BLUNT TORSO TRAUMA

pediatric perspective

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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

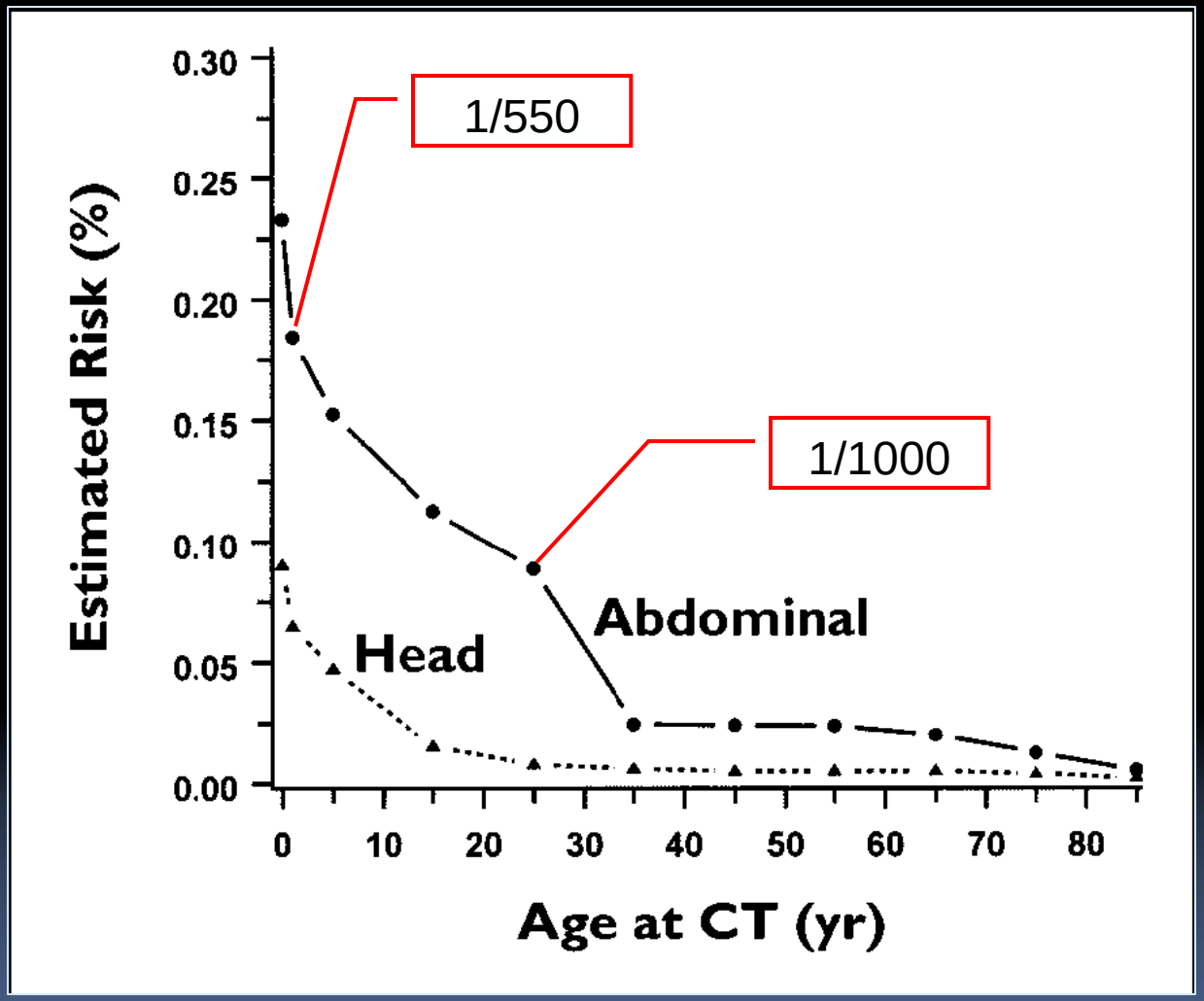
- Case
- Radiation Risks of computer tomography
- Common injuries
  - Intra-abdominal Injury (IAI)
- Role of screening tests
- Pediatric Bedside Ultrasound

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 <u>cancer MORTALITY</u>

- 1 per 1000 pediatric CT
- 1 per 3000 adult CT



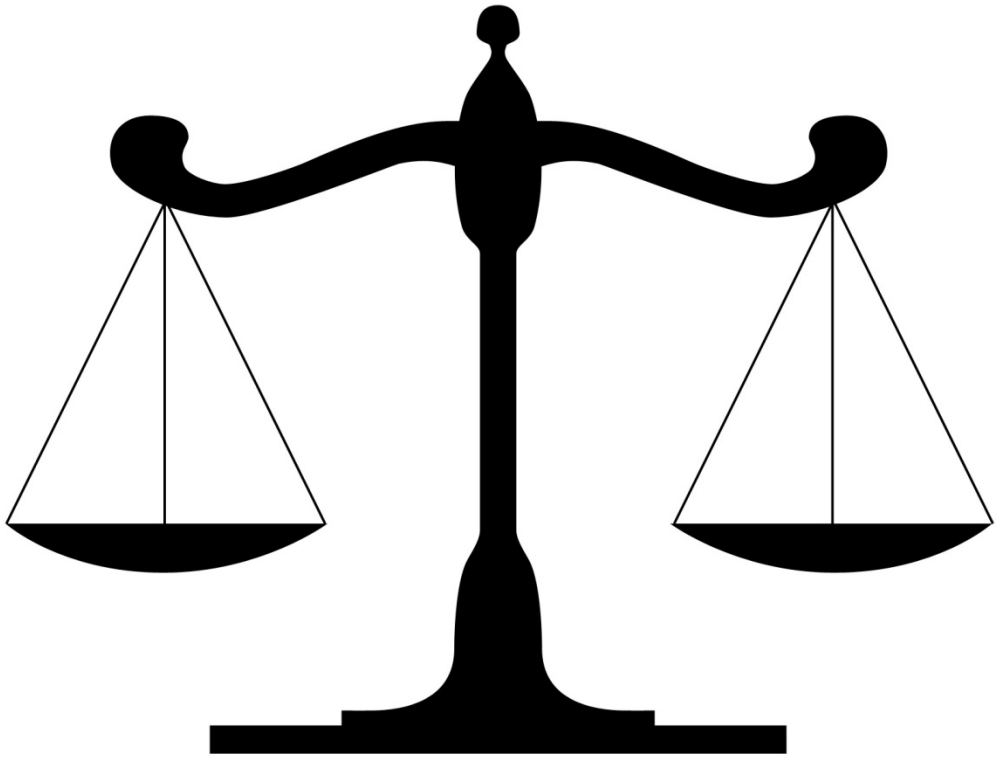
Brenner et al. NEJM 2001

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 <u>severe</u> 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

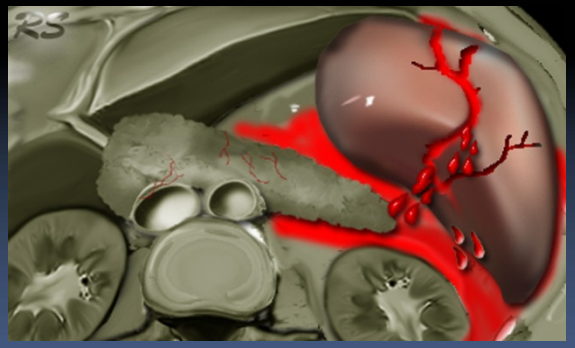
Intra Abdominal Injury

- Most common injuries
  - Liver
  - Spleen
  - Kidney
- Less common include
  - Hollow viscus
  - Pancreas
  - Bladder

Spleen

Splenic CT Injury Grading Scale

Grade I	Laceration(s) < 1 cm deep Subcapsular hematoma < 1cm diameter
Grade II	Laceration(s) 1-3 cm deep Subcapsular or central hematoma 1-3cm 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 > 10cm diam
Grade V	Splenic tissue maceration or devascularization



Stable Patient with IAI: Non-operative Management

American Pediatric Surgical Association Guideline 2000

	CT Grade*			
	I	II	III	IV
ICU stay (d)	None	None	None	1
Hospital stay (d)	2	3	4	5
Predischarge imaging†	None	None	None	None
Postdischarge imaging‡	None	None	None	None
Activity restriction (wk)	3	4	5	6

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

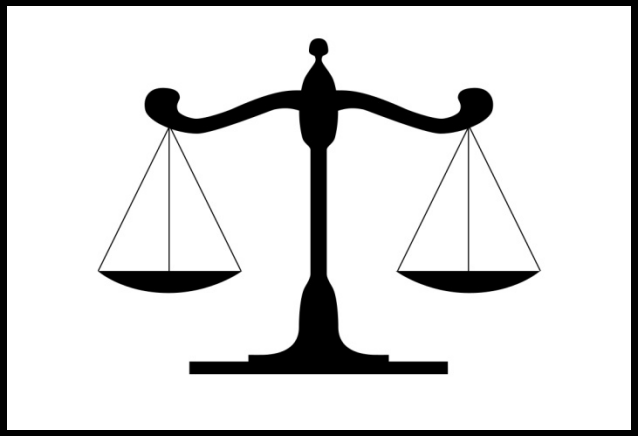
- Regardless of conservative strategy, >95% managed successfully with no intervention

- 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)

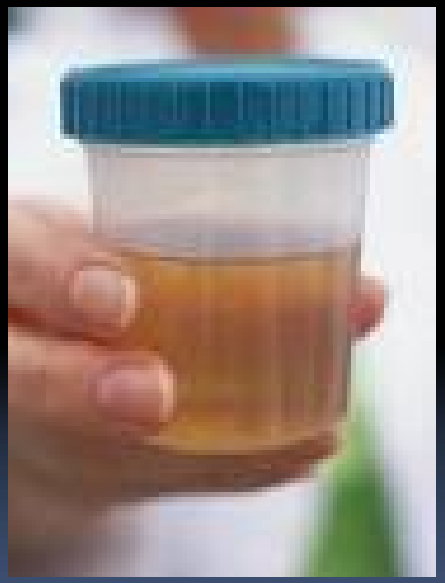
So what to do …



- 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



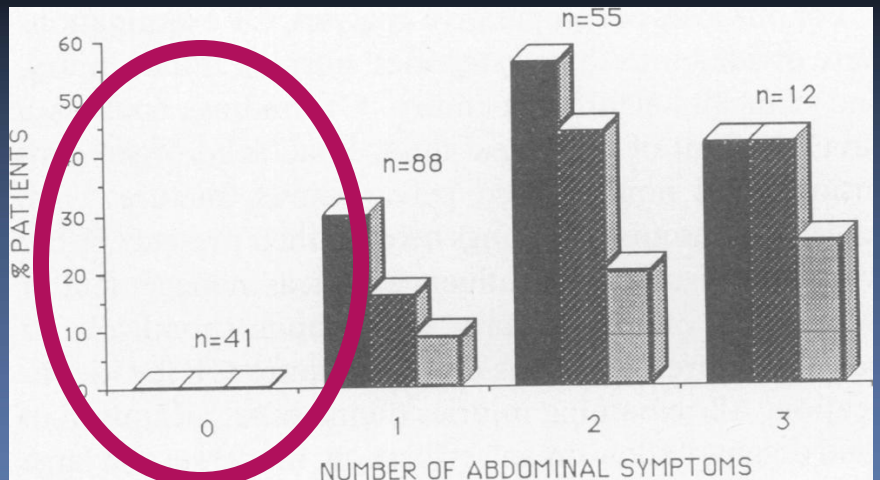
Risk Stratification via investigations

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:

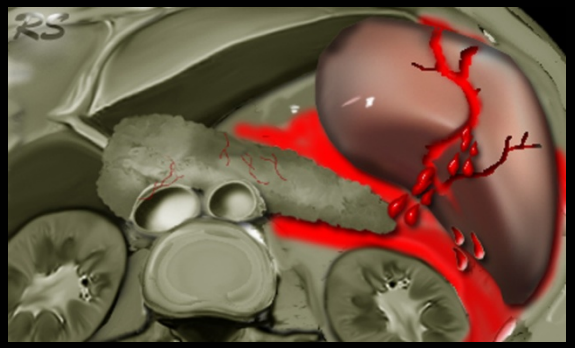
identify elements of physical exam and laboratory data predictive of IAI

Identification of children with intra-abdominal injuries after blunt trauma. Annals of Emergency Medicine 2002, 39: 500-509.

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.*

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

	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.

Age, y	Mechanism	Injury*	Hemoperi-toneum†	Physical Examination Abnormalities	Laboratory Abnormalities	Hospital Course
0.75	MVC	Liver (II)	No	None	Increased ALT/AST	Observation
1.5	Fall 15 ft	Liver (I)	No	None	Increased ALT/AST, hematuria (40 RBCs/hpf)	Observation
1.6	Auto versus ped	Liver (I)	No	None	Increased ALT/AST	Observation
1.7	Auto versus ped	Liver (I)	Yes	Back abrasion	Increased ALT/AST, hematuria (6 RBCs/hpf)	Observation
2.3	Auto versus ped	Liver (I)	No	None	Increased ALT/AST, hematocrit (29%)	Observation
2.5	MVC	Liver (I), adrenal	No	Chest contusion	Increased ALT/AST	Observation
3.7	Fall	Liver (I)	Yes	None	Hematocrit=29%	Observation
4.2	Auto versus ped	Spleen (II)	Yes	Abdominal tenderness developed in the ED	Hematocrit=28%, hematuria (6 RBCs/hpf)	Blood transfusion
4.8	Auto versus ped	Liver (II)	Yes	Abrasions to pelvis	Increased ALT/AST	Observation
9‡	MVC	Kidney (I)	No	None	Hematocrit decreased 8% points in the ED	Observation
10	Auto versus bike	Spleen (II)	No	Flank/chest abrasion	Increased ALT/AST	Observation
10.9	Fall	Kidney (II)	No	Chest/back tenderness/abrasion	Hematuria (314 RBCs/hpf)	Observation
12.2‡	Fall	Spleen (II)	Yes	Chest tenderness/rib fractures	None	Observation
15	MVC	Liver (III)	Yes	Back tenderness	Increased ALT/AST, hematuria (175 RBCs/hpf)	Observation
15	Auto versus ped	Spleen (II)	Yes	Abdominal abrasion, GCS score of 14, seizure then intubated	Hematuria (6 RBCs/hpf)	Laparotomy
15	Auto versus bike	Liver (I)	No	Chest/back tenderness, abdominal tenderness developed in the ED	Increased ALT/AST	Observation

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

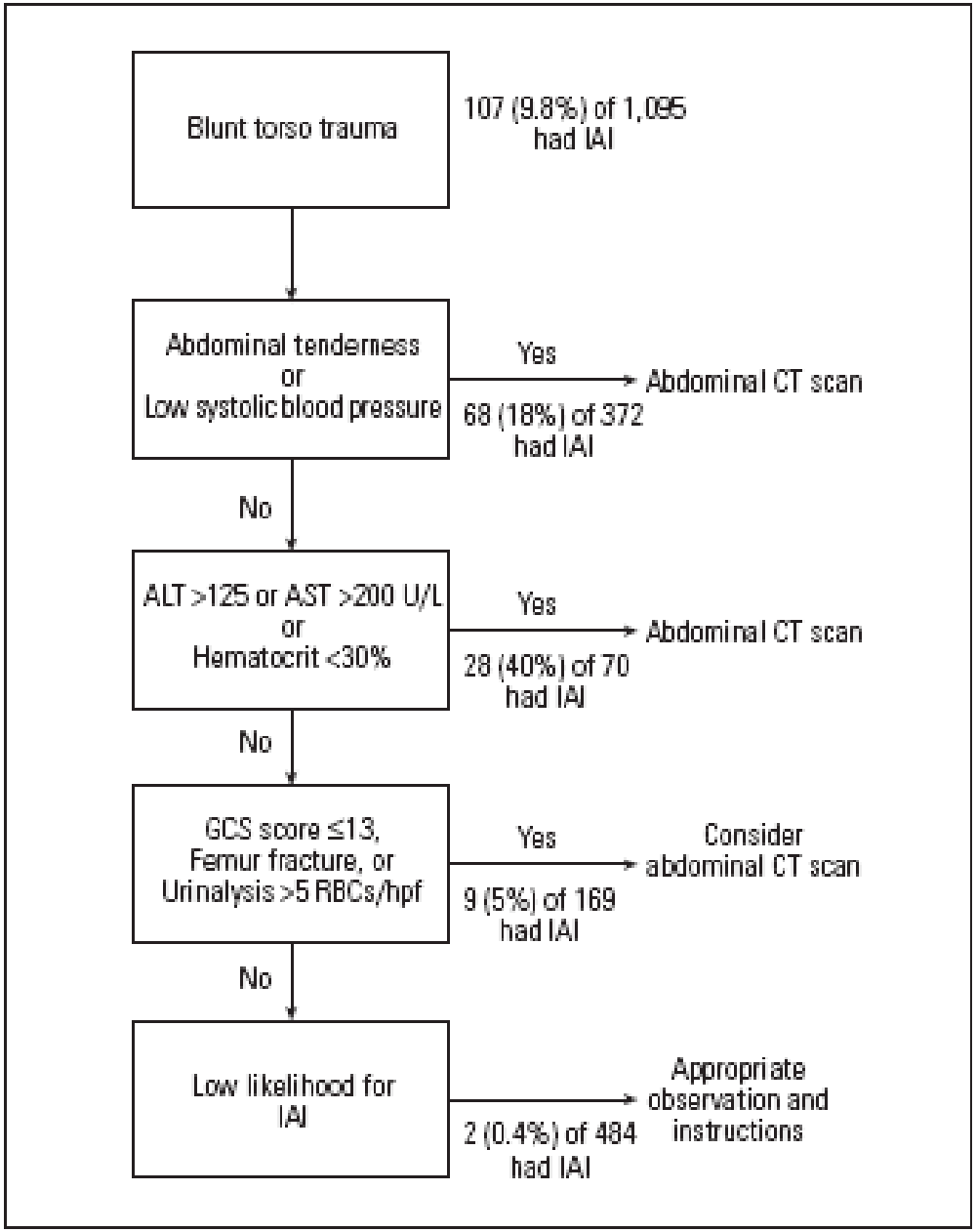
*Injury grade is provided in parentheses after each injury.[52-54]

†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.



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)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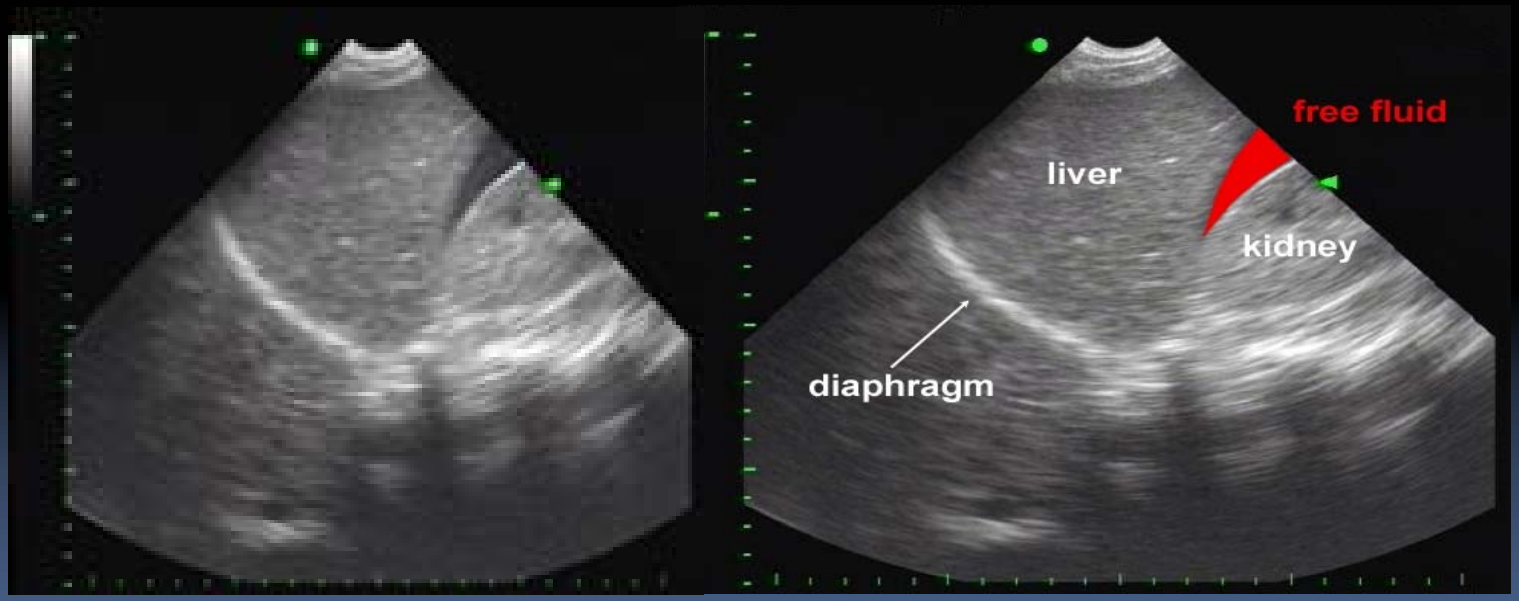
BUCKLE UP
OR AT LEAST WEAR A HELMET
searchID: mban2408

Focused Assessment with Sonography in Trauma (aka FAST)

FAST

- Morison's Pouch (RUQ)

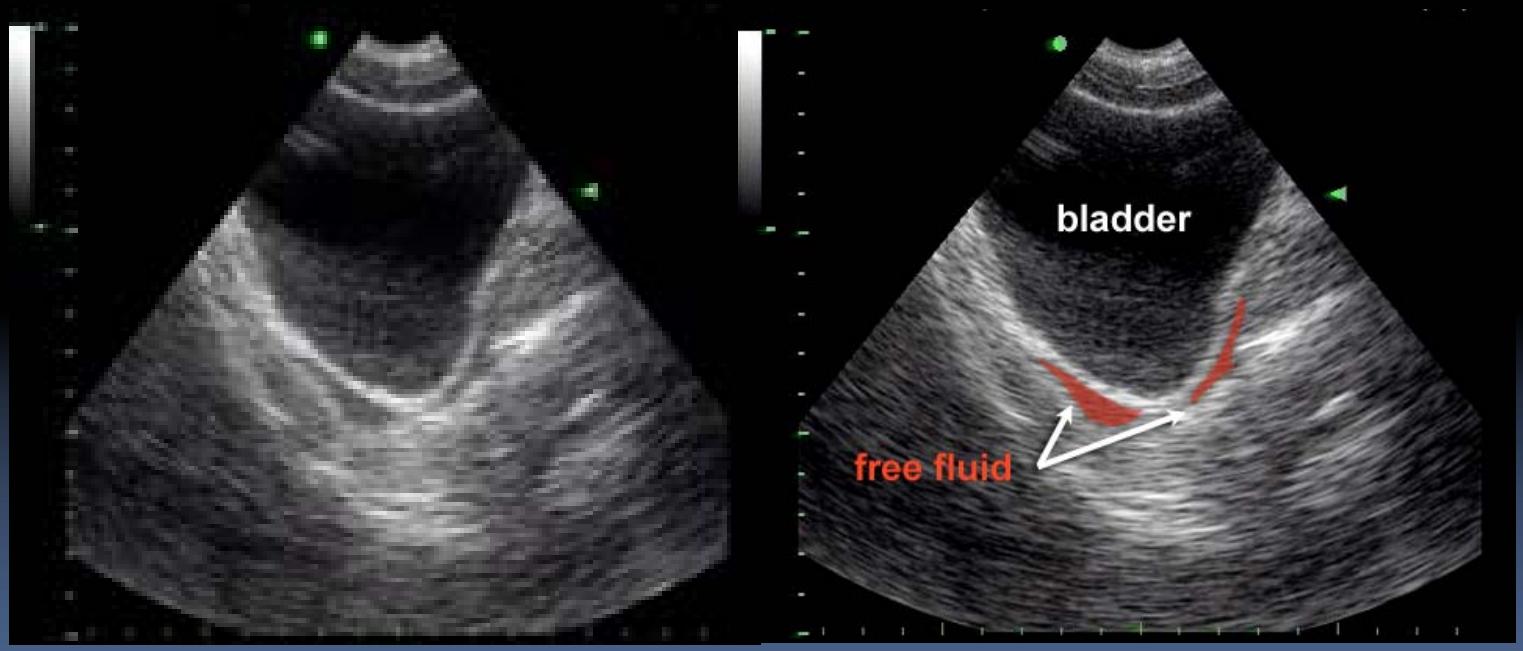


FAST

- 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

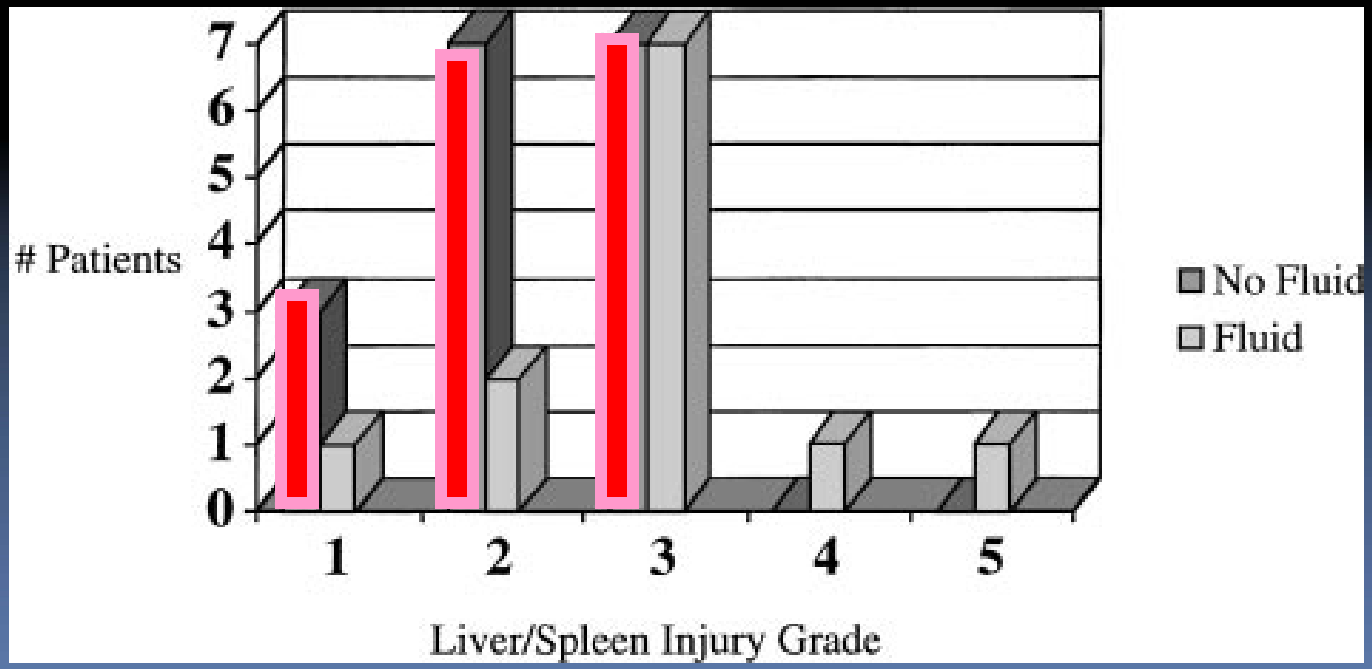
- Free fluid vs. parenchymal
- Radiology based studies
- Ex. Richards et al. 1999

Liver Injury CT Grade	Sensitivity Free Fluid	Sensitivity Free Fluid ± Parenchymal
1	17 %	26 %
2	74 %	80 %
3	97 %	97 %
4	100 %	100 %
5	100 %	100 %

Free Fluid

Emery et al. 2001

- Observational study in children
- Outcome: <u>any</u> 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%

↓ BP 100% Sensitivity

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

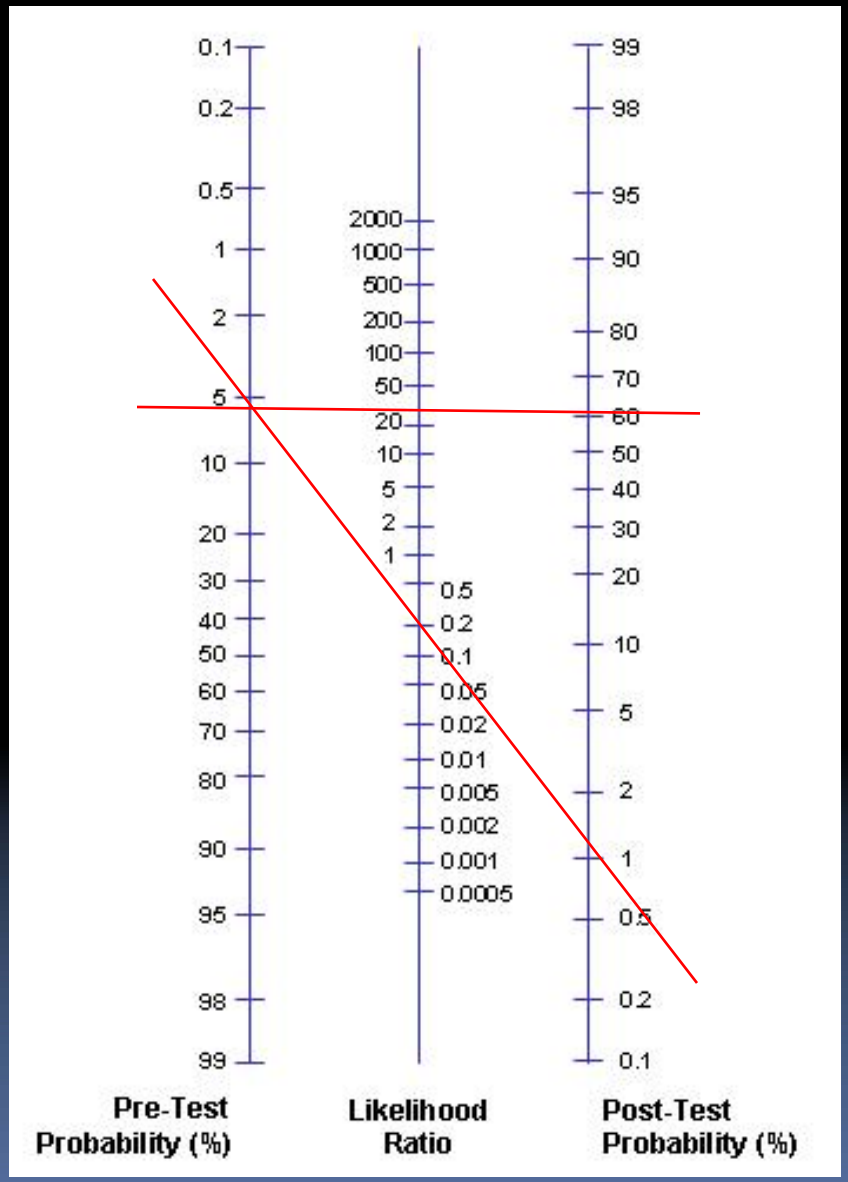
Patrick et al. 1998

- 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

U/S Protocol	FAST (free fluid)	FAST (free fluid)	FAST (free fluid and solid organs)
Outcome of interest	Hemoperitoneum	Any IAI	Any IAI
Sensitivity	80%	66%	82%
Specificity	96%	93%	97%
Likelihood ratio +	22.9	9.8	24.5%
Likelihood ratio -	0.2	0.37	0.18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98
95
90
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70
60
50
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10
5
2
1
0.5
0.2
0.1
Pre-Test Probability (%)
Likelihood Ratio
Post-Test Probability (%)

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

	Sensitivity	Specificity	PPV	NPV
Physical Exam	81%	73%	47%	93%
FAST	70%	100%	100%	92%
P/E + FAST	100%	75%	54%	100%

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%*

	Sensitivity	Specificity	PPV	NPV
FAST	50%	91%	68%	83%
FAST + LFTs	88%	98%	94%	96%

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

	Sensitivity	Specificity	PPV	NPV
Initial U/S	31%	99.8%	95%	92%
Second U/S	72%	99.8%	98%	97%

Serial FAST

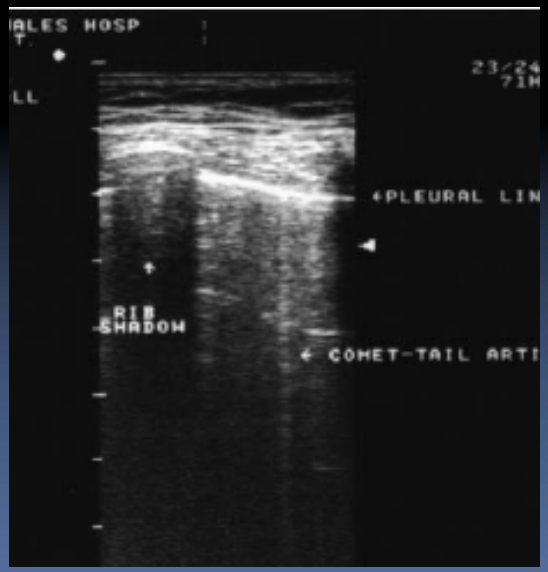
Blackbourne et al. 2004

- 44% FAST negative had CT/OR
  - 2/501 (0.4%) Neg-Neg → OR (hollow-viscus)
  - 10/26 (35 %) Neg-Pos → OR

Advanced trauma application

- <u>Pneumothorax</u>
  - Bedside u/s more sensitive than supine CXR

    Sensitivity → **98% vs. 75%**

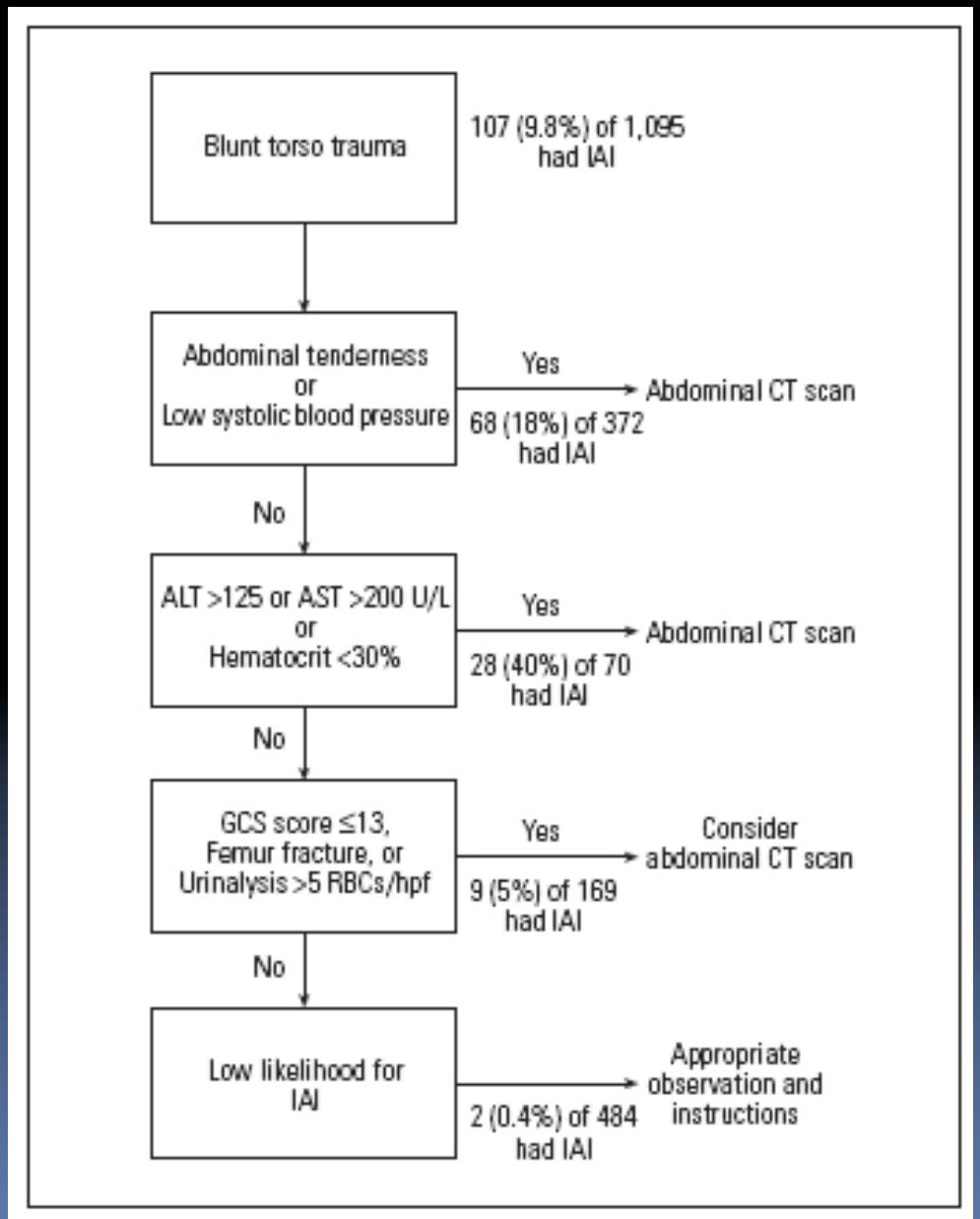


Bedside Ultrasound

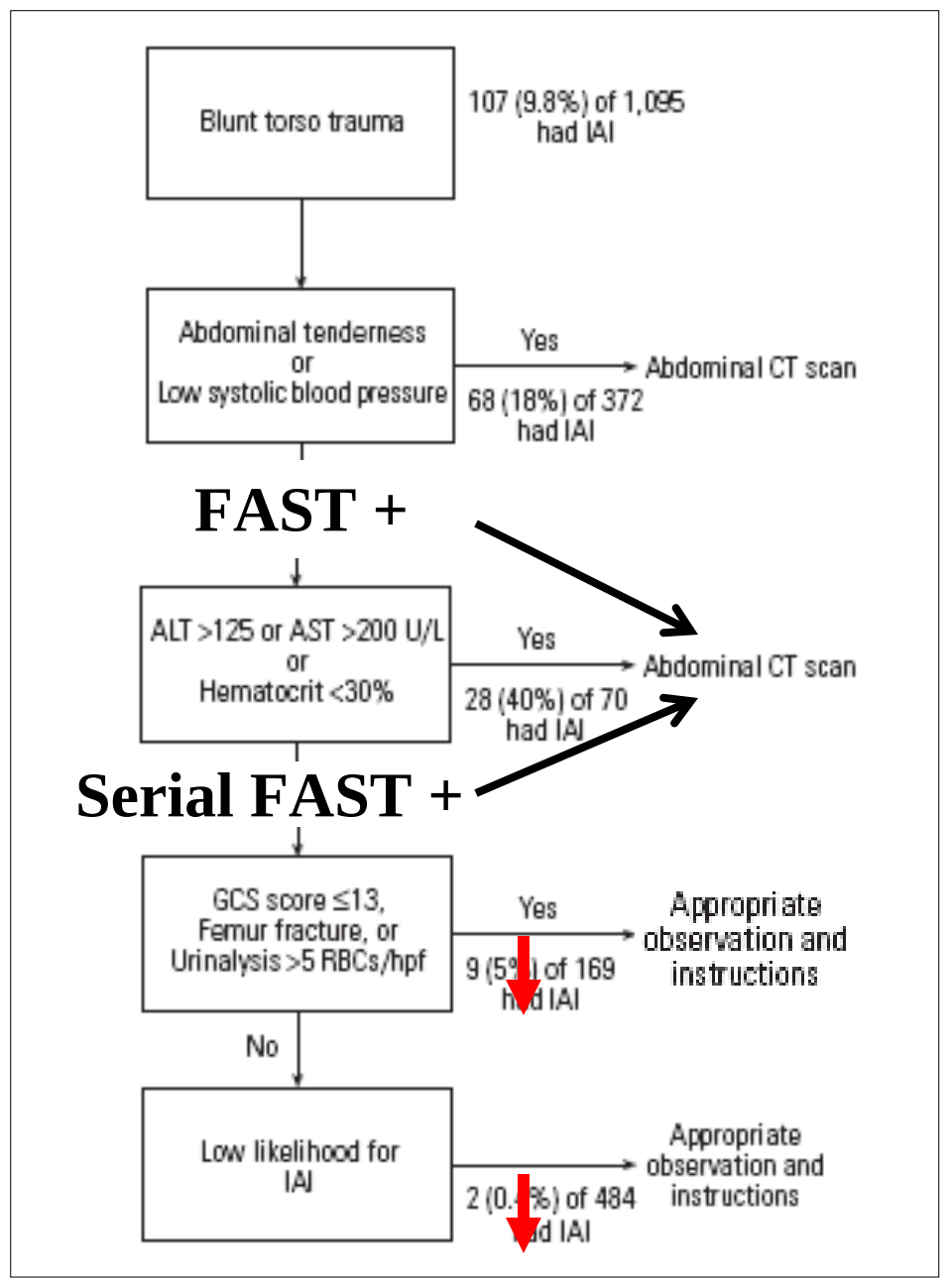
Clear role in pediatric BAT

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

Proposed Algorithm



Potential Algorithm



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 <u>severe</u> injuries
  - Need to ensure no harm

- Educate / Primary prevention