Disclosures

- **Smith and Nephew:** Teach
- **Synthes:** Consultant

- No royalties
- Nothing relevant to this lecture
Whose Burden??
Ambrose Pare (1510-1590)

He was kicked by his horse and sustained an open tibia fracture. He manually removed the clot and loose bone fragments, and reduced and splinted his own fracture.
“Even such an exquisite regimen could not protect me against the fever that seized me on the 11th day, with drainage which caused me an abscess which suppurated a long time.”

“I believe all of this happened because of some humor retained in the part”

Long illness and much suffering … Pare went on to recover and walk

His horse did not fare as well.
38 yo smoker s/p MVA - DUI
ORIF at 20 days s/p ex-fix

Infection 6 weeks post-op

Plate retained and infection suppressed
The real “burden” of osteomyelitis

Out of work for 10 months, narcotic problem, lost her kids to her ex-husband, in debt
“The germ is nothing, it is the terrain in which it grows which is everything”

Louis Pasteur

*on his deathbed*
Host Status
Cierny – Mader classification 1985

A- host - Good immune / delivery system

B- host - Compromised host
  \[B^L\] – locally compromised
  \[B^S\] – systemically compromised
  \[B^C\] – combined

C- host – requires suppressive / no treatment
  - minimal disability
  - unable to tolerate surgery
Patient Comorbidities – B host
Cierny 2011

Local
- Chronic edema
- Venous stasis
- Vascular disease
- Arteritis
- Excessive scarring
- Radiation tx
- Obesity

Systemic
- Malnutrition
- Immune Deficiency
- Malignancy
- Hypoxemia
- Diabetes
- Nicotine Use
- Advanced Age
- Bleeding Diathesis
Whose Burden??
“Every wounded man who develops suppuration has the right to ask his surgeon to justify it”

Unconscious guilt - if the patient is ours, the infection is our fault

….we have failed.

Alex Carrel 1918

Klem 1989
Unconscious Guilt

• Like the 5 stages of grief
  ......the first is denial

• Leads to delayed diagnosis

• Interferes with rational thought and planning
Unburden ourselves from guilt
Think rationally – or refer

Remember:
“Every operation in surgery is an experiment in bacteriology”

Sir Berkely Moynihan
(1865-1936)
Whose Burden??

$\cdots\cdots\cdots\cdots$
When is it called Osteomyelitis?

No hard and fast rules

Chronicity > 2 weeks

Devitalized bone

Well established bacterial colonies

Synonomous with a hardware related deep infection?
Etiology - Osteomyelitis

- Hematogenous
- Post-surgical
  - ORIF
  - Total Joint Replacement
- Post-traumatic: Open fracture
  - Civilian
  - Military
Osteomyelitis - Overview

- 50,000 admissions/yr.
- 80% S Aureus    MRSA: 33-55%
- Hematogenous: 85% < 17 yo
  - MRSA  6%  (1999-2001)
    (worse outcomes)
- >50% of adult patients: post-traumatic
Osteomyelitis - Overview

- Long bone fractures
  - 11.5 per 100,000/year
  - > 350,000 ORIF/year
  - Infection rates 2-25%

- Total joint replacements
  - > 750,000/year
  - Infection rates 1-3%
Prosthetic Joint Infection

Primary:
- Hip ~ 1.7%
- Knee ~ 2.1%

Revision: 3% infection rate

60% from direct contamination
34% risk of infection from bacteremia
### U.S. Total Joint Infections

<table>
<thead>
<tr>
<th>Year</th>
<th>Admissions</th>
<th>Incidence/100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>19,972</td>
<td>74</td>
</tr>
<tr>
<td>2004</td>
<td>32,495</td>
<td>107</td>
</tr>
</tbody>
</table>

$280$ million/year on prosthetic joint infections in the U.S.
Prosthetic Joint Infection outcome by host type

Cierny and DiPasquale CORR 2002

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>High Risk (&gt;3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attempted Reimplantation</td>
<td>91%</td>
<td>66%</td>
<td>24%</td>
</tr>
<tr>
<td>2 year Implant survival</td>
<td>100%</td>
<td>86%</td>
<td>0%</td>
</tr>
</tbody>
</table>

2 deaths
1 amputation

“Adverse outcomes in all treatment groups in which the host was compromised by 3 or more comorbidities”
Traumatic Etiology

Military:
- High energy – A host

Civilian:
- Variable energy – B host (60%)
Wounded Warriors

Burden of the extremity wound
### Extremity Wounds

*Owens JOT 2007*

**Iraq: 2002-2005**

1566 soldiers – 6609 combat wounds

<table>
<thead>
<tr>
<th></th>
<th>WWII</th>
<th>Korea</th>
<th>Vietnam</th>
<th>Desert Storm</th>
<th>OIF OEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>23%</td>
<td>29%</td>
<td>27%</td>
<td>23%</td>
<td>28%</td>
</tr>
<tr>
<td>Lower</td>
<td>35%</td>
<td>36%</td>
<td>34%</td>
<td>48%</td>
<td>26%</td>
</tr>
<tr>
<td>Total</td>
<td>58%</td>
<td>65%</td>
<td>61%</td>
<td>71%</td>
<td>54%</td>
</tr>
</tbody>
</table>

50-70% of all wounds are extremity
Extremity Wounds
Owens JOT 2007

Fractures as proportion of extremity wounds

<table>
<thead>
<tr>
<th>Conflict</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>23%</td>
</tr>
<tr>
<td>Vietnam</td>
<td>27%</td>
</tr>
<tr>
<td>Desert Storm</td>
<td>39%</td>
</tr>
<tr>
<td>OIF/OEF</td>
<td>26%</td>
</tr>
</tbody>
</table>

>25% of extremity wounds are fractures
TABLE 4. Distribution of Fractures in Operation Iraqi Freedom/Operation Enduring Freedom

<table>
<thead>
<tr>
<th>Fracture</th>
<th>Closed</th>
<th>Open</th>
<th>Total</th>
<th>Percent Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clavicle</td>
<td>6</td>
<td>7</td>
<td>13</td>
<td>53</td>
</tr>
<tr>
<td>Scapula</td>
<td>4</td>
<td>28</td>
<td>32</td>
<td>87</td>
</tr>
<tr>
<td>Humerus</td>
<td>16</td>
<td>106</td>
<td>122</td>
<td>86</td>
</tr>
<tr>
<td>Forearm</td>
<td>23</td>
<td>107</td>
<td>130</td>
<td>82</td>
</tr>
<tr>
<td>Hand</td>
<td>20</td>
<td>144</td>
<td>164</td>
<td>87</td>
</tr>
<tr>
<td>Total upper</td>
<td>69</td>
<td>392</td>
<td>461</td>
<td>85</td>
</tr>
<tr>
<td>Femur</td>
<td>16</td>
<td>107</td>
<td>123</td>
<td>86</td>
</tr>
<tr>
<td>Leg</td>
<td>45</td>
<td>173</td>
<td>218</td>
<td>79</td>
</tr>
<tr>
<td>Foot</td>
<td>27</td>
<td>86</td>
<td>113</td>
<td>76</td>
</tr>
<tr>
<td>Total lower</td>
<td>88</td>
<td>366</td>
<td>454</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>157</td>
<td>758</td>
<td>915</td>
<td>82</td>
</tr>
</tbody>
</table>

~80% of all fractures are open
A little math……

50% of all wounds involve extremity
25% of all extremity wounds are fractures
80% of all fractures are open

\[0.5 \times 0.25 \times 0.80 = 0.10\]

10% of all wounds are open fractures
## Resource Utilization

**Iraq: 2001-2005**

1333 soldiers

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Ave Inpatient days</th>
<th>Resource Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head/neck</td>
<td>14.4</td>
<td>$13,334,162 (20%)</td>
</tr>
<tr>
<td>Thorax</td>
<td>13.1</td>
<td>$3,416,233 (5%)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>13.9</td>
<td>$6,627,491 (10%)</td>
</tr>
<tr>
<td>Extremity</td>
<td>17.9</td>
<td>$42,355,395 (65%)</td>
</tr>
</tbody>
</table>

50% of injuries

65% of total resources
Readmissions
Masini J. Trauma 2011

2001-2005: 1337 soldiers / 2899 readmissions
64% related to extremity injuries
70% of injured soldiers – 1 extremity readmission

Reason for readmission:

<table>
<thead>
<tr>
<th>ICD - 9 Code</th>
<th>Rehospitalizations (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonunion of fracture</td>
<td>5%</td>
</tr>
<tr>
<td>Post-operative infection</td>
<td>3%</td>
</tr>
<tr>
<td>Amputation stump complication</td>
<td>2%</td>
</tr>
<tr>
<td>Amputation stump infection</td>
<td>2%</td>
</tr>
<tr>
<td>Aftercare for surgery</td>
<td>1%</td>
</tr>
</tbody>
</table>
Iraq: 2001-2005 1333 soldiers

Total disability costs – $2 billion
$134 million for extremity disability
Disability Assessment
Masini JOT 2009

64% of soldiers with an extremity injury

Unfit to return to duty

Etiology:
1. LE amputation
6. UE amputation
20. Osteomyelitis

Grade III tibia: 22% chance of return
with osteo: 8%
The Extremity Wound

- Resource utilization
- Reason for readmission
- Disability payments
- Unfit to RTD

65%
Infectious complications/amputations

Huh J. Trauma 2011

Fate of type III open tibial fractures

2003 – 2007  213 fx’s

limb salvage   78%
early amputation 17%
late amputation  5% (13 mo)

Overall:  27% deep infection rate
17% osteomyelitis
**Infectious complications/amputations**  
*Huh J. Trauma 2011*

### Distribution of Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>Limb Salvage</th>
<th>Early Amputee</th>
<th>Late Amputee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Infection</td>
<td>21%</td>
<td>42%</td>
<td>73%</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>14%</td>
<td>17%</td>
<td>55%</td>
</tr>
<tr>
<td>Flap Failure</td>
<td>1%</td>
<td>6%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Prior to definitive amputation

Infection and osteomyelitis **drives** amputation
Fate of grade III tibia fractures
Burns et al J. Trauma 2012

Effect of Infection on Amputation rate and Osseous Union

<table>
<thead>
<tr>
<th>Condition</th>
<th>Amputation Rate (%)</th>
<th>Time To Union (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Infection</td>
<td>15.5</td>
<td>8.64</td>
</tr>
<tr>
<td>Deep Infection</td>
<td>40.4</td>
<td>11.2</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>34.3</td>
<td>11.0</td>
</tr>
</tbody>
</table>
Economic Burden
Masini et al

2001-2011:

Total **initial inpatient cost** for wounded warriors:
$1 billion - 2/3rds ($667 million) extremity injuries
~5% for infections and osteomyelitis

Total **rehospitalization costs**:
$208 million - $139 million for extremity care
~20% for infection and osteomyelitis
Microbiology of Wounds
Johnson et al CID 2008, Brown et al J. Trauma 2010

Grade III Tibia fractures

• Early (<14 days):
  Acinetobacter, Pseudomonas, Entero.
  mixed gm +  (early gm+ coverage)

• Late: (deep infection/osteomyelitis)
  Staph Aureus 100%  MRSA (31%)
  Enterobacter, Klebsiella, Pseudomonas

• Minimal correlation
Drug Resistance - History

Methicillin introduced in 1961

• 6 months later….
  3 Methicillin - resistant isolates identified

• 7 years later…..
  6 countries reported MRSA

• 1991:  MRSA 25% of ICU S. Aureus

• 1999:  MRSA 50% of ICU S. Aureus

• 2007:  94,000 MRSA infections/year
  19,000 deaths from MRSA

• Tip of the iceberg
It took 60 years for penicillin to become a placebo
Civilian Post – Traumatic Osteomyelitis

*Harris JOT 2009, Bosse NEJM 2002*

Observational LEAP study 1994-1997:
569 Type III open tibia fractures:

**Complications: most common**
- Wound infection: 28%
- Nonunion: 24%
- Wound breakdown: 9%
- Osteomyelitis: 8%
Civilian Post – Traumatic Osteomyelitis

Observational LEAP study 1994-1997:
569 Type III open tibia fractures:

Osteomyelitis by treatment group:

- limb salvage: 9%
- early amputation: 0% post amp
- late amputation: 40% post amp
(50% after 24 mo)
Observational LEAP study 1994-1997: 569 Type III open tibia fractures:

Osteomyelitis by fracture type:

- type IIIA: 18.5%
- type IIIIB: 11.1%
- type IIIIC: 27.3%
- amputation overall: 3.1%
### Economics of Limb Salvage

*Mackenzie et al JBJS 2007*

From LEAP study:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td>$91,100</td>
<td>$81,300</td>
</tr>
<tr>
<td>Projected Lifetime</td>
<td>$509,200</td>
<td>$163,200</td>
</tr>
<tr>
<td>Prosthetic costs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unprecedented Survival

• Civilian MVA: airbags/seatbelts and rapid transport

• Military: body armor and rapid transport

• Extremity injuries determine:
  Length of stay, cost, disability, readmission

• Within extremity injuries:
  wound care, infections, osteomyelitis, and late amputations drive resource utilization
Osteomyelitis – Treatment Outcome
Yun, Branstetter, Murray J. Trauma 2008

2003-2006: Brooke Army Medical Center

2854 admissions → 664 orthopedic

103 osteomyelitis

83% eradicated   17% recurrence
1672 cases of chronic osteomyelitis treated over 21 years
Summary - Osteomyelitis

• Patient carries the real burden –
  - focus of what we do

• Surgeons carry the psychological burden – confront it

• Society bears the $$ cost
Summary-Osteomyelitis

• Extremity injuries drive trauma costs
• Implant related infections, osteomyelitis, are very expensive
• Late amputations are often the result of infection
• Multi drug resistant organisms are on the rise rapidly – stay on top of this data
• The B-host remains a challenge
Thank You!