Ballistic Fractures of the Lower Extremities: A Review of Complications from a Level I Trauma Center

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Podium Presentation AAOS 2013
Abbott Society 2014

GENERAL CONSIDERATIONS

- 1900-2000 over 233 million guns in the US
- Cost of medical Rx yearly $2.7 billion, mostly uncompensated care
- Estimated $50 million/yr urban hospitals
- 40-50K deaths/year in US

Introduction

- Gunshot injuries are a major source of traumatic injury seen in civilian populations
- Estimated 57 million gun owners in the US
- In 2010, there were 73,505 nonfatal gunshot injuries
  - 24 injuries/100,000 people
  - Represents an increase of 6,736 injuries from 2009 and a rise of 5,200 over the past ten year average

Disclosure

No disclosures or COI
Treatment: Historical Aspects

CIVIL WAR

- Union surgeons: 30K amputations with 26% mortality
- No antibiotics
- Initially, all penetrating extremity wounds: amputation
  
Assassination of President Garfield

- July 2, 1881
- Shot arm and back
- Lister had spoken to surgical societies in Boston, NYC, and Philadelphia March 1881 on “aseptic surgery”
- Priority: removal of bullet (passing by doctor tried to remove bullet on floor of railroad station)
- Alexander Graham Bell developed metal detector to find bullet
- Multiple MD’s put unsterilized fingers and probes into wound
- Died of sepsis 80 days later

Gunshot Fx’s in Civilian Practice

- 72 low energy GSW’s: 25 UE, 9 tibia, femur 8, knee 7, hip 2
- Majority Rx: superficial debridement and closed Rx
- Majority: no antibiotics
- 2/72 wound infections
- “Conservative management of civilian GSW’s”
Current Grady Management of Low Energy Extremity GSW’s

- Initial management: vascular assessment (ABI), neurological assessment, minor debridement
- Tetanus
- 1 parenteral dose of cephalosporin antibiotics
- Splinting or traction
- Elective ORIF

Hypotheses for Lower Extremity GSW’s

- ? Overall complication rate ↑ with ballistic fractures in comparison to non-ballistic fractures
- ? Anatomic correlation with complications: acute compartment syndrome, vascular injuries and surgical site infection
- Timing of ORIF correlation to SSI

Materials and Methods

Methods

- Level III, retrospective analysis
- Emory and Grady Institutional Review Board approval
- Patients admitted to Grady Memorial Hospital from January 1st, 2006 to June 30th, 2011, with ballistic fractures to the lower extremity
- Patients identified through trauma registry, and detailed chart review performed
Methods

• Inclusion Criteria
  – Ballistic fractures to the lower extremity distal to the hip joint
  – Intra-articular gunshot wounds to the knee without fracture
  – High and low velocity injuries

• Exclusion Criteria
  – Ballistic injuries to the lower extremities without associated fracture
  – Incomplete records

Results

• 418 patients with 488 lower extremity ballistic fractures were included
• Mean age 30, range 14-71
• 392 male, 21 female

Results – Incidence by Fracture Location

<table>
<thead>
<tr>
<th>Fracture Classification</th>
<th>Number of Fractures</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur proximal 1/3</td>
<td>94</td>
<td>19.3%</td>
</tr>
<tr>
<td>Femur mid 1/3</td>
<td>46</td>
<td>9.4%</td>
</tr>
<tr>
<td>Femur distal 1/3</td>
<td>113</td>
<td>23.2%</td>
</tr>
<tr>
<td>Patella</td>
<td>18</td>
<td>3.7%</td>
</tr>
<tr>
<td>Intra-articular fracture</td>
<td>2</td>
<td>0.4%</td>
</tr>
<tr>
<td>Tibia prox 1/3</td>
<td>48</td>
<td>9.8%</td>
</tr>
<tr>
<td>Tibia mid, distal 1/3</td>
<td>66</td>
<td>13.5%</td>
</tr>
<tr>
<td>Fibula prox 1/3</td>
<td>54</td>
<td>11.1%</td>
</tr>
<tr>
<td>Fibula mid, distal 1/3</td>
<td>38</td>
<td>7.8%</td>
</tr>
<tr>
<td>Foot</td>
<td>29</td>
<td>5.9%</td>
</tr>
<tr>
<td>Total</td>
<td>488</td>
<td>100%</td>
</tr>
</tbody>
</table>
Vascular Injuries

Vascular Injury

- Defined as vascular compromise found through advanced imaging or surgical exploration
- 49/488 (10%)
- Proximal 1/3 Fibula Fractures
  - 8/34 (23.5%), RF 2.34, p < 0.05

Acute Compartment Syndrome

- 72/488 (14.8%) developed ACS
- Proximal 1/3 Fibula Fractures
  - 12/34 (35.3%) developed ACS
  - Risk Ratio: 2.39, p < 0.05
Compartment Syndrome in the Presence of Vascular Injury

- 40 out of 49 cases of vascular injury developed associated compartment syndrome (unclear if prophylactic vs therapeutic fasciotomies)
- 81.6%, \( p < 0.001 \)

<table>
<thead>
<tr>
<th></th>
<th>Compartment Syndrome</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular Injury</td>
<td>Not Present</td>
<td>Present</td>
</tr>
<tr>
<td>Not Present</td>
<td>407</td>
<td>32</td>
</tr>
<tr>
<td>Present</td>
<td>9</td>
<td>40</td>
</tr>
</tbody>
</table>

Surgical Site Infections

Infection

- Defined as any soft tissue compromise at the site of surgery or injury requiring parenteral antibiotics or surgical intervention
- 5 patients excluded from analysis due to incomplete records
- 54/483 (11.2%)

- Distal 1/3 Tibia Fractures
  - 15/65 (23.1%), RF 2.06, \( p < 0.05 \)
- Middle to distal 1/3 Fibula Fractures
  - 9/37 (24.3%), RF 2.18, \( p < 0.05 \)
- Proximal 1/3 Tibia Fractures
  - 10/48 (20.8%), RF 1.86, \( p = 0.062 \)
  - Trend towards infection, not significant
- Proximal 1/3 Femur Fractures
  - 2/93 (2.2%), RF 0.19, \( p < 0.05 \)
  - Significantly lower infection risk
Infection in the Presence of Compartment Syndrome

- 22 out of 71 cases of compartment syndrome developed associated infection
- 31%, p < 0.001

<table>
<thead>
<tr>
<th>Infection</th>
<th>Not Present</th>
<th>Present</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compartment Syndrome</td>
<td>380</td>
<td>32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Present</td>
<td>49</td>
<td>22</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Infection in the Presence of Vascular Injury

- 14 out of 49 cases of vascular injury developed associated infection
- 28.5%, p < 0.001

<table>
<thead>
<tr>
<th>Infection</th>
<th>Not Present</th>
<th>Present</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular Injury</td>
<td>394</td>
<td>40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Present</td>
<td>35</td>
<td>14</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SSI at Grady

- All Surgery: 89/2275 (2010) 3.9%
- ORIF GSW’s 54/483 11%
- ORIF HIV Pos: 15/64 23%
  (CD-4 counts < 200, albumen < 2.5, polytrauma statistically significant (p<0.005)
  Clin Orthop Rel Res 2012

Timing of ORIF and SSI

- ORIF GSW's 11%
Timing of Surgery and SSI

- 54/483 GSW’s: SSI (11%)
- 75.9% of SSI had surgery < 48 hrs from GSW (p=0.026)
- 55.6% of SSI had surgery < 24 hrs from GSW
- Mean time from GSW to SSI 1.3 + 2.9 days (p=0.010)

Discussion

Conclusions this Study

1. There are complications with ballistic fx’s compared to non-ballistic fx’s
2. Isolated proximal fibular fx’s have statistically incidence of ACS and vascular injuries (although “orthopaedically benign”, should always be admitted for observation)
3. Incidence of SSI with early fixation (24hrs) of ballistic fx’s
VERTEBRAL ARTERY INJURY (VAI) FOLLOWING BLUNT CERVICAL TRAUMA

Thomas J Moore MD
David V Feliciano MD
Presented at AOA Annual Meeting
Quebec City, June 6, 2008

The Surgical Treatment of Adult Acquired Spasticity

VARIABLES ASSOCIATED WITH POSTOPERATIVE INFECTION IN HIV-POSITIVE ORTHOPAEDIC TRAUMA PATIENTS

Thomas J Moore MD
Whitney Barnes BS
Christopher Hermann BS
George G Guild MD
Podium Presentation AAOS 2011
Clin Ortho Rel Res 2012

Future Studies
GSW WOUNDS TO THE HIP

- Ashook Reddy MD
- Thomas J Moore MD
- Mary Jo Albert MD
- James Roberson MD
- Kelly Day Presentation

MATERIALS AND METHODS

- 14 pts with GSW to hip at Grady Hospital 1991-1995
- Ave age 23.5 yrs—all male
- 11 pts with FNF, intertrochanteric fx or femoral head fx
- 3 pts with intraarticular bullet with no fx
- 11 pts with no other associated injuries, 2 had associated arterial injury, 1 pt had intra-abdominal injury requiring laparotomy

RESULTS

- Final F/U ave. 13 mos
- 9/14 pts fx’s healed with no sequelae with return to pre-injury status
- 1 pt with AVN of femoral head
- 1 adolescent with greater trochanteric overgrowth
- 2 pts with nonunion of FNF and AVN
- 2 pts systemic lead intoxication requiring chelation

CASE REPORT

- 1 yr post injury: N/U of FNF, AVN, “lead arthrogram”
- Intermittent abd pain, fatigue, memory loss
- Htc 22%, microcytosis, basophilic stippling on peripheral stain, reticulocyte count 8.7%
- Serum lead level 270 ug/dl (normal 0-71 ug/dl)
CASE REPORT-TREATMENT

- Chelation with DMSA for 5 days
- Transfusion 2 units pRBC’s
- THR
- DMSA restarted 2 weeks post-op
- Serum lead level 2 weeks post op 146 ug/dl
- 24 hr urine lead level 13639 mcg (nl 0-80mcg)

Serum Lead Levels in GSW’s in Adolescents

ELEVATION OF BLOOD LEAD LEVELS WITH EXTRA-ARTICULAR RETAINED MISSILE

- 120 pts with extra articular GSW’s and 120 control pts
- Serum lead levels, zinc levels, Hbg levels
- 4 % significantly elevated lead levels in GSW group (0 % in control group)
- Longer duration of retained missile not associated with elevated levels
- Hypermetabolic states associated with elevated serum lead levels

Nguyen A,( Bellevue, Cook Co Dept. of Emergency Medicine)
J of TRAUMA, 2005

ELEVATION OF BLOOD LEAD LEVELS WITH EXTRA-ARTICULAR RETAINED MISSILES

- Lead stores are stored in bone and released with hypermetabolic states
- Surgery, alcohol intoxication, drug intoxication, DKA, hyperthyroidism, sepsis, pregnancy, fractures and lactation are known to elevate serum lead levels

Nguyen A,( Bellevue, Cook Co Dept, of Emergency Medicine)
J of TRAUMA, 2005
**Physiologic Aspects of Open Epiphysis**

- Extremities with open epiphysis have increased overall blood flow (activity on Tc bone scan).
- Fractures in long bones with open epiphysis have prolonged hypermetabolic state, including remodelling stage, (can last several yrs).

**Blood Lead Concentration in Children After GSW's**

- 23 children with retained bullets.
  - Defined elevated lead level >30 ug/ml.
  - No child had elevated lead level (their criteria).
  - However, 11/23 would have had elevated levels using current CDC criteria.
  

**Lead Toxicity Associated with a GSW-Induced Femoral Fracture**

- Extraarticular extremity GSW's: ↑ serum lead for 3 mos.
  - ↑ with hypermetabolic status (ie fracture), size of remaining bullet.
  - Recommend: baseline lead level at initial Rx, 2 weeks, monthly x 2 and at 1 yr post GSW.
  
  Dougherty, JBJS 2009.

**Childhood Lead Poisoning: Too Little Too Late**

- CDC “acceptable” children lead level <10 ug/dl.
- CDC level of “case management” or level of concern > 5 ug/dl (CDC 9-23-2012).
- Risk groups: impoverished children in older homes or more affluent children in renovated houses.
- 1970’s: 88% < 6 yrs old had serum lead levels >10 ug/dl.
- Lead banned from paint 1978, and by early 1990’s, < 5% children had serum lead levels > 10 ug/dl.
- 1997-98: shift away from universal testing to targeted testing at-risk children (CDC, Am Acad Peds).

Lanphear, B, JAMA, 2005.
INTELLECTUAL IMPAIRMENT IN CHILDREN WITH BLOOD LEVEL CONCENTRATIONS BELOW 10 UMG/DL

• Elevated lead levels may underlie some of the prevalent health disparities found in socially disadvantaged children
• School failure and criminal behaviors may be associated

Canfield  *N Eng J Surg* 2003

Proposed Study

• Serum lead levels in adolescents s/p extremity GSW at 2 month intervals
• Control group
• ? Ability to measure lead load in retained bullets (Ga Tech)

End of the line for the Lead Bullet-Bans Force Switch to “Green” Bullets

• Lead bullets harm the environment by contaminating groundwater
• California banned lead bullets for hunting by 2019
• Military plans to phase out lead bullets by 2018
• Expected to cost of ammunition as cooper more expensive
**GSW to the Spine**

- 14% of Spinal Cord Injuries
- Rarely need operative stabilization for structural problems
- Focus on spinal cord injury
- Standard antibiotic prophylaxis

**Timing of ORIF and SSI**

**Fracture Fixation**

- Prospective Trial
  - Acute vs delayed IMN of ballistic femoral shaft fractures from low velocity GSW
  - No difference in
    - Infection
    - Delayed union
    - Nonunion

Hollman J Ortho Trauma, 1990.
### Comparison between Infection or Not

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n=485)</th>
<th>No (n=431)</th>
<th>Yes (n=54)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days from Injury to 1st Surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never has a surgery</td>
<td>66/485(13.6%)</td>
<td>66/431(15.3%)</td>
<td>0/54(0.0%)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>3+ Days</td>
<td>59/485(12.2%)</td>
<td>50/431(11.6%)</td>
<td>9/54(16.7%)</td>
<td></td>
</tr>
<tr>
<td>2 Days</td>
<td>81/485(16.7%)</td>
<td>57/431(13.2%)</td>
<td>14/54(25.9%)</td>
<td></td>
</tr>
<tr>
<td>1 Day</td>
<td>159/485(32.8%)</td>
<td>148/431(34.3%)</td>
<td>11/54(20.4%)</td>
<td></td>
</tr>
<tr>
<td>0 Day</td>
<td>140/485(28.9%)</td>
<td>110/431(25.5%)</td>
<td>30/54(55.6%)</td>
<td></td>
</tr>
<tr>
<td>Days from Injury to 1st Surgery (Including 'Never has a surgery')</td>
<td>186/485(38.4%)</td>
<td>173/431(40.1%)</td>
<td>13/54(24.1%)</td>
<td>0.030*</td>
</tr>
<tr>
<td>0-1 Day</td>
<td>209/485(43.1%)</td>
<td>185/431(42.9%)</td>
<td>24/54(44.4%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days from Injury to 1st Surgery (Min-Max)</th>
<th>[0.0 - 72.0]</th>
<th>[0.0 - 72.0]</th>
<th>[0.0 - 18.0]</th>
<th></th>
</tr>
</thead>
</table>

### Introduction

- Gunshot injuries are a major source of traumatic injury seen in civilian populations
- Estimated 57 million gun owners in the US
- In 2010, there were 73,505 nonfatal gunshot injuries
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**CDC**