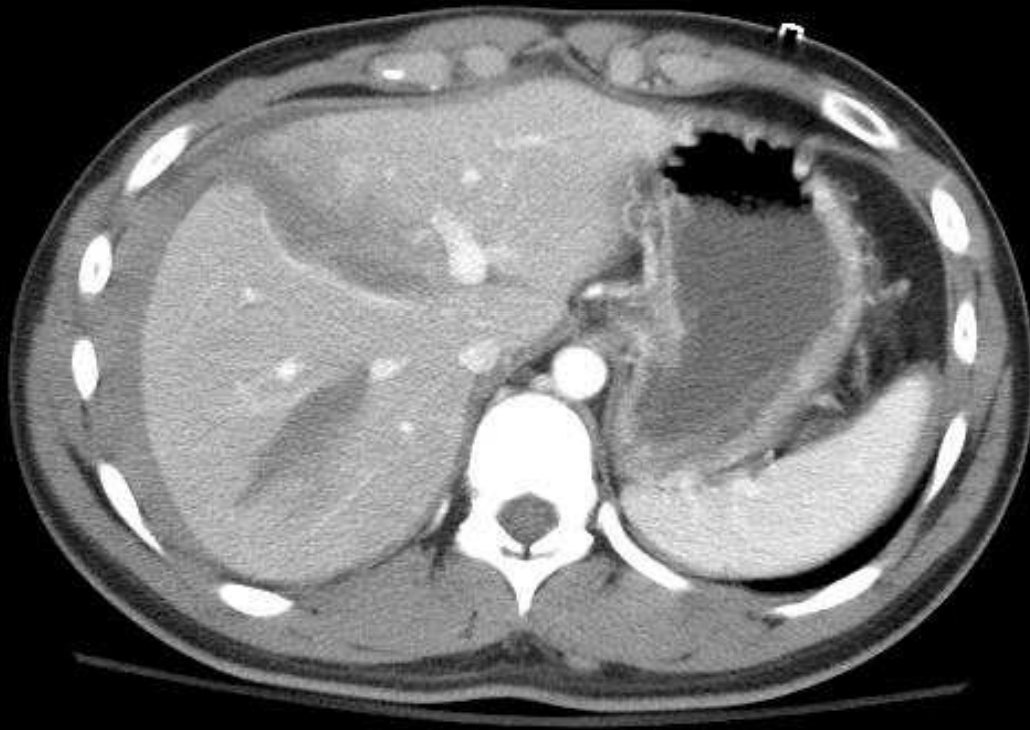


# Evaluation of Children with Blunt Abdominal Trauma



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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) 2<sup>nd</sup> leading cause (~25%)
- Most preventable deaths and morbidity due to:
  - Airway obstruction/respiratory failure
  - Secondary brain injury from expanding ICH



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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 IAIs 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: bowel 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  
(*Taylor 1994; Holmes 1999, 2002, 2013*)
    - *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)

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





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# Seat Belt Injury

Injury pattern seen most in children, also in adults

Patient flexes over the lap belt

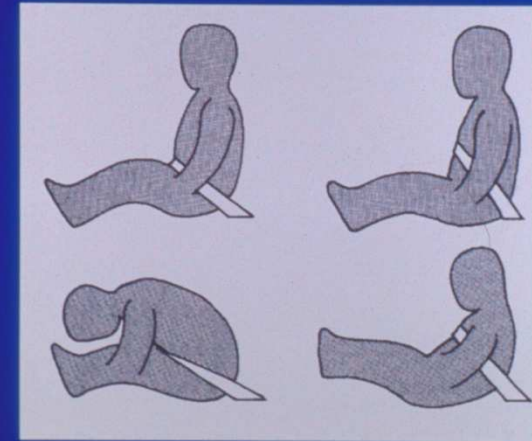
- May occur despite use of shoulder harness

Lumbar spine fracture

Chance fracture

Gastrointestinal injury

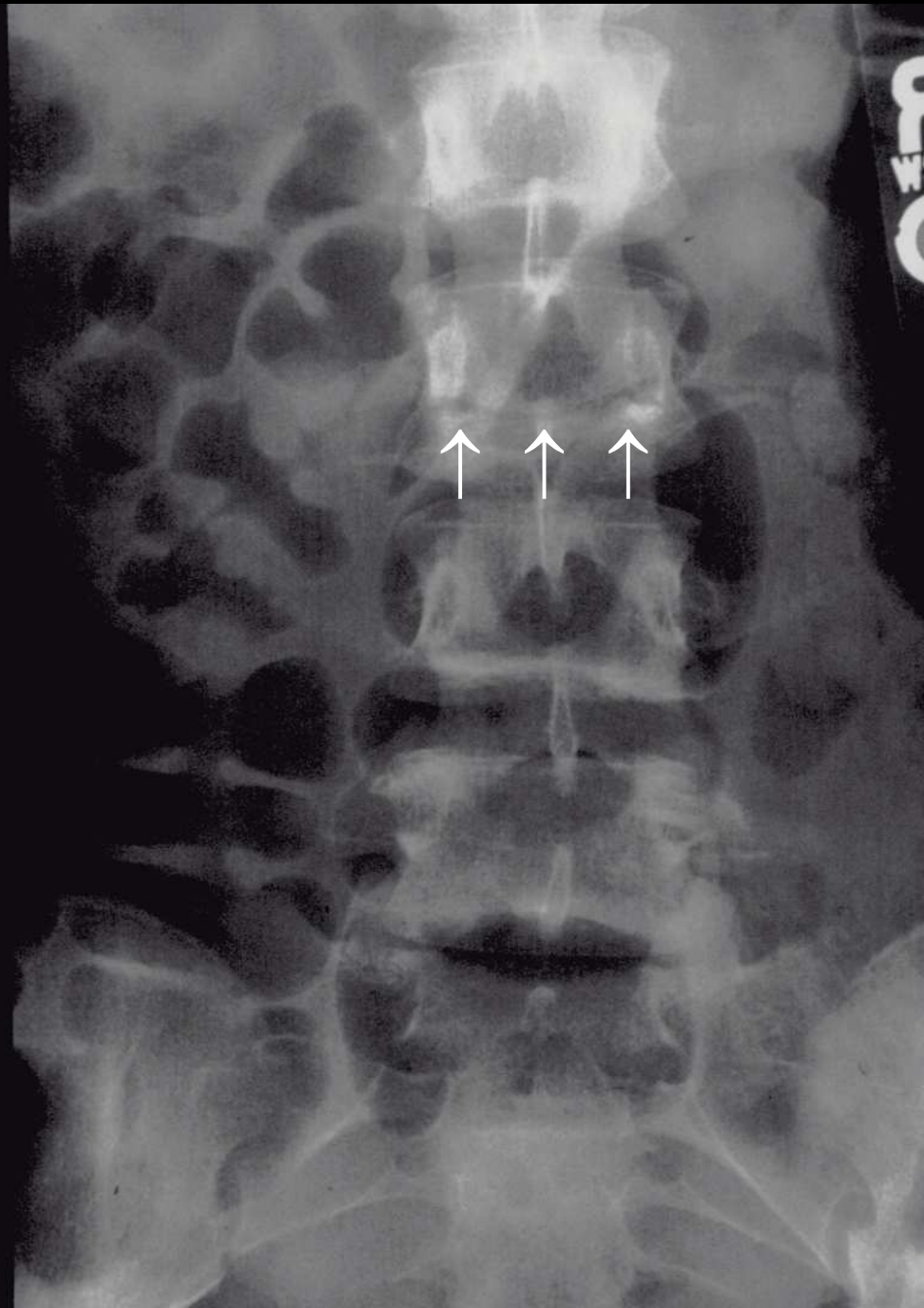
## Injury associated with Seatbelt Use







Chance  
Fracture









# Seat Belt Sign & IAI

Borgialli, Acad EM 2012 (Abstract)

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  $\geq$  13
- Sensitivity of abdominal tenderness for patients with IAI:



# Mental Status and Reliability of the Abdominal Exam

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  - **GCS = 14: 57% (95% CI 42, 70%)**

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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*)
  - Holmes, Ann Emerg Med 2002 (*prospective study: 1095 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:  
AST >200 or ALT >125 (*Holmes, Ann Emerg Med 2002*)
- ALT > AST with Liver injury indicates injury > 12 hours old (*Baxter, Child Abuse & Neglect 2007*)

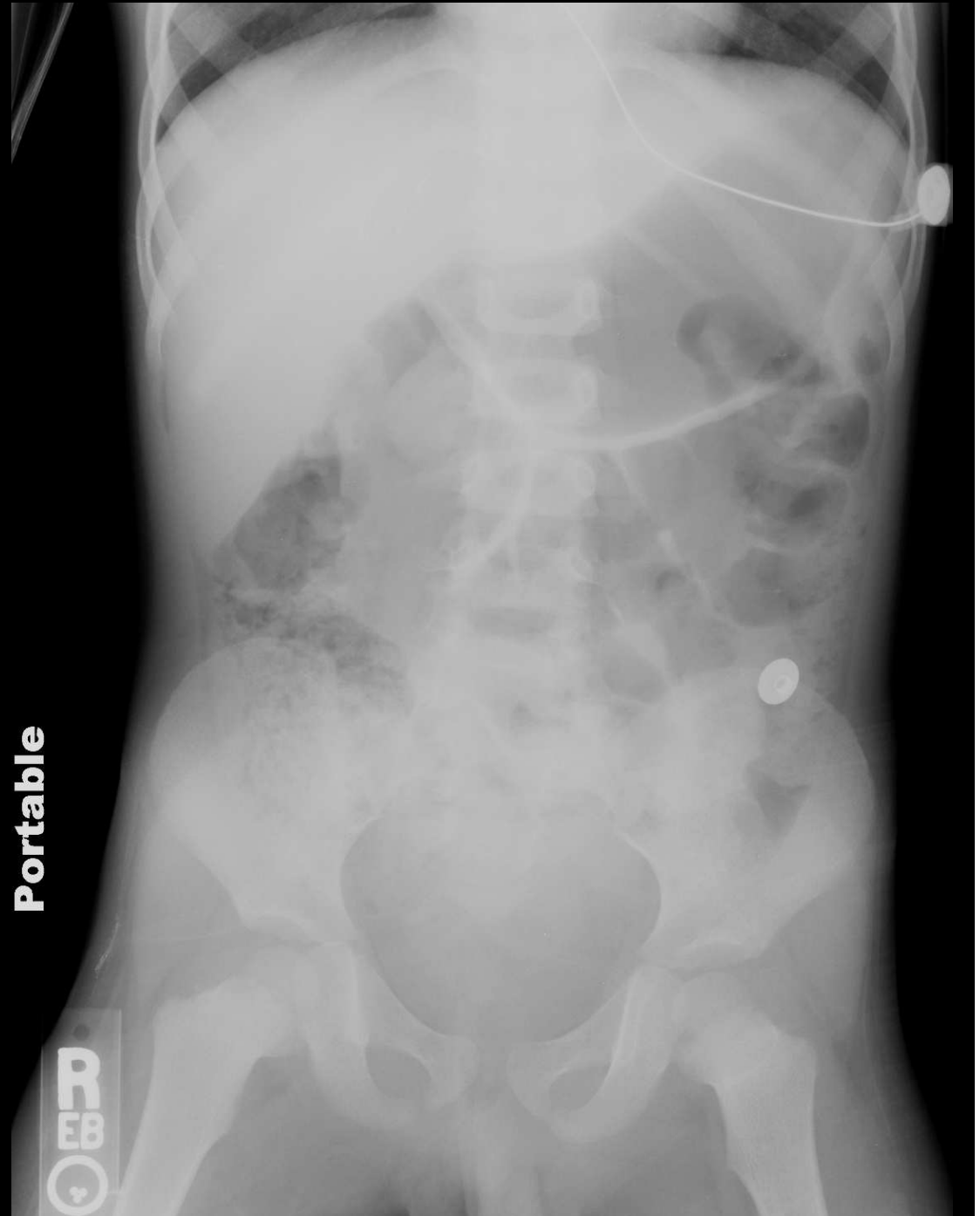
# Amylase/Lipase

- 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 (*Buechter 1990, Simon 1994, Holmes 1999*)

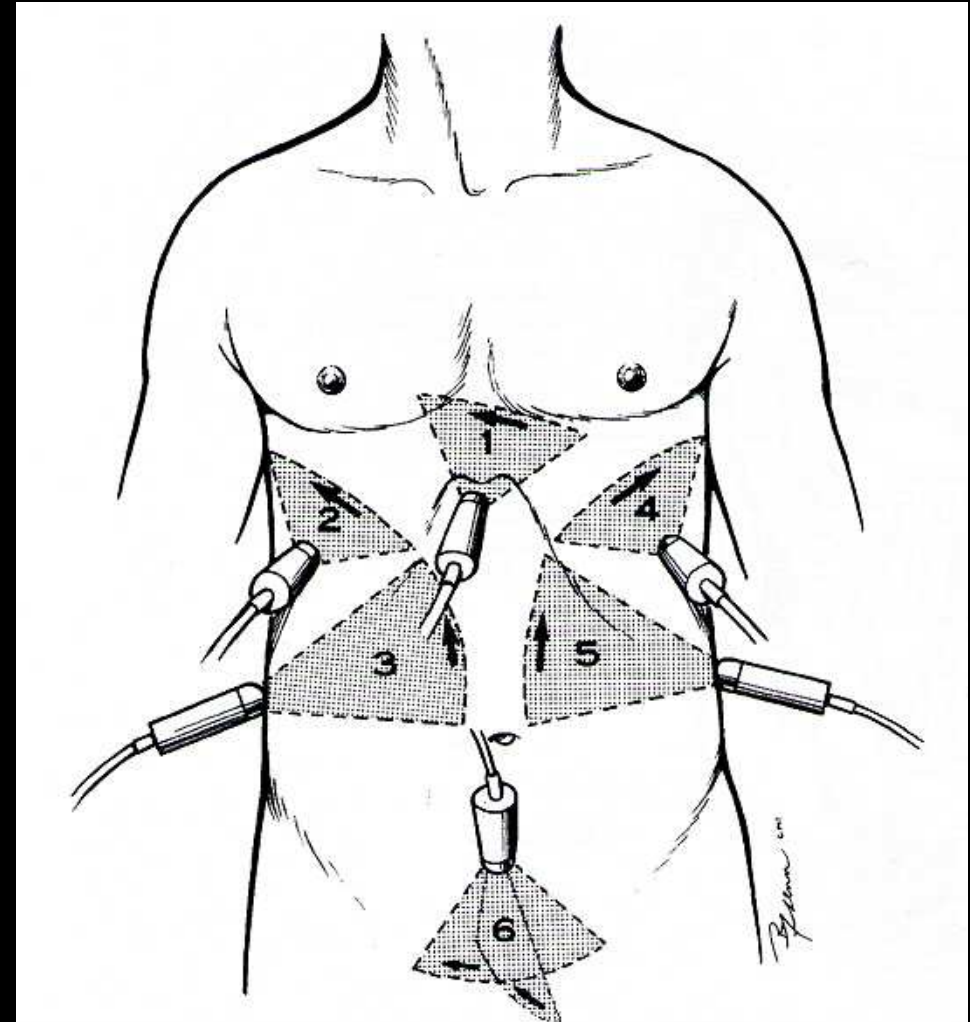
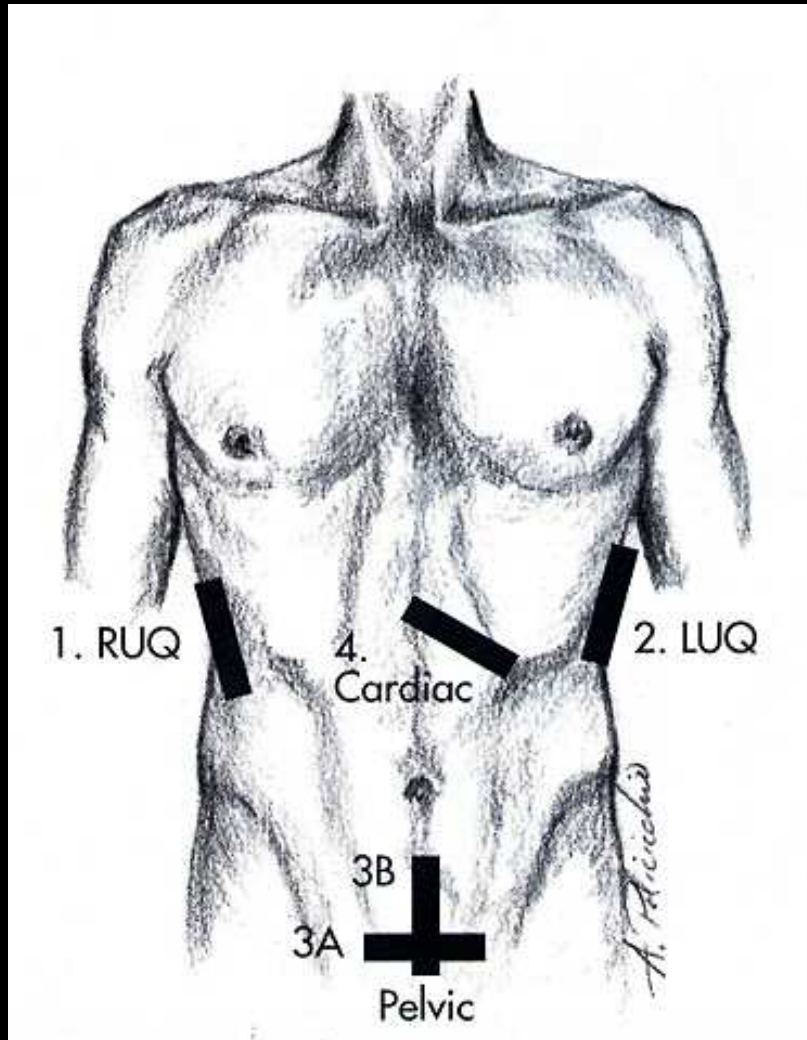
# Radiologic Imaging in Children with Blunt Trauma



# 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 IAIs: 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 d

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)

Clinical Suspicion	Rate of FAST use	RR of abdominal CT (FAST vs. no FAST)
<1% risk of IAI	11.0%	0.83 (0.67, 1.03)
1 – 5% risk of IAI	13.5%	<b>0.81 (0.72, 0.91)</b>
6 – 10% risk of IAI	20.5%	<b>0.85 (0.78, 0.94)</b>
11 – 50% risk of IAI	23.2%	0.99 (0.94, 1.05)
> 50% risk of IAI	30.7%	0.97 (0.91, 1.05)

# 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 contrast 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

Holmes, Ann Emerg Med 2002; 35:500

- 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:

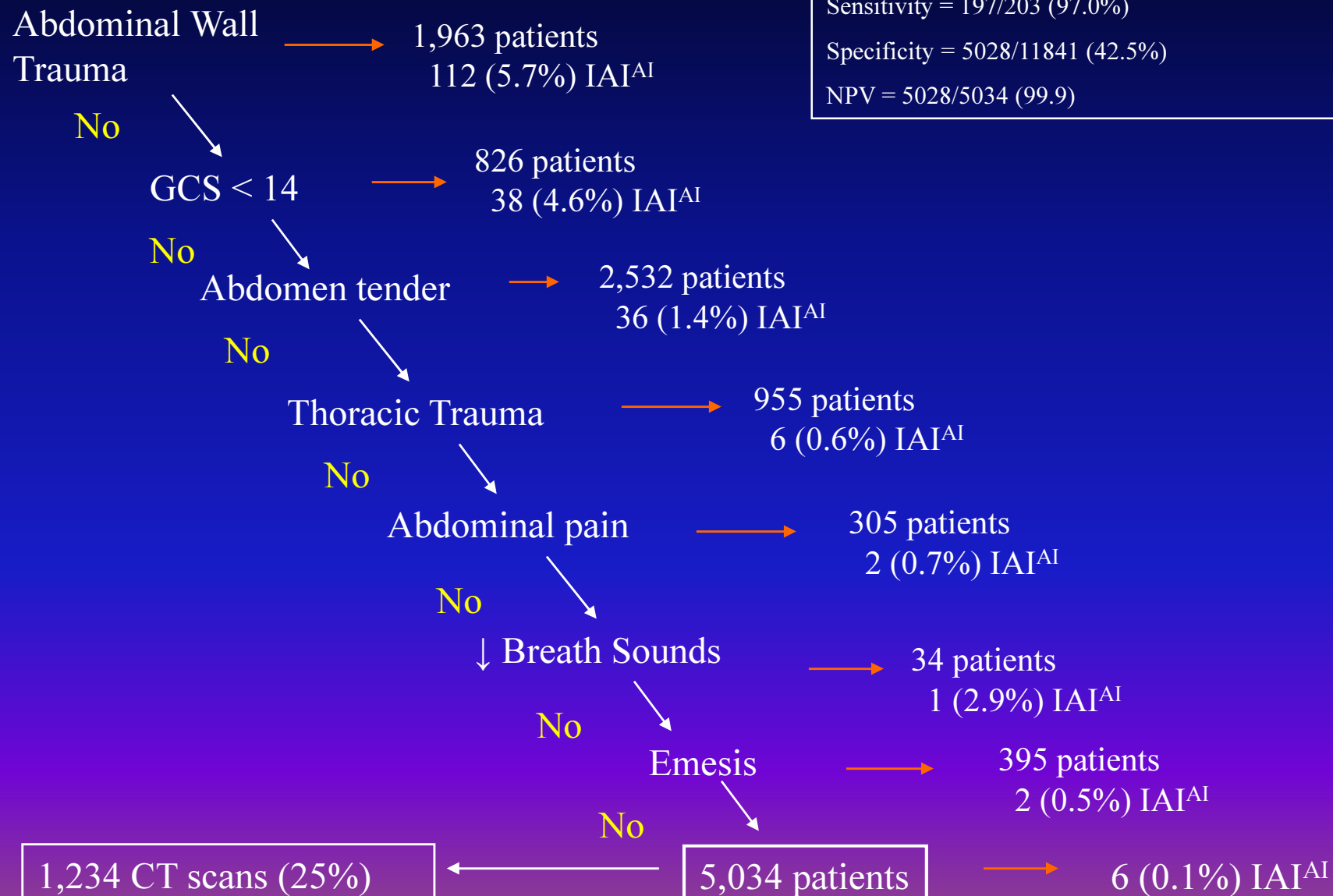
- Variables in the Decision Instrument:
  - Low systolic blood pressure
  - Abdominal tenderness
  - Femur fracture
  - Elevated liver enzymes:
    - $AST > 200 \text{ U/L}$  or  $ALT > 125 \text{ U/L}$
  - Urinalysis  $> 5 \text{ rbc/hpf}$
  - Initial hematocrit  $< 30\%$

# PECARN Abdominal Injury Decision Instrument

Holmes, Ann Emerg Med 2013; 62:107

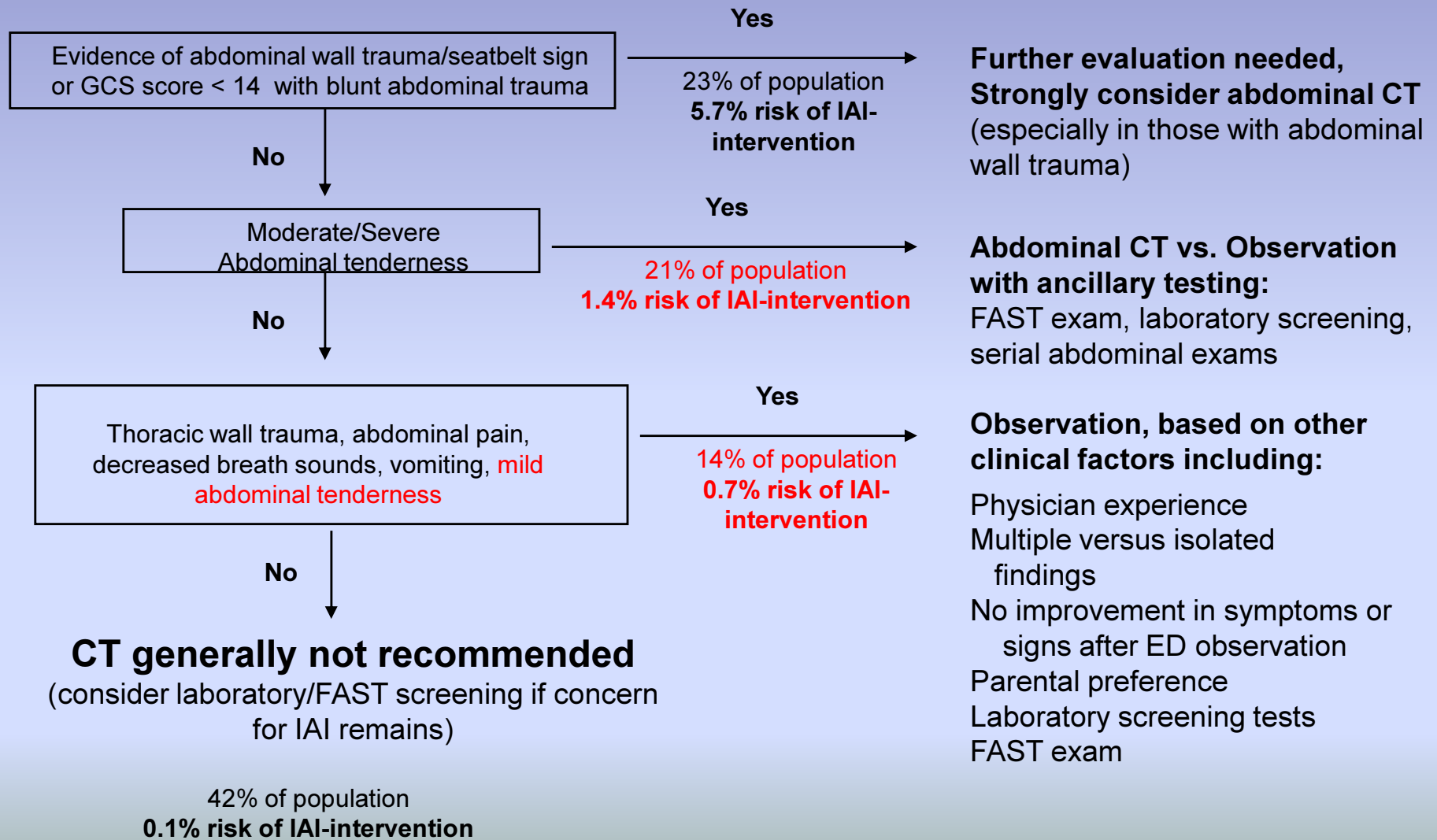
- Prospective multicenter study May 2007 - Jan 2010
- < 18 years w/ blunt abdominal trauma evaluated in ED (explicit exclusion criteria)
- Clinical data recorded before abdominal CT (if done)
- Follow-up obtained on all patients:
  - Discharged patient: Telephone follow-up
  - Admitted patients: medical record review
- Primary outcome: IAI undergoing therapy (IAI<sup>AI</sup>)
- Analysis: Recursive Partitioning (CART)

# Results: Prediction Rule for IAI<sup>AI</sup> (n=12,044)



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**



# IAIAI Not Identified by the Rule

Holmes, Ann Emerg Med 2013; 62:107

Age	Mech	Clinical	Injury	Rx
2yr	Auto-Ped	Hematuria	Renal*	Blood Rx
2yr	Fall	↑ LFTs	Liver, GI*	IV fluid
16yr	MCA†	Femur Fx	Spleen, GI*	Angio
17yr	MVC	ETOH	Spleen, Renal*	Angio
17yr	MVC	Distract inj	Spleen*	Angio
17yr	MVC	ETOH	Spleen*	Angio

# 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

