Evaluation of Children with Blunt Abdominal Trauma

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Objectives

- Epidemiology of intra-abdominal injury (IAI)
- Physical examination findings with IAI
- Laboratory abnormalities associated with IAI
- Diagnostic testing for IAI
Pediatric IAI: Epidemiology

- Trauma is the leading cause of death in children > 1 year in the USA
- TBI is the primary cause of death in ~70%
- Torso trauma (abdominal, thoracic) 2nd leading cause (~25%)

- Most preventable deaths and morbidity due to:
  - Airway obstruction/respiratory failure
  - Secondary brain injury from expanding ICH
Pediatric IAI: Epidemiology

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Most preventable deaths and morbidity due to:
- Airway obstruction/respiratory failure
- Secondary brain injury from expanding ICH
- Unrecognized/under-treated IAI
Pediatric IAI: Epidemiology

- Most common mechanisms of injury:
  - MVA, auto vs. pedestrian, falls
- Frequency of injured organs:
  - Spleen: 40%
  - Liver: 40%
  - Kidney: 30%
  - GI: 15%
  - Pancreas: 2%
- Many children will have more than one injured organ
Pediatric IAI: Epidemiology

- More than 600,000 children with blunt abdominal trauma evaluated annually in U.S. EDs
- 15-25% of these undergo abdominal CT
- However...
  - < 10% of abdominal CTs demonstrate injury
  - Relatively few patients with IAI require specific therapy: blood transfusion most common
Pediatric IAI: Epidemiology

- Compared to adults: relatively larger organs, less abdominal wall protection
- Chest wall more flexible:
  - energy transferred to the spleen and liver
- The evaluation of abdomen particularly difficult in preverbal children
- ~25% of children with IAIIs will have no abdominal tenderness
Childhood Abdominal Trauma: Controversies

- Controversy over:
  - Reliability of the physical examination
  - Role of laboratory tests
  - Ultrasound: Utility in children?

- *Abdominal CT is the Gold Standard, but has risks.*
Patient History

- Mechanistic injury patterns helpful:
  - MVA with seat belt sign: bowl and mesenteric injuries
  - MVA: high speed & no seat belt
  - Auto v. Ped: > 30 Km/hour
  - Fall > 3 meters
  - Handlebar injury: pancreas and duodenum
  - Abuse: liver and spleen
Handlebar Injury
Handlebar Injury
Abdominal Examination

• Abdominal tenderness:
  – ↑risk of IAI after adjusting for other findings
    • *Adjusted odds ratio = 5.8 (95% CI 3.2, 10.4)*
  – ~75% of alert patients with IAI have abdominal tenderness
• Gastric distention may complicate exam
Abdominal Examination
Adelgais, Acad Emerg Med 2013 (Abstract)

- Abdominal tenderness (relative risk of IAI):
  - Mild: RR=3.0 (95% CI 2.3, 4.0)
  - Moderate: RR=9.4 (95% CI 7.6, 11.6)
  - Severe: RR=19.4 (95% CI 15.4, 24.4)

- Location of abdominal tenderness (RR of IAI):
  - Diffuse: RR=9.0 (95% CI 7.4, 11.0)
  - Above umbilicus: RR=7.0 (95% CI 5.7, 8.6)
  - Below umbilicus: RR=2.7 (2.0, 3.7)

All compared to no abdominal tenderness
## Abdominal Examination
Adelgais, Acad Emerg Med 2013 (Abstract)

<table>
<thead>
<tr>
<th></th>
<th>IAI present (%)</th>
<th>No IAI (%)</th>
<th>Relative Risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal Distention</td>
<td>61/631 (9.7%)</td>
<td>136/10380 (1.3)</td>
<td>7.4 (5.5, 9.9)</td>
</tr>
<tr>
<td>Absent Bowel Sounds</td>
<td>48/483 (9.9%)</td>
<td>562/9004 (6.2)</td>
<td>1.6 (1.2, 2.1)</td>
</tr>
<tr>
<td>Peritoneal Irritation</td>
<td>60/554 (10.8%)</td>
<td>76/10100 (0.8)</td>
<td>9.3 (7.6, 11.5)</td>
</tr>
<tr>
<td>Blood on Rectal Examination</td>
<td>3/295 (1.0%)</td>
<td>31/4771 (0.6)</td>
<td>1.5 (0.5, 4.5)</td>
</tr>
</tbody>
</table>
Seat Belt Injury

Injury pattern seen most in children, also in adults
Patient flexes over the lap belt
  - May occur despite use of shoulder harness
Lumbar spine fracture
Chance fracture
Gastrointestinal injury
Chance
Fracture
Prospective, multicenter study
3,740 children after MVA
585 with “Seat Belt Sign”

IAI with seat belt sign: 19%
IAI without seat belt sign: 12%
(relative risk = 1.6)

↑ risk primarily due to ↑ GI injuries
IAI occurred in small percent with seat belt sign but without initial abdominal tenderness – need observation/good discharge instructions
Mental Status and IAI

- Children with decreased LOC have impaired ability to perceive abdominal pain (*Beaver, J Ped Surg 1987*)
- Physical exam therefore unreliable in these patients
- Mental status in patients with IAI:
  - GCS < 14 in ~ 30% (*Holmes, Ann Emerg Med 2002*)
  - GCS < 15 in ~ 45% (*Holmes, AEM 1999*)
  - GCS = 15 in 55%
Mental Status and Reliability of the Abdominal Exam
Adelgais, AEM 2013 (Abstract)

- Prospective, multicenter study (PECARN)
- 11,277 patients with GCS ≥ 13
- Sensitivity of abdominal tenderness for patients with IAI:
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  - GCS = 14: 57% (95% CI 42, 70%)
  - GCS = 15: 79% (95% CI 75, 82%)
Chest Injury and IAI

- Be aware of tenderness/injury to costal margin as these ribs protect the spleen and liver

- Association with IAI in prospective study of adults:
  - 3% with isolated left lower ribs had IAI (Holmes, Ann Emerg Med 2005)

- Association with IAI in retrospective pediatric studies: (Taylor, Radiology 1994)
Chest Injury

- In prospective pediatric study, chest tenderness ↑ risk of IAI (univariate), but not in multivariate analysis (*Holmes Ann Emerg Med 2002*)
  - Limitations as costal margin injury not specifically addressed

- PECARN study
  - RR of IAI in patients with costal margin tenderness: 3.7 (95% CI 3.2, 4.2)
Laboratory Analysis and IAI

- Multiple laboratory tests historically utilized to screen patients for possible IAI
  - AST, ALT, hematocrit, lipase, amylase, bicarbonate, urinalysis

- Prior studies have conflicting results and are limited in design:
  - small, retrospective, or univariate analysis
Urinalysis

- **Urinalysis a marker of IAI:**
  - Gross hematuria: IAI present in up to 50% of children with this finding: ABDOMINAL CT
  - Microscopic hematuria in ~30% of children with IAIs:
    - > 5 rbc/hpf (Issacman 1993, Holmes 2002)
    - > 20 rbc/hpf (Lieu, Pediatrics 1988)
    - > 50 rbc/hpf (Money, J Urol 1986)
    - > 100 rbc/hpf (Hashmi, J Emerg Med 1995)
Hematocrit

- Blood loss drops hematocrit level
- Delay between significant blood loss and hematocrit drop
  - ~2 hours if no fluid replacement, *Ebert J Clin Investigations* 1941
Hematocrit

- Hematocrit < 30% significant predictor of IAI
  - Taylor. Radiology 1994 (retrospective study: 1000 pts)

- Serial hematocrit levels associated with IAI
  - IAI results in hematocrit drop
  - No evidence of benefit in obtaining serial hematocrit levels to screen for otherwise unsuspected IAI
Liver (AST/ALT) Enzymes

- AST/ALT (SGOT, SGPT) rise immediately after hepatic injury
- Degree of elevation does not always correlate with grade of liver injury
- Elevations of 3-4x normal should generate concern for hepatic injury:
  \[ \text{AST} > 200 \text{ or } \text{ALT} > 125 \] (Holmes, Ann Emerg Med 2002)
- ALT > AST with Liver injury indicates injury > 12 hours old (Baxter, Child Abuse & Neglect 2007)
Amylase/Lipase

- Used to identify pancreatic or bowel injury
- Elevated amylase often salivary
- In pancreatic injury, enzymes increase 24 – 48 hours after the injury
- Not shown to be a useful predictor of IAI (poor sensitivity and PPV) in pediatric trauma patients

Radiologic Imaging in Children with Blunt Trauma
Radiologic Imaging
Abdominal Ultrasound (FAST)
Abdominal Ultrasound in Trauma

- Evaluate:
  - Hemoperitoneum (FAST examination)
  - Solid organ injury and hemoperitoneum
- Rapidly performed at patient bedside
- Frequently used in evaluation of adult trauma patients:
  - Two RCTs ↓ abdominal CT use (Rose J Trauma, Melniker Ann Emerg Med)
- Less frequently for pediatric patients
  - USA pediatric centers: 15%
Abdominal Ultrasound in Trauma

- Not as sensitive as CT for IAI

- Meta-analysis of Pediatric studies (Holmes, J Ped Surg 2007):
  - Sensitivity for hemoperitoneum: 80% (95% CI 76, 84)
  - Sensitivity for all IAI: 66% (95% CI 56, 75%)
  - LR (+): 14.5
  - LR (-): 0.36
Abdominal Ultrasound in Trauma

- May allow risk stratification for CT scan
- Best performance in hypotensive children
  - Sensitivity: 100% for children hypotensive from abdominal blood loss (*Holmes, J Ped Surg 2001*)

- Clinical implications unclear in children considered at significant risk for IAI
  - Ultrasound (+) → straight to Abdominal CT
  - Ultrasound (-) → Abdominal CT if at moderate/high risk
    - A negative FAST exam may alleviate abdominal CT in lower risk children (<10% risk of IAI)
Abdominal Ultrasound in Trauma

Menaker, Acad Emerg Med 2012 (Abstract)

- PECARN multicenter (n=20) study
- FAST used in 14% of children with blunt torso trauma
- Risk of IAI based on clinician suspicion
- Determined rate of abdominal CT use in patients with and without FAST exam stratified by clinician suspicion
## Abdominal Ultrasound in Trauma

**Menaker, Acad Emerg Med 2012 (Abstract)**

<table>
<thead>
<tr>
<th>Clinical Suspicion</th>
<th>Rate of FAST use</th>
<th>RR of abdominal CT (FAST vs. no FAST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1% risk of IAI</td>
<td>11.0%</td>
<td>0.83 (0.67, 1.03)</td>
</tr>
<tr>
<td>1 – 5% risk of IAI</td>
<td>13.5%</td>
<td>0.81 (0.72, 0.91)</td>
</tr>
<tr>
<td>6 – 10% risk of IAI</td>
<td>20.5%</td>
<td>0.85 (0.78, 0.94)</td>
</tr>
<tr>
<td>11 – 50% risk of IAI</td>
<td>23.2%</td>
<td>0.99 (0.94, 1.05)</td>
</tr>
<tr>
<td>&gt; 50% risk of IAI</td>
<td>30.7%</td>
<td>0.97 (0.91, 1.05)</td>
</tr>
</tbody>
</table>
Abdominal Ultrasound

**Arguments against:**
- Insufficient sensitivity
- Most IAIs managed non-operatively
- False sense of security
- “Over-triage” to the OR

**Arguments for:**
- Sensitive in unstable patients
- Bedside availability
- May decrease CT use in low risk patients
- “Risk stratification”/CT prioritization

- Ultrasound should not replace CT in those that need abdominal CT
Abdominal CT for Pediatric Trauma

- Gold standard for diagnosis of IAI
- IV contract needed but no oral contrast
  - Ellison, *AEM* 2013 (abstract)
- Excellent sensitivity for solid organ injuries
- New generation (Helical CT) scanners:
  - Good sensitivity (85-95%) for GI injuries
  - Limited (~50%) sensitivity for pancreatic injuries
  - *Consider admitting patient if high risk for GI/pancreatic injury despite normal CT*
Abdominal CT Scan – Risks

- Sedation: patient must be still for the CT, potential complications from sedation
- Transfer outside the ED
- Charges for abdominal CT …….
- Radiation exposure
Radiation Exposure from CT

- CT scan exposes the child to 500X the compared to a chest radiograph
- Radiation exposure may cause a malignancy
- Children at increased risk compared to adults
- Risk of death from radiation-induced malignancy from one abdominal CT scan (Migloretti. JAMA Peds 2012)
  - Child < 5 year old: < 1/ 300 - 670 CT scans
  - Child 5-14 years old: 1/ 370 – 700 CT scans
Identifying Children at Risk for IAI

- Prospective study
- 1,095 children (0–16), explicit entry criteria
- 664 with definitive diagnostic tests and remainder with clinical (telephone) follow-up
- Multivariate analysis
- Performance of decision instrument:
  - Sensitivity: 98% (95% 93, 100%)
  - NPV: 99.6% (95% 99, 100%)
Variables placing Child at Risk:

- **Variables in the Decision Instrument:**
  - Low systolic blood pressure
  - Abdominal tenderness
  - Femur fracture
  - Elevated liver enzymes:
    - AST > 200 U/L or ALT > 125 U/L
  - Urinalysis > 5 rbc/hpf
  - Initial hematocrit < 30%
PECARN Abdominal Injury Decision Instrument

- Prospective multicenter study May 2007 - Jan 2010
- < 18 years w/ blunt abdominal trauma evaluated in ED (explicit exclusion criteria)

- Clinical data recorded before abdominal CT (if done)
- Follow-up obtained on all patients:
  - Discharged patient: Telephone follow-up
  - Admitted patients: medical record review

- Primary outcome: IAI undergoing therapy (IAI^AI)
- Analysis: Recursive Partitioning (CART)
Results: Prediction Rule for IAI

(n=12,044)

1,963 patients
112 (5.7%) IAI

826 patients
38 (4.6%) IAI

2,532 patients
36 (1.4%) IAI

955 patients
6 (0.6%) IAI

305 patients
2 (0.7%) IAI

34 patients
1 (2.9%) IAI

395 patients
2 (0.5%) IAI

5,034 patients
6 (0.1%) IAI

1,234 CT scans (25%)

Sensitivity = 197/203 (97.0%)
Specificity = 5028/11841 (42.5%)
NPV = 5028/5034 (99.9)
Figure 3: Suggested algorithm for evaluation of children with blunt torso trauma

Evidence of abdominal wall trauma/seatbelt sign or GCS score < 14 with blunt abdominal trauma

- Yes 23% of population 5.7% risk of IAI-intervention
  - Further evaluation needed, Strongly consider abdominal CT (especially in those with abdominal wall trauma)

- No
  
  Moderate/Severe Abdominal tenderness

- Yes 21% of population 1.4% risk of IAI-intervention
  - Abdominal CT vs. Observation with ancillary testing:
    - FAST exam, laboratory screening, serial abdominal exams

- No
  
  Thoracic wall trauma, abdominal pain, decreased breath sounds, vomiting, mild abdominal tenderness

- Yes 14% of population 0.7% risk of IAI-intervention
  - Observation, based on other clinical factors including:
    - Physician experience
    - Multiple versus isolated findings
    - No improvement in symptoms or signs after ED observation
    - Parental preference
    - Laboratory screening tests
    - FAST exam

- No
  
  CT generally not recommended
  (consider laboratory/FAST screening if concern for IAI remains)

  42% of population 0.1% risk of IAI-intervention
<table>
<thead>
<tr>
<th>Age</th>
<th>Mech</th>
<th>Clinical</th>
<th>Injury</th>
<th>Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>2yr</td>
<td>Auto-Ped</td>
<td>Hematuria</td>
<td>Renal*</td>
<td>Blood Rx</td>
</tr>
<tr>
<td></td>
<td></td>
<td>↑ LFTs</td>
<td>Liver, GI*</td>
<td>IV fluid</td>
</tr>
<tr>
<td>16yr</td>
<td>MCA†</td>
<td>Femur Fx</td>
<td>Spleen, GI*</td>
<td>Angio</td>
</tr>
<tr>
<td>17yr</td>
<td>MVC</td>
<td>ETOH</td>
<td>Spleen, Renal*</td>
<td>Angio</td>
</tr>
<tr>
<td>17yr</td>
<td>MVC</td>
<td>Distract inj</td>
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ED Treatment of Children with IAI

Keep child warm
Two large bore IVs
Serial hematocrits
Type & screen
Surgery consult
ICU admission & appropriate transfer

Essentially all solid organ injuries managed non-operatively
Summary: Exam

- High risk physical examination findings for IAI:
  - GCS < 14: unable to evaluate the abdomen
  - Abdominal wall trauma: contusion/abrasion/seat belt sign
  - Abdominal tenderness
    - Severe/moderate tenderness >>>>> mild tenderness
  - Additional variables (PECARN rule) to stratify into very low risk category
Summary: Labs

- High risk laboratory findings for IAI:
  - Elevated AST/ALT (3-4x normal)
  - Hematuria: especially gross hematuria
  - Low hematocrit: <30%
  - Amylase/Lipase ↑ over 24/48 hours
Summary: Imaging

- No role for plain x-rays of the abdomen
- Abdominal Ultrasound:
  - Use if hypotensive to direct management
  - May risk stratify children for CT scan
  - May alleviate the need for CT in lower risk children
    - Child with 1-10% risk of IAI and normal FAST exam at very low risk for therapy
Summary: CT

- Abdominal CT:
  - Gold standard for diagnosing IAI
  - Variables available to risk stratify patients
    - Strongly consider in patients with high risk findings, but be cognizant of radiation risks