Janusz Sokolowski
Chair of Emergency Medicine
Wroclaw Medical University

# INFECTION PROTECTIVE ROLE OF HYPERBARIC OXYGENATION IN TRAUMA PATIENTS

1 st Critical Care and Emergency Medicine Congress, 6-8 November 2013, Istanbul

# Definition

**Respiration of pure oxygen during a whole body exposure to ambient pressure *exceeding* the normal atmospheric pressure of 1 ata in a pressure vessel.**

Usually pressure between 2 and 3 ata is used.

Oxygen application via mask, endotracheal tube, or head-tent

Multi- , monoplace chamber


T.MARCINIAKA

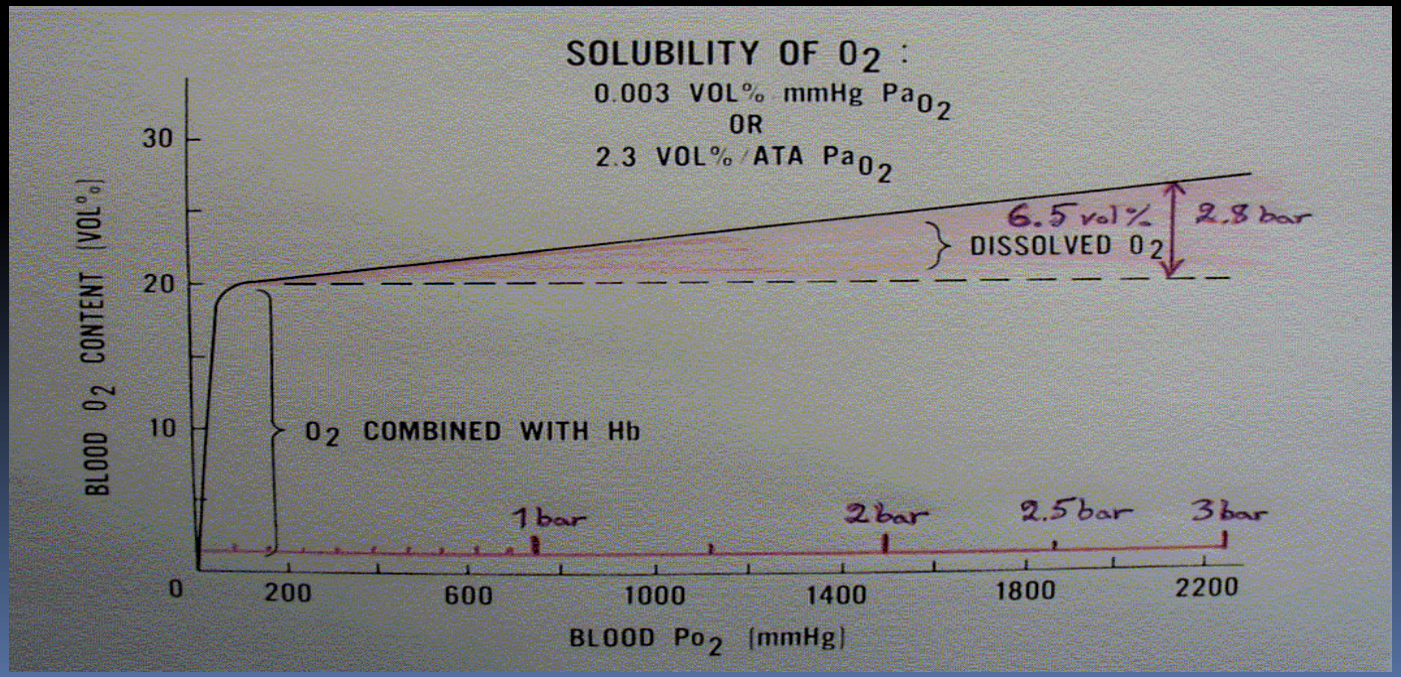

HAUX
B
O

# Objectives

- Mechanisms of HBO
- Crush injuries

# Low tissue $PO_2$

- Crush injury
- skeletal muscle-compartment syndrome
- failing grafts and flaps.



# Acute Traumatic Peripheral Ischemia

- vascular damage,
- Edema + hypoxia (compartment syndrome)

# Posttraumatic edema and low $PO_2$

- detrimental effects on wound-healing
- WBC killing becomes compromised in the often heavily contaminated tissues
- predisposition for infection

| Gustilo's classification of open fractures | | Complication rate | |
|---|---|---|---|
| Type | Mechanism | Infection | Amputation |
| I | Small laceration <1cm | minimal | |
| II | Large laceration but minimal soft tissue damage | 3% | |
| III | Crush Injuries | | |
| | A: Sufficient soft tissue to close wound | 4% | |
| | B: Flaps or grafts required to cover bone | 52% | 16% |
| | C: Major vessel injury | 42% | 42% |

# Traumatic ischemia

## *“Crush Injury”* (Definition M. Strauss)

1 **Two or more tissues involved**

(e.g. Muscle, bone, skin, connective, nerve)

2 **A gradient of tissue injury exists**

irreversible damage - minimally traumatized

3 **Viability of tissue in question**

Functional impairment to be expected. Therapy aimed at enhancing survival of the “gray-zone”

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The Journal of
Bone and Joint Surgery
American Volume
VOLUME 82-A, NO. 12 DECEMBER 2000

# Short-Term Wound Complications After Application of Flaps for Coverage of Traumatic Soft-Tissue Defects About the Tibia

ANDREW N. POLLAK, MELISSA L. MCCARTHY, ANDREW R. BURGESS, AND THE **LOWER EXTREMITY ASSESSMENT PROJECT** (LEAP) STUDY GROUP

# LEAP – 24 months

- **Amputation group**

- Reamputaton – 5,4%
- Delayed healing– 9,1%
- osteomyelitis– 3,1%
- Wound infection– 15,4%

- **Limb salvage attempts group**

- Delayed amputation– 3,9%
- Non union – 10,9%
- Delayed healing of the wound– 3,9%
- osteomyelitis– 9,4%
- Other infection– 13,9%

LEAP
Poor quality of life
in both group

# Optimal trauma managemant

- Reduced tissue loss
- Reduced complications
  - Functional loss and scarring
  - **Infection**
  - Non union
  - Chronic pain
- Trauma recovery enhancement
- **Reduced operations and length of stay**
- **Lower costs**

# Infection control & HBO

- Hypoxia a major predisposing factor for infections:
  - Crush injuries
  - Diabetes
  - Smoking

**Oxygen inhibits anaerobes directly**
**Hypoxic environment favours infection**
**Restoration of normoxia provides prophylaxis and normal response to infection**
**Hyperoxia enhances PMN response**

# Hyperbaric Oxygen Mechanisms

## Effects on Crush Injuries:

*Hyperoxygenation* =>

- Improvement of oxygen delivery and preservation of tissue viability in ischemic and hypoperfused areas
- Prevention progressive ischaemia
- Reduction of edema (vasocontriction, oxygen osmosis)
- **Anti-bacterial adjuvant therapy**
- **Prevention of infection**

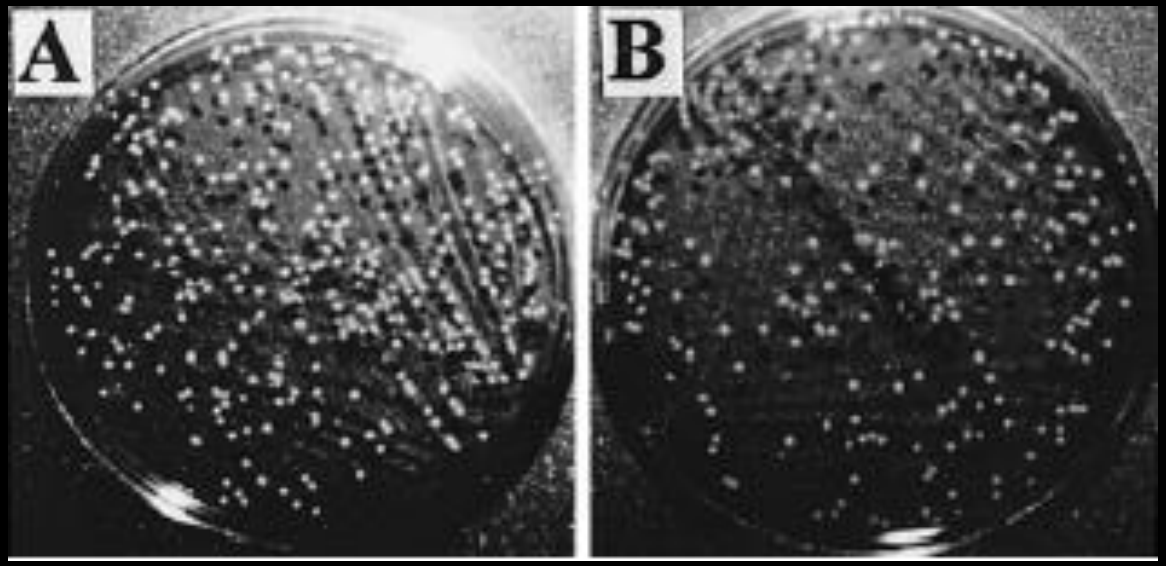
Clin Infect Dis. 1992;14:720-40

# Oxygen tensions and infections: modulation of microbial growth, activity of antimicrobial agents, and immunologic responses; a Review

**Park MK** **Myers RA** **Marzella L** Department of Pathology, School of Medicine, University of Maryland, Baltimore

Oxygen tensions play an important role in the outcome of infections

1. Oxygen is cidal or static for microorganisms that lack defenses against oxidants
2. Oxygen tensions also affect the activity of antimicrobial agents. In general, hyperoxia potentiates while anaerobiosis decreases the activity of many antimicrobial drugs
3. Elevates oxygen tensions in infected tissues facilitate oxygen-dependent killing by leukocytes




**Hyperbaric hyperoxia suppresses growth of *Staphylococcus aureus*, including methicillin-resistant strains**

Isao Tsuneyoshi[1,2], Walter A. Boyle III[1], Yuichi Kanmura[2], and Toushiro Fujimoto[3]

J Anesth (2001) 15:29-32

- Arch Surg. 1997 Sep;132:991-6.

## Wound hypoxia and acidosis limit neutrophil bacterial killing mechanisms

**Allen DB, Maguire JJ, Mahdavian M, Wicke C, Marcocci L, Scheuenstuhl H, Chang M, Le AX, Hopf HW, Hunt TK.**

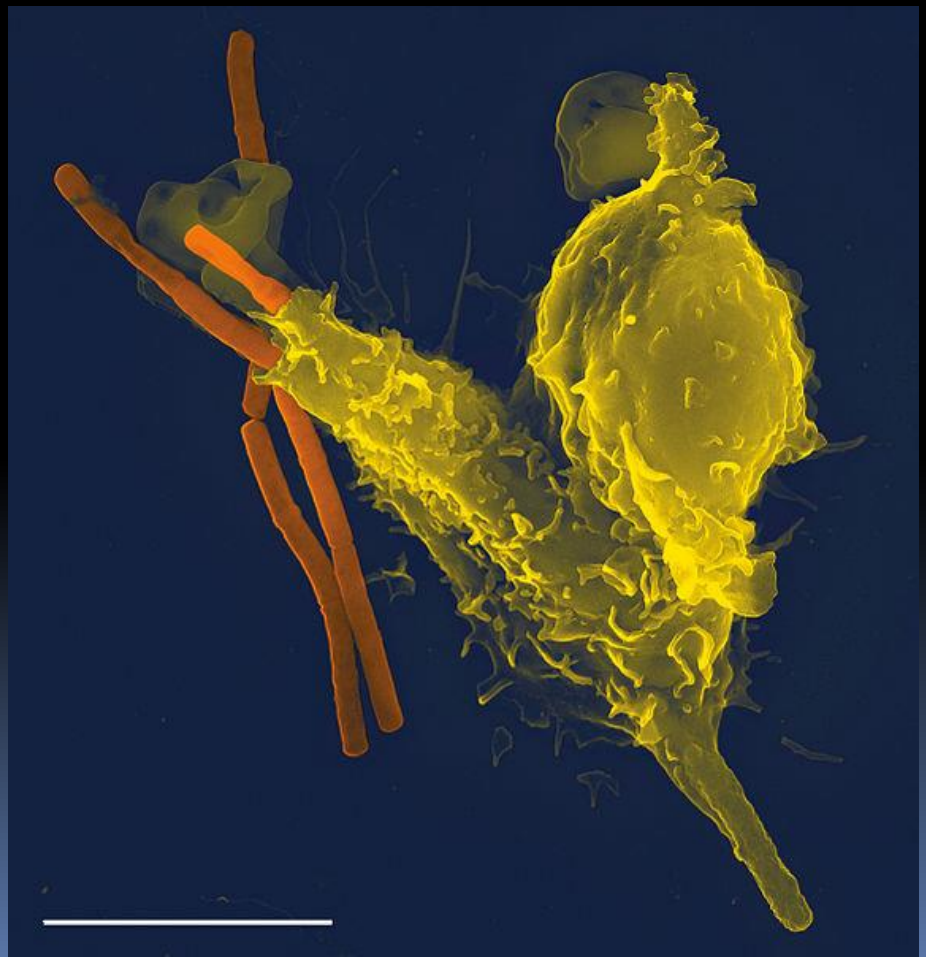
Department of Anesthesia, University of California, San Francisco, USA

**RESULTS:** Neutrophil $O_2$ consumption and $O_2$ burst production were dependent on $PO_2$ throughout the range tested.

Half-maximal oxidant production at $PO_2$ 6 to 11 kPa
Maximal oxidant production at $PO_2$ > 40kPa

**CONCLUSIONS:** Leukocyte bacterial killing capacity as measured by oxygen consumption and superoxide production are substantially impaired at the low oxygen tensions often found in wounds.

# HBO exposure increases both the respiratory burst and phagocytic capacity



# HBO and antibiotics

**synergy with:**

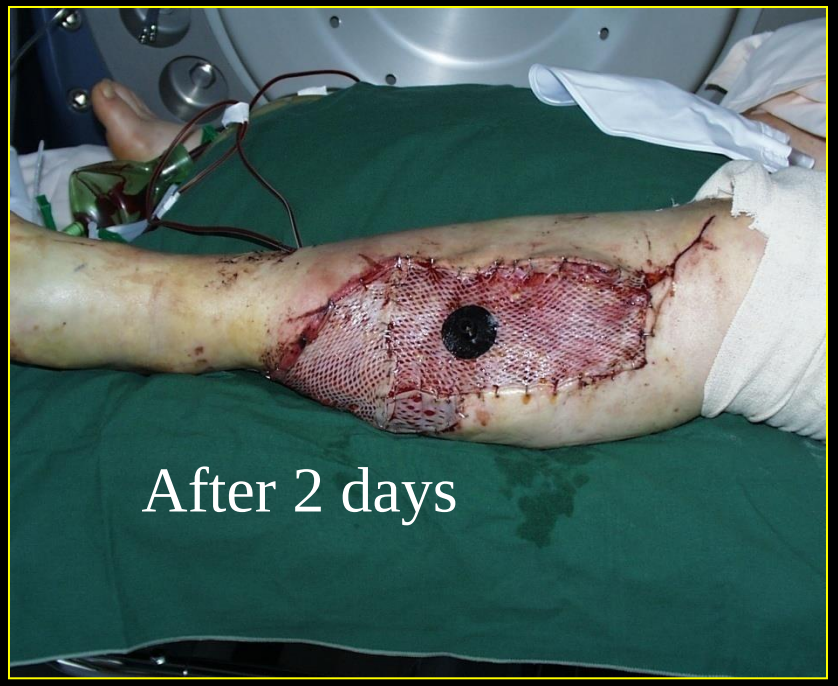
aminoglicosides
vancomycin
chinolons

# Antimicrobial Effects

## summary

- Leucocyte bacterial killing capacity
  - ”oxidative burst”
- Bacteriostatic effect
- Clostridium Perfringens
  - Alphatoxin production 


HBO
CRUSH Injuries


After 2 days


After 7 days(14th HBO session)


After 2 weeks

| | | | | | |
|---|---|---|---|---|---|
| Monies-Chass (17) | Case series. No control group/III | 7 patients with severe vascular trauma and associated fractures to the lower extremities. All treated surgically. All had signs of ischemia postoperatively. | 2 h at 2.8 ATA every 4 h postoperatively. Mean 9.5 treatments. | Ischemia disappeared in 6 cases. Dry gangrene of toes that required amputation in one patient. No HBO complications. | Yes |
| Shupak (18) | Case series. No controls/III | 13 patients with traumatic injuries to lower limbs; 10 had major arterial injury and had associated fractures. | 90 min at 2.4 ATA b.i.d. after surgery. Mean 5 treatments. | Complete limb salvage in 8 patients. In 4 patients, ischemia level was lowered distally. 3 patients had BKA. 1 patient had AKA, and 1 showed no improvement. No oxygen toxicity. | Yes |
| Strauss (19) | Case series. No controls/III | 20 patients with compartment syndrome. First group, 10 patients compartment pressure ranged from 15 to 48 mm Hg. Second group, 10 patients compartment pressure not reported. | First group 90 min at 2 ATA b.i.d.–t.i.d. Mean 12 treatments. Second group had HBO after fasciotomy. Mean 36 treatments. | None of the first group of patients required fasciotomy, and all recovered without sequel. Second group "difficult to quantitate objectively the benefits of HBO." | Yes |
| Radonic (20) | Retrospective case series/III | 13 patients with crural arteries injury. 10 had associated fractures. All treated surgically in conjunction with HBO. | 7–21 sessions of 60–120 min at 2.18 ATA | In HBO patients, outcome (function) was very good 2, good 3, fair 7, and one had BKA. In non-HBO patients, outcome was very good 4, good 3, fair 4, BKA 3 patients. AKA 2 (one had BKA initially). | Yes |
| Bouachour (21) | PRCT/I | 36 patients with Gustillo type II–III injury. Patients with peripheral arterial occlusive disease were excluded. All patients underwent surgical management within 6 h of injury. | After surgery, 18 patients received HBO 90 min at 2.5 ATA b.i.d. for 6 days, and 18 received placebo. | Complete wound healing without necrosis requiring excision in 17 patients of HBO group *vs.* 10 of placebo group ($P < 0.01$). Repetitive procedures in 33% placebo group *vs.* 6% in HBO group ($P < 0.05$). There were no complications from HBO. | Yes |
| Kiyoshige (22) | Small series. No control/III | 6 patients, 10 amputated digits Treatment replantation and HBO. | HBO 2 ATA 1 h for 5 days. | 7 survived. | Yes |
| Matos (23) | Case series. No control group/III | 23 patients with type III crush injuries; grade IIIA (7), grade IIIB (13), grade IIIC (3). All patients except two had surgery within 24 h of injury and HBO within 72 h. | 2.36 ATA for 90 min b.i.d.–q.d. Average of 12 HBO treatments. | 20 had preservation of the threatened limb. The 3 failures underwent transtibial amputation. | Yes |

# Murnau Trauma Centre

## Comlication Rates :

| | | *infections* | | *amputations* | |
|---|---|---|---|---|---|
| Injury Grade | | IIIB | IIIC | IIIB | IIIC |
| ***Gustilo*** | (37 pat.) | 52% | 42% | 16% | 42% |
| ***Murnau HBO*** | (88 pat.) | 24% | 40% | 9% | 31% |
| *lower extremities* | (38 pat.) | 39% | 53% | 17% | 27% |
| *upper extremities* | (50 pat.) | 9% | 33% | 0% | 33% |


100% $O_2$

2,5 ATA - 90 min

Hyperbaric chamber

24h after injury

# Chair of Emergency Medicine Wroclaw Medical University 2004-2006

- Efficacy of Hyperbaric Oxygen Therapy in the treatment of crush injuries of the limbs

- - local progression
- - infectious complications (local, septic)
- -number of amputations

# Material 2004 - -2006

- Gustilo 3B – 17
- Gustilo 3C – 2

# Crush injuries

- Time to $HBO_2$:
- 1st day: 9 patients
- >1 -7 days (3,9 days): 10 patients

# Infectious complications

- Early $HBO_2$
- o

- Delayed $HBO_2$
- G IIIB – MSSA
- G IIIB – Pseudomonas aeruginosa
- Compartment syndrome – MSSA
- G IIIB – E. coli

- This study shows the effectiveness of HBO in improving wound healing; decrease number of wound infections, and reducing repetitive surgery in crush injuries of the limbs. $HBO_2$ is a useful adjunct in the management of severe (grade III) crush injuries of the limbs.

# Crush injury treatment protocol:

- Shock management
- Immediate and repeated surgical debridement and irrigation of the wound, fasciotomies, stabilization of bones, vascular and nerval repair
- Appropiate wound closure (bone coverage)
- Antibiotic therapy
- *HBOT*
- Pain management

# HBO In TRAUMA

- Designated Major Trauma Centre
- Big, bed capable  Hyperbaric chamber
- Close to ICU & Emergency departement