UPMC | CHILDREN'S HOSPITAL OF PITTSBURGH

Imaging in Pediatric Trauma

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PTSF Annual Meeting
October 19, 2020


Children's
Hospital of Pittsburgh
of UPMC

A case…

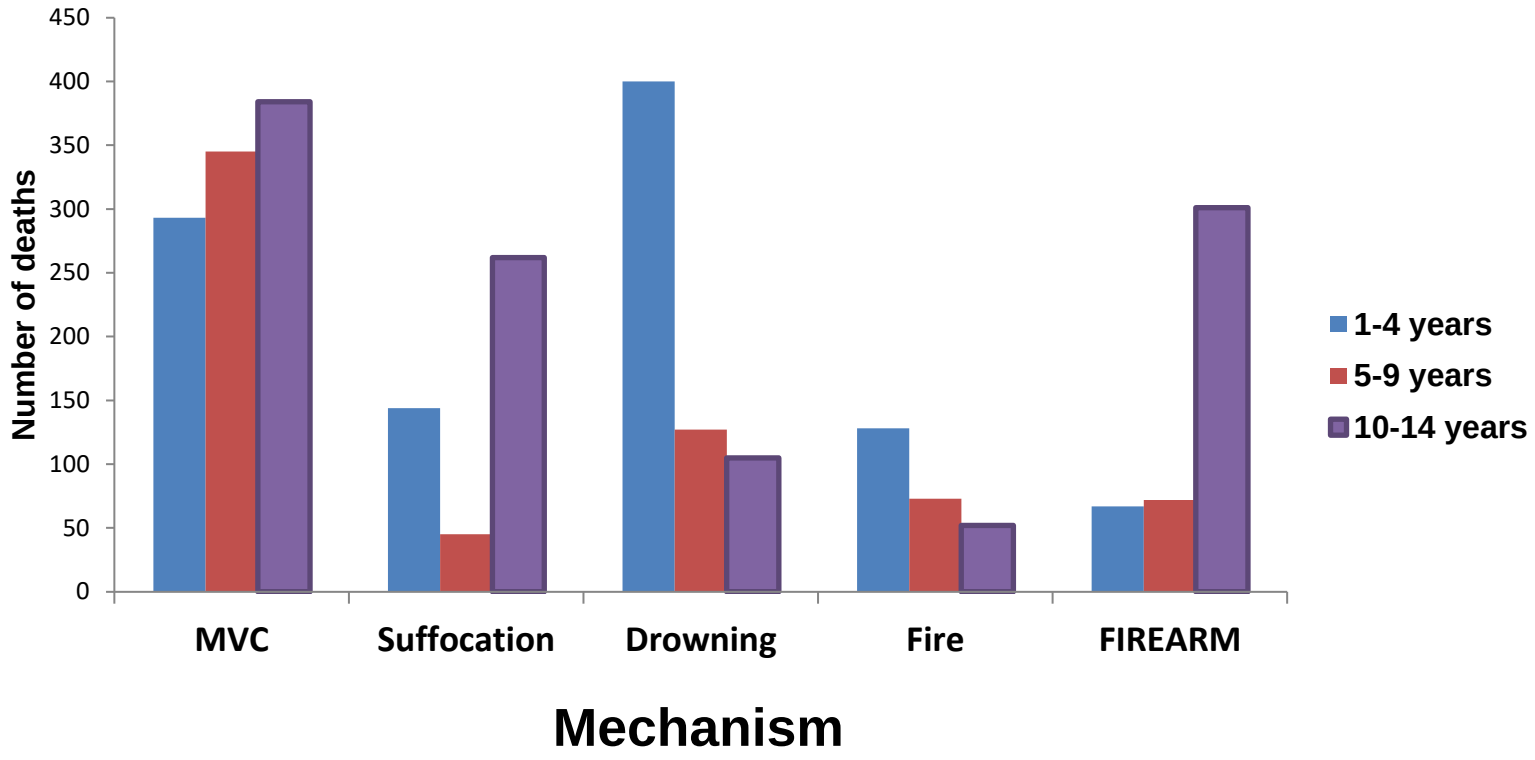
- 8 yo bike crash
- No loss of consciousness
- Complains of shoulder and abdominal pain
- Vitals normal for age
- “handle-bar” mark on abdomen

Leading cause of death, 2010

Rank	<1	1-4	5-9	10-14	15-24
1	Congenital Anomalies 5,107	Unintentional Injury 1,394	Unintentional Injury 758	Unintentional Injury 885	Unintentional Injury 12,341
2	Short Gestation 4,148	Congenital Anomalies 507	Malignant Neoplasms 439	Malignant Neoplasms 477	Homicide 4,678
3	SIDS 2,063	Homicide 385	Congenital Anomalies 163	Suicide 267	Suicide 4,600
4	Maternal Pregnancy Comp. 1,561	Malignant Neoplasms 346	Homicide 111	Homicide 150	Malignant Neoplasms 1,604
5	Unintentional Injury 1,110	Heart Disease 159	Heart Disease 68	Congenital Anomalies 135	Heart Disease 1,028

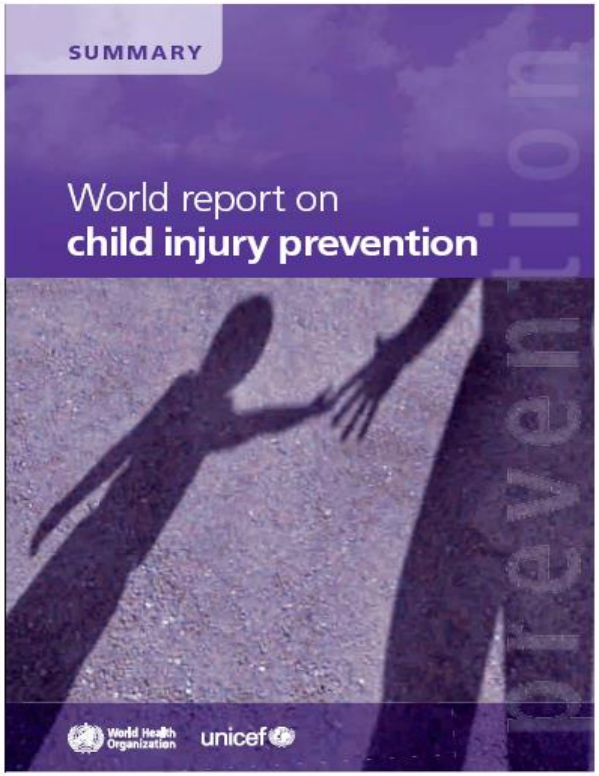
Centers for Disease Control and Prevention
National Center for Injury Prevention and Control

Intentional and unintentional deaths in children ages 1-14 years, 2014



World report on child injury prevention

- World Health Organization and UNICEF
- Published December 10, 2008



- 830,00 die yearly as a result of unintentional injuries
- Road traffic injuries are leading cause of death for children over 9 years
- Road traffic injuries and falls are the main causes of injury-related child disabilities
- Injury prevention initiatives work and are cost effective

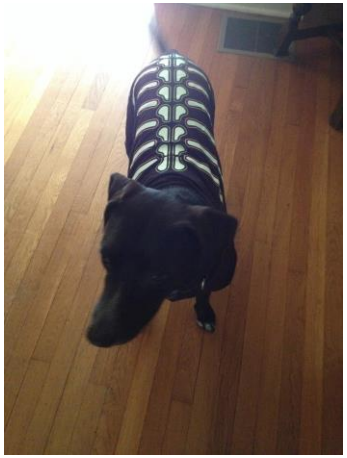
Child injuries have been neglected for many years, and are largely absent from child survival initiatives presently on the global agenda. Through this *World report on child injury prevention*, the World Health Organization, the United Nations Children's Fund and many partners have set out to elevate child injury to a priority for the global public health and development communities. The knowledge and experience of nearly two hundred experts from all continents and various sectors were invaluable in grounding the report in the realities faced in many countries.

Bottom line…

- Injuries are the number 1 killer of kids
- The most frequent mechanisms of injury are low velocity (like falls)
- BUT some are not…motor vehicle crashes, firearms
- And it’s often difficult to tell how severely injured a child is…

Back to the ED…Veterinary Medicine???

- Hard to evaluate
- Non verbal
- Scared
- Distracting injuries
- Wouldn't it be nice to wave a wand and figure out who was injured and who was OK???



CT scans

- Disproportional amount of radiation exposure
  - 15% procedures
  - 75% radiation dose
- Indications and numbers of scans have increased dramatically
  - Over 10% of all CT scans are performed on children
  - Estimated 7 million scans/year
- CT scanning can be performed using a wide range of techniques with variable radiation exposure

What is the risk of diagnostic radiation in the pediatric population?

- Risk assessment based upon computer models and epidemiologic data from survivors of atomic bomb radiation
  - One estimate: 1 fatal cancer/1000 CT scans performed in a young child
- Low dose radiation
- National Academy of Sciences (2005): “the risk of cancer proceeds in a linear fashion at lower doses **without a threshold** and the smallest dose has the potential to cause a small increased risk to humans.”

Population-based studies relating CT scans to cancer in children

- UK-NCI: positive association between CT radiation dose and risk of brain tumors (Pearce, Lancet, 2012)
- Australia: increased risk of brain tumors and leukemia in children exposed to CT (Mathews BMJ, 2013)
- Denmark: exposure to CT radiation increased brain tumor risk (Meulepas, J Natl Cancer Inst, 2019)

MOST OF THIS DATA IS REGARDING **BRAIN** IMAGING AND CHILDREN RECEIVING **MULTIPLE** CT SCANS

Ionizing Radiation…circa, 2000

TABLE 1 Estimated Medical Radiation Doses for a 5-Year Old Child

	mSv	CXR equiv
3-view ankle	0.0015	1/14th
2-view chest	0.02	1
Tx 99m radionuclide gastric emptying	0.06	3
Natural background (Denver)	3.5	175
Head CT	4	200
Chest CT	3	150
Abdomen CT	5	250

Brody, *Pediatrics*, 2007

Rice, *JPS*, 2007

- Children more sensitive to radiation effects than adults
  - Growing organs
  - Long latent period of oncogenic effect (varies with type of cancer)
  - For CT, any given exposure results in a dose that is relatively higher since kid's have a smaller cross-sectional area

Radiation is all around us (its natural)

- Breathing…2.2 mSv/yr
- Breathing in Denver (or the Alps)…3.5 mSv/yr
- Flying…0.03mSV/flight…or one CXR (depending on duration and altitude)

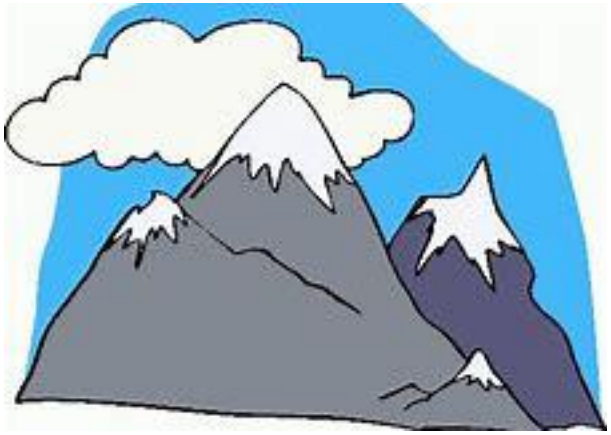


Image Gently

- Alliance of organizations dedicated to “raising awareness in the imaging community of the need to ***adjust*** radiation dose when imaging children”
- Downloadable pediatric dose-adjustment protocols
- Information for parents and physicians
- www.imagegently.org

The Image Gently Alliance

ALARA

(**A**s **L**ow **a**s **R**easonably **A**chievable)

- Is an alternative technology suitable?
  - MRI (often requires sedation)
  - Ultrasound
- CT parameters should be adjusted for pediatric patients
- Limit the number of times (or phases) the child is scanned
  - Arterial/venous phase scans
  - With/without contrast scans
- Limited scans

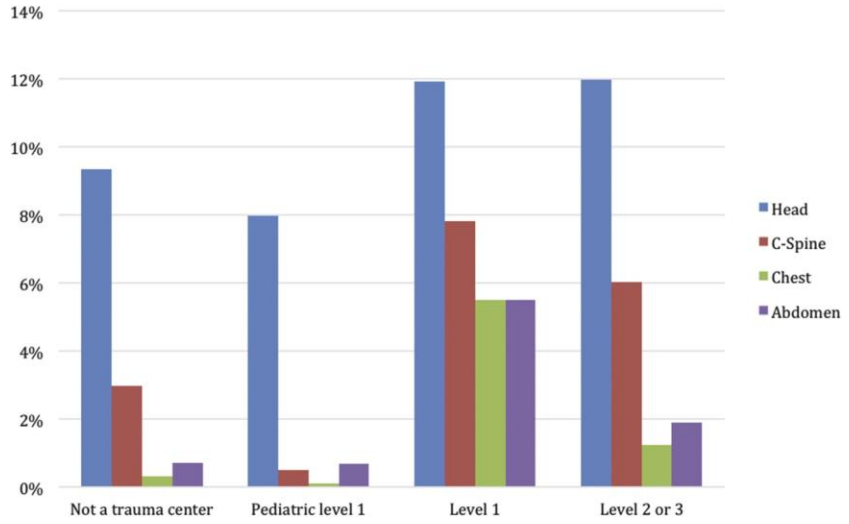
And this isn't just the right thing to do…

- In the US, REIMBURSEMENT for CT tied to compliance with "smart dosing" (in effect 2016)
- NEMA XR-29 standard
  - Standardized reporting of dose
  - Dose check features
  - Automatic exposure control
  - Adult and pediatric protocols

- Up to 15% decrease in medicare reimbursement

1. Reduce the dose (ALARA principles)
2. Only scan kids who NEED scans

Wide variation of imaging practice within the trauma community



Marin, J Pediatr, 2015

- Head CT is the most commonly performed scan
- Pediatric Level 1 Trauma Centers perform the fewest CT scans
- Lower radiation exposure at pediatric centers

	RF	PTC	*p*
Head CT	864 ± 79 (26)	588 ± 78 (28)	<0.01
Chest CT	1,980 ± 287 (23)	768 ± 147 (21)	<0.01
Abdomen/pelvis CT	911 ± 189 (51)	260 ± 41 (67)	<0.01

Brinkman, JTACS, 2015


There are no small
CRASHES.
Respect the power.
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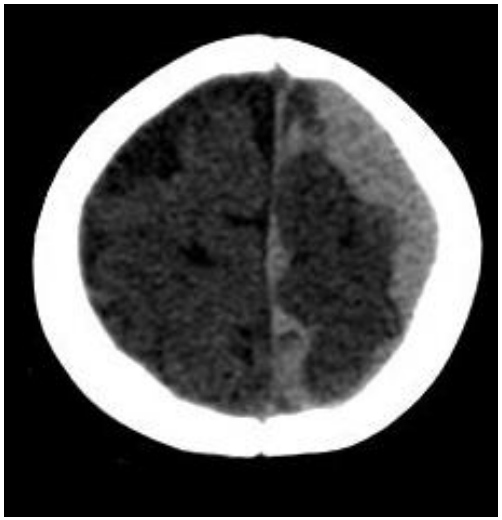
Children's Hospital of Pittsburgh of UPMC
KOHL'S Cares

Traumatic Brain Injury

- Leading cause of death in kids
- Over 3000 deaths/yr in children less than 14 years
- Over 3 million kids suffer concussions
- WHO NEEDS TO BE IMAGED???



Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study

Nathan Kuppermann, James F Holmes, Peter S Dayan, John D Hoyle, Jr, Shireen M Atabaki, Richard Holubkov, Frances M Nadel, David Monroe, Rachel M Stanley, Dominic A Borgialli, Mohamed K Badawy, Jeff E Schunk, Kimberly S Quayle, Prashant Mahajan, Richard Lichenstein, Kathleen A Lillis, Michael G Tunik, Elizabeth S Jacobs, James M Callahan, Marc H Gorelick, Todd F Glass, Lois K Lee, Michael C Bachman, Arthur Cooper, Elizabeth C Powell, Michael J Gerardi, Kraig A Melville, J Paul Muizelaar, David H Wisner, Sally Jo Zuspan, J Michael Dean, Sandra L Wootton-Gorges, for the Pediatric Emergency Care Applied Research Network (PECARN)*

PECARN

Conducting High Priority, High-Quality Research in Pediatric Emergency Care

Lancet 2009: 374: 1160-70

- **Abnormal GCS/mental status**
- Occipital, parietal, temporal hematomas
- Palpable skull fracture, basilar skull fracture
- LOC, severe mechanism of injury, vomiting

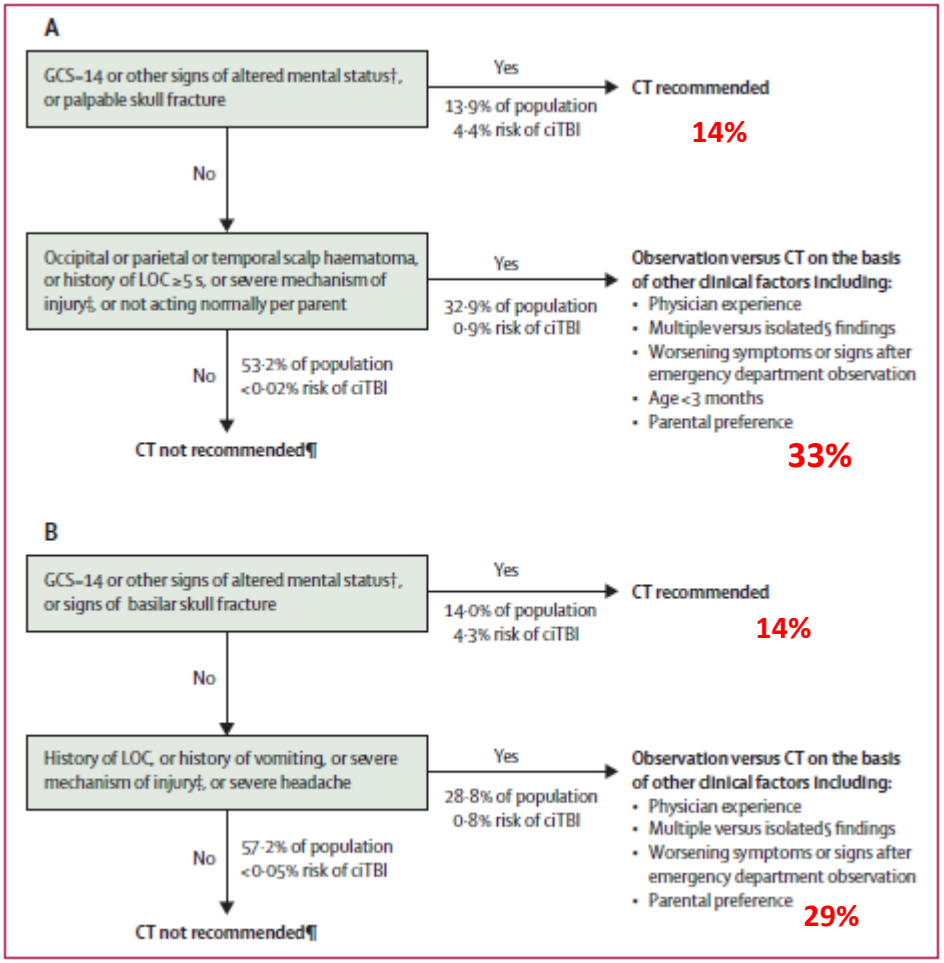
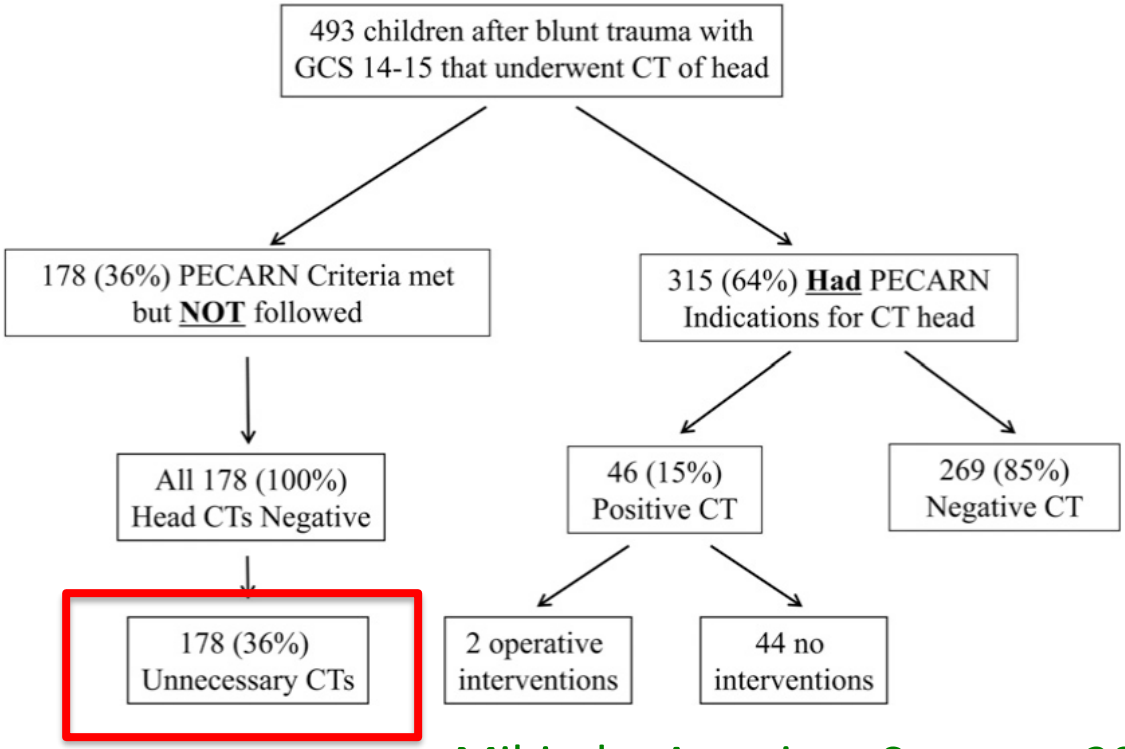


Figure 3: Suggested CT algorithm for children younger than 2 years (A) and for those aged 2 years and older (B) with GCS scores of 14–15 after head trauma*

Example of application of the PECARN head injury guidelines

From the University of Florida, Jacksonville



Mihindu, American Surgeon, 2015

PECARN head injury guidelines

- At least 80+ pubmed citations
- Multiple validation studies, across different populations, mechanisms of injury, countries
- Demonstrated to be cost-effective (Ann Emerg Med, 2015)
- “Augment” clinical decision making
- Identifies a population at very low risk of injury
- NOTE: guidelines do NOT apply to abusive head trauma (no accurate history)

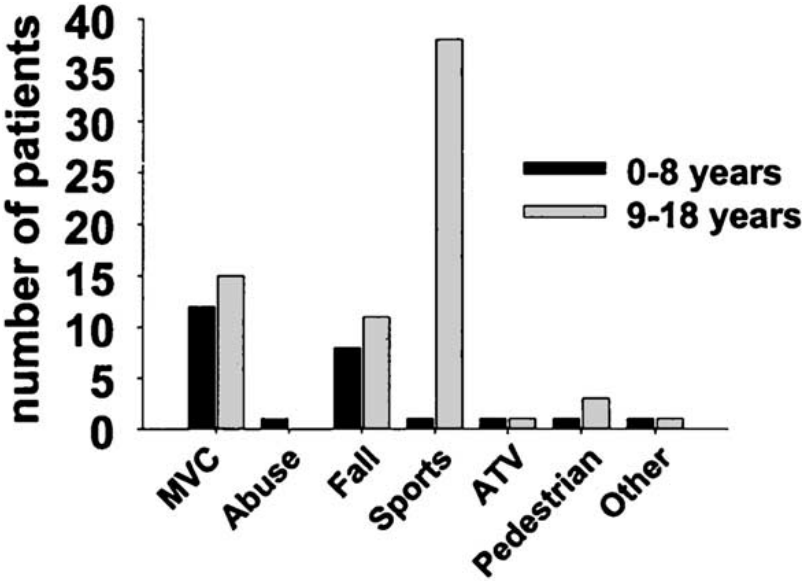
Bottom line

- Decision rule can help determine which kids with a head injury would NOT benefit from CT imaging
- Most kids with concussions don’t require a head CT…BUT do require follow up and guidelines regarding when to return to cognitive and physical activity


Swallowing Button Batteries CAN BE FATAL
Children's Hospital of Pittsburgh of UPMC
chp.edu/kohlssafety
KOHL'S Cares

What about the cervical spine…a few pearls about C-spine injuries in kids

- Large head size provides increased momentum
- Lack of muscle strength
- Fulcrum of cervical mobility: C2-C3-- 60-70% of C-spine fractures in kids <8 years occur at C1 or C2
- What is the role of CT scan in diagnosis



Clinical Clearance of the Cervical Spine in Blunt Trauma Patients Younger Than 3 Years: A Multi-Center Study of the American Association for the Surgery of Trauma

The Journal of **TRAUMA®** *Injury, Infection, and Critical Care* • Volume 67, Number 3, September 2009

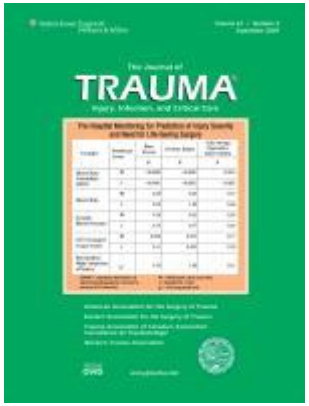


TABLE 1. Use of Cervical Spine Computed Tomography According to the Type of Trauma Center

	CT Performed n (%)	*p*	Relative Risk	95% CI
Level I Pediatric Trauma Center in pediatric hospital (n = 5155)	900 (17.5)			
Level I Pediatric Trauma Center in adult hospital (n = 3174)	1210 (38.0)	<0.0001*	2.2	2.0, 2.4
Level I Adult Trauma Center (n = 5096)	1222 (24.0)	<0.0001*	1.3	1.2, 1.5
Level II Adult Trauma Center (n = 57)	26 (45.6)	<0.0001†	1.9	1.4, 2.5

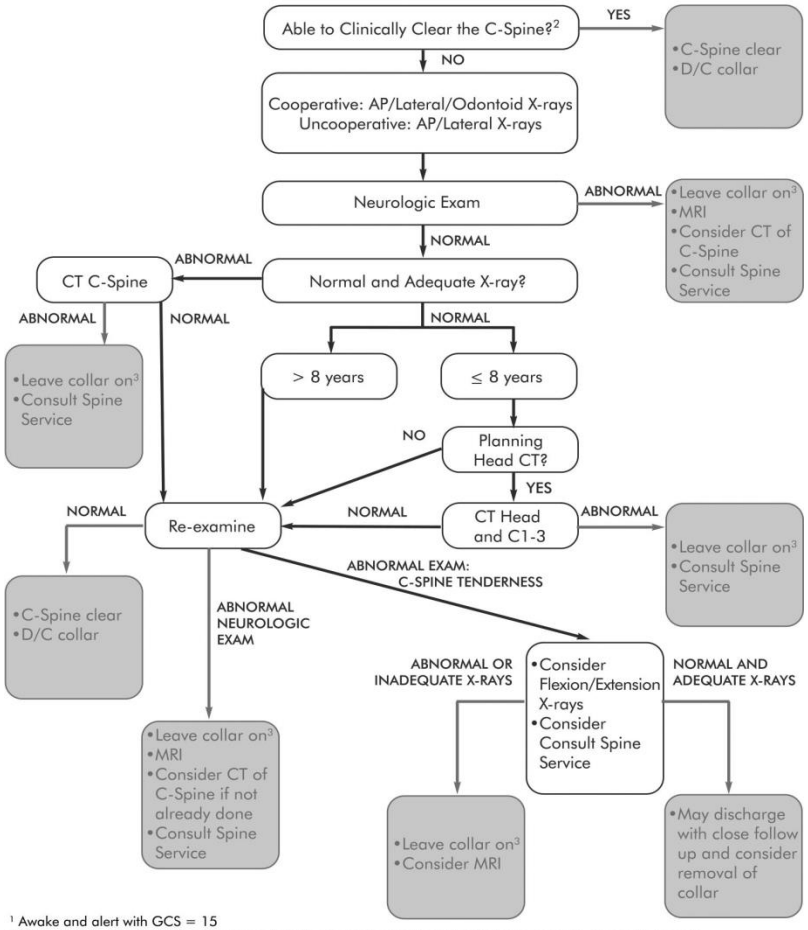
TABLE 3. Independent Predictors of Cervical Spine Injury

Variable	Odds Ratio	95% CI	*p*
GCS ≥14	12.5	5.0–31.6	<0.001
MVC	5.1	2.8–9.0	<0.001
$GCS_{EYE} = 1$	6.9	3.4–14.2	<0.001
Age >2 yr	2.2	1.2–4.0	<0.001

- **Abnormal GCS**
- **Motor vehicle crash**

Trauma Association of Canada Pediatric Subcommittee National Pediatric Cervical Spine Evaluation Pathway: Consensus Guidelines

Trauma Association of Canada (TAC) National Pediatric C-Spine Evaluation Pathway: Reliable[1] Clinical Exam



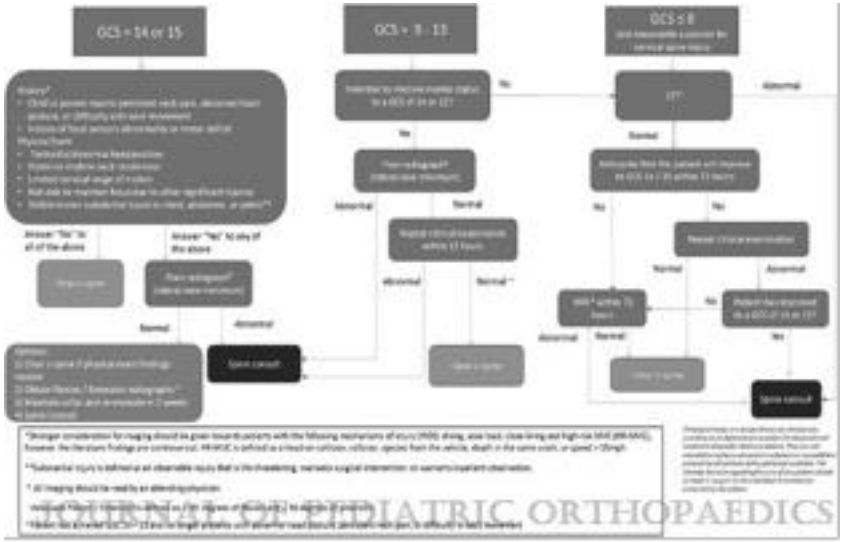
[1] Awake and alert with GCS = 15
[2] Meets NEXUS criteria AND moves head in flexion/extension AND rotate 45 degrees to both sides with no pain.
[3] Change to long term cervical spine collar as soon as appropriate.

- **Clinical clearance**
- **Neurologic examination**
- **Plain films**

A Standardized Protocol for Cervical Spine Evaluation in Children Reduces Imaging Utilization: A Pilot Study of the Pediatric Cervical Spine Clearance Working Group Protocol

Pennell, Christopher MD[*]; Gupta, Jayesh BS[†]; March, Michael BS[†]; Arthur, L. Grier MD[*,†]; Lindholm, Erika MD[*]; Herman, Martin MD[†,‡]; Grewal, Harsh MD[*,†]

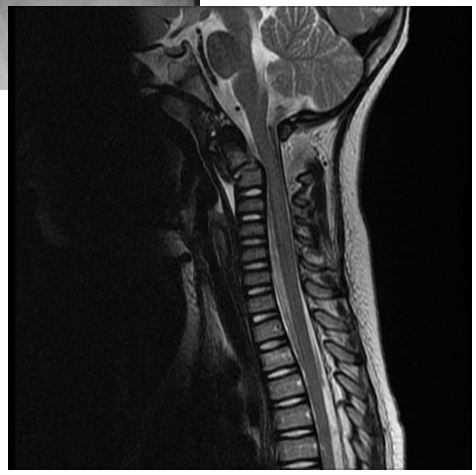
September, 2020



	Pre-SP (n = 248)	Post-SP (n = 111)	P
No imaging (%)	15.3	43.2	< 0.001
X-ray (%)	70.2	55.0	0.005
Computed tomography (%)	14.5	5.4	0.013
Magnetic resonance image (%)	6.9	7.2	0.904

SP indicates standardized protocol.

What about plain films???



Reduction of radiation exposure in pediatric patients with trauma: cephalic stabilization improves adequacy of lateral cervical spine radiographs

Afif N. Kulaylat [a], Joshua G. Tice [b], Moran Levin [f], Allen R. Kunselman [c], Sosamma T. Methratta [d], Robert E. Cilley [e,*]

Journal of Pediatric Surgery (2012) 47, 984–990

Downward traction on the arms and manual stabilization of the head significantly increases the ability to obtain adequate lateral c-spine images

Finally, do we really need collars at all???

- Growing body of literature suggesting that routine cervical spine immobilization is not required
- Sundstrom, J Neurotrauma, 2014
  - Existing evidence for using collars is weak
  - Under-appreciation of potential adverse effects of cervical collars
    - Delay in definitive care
    - Difficulty with intubation
    - Elevation of intracranial pressure (jugular venous compression)
    - Pressure ulcers

Bottom line…

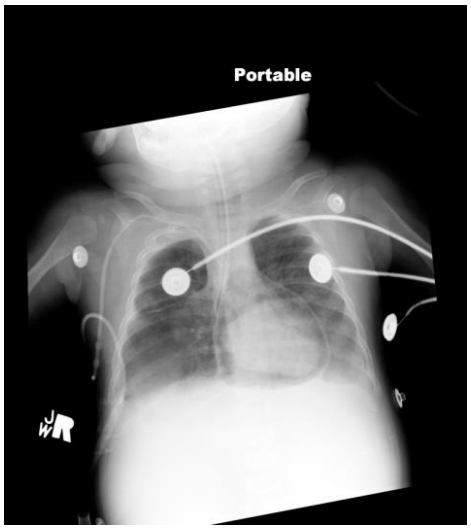
- Not all kids require imaging to clear their necks
- Plain films are a useful screening tool
- Physical exam, mechanism of injury and altered GCS are important elements for decision making
- In conjunction with our EMS colleagues, we should critically examine our practices surrounding spinal immobilization

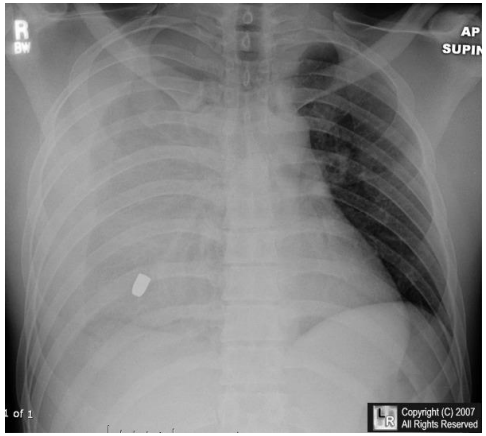
DON'T DRIVE DISTRACTED.

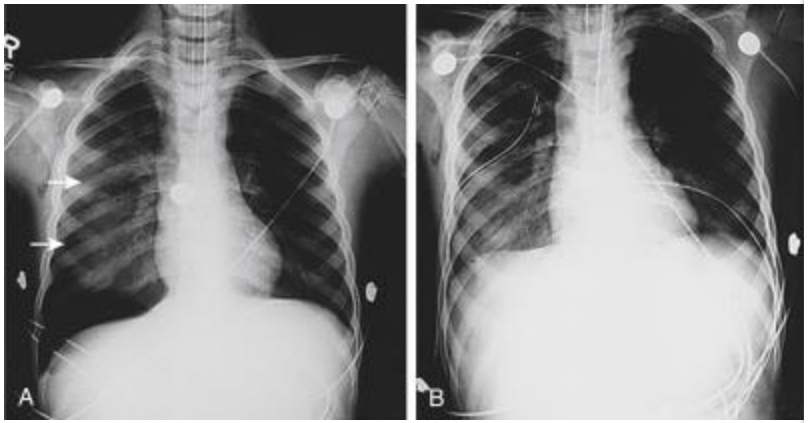
Halos Only Look Good On Angels

Chest

- Life-threatening intrathoracic injuries are uncommon in children
- Mechanism—low velocity
- Chest wall/mediastinum are more pliable







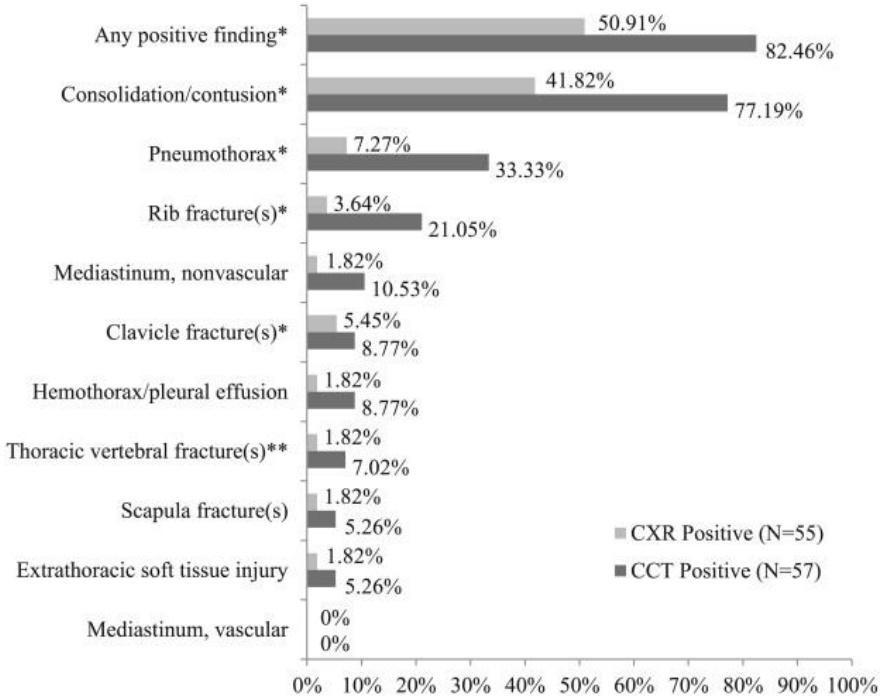


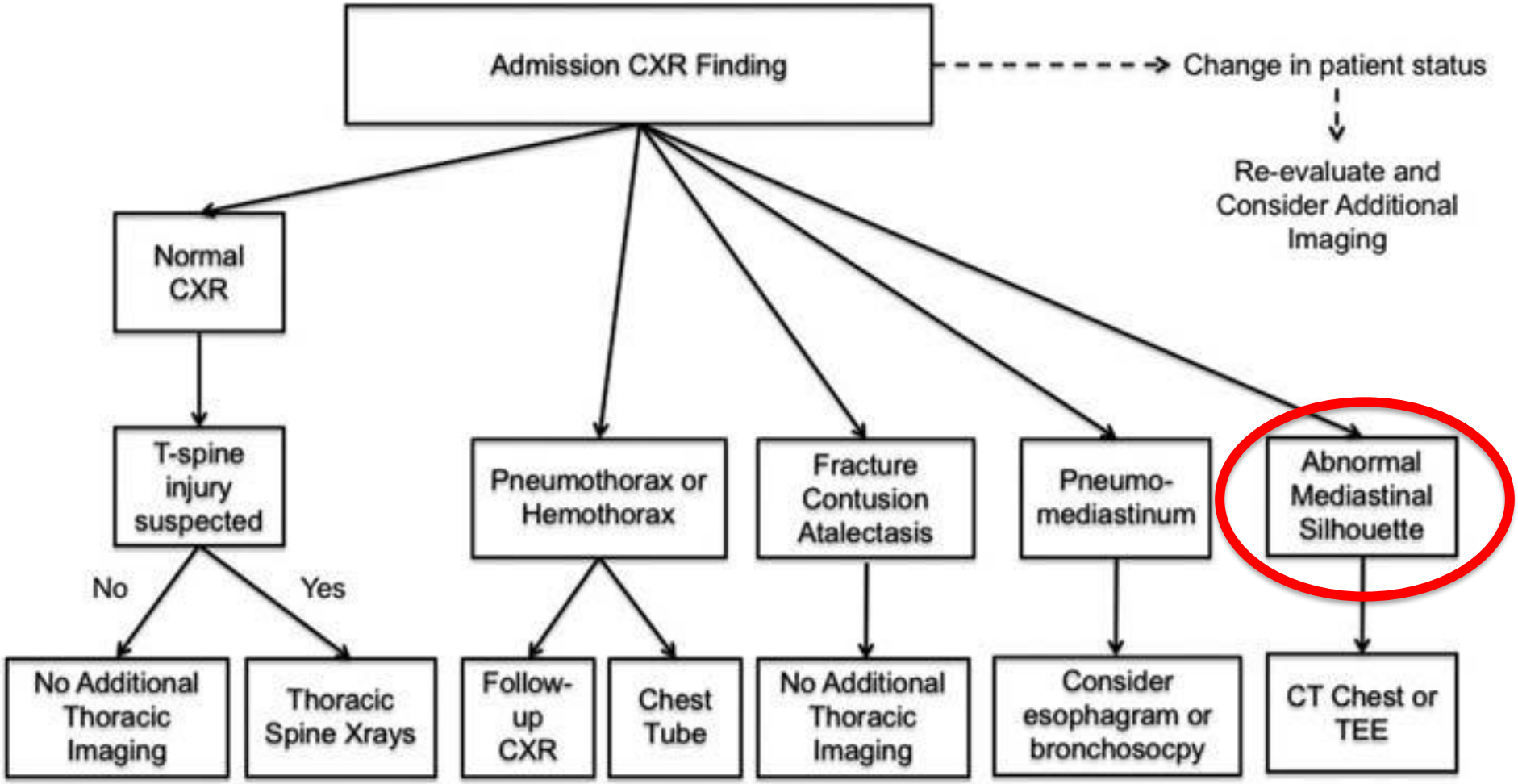
Fig. 2. Injuries identified on CCT and CXR. *P < 0.05. ∗∗Thoracic vertebral fracture identified on thoracic spine radiographs, not on CXR. None of the remaining children with thoracic vertebral fractures were imaged with thoracic spine radiographs.

Courtenay M. Holscher, Leonard W. Faulk, Ernest E. Moore, Clay Cothren Burlew, Hunter B. Moore, Camille L. Stewart, Fredric M. Pieracci, Carlton C. Barnett, Denis D. Bensard

Chest computed tomography imaging for blunt pediatric trauma: not worth the radiation risk1

Journal of Surgical Research, Volume 184, Issue 1, 2013, 352–357

http://dx.doi.org/10.1016/j.jss.2013.04.044



Note: mean age in study was 7 years.

Golden, J Trauma Acute Care Surg, 2016


Infants sleep ALONE,
on their BACK,
in a CRIB,
so parents can sleep tight.
www.chp.edu/kohlssafety
Children's Hospital of Pittsburgh of UPMC
KOHL'S Cares

Evaluation of blunt abdominal trauma in children

- Low incidence (6-13% of injured kids)

- History and physical exam
- Laboratory studies: CBC, LFT's, amylase, lipase, T&C
- Imaging:
  - Plain films-minimal utility
  - Ultrasound (FAST)
  - Computed Tomography
- Diagnostic Laparoscopy

Physical Exam

- Abnormal physical exam has the highest predictive value for the presence of an intra-abdominal injury
- Abdominal tenderness, abrasions, contusions
- Seat belt or handlebar marks
- Other injuries (long bone fractures, particularly femur fractures)

Laboratory Studies

- No panel of laboratory studies is **diagnostic** of intra-abdominal injury
- ALT>131, AST>200, UA >5 RBC/HPF performed best in regression models *(Holmes, 1999, 2002, 2010; Cotton, 2004; Flood, 2006)*
- AST>200 is part of a validated decision rule *(Streck, 2017, Arbra, 2018)*
- May be most useful in determining who requires further imaging

What about ultrasound???

- Point of care ultrasound ("FAST")
  - About 50% of kids with documented injury by CT have a positive intra-abdominal FAST
  - Low sensitivity and poor positive predictive value. (Benya, AJR, 2000; Coley, J Trauma, 2000; Emery, J Pediatr Surg, 2001, Scaife, 2013)
  - Alternatively, a positive FAST is strongly suggestive of intra-abdominal injury, but not necessarily the need for surgery (Fox, 2011)
- The presence of free fluid alone does not necessitate operative intervention in stable children
- And lack of free fluid does not necessarily mean NO injury
- Possible utility in combination with laboratory studies to decrease the number of CT scans performed

“FAST is not always better…”

- Single center, randomized trial of 950 hemodynamically stable children with blunt torso trauma
- Trauma bay ultrasound did not decrease the number of abdominal CT scans, ED length of stay, charges, or incidence of missed injuries
- “These findings do not support the use of FAST in this setting”

Holmes, JAMA, 2017

FAST as a screening study…

(McGaha, JTACS, 2019)

- Prospective study of 10 Level 1 Pediatric Trauma Centers
- 1008 patients, <18yrs; 292 with FAST exam
- Endpoint: failure of non-operative management of blunt liver or spleen injury
- Negative predictive value: 97%
- Positive predictive value: 13%
- "…may be useful clinically in determining which patients are not at risk of failure of non-operative management…"

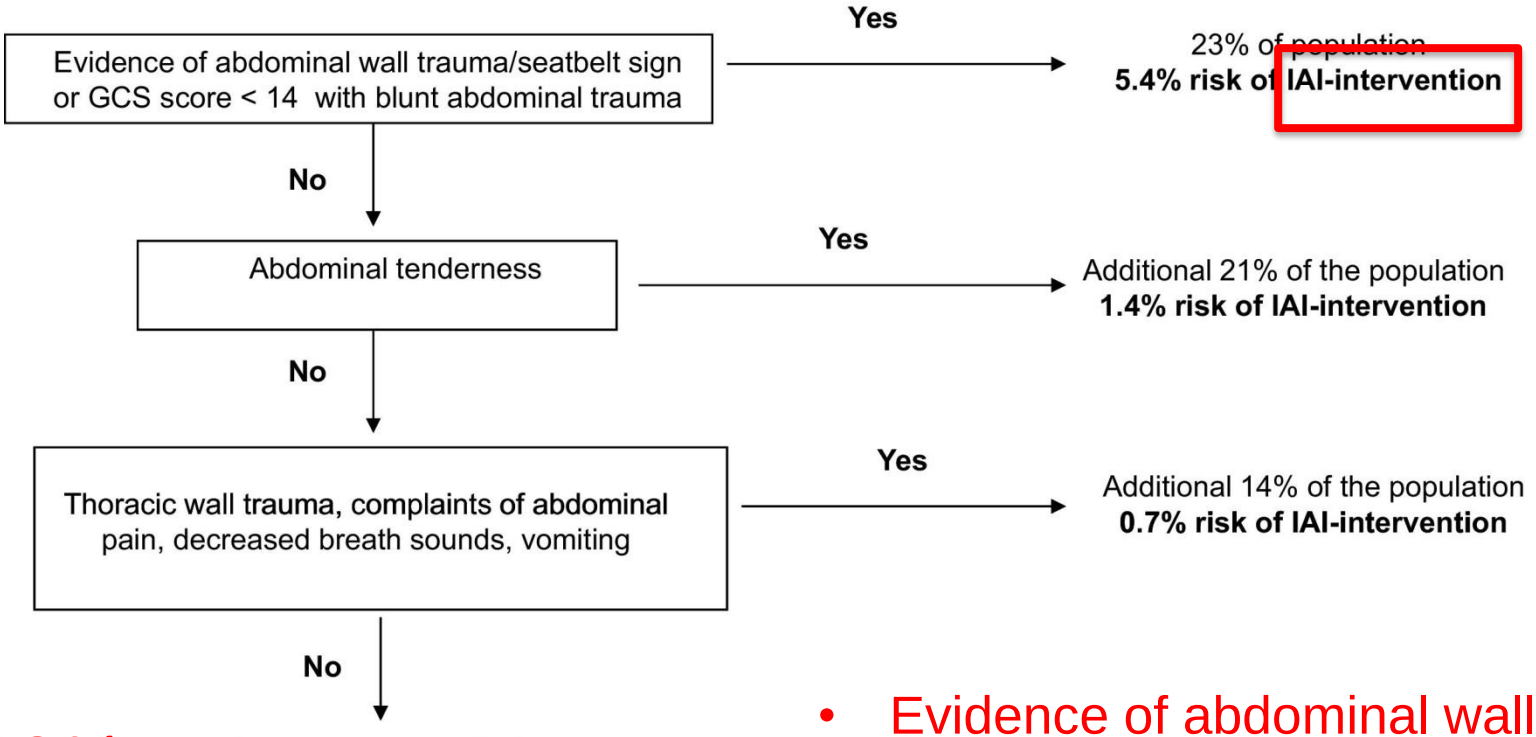
CT scan

- Provides diagnostic information for the hemodynamically stable child with evidence of intraabdominal injury
- Excellent for the evaluation of solid organ injury and retroperitoneal injuries
- Intestinal injuries more difficult to detect
  - Free fluid without solid organ injury
  - Bowel wall thickening
  - Multiple fluid filled loops of bowel
  - Free intraperitoneal air/contrast extravasation

Kurchubasche, Arch Surg, 1997

Identifying Children at Very Low Risk of Clinically Important Blunt Abdominal Injuries

Annals of Emergency Medicine 2013, 62:2



42%

Not evaluated:

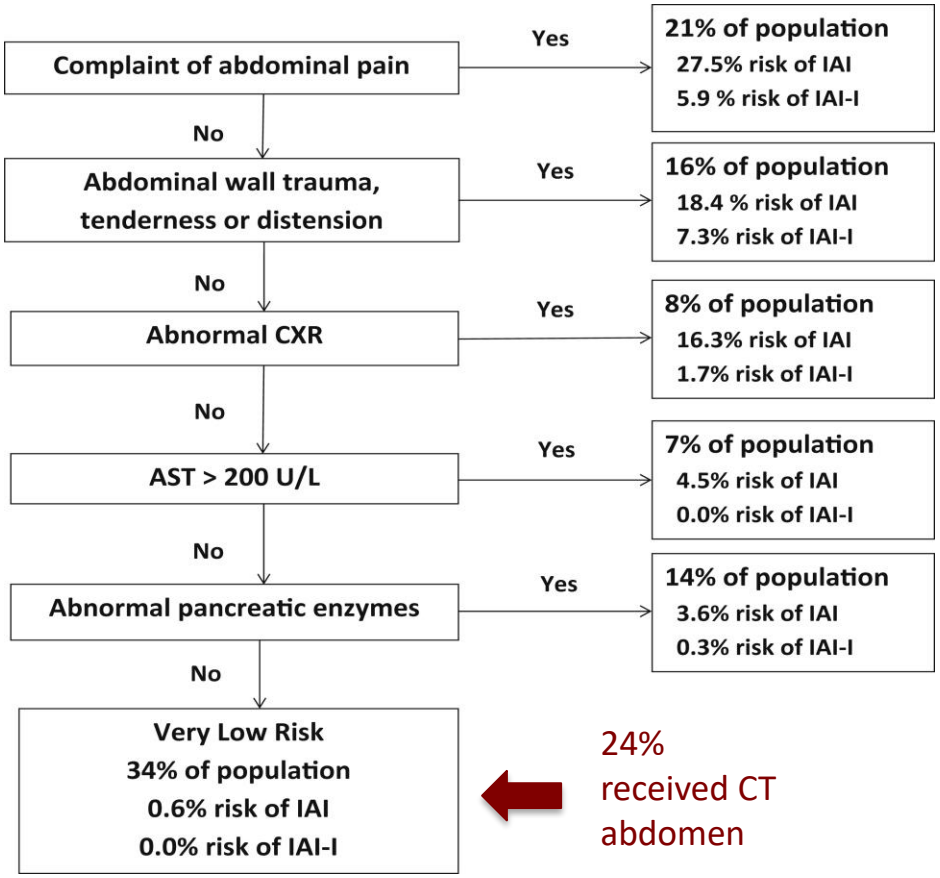
- Ultrasound
- Laboratory studies
- UA

- Evidence of abdominal wall trauma/seatbelt sign
- GCS<14 with abdominal trauma
- Abdominal tenderness
- Chest wall trauma, pain, vomiting

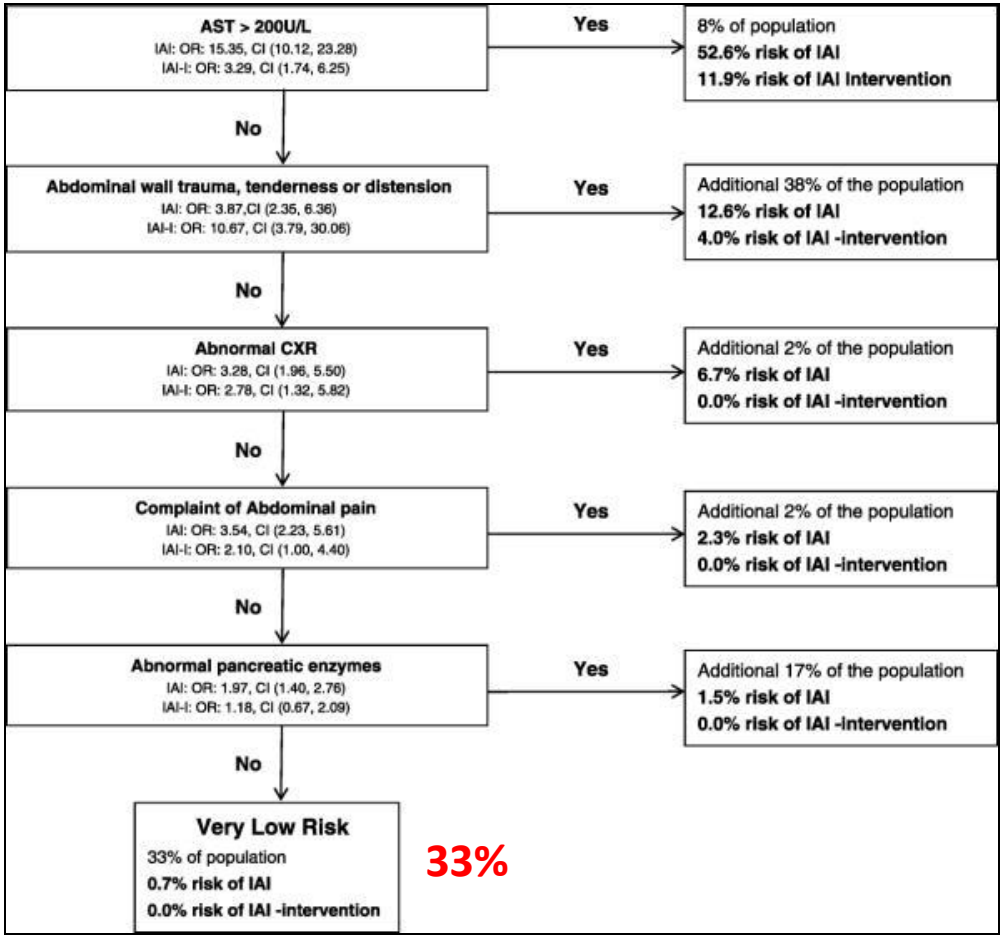
Identifying Children at Very Low Risk for Blunt Intra-Abdominal Injury in Whom CT of the Abdomen Can Be Avoided Safely

Streck, JACS, 2017

- Prospective study; 14 sites
- 10% rate of abdominal injury
- Intervention defined as: OR, IR, transfusion or death
- Developed a prediction rule
  - Abdominal pain
  - Signs of abdominal trauma
  - Abnormal CXR
  - AST>200 U/L
  - Abnormal pancreatic enzymes
- Negative predictive value: 99.4%; 100% for injury requiring intervention



Validation study



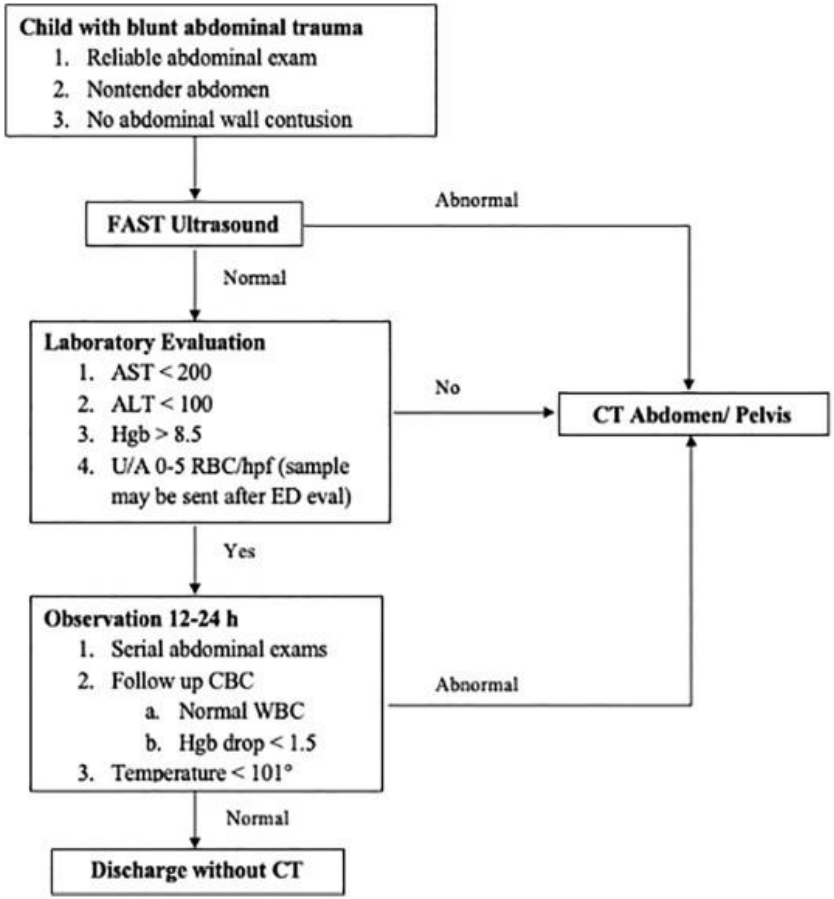
- PECARN public use data-set (<16 years)
- Negative predictive value 99.3% for ANY intra-abdominal injury
- 46.8% of “very low risk” patients underwent CT

Arbra, J Trauma Acute Care Surg, 2018

Evaluation of an evidence-based guideline to reduce CT use in the assessment of blunt pediatric abdominal trauma

Michaela Gaffley 1 , Lucas P Neff 2 , Leah M Sieren 2 , Kristen A Zeller 2 , Thomas Pranikoff 2 , Tammy Rush 2 , John K Petty

J Pediatr Surg, 2020

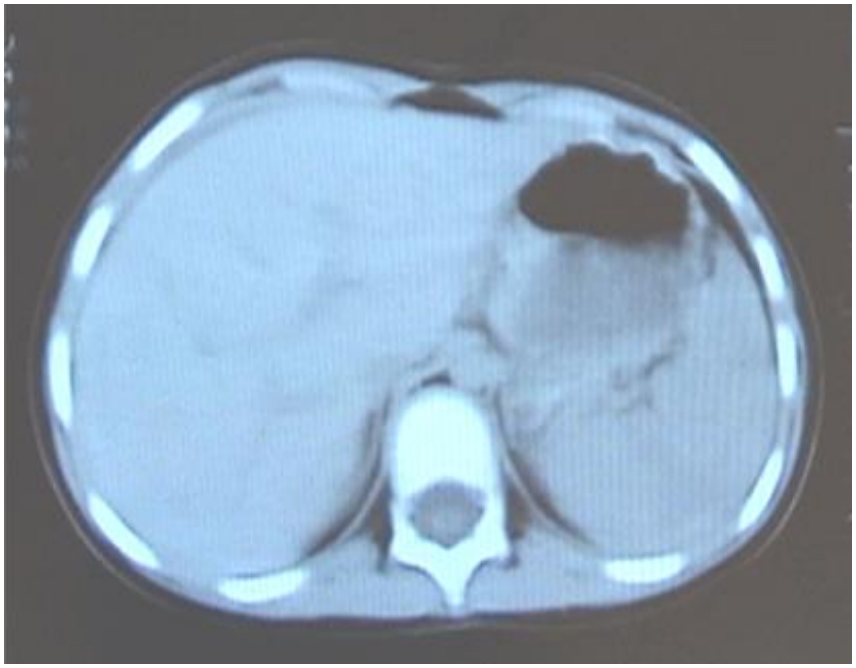


	Preprotocol	Postprotocol	P-value
N	460	538	
CT scan rate	222 (48.3%)	198 (36.85)	0.0003
LOS	2 (1-3)	2 (1-3)	0.65
intervention	6 (1.3%)	13 (2.4%)	0.2
Discharge to home	453 (98.5%)	528 (98.1%)	0.72

A word about endpoints…

- Is the endpoint the presence of
  - Any injury?
  - An injury that resulted in a trip to the OR?
  - An injury that required blood transfusion?
- Should be when the results of the study change clinical management
- In children, one of the biggest concerns is when to return to play

Splenic Injury?

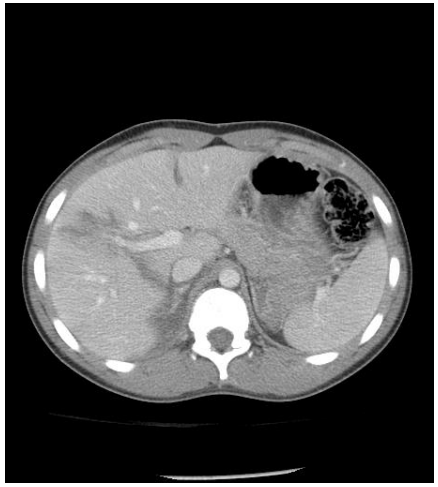


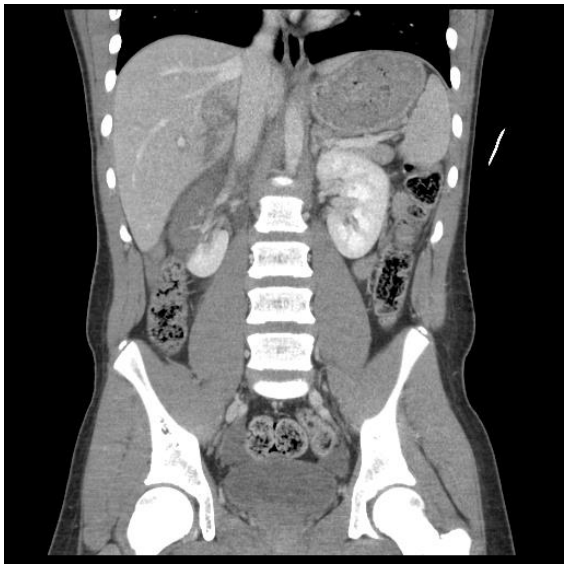
Finally…

- CT provides valuable information regarding areas that are difficult to evaluate using ultrasound:
  - Retro-peritoneum
  - Kidneys
  - Pancreas
  - Spine
  - Abdominal vessels

Back to the original case…

- 8 yo bike crash
- No loss of consciousness
- Complains of shoulder and abdominal pain
- Vitals normal for age
- “handle-bar” mark on abdomen





- Since the child had a normal mental status, no CT of the head was performed
- He had a normal PE of the neck, and the collar was cleared
- CXR was normal
- FAST was negative for free fluid
- Because of the presence of the handlebar mark and abdominal tenderness, CT scan of abdomen and pelvis was obtained with IV contrast
- Shoulder films were negative

Another case…

- 16 yo restrained front seat passenger MVC
- Short loss of consciousness, GCS 15 in the ED
- HR 90; SBP 120
- c/o abdominal pain
- On PE: abdomen tender, seat belt mark
- IMAGING??

- Transected proximal jejunum
- Localized infrarenal aortic disruption
- L2 Chance fracture

Summary

- CT is a POWERFUL *diagnostic* tool
- It comes with some cost
- Imaging protocols should be adjusted for pediatric patients
- For an individual patient, risk can be decreased by following best practices (ALARA)
- For children in general, tools are available to assist in determining who will benefit the most from a CT
- Clinical pathways are an effective means to limit unnecessary imaging
- BUT the information provided by CT can be life-saving

???