Hyperbaric Dosing Guidelines

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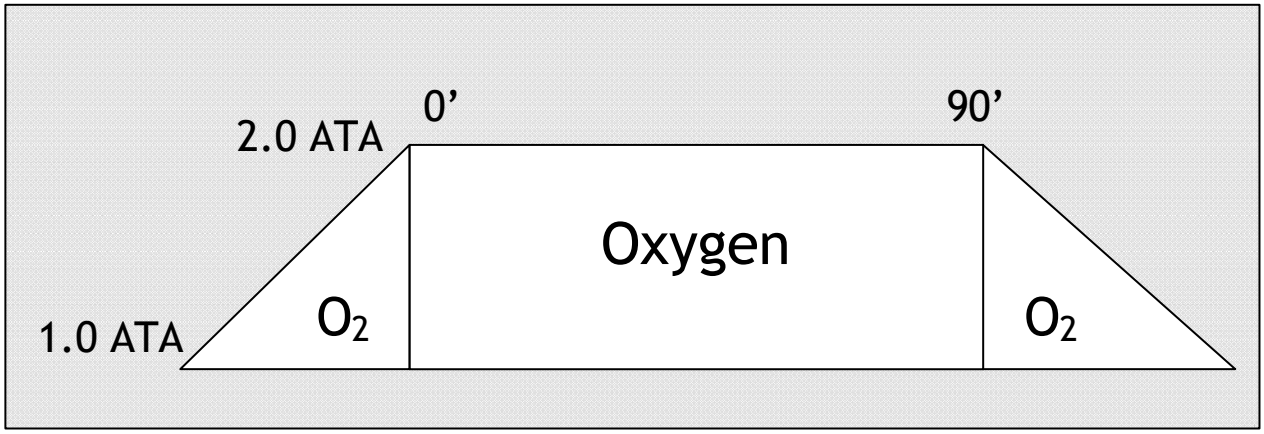
Introduction:

The optimal oxygen dose (pressure, duration, frequency, course) for most hyperbaric medicine's indications is poorly validated. Present day protocols are based largely on work conducted by the U.S. Navy to determine safe pressure/time exposure periods for treatment of decompression sickness. Protocols for decompression sickness are founded on that research, a sound mechanistic rationale and extensive clinical experience. So too the treatment of Clostridial gas gangrene, which is considered maximized at 3.0 ATA oxygen. Protocols in use to treat other infections, deficient healing states and several additional uses lack optimal dosing data. This helps explain considerable variance in the treatment approach as protocols are based more on prevention of CNS oxygen toxicity than a precise dose of oxygen for a specific condition.

Common clinical multiplace dosing involves a 2.36 ATA (45 fsw) *chamber* pressure for elective indications. This generates a hyperbaric *oxygen* pressure somewhat less than 2.36 ATA when patients wear a traditional oral nasal mask. Increasingly, multiplace practitioners have reduced their chamber pressure to 2.0 ATA when patient hoods are used as they represent a more effective oxygen delivery system. This change was principally undertaken to reduce the risk of inside attendant decompression sickness associated with the higher pressure.

The dosing guidelines that follow have been coalesced from available literature, practice recommendations of various professional hyperbaric associations and our experience.

2.0 ATA oxygen x 90 minutes



Indications

Acute exceptional blood loss anemia

Acute peripheral ischemia/crush injury (absent associated ischemia-reperfusion component)

Acute thermal burn injury

Central retinal artery occlusion

Chronic osteomyelitis (without E. Coli or pseudomonas isolates)

Compromised skin flap (absent associated ischemia-reperfusion component)

Diabetic wounds of the lower extremity

Intracranial abscess

Late radiation soft tissue injury

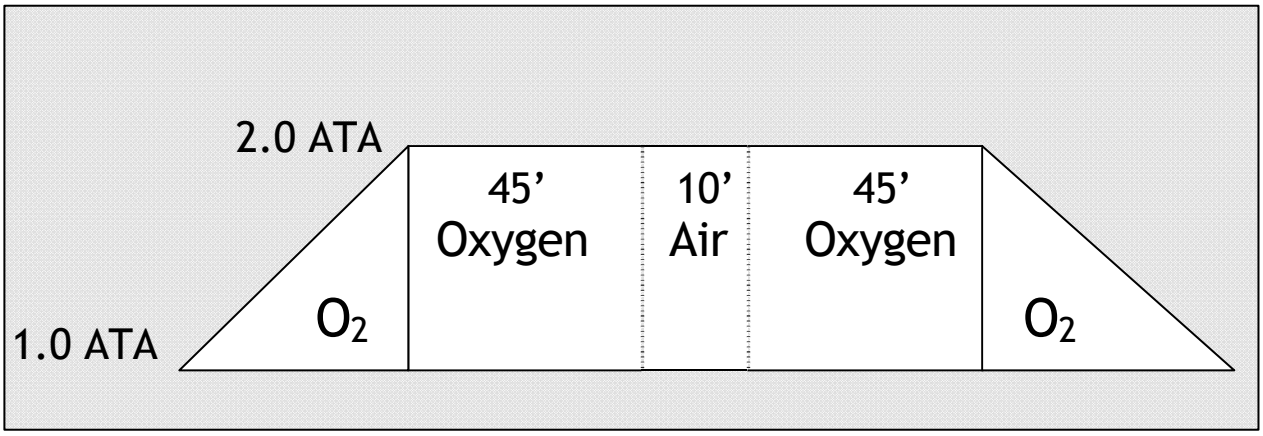
Other problem wounds

Preparation of wounds for skin grafting

Sudden sensorineural hearing loss

2.0 ATA oxygen x 90 minutes with 10 min air break

(High Seizure Risk)



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Diabetic wounds of the lower extremity

Intracranial abscess

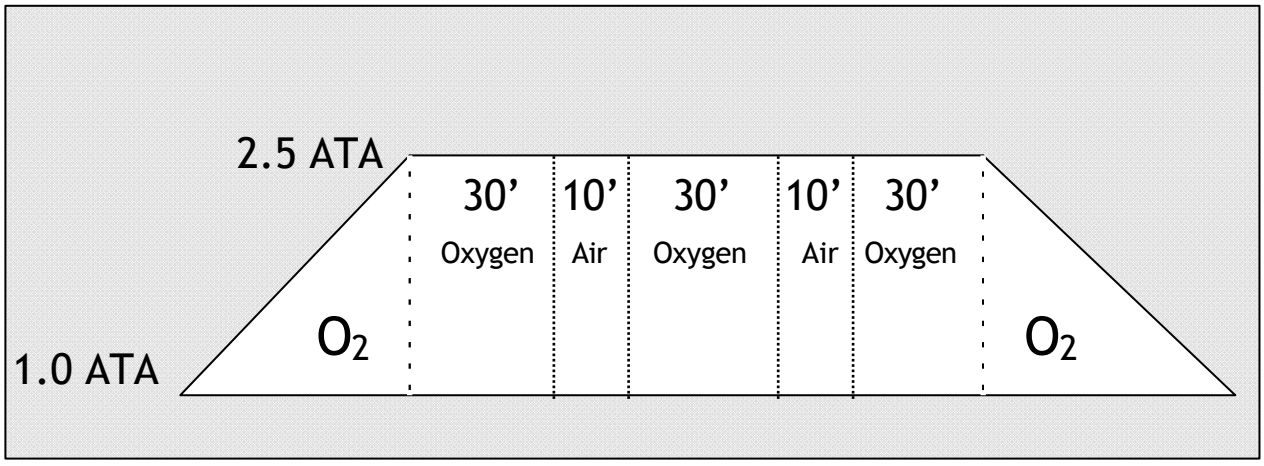
Late radiation soft tissue injury

Other problem wound support

Preparation of wounds for skin grafting

Sudden sensorineural hearing loss

2.5 ATA oxygen x 90 minutes



Indications

Acute peripheral ischemia/crush injury (involving ischemia-reperfusion component)

Chronic osteomyelitis (pseudomonas or E. coli isolates)

Compromised skin flap (with ischemia-reperfusion component)

Osteoradionecrosis - mandible

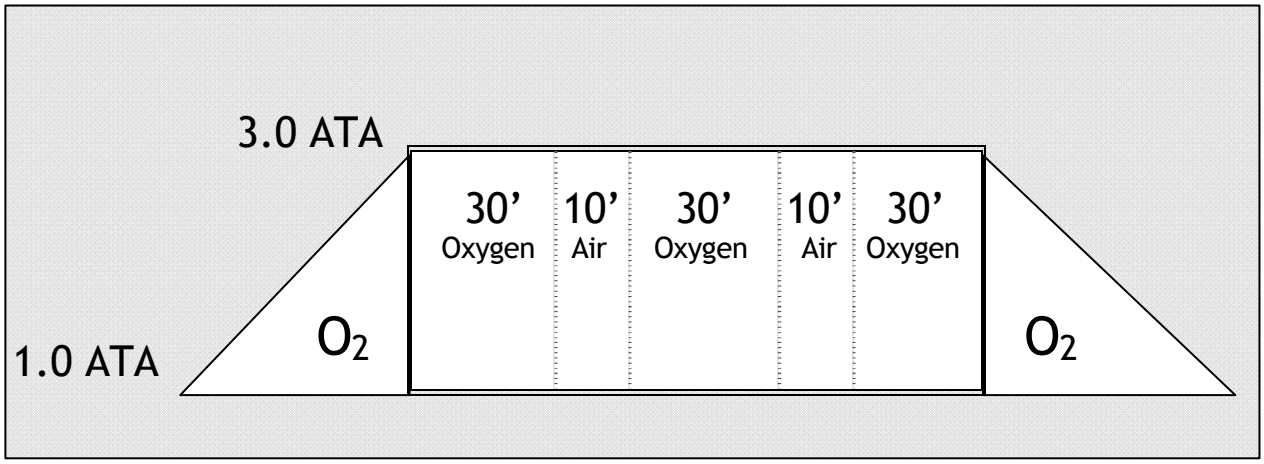
Late radiation tissue injury prophylaxis

Necrotizing soft tissue infections

Replantation limb/digit

Selected invasive fungal infection (aspergillosis; mucormycosis)

3.0 ATA oxygen x 90 minutes



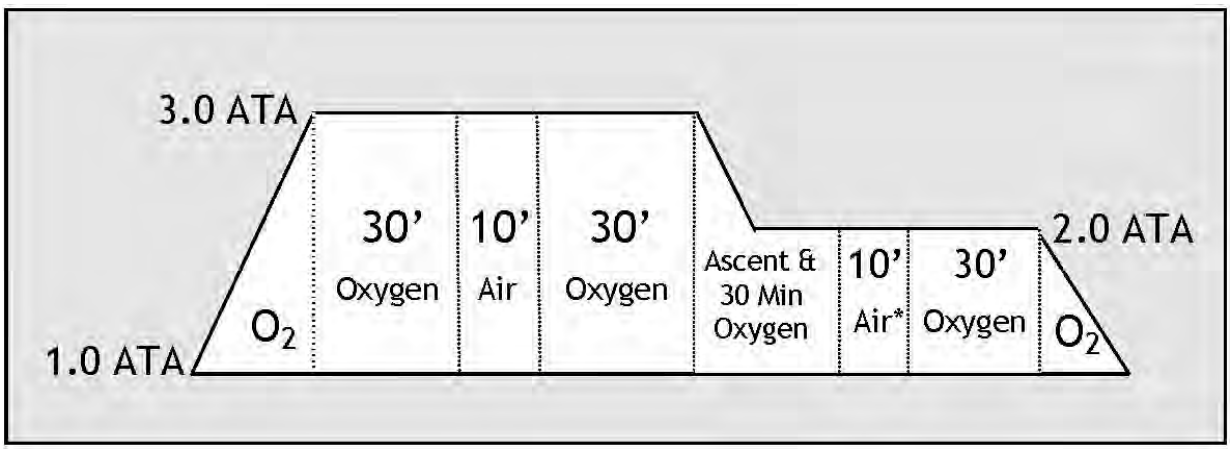
Indications

Acute carbon monoxide poisoning

Clostridial myonecrosis (gas gangrene)

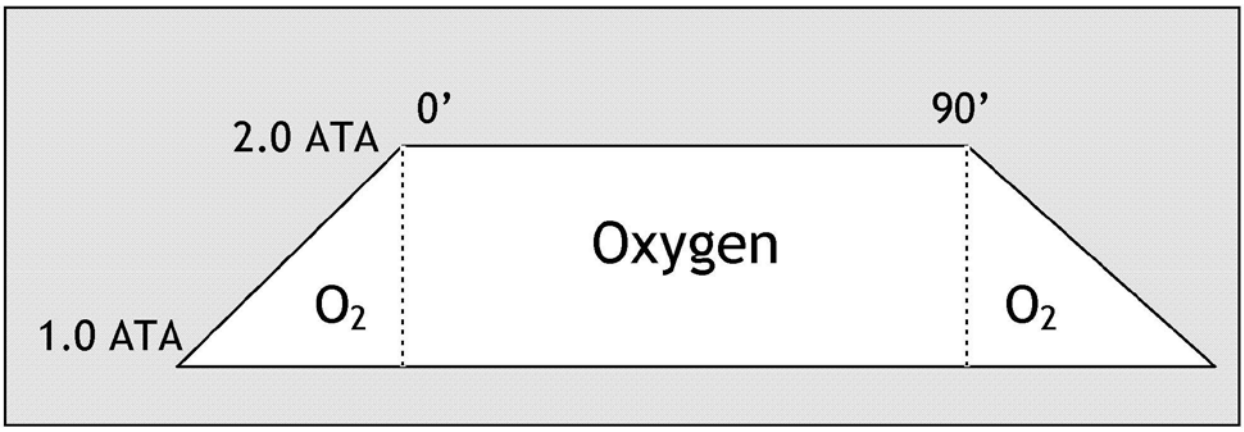
NBS Table ‘E’

Treatment 1



*Initiated 30 minutes after leaving 3.0 ATA

Treatments 2 and 3



Indication

Acute Carbon Monoxide Poisoning (adult and non-pregnant patients)

Treatment Table 5

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1)
5. Treatment Table may be extended two oxygen-breathing periods at the 30-foot stop. No air break required between oxygen-breathing periods or prior to ascent.
6. Tender breathes 100 percent O_2 during ascent from the 30-foot stop to the surface. If the tender had a previous hyperbaric exposure in the previous 18 hours, an additional 20 minutes of oxygen breathing is required prior to ascent.

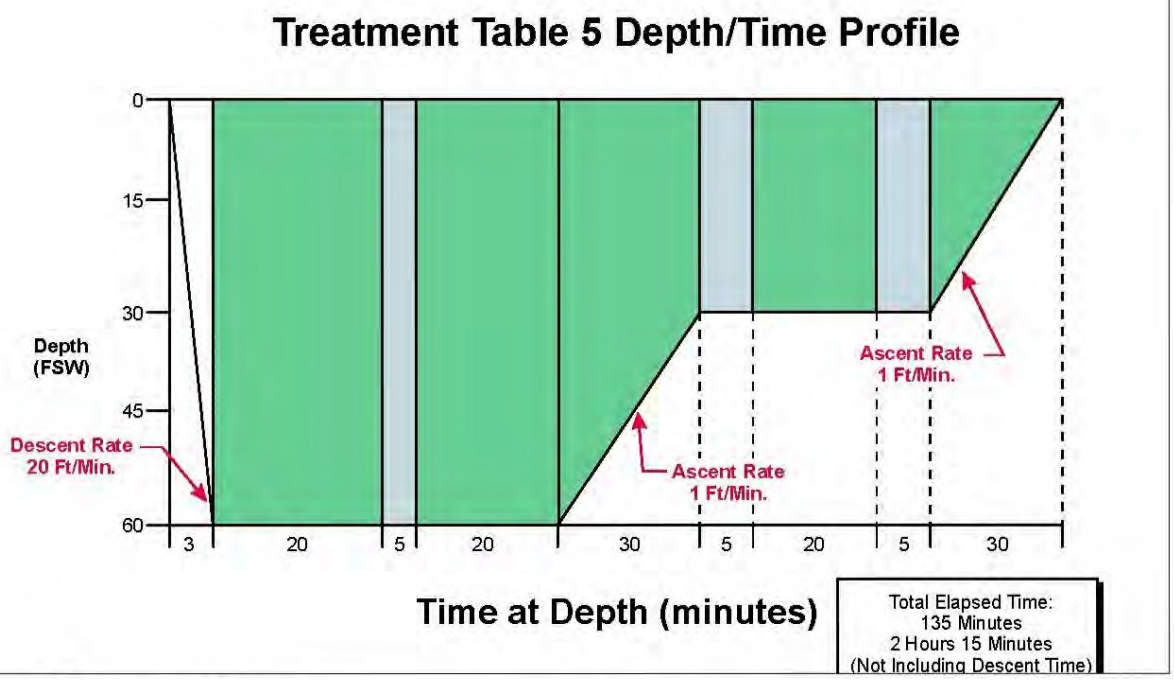


Figure 17-4. Treatment Table 5.

*In a hyperbaric monoplace chamber operating on psig measurements, compress at the rate patients can comfortably tolerate and decompress at a rate of 1 psig every 2 mins.

30 fsw = 13.3 psig (1.9 ATA)
60 fsw = 26.7 psig (2.8 ATA)

Treatment Table 6

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1).
5. Table 6 can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (15 minutes on air and 60 minutes on oxygen), or both.
6. Tender breathes 100 percent O_2 during the last 30 min. at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 feet. If there has been more than one extension, the O_2 breathing at 30 feet is increased to 60 minutes. If the tender had a hyperbaric exposure within the past 18 hours an additional 60-minute O_2 period is taken at 30 feet.

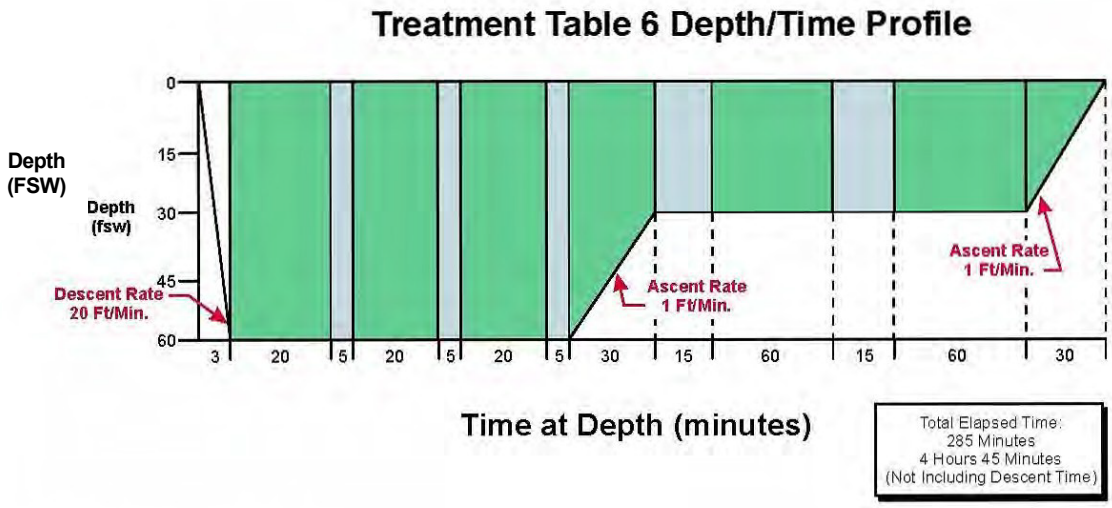


Figure 17-5. Treatment Table 6.

*In a hyperbaric monoplace chamber operating on psig measurements, compress at the rate patients can comfortably tolerate and decompress at a rate of 1 psig/2 min

30 fsw = 13.3 psig (1.9 ATA)
60 fsw = 26.7 psig (2.8 ATA)

Treatment Table 9

1. Descent rate - 20 ft/min.
2. Ascent rate - 20 ft/min. Rate may be slowed to 1 ft/min depending upon the patient's medical condition.
3. Time at 45 feet begins on arrival at 45 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, oxygen breathing may be restarted 15 minutes after all symptoms have subsided. Resume schedule at point of interruption (see paragraph 20-7.11.1.1).
5. Tender breathes 100 percent O_2 during last 15 minutes at 45 feet and during ascent to the surface regardless of ascent rate used.
6. Patient may breathe air or oxygen during ascent.
7. If patient cannot tolerate oxygen at 45 feet, this table can be modified to allow a treatment depth of 30 feet. The oxygen breathing time can be extended to a maximum of 3 to 4 hours.

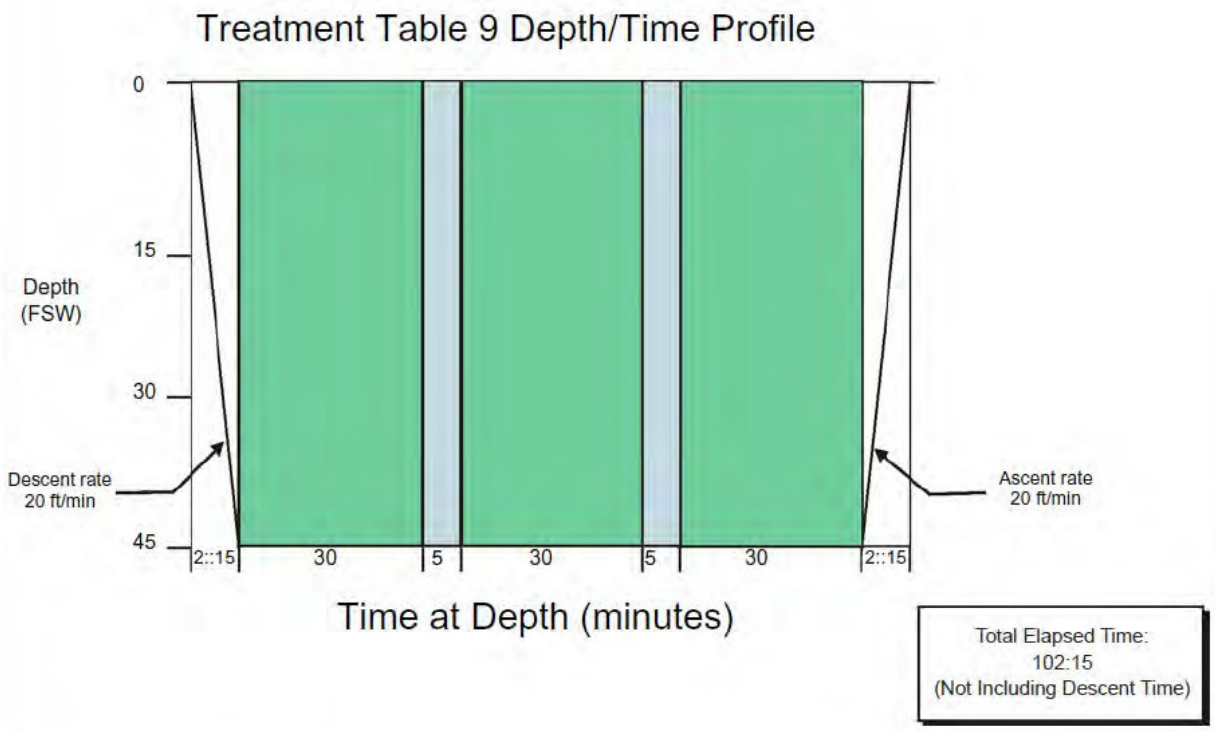


Figure 20-10. Treatment Table 9.

*Compress and decompress at a rate patients can comfortably tolerate.
45 fsw = 20 psig (2.36 ATA)

1. CARBON MONOXIDE POISONING

-including smoke inhalation and cyanide poisoning

Hyperbaric oxygen serves to:

i. hasten elimination of carbon monoxide from hemoglobin and other tissues

ii. oxygenate hypoxic tissues via increases in physically dissolved oxygen, and

iii. antagonize brain lipid peroxidation

HBO Protocol:

Options exist. One is the 2002 'Weaver Protocol.' (an RCT that did not include pregnant or pediatric patients). This involves three treatments, Q 8 hours within 24 hours in accordance with the NBS Table E. Prior to the Weaver study, initial treatment was 3.0ATA oxygen for 90 minutes. Where symptoms persist, or a post-treatment psychometric test appears abnormal, repeat treatment is administered within eight to twelve hours at 2.0ATA oxygen. Weaver's 2023 RCT, however, determined no difference in outcome between one and three treatments.

Utilization Review: 3 treatments

2. CEREBRAL ARTERIAL GAS EMBOLISM

-decompression or iatrogenically induced

Hyperbaric oxygen serves to:

i. reduce/eliminate intravascular and other free gas formation

ii. oxygenate ischemic/hypoxic tissues

iii. reduce edema

HBO Protocol:

US Navy Treatment Table 6; with extensions at 60fsw and/or 30fsw, if indicated. Where symptoms or neurological findings remain, repeat HBO, therapy using US Treatment Table 9 on a QD or BID basis, depending upon severity/response.

Utilization Review: 10 treatments.

3. CLOSTRIDIAL GAS GANGRENE

Hyperbaric oxygen serves to:

i. halt production of alpha toxin

ii. limit bacterial proliferation

iii. oxygenate ischemic/hypoxic tissues

iv. improve host defenses

HBO Protocol:

3.0ATA oxygen for 90 minutes. Treatments are given Q. 8 hrs. in the first 24 hrs. Subsequent treatments are given on a BID basis. Ideally, the first treatment should precede surgical debridement, when possible. However, surgical delays to effect transfer of a patient to an institution with a hyperbaric facility are to be avoided. Termination of HBO therapy is based upon toxin response (resolution of hemolysis) unless preparation of resultant wounds for grafting is indicated.

Utilization Review: 10 treatments

4. DECOMPRESSION SICKNESS

Hyperbaric oxygen serves to:

i. overcome intravascular and other free gas formation

ii. oxygenate hypoxic/ischemic tissues

iii. suppress/treat edema

iv. hasten elimination of inert gas

HBO Protocol:

Type I DCS. US Navy Treatment Table 5

Type II DCS. US Navy Treatment Table 6, with extensions at 60fsw and/or 30fsw as indicated.

Where symptoms or neurological findings remain, use US Navy Treatment Table 9. Maintain Table 9 until the patient is asymptomatic or two consecutive treatments have been provided without sustained improvement.

Utilization Review: 10 treatments

5. MANDIBULAR OSTEORADIONECROSIS

Hyperbaric oxygen serves to:

Stimulate angiogenesis, thereby overcoming radiation-induced hypocellular, hypo-vascular, hypoxic tissue. The “3 H Syndrome”.

HBO Protocol:

"The Marx Protocol"

Stage I Small (<3cm) exposed bone. No soft tissue fistula or evidence of fracture. 30 treatments at 2.5ATA oxygen for 90 minutes five days weekly.

Discontinue antibiotics; wound care-saline rinses or self-irrigation only. No bone is surgically removed during Stage I. Wound examined after 30 treatments.

With definite clinical improvement the patient may continue for a total of 40 treatments, to achieve full mucosal cover, if necessary. If no apparent improvement is evident after 30 treatments, patient is classified as a Stage I non-responder and advanced to Stage II.

Stage II Following those initial 30 treatments, the patient undergoes local surgical debridement followed by 10 additional treatments at 2.5ATA oxygen for 90 minutes five days weekly. If the wound dehisces, leaving exposed bone, the patient is identified as a Stage II non-responder and advanced to Stage III.

Stage III Are failed Stage II or those who present initially with extensive bone exposure, pathological evidence of fracture, loss of alveolar bone height and/or fistula. Following 30 treatments (not repeated if previous Stage II) at 2.5ATA oxygen for 90 minutes the patient undergoes a transoral partial jaw resection with fixation. Primary closure of soft tissue defect occurs at this point.

Ten additional hyperbaric treatments follow then the patient advanced to Stage III-R.

Stage III-R Approximately ten weeks after resection the soft tissue defect is commonly healed, and the potential graft recipient bed typically free of infection and contamination.

Formal mandibular reconstruction is undertaken, followed by 10 additional hyperbaric treatments if indicated.

Note: Mandibular resection/reconstruction in the modern era involves a microvascular surgery-based single stage resection and reconstruction using a free (commonly fibula) flap. This is undertaken without peri-operative HBO therapy. The Marx Stage III approach would likely be employed today in the absence of a microvascular capabilities.

Utilization Review: 60 treatments.

6. ACUTE EXCEPTIONAL BLOOD LOSS ANEMIA

Hyperbaric oxygen serves to:

ii. increase physically dissolved oxygen concentrations

iii. overcome hypoxic/ischemic tissue states

HBO Protocol:

Highly individualized/case-by-case based upon degree of oxygen debt. Hyperbaric treatment, at 2.0ATA oxygen (higher pressures can be considered in more severe cases) for 60-120 minutes, based upon resolution of clinical signs of ischemia, and general status of the patient.

Repeat HBO therapy based upon the patient's clinical condition and rate of "surface interval" deterioration. Treatment frequency may be as short as 1-2 hrs. but more commonly 4-8 hrs.

Utilization Review: Not Applicable (guided by clinical response)

Treatments can be terminated once the patient has improved to the point of no further marked ischemia/hypoxia. HBO may be discontinued when red blood cells have been replaced in sufficient numbers to alleviate preceding signs and symptoms and no remaining evidence of tissue/organ ischemia.

7. ACUTE THERMAL BURNS

Hyperbaric oxygen serves to:

i. limit tissue fluid losses

ii. support marginally perfused subjacent tissues

iii. limit conversion of second degree burns to third degree

iv. minimize edema

v. promote wound closure

HBO Protocol:

2.0ATA oxygen for 90 minutes TID in the first 24 hours in severe cases.

All subsequent treatments are typically provided on a BID basis, again at 2.0ATA oxygen for 90 minutes.

To maximize benefit, HBO should be initiated as soon as possible after wounding. Delays greater than 24 hrs. may limit potential benefit.

Utilization Review: 30 treatments

8. COMPROMISED SKIN GRAFTS AND SKIN FLAPS

-preparation for grafting

Hyperbaric oxygen serves to:

i. improve development of wound granulation tissue

ii. improve angiogenesis

iii. support marginally perfused tissue

iv. improve host responses

HBO Protocol:

A. Preparation for grafting.

2.0ATA oxygen for 90 minutes, on a QD basis five days weekly, typically as an outpatient. Revaluation after 15 treatments (clinically and per transcutaneous oximetry). If there has been no evidence of improved response during this period, consideration should be given to classifying patient a non-responder. If improved healing evident, any further HBO should be coordinated with the surgical specialists to maximize the preparation phase.

B. Where HBO therapy is sought to support threatened skin flaps:

Flap problem mts be identified. Most complications are surgically resolvable. Adequacy of perfusion (consider $tcpO_2$) must exist and time to initiation must be minimal.

2.0ATA oxygen for 90 minutes, on a BID basis initially.

Where response to HBO therapy is apparent, and the flap appears increasingly variable, consider reducing frequency to QD.

Utilization Review: 20 treatments

9. CRUSH INJURY; COMPARTMENT SYNDROME

-other acute ischemias

Hyperbaric oxygen serves to:

i. provide interim oxygenation to hypoxia/ischemic tissue beds

ii. reduce edema

iii. reduce compartment pressures

iv. augment limb salvage

HBO Protocol:

2.0ATA oxygen (2.5ATA oxygen when involving an ischemia-reperfusion component) oxygen for 90 minutes, TID in the first 24 hrs. in severe cases. The value of HBO will be maximized if it is instituted within several hours of injury.

Utilization Review: 14 treatments

10. NECROTIZING SOFT TISSUE INFECTIONS

-including Fournier's Disease

Hyperbaric oxygen serves to:

i. improve host antimicrobial responses

ii. oxygenate hypoxic tissue beds

iii. demarcate potentially viable from non-viable tissue, thereby limiting degree of any ablation.

HBO Protocol:

2.5ATA oxygen for 90 minutes, on a BID basis, initially. As clinical condition improves, and debridement decreases in frequency, consider QD for the next 2-3 days before reevaluating any further need for HBO.

Utilization Review: 30 treatments

11. RADIATION INJURED TISSUE PROPHYLAXIS

Hyperbaric oxygen serves to:

i. stimulate neo-angiogenesis within the hypocellular, hypo-vascular hypoxic tissue bed secondary to late radiotherapy effects.

ii. improves regional vascular density, to better support the healing responses secondary to surgical wounding.

HBO Protocol:

2.5ATA oxygen for 90 minutes QD, five days weekly, for 20 treatments.

Planned surgical procedures undertaken after 20 treatments. Timing of surgery after 20 treatments is not critical. Marx reports delays of several weeks/months have not compromised outcomes.

Immediately (within 24 hrs.) after surgery, patient undergoes post-operative HBO, again at 2.5ATA oxygen for 90 minutes, for 10 treatments, five days weekly.

12. RADIATION TISSUE DAMAGE

-integument and all other soft tissue sites

Hyperbaric oxygen serves to:

i. Reestablish wound oxygen gradient, inducing angiogenesis within the hypocellular, hypo-vascular, hypoxic tissue bed.

ii. prepare partial and full thickness tissue defects for definitive coverage.

HBO Protocol:

2.0ATA oxygen for 90 minutes on a QD basis five days weekly. Reassessment after 20 treatments. If wound progress evident, (clinically and per transcutaneous oximetry) consider holding HBO for seven days. If a critical mass of angiogenesis has been generated, healing is likely to continue spontaneously. If the seven-day follow-up does not result in a sustained healing response, 5- 10 additional treatments are employed. Continue this process until sustained healing evident or until reaching **Utilization Review.**

Utilization Review: 60 treatments

13. REFRACTORY OSTEOMYELITIS

Hyperbaric oxygen serves to:

i. oxygenate hypoxic/ischemic tissues.

ii. augment host antimicrobial responses

iii. produce angiogenesis within the compromised vasculature of chronically infected bone

iv. augment antibiotic therapy

v. augment osteoclastic activity

HBO Protocol:

2.0ATA oxygen for 90 minutes on a BID basis, with inpatients. A QD protocol is acceptable in outpatient therapy. Once the infection appears under control, frequency can be reduced to QD. The extent of the treatment course is not well established, and some controversy exists. Between 20 and 40 treatments will usually be necessary.

Caution should be exercised to avoid premature closure of any soft tissue sinus drainage tracts while underlying bony infection persists.

Where pseudomonas or E. coli is isolated, some prefer 2.5ATA oxygen pressure.

Utilization Review: 60 treatments

14. SELECTED PROBLEM WOUNDS

-diabetic foot wounds, other deficient healing states

-compromised amputations

Hyperbaric oxygen serves to:

i. Reestablish wound oxygen gradient

ii. generate neo-angiogenesis in areas of relative ischemia

iii. augment host antimicrobial responses

iv. prepare wounds for definitive coverage

HBO Protocol:

2.0ATA oxygen for 90 minutes five days weekly. Provide BID therapy should wounds appear limb threatening. Outpatients are managed on a QD basis.

Reassessment after 15 treatments, including $tcpO_2$. Absent any improvement the patient is a possible non-responder and should be worked up for other etiologies that may have been missed.

Where improvement is evident, continue the 5-days weekly dosing. As the wound continues to improve, consider holding HBO therapy, and certainly once tcpO2 values have essentially normalized.

The objective is to reach/identify the point at which the patient becomes locally host-competent and sustains the healing process in the absence of continued HBO.

Utilization Review: 30 treatments

15. INTRACRANIAL ABSCESS

Hyperbaric oxygen serves to:

i. enhance host defenses

ii. reduce peri-focal brain edema

iii. augment treatment of anaerobic flora, and

iv. augment treatment of concomitant skull necrosis

HBO Protocol:

2.0 or 2.5ATA oxygen for 90 minutes. Provide BID or QD, depending upon the patient's neurological status.

The number of hyperbaric treatments is governed by each respective case, in accordance with clinical and radiologic findings.

Utilization Review: 20 treatments

16. SUDDEN SENSORINEURAL HEARING LOSS

HBO Protocol:

2.0-2.5 ATA oxygen for 90 minutes once daily five days weekly for 10 treatments. An additional 10 treatments may be provided, following reevaluation by the referring ENT specialist.

Self-referred patients thought to be suffering SSNHL should first be referred to ENT for definitive testing, including MRI to rule out neuroma/meningioma.

Utilization Review: 20 treatments

17. ACUTE RETINAL ARTERY INSUFFICIENCY

-to include both central and partial retinal occlusion, arterial branch occlusion, and central retinal vein occlusion

Hyperbaric oxygen serves to:

i. provide immediate augmentation of choroidal oxygen supply

ii. provide on-going support of choroidal oxygen supply until circulation is restored by recanalization

HBO Protocol:

Compress to 2.0ATA oxygen for a planned 90 minutes of oxygen breathing

If there is no response within 5 minutes at 2.0ATA oxygen, compress slowly to pressure of visual improvement, not to exceed 2.8ATA oxygen. Two 10-minute breaks are provided for all treatment pressures more than 2.0 ATA. If vision is improving, treat at the pressure achieved on a 90-minute BID basis. If there is no improvement at 2.8ATA oxygen after a 20-minute oxygen breathing period, consider employing US Navy Treatment Table 6.

Continue BID treatments until three consecutive days with no/no additional visual improvement. If the patient is a non-responder, this end point will be following the first three days of treatment.

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