Osteoradionecrosis (ORN)

- 5% of patients irradiated in the jaw may develop chronic radiation injury.
- When tooth extracted, they typically fail to heal and develop ORN.
- HBO2 used before and after tooth extraction promotes neovascularization and PREVENTION of ORN.
- Also HBO2 is critical to aid surgical reconstruction of ORN.
- Success rate – 90%
Osteoradionecrosis (ORN)

69 y/o, XRT 1999; ORN with exposed bone

30 HBO2 Tx with resolution
Tissue Oxygen Levels in Radiated

Osteoradionecrosis (ORN) of the Jaw

- Prophylaxis for tooth extraction to irradiated bone
  - (20 pre-op then 10 post-op HBO2 Tx)

- Treatment of ORN
  - (30 pre-op, then 10 post-op HBO2 Tx)

Important: Nutrition, surgery, smoking cessation, antibiotics, vitamin D, etc.
Radiation enteritis treated with HBO2
Radiation Proctitis
Treatment with HBO₂

• 27 men with proctitis following radiation for prostate cancer
• Average 36 HBO₂ treatments (29-60)
• Bleeding resolved in 48%, improved in 28%
• Pain improved in 75%

Dall’Era MA, Hampson NB, Corman JM. J Urol 2006.
HBO₂ for Radiation Cystitis

- 62 patients treated for hemorrhagic radiation cystitis
- 49 (80%) experienced complete resolution or marked improvement in hematuria
- When performed, 77% had objective improvement on post-HBO₂ cystoscopy
- When treated < 6 months after onset of hematuria, 96% response

Corman JM, Hampson NB. *J Urol* 2003
Chong KT, Hampson NB, Corman JM. *J Urol* 2005
Treatment Protocol

- Duration of the HBO\textsubscript{2} course must be individualized, based upon:
  - Patient's clinical response
  - Radiological findings
Chronic Refractory Osteomyelitis
Classification of Osteomyelitis

• Acute Osteomyelitis
  • Is a suppurative infection of bone
  • or bone marrow
    • Typically accompanied by
      • Surrounding edema
      • Vascular congestion
      • Small vessel thrombosis

• Chronic Osteomyelitis
  • Results when a nidus of infected dead bone remains
    accompanied by a surrounding ischemic soft tissue
    envelope and a chronic clinical course
### Classification of Osteomyelitis

- **Refractory Osteomyelitis**
  - Is a chronic osteomyelitis which has
    - persisted or recurred after “appropriate interventions” have been performed or
    - acute osteomyelitis which has not responded to “accepted management techniques”
  - Often involves compromised hosts
  - More specifically:
    - Chronic osteomyelitis is classified as **refractory** when it has failed to respond to a combination of definitive surgical debridement and a period of 4 to 6 weeks of appropriate antibiotic therapy.
Clinical Diagnosis of Osteomyelitis

- Probing to bone in infected pedal ulcers is a clinical sign of underlying osteomyelitis in diabetic patients
  - sensitivity of 66%
  - specificity of 85%
  - positive predictive value of 89%
  - negative predictive value of 56%

- If you can palpate small bones of the feet in diabetics, consider it osteomyelitis until proven otherwise

Grayson ML, JAMA 1995;273:721-723
Radiological Diagnosis of Osteomyelitis

- Plain film rarely useful (unless late)
  - good for foreign bodies

- Bone scan nonspecific
  - Especially in patients with neuropathic osteoarthropathy, also known as “Charcot joint”
  - Can be useful when MRI is not an option

- MRI (gold standard for radiological diagnosis)
  - T1 – weighted image (low signal intensity)
  - T2 fat-saturated image (hyperintense signal)
  - T1 fat-saturated image post-gadolinium (enhancement)

Axial unenhanced T1-weighted spin-echo image of right forefoot shows decreased intramedullary T1 signal within 2nd toe with a confluent pattern (arrowhead) localized to area of surgically proven osteomyelitis.
Osteomyelitis

- Infected bone is hypoxic

  - Normal Oxygen Tension (21% O\textsubscript{2} at sea level)
    - Healthy Bone = 45 mmHg
    - Infected Bone = 21 mmHg

  - Hyperbaric Oxygen Tension (100% O\textsubscript{2} at 2 ATA)
    - Healthy Bone = 321 mmHg
    - Infected Bone = 104 mmHg

* Rabbit animal model
HBO₂ & Antibiotics with Osteomyelitis

Mendel et al.  
*Undersea Hyperb Med* 26:169, 1999
Osteomyelitis Treatment Protocol

• “Appropriate therapy” includes:
  • **Aggressive antibiotics**
    • At least 42 days
    • antibiotics should be culture-directed
    • PICC line for outpatient management
  • **Aggressive surgical debridement**
    • remove infected/dead bone, as well as involved hardware if possible
    • consider antibiotic beads
  • **Educate on dietary needs**
    • e.g., malnutrition (protein), vitamin D, Vitamin C, Vitamin A, Zinc
  • **Address comorbidities**
    • e.g., diabetes, venous stasis, smoking cessation, renal/liver failure
  • **Vascular evaluation/intervention if indicated**

• **HBO₂ is not an approved indication for acute osteomyelitis**
Chronic Refractory Osteomyelitis Treatment Protocol

- HBO₂ as adjunctive therapy
  - Treat at 2.0 to 2.4 ATA once or twice daily
  - Oxygen administered 90 to 120 minutes per session
  - Treatment range: typically 30 to 40 treatments
    - may require up to 60 treatments
      - sessions will be required to achieve sustained therapeutic benefit.
Benefits of HBO\textsubscript{2} in Osteomyelitis

- **Tissue oxygen tension restored to > 30 mmHg**
  - required by Neutrophils to destroy bacteria by oxidative killing mechanisms

- **Direct suppressive effect on anaerobic pathogens**

- **Augments transport of certain antibiotics across bacterial cell walls**
  - active transport of antibiotics (e.g. gentamicin, tobramycin, amikacin) across bacterial cell walls does not occur if tissue oxygen tensions are below 20 to 30 mmHg

- **Enhances osteogenesis**

- **Reduces tissue edema**

- **Promotes capillary angiogenesis**

- **Prevents polymorphonuclear leukocytes from adhering to damaged blood vessel linings**
  - decreases the degree of inflammation which may accompany the surgical treatment of refractory osteomyelitis

- **Can reduce treatment costs of complicated refractory osteomyelitis by approximately 5x**
  - 1987 estimated per case costs reduced from $115,000 to $20,000
Case: Osteomyelitis

- 24 y/o healthy female, MVA with clavical, spine, and pelvic fractures
- 4 days in hospital, then discharged. Admitted 2 weeks later with severe “neuropathic” hip pain
- No improvement, MRI 2 months later showed septic arthritis of hip, osteomyelitis of the femoral head, and soft tissue abscesses
Case: Osteomyelitis

- Patient underwent incision and drainage, staph aureus
- Had hip fusion, hardware
- Received 44 HBO2 treatments, vancomycin therapy
- One year later, resumed normal activities such as swimming and hiking, still bothered by hip fusion

Traction during HBO2 sessions
Diabetic Ischemic Wound
Before HBO₂

59 yo M. Malperferan’s ulcer, osteomyelitis.
WBC = 11.7, CRP = 19, ESR = 174
Diabetic Ischemic Wound

- Orthopedic surgeon recommended midfoot amputation, (patient refused).

- Treatment: off-loading, local debridement, Regranex, wound care, HBO₂, IV antibiotics.

- After 26 HBO₂ treatments, continued wound care and Regranex.
Diabetic Ischemic Wound + HBO₂

5 weeks after HBO₂
Remained healed
18 months later.
Ischemic Diabetic Foot Ulcer RCT

- 70 patients (35 HBO2, 33 control)

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>HBO2 (38.8 ± 8 sessions)</th>
<th>Control (33.3%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amputations</td>
<td>3 (8.6%)</td>
<td>11</td>
<td>0.016</td>
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</tbody>
</table>

(Faglia, Diabetic Care, 1996)
Diabetic Ischemic Wound

(Selection Criteria for HBO$_2$)

- Refractory problem wound
- “Optimal” large vessel blood flow
- Confirmation of wound hypoxia
- Elevation of wound O$_2$ tensions with HBO$_2$ to > 200 mm Hg:
Approach to Wound Healing

- Optimal glycemic control
- Lowest dose of immunosuppressive Rx
- Debridement
- Infection control
- Nontoxic dressing
- Optimize vascular flow
- Smoking cessation
- Pressure reduction
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