Pediatric Abdominal Trauma

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Disclosures

I have no financial relationships relevant to this presentation

Learning Objectives

- Know indications and protocols for imaging pediatric blunt abdominal trauma patients
- Be familiar with guidelines for management of this patient population
- Recognize imaging findings that may indicate a need for intervention or change in management

Indications & Protocols

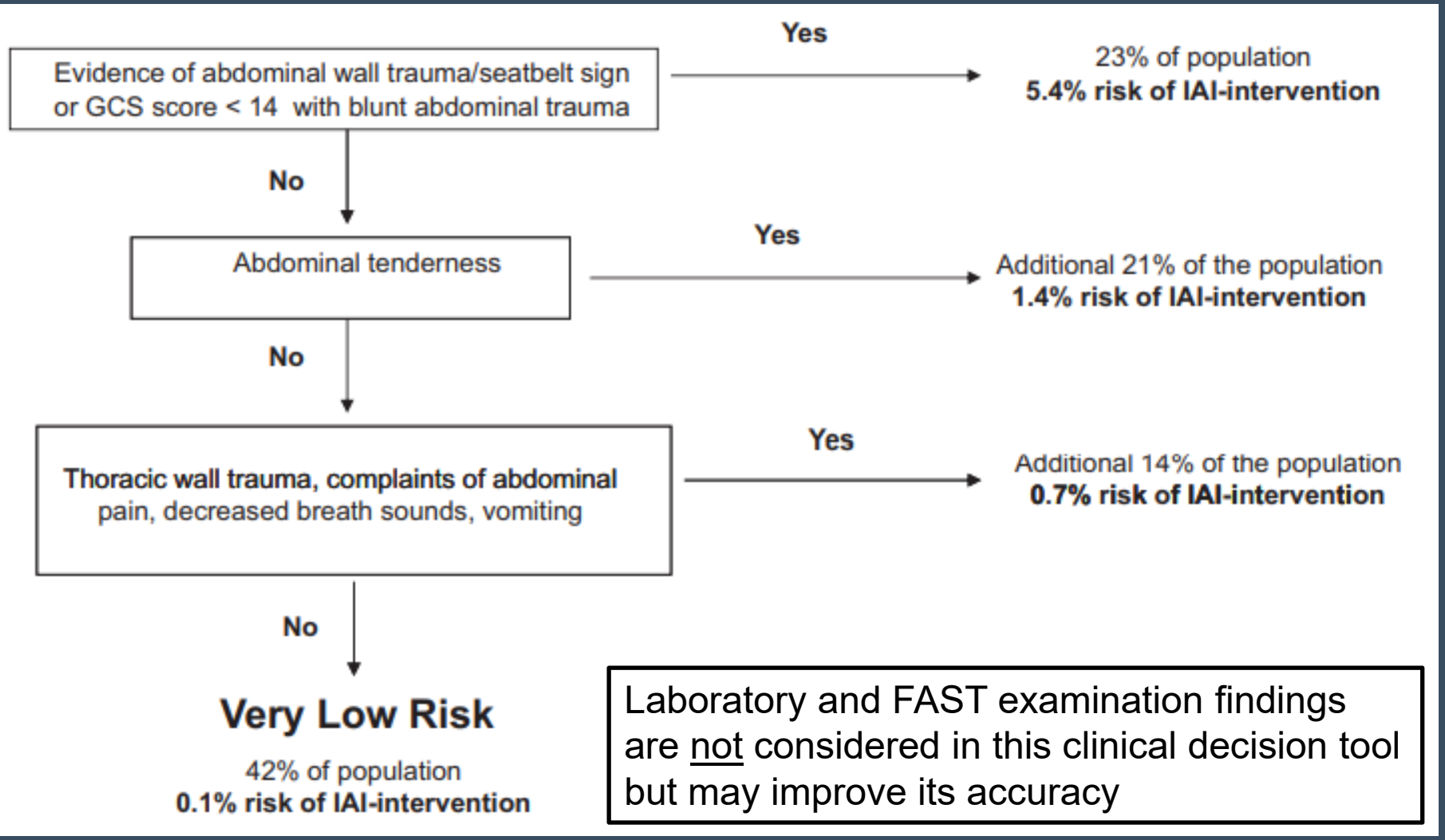
Children are not just little adults

Risk of Radiation Exposure

- ↑ Risk for radiation-induced carcinogenesis
  - More active organ and tissue growth
  - Longer life expectancy during which potential oncogenic effects of radiation can manifest

- Methods of decreasing radiation exposure:
  - Perform studies when indicated
  - Diagnostic techniques with radiation doses ALARA

Abdomen & Pelvis Trauma: Imaging Indications



Laboratory and FAST examination findings are not considered in this clinical decision tool but may improve its accuracy

Intent is to identify patients at very low risk of intraabdominal injury requiring intervention who do not need CT imaging.

Findings are **NOT** meant to suggest that all patients with 1 or more variables require CT imaging.

Holmes JF, Lillis K, Monroe D, Borgialli D, Kerrey BT, Mahajan P, Adelgais K, Ellison AM, Yen K, Atabaki S, Menaker J. Identifying children at very low risk of clinically important blunt abdominal injuries. Annals of emergency medicine. 2013 Aug 1;62(2):107-16.

CT Protocols for Children

- SPR document
  - How to Develop CT Protocols for Children
  - https://www.imagegently.org/portals/6/procedures/protocols.pdf

- kVp and mAs adjusted to patient size/age
- Automatic exposure control
- Iterative Reconstruction
- Appropriate field of view (FOV)
- Multiphase acquisition only when indicated

Abdomen & Pelvis Trauma: Imaging Protocols

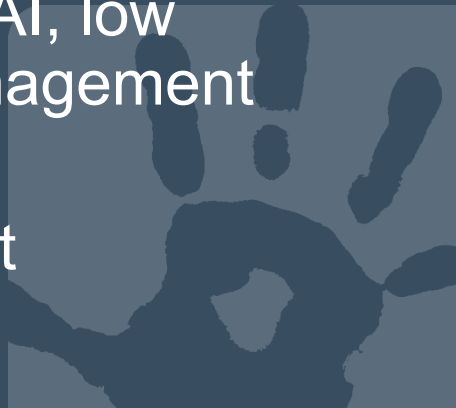
- CT abdomen and pelvis
  - FOV: Lower chest above diaphragms to symphysis pubis
  - Phase: Portal-venous
  - Contrast: IV contrast (2 mL/kg, max 120 mL), NO oral contrast

Abdomen & Pelvis Trauma: Imaging Protocols

- CT abdomen and pelvis with IV contrast
  - No oral contrast
    - No difference in sensitivity for intra-abdominal injury (IAI)
    - Minimal increased specificity: 84.7% (95% CI 82.2%-87.0%) vs 80.8% (95% CI 79.4%-82.1%)
  - Multiphase scanning is NOT used routinely on all patients
    - May be helpful in select patients
      - Renal collecting system disruption
      - Problem-solving tool
    - Guidelines for management are largely non-operative and based on hemodynamic status

Abdomen & Pelvis Trauma: Imaging Indications

- FAST
  - Early studies encouraging
    - PECARN: patients with low-moderate clinician suspicion for IAI less likely to undergo CT with use of FAST
  - Subsequent studies
    - Randomized control trial among hemodynamically stable children with blunt trauma showed no change in management, CT utilization, ED length of stay, missed IAI
    - Multicenter prospective study showed low sensitivity for IAI, low sensitivity for IAI requiring intervention, rarely impact management
  - Variable rate of utilization, expertise
  - More investigation needed to determine role in pediatric blunt abdominal trauma



Abdomen & Pelvis Trauma: Imaging Indications

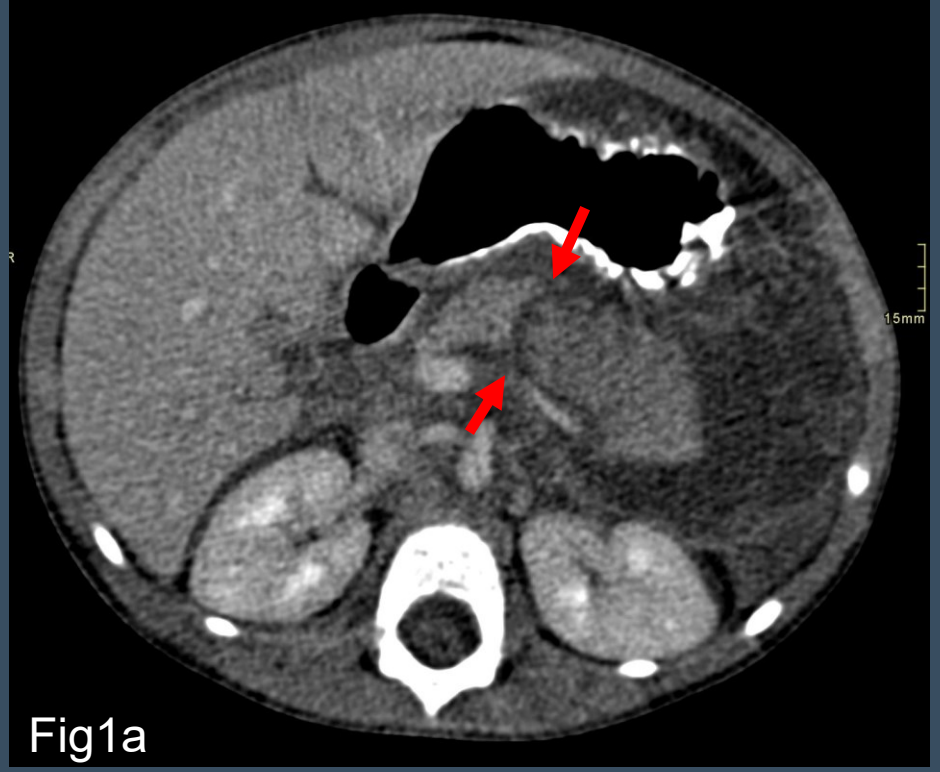
- Abdominal US
  - Limited role in acute setting due to poor sensitivity for detection of IAI

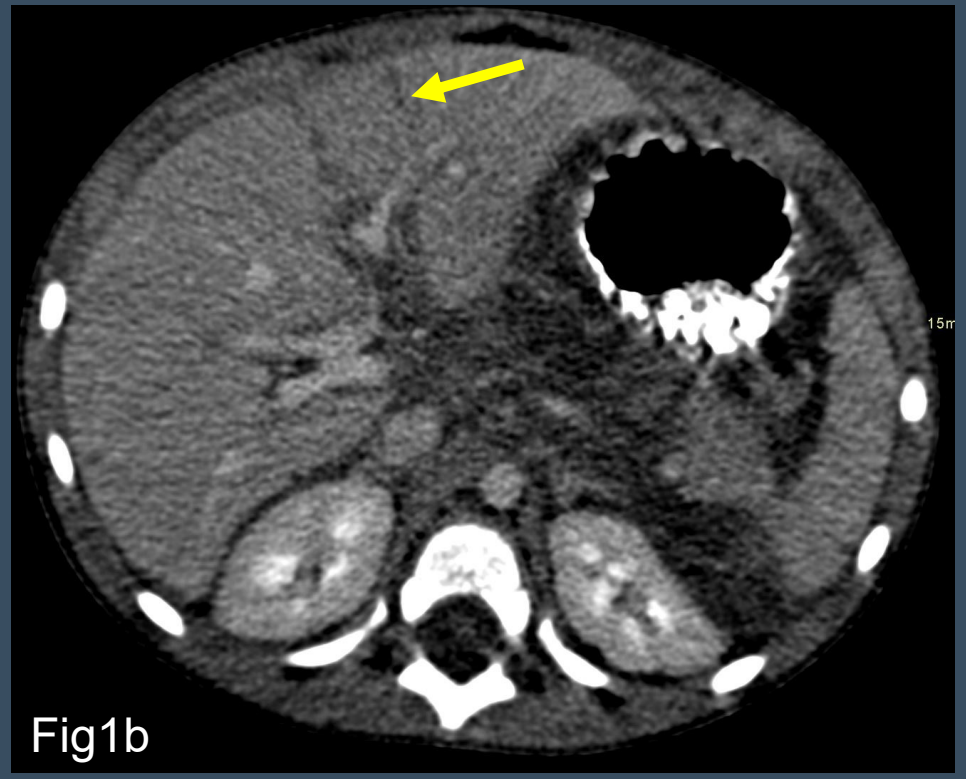
- CEUS
  - Better test characteristics
  - Not readily available
  - Image acquisition more labor intensive

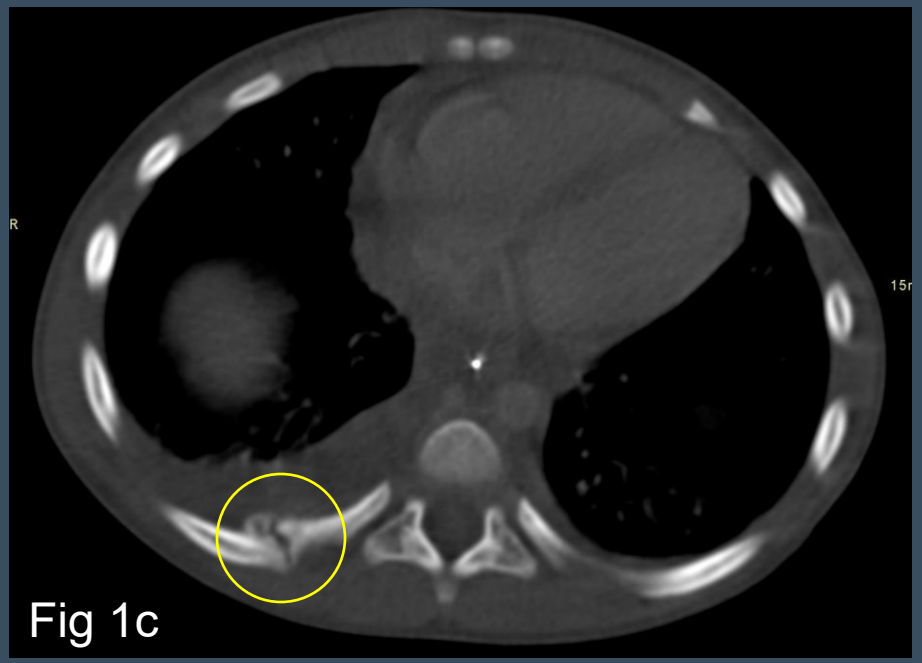
Abdomen & Pelvis Trauma: Imaging Indications

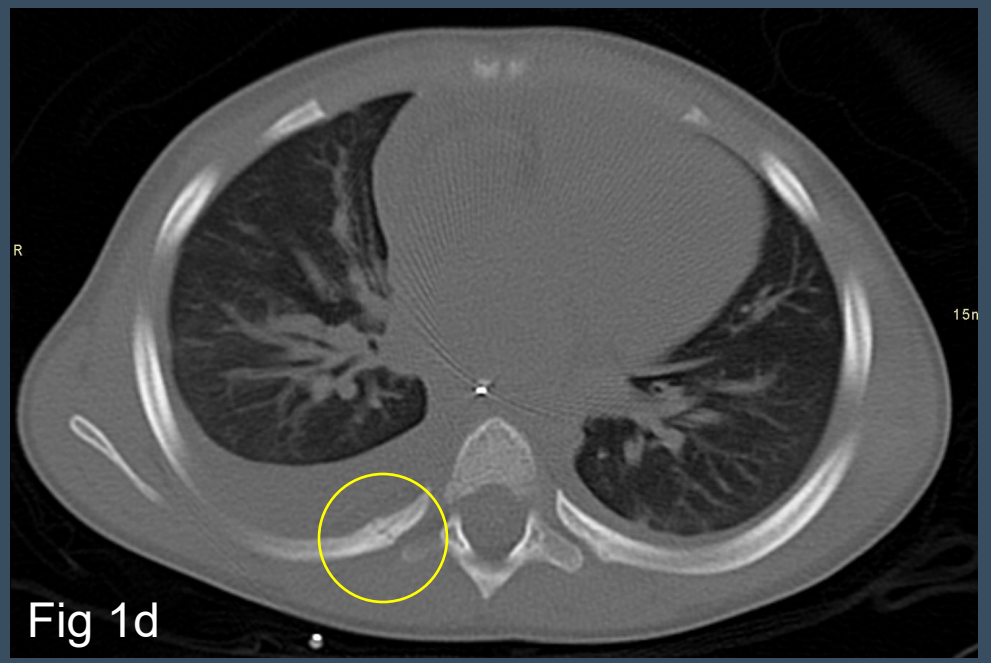
- MRI
  - Limited use in acute setting
  - May be considered to evaluate integrity of pancreatic duct
    - MRCP vs ERCP
      - MRCP less invasive and allows for visualization of surrounding soft tissues
      - ERCP may provide opportunity for intervention

Cases









CASE 1

Figure 1: 2-year-old with worsening abdominal pain and emesis over multiple days and rash. Left hepatic lobe laceration (→) and pancreas transection (→) (a, b). Multiple healing posterior rib fractures (O) (c).

Child abuse

Child Physical Abuse

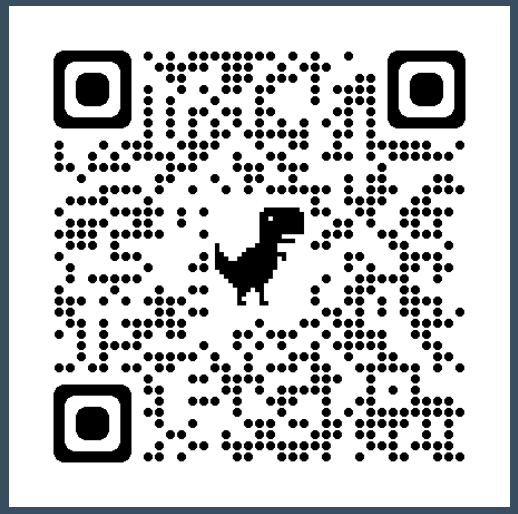
Variant 4. Child. Suspected physical abuse. Suspected thoracic or abdominopelvic injuries (eg, abdominal skin bruises, distension, tenderness, or elevated liver or pancreatic enzymes). Initial imaging evaluation.

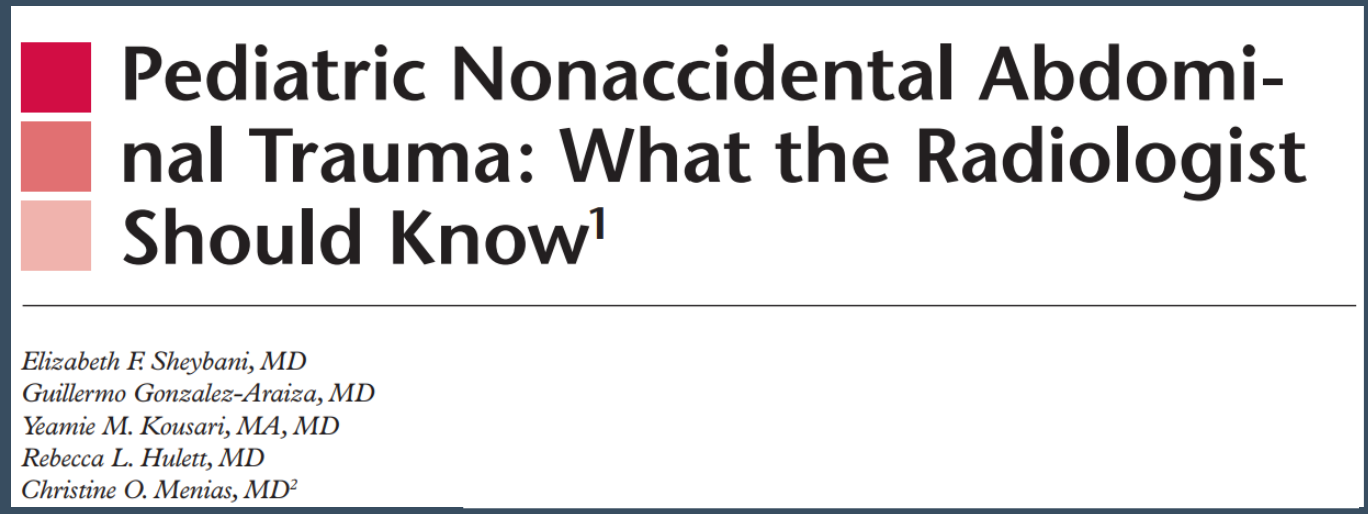
Radiologic Procedure	Rating	Comments	RRL
X-ray skeletal survey	9		☢☢☢
CT abdomen and pelvis with IV contrast	9		☢☢☢☢
CT chest with IV contrast	6	This procedure may be combined with CT abdomen/pelvis with IV contrast if there is concern for intrathoracic injury.	☢☢☢☢
CT head without IV contrast	6	Use this procedure in the emergent setting if there is suspicion for concurrent intracranial injury.	☢☢☢

Expert Panel on Pediatric Imaging: et al. “ACR Appropriateness Criteria® Suspected Physical Abuse-Child.” Journal of the American College of Radiology : JACR vol. 14,5S (2017): S338-S349. doi:10.1016/j.jacr.2017.01.036

Child Physical Abuse

- Hollow viscus and pancreatic injuries are disproportionately more common in abuse compared to accidental injury mechanisms
- Duodenal injuries
- Pancreatitis, pancreatic injury
- Liver injury, left lobe

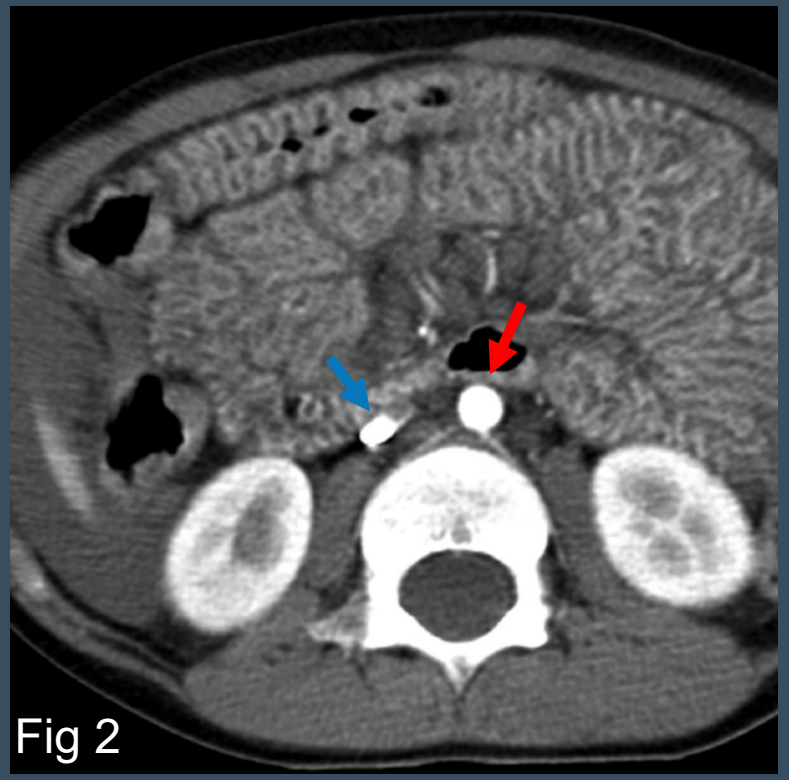




Pediatric Nonaccidental Abdominal Trauma: What the Radiologist Should Know[1]

Elizabeth F. Sheybani, MD
Guillermo Gonzalez-Araiza, MD
Yeamie M. Kousari, MA, MD
Rebecca L. Hulett, MD
Christine O. Menias, MD[2]

CASES 2 & 3



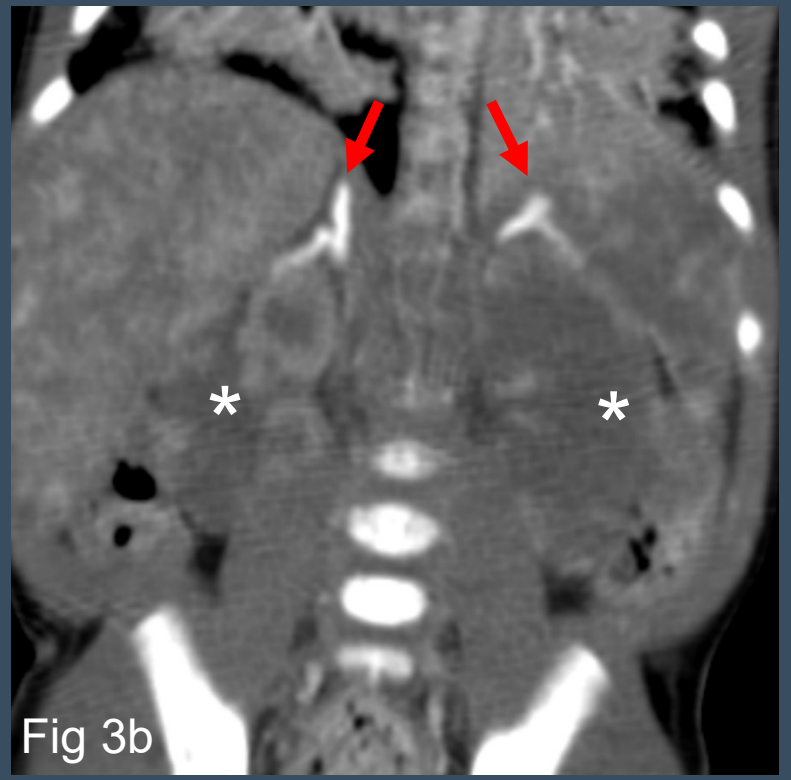


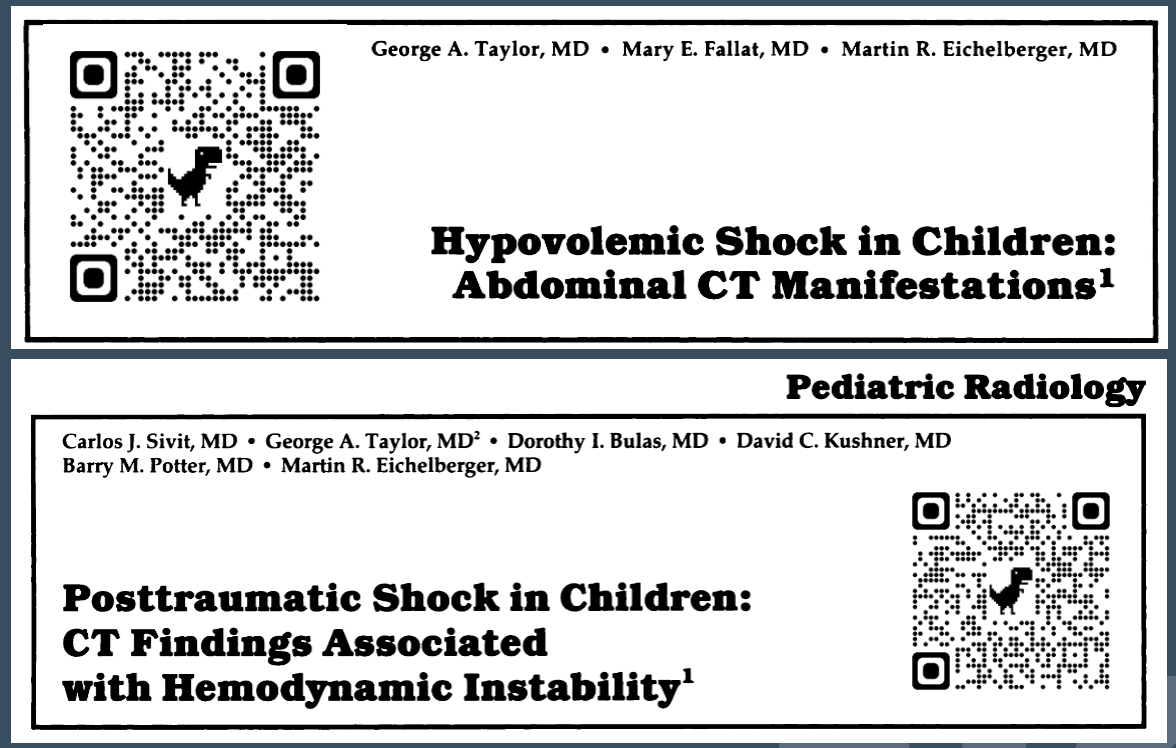
Figure 2: Pediatric trauma patient. Diffuse small bowel wall thickening and hyper-enhancement, densely enhancing IVC (→) and aorta (→), and ascites.

Figure 3: Pediatric patient. Bowel is diffusely fluid-filled and dilated. Intensely enhancing adrenal glands (→), heterogeneous enhancement of the liver, and predominantly low attenuation of the kidneys (*) and spleen.

Hypoperfusion Complex

Hypoperfusion Complex

- Diffuse fluid-distended bowel with wall thickening and abnormal enhancement
- Abnormal enhancement of solid organs
- Dense enhancement of small caliber vessels
- Kidneys: Typically intense & prolonged enhancement
  - Rarely, decreased enhancement <10 HU (poor prognosis)
- Spleen: Decreased enhancement, >30 HU less than liver (lower attenuation may be associated with worse prognosis)



George A. Taylor, MD • Mary E. Fallat, MD • Martin R. Eichelberger, MD

Hypovolemic Shock in Children: Abdominal CT Manifestations[1]

Pediatric Radiology

Carlos J. Sivit, MD • George A. Taylor, MD[2] • Dorothy I. Bulas, MD • David C. Kushner, MD
Barry M. Potter, MD • Martin R. Eichelberger, MD

Posttraumatic Shock in Children: CT Findings Associated with Hemodynamic Instability[1]

Normal BP → 19% hypotensive within 10 minutes

Emergent communication to referring physician!

CASES 7 & 8

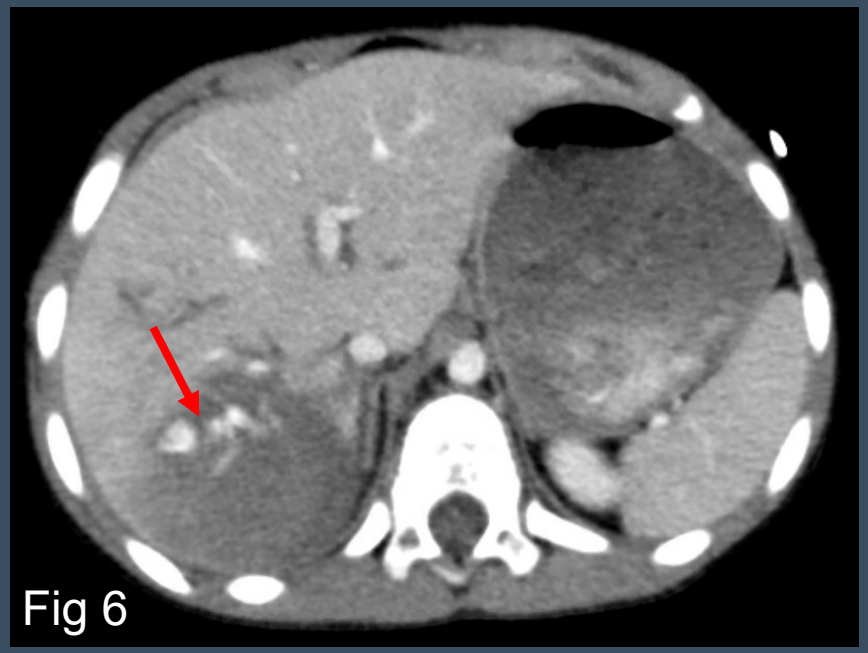


Figure 7: 6-year-old hit by a car. Lacerations with contrast extravasation (→) contained within the parenchyma.

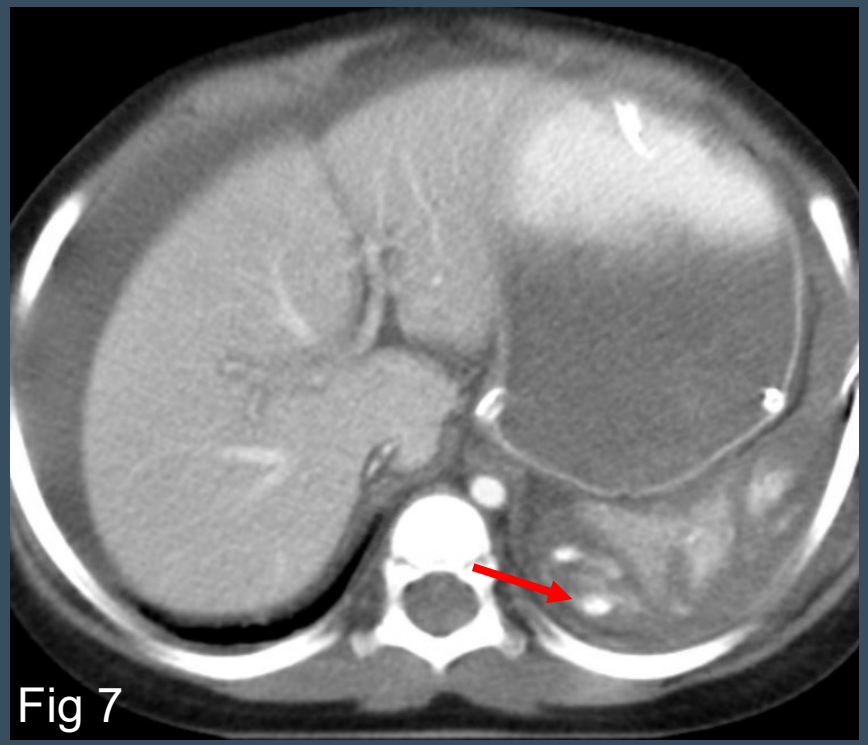
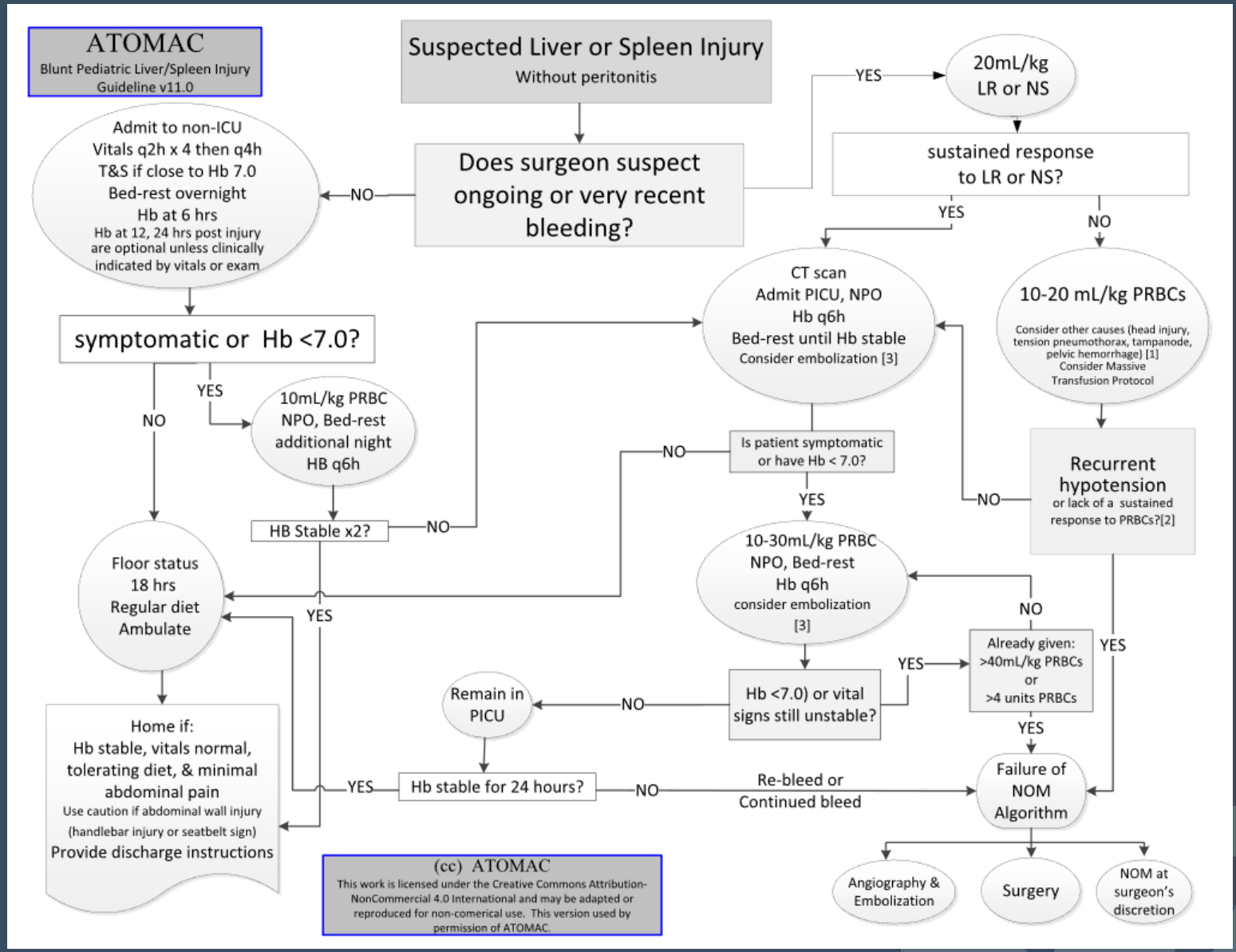


Figure 8: 2-year-old after a motor vehicle accident. Lacerations and multiple ill-defined hyperdensities (→) in the extraparenchymal perisplenic region compatible with contrast extravasation and a grade 5 injury.

ATOMAC Guideline



Notrica DM, Eubanks III JW, Tuggle DW, Maxson RT, Letton RW, Garcia NM, Alder AC, Lawson KA, St Peter SD, Megison S, Garcia-Filion P. Nonoperative management of blunt liver and spleen injury in children: Evaluation of the ATOMAC guideline using GRADE. Journal of Trauma and Acute Care Surgery. 2015 Oct 1;79(4):683-93.

Updated APSA Blunt Liver/Spleen Injury Guidelines

Admission

- **ICU Admission Indicators**
  - Abnormal vital signs after initial volume resuscitation
- **ICU**
  - Activity - Bedrest until vitals normal
  - Labs – q6hour CBC until vitals normal
  - Diet – NPO until vital signs normal and hemoglobin stable
- **Ward**
  - Activity - No restrictions
  - Labs - CBC on admission and/or 6 hours after injury
  - Diet – Regular diet

Procedures

- **Transfusion**
  - Unstable vitals after 20 mL/kg bolus of isotonic IVF
  - Hemoglobin < 7
  - Signs of ongoing or recent bleeding
- **Angioembolization or Operative Exploration**
  - Signs of ongoing bleeding despite pRBC transfusion
  - Angioembolization is not indicated for contrast blush on admission CT without unstable vitals
  - Operative exploration may be indicated when additional procedures or information needed

Set Free

- Based on clinical condition **NOT** injury severity (grade)
- Tolerating a diet
- Minimal abdominal pain
- Normal vital signs

Aftercare

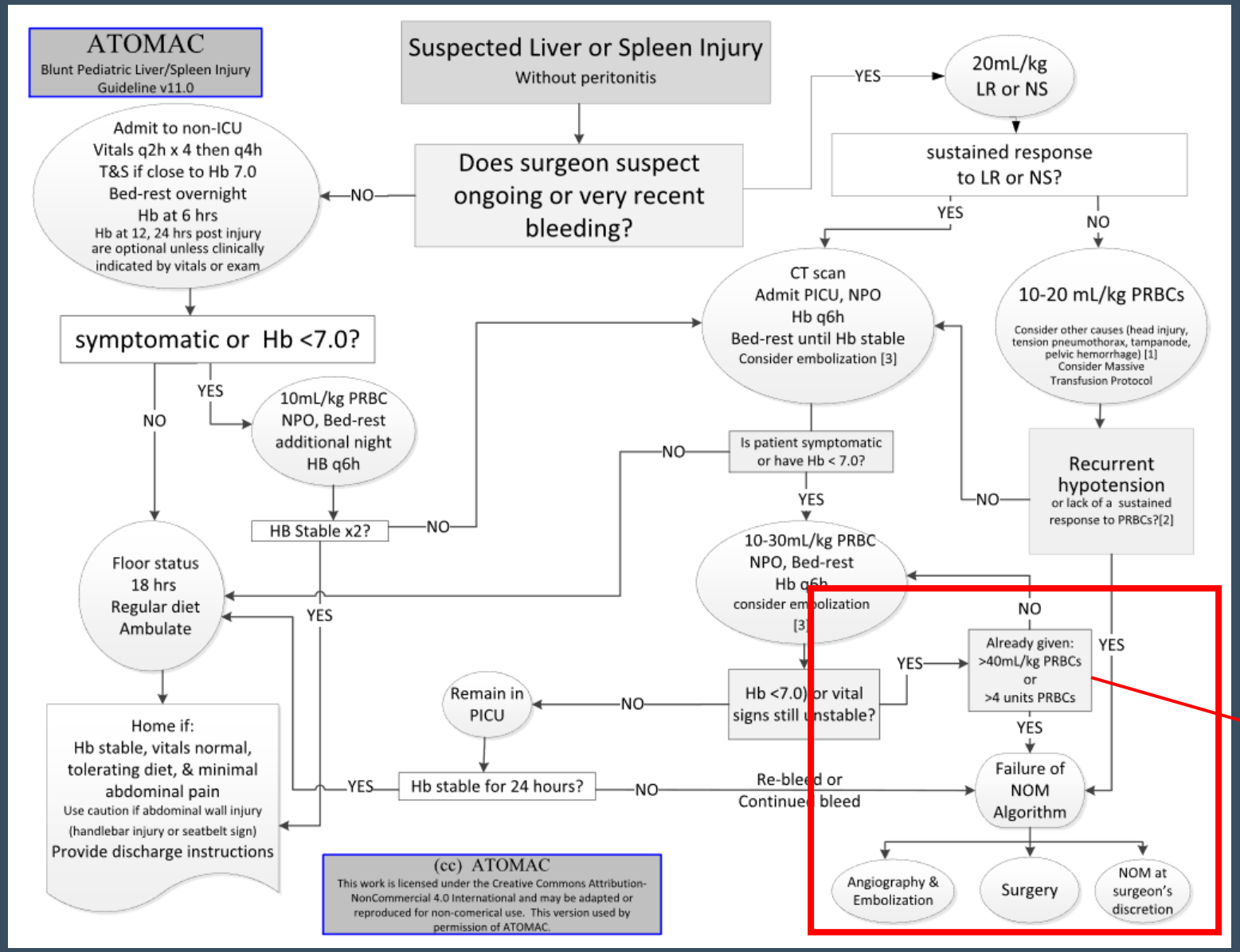
- **Activity Restriction**
  - Restricting activity to grade plus 2 weeks is safe
  - Shorter restrictions may be safe but there is inadequate data to support decreasing these recommendations
- **Follow up Imaging**
  - Routine imaging is not indicated in asymptomatic patients with low grade injuries
  - Consider imaging for ***symptomatic*** patients with prior high grade injuries

APSA & ATOMAC Guidelines

	APSA	ATOMAC
Angioembolization (AE)	• Majority of pediatric patients achieve successful non-operative management of blunt liver or spleen injury without AE • May have a role in select high-grade injuries, injuries that continue to bleed resulting in hemodynamic compromise • Prophylactic AE in hemodynamically stable patients is not indicated, even in presence of arterial extravasation	

Williams RF, Grewal H, Jamshidi R, Naik-Mathuria B, Price M, Russell RT, Vogel A, Notrica DM, Stylianos S, Petty J. Updated APSA Guidelines for the Management of Blunt Liver and Spleen Injuries. Journal of pediatric surgery. 2023 Mar 23.

Angioembolization in Pediatric Patients



- Increased physiologic reserve of children in response to volume loss
- Transfusion volume thresholds from prior studies
  - Adult: 10-15 ml/kg
  - Pediatric 40-80 ml/kg
- NOM success ~90%
- Hemorrhage control from single session embolization 80-100%

Increased physiological reserve in response to volume loss

CASE 9

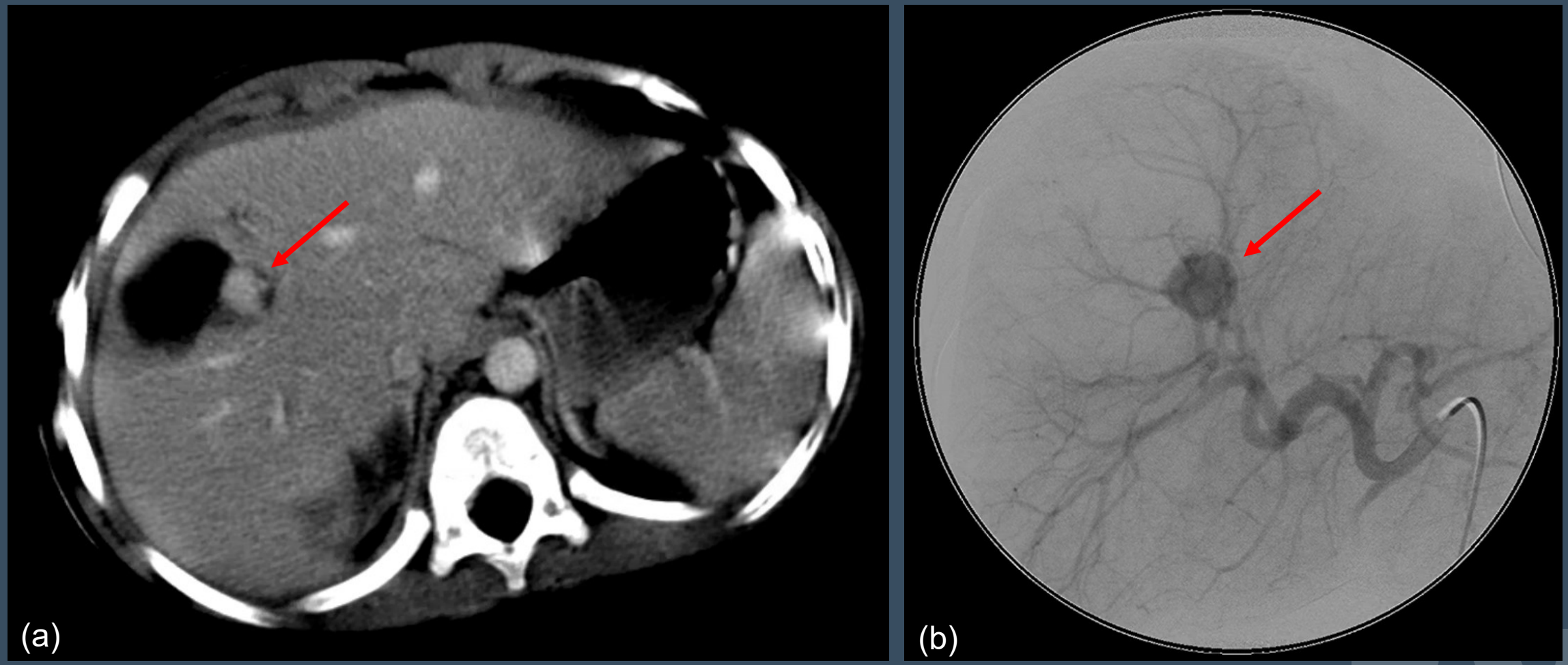


Figure 9: Pediatric patient 2-weeks post MVA with melena and fever. (a) Hyperdense focus in the right hepatic lobe adjacent to a site of healing laceration/hematoma (→). Angiogram (b) with selective common hepatic artery injection confirms the presence of a right hepatic artery branch pseudoaneurysm (→).

CASE 10

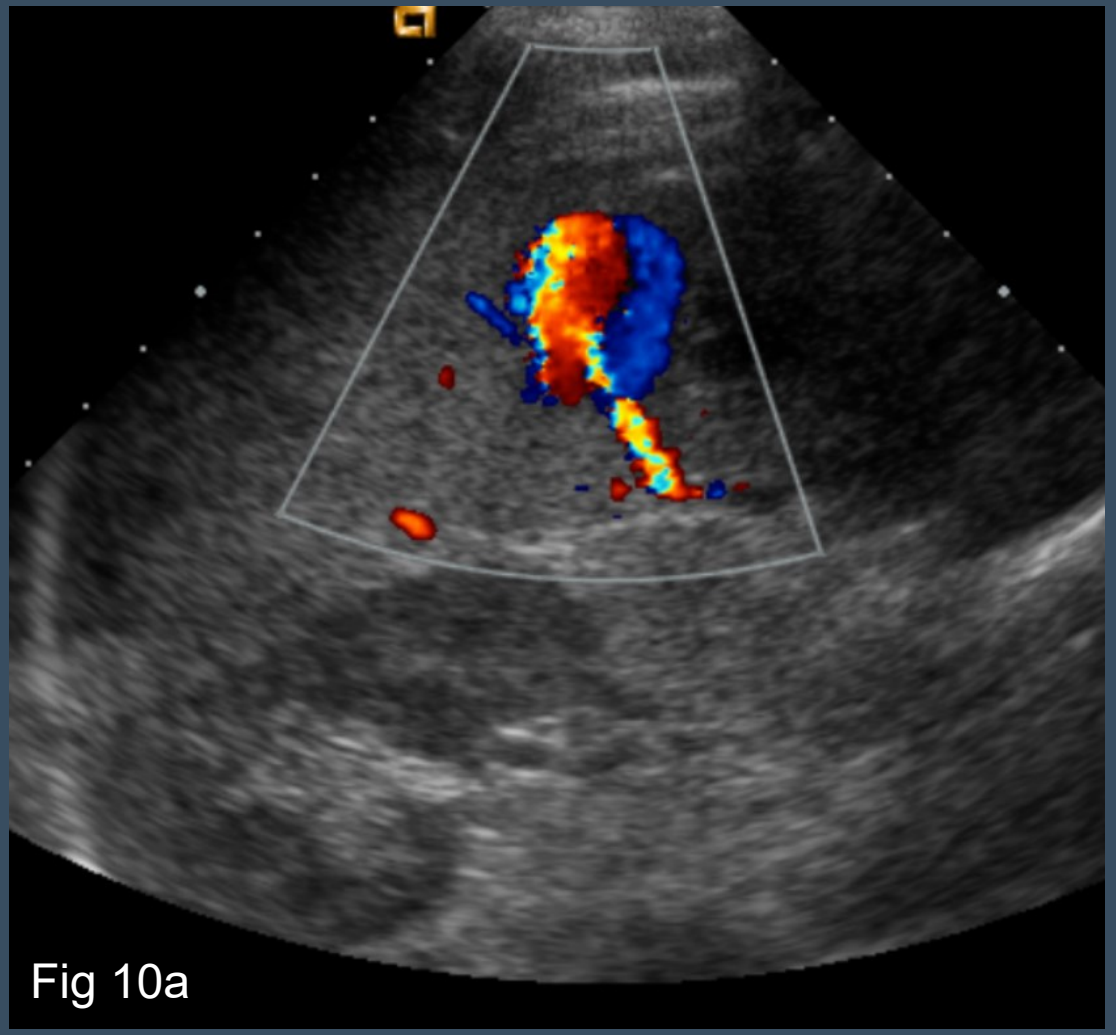


Fig 10a

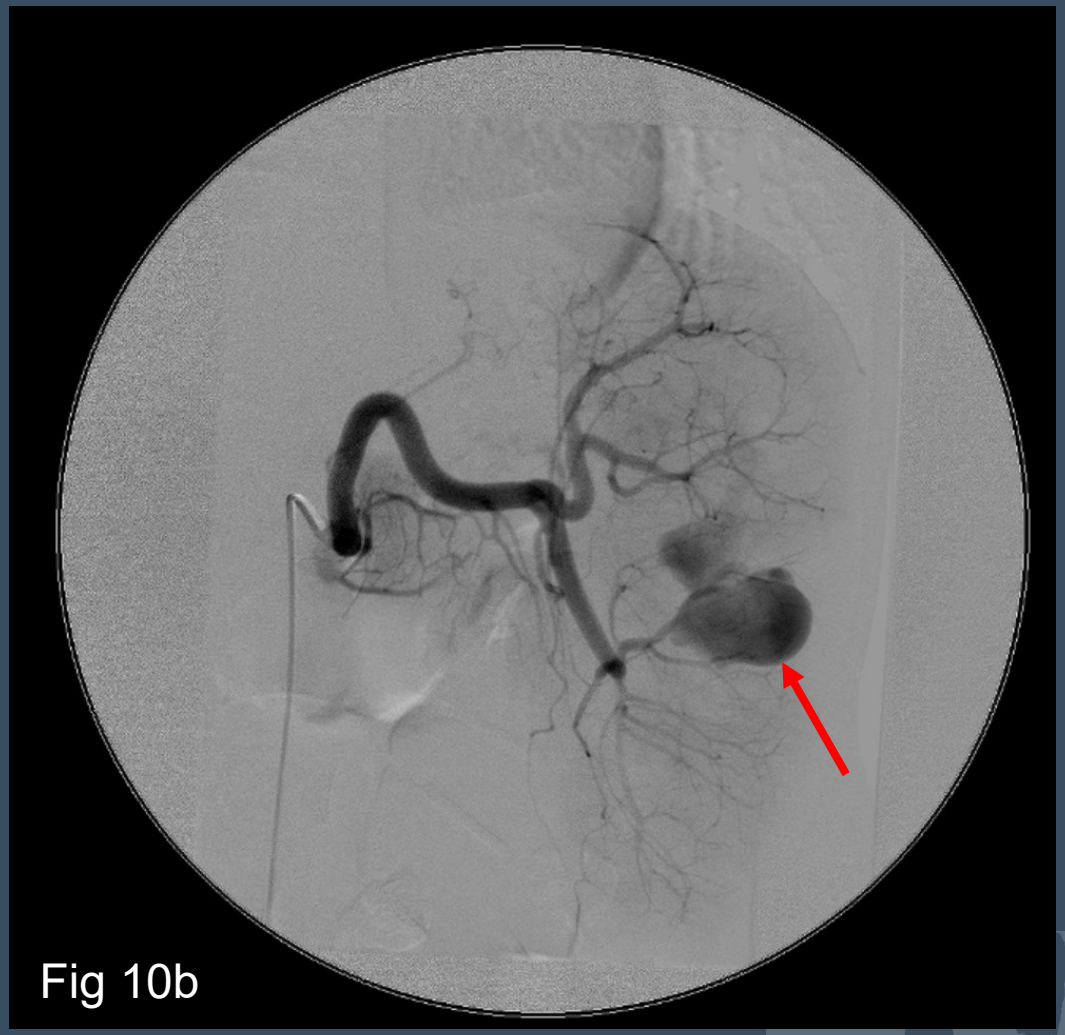


Fig 10b

FIgure10: 10-year-old with left upper quadrant pain 3 weeks after blunt traumatic injury with a splenic laceration. (a) “Yin – yang” sign of bidirectional swirling flow compatible with pseudoaneurysm. Angiogram with selective splenic artery injection (b) confirms the presence of a pseudoaneurysm (→).

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Pseudoaneurysms in Pediatric Patients

- Routine screening not widely accepted practice in North America
- Pseudoaneurysms rare in previous prospective studies with CT follow-up imaging 2-3 months after presentation
- Insufficient evidence to warrant routine post-injury imaging based on GRADE analysis of >69,000 pediatric trauma patients with solid organ injury

- Early imaging follow-up likely capturing natural evolution of the injury
  - Durkin N, et al: Resolution of pseudoaneurysm on 2 week follow-up in 10/11 asymptomatic patients
  - Safavi A, et al: 7/10 splenic pseudeoaneurysms spontaneously thrombosed within 12 days

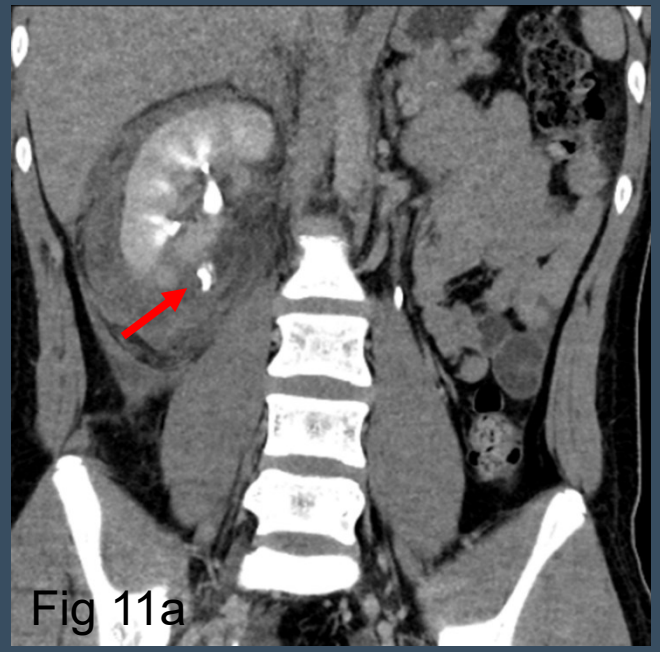


Fig 11a

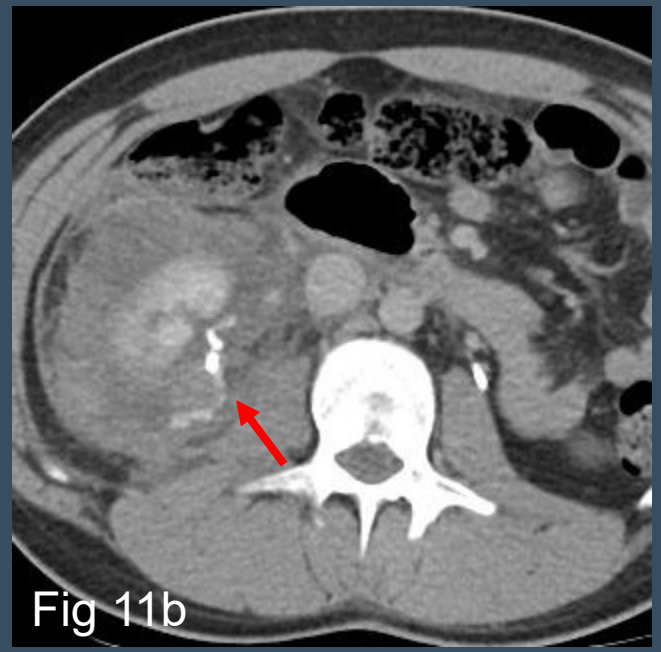


Fig 11b

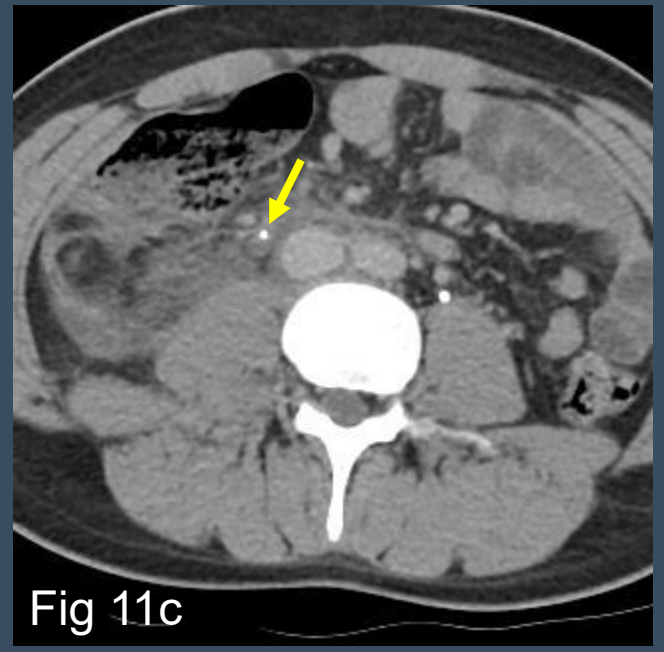


Fig 11c


Fig 11d

Case 11

Figure 11: 14-year-old after skiing accident. Delayed images show grade IV laceration with urinary contrast extravasation from lower pole collecting system (→) (a,b). Contrast present in the distal ureter (→) (c). (d) Ureteral stent placed.

EAST & PTS Blunt Renal Trauma Management Guidelines

In pediatric patients with blunt renal trauma of all grades, should operative management vs nonoperative management be performed to decrease the incidence of renal loss, blood transfusion, urinoma formation, additional procedures, and additional imaging in hemodynamically stable patients?

In pediatric patients with blunt renal trauma of all grades we strongly recommend nonoperative management versus operative management in hemodynamically stable patients.

Predictors of need for intervention:
Arterial contrast extravasation
Collecting system extravasation
Medial renal laceration
Perirenal hematoma >3.5 cm
Lack of contrast in ureter on delayed images

CASE 13

Figure 13: Grade V renal injury. Right kidney laceration with arterial contrast extravasation (→) (a). Subsegmental renal artery extravasation on angiography (b). Post embolization image (c).

Blunt Renal Trauma Guidelines

EAST/PTS

In hemodynamically stable pediatric patients with high-grade AAST renal injuries from blunt trauma (III – V), and ongoing or delayed bleeding, should angioembolization versus surgical intervention be performed to decrease incidence of renal loss, blood transfusion, and complications?

In hemodynamically stable pediatric patients with high-grade (AAST grade III-V) renal injuries from blunt trauma, we strongly recommend angioembolization vs surgical intervention for ongoing or delayed bleeding.

APSA

What is the role of interventional radiology in the acute treatment of solid organ injury?

Arterial embolization is a useful tool in the non-operative management of solid organ injuries in patients with an arterial blush on imaging AND hemodynamic compromise from ongoing bleeding. Prophylactic embolization in hemodynamically stable patients, even if an arterial blush is noted on imaging is NOT indicated.

Society of Interventional Radiology Position Statement on Endovascular Trauma Intervention in the Pediatric Population

4.	Nonoperative management should be the first line treatment in *hemodynamically stable* pediatric patients with blunt abdominal trauma with or without contrast extravasation. (Level of Evidence: C, Strength of Recommendation: Strong)
5.	Implementation of a treatment algorithm in *hemodynamically stable* patients can safely reduce cost of care in pediatric solid organ trauma patients. (Level of Evidence: D, Strength of Recommendation: Moderate)
6.	In children with liver injury, with or without contrast extravasation on CT imaging and *fluctuations in hemodynamic stability*, arterial embolization is an effective means of treatment. (Level of Evidence: C, Strength of Recommendation: Moderate)*
7.	SAE may be a useful adjunct in patients with high grade splenic injuries and fluctuations in hemodynamic stability after a trial of NOM. (Level of Evidence: C; Strength of Recommendation: Moderate)
8.	In patients with high grade splenic injuries and contrast extravasation in the setting of hemodynamic stability, prophylactic SAE is rarely indicated. (Level of Evidence: C; Strength of Recommendation: Strong)
9.	Selective arterial embolization for blunt renal injury in pediatrics may be considered for hemodynamically stable patients with ongoing bleeding to improve renal salvage. (Level of Evidence: D; Strength of Recommendation: Weak)
14.	Angiography and embolization may be considered for the treatment of bleeding complications associated with pediatric pelvic trauma. (Level of Evidence: D; Strength of Recommendation: Weak)

Nonoperative management should be first line in hemodynamically stable pediatric patients

Liver injury + fluctuation in hemodynamic stability +/- contrast extravasation → embolization is effective

High grade splenic injuries + fluctuations in hemodynamic stability after trial of NOM → embolization my be useful

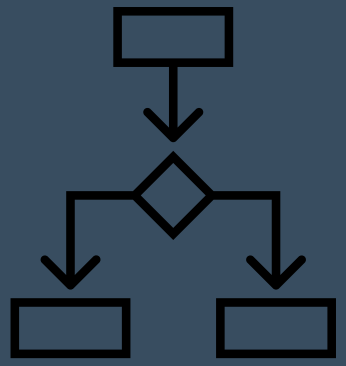
Blunt renal injury + hemodynamically STABLE + ongoing bleeding → embolization may be considered

Bleeding complications associated with pediatric pelvic trauma → consider angiography and embolization

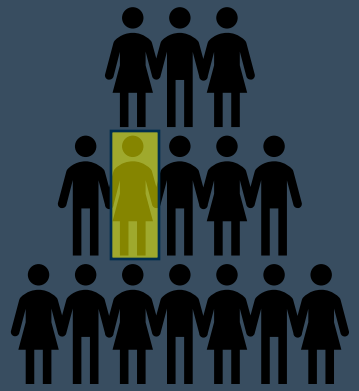
*Single phase acceptable (personal communication with authors)

Annam A, Alexander ES, Cahill AM, Foley D, Green J, Himes EA, Johnson DT, Josephs S, Kulungowski AM, Leonard JC, Nance ML, Patel S, Pezeshkmehr A, Riggle K, Society of Interventional Radiology Position Statement on Endovascular Trauma Intervention in the Pediatric Population, Journal of Vascular and Interventional Radiology (2024), doi: https://doi.org/10.1016/ j.jvir.2024.04.002.

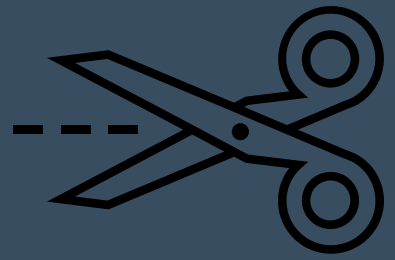
Summary



Know imaging algorithms



Refrain from routine multiphase acquisitions



Identify findings that may indicate need for intervention/surgery

Communicate with IR and surgery

Cleveland Clinic Children's