure gage is not mounted on the vessel itself, it should be ascertained that the gage is installed on the system in such a manner that It correctly indicates actual pressure in the vessel.
4) The Inspector shall verify that the vessel is provided with a drain opening.
5) The system should have a pressure gage designed for at least the most severe condition of coincident pressure in normal operation. This gage should be clearly visible to the person adjusting the setting of the pressure control valve. The graduation on the pressure gauge shall be graduated to not less than 1.5 times the MAWP of the vessel.
6) Provisions should be made to calibrate pressure gages or to have them checked against a standard test gage.
7) Any vents and exhausts should be piped at least 10 feet from any air intake.
8) Venting should be provided at all high points of the piping system.

Inspection of Viewports / Window

1) Each window should be individually identified and be marked in accordance with PVHO-1
2) If there are any penetrations through windows, they must be circular.
3) Windows must be free of crazing, cracks and scratches.
4) Windows and viewports have a maximum interval for seat/seal

inspection and refurbishment. Documentation should be checked to ensure compliance with PVHO- 2, Table 7.1.3.

Inspection of Pressure Relief Devices

1) Pressure relief devices must have a quick opening manual shutoff valve installed between the chamber and the pressure relief device, with a frangible seal in place, within easy access to the operator.
2) The pressure relief device shall be constructed in accordance with ASME Gode Section Vlll.
3) The discharge from the pressure relief device must be piped outside to a safe point of discharge.
4) Rupture disks may be used only if they are in series with a pressure relief valve, or when there is less than 2 cubic feet of water volume.
5) Verify that the safety valve is periodically tested either manually by raising the disk from the seat or by removing and testing the valve on a test stand.

Acceptance Criteria (PVHO certified technician only)

The following forms are required to be completed:

1) Form PVHO-1 Manufacturer's Data Report for Pressure Vessels for Human Occupancy
2) Form PVHO-2 Fabrication Certification for Acrylic Windows
h) All PVHO's under the jurisdiction of the U.S. Coast Guard must also comply with 46 CFR Part 197.

References: PVHO-1, PVHO – 2, AMSE website

Date:_____

Name:_____

Post Test Chamber Inspection

1. Because of the human occupancy element, these vessels should have a depressurization rate less than 145 PSI/sec

. (circle) True False

2. The Inspector should closely examine the condition of the pressure vessel for corrosion, damage, dents, gouges or other damage

3. In general, a visual inspection of the vessel's insulated surfaces should be conducted once per year.

(circle) True False

4. If a patient is at 2 ATA and you decompress the chamber at a rate of 5.0 psi/min how long will it take the patient to decompress?

__ ____

Pressure relief devices must have a quick opening manual shutoff valve installed between the chamber and the pressure relief device, with a frangible seal in place, within easy access to the operator.

(circle) True False

LEFT BLANK INTENTIONALLY

Insert your chambers yearly
Service / Maintenance Report(s) Here

(See attached sample)

QUARTERLY QUALITY ASSURANCE OF EMERGENCY PROCEDURES

REQUIREMENTS: One Fire Safety Drill each quarter. Choose one of the other three topics each quarter.

TOPICS	DATE	MET	NOT MET	COMMENTS
Fire Safety				
Cardiac/Respiratory Arrest				
Pneumothorax Under Pressure				
Seizures in the Hyperbaric Chamber				

SAFETY DIRECTOR_____**MEDICAL DIRECTOR**_____

DEPARTMENT OF HYPERBARIC MEDICINE

II. HYPERBARIC ADVERSE EVENTS

ADVERSE EVENTS

1. Ear Squeeze
2. Sinus Squeeze
3. Oxygen Toxicity – *CNS & Pulmonary*
4. Nausea / Vomiting
5. Pneumothorax

ADVERSE EVENTS

6. Air Embolism
7. Seizure – *Oxygen Related, Diabetic Related , Other*
8. Confinement Anxiety
9. Diabetic Reaction
10. Other – *Please Specify*

MONTH: _____

	Adverse Events	Intervention	Comments

SAFETY DIRECTOR_____MEDICAL DIRECTOR_____

Notes: