HBOT: An Essential Component for the Regenerative Treatment of Pain from Sports Injuries, Chronic Inflammation and Infection

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Advancing Hyperbaric Medicine Globally in the 21st Century
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Preface: Law of Gravity

- 1686: Sir Isaac Newton first published: mutual attraction of bodies in nature

- 1798: First test of Newton’s theory of gravitation between masses in the laboratory - Cavendish experiment

- 1915: Einstein’s general theory of relativity: gravity as a distortion of spacetime caused by the presence of matter or energy
Preface: Bernoulli Principle

Lower pressure is caused by the increased speed of the air over the wing.

Since the pressure is higher beneath the wing the wing is pushed upwards.
Disclaimer

- I have no relevant financial relationships with any commercial interests to disclose.

- The content of this presentation has been peer reviewed for fair balance and evidence based medicine.
Advanced Evidence Based Medicine = Creative Expertise

Advanced evidence based medicine is not rule following. There are five levels of learning:

The Novice Stage: Learns the basic rules and applies them mechanically with no attention to context.

Second and Third Stages: Increasing depth of knowledge and sensitivity to context when applying rules.

Fourth and Fifth Stages: Rule following gives way to expert judgments - characterized by rapid, intuitive reasoning informed by imagination, common sense, and judiciously selected research evidence.
Advanced Evidence Based Medicine = Creative Expertise

Creative People [Creative Brains] have an “openness to new experience that permits them to observe things than others cannot... [this] openness is accompanied by a tolerance for ambiguity. Creative people do not crave the absolutism of a black and white world; they are quite comfortable with shades of gray. In fact, they enjoy living in a world with unanswered questions and blurry boundaries.”

HBOT: An Essential Component for the Regenerative Treatment of Pain from Sports Injuries, Chronic Inflammation and Infection

I. Introduction to HBOT

II. HBOT: Mechanisms for Addressing Chronic Pain

III. HBOT: Treatment for Sports Injuries

IV. HBOT: Upregulates Pluripotent Adult Stem Cells (aka VSELs - Very Small Embryonic-Like Stem Cells) in the Blood

V. VSELs over MSCS: Regenerative Treatments with Pluripotent Stem Cells for Sports Injuries and Arthritis

VI. HBOT: Adjunctive to IV Therapies for Chronic Infection
Introduction to HBOT: Physics

- Henry’s Law of Gas Solubility: The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid.
- Increasing the atmospheric pressure increases the amount of gas that is dissolved into a fluid.
- Oxygen → Blood Plasma
Introduction to HBOT: Physiology

- **What Gets Hyper-Oxygenated?**
  - Blood Plasma
  - Cerebrospinal Fluid
  - Lymph Fluid

- **Clinical Hyperbaric Pressures**
  - 7 - 22 psi
  - 10 - 15 normal amount of oxygen
  - Bypasses body’s normal system of transporting oxygen
Introduction to HBOT: Mechanism of Action

- Limits ischemic damage, cell death, inflammation
- Promotes collagen synthesis (fibroblast stimulation)
- Decreases lactate production and tissue acidosis
- Aids in oxygen dependent killing of bacteria - WBC
- Limits leukocyte adhesion and degranulation
- Decreases tissue edema
HBOT: Mechanisms for Addressing Chronic Pain
HBOT: Mechanisms for Addressing Chronic Pain

- Decreases inflammation, reduces hypoxia, and improves microcirculation
- For neuropathic pain, analgesic and antinociceptive effects are due to cellular modulation
  - Autophagy in the mitochondria of microglia (mitophagy) (Han et al., 2017)
HBOT: Mechanisms for Addressing Chronic Pain

- Mitochondria are the primary source of ROS
- ROS can:
  - Induce mutations in mtDNA causing protein deficiencies
  - Restrict ability to self-repair, leaving cells more vulnerable to ROS attack
  - Damage mitochondrial proteins and lipids by inducing oxidative stress

(Nie et al., 2015; Koirala et al., 2013; Lupfer et al., 2013)
HBOT: Mechanisms for Pain
Latent mitochondria are like campfires left burning all night
HBOT: Addressing Chronic Pain with Mitophagy

- HBOT modulates cellular autophagy (mitochondria of microglia) and directly reduces pain
- Appropriate clearance of mitochondria is important for maintaining homeostasis in cells
HBOT: Addressing Chronic Pain with Mitophagy
Mitophagy study with 80 rats (Han et al., 2017)

- 20 rats were given a CCI (chronic constriction injury); 20 rats got CCI+ HBOT
- 20 rats were sham CCI and 20 rats were controls
- All 80 rats were given CSI (a mitophagy) before testing
- MMP was used to measure mitophagy (lower MMP observed with more mitophagy)
HBOT: Addressing Chronic Pain with Mitophagy
Mitophagy study with 80 rats (Han et al., 2017)

- HBOT improved mitochondrial permeability via transitive pores on the mitochondrial membrane
- More permeability results in more mitophagy (see as lowered MMP) which reduces ROS calming neuro-inflammation and pain

Control & Sham - minimal to no mitophagy (no change in MMP)
MMP: Mitochondrial membrane potential
CCI: Chronic constriction injury
Mitophagy is putting the mitochondrial fires out by involuting the ashes and soil upon the remaining embers. Without mitophagy, wildfires (of pain) get out of control.
Fun Fact #1: What else encourages cellular autophagy (including neuronal autophagy)?

Intermittent Fasting!

Dr. Yoshinori Ohsumi Wins Nobel Prize for this discovery)

https://www.garmaonhealth.com/intermittent-fasting-cellular-autophagy/
HBOT: Other Mechanisms for Addressing Chronic Pain
(Zhao, B., Pan, Y., Xu, H., & Song, X., 2017)

- Suppresses pro-inflammatory cytokines, such as IL-1, IL-6 and TNF-alpha and simultaneous releases anti-cytokines

- Suppresses astrocyte activation and inflammatory responses (stopping gliosis) by:
  - Increasing TNF-α
  - Decreasing Kindlin-1 and Wnt-10a in the dorsal root ganglia (DRG), spinal cord, and hippocampus of rats
HBOT: Mechanisms for Chronic Pain: Case Study

- 40 year old spinal cord injury (C4 burst fx from mtn biking accident) paraplegic patient with chronic spasticity and pain in lower extremities

- Reports almost immediate reduction in neuroplasticity, inflammation, and pain when treated in a HBOT chamber at 2.4 ATA
HBOT: Upregulates Pluripotent Adult Stem Cells (aka VSELs - very small embryonic-like stem cells) in the blood
“[Hyperbaric oxygen therapy] is the safest way clinically to increase stem cell circulation, far safer than any of the pharmaceutical options.”

Stephen Thom, MD, Ph.D. (2005)
HBOT: Upregulates Pluripotent Stem Cells in the Blood

- Mean CD34+ population in blood of humans before and after HBO2 treatments
- Data are the fraction of CD34+ stem cells within the gated population using blood obtained from 26 patients before and after their 1st, 10th, and 20th HBO2 treatment

(Thom, et al., 2006)
HBOT: Upregulates Pluripotent Stem Cells in the Blood

- 2 hours = 3x amount of stem cells circulating stem cells in your blood
- 20 sessions = 800% more stem cells circulating stem cells in your blood
- Released through a nitric oxide process stimulated by HBOT
Repairing tissue damage with endogenous VSELs and growth factors is the body’s primary way to stop the cause pain.

VSELs can be also harvested by blood draw, isolated, and activated.

HBOT: Upregulates Pluripotent Stem Cells (VSELs) in the Blood
Many stem cell clinics are focused on the use of mesenchymal stem cells (MSCs)

MSCs are derived from bone marrow, umbilical, or fat

MSCs have merit for homologous use (bone marrow to bone marrow or fat to fat transplantation)

MSCs do not actually transform, in vivo, to new tissues
<table>
<thead>
<tr>
<th>Pluripotent (VSELs)</th>
<th>Multipotent (Mesenchymal)</th>
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<tbody>
<tr>
<td>Recently discovered in peripheral blood</td>
<td>From bone marrow, fat, and cord blood</td>
</tr>
<tr>
<td>Also known as very small embryonic-like stem cells (VSELs)</td>
<td>Mesenchymal stem cells (MSCs)</td>
</tr>
<tr>
<td>Does not have a specialized trajectory of development</td>
<td>On a development trajectory</td>
</tr>
<tr>
<td>Give rise to all the cell types</td>
<td>Specialization potential limited to one or more cell lines</td>
</tr>
<tr>
<td>Lineage uncommitted</td>
<td>Lineage committed</td>
</tr>
<tr>
<td>Long lifespan</td>
<td>Short-lived</td>
</tr>
<tr>
<td>Not restricted by FDA</td>
<td>Increased FDA restriction for non-homologous tissue use</td>
</tr>
<tr>
<td>Best for regeneration</td>
<td>Best for homologous use</td>
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Clinical Indications

**Multipotent (Mesenchymal)**
- Tissue Replacement (Homologous Only):
  - Bone marrow transplant
  - Breast, lips, cheeks, eyes, buttocks
- Systemic inflammatory conditions:
  - Autoimmune disorders
  - Acute renal failure
  - Myocardial infarction
  - Type I diabetes
  - Graft-vs-host disease
  - Systemic lupus
  - Pulmonary fibrosis

**Pluripotent (VSELs)**
- Degenerative diseases:
  - Diabetes
  - Osteoarthritis / osteoporosis
  - Alzheimer’s disease
- Regenerative applications:
  - Traumatic brain injury
  - Joint / ligament repair
  - Anti-aging
  - Post cancer treatment
  - Fertility
Mesenchymal Stem Cells (Multipotent): Clinical Indications

- These cells **do not** develop into new cartilage cells - they only provide growth factors

- Therapeutic effects are short-lived
  - “Recent studies have suggested that less than 1% of systemically administered MSCs persist for longer than a week following injection” (Parekkadan & Milwid, 2010, pg 2).
Harvesting of bone marrow and fat can be unpleasant
  • Repeat harvesting is limited
  • Immunomodulatory effects can predispose the patients to more infections or even cancer
  • Reduces inflammation for 6 months - 2 years but have limited regenerative benefits

Mesenchymal Stem Cells (Multipotent): Dangers
Lineage uncommitted pluripotent stem cells can produce all types of cells in the germ layer
Pluripotent Stem Cells (VSELs)

Displaced (5mm) C-7 proximal spinal fracture failed to heal 9 months post trauma.

4 months post-treatment of peripheral blood-based stem cells - the fracture is fully healed.
Regenerative Treatments with HBOT and Pluripotent Stem Cells for Sports Injuries and Arthritis
HBOT for Sports Injuries

- Reduces swelling
- Blunts the inflammatory process
- Improves range of motion earlier/ PT
- Increases and enhances tissue growth
  - Fibroblast and osteoblast proliferation
- Improves bone regeneration-faster and stronger fracture repair
Case Study

- Injured on January 5th 2009
- Shearing fracture, surgically repaired
- High risk for Non-Union
- Started HBO January 7th 2009
- 30 tx over 6 week period
- Cleared to ski March 3rd 2009
Professional Sports - Twelve NFL teams own HBOT chambers

- “Ward is using hyperbaric chamber to accelerate recovery” - USA Today

- “Football superstar Terrell Owens used hyperbaric oxygen therapy to hasten his recovery from an ankle injury so that he could play in the Super Bowl.” - Fox Sports

- Cincinnati Bengals defensive tackle Bryan Robinson says “hyperbaric oxygen therapy was the catalyst in getting a nagging ankle injury to heal.” - Cincinnati Inquirer

- “Linebacker Kevin Burnett credits hyperbaric oxygen therapy for helping him get back onto the playing field quickly after surgery to repair cartilage damage in his knee.” - Dallas Cowboys Official Weekly
HBOT and Brain Injuries

- Induces neuroplasticity
- Increases tissue oxygenation
- Generates new capillary networks
- Restores blood supply
- Increases stem cells in the blood
Traumatic Brain Injury: Pre Treatment

- 10 treatments in a HBOT medical grade facility
  - 1.5 to 1.75 ATA
  - Or at least 3-4 weeks in a home HBOT chamber
- Stem cell enhancing supplements are taken 2 weeks before stem cell harvesting
Protocol for Traumatic Brain Injury: PRP and VSEL Treatment

Day 1:
- Consultation
- HBOT
- Cranial therapy
- IV therapy
- Intranasal (IN) PRP and insulin

Day 2:
- IV and IN NAD+
- IV and IN pluripotent stem cells (VESLs) from the blood
- HBOT
Protocol For Traumatic Brain Injury: Post Treatment

- Medical grade HBOT: 10-30x (at 1.5 to 1.75 ATA) over next month
  - Repeat 20 treatments at 3 months; repeat 20 treatments at 6 months
- Alternative: Home low pressure O2 chambers (at 1.3 ATA) 5-7 days/week for 1.25 hours for 3 months
  - Then at least 4 days/week for 9 months
- Home administration of intranasal insulin 10 days or more
- PT, cranial osteopathy, functional medicine (including hormone management), and other therapeutic modalities (vision therapy, neurofeedback, LLLT, ketogenic diet)
“In June 2017, I went in for my second intranasal stem cell procedure and by August I felt well enough that I started saying yes again to facilitating events and speaking gigs. I also experienced relief from anxiety. With the stem cell procedures, the results were never immediate but 8-12 weeks post procedure I experienced a noticeable jump in my healing. Even though, I’m still not 100% back to what I was, TBI Therapy has turned me into a TBI THRIVER, not just a survivor. I’m happy. I enjoy life again, can travel and am doing work in the world that’s more aligned with myself than ever.”
“I am now officially 5 weeks post intranasal/IV stem cell and PRP treatment and the results for me have been are nothing short of MIRACULOUS! Trust me when I say that losing who you are from a traumatic brain injury is absolutely devastating! Over the years I learned how to coexist with my brain injury and the issues that came along with it but only a select few close to me could tell I was still struggling at times. Until now... Popeye may have his spinach but I have stem cells and PRP! Yes, my brain is strong!”
80 year old with tricompartmental arthritis x 10 years, confirmed by xray, worse in R knee

Treated with VSELs in Bilat Knee joints, menisci, and associated ligaments on 2/9/2018

Reports on 4/13/2018 that her left knee does not hurt

Reports improvements in walking with less R knee pain on 6/7/2018. Patient provided booster PRP injection into R knee joint and IT band at 6/7/2018

"The only consistent symptom I have is that it is always uncomfortable when I stand up from a sitting position and when I first get up in the morning. Usually just a few steps and the discomfort is gone."
HBOT: Adjunctive to IV Therapies for Chronic Infection
HBOT: Adjunctive to IV Therapies for Chronic Infection

- HBOT alone: Helps Osteomyelitis, subcutaneous infections, systemic infections such as herpes, EBV, etc.
- HBOT (2.0+ ATA) + IV ascorbate (in excess of 50g), has an even greater effect on many chronic infectious conditions (including chronic viral (like EBV), immunosuppression, and post-Lyme syndrome)
HBOT: Adjunctive to IV Therapies for Chronic Infection: Driving the Fenton Reaction with Ascorbate

- With catalytic metal ions, ascorbate has pro-oxidant effects
- Ascorbate reduces ferric (Fe$^{3+}$) to ferrous (Fe$^{2+}$) iron. Increase Ascorbate = Increase Fe$^{2+}$
  - AscH$^- + Fe^{3+} \rightarrow Asc\bullet^- + Fe^{2+}$
- Fe$^{2+}$ can readily react with O$_2$, reducing it to superoxide radical. Increase O$_2$ = Increase O$\cdot^-2$
  - Fe$^{2+} + O_2 \rightarrow Fe^{3+} + O\cdot^-2$
- The superoxide radical dismutates to H$2O_2$ and O$_2$
  - O$\cdot^-2 + O\cdot^-2 + 2H^+ \rightarrow H_2O_2 + O_2$ Increased H$2O_2$
In a classic Fenton reaction, Fe2+ reacts with H2O2 to generate Fe3+ and the very oxidizing hydroxyl radical.

Fe2+ + H2O2 → Fe3+ + OH• + OH-

This OH radical is incredibly deadly to viruses, bacteria, spirochetes, other pathogens, and, reportedly cancer cells.

Healthy cells are protected from peroxide radicals by the enzyme catalyze.
HBOT: Adjunctive to IV Therapies for Chronic Infection: Driving the Fenton Reaction with Ascorbate

- Stimulating this reaction can create interferon like side effects in the patients
- Patients report areas of prior injuries or inflammation can get flared up, achy, or significantly painful
- Most patients report abdominal/diaphragmatic pain that resolves within 2-20 minutes after getting out of the chamber
- Fun Correlation: This is further evidence that the increased presence of ROS leads to nociceptive pain
Patients may need more bioavailable iron: the typical range for the iron dose is 1 part of Fe per 5-25 parts of H2O2.

**pH adjustment to 3-5:** if the pH is too high the iron precipitate in Fe(OH)3 and will decompose the H2O2 to oxygen.

- Basically, the optimal pH occurs between 3 and 6.
- Do not give the patient a neutralized bag of ascorbate—pH must be at least than 5-6 in the bag.
Case Report: Lyme Disease

History

- 60 yo female reported diagnosis of Lyme disease with HHV6, EBV, M.Pn, Babesia, Erlichia
- R ocular pain, R vision loss, extreme fatigue, diagnosed with 9 bands/10 bands for Borellia - Treated with Doxycycline and unspecified antibiotic
- Worsened with intractable R eye pain, vision loss, extreme sensitivity to light, tingling in her R UE and LE and wheelchair bound after 6 months
- Received IV Rocephin and other antibiotics including Doxycycline and Azithromycin, and nutritional IV therapies including EDTA, turmeric, ascorbate, alpha lipoic acid, glutathione, and amino acids
- Walking again but still suffered extreme R eye pain, vision loss, migraine headache pain, elevated liver function tests, elevated lipase, chronic fatigue, and skin rash
- Reported being unable to work and bed ridden with fatigue
Case Report: Lyme Disease

Treatment

- IV sodium ascorbate
  - Up to 95 g non-corn based ascorbate with minerals (Ca, Mg, K) 3 days/week

- Hyperbaric oxygen therapy
  - Up to 2.4 ATA (1 hour after receiving IV ascorbate) 3 days/week

- After 20 weeks:
  - Improvement in condition of pancreatitis with a resolution of her lipase value and liver function tests
  - Less fatigue and improved energy to think more clearly, improved ability to stay up later and take walks during the afternoon
  - Improvement in her eye pain and ability to use the computer for more than 5 minutes at a time

- Referred to a holistic ophthalmologist for continued care
Case Report: Lyme Disease

- Chronic Lyme disease is often accompanied by toxins and viruses that cannot be eliminated by simply using antibiotic therapy.

- Without HBOT and Vitamin C treatment, this patient would not have gotten better.
Case Report: Mold Toxins

- 34 yo male with L temporal glioma and seizure condition - likely secondary to mold toxins in home
- 11/2017 Diagnosed with glioma - surgically removed
- 12/2017 Tumor just as large as before removal
- 3/2018 Moved out of condo and began IV Ascorbate and HBOT
- 4/2018-6/2018 Chemo therapy and radiation therapy, continued IV ascorbate 1-2x/week at 60 g (stopped HBOT due to seizure)
- 6/26/2018 Complete resolution - no tumor at all seen on MRI, no seizures
- Played intense soccer game with no issues
Highly metastatic cells derived from a spontaneous brain tumor in VM-DK Inbred mouse AA-induced cell death:

- VM-DK cells were grown in monolayer and analyzed at 0.001 mM AA to determine cytotoxicity.

AA and HBOT Combination:

- Cells were treated with HBOT (100% O2, 40 min, 2.5 ATA) and AA concentrations were determined to assess the synergic effect of AA and HBOT.

AA concentration below 0.5 mM was used since 0.5 mM AA already induces high cell death.

**Experimental Design**

VM-DK cells were treated with one session of HBOT (100% O2, 40 min, 2.5 ATA) and AA concentrations below 0.5 mM were used since 0.5 mM AA already induces high cell death.

**Ascorbic Acid Inhibits VM-M3 Cells In Vitro**

**Ascorbic Acid Concentration (mM)**

<table>
<thead>
<tr>
<th>Ascorbic Acid Concentration (mM)</th>
<th>Cell Death (%)</th>
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<tbody>
<tr>
<td>0.1 mM AA</td>
<td>100</td>
</tr>
<tr>
<td>0.5 mM AA</td>
<td>90</td>
</tr>
<tr>
<td>1 mM AA</td>
<td>80</td>
</tr>
<tr>
<td>5 mM AA</td>
<td>70</td>
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</table>

**Cytotoxicity**

- AA and HBOT combination significantly induced cell death: (A,B) 24 hours treatment with 0.5, 1, and 5 mM AA significantly increased cytotoxicity compared to control and all other tested concentrations (One-way ANOVA, p<0.001).

**Conclusion**

- Ascorbic acid (AA) may decrease VM-M3 cell death in a concentration-dependent manner.

**Additional Preliminary Findings**

**Effect of NAC on AA-mediated cytotoxicity**

<table>
<thead>
<tr>
<th>NAC Concentration (mM)</th>
<th>Cytotoxicity</th>
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<tbody>
<tr>
<td>0.01 mM NAC</td>
<td>*****</td>
</tr>
<tr>
<td>0.05 mM NAC</td>
<td>*****</td>
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<tr>
<td>0.1 mM NAC</td>
<td>*****</td>
</tr>
<tr>
<td>0.3 mM NAC</td>
<td>*****</td>
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<tr>
<td>0.5 mM NAC</td>
<td>*****</td>
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**Antioxidant NAC attenuates the effect of AA in vitro: 24 hour treatment with 0.5 mM NAC mitigated AA-induced cytotoxicity (One-way ANOVA, p<0.001).**

**Figure 1.** AA mediates VM-M3 cell death in a concentration-dependent manner. (A,B) 24 hour treatment with 0.5, 1, and 5 mM AA significantly increased cytotoxicity compared to control and all other tested concentrations (One-way ANOVA, p<0.001).

**Figure 2.** AA may decrease VM-M3 cell death in a concentration-dependent manner. (A,B) 24 hour treatment with 0.5, 1, and 5 mM AA significantly increased cytotoxicity compared to control and all other tested concentrations (One-way ANOVA, p<0.001).

**Figure 3.** Antioxidant NAC attenuates the effect of AA in vitro: 24 hour treatment with 0.5 mM NAC mitigated AA-induced cytotoxicity (One-way ANOVA, p<0.001). Dose of AA was also considered significant when compared to control and control + NAC (p<0.001). The addition of NAC did not affect cell control at 0.5 mM AA.

**Figure 4.** HBOT and AA synergies in vitro: 24 hour treatment with 0.5 mM AA significantly increased cytotoxicity compared to all other treatments (One-way ANOVA, p<0.001). Dose of AA was also considered significant when compared to control, AA-D, and control + HBOT (p<0.01). The addition of HBOT did not affect control cell at 0.5 mM AA.

**Conclusions:**

- High-dose AA alone mediates an anti-cancer effect in vitro and exhibits cytotoxicity through an oxidative stress mechanism.

- Observations indicate that high-dose AA should be further investigated as an adjuvant to the current standard of care.

- Further studies include:
  - Evaluating the effect of HBOT on the proliferation of AA-treated VM-DK cells.
  - Evaluating role of hydroxyl peroxide (HOCl) in AA-induced cytotoxicity with treatment of catalase - an enzyme that breaks down H2O2 to water and oxygen.
1) Physician who treat patients with chronic orthopedic or neuropathic pain or inflammation should consider the primary use of HBOT to alleviate that pain or as an adjunctive therapy in combination with other modalities to effectively address the source of the pain.

2) Stem cell mobilization by HBOT is perhaps one of the most effective uses of the HBOT in regenerative medicine. These stem cells can be extracted easily from the blood and injected locally to address a variety of pain conditions.

3) Used in combination with high dose ascorbate, HBOT can be one of the most effective ways to eliminate pathogens in patients suffering from acute, chronic, localized, or systemic infections.
"Facts, like telescopes and wigs for gentlemen, were a seventeenth-century invention."

TBI Therapy

Treats TBI patients by combining regenerative therapies: HBOT, stem cells, PRP, and nutritional therapies.

tbitherapy.com

ASPN INTEGRATIVE MEDICINE

Treats chronic pain and major medical problems using natural and alternative medicine whenever possible.
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