BLUNT TORSO TRAUMA

pediatric perspective

Sasha Dubrovsky, MSc MD FRCPC
Pediatric Emergency Medicine
Montreal Children’s Hospital - MUHC
October 2010
Learning objectives

1. Discuss diagnostic goals in pediatric trauma
   - Diagnose All vs. Severe Injuries
   - Risks vs. benefit of CT Scan

2. Recognize which blunt torso trauma patients are at high risk for injuries

3. Role of bedside U/S in pediatric trauma
Trauma

- # 1 killer children > 1 years old
- 20% ED visits trauma related
- Predominant mechanism → BLUNT
  - MVC
  - Auto vs. Pedestrian
  - Bicycle-related
  - Fall
Major Trauma

- Head
  - Most common injury
  - Responsible for 80% trauma deaths
- Thorax
  - Account for ~15% trauma related deaths
- Abdomen
  - Common cause of initially missed fatal injuries
Pediatric ED’s Trauma Paradigm:

- **Assess all trauma patients**
  - Minor
  - Major
  
  Both at risk of occult injury

- **Diagnose and manage**
  - Clinically apparent injuries
  - Occult injuries

- **Do no harm**
  - Ex. CT radiation
  - Ex. Missed serious injuries
Overview

- Case
- Radiation Risks of computer tomography
- Common injuries
  - Intra-abdominal Injury (IAI)
- Role of screening tests
- Pediatric Bedside Ultrasound
Computed tomography

- Imaging gold standard
- Cost
- Sedation and transport considerations
- Severe injuries less common than in adults
- Most injuries managed conservatively
- Radiation Risks
Radiation imparts an increased lifetime risk of cancer MORTALITY

- 1 per 1000 pediatric CT
- 1 per 3000 adult CT
Brenner et al. NEJM 2001
Lifetime attributable cancer mortality risk as a function of age for a single typical CT examination
ALARA

As Low As Reasonably Achievable Principle

- Limiting number of CT scans ordered (Physician)
- Size-based adjustments of scanning parameters (Radiology Department)
Who should get CT?

- Is there a way to stratify those at higher risk of serious injury and need for intervention?
  - Ex: Head Injury → CATCH, PECARN, Canadian CT
  - Ex: C-Spine → NEXUS, Canadian c/spine
Who should get CT?

- How to select out those blunt trauma patients at highest risk of severe injury to the abdomen?
Intra-Abdominal Injuries (IAI)

- Seen in 10-30% pediatric multisystem traumas
- Common cause of initially unrecognized fatal injuries
- Mechanism
  - MVC (especially lateral impact MVC, seat belt use, ejected)
  - Pedestrian
  - Falls (especially >10 feet)
  - Abuse/Assault
Intra Abdominal Injury

- Most common injuries
  - Liver
  - Spleen
  - Kidney

- Less common include
  - Hollow viscus
  - Pancreas
  - Bladder
## Spleen

### Splenic CT Injury Grading Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
</table>
| Grade I | Laceration(s) < 1 cm deep  
| | Subcapsular hematoma < 1 cm diameter |
| Grade II | Laceration(s) 1-3 cm deep  
| | Subcapsular or central hematoma 1-3 cm diam |
| Grade III | Laceration(s) 3-10 cm deep  
| | Subcapsular or central hematoma 3-10 cm diam |
| Grade IV | Laceration(s) > 10 cm deep  
| | Subcapsular or central hematoma > 10 cm diam |
| Grade V | Splenic tissue maceration or devascularization |
### Stable Patient with IAI: Non-operative Management

**American Pediatric Surgical Association Guideline 2000**

<table>
<thead>
<tr>
<th>CT Grade*</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU stay (d)</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Hospital stay (d)</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Predischarge imaging†</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Postdischarge imaging†</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Activity restriction (wk)</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Non-operative Management

McVay et al. 2008
“Throw out the grade book” for stable patients

- Admit x 24 hours
- NPO and bedrest
- Serial exam
- Serial HCT @ 6, 12, 24 hours (HCT>0.21)
- Clinic in 1 month with U/S
Regardless of conservative strategy, >95% managed successfully with no intervention.

- Of those who fail, become apparent clinically
  - Mainly high grade injuries (Grades 4+)
  - Clear discharge instruction
    - Ex. Delayed Splenic Bleed rate 0.33%-1.4%

(Davies et al. 2009, Zarzour et al. 2009)
So what to do …

- Risk vs. benefit
- Trauma center philosophy

- Identify ALL
  - Then need to scan ALL

- Identify Severe
  - Need to identify strategy to identify those at high risk
Risk Stratification based on investigations

- To dip or not to dip? That is the question
Taylor et al 1988
- 378 children with CT Abdomen
- Hematuria in 68%

- Hematuria ↑ risk (1.6 fold) of any IAI
  - liver (33%) spleen (37%) renal (27%)

- However, only Symptomatic Hematuria at ↑ risk
Risk Stratification via investigations

Holmes et al. 2002

- Prospective observational study, age < 16
- 1095 patients enrolled, trauma team activation

Goal:

identify elements of physical exam and laboratory data predictive of IAI

Imaging or Look inside in 664/1095 (64%)

36% not investigated → NO apparent cases of missed IAI
(1 week phone f/u + rechecked registry at end of study)
- 10% intra-abdominal injury
- Mean age 8.4 ± 4.8 years
- 73% had free fluid

- Organs injured:
  - Liver 41%
  - Spleen 38%
  - GI tract 23%
  - Urinary tract 15%
  - Multiple Injury 22%
85% patients with IAI had physical exam findings suggestive

- Abdominal tenderness
- ↓ BP
- Femur Fracture
- GCS ≤ 13 (“unreliable exam”)

15% OCCULT intra-abdominal injury
Accuracy of the predictors* of intra-abdominal injury.

<table>
<thead>
<tr>
<th>Clinical Finding</th>
<th>Sensitivity, % (95% CI)</th>
<th>Specificity, % (95% CI)</th>
<th>PPV, % (95% CI)</th>
<th>NPV, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low systolic blood pressure</td>
<td>10 (5–18)</td>
<td>98 (98–99)</td>
<td>42 (23–62)</td>
<td>91 (89–93)</td>
</tr>
<tr>
<td>Abdominal tenderness</td>
<td>58 (48–67)</td>
<td>71 (68–73)</td>
<td>18 (14–22)</td>
<td>94 (92–96)</td>
</tr>
<tr>
<td>Femur fracture</td>
<td>10 (5–18)</td>
<td>95 (94–97)</td>
<td>19 (10–32)</td>
<td>91 (89–92)</td>
</tr>
<tr>
<td>Initial hematocrit &lt;30%</td>
<td>14 (8–22)</td>
<td>98 (96–98)</td>
<td>38 (23–55)</td>
<td>91 (89–93)</td>
</tr>
<tr>
<td>ALT &gt;125 and/or AST &gt;200 (U/L)</td>
<td>50 (40–60)</td>
<td>96 (94–97)</td>
<td>54 (44–65)</td>
<td>95 (93–96)</td>
</tr>
<tr>
<td>Urinalysis &gt;5 RBCs/hpf</td>
<td>50 (40–60)</td>
<td>89 (87–91)</td>
<td>32 (25–40)</td>
<td>94 (93–96)</td>
</tr>
<tr>
<td>Any of the above</td>
<td>98 (93–100)</td>
<td>49 (46–52)</td>
<td>17 (14–20)</td>
<td>99.6 (99–100)</td>
</tr>
</tbody>
</table>

IAI Present (N=107)  IAI Absent (N=988)

| Presence of any 1 of the 6 predictors* | 105 | 482 |
| Absence of all 6 predictors           | 2   | 506 |
Table 4.

Description of the 16 patients with intra-abdominal injuries who had neither abdominal tenderness, femur fracture, nor low systolic blood pressure, and had a GCS score of more than 13.

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Mechanism</th>
<th>Injury*</th>
<th>Hemoperitoneum†</th>
<th>Physical Examination Abnormalities</th>
<th>Laboratory Abnormalities</th>
<th>Hospital Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>MVC</td>
<td>Liver (II)</td>
<td>No</td>
<td>None</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
<tr>
<td>1.5</td>
<td>Fall 15 ft</td>
<td>Liver (I)</td>
<td>No</td>
<td>None</td>
<td>Increased ALT/AST, hematuria (40 RBCs/hpf)</td>
<td>Observation</td>
</tr>
<tr>
<td>1.6</td>
<td>Auto versus ped</td>
<td>Liver (I)</td>
<td>No</td>
<td>None</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
<tr>
<td>1.7</td>
<td>Auto versus ped</td>
<td>Liver (I)</td>
<td>Yes</td>
<td>Back abrasion</td>
<td>Increased ALT/AST, hematuria (6 RBCs/hpf)</td>
<td>Observation</td>
</tr>
<tr>
<td>2.3</td>
<td>Auto versus ped</td>
<td>Liver (I)</td>
<td>No</td>
<td>None</td>
<td>Increased ALT/AST, hematocrit (29%)</td>
<td>Observation</td>
</tr>
<tr>
<td>2.5</td>
<td>MVC</td>
<td>Liver (I), adrenal</td>
<td>No</td>
<td>Chest contusion</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
<tr>
<td>3.7</td>
<td>Fall</td>
<td>Liver (I)</td>
<td>Yes</td>
<td>None</td>
<td>Hematocrit=28%, hematuria (6 RBCs/hpf)</td>
<td>Observation</td>
</tr>
<tr>
<td>4.2</td>
<td>Auto versus ped</td>
<td>Spleen (II)</td>
<td>Yes</td>
<td>Abdominal tenderness developed in the ED</td>
<td>Hematocrit=28%, hematuria (6 RBCs/hpf)</td>
<td>Blood transfusion</td>
</tr>
<tr>
<td>4.8</td>
<td>Auto versus ped</td>
<td>Liver (II)</td>
<td>Yes</td>
<td>Abrasions to pelvis</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
<tr>
<td>9*</td>
<td>MVC</td>
<td>Kidney (I)</td>
<td>No</td>
<td>None</td>
<td>Hematocrit decreased 8% points in the ED</td>
<td>Observation</td>
</tr>
<tr>
<td>10</td>
<td>Auto versus bike</td>
<td>Spleen (II)</td>
<td>No</td>
<td>Hank/chest abrasion</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
<tr>
<td>10.9</td>
<td>Fall</td>
<td>Kidney (II)</td>
<td>No</td>
<td>Chest/back tenderness/abrasion</td>
<td>Hematuria (175 RBCs/hpf)</td>
<td>Observation</td>
</tr>
<tr>
<td>12.2†</td>
<td>Fall</td>
<td>Spleen (II)</td>
<td>Yes</td>
<td>Chest tenderness/rib fractures</td>
<td>None</td>
<td>Observation</td>
</tr>
<tr>
<td>15</td>
<td>MVC</td>
<td>Liver (II)</td>
<td>Yes</td>
<td>Back tenderness</td>
<td>Increased ALT/AST, hematuria (175 RBCs/hpf)</td>
<td>Observation</td>
</tr>
<tr>
<td>15</td>
<td>Auto versus ped</td>
<td>Spleen (II)</td>
<td>Yes</td>
<td>Abdominal abrasion, GCS score of 14, seizure then intubated</td>
<td>Hematuria (6 RBCs/hpf)</td>
<td>Laparotomy</td>
</tr>
<tr>
<td>15</td>
<td>Auto versus bike</td>
<td>Liver (I)</td>
<td>No</td>
<td>Chest/back tenderness, abdominal tenderness developed in the ED</td>
<td>Increased ALT/AST</td>
<td>Observation</td>
</tr>
</tbody>
</table>

MVC, Motor vehicle crash; Auto versus ped, automobile versus pedestrian; IV, intravenous.

*Injury grade is provided in parentheses after each injury.52,54
†Hemoperitoneum identified by abdominal CT scan or at laparotomy.
‡Patient did not have any of the 6 predictors of intra-abdominal injury.
Figure 3.
Suggested algorithm for evaluation of children with blunt torso trauma. IAI, Intra-abdominal injury.

**Blunt torso trauma**

- **Abdominal tenderness or low systolic blood pressure**
  - Yes → Abdominal CT scan
    - 68 (18%) of 372 had IAI
  - No
    - **ALT >125 or AST >200 U/L or Hematocrit <30%**
      - Yes → Abdominal CT scan
        - 28 (40%) of 70 had IAI
      - No
        - **GCS score ≤13, Femur fracture, or Urinalysis >5 RBCs/hpf**
          - Yes → Consider abdominal CT scan
            - 9 (5%) of 169 had IAI
          - No
            - **Low likelihood for IAI**
              - 2 (0.4%) of 484 had IAI

**Appropriate observation and instructions**
Validation Study: Holmes et al. 2009

Pediatric Validation Study

- 1119 patients, 14% IAI
- 68% Positive rule → 20% IAI
- 32% Negative rule → 2% IAI
  - Sensitivity 95%
  - 7/8 missed → observation alone
  - 1/8 Non-therapeutic laparotomy (seatbelt)
Buckle up or at least wear a helmet.
Focused Assessment with Sonography in Trauma (aka FAST)
FAST

- Morison’s Pouch (RUQ)
FAST

- Left Upper Quadrant
FAST

- Pelvic
Adult FAST

“SOAP” RCT Trial by Melinker et al. 2006

- Decreased time to operative care (57 vs 166 min)
- Shorter hospital lengths of stay (6 vs 10 days)
- Less likely to have CT Torso
- Lower hospital charges
- Fewer complication rates
Pediatric FAST

No clear role

- Conservative management for most
- FAST less sensitive
- Not well studied
Why is literature so confusing?

- **U/S Performer:** Trauma Team Leader (TTL) vs. Radiology
  Diverse training/experience

- **U/S Goal:** Free fluid vs. Parenchymal vs. both

- **Free fluid:** Absent in up to 30% pediatric IAI

- **Population:** Severe trauma vs. All trauma

- **Outcome:** CT vs. Clinical Course
FAST Performer

When looking for free fluid
Radiology = TTL (surgical or ED)
## U/S Goal

- Free fluid vs. parenchymal
- Radiology based studies
- Ex. Richards et al. 1999

<table>
<thead>
<tr>
<th>Liver Injury CT Grade</th>
<th>Sensitivity Free Fluid</th>
<th>Sensitivity Free Fluid ± Parenchymal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17%</td>
<td>26%</td>
</tr>
<tr>
<td>2</td>
<td>74%</td>
<td>80%</td>
</tr>
<tr>
<td>3</td>
<td>97%</td>
<td>97%</td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Free Fluid

Emery et al. 2001
- Observational study in children
- Outcome: any IAI on CT
  - Sensitivity 45%, Specificity 88%, NPV 81%
  - Most of false negative low grade
Population

Holmes et al. 2001

Normotensive
- Sensitivity 82%, Specificity 95%, NPV 97%

Hypotensive (n=13)
- Sensitivity 100%, Specificity 100%, NPV 100%

98% (n=187) negative FAST conservatively managed
- 2 GI tract injury \ 2 liver (↑ LFTs)
Outcome

- Soudack et al. 2004 (radiology)
  - 313 pediatric patients
  - Outcome: + CT/OR or Normal follow-up
  - Sensitivity 93% specificity 97% PPV 95% NPV 96%
  - 65% FAST negative → No IAI \ nor late complications

Since introduction of FAST, ↓ use of CT
FAST by Pediatric TTL

Thourani et al. 1998
- 196 patients <15 years old by PGY 3 +
- Sensitivity 80%  Specificity 100%  NPV 96%
  - 2 false negative
    - 2 yo Trace fluid no IAI
    - 11 yo Pedestrian with repeat FAST + and splenic injury
FAST by pediatric TTL

Patrick et al. 1998

- 230 children with BAT
- Sensitivity 71% Specificity 100% NPV 93%
- Sensitivity 100% for Significant free fluid
Meta-analysis Pediatric FAST

- Holmes et al. 2007
  - 25 studies, all cohort, 3838 children

<table>
<thead>
<tr>
<th>U/S Protocol</th>
<th>FAST (free fluid)</th>
<th>FAST (free fluid)</th>
<th>FAST (free fluid and solid organs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hemoperitoneum</td>
<td>Any IAI</td>
<td>Any IAI</td>
</tr>
<tr>
<td>Outcome of interest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>80%</td>
<td>66%</td>
<td>82%</td>
</tr>
<tr>
<td>Specificity</td>
<td>96%</td>
<td>93%</td>
<td>97%</td>
</tr>
<tr>
<td>Likelihood ratio +</td>
<td>22.9</td>
<td>9.8</td>
<td>24.5%</td>
</tr>
<tr>
<td>Likelihood ratio -</td>
<td>0.2</td>
<td>0.37</td>
<td>0.18</td>
</tr>
</tbody>
</table>
ENHANCING THE SENSITIVITY OF FAST
Physical Exam with FAST

Suthers et al. 2004

- Prospective observational study <17 yo
- 180 children screened → 120 had FAST/ P/E / CT
- Mean age 10, ISS 13, mostly blunt trauma

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Exam</td>
<td>81%</td>
<td>73%</td>
<td>47%</td>
<td>93%</td>
</tr>
<tr>
<td>FAST</td>
<td>70%</td>
<td>100%</td>
<td>100%</td>
<td>92%</td>
</tr>
<tr>
<td>P/E + FAST</td>
<td>100%</td>
<td>75%</td>
<td>54%</td>
<td>100%</td>
</tr>
</tbody>
</table>
LFTs and FAST

Sola et al. 2009 (Jackson Memorial, Miami)

- Retrospective review 400 patients
- Mean age 9, Mean ISS 16
- Any injury on CT (including injuries with no free fluid)
  - FAST alone: FN=67, >2/3 low grade liver/spleen
  - If take out low grade, FAST sensitivity >80%

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST</td>
<td>50%</td>
<td>91%</td>
<td>68%</td>
<td>83%</td>
</tr>
<tr>
<td>FAST + LFTs</td>
<td>88%</td>
<td>98%</td>
<td>94%</td>
<td>96%</td>
</tr>
</tbody>
</table>
Serial FAST

Blackbourne et al. 2004

- Serial FAST within 24 hours by TTL (on-call residents)
- Mean age 39 [1-90], mean time to 2nd FAST 4 hours
- Outcome: clinical course

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial U/S</td>
<td>31%</td>
<td>99.8%</td>
<td>95%</td>
<td>92%</td>
</tr>
<tr>
<td>Second U/S</td>
<td>72%</td>
<td>99.8%</td>
<td>98%</td>
<td>97%</td>
</tr>
</tbody>
</table>
Serial FAST

Blackbourne et al. 2004

- 44% FAST negative had CT/OR
  - 2/501 (0.4%) Neg-Neg $\rightarrow$ OR (hollow-viscus)
  - 10/26 (35 %) Neg-Pos $\rightarrow$ OR
Advanced trauma application

- **Pneumothorax**
  - Bedside u/s more sensitive than supine CXR
  - Sensitivity \(\rightarrow\) 98% vs. 75%
Bedside Ultrasound

Clear role in pediatric BAT

→ screens for those at high risk severe IAI (i.e. high grade injury)
Proposed Algorithm

1. Blunt torso trauma
   - 107 (9.8%) of 1,095 had IAI

2. Abdominal tenderness or Low systolic blood pressure
   - Yes: Abdominal CT scan
     - 68 (18%) of 372 had IAI
   - No

3. ALT >125 or AST >200 U/L or Hematocrit <30%
   - Yes: Abdominal CT scan
     - 28 (40%) of 70 had IAI
   - No

4. GCS score ≤13, Femur fracture, or Urinalysis >5 RBCs/hpf
   - Yes: Consider abdominal CT scan
     - 9 (5%) of 169 had IAI
   - No

5. Low likelihood for IAI
   - 2 (0.4%) of 484 had IAI
   - Appropriate observation and instructions
Potential Algorithm

Blunt torso trauma

Abdominal tenderness or Low systolic blood pressure

Yes
Abdominal CT scan

68 (18%) of 372 had IAI

ALT >125 or AST >200 U/L or Hematocrit <30%

Yes
Abdominal CT scan

28 (40%) of 70 had IAI

GCS score ≤13, Femur fracture, or Urinalysis >5 RBCs/hpf

Yes
Appropriate observation and instructions

9 (5%) of 169 had IAI

No

Low likelihood for IAI

Appropriate observation and instructions

2 (0.4%) of 484 had IAI

FAST +

Serial FAST +
Summary

- Occult abdominal injuries up to 10%
- Most injuries managed conservatively
- CT-SCAN ALL NOT INDICATED
  - select those at high risk of severe injuries
    - Serial Exams
    - Serial Bedside U/S
    - CXR
    - Screening HCT, LFT, U/A
Conclusion

- As pediatric trauma experts
  - Need to diagnose severe injuries
  - Need to ensure no harm

- Educate / Primary prevention