October
2024

HYPERBARIC MONTHLY MEETING

SerenaGroup
Building the Nation's Leading Wound Care Team

TOPIC:

October – Physiology of HBOT and When to Consider Continuation

PRESENTED BY:

Ally

Guest Appearances: Samantha and Kaylyn from Chambersburg

Definitions

Angiogenesis - the development of new blood vessels

Osteogenesis – the formation of bone

Ischemia - an inadequate blood supply to an organ or part of the body

Necrosis - the death of most or all of the cells in an organ or tissue due to disease, injury, or failure of the blood supply

Collagen - the main structural protein found in skin and other connective tissues

Reperfusion Injury - vascular, myocardial, or electrophysiological dysfunction brought about by the return of blood flow to ischemic tissue

Breakdown of...

- Chronic Refractory Osteomyelitis
- Diabetic Foot Ulcer
- Soft Tissue and Osteo Radionecrosis
- Failed Flap/Graft

Chronic Refractory Osteomyelitis (CROM)

- Decreased oxygen tensions, typically associated with bony infections, can be returned to normal or above normal levels during HBOT.
- Neutrophils require tissue oxygen tensions of 30-40 mmHg to destroy bacteria by oxidative killing mechanisms. Leukocyte mediated killing of aerobic Gram-negative and Gram-positive organisms, including Staphylococcus aureus, is restored when the low oxygen tensions intrinsic to osteomyelitic bone are increased to physiologic or supra-physiologic levels. Additionally, HBOT therapy has been noted to exert a direct suppressive effect on anaerobic infections.
- In addition to enhanced leukocyte activity, HBOT can enhance the transport and augment the efficacy of antibiotic action. (cefazolin and HBOT therapy produced a 100-fold greater reduction in bacterial counts than either antibiotics or HBOT alone.) Comparable effects are also seen with HBOT in mitigating localized soft tissue infections. A research study demonstrated a 46% reduction in infection resolution time from a mean of 13 to only 6 days when HBOT was added to antibiotics in the management of soft tissue infections. As infected soft tissues often act as conduits for initiating and sustaining bone infections, HBOT's benefit in ameliorating soft tissue infections may be critical to its overall efficacy in refractory osteomyelitis.
- There is evidence that HBOT enhances osteogenesis. Remodeling of bone by osteoclasts is an oxygen-dependent function. As previously noted, HBOT can restore physiologic or provide supra-physiologic oxygen tension in hypoxic bone environments, thus osteoclast function in infected bone can be improved.
- CROM is characterized by both acute and chronic sources of ischemia. HBOT has been shown to be effective in reducing tissue edema, lowering intra-compartmental pressures and ameliorating the detrimental effects of inflammatory reactions. Over the longer term, HBOT can be used to promote new collagen formation and capillary angiogenesis in both hypoxic bone and surrounding tissues. By creating a sustained increase in the arterial perfusion of previously hypoxic bone and soft tissues, HBOT can reduce the susceptibility of these tissues to recurrent infection and necrosis.

CROM in Layman's Terms

- Bone infections cause a decrease in oxygen in the bone, HBOT increases the oxygen in the bone to normal or even above normal levels.
- HBOT increases the body's natural ability to fight infections and can suppress infection.
- HBOT can enhance the transport and augment the efficacy of antibiotic. (basically, making the antibiotic work better and get to where we need it to go)
- Osteomyelitis creates ischemia in the bone, causing necrosis. HBOT stimulates osteoclast function, making the bone stronger and rebuilding it after damage caused by osteomyelitis, essentially creating osteogenesis.
- HBOT can be used to promote new collagen formation and capillary angiogenesis in both the bone and surrounding tissues.
- By improving the health of the bone and surrounding soft tissues, the likelihood of Osteomyelitis recurring is reduced. And, as we know, the benefits of hyperbaric are usually lasting.

CROM & HBOT When to Continue

- Initially, 20-30 treatments may be ordered. Reassessments every 10 treatments.

- We should consider continuation when our documentation supports that the patient is showing signs of improvement and/or the physician can base their judgement on the severity of disease noted on diagnostic imaging.

- HBOT should be stopped if/when we can no longer justify that the patient is improving or needs to improve.
  - For a patient WITH a wound, this documentation may look like “exposed bone has started to cover over with soft tissue after 30 treatments of HBOT. Will continue HBOT to promote osteogenesis and bone and ulcer healing, as well as to decrease the likelihood of Osteomyelitis recurrence.”
  - For a patient WITHOUT a wound, the documentation may need to reference follow up imaging to be supportive of continuation. “Patient is tolerating HBOT well and is complaining of decreased pain, due to the extent of bone damage, we will continue HBOT for an additional 10 treatments and will consider repeat imaging at that time.”

  - ***HBOT does not need to be discontinued for CROM patients just because the wound heals. They’re in hyperbaric for treatment of the bone. Soft tissue is easier and faster to heal than bone.

Diabetic Foot Ulcer

- A basic pathway to non-healing is the interplay between tissue hypoperfusion, resulting hypoxia, and infection. Evidence demonstrates that intermittent oxygenation of hypo-perfused wound beds, mitigates many of these impediments and sets into motion a cascade of events that leads to wound healing. Physiologically, this produces a directly proportional increase in the plasma volume fraction of transported oxygen that is readily available for cellular metabolism. Availability of substrate for oxygen dependent enzymatic reactions critical to repair and resistance to infection is even more important than normalizing metabolic rate. Furthermore, oxidants appear to be among the most important signals that control the healing process, and this may be another mechanism for the benefits of HBOT in hypoxic wounds. Oxygen diffusion varies in a direct linear relationship to the increased partial pressure of oxygen present in the circulating plasma caused by HBOT. This significant level of hyperoxygenation allows for the reversal of localized tissue hypoxia, which may be secondary to ischemia or to other local factors within the compromised tissue.
- In the hypoxic wound, HBOT acutely corrects the pathophysiology related to oxygen deficiency and impaired wound healing. A key factor in HBOT's enhancement of the hypoxic wound environment is its ability to establish adequate oxygen availability within the vascularized connective tissue compartment that surrounds the wound. Proper oxygenation of the vascularized connective tissue compartment is crucial to the efficient initiation of the wound repair process and becomes an important rate-limiting factor for the cellular functions associated with several aspects of wound healing.
- Neutrophils, fibroblasts, macrophages, and osteoclasts are all dependent upon an environment in which oxygen is not deficient to carry out their inflammatory or repair functions. Improved leukocyte function of bacterial killing and antibiotic potentiation, have been demonstrated. Suppressing growth of many bacterial toxins occurs when tissue oxygen values are elevated, which occurs during HBOT. Dulling of systemic inflammatory responses and prevention of leukocyte activation and adhesion following ischemic reperfusion are effects that may persist after completion of HBOT.
- Stimulation of tissue growth supporting wound healing has also been demonstrated by a variety of mechanisms: 1) Vascular endothelial growth factor (VEGF) release is stimulated, and platelet derived growth factor (PDGF) receptor appearance is also induced. 2) Persistent increases in nitric oxide in wound fluid of diabetic ulcers is associated with increased granulation tissue formation and wound closure when patients are exposed to HBOT.
- The net result of HBOT is improved local host immune response, clearance of infection, enhanced tissue growth and angiogenesis leading to progressive improvement in local tissue oxygenation and healing of hypoxic wounds.

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To make a long story short…

DFUs & HBOT Explained

- HBOT increases oxygenation in the blood plasma and subsequently the wound, reducing hypoxia.
- All of the following are dependent upon an environment in which oxygen is not deficient in order to carry out their specific inflammatory or repair functions…
  - Neutrophils (white blood cells that are your body's first line of defense in an immune response)
  - Fibroblasts (the most common cell in connective tissue – collagen),
  - Macrophages (white blood cell that surrounds and kills microorganisms, removes dead cells, and stimulates the action of other immune system cells.)
  - Osteoclasts (initiate normal bone remodeling and mediate bone loss in pathologic conditions by increasing their resorptive activity)
  - White blood cells (increase the body's natural ability to fight infection)
- Stimulation of tissue growth, creating an increase in granulation tissue and wound healing.
- Overall, improved immune response, clearance of infection, enhanced tissue growth, and angiogenesis lead to progressive improvement in wound healing.

Diabetic Foot Ulcer: When to Consider Continuation

Initially, 20-30 treatments may be ordered. Reassessments every 10 treatments.

The hyperbaric provider should consider continuation when we can document improvement with HBOT, such as decrease in wound size, increase in granulation tissue or healthy bleeding.

Based on medical necessity, HBOT should be stopped if/when the wound is no longer showing signs of improvement or is healed.

***The goal of HBOT is NOT to treat the wound until closure. The goal is to stimulate healing, reduce the risk of amputation, fight infection. (See photo)

Soft Tissue and Osteoradionecrosis

- Because a consistent cause and manifestation of radiation injury is vascular obliteration and stromal fibrosis, the known impact of hyperbaric oxygen in stimulating angiogenesis is an obvious and important mechanism whereby HBOT is effective in radiation injury. HBOT induces neovascularization in hypoxic tissues. Marx has demonstrated the enhanced vascularity and cellularity in heavily irradiated tissues after hyperbaric oxygen therapy by comparing histologic specimens from patients pre- and post- hyperbaric oxygen.
- The impact of hyperbaric oxygen in terms of its beneficial effects in irradiated tissues:
  - 1) Hyperbaric oxygen stimulates angiogenesis and secondarily improves tissue oxygenation;
  - 2) Hyperbaric oxygen reduces fibrosis

Let’s break it down!

Delayed Radiation Damage & HBOT

- Radiation kills everything in its path, good or bad.
- HBOT stimulates angiogenesis, growing new blood vessels. This improves tissue oxygenation.
- HBOT improves vascularity in irradiated bone.
- HBOT reduces fibrosis (fibrosis is thickening or scarring of tissue.)

Marx Protocol for ORN

Prophylactic ORN

20 pre-op HBO treatments
10 post-op HBO treatments

Confirmed ORN

30 pre-op HBO treatments
10 post-op HBO treatments

If there is concern for healing after the initially prescribed protocol, continuation may be considered with appropriate documentation to support further HBO treatments. Such as "mandible is still exposed after extractions and debridement of mandible. Will order an additional 10 HBO treatments to support healing and to prevent further complications of ORN or infection."

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Soft Tissue Radionecrosis & When to Consider Continuation

- Initially, 30 treatments may be ordered. Reassessments every 10 days.
- We should consider continuation when we can justify improvements with HBOT but still aren't out of the "danger zone" for backsliding/wound regression.
- HBOT should be stopped if/when wound heals or the wound is not responding to HBOT at any 10 treatment assessment.

Compromised/ Failed Flap & Graft

- If a flap is found to have less than adequate oxygen after it has been transferred, hyperbaric oxygen can help maximize the viability of the flap or graft while vascularization takes place which can reduce the need for repeat flap procedures.

- Mechanisms underlying these beneficial effects include increased oxygenation, improved fibroblast function, neovascularization, and amelioration of ischemic reperfusion injury by reducing post-operative edema and limiting venous congestion, while accelerating angiogenesis.

Let’s translate that to plain English…

Compromised/ Failed Flap & Grafts Explained…

- Flaps and grafts are one of the only indications for hyperbaric in the outpatient setting that are considered to be acute, because flap/graft salvage has to be done quickly. (“Time is tissue”- the more time that passes without adequate perfusion, the more tissue will die)
- When blood flow is reintroduced to an area, cells can swell, burst, and die.
- HBOT can be the difference between a graft going from Figure A to Figure B, instead of Figure C which would eventually die and need to be repeated.

Figure A.

Figure B.

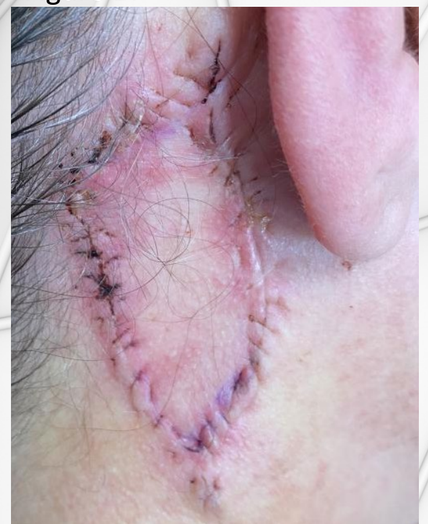
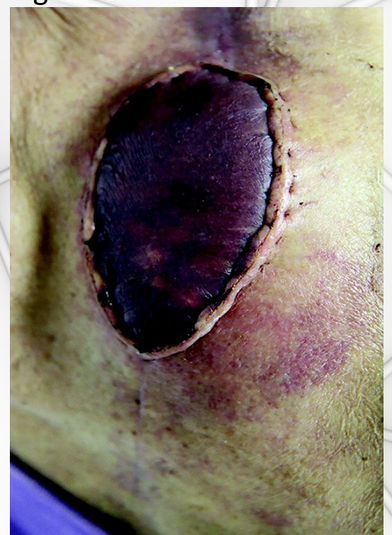


Figure C.



Failed Flap/Graft & When to Consider Continuation

- Initially, 5-10 treatments may be ordered. Reassessments every day. This is different from our normal assessments because we are checking for signs that the graft or flap is perfusing and starting to take.
- We should consider continuing HBOT until we see evidence of revascularization/perfusion.
- HBOT should be stopped if/when the wound is no longer dusky, cold, purple, necrotic and has shown signs of integrating with healthy blood flow or the opposite, if the flap or graft has completely necrosed and needs surgical intervention to repeat the procedure or debride the necrotic tissue. At that time, we may need to consider a new series of HBOT for a new compromised graft/flap.
- ***Again, the goal is not to treat them until complete healing, but to get them on the path to where the graft or flap can survive. More than 20 treatments is very hard to justify medical necessity for.

QUESTIONS?

SOURCES

- UHMS.org
- Hyperbaric Oxygen Therapy for the Compromised Graft or Flap - PMC (nih.gov)

QUIZ

QUESTION 1

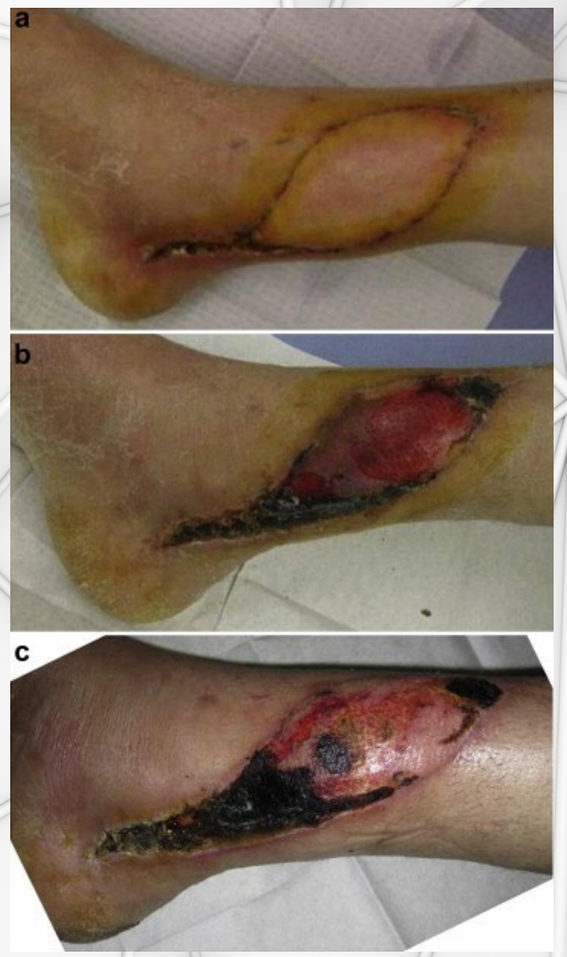
What is angiogenesis?

Answer

The growth of new blood vessels.

QUESTION 2

How often should a reassessment be performed on a failed flap patient?



Answer

Daily.

QUESTION 3

How does hyperbaric work for a Wagner Grade 3 DFU?

A. Angiogenesis
B. Increase’s the body’s natural ability to fight infection
C. Increases Oxygen gradient in the ulcer
D. All of the above

Answer

D. All of the above

QUESTION 4

How often should a reassessment be performed for DFU, CROM, or radiation injury?

answer

Every 10 treatments.

QUESTION 5

Define osteogenesis.

answer

The new formation of bone.

HOUSEKEEPING

HBO COURSE

Education Checklist

Outpatient/Ambulatory

ROUND TABLE?

COMING UP NEXT MONTH

Topic: Diabetes Management for the Hyperbaric Patient

Presenter: ACMH

Date: November 5th, 12 pm est.

HYPERBARIC CONTACTS

THANK YOU!

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