Be Aware of the Seat Belts that Save Lives

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CoxHealth

Overview

- Seat belts save lives
- Seat belt injury patterns
- Seat belt sign
- Vertebral injuries
- Blunt hollow viscus injury
- Blunt abdominal wall hernia
- Blunt cerebrovascular injury

Worsening situation

Top 10 leading causes of death

<table>
<thead>
<tr>
<th>Rank</th>
<th>Disease of Injury</th>
<th>2004</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ischaemic heart disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cerebrovascular disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lower respiratory infections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Chronic obstructive pulmonary disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Diarrhoeal diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>HIV/AIDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ischaemic heart disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cerebrovascular disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lower respiratory infections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Pneumonia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

www.decadeofaction.org
History of Seatbelts
- 1885 – First patent for safety belt
- 1955 – Ford offers first seat belt as option
- 1958 – Saab introduced seat belts as standard
- 1959 – Volvo introduces 3-point seatbelt
- 1968 – US law required all cars to have seatbelts
- 1970 – First law to mandate seat belt use in Victoria, Australia
- 1984 – New York is first state to mandate seat belt use

Motor Vehicle Crashes
- MVC’s one of the leading causes of death
- 2011 – 32,367 deaths due to MVC
  - 2.22 million injuries
- Seat belt use is single most effective way to save lives and reduce injuries
- Wearing seat belts can reduce injuries and deaths in crashes by approximately 50%

Without a seatbelt
- Car approaches a tree at 30 m/sec. What force is needed to stop the 60 kg driver in 0.1 sec?

\[ F = m(v_f - v_i) \]
\[ F = 60\text{ kg} (0 \text{ m/s} - 30 \text{ m/s}) \]
\[ F = -18000 \text{ N} \]
With a Seatbealt

- Task of seatbelt is to stop you with the car so that your stopping time is 4-5 times greater
- Car approaches a tree at 30 m/sec. What force is needed to stop the 60 kg driver in 0.1 sec?
  
  \[ F (0.5 \text{ s}) = 60\text{kg} (0 \text{ m/s}) - 60\text{kg} (30 \text{ m/s}) \]
  \[ F (0.5 \text{ s}) = 1800 \text{ Ns} \]
  \[ F = -3600 \text{ N} \]
  
  -3600 N vs -18000 N

CDC

- Deaths
  - 2015 - 35,092 died in MVC
  - 59% who died aged 20-44 were unrestrained

- Injuries
  - 2015 - 2.5 million injuries due to MVC
  - Young adults (18-25) have highest crash related non-fatal injury rates

- Costs
  - Non-fatal crash injuries resulted in $48 billion in lifetime medical and work loss costs in 2010

CDC

- Who is least likely to wear seatbelts?
  - Young adults
  - Men
  - Rural
  - Rear seat passengers
  - Those in secondary seat belt law states or no seat belt law states
CDC

- Seat belts
  - Reduce serious crash-related injuries by ½
  - Seatbelts saved almost 14,000 lives in 2015
  - Could have saved an additional 2,814

- Primary seat belt law
  - 92%

- Secondary seat belt law
  - 85%

Missouri

**Motor Vehicle Occupant Deaths**

- Number of Deaths, 2009–2012
- Rate of Deaths by Age per 100,000 population, 2012

**Restraint Use**

- Percentage of Drivers and Front Seat Passengers Wearing Seat Belts
  - National: 86%
  - Missouri: 79%

NTDB study – Nash et al, Amer Surg, Feb 2016

- 2009 data
- All victims in MVC stratified into seat belt or not
- Total MVC 235,215
- 150,161 patients in study
  - 72,394 with seat belt

NTDB study – Nash et al, Feb 2016

- Young, male patients least likely to wear seat belt
- Restrained drivers
  - Lower ISS
  - Lower Abbreviated Injury Score
  - Less solid organ injury (9.7% vs 12%, P < 0.001)
  - Lower GCS
  - Shorter LOS and ICU
  - Lower mortality (1.9% vs 3.3%, P < 0.001)
    - Confirmed with adjusted odds ratio (0.5, 95% confidence)
  - HIGHER hollow viscous injury (1.9% vs 1.3%, P < 0.001)

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<table>
<thead>
<tr>
<th>Table 2</th>
<th>Injury Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>seat belt</td>
<td>/ (s) = 73,284</td>
</tr>
<tr>
<td>head AIS = 3</td>
<td>23,541 (15.5%)</td>
</tr>
<tr>
<td>chest AIS = 3</td>
<td>20,716 (12.8%)</td>
</tr>
<tr>
<td>abdominal AIS = 3</td>
<td>3,265 (2.2%)</td>
</tr>
<tr>
<td>lower extremity AIS &gt; 3</td>
<td>18,270 (12.7%)</td>
</tr>
<tr>
<td>ISS mean ± standard deviation</td>
<td>15.0 ± 9.3</td>
</tr>
<tr>
<td>P</td>
<td>17.446 (11.1%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Air Bag Status and Seat Belt Impact on Injury Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>air bag status</td>
<td>/ (s) = 150,161</td>
</tr>
<tr>
<td>present, not deployed</td>
<td>5,066</td>
</tr>
<tr>
<td>present, deployed</td>
<td>18,062</td>
</tr>
<tr>
<td>present, not deployed</td>
<td>10,335</td>
</tr>
<tr>
<td>present, deployed</td>
<td>18,062</td>
</tr>
<tr>
<td>P</td>
<td>186 (3.5%)</td>
</tr>
</tbody>
</table>
Drivers more likely to wear seatbelt than passenger
Air bags alone were at increased risk of LE injury (relative risk 1.10, P < 0.001)
Incidence of seat belt use – 47%
  Far different than CDC reported rate of 85%

Hollow viscus injury increase
  Supported by other studies
  Rutledge et al, J Trauma, 1991

Prospective study Apr 2006 to Oct 2007 in UAE
Goal of study
  effects of seat belt
  injury pattern
  outcomes

766 patients
  631 (83%) unrestrained

- 17.6% used seat belt
- 10% female, 20% male

Unrestrained patients
- 99% rear seat passengers
- Higher ejection % (15% v 1%, P < 0.001)
- Higher AIS (P < 0.001)
- Higher ISS (P < 0.001)
- Lower GCS (P < 0.006)

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Table 2: Distribution of injuries of vehicle occupants by anatomic body region (n = 786).

<table>
<thead>
<tr>
<th>Body region</th>
<th>Belted (n = 135)</th>
<th>Unbelted (n = 631)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>59 (43.7%)</td>
<td>323 (51.2%)</td>
<td>0.11</td>
</tr>
<tr>
<td>Face</td>
<td>55 (40.7%)</td>
<td>244 (38.7%)</td>
<td>0.65</td>
</tr>
<tr>
<td>Neck</td>
<td>13 (9.6%)</td>
<td>42 (6.7%)</td>
<td>0.26</td>
</tr>
<tr>
<td>Thorax</td>
<td>45 (33.3%)</td>
<td>220 (34.9%)</td>
<td>0.73</td>
</tr>
<tr>
<td>Abdomen</td>
<td>18 (13.3%)</td>
<td>88 (14.0%)</td>
<td>0.99</td>
</tr>
<tr>
<td>Back</td>
<td>13 (9.6%)</td>
<td>99 (15.7%)</td>
<td>0.08</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>3 (3.7%)</td>
<td>39 (6.2%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>7 (5.2%)</td>
<td>27 (4.3%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>3 (3.7%)</td>
<td>28 (4.4%)</td>
<td>0.33</td>
</tr>
<tr>
<td>Upper extremity</td>
<td>51 (37.8%)</td>
<td>226 (35.8%)</td>
<td>0.67</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>37 (27.4%)</td>
<td>224 (35.5%)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

* P-cell or Fisher’s exact test as appropriate

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Table 4: Studied severity markers in RTC-injured vehicle occupants comparing those using a seat belt and those not using it.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Belted (n = 135)</th>
<th>Unbelted (n = 631)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISS</td>
<td>6.1 (6.4)</td>
<td>9.36 (9.6)</td>
<td>0.001</td>
</tr>
<tr>
<td>TRS</td>
<td>12 (0.12)</td>
<td>11.8 (0.69)</td>
<td>0.003</td>
</tr>
<tr>
<td>GCS</td>
<td>14.8 (1.1)</td>
<td>14.1 (2.4)</td>
<td>0.006</td>
</tr>
<tr>
<td>Total hospital stay (days)</td>
<td>5.3 (7.7)</td>
<td>9.6 (15.2)</td>
<td>0.005</td>
</tr>
<tr>
<td>Operations needed</td>
<td>23 (17%)</td>
<td>166 (26.3%)</td>
<td>0.027</td>
</tr>
<tr>
<td>ICU admission</td>
<td>6 (4.4%)</td>
<td>98 (15.5%)</td>
<td>0.0003</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>6 (3.8)</td>
<td>69 (6.8)</td>
<td>0.3</td>
</tr>
<tr>
<td>Mortality</td>
<td>2 (1.5%)</td>
<td>15 (2.4%)</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Data are presented as the mean (SD) or number (%), as appropriate.
RTC: Road traffic collision, ISS: Injury Severity Score, GCS: Glasgow Coma Scale, ICU: Intensive care unit

* Mann–Whitney U-test, P-cell test, or Fisher’s exact test as appropriate
Nebraska study— Han et al, Traf Inj Prev, 2015; 16, 605-610

- Seat belt use and specific injury patterns
- Nebraska Crash Outcome Data Evaluation System
- 2006-2011
- 10,479 MVC with injury requiring hospitalization
  - 4,439 male
  - 6,040 female

Case Presentation

- 6 yo boy
- Head on MVC
- Rear seat passenger in adult 3 point seatbelt
- Multiple deaths at scene
- PE – Deep laceration to abdomen, muscle layers transected, No LE movement
- FAST - ? Fluid
- CT – Free air, Abdominal hernia, T3 fracture, Thoracic cord transection
Case Presentation

- Urgent damage control laparotomy
- Bowel resection
- Chest tube
- Transferred to Pediatric Spine institution

Seat belt Syndrome

- First described by J Garrett in 1962
- Classic triad
  - Abdominal wall bruising
  - Internal abdominal injury
  - Spinal fracture
- Rapid deceleration forces caused by hyperflexion of torso and consequent compression of abdomen around lap belt

Seatbelt Syndrome in Children

- Partners for Child Passenger Safety study
  - Seat belt sign prevalence - 1.3%
  - Serious abdominal injury – 0.21%
- Prospective multicenter study
  - Seat belt sign incidence – 16%
  - Abdominal injury – 6.7%
    - Borgalli et al, Acad Emerg Med, 2004;11:1440-1448
Seatbelt Syndrome in Children
Szadkowski et al, Ped Emer Care, Feb 2017

- Children presenting with seat belt sign
  - 9-21% solid organ injury
  - 11-25% GI injury
  - 75% hollow viscous injury
  - 50% spinal injury

- Paris et al, J Ped Surg, 2010;45:921-924
- Shepherd, Emerg Med Australas, 2006;18:57-63

- Most common site of intestinal injury
  - Jejunum
  - Duodenum
  - Ileum
  - Cecum

CT Scan indicators of bowel injury
- Pneumoperitoneum
- Bowel wall thickening
- Streaking of mesenteric fat
- Unexplained peritoneal fluid

- Cox et al, Clin North Am, 1996;34:879-886

Seatbelt Syndrome in Children
Szadkowski et al, Ped Emer Care, Feb 2017

- Chance Fracture
  - First described by Dr Chance in 1948
  - Flexion distraction injury
  - Up to 40-90% of vertebral fractures in restrained MVC

- Partners for Child Passenger Safety study
  - Presence of an intra-abdominal injury increases risk of vertebral fracture
  - Reported incidence of 15%
    - Lust et al, J Ped Surg, 2004;39:972-975
Current AAP Recommendations

- Infants and toddlers under 2 yo should ride in rear-facing seats.
- Children 2 and older should use a forward-facing seat for as long as possible (generally until 65-80 lbs.).
- Children who have outgrown a forward-facing seat should use a booster seat until the lap-and-shoulder belt fits properly (generally 4 ft 9 in and between 8 and 12 yo).
- Children should always use lap-and-shoulder belts once they’ve outgrown booster seats.
- Children should ride in the back seat until age 13 yo.

Campaigns

Case Presentation

- 14 yo high speed head-on collision
- Lap belt in rear seat
- +LOC
- Diffuse abdominal pain
- Moderate back pain
- Seat belt sign noted
- CT identified
  - Mandible fracture
  - Hemoperitoneum
  - Grade 2 liver laceration
  - L3 fracture(bil pedicle, facets, lamina, and TP)
Case Presentation
- Normal labs
- No surgical intervention
- Discharged home PID 5 with lumbar brace

Case Presentation
- PID 11
  - Admitted with worse abdominal pain, bilious emesis, and fever
  - X-ray showed ileus vs SBO
  - CT showed improvement in SBO and less ascites
  - Discharged 2 days later

Case Presentation
- PID 18
  - Readmitted for abdominal pain, emesis, and distension
  - Upper GI with high grade SBO
  - Ex lap showed dense adhesions due to bowel injury
  - 18 inches of jejunum resected
**Hollow Viscus Injury**


- **Bowel affected**
  - Small intestine (55%), colon (25%), duodenum (10%)

- **Types of injury**
  - Serosal/seromuscular
  - Full-thickness
  - Blowout
  - Mesentery
    - Bruising
    - Hematoma
    - Disinsertion

- **Intestinal and mesenteric injuries**
  - Fairly rare
  - 3-5% of all blunt abdominal trauma
  - Third most common after liver and spleen laceration

- **MVC cause in over 70-90%**

- **Greater risk for passengers compared to driver**

- **Seat belts may play a causative role**
  - More common with lap belt, but seen in 3-point harness

- **Mechanism**
  - Direct impact
    - Energy passes from surface to body core
    - Velocity plays major role
    - Lacerations, tearing, bruising
  - Deceleration
    - Sudden velocity change to zero
    - Mesenteric disinsertion
    - Increased luminal pressure
      - Abrupt abdominal compression to air-filled intestine
      - Proximal jejunum
Hollow Viscus Injury

- **Diagnosis**
  - High index of suspicion
  - Mechanism of injury
  - Clinical exam
  - Seat belt sign

- **CT findings**
  - Loss of bowel continuity
  - Bowel wall thickening
  - Mesenteric infiltration
  - Enhancement defect
  - IV extravasation
  - Pneumoperitoneum
  - Mesentery thrombosis

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**Matsushima et al, World J Surg, 2013**

- Diagnosis remains difficult despite new technology
- 67 patients (0.8%) with HVI from 2002-2009
- 61% had abdominal pain
- 85% had wbc > 10k
- 17% elevated amylase
- CT with finding – 81%
  - Free fluid – 57%
  - Mesentery stranding – 30%
  - Bowel thickening – 24%
  - Mesentery hematoma
- Ischemic HVI harder to diagnose
Hollow Viscus Injury

  - 11 year experience with HVI
  - 41 patients
  - Stratified into two groups
    - Interval to OR <24h
    - Interval to OR ≥24h
  - 70% MVC, 8% MCA
  - 41% jejunum, 22% colon, 15% ileum, 10% duodenum

- LOS, vent days, ARDS greater in >24h
- Mortality rate not significant
- Patient transfers more likely to experience delay

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group One (&lt;24 h)</th>
<th>Group Two (≥24 h)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (%)</td>
<td>36 (77.2)</td>
<td>11 (22.8)</td>
<td>0.0394</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>11 ± 8.9</td>
<td>24.5 ± 22.9</td>
<td>0.0076</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>3.5 ± 2.1</td>
<td>10.7 ± 22.7</td>
<td>0.0482</td>
</tr>
<tr>
<td>Ventilator days</td>
<td>31 ± 6.3</td>
<td>148 ± 193</td>
<td>0.0045</td>
</tr>
<tr>
<td>Blood products (units)</td>
<td>6.5 ± 4.5</td>
<td>11.7 ± 7.7</td>
<td>0.0555</td>
</tr>
<tr>
<td>Antibiotic treatment (days)</td>
<td>4.5 ± 1.4</td>
<td>9.3 ± 3.7</td>
<td>0.1316</td>
</tr>
<tr>
<td>Number of complications</td>
<td>6.5 ± 1.7</td>
<td>1.1 ± 1.0</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

Case Presentation

- 16 yo male s/p head on MVC
- Rear seat passenger
- 3 point seatbelt
- PE – Seat belt injury, large fascial defect
- FAST – positive
- CT – Large defect to abdominal wall, near evisceration, Free air, free fluid
Case presentation

- Emergent damage control laparotomy, small bowel resection x 3, colon resection x 1, wound vac

- PID#2 – Planned exploratory laparotomy, entero-entero anastamosis x 2, colo-colonic anastamosis, wound vac

- PID#4 – Complex ventral hernia repair, Bilateral myofascial release, Use of bio-synthetic mesh placement, debridement non-viable tissue, wound vac
Blunt Abdominal Wall Hernia

- First reported in 1906
- Incorrect placement of lap belt
  - Across abdomen rather than pelvis
- Rare entity
  - <1% of all blunt trauma
- Classification system

Table 1: Grading of abdominal wall (AW) disruptions and results

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Subcutaneous tissue contusion</td>
<td>Not stated</td>
</tr>
<tr>
<td>II</td>
<td>AW muscle laceration</td>
<td>Not stated</td>
</tr>
<tr>
<td>III</td>
<td>Single AW muscle disruption</td>
<td>11 (25%)</td>
</tr>
<tr>
<td>IV</td>
<td>Complete AW muscle disruption</td>
<td>21 (48%)</td>
</tr>
<tr>
<td>V</td>
<td>Complete AW disruption with herniation of abdominal contents</td>
<td>12 (27%)</td>
</tr>
<tr>
<td>VI</td>
<td>Complete AW disruption with incarceration</td>
<td>0</td>
</tr>
</tbody>
</table>

- Most common associated injuries
  - Intra-abdominal injury – 53%
  - Bony injury (pelvis, rib, spinal) – 33%

- Optimal timing of repair still up for debate
- Tension free repair recommended
- Use of mesh recommended if possible

- Liasis, J Trauma, 2013;74:1156-1162
Blunt Abdominal Wall Hernia

- Retrospective study on incidence and repair
  - Jan 2003-Dec 2013
  - 53,030 patient evaluated
  - 41 patients presents with Grade 3-6 TAWH (0.08%) MVC (59%), MCA (20%)
  - 65% of MVC patients were restrained
  - Pelvic fracture most common concomitant injury

- Most hernia identified at time of surgery (61%) 30% identified with CT
- Lower quadrant most common location

**Table 2 Location of TAWH**

<table>
<thead>
<tr>
<th>Location of TAWH</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right upper quadrant</td>
<td>1</td>
</tr>
<tr>
<td>Left upper quadrant</td>
<td>3</td>
</tr>
<tr>
<td>Right lower quadrant</td>
<td>18 (41%)</td>
</tr>
<tr>
<td>Left lower quadrant</td>
<td>13 (30%)</td>
</tr>
<tr>
<td>Right + left upper quadrant</td>
<td>0</td>
</tr>
<tr>
<td>Right + left lower quadrant</td>
<td>9</td>
</tr>
</tbody>
</table>

Case Presentation

- 21 yo female s/p mvc
- Front seat passenger
- Restrained
- PE – sedated, GCS 7, Right neck seat belt sign
- CT head, neck, chest, abdomen, & pelvis – negative
- Patient did not improve neurologically
- PID#3 – MRI/MRA head and neck
  - Right internal carotid dissection with flap
  - Mild DAI
- Discharge PID 10 to rehab
Blunt Cerebrovascular Injury

- Injury occurs in 1% of all blunt trauma
  - Miller et al, Ann Surg, 2002;236:386

- Untreated blunt carotid injury
  - 23-28% - Mortality rate
  - 48 -58% of survivors have permanent neurologic deficit
    - Fabian et al, Ann Surg, 1996;225:703

- Expectant management not appropriate unless contraindications to treatment

Blunt Cerebrovascular Injury

- Injury Grading Scale
  - Grade I – Intimal irregularity <25%
  - Grade II – Dissection or intramural hematoma >25%, or visible flap
  - Grade III – Pseudoaneurysm or small AV fistula
  - Grade IV – Complete occlusion
  - Grade V – Transection with active extravasation
    - Biff et al, J Trauma, 1999;47:855

Factors/Explanations of BCVI
• Blunt cerebrovascular injury
• Intracranial lesions
• Carotid-cavernous fistula
• Carotid blowout

Baseline Characteristics
• Age <45 years
• Hypertension
• Diabetes
• History of stroke
• History of head injury
• History of smoking

Risk Factors for BCVI
• Blunt extracranial carotid injury
• Anticoagulation
• Hypercoagulable state

Diagnosis
• Clinical examination
• CT scan
• Carotid Doppler ultrasound
• Carotid angiogram

Management
• Supportive care
• Medical management
• Endovascular or surgical interventions

Injury and Clinical Presentation
• Grade I
• Grade II
• Grade III
• Grade IV
• Grade V

Guidelines for BCVI
• Early diagnosis
• Early intervention
• Multidisciplinary approach

References
• Biff et al, J Trauma, 1999;47:855
• Miller et al, Ann Surg, 2002;236:386
• Fabian et al, Ann Surg, 1996;225:703
Blunt Cerebrovascular Injury

- Treatment
  - No randomized controlled studies
  - Mainstay management is antithrombotic therapy
    - Heparin
    - Coumadin
    - Antiplatelet therapy (aspirin)
  - Retrospective studies show reduced rates of neurologic morbidity and mortality with anticoagulation
  - Endovascular intervention can be considered

Blunt Cerebrovascular Injury

- Agent of Choice
  - General consensus is to use heparin

- 301 patients with blunt cerebrovascular injury
  - Received heparin, aspirin, or clopidogrel
  - No significant difference in injury healing
  - No significant difference in progression of injury grade
    - Cothren et al, Arch Surg, 2009;144:685

- 22 patient prospective study of blunt carotid injury
  - Heparin vs aspirin
  - No difference in neurologic outcome
    - Wahl, J Trauma, 2002;52:896