Hyperbaric Medicine Consultation and Case Management

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Hyperbaric Medicine
Consultation and Risk Assessment

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Hyperbaric Medicine
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Introduction

- Hyperbaric oxygen therapy is generally consider to be a safe therapeutic modality.
- Complications are generally limited to minor otic barotrauma and the occasional oxygen toxicity seizure.
- Complications may arise that can result in significant morbidity or death.

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Considerations

- Risks may be attributable to:
  - Effects of a high pressure environment
  - Effects of hyperoxia
  - Underlying patient factors and/or co-morbidities
- Proper patient selection requires a systematic analysis of the above factors in concert with the specific indication(s) for HBO.

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Consultation and Risk Assessment

Introduction

- A comprehensive history and directed physical exam should be performed to better identify patient risks within the HBO setting.
- The history and physical exam should specifically address potential areas of concern with respect to exposures to high ambient pressures, significant pressure changes, and a concentrated oxygen environment.

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Consultation and Risk Assessment

Comprehensive Past Medical History

- Special attention should be given to the following systems:
  - Cardiac
  - Pulmonary
  - CNS
  - Ophthalmic
  - Endocrine

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Comprehensive Past Surgical History

- Special attention should be given to the following:
  - Thoracic, lung, or cardiac surgery
  - ENT procedures
  - Ophthalmic surgery
  - Implantable devices

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Directed Physical Exam

- Physical exam findings with specific attention to:
  - Ophthalmic
  - Cardiac
  - Pulmonary
  - Neurologic

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Medication History

- Current / past Rx medications
- Chemotherapeutic drugs
- Hypoglycemic medications
- OTC drugs
- Nutriceuticals
- Alternative meds
- Transdermal drugs
- Implantable drug delivery systems
- Topical medications

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Medication History

- Consideration should be given to medications which may:
  - Lower seizure threshold
  - Enhance oxygen toxicity
  - Promote pulmonary or cardiac toxicity
  - Inhibit wound healing
  - Enhance fire risk

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Laboratory and Radiological Evaluation

- Studies should be considered based on the clinical history, exam and presentation.
- May include the following:
  - Serum glucose
  - ABGs
  - TSH
  - Hgb
  - Anticonvulsant levels
  - Drug screen
  - Pregnancy test
  - CXR/Chest CT
  - Ventilation Scan
  - PFTs

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Introduction

- Attention should be directed towards avoiding or mitigating the potential risks inherent to hyperbaric oxygen.
- Subsequent treatments should be preceded by obtaining an interval history and a brief exam primarily directed at vital signs, ears and sinuses, and the cardiopulmonary systems respectively.

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Historical Considerations

- Fire
- Barotrauma
  - Otic
  - Sinus
  - Dental
  - Pulmonary
- CAGE
- Cataracts
- Myopia
- Seizure
- Exacerbation of CHF
- Claustrophobia

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Fire Risk

- Avoid additional fuel in the chamber.
- Assess for contraband.
- Consider safety of implantable devices with particular attention directed at ICDs.
- Remove medication patches.

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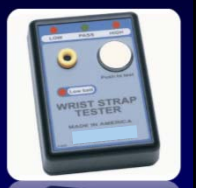
Proper Grounding

- NFPA 99 – 2005 Edition
  20.3.1.5.3.2
  "In Class A and B chambers with atmospheres containing more than 23.5% oxygen by volume, electrical grounding of the patient shall be ensured by the provision of a high-impedance conductive pathway in contact with the patient's skin."



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Otic/Sinus/Dental Barotrauma

- Otic barotrauma is the most common complication of HBO therapy.
- Typically can be avoided with proper patient education and appropriate compression rates.
- Patients with a h/o head and neck radiation or upper airway congestion are at greater risk.
- Patients with previous perforation are at greater risk for recurrent TM rupture.

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Otic/Sinus/Dental Barotrauma

- Consideration should be given to PE tubes for those who can not easily undergo compression or have recurrent barotrauma.
- Needle myringotomy should be considered for emergent indications where patients are intubated or unable to follow commands.

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Prophylactic Myringotomy

- Utilize a 22 ga. spinal needle bent at an angle.
- Hotchkiss operative oticoscope facilitates procedure.

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Otic/Sinus/Dental Barotrauma

- Sinus barotrauma is less common but can cause significant morbidity.
- Contributing pathological factors include:
  - Deviated septum / Polyps
  - Allergies
  - URI
  - Neoplasms
  - Therapeutic radiation

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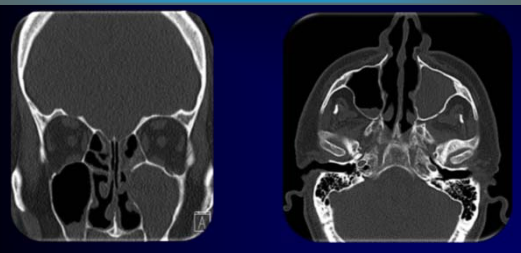
Otic/Sinus/Dental Barotrauma



Maxillary sinus squeeze with hemorrhage

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Pulmonary Barotrauma

~ transtracheal pressures of 70-80mmHg
- Polack & Adams, 1932

- Alveolar membrane failure
- A change in transpulmonary pressure of 70 – 80 mmHg is sufficient.
- Equivalent to an ascent from a depth of only ~1 meter of sea water (1.5 psi).

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Pulmonary Barotrauma

- A positive relationship exists between adhesions, pleural damage, and pneumothorax.
- A negative relationship exists between parenchymal damage and fixed structures such as scars.

Calder IM. Autopsy and experimental observations on factors leading to barotrauma in man. *Undersea Biomedical Research* 1985;12:165-182.

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Predisposing Factors

- Obstructive diseases
  - Asthma
  - COPD
  - Emphysema
- Obstructive lesions
  - Broncholiths
  - Foreign body
  - Neoplasm

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Predisposing Factors

- Pulmonary scarring / traction
  - Trauma
  - Infection / inflammation
  - Thoracic surgery
  - Interstitial fibrosis
  - Granulomatous disease
  - Connective tissue disease

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Definitive Pulmonary Barotrauma Risks

- Untreated pneumothorax
- History of spontaneous pneumothorax
- Bronchogenic cyst
- Bullous lung disease

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Untreated Pneumothorax

- Absolute contraindication to HBO
- Expiratory Chest films should be obtained in patients who have:
  - Sustained chest trauma
  - Undergone chest compressions
  - Undergone chest procedures – especially central venous catheterization

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Spontaneous Pneumothorax

- Patients who have experienced a spontaneous pneumothorax are at risk for recurrences.
  - Particularly true within the succeeding 12 months
  - Patients who have not undergone pleurodesis

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British Thoracic Society Air Travel Recommendations - 2011

- Previous pneumothorax
  - Treated with thoracotomy and surgical pleurodesis / talc insufflation, then no subsequent travel restriction
  - Non-talc pleurodesis associated with a continued risk of recurrence
  - With no definitive procedure, recurrence is expected and air travel is not recommended

British Thoracic Society Standards of Care Committee Air Travel Working Party. *Thorax*, 2011;66:i1ei30

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British Thoracic Society Air Travel Recommendations - 2011

- Traumatic pneumothorax
  - Flight allowed 2 weeks after full radiographic resolution
- Thoracic surgery
  - Air travel should be delayed for at least 2 weeks after uncomplicated surgery.
  - CXR confirmation of pneumothorax resolution
  - Careful medical assessment prior to flight

British Thoracic Society Standards of Care Committee Air Travel Working Party. *Thorax*, 2011;66:i1ei30

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Gas Resorption

Breathing 100% oxygen at 2.8 ATA may enhance the resorption of extrapleural air by some 30 fold relative to air breathing at 1 ATA

Van Liew AD, Schoenfisch WH, et.al. Exchanges of N_2 between a gas pocket and tissue in a hyperbaric environment. *Respir Physiol*, 1968;6: 23-28.

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Gas Resorption

- Gas embolism is more frequently encountered in association with diving activities.
- Gas embolism appears to be rare in pulmonary barotrauma resulting from mechanical ventilation, exposure to altitude, or in the setting of spontaneous pneumothorax.

Moon R, Stolp B. Diving and the lung. *SPUMS*, 1997;27:205-218.

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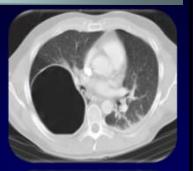
Bronchogenic Cyst

- A number of fatalities have been reported in patients with a bronchogenic cyst exposed to decreased ambient pressures.
- At least 6 reported cases of CAGE during air travel
- One case with excursion to altitude on a railway in the Bernese Alps



Air Embolism during an Aircraft Flight in a Passenger with a Pulmonary Cyst: A Favorable Outcome with Hyperbaric Therapy . *Anesthesiology* - Volume 101, Issue 2 (August 2004)

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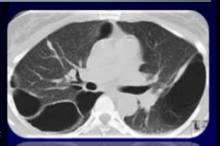
Bullous Emphysema

- Wolf (1990) and Rivalland (2010) reported CAGE occurring during HBO treatment.
- Churchill (2006) reported successful treatment of patient with COPD despite long time constants (range 2-18 min).
- Patient with bullous disease and a time constant in excess of 40 minutes was excluded from HBO.



Wolf, HK et al. Barotrauma and air embolism in hyperbaric oxygen therapy. *Am J Forensic Med Pathol* 1990;11:49-53.
Rivalland G, Mitchell SJ. Pulmonary barotrauma and cerebral arterial gas embolism during hyperbaric oxygen therapy. *Aviation, Space, and Environmental Med* 2010;81:888-890.
Churchill, S Weaver, LK. Hyperbaric oxygen in patients with delayed ventilation. *UHMS* 2006;33:350.

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Patient Assessment

- Consider pre-treatment CXR based on history and physical exam findings.
- Inform radiologist of concern over cystic or bullous disease with intention of HBO therapy.
- Chest CT is more sensitive for identification of cystic lesions but likely too sensitive.
- Reserve CT scanning for highly suspicious cases and those with equivocal CXRs.

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Patient Assessment

- PFTs have not been predictive with regards to pulmonary barotrauma in the HBO setting.
- ABGs can identify those with CO_2 retention and blunted respiratory drive under hyperoxia.
- Inert gas ventilation scans have been suggested to assess for lung segments with excessively long time constants.
- Ventilation scans may over estimate the risk due to inert gas vs. oxygen.

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Patient Management

- Maximize medical therapy for obstructive lung disease as applicable.
- Bronchodilators should be utilized prior to HBO for those with reversible airway compromise.
- Bronchodilators should be made available in the chamber for use prior to decompression as needed.

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Patient Management

- Exercise caution with heavy sedation and paralytic agents.
- Consider prophylactic tube thoracostomy with Heimlich valve as appropriate.
- Utilize a slow decompression rate (0.5 psi/min).

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Pulmonary Pathology

- HBO is generally well tolerated in patients with underlying lung pathology.
- Tension pneumothorax is rarely encountered as a result of HBO.
- Decompression, in the setting of a pneumothorax, can typically be accomplished without clinical decompensation.

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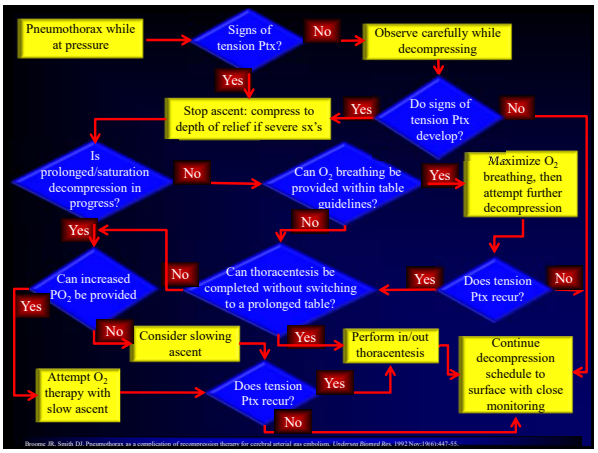

Broome JR, Smith DJ. Pneumothorax as a complication of recompression therapy for cerebral arterial gas embolism. *Undersea Biomed Res.* 1992 Nov;19(6):447-55.

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Hyperthyroidism

- Hyperthyroidism is a relatively common disorder and may go clinically undiagnosed i.e. low levels of TSH without overt clinical symptoms.

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Hyperthyroidism

- Hyperthyroidism increases the susceptibility to oxygen toxicity in both lung and brain.
- Exogenous sources must also be considered.

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Hyperthyroidism

- Consider TFTs if clinical findings are suggestive of hyperthyroidism: tremor, hyperreflexia, tachycardia, HTN, weight loss.
- Be mindful of those who may escalate the dose of their thyroid replacement medication prescribed for a hypothyroid state.

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CNS Oxygen Toxicity

- Oxygen toxicity is relatively rare in oxygen pressure ranges < 2.0 ATA (~1:10,000 tx).
- Patients treated at higher pressures or with a higher acuity are at greater risk.
- Patient should be screened and treated for predisposing factors where applicable.

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CNS Oxygen Toxicity

- The risk of seizures induced by HBO in epileptic patients is not known.
- Donald (1947) reported no increase in susceptibility in 5 epileptics studied in oxygen diving.
- HBO has been used to kindle seizures in laboratory animals.

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CNS Oxygen Toxicity and Predisposing Factors

- Hyperthermia (Temp > 100° F)
- Hypermetabolic states
- Hypoglycemia
- Hypomagnesemia
- Hypercapnia (acute)
- Hyperthyroidism
- Hyperinsulinemia

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CNS Oxygen Toxicity and Predisposing Factors

- Systemic sympathomimetic drugs
- Corticosteroids
- Aspirin
- Opiates
- Ascorbic Acid (high doses)
- Penicillin (high dose)
- Second generation anticonvulsants (carbonic anhydrase inhibition)

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CNS Oxygen Toxicity and Predisposing Factors

- Oxygen toxicity seizures have been shown to increase the risk of subsequent seizures for several days following the event.
- Chavko (2002) reported a significant increase in Brain Derived Neurotrophic Factor (BDNF) after hyperbaric oxygen induced seizures.

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CNS Oxygen Toxicity and Predisposing Factors

- BDNF levels remained elevated in the cortex 2 hours after the seizure and returned to the control level after 24 hours.
- Elevated BDNF levels following HBO induced seizures may increase sensitivity to hyperbaric hyperoxia for several days.

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Patient Management

- Check blood glucose in all diabetics prior to treatment.
- Assess caloric intake and hypoglycemic medication dosing prior to treatment.
- Supplement blood glucose prior to and during HBO treatment as appropriate.

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Patient Management

- Control fever with appropriate antipyretics when possible.
- Treatment protocol should be adjusted for elevated temperatures.
- Consider altering subsequent treatment protocol after an oxygen toxicity seizure.

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Congestive Heart Failure

- Exacerbation of CHF is a known but, relatively uncommon complication of HBO.
- Affected patients usually develop symptoms late in the 90 minute HBO treatment.
- There appears to be no strong correlation with LV ejection fraction.
- No clear clinical predictors other than degree of decompensation.

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Congestive Heart Failure

- Underlying mechanism of pulmonary edema is not entirely clear.
- There is likely an adverse effect on ventricular wall stress.
- Grassi (2007) reported no evidence of increased B-type natriuretic peptide (BNP) in normal subjects in HBO.
- Yildiz (2008) reported increased NT-proBNP in diabetic patients without overt failure in HBO.

Grassi, P. B-type natriuretic peptide in healthy subjects after exposure to hyperbaric oxygen at 2.5 ATA. *Aviat Space Environ Med* 2007;78:52-53.
Yildiz, S. N-terminal pro-B-type natriuretic peptide levels increase after hyperbaric oxygen therapy in diabetic patients. *Clin Invest Med* 2008;31:E231-E235.

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Management of the Cardiac Patient

- All patients with h/o CHF should be maximally medically managed and well compensated prior to a trial of pressure if the clinical condition allows.
- Lower treatment pressures will potentially lessen the increase in left ventricular afterload.
- Theoretically, air breaks may be of benefit in reducing the oxygen induced vasoconstriction and resulting increased afterload.

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Management of the Cardiac Patient

- Blood pressure should be adequately controlled.
- Anxiety associated with HBO treatments should be adequately addressed.
- Particular attention should be given to the diabetic patient.
- ? Usefulness of BNP assessment

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Predisposing Risk Factors for Cataracts

- Advancing age
- Female predilection
- Exposure to ionizing radiation or UV light
- Corticosteroids
- Alcohol abuse
- Diabetes
- Smoking
- Vitrectomy with intraocular gas

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Pathology

- Oxidation of lens components has been demonstrated.
- Abnormal protein cross-linking
- Loss of soluble protein
- Increase in insoluble proteins
- Decreased levels of glutathione
- Elevated levels of oxidation products

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Case Report

- Palmquist (1984) – reported a nearly a 50% occurrence of cataracts in patients receiving 150-850 HBO treatments (2-2.5 ATA x 100minutes) over a period of 2-12 months.
- Those with clear lenses prior to HBO developed a greater myopic shift during treatment.

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Case Report

- Gazell (2007) – reported development of bilateral cataracts in a 49 y/o patient after 48 HBO treatments at 2.5 ATA.
- 50 y/o WF s/p XRT at the age of 13 treated with HBO for laryngeal radionecrosis.
  - Received 60 treatments at 2.5 ATA
  - Developed increasing myopia 4 months after HBO
  - Diagnosed with bilateral cataracts.

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Myopia

- Evanger (2011) – studied the effects of HBO on phakic and pseudophakic patients.
- HBO at 2 – 2.4 ATA x 90min x 20-30 days.
- Myopic shifts occurred in phakic patients only.
- Biometric measurements indicate that myopic shifts are secondary to changes in the crystalline lens

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Patient Management

- Judicious use of HBO should be employed.
  - Treat only to point of maximal benefit.
  - Treat until patient is competent to heal.
- Obtain an adequate informed consent particularly in patients at higher risk for cataracts.
- Monoplace chamber or head tent conveys the greatest risk.

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In Summary

- HBO remains as safe and effective therapy.
- A careful pretreatment assessment will allow for identification of specific addressable risks.
- Performance of interval patient evaluations will assure continued patient safety and quality of care.
- An ounce of prevention pays significant dividends.

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Hyperbaric Medicine Service
Physician Orders - Level 1

Patient Label:

Diagnosis:_____

ICD 9 Code(s): _____

PHYSICIAN ORDERS

Hyperbaric Oxygen Therapy at _____ ATA O2 for 90 minutes for # _____ TX's.

For a total of _____ TX's. Re-evaluate after how many treatments?: _____

☐ CO Protocol ☐ DCI Protocol: Table _____

☐ Pre treatment CXR ☐ Pre treatment 12-lead ECG ☐Blood sugar pre TX

10 min air break(s) q TX: ☐ one ☐ two ECG monitoring q TX:_____

tcP02 study _____ ☐ In-chamber ☐ Normobaric Repeat tcP02 study after 14 treatments: _____

Medications: _____

Lab works: _____

Other: _____

☐ Bilateral soft 100% cotton restraints: Rationale: ☐ Medical ☐ Behavioral
(Order expires in 24hrs & applies during HBO treatment only; Patient to be assessed every 15 minutes)

_____ _____
HBO Physician Signature **Date/Time**

_____ _____
HBO Nurse Signature **Date/Time**

PHYSICIAN ORDERS

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