Notable Grand Rounds
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Michael & Marian Ilitch
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MISSED INJURIES IN PEDIATRIC TRAUMA AND HOW TO AVOID THEM

April 26,2023

About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That “Mortality and Morbidity” conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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Missed Injuries in Pediatric Trauma and How To Avoid Them

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This paper is derived from Dr. Groner's speech for the annual Jack Hertzler Lecture held under the auspices of the Children's Hospital of Michigan Foundation and delivered at Surgical Grand Rounds of the Wayne State University School of Medicine on April 26,2023

Objectives

The objectives of this paper are:

1. To help surgeons recognize injuries or conditions that are difficult to detect in pediatric trauma;
2. To describe two types of bias that may increase the risk of missed injuries; and
3. To describe a standardized approach to pediatric trauma that will reduce missed injuries.

It discusses key issues concerning the primary, secondary, and tertiary surveys of the patient, interspersed with case studies to illustrate issues concerning symptoms missed during them.

Primary Survey (Modified)

Dr. Daniel J. Scherzer, a physician in the emergency department at my institution, has usefully modified the traditional ABCDE primary survey protocol taught in Advanced Trauma Life Support (ATLS) to include *alertness*. The modified protocol is thus:

A. **Alertness** and Airway
B. Breathing
C. Circulation
D. Disability
E. Exposure

Alertness

Alertness is important to monitor not just in trauma patients but also in pediatric acute

care surgical patients. Note that *Alertness* comes before *Airway*, the reason being that a pediatric patient with a suspected ruptured appendix or other major illness who is not alert is clearly worrisome and perhaps may be even in septic shock. Children are generally not intoxicated or impaired by drugs. If they are not alert, it is more likely that they are seriously ill.

Using the SALT (**s**ort, **a**ssess, **l**ife-saving interventions, **t**reatment and/or **t**ransport) mass-casualty triage system, in an incident with multiple casualties and many responders, lightly injured (alert) ambulatory patients are the least seriously injured and lowest priority and assigned to any medical students present; patients who are immobilized but alert enough to respond in some manner are medium priority and assigned to residents present; and the rest—those who are most in need—are assigned to the attendings and fellows present for immediate evaluation.

The SALT system does not involve checking pulses and other vital signs. It is based purely on *alertness*, and it works also for individual pediatric patients—a child who is not alert is a cause for concern.

An alert child responds to verbal stimuli, Is oriented to the environment (person, place) and can talk and answer questions, even if scared or crying. An alert infant tracks you with its eyes, responds to sounds and touch, and is usually consolable if crying. Most children find the trauma room environment terrifying, so a child who does not respond may be in shock, hypoxic, or have a severe brain injury.

The key point is to beware the somnolent child!

Alertness Case Study

A teenaged African-American female crashed her bicycle while riding down a hill. She was not wearing a helmet and struck her head on concrete, but was able to ride home. She complained of headache and vomited several times, so her mother called 911.

EMS reported that the child was combative en route to the ED, where she continued to be uncooperative and restless—yelling and cursing and refusing to answer questions. Her electronic health record showed she had been to the hospital for several behavioral health visits—a fact that caused particular concern. Her heart rate = 62, BP = 138/85, and RR = 10.

Upon examination, the primary ABCDE assessment was:

A. **Alertness**: cursing, won't respond to questions; **Airway**: intact
B. **Breathing**: equal breath sounds
C. **Circulation**: pulses intact
D. **Disability**: does not follow commands
E. **Exposure**: abrasion on right side of head, over her right temple.

A secondary survey found the same and in addition noted that her eyes would open only to painful stimuli and she did not localize painful stimuli. The patient's Glasgow Coma Score (GCS) was 2 + 3 + 3 (eye/verbal/motor, respectively) for a total of 8. A GCS score =< 8 indicates the need for immediate intubation. (GCS is a rough and ready measures of eye opening, verbal response, and motor response—**Fig 1**(next page; see **Fig. 2** on page 4 for the infant GCS scale, which is a little less reliable and a little harder to do)

Eye opening

Criterion	Observed	Rating	Score
Open before stimulus	✔	Spontaneous	4
After spoken or shouted request	✔	To sound	3
After finger tip stimulus	✔	To pressure	2
No opening at any time, no interfering factor	✔	None	1

Verbal response

Criterion	Observed	Rating	Score
Correctly gives name, place and date	✔	Orientated	5
Not orientated but communication coherently	✔	Confused	4
Intelligible single words	✔	Words	3
Only moans / groans	✔	Sounds	2
No audible response, no interfering factor	✔	None	1

Criterion	Observed	Rating	Score
Obey 2-part request	✔	Obeys commands	6
Brings hand above clavicle to stimulus on head neck	✔	Localising	5
Bends arm at elbow rapidly but features not predominantly abnormal	✔	Normal flexion	4
Bends arm at elbow, features clearly predominantly abnormal	✔	Abnormal flexion	3
Extends arm at elbow	✔	Extension	2
No movement in arms / legs, no interfering factor	✔	None	1
Paralysed or other limiting factor	✔	Non testable	NT

Fig. 1. Glasgow Coma Score

GCS resources
Watch the videos:
http://www.glasgowcomascale.org
Note: You must interact with the patient to calculate GCS!
"When all else fails, examine the patient!

It is barely detectable in **Fig. 3** but crystal clear in **Fig. 4** that this patient had a classic epidural hematoma, yet it was missed. When the neurosurgeon arrived he deduced instantly that the patient likely had a serious problem from hitting her head, having a lucid interval followed by a decrease in neurologic status. She was taken to the OR, where the hematoma was drained. The patient recovered.

But why was the epidural hematoma missed in the first place? It was a failure of pattern recognition: The importance of injury mechanism and symptoms were not recognized because our brains are wired to miss injuries. In short, we are easily *biased*.

There are two types of bias: Confirmation bias and implicit bias

Confirmation Bias

People tend to favor information that reinforces the things they already think or believe and to reject information that they do not believe. We betray confirmation bias by:

Eye Opening	Open spontaneously	+4
	Open to verbal stimuli	+3
	Open to pain only	+2
	No response	+1
Verbal Response	Coos, babbles	+5
	Irritable cries	+4
	Cries in response to pain	+3
	Moans in response to pain	+2
	No response	+1
Motor Response	Moves spontaneously/purposefully	+6
	Withdraws to touch	+5
	Withdraws to pain	+4
	Flexor posturing to pain	+3
	Extensor posturing to pain	+2
	No response	+1

Fig. 2. Infant GCS scale

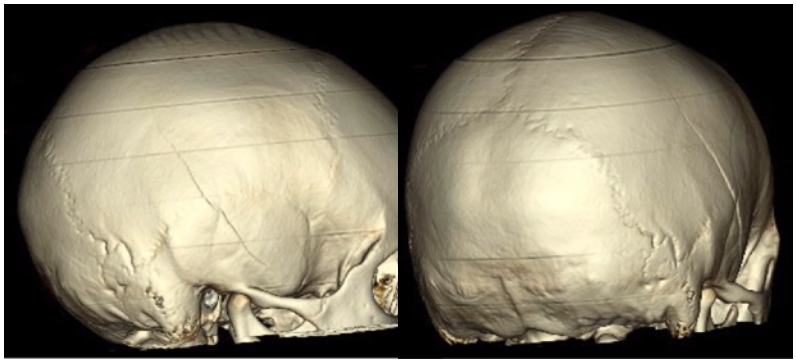

Fig. 3. Normal or Abnormal?

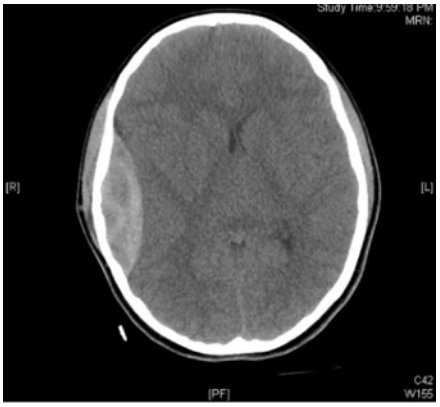

Fig. 4. Epidural Hematoma with midline shift - emergency!

- Not seeking out objective facts
- Interpreting information so that it supports our belief
- Remembering details that support our belief
- Ignoring information that challenges our belief

The instruments in an airplane cockpit provide objective facts, and pilots who do not believe their instruments tend to have bad outcomes. For example, John F. Kennedy Jr. crashed his Piper Saratoga in 1999 because he flew into clouds, became disoriented, and did not trust his instruments.. Kobe Bryant's fatal helicopter crash in January 2020 also occurred in cloudy conditions; in this case a professional pilot's failure to rely on the instruments was thought to be the fatal factor.

In the case at hand, the care team did not pay due attention to what their what their instruments were telling them—a significant head injury, a lucid interval, a decline in mental status, clear abrasions to the head, a low GCS score, and vital signs showing bradycardia and hypertension. This scenario clearly points to someone with an epidural hematoma, not a mental health issue.

Implicit Bias

The term describes having attitudes towards people, or associating stereotypes with them, without conscious knowledge. Because it is unconscious, it can affect decision making, particularly in high stress situations.

Unfortunately, multiple studies have found that implicit bias is rampant in healthcare, with reports of race/ethnicity-based disparities in abusive head trauma evaluation and reporting, laboratory and radiological testing in pediatric ED visits, and in the pain management of limb fractures.

(To find out if you have implicit bias I recommend taking the tests available online at https://implicit.harvard.edu/implicit/takeatest.html.)

Airway

Case Study #1

A 4 year old girl (**Fig. 5**) was an unrestrained front-seat passenger in a motor vehicle crash. She was brought to the trauma room with C-spine and backboard. She was awake, alert, and able to move all four extremities. She had facial lacerations, a bloody nose, and missing teeth. She said repeatedly: "I need to sit up."

Airway obstruction is easy to miss in young children, who might not say "I can't breathe" but something like what this little girl said, or even more urgent: "I need to sit up *NOW*" or "I AM GOING TO SIT UP!"—which may be the child's last words before respiratory arrest. The onset of hypoxia in children can be subtle, and combativeness can be a sign of hypoxia or (worse) hypercarbia.

When possible, let the child sit up. If there is concern for a cervical spine injury, the head of the bed can be raised with the team helping to stabilize the neck. Secretions can be

Fig. 5. 4-year old needing to sit up

sucked—gently—from the oropharynx, and preoxygenation can be performed with the patient sitting, if necessary.

Intubation in children with airway obstruction is extremely difficult, so an experienced airway manager is needed along with a surgeon experienced in tracheostomy. If the airway is lost, the child will die.

Case Study #2
The lips and part of the face of a pre-teen boy with a history of substance abuse were frozen to the metal when he tried to "huff' gas from a propane tank (**Fig 6**). The first responders managed to separate his skin from the metal and he was brought to the ER sitting up on a stretcher, breathing noisily, and appearing very anxious.

Airway obstruction was diagnosed and the patient was taken to the OR. An IV was started for medications and an anesthesiologist and an airway surgeon were present. The options were nasotracheal intubation or emergency tracheostomy. He underwent the tracheostomy (a very difficult procedure in children) and recovered.

Breathing
Blunt thoracic injuries are easy to miss in pediatric trauma patients. Injury from pneumothorax, hemothorax, and pulmonary contusion, are relatively rare, and can occur without rib fractures or external signs of chest trauma in pediatric patients because their chest wall is quite pliable.

Fig. 6. Face that was frozen to a propane tank (L); after tracheostomy (R)

Pitfalls in recognizing tension pneumothorax in children include its rarity in blunt pediatric trauma; in addition hypovolemic children will not have distended neck veins. Performing an intubation on a child with a tension pneumothorax will usually make the situation worse.

Case Study #3
An 8 year old girl crashed her bicycle while on vacation. A local clinic cleared her to fly back to Columbus OH on a commercial flight but on arrival she was taken straight to the ED with dyspnea. **Fig. 7** shows the chest before and after draining.

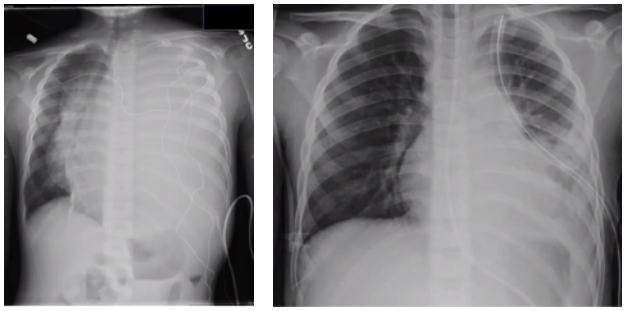

Fig. 7. Imaging from Case #3

Why was this injury missed? First of all, as noted, hemothorax is a rare injury in children; second, the local clinic, a non-trauma center, may not have performed full ATLS (advanced trauma life support) exam (including chest exam and radiograph), and third, children have excellent pulmonary reserve and may not complain of shortness of breath.

Flying was dangerous for this patient, because of the danger of pneumothorax and

the expansion of gas in the lower pressure inside an airplane cabin at altitude.

Circulation
Failure to recognize hemorrhagic shock is the most common mistake made by practitioners when they evaluate pediatric trauma patients, and that can have severe consequences.

Pediatric blood volume is normally about 80 ml/kg and the correct fluid bolus for initial pediatric trauma resuscitation is 20 ml/kg WARM normal saline or LR. For severe hemorrhagic shock, the initial fluid may be blood.

A missed or delayed diagnosis of severe hemorrhagic shock in a pediatric trauma patient is more likely if the physician ignores the nurse who reports a low blood pressure. Nurses who check vital signs on many patients every day tend to be very accurate and are unlikely to get it wrong. Due deference should be paid to their expertise.

A low blood pressure reading in the trauma room is probably real, and a low blood pressure is strongly associated with significant hemorrhagic shock. *The physician must not ignore this warning—it may be the only one s/he gets.*

Case Study #4
A 5 year old female ran in front of a car that was moving at ~15 mph. She was struck in the rib/hip area and knocked to the ground. There was no LOC, no fx or bleeding, and one episode of vomiting. When she arrived at the ED her mother was holding her and she had no collar.

The drop in BP to 75/36 (see case log opposite) was missed in the flurry of activity. All of the heart-rate readings indicated tachycardia. CT (**Fig. 8**, next page), however, revealed a significant (grade 4) liver laceration and a massive (grade 5) splenic laceration.

These injuries were initially missed probably from a combination of (a) treating a single low BP reading as "just one drop", (b) the persistent tachycardia, and (c) the patient's complaints of thirst (hypovolemia). The need for an interpreter suggests some implicit racial or ethnic bias may also have been a factor.

Case Log

0857: Arrived in ED as level 2 alert + language barrier; interpreter paged
0859: 100% NRB applied
Pt. placed in aspen collar
0900: Initial VS: HR 112 RR 33 GCS 15
0901: *Initial exam*:
- PERRL
- Intermittent abdominal pain
- Abdomen slightly distended, pushes hand away but generally soft; ? tenderness
- Superficial abrasion to L nares and L corner of lower lip; hematoma over L frontal bone with overlying abrasion
- Denies c-spine tenderness on palpation
- Plan: C-spine films, Chest and pelvis x-rays, H&H, LFTs,
- UA, CT head

0906: HR 110 RR 28 BP 111/83
0907: Labs/portable x-rays ordered
0910: Lat. c-spine, chest and pelvis portable x-rays IMPRESSION:
Normal trauma series
0915: HR 108 RR 28 **BP 75/36**
0918: H/H 10/29.9
GCS = 15 - complains of thirst
0921: Repeat VS HR 121 RR 20 BP 88/46

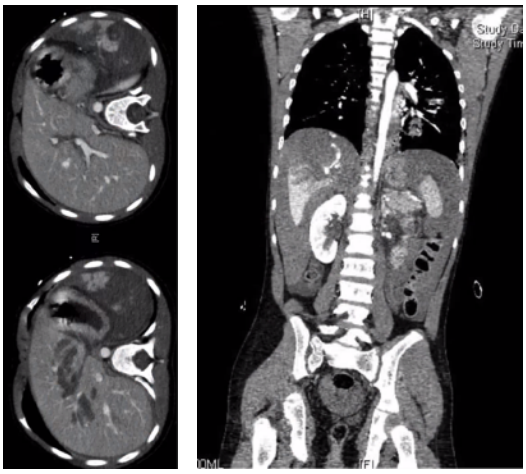

Fig 8. CT from Case Study $4

Disability

A basic neurologic examination includes a determination of mental status using the Glasgow Coma Score and peripheral motor/sensory function ("Wiggle your toes"), which are easy to administer.

Peripheral nerve injuries are missed more often than central injuries

Case Study #5

A 6 year old girl was restrained inside a car that crashed. She was transferred from another hospital and admitted to the floor at 3 am.

In primary and secondary surveys no neurologic abnormalities were noted. Apart from a note by a resident that the patient seemed "sleepy", no neurologic deficits were noted (GCS = 15) and cervical spine series and CT were both normal.

But in a tertiary survey, the APN could not get the child to move her lower extremities and there was no sensation there. An MRI was ordered. It showed (**Fig 9**) that she had a bad spinal cord contusion, which explained her paraplegia and her bladder dysfunction.

Fig 9. MRI from Case Study #5

The contusion was missed because nobody asked the patient to move her legs.

Exposure

A patient who is not completely undressed and carefully examined for injuries, neurologic status, and vascular status is at risk. In one historical case, a trauma medical director lost his job after a patient who had been stabbed in the chest went into cardiac arrest and died despite management of his injury. When the patient was rolled over, another stab wound was found in his back—it had been completely missed.

As well as risk to the patient, such mistakes are at east embarrassing to the team that made them. **Fig. 10** is an example of such a mistake.

Fig 10. Always undress the patient completely, to avoid serious risk to the patient and embarrassment later

It is important too, after removing all clothing, to use external warming devices to keep pediatric patients warm.

Secondary and Tertiary Surveys
While in the trauma room and before being taken for imaging studies all patients should receive a secondary head-to-toe evaluation, with all injuries again catalogued and documented. Comatose patients are especially susceptible to having injuries missed.

Tertiary surveys are vital to catch anything that may have been missed in the heat of the battle to stabilize the patient. They are performed only on admitted trauma patients, as another head-to-toe evaluation the morning after admission, by an APN or resident. Again, all injuries, imaging findings, and abnormal labs are documented in progress notes. *Tertiary surveys have a proven track record of finding missed injuries.*

Bowel Injury
In children, significant injury to the intestine is most often caused by blunt mechanism. Injury can occur anywhere from duodenum to colon and may be difficult to recognize on imaging studies. For example:

Case Study #6
A 14 year old female was the rear-middle-seat passenger in a vehicle that crashed head-on at 45 mph. She was restrained with only a lap belt. The driver (her grandmother) died at the scene.

The patient arrived at the trauma room complaining of left thigh pain. The primary survey revealed:

- Airway intact, in cervical collar, no neck tenderness
- Bilateral breath sounds intact
- Palpable pulses in all extremities, good refill
- GCS = 15, sensation and motor intact
- Obvious deformity of thigh on left

…and the secondary survey revealed:

- No facial or head injuries
- No neck pain
- No tenderness on chest
- Mild abdominal distention, no tenderness
- Minor abrasion around umbilicus

After x rays found a fractured femur (**Fig. 11**) (indicating considerable energy was involved in the crash—something to keep in mind) the patient was prepared for the OR for the fracture. A prior CT performed for abdominal tenderness revealed a small amount of free intraperitoneal fluid but identified no injuries.

Fig. 11. Two views of the fractured femur (Case Study #6)

The femur was repaired with an IM nail, the patient was transfused with 1 unit of blood, and the orthopedic team ordered a regular diet post-operatively.

On POD #1 a tertiary survey conducted by an APN noted minimal abrasions on the abdomen, mild distention, voluntary guarding, generalized abdominal tenderness,

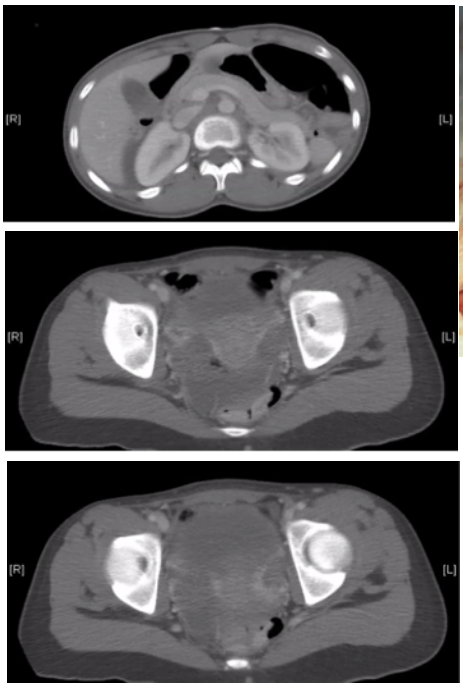

Fig. 12. CT scan from Case Study

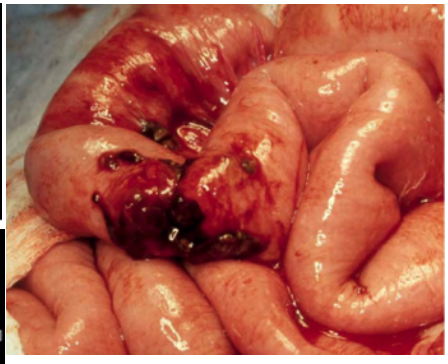

Fig. 13. Result of lap belt injury

Fig. 14. Lap belt abrasions

and percussion tenderness. The nurse made a point of telling the surgeon about the tenderness, so they reviewed the CT scan (**Fig. 12**) again, noting the considerable amount of free fluid. The pelvic images show the uterus totally surrounded by fluid—by blood.

To summarize: the patient is a restrained passenger with abdominal pain and tenderness, periumbilical abrasions, and free fluid but no solid organ injury showing on the CT scan.

It was decided she needed a “Bard Parker scan”, cutting with the scalpel rather than using a scope. The result was graphic—see **Fig. 13**.

Lap belt crush injuries are associated with:

- Bowel perforation
- Chance fracture of the spine
- Solid organ injury
- Duodenal injury
- Major vascular injury (rare)
- Delay in diagnosis

Fig. 14 shows the external abrasions. It is a strong warning of probable internal injury, such as small bowel injuries, hematomas, "blow out" perforations, and devascularized segments.

A small bowel injury may be a direct result of trauma or caused by compression of a closed loop of intestine against the spine. In a frontal collision, the weight of the contents of the intestine are force-multipled sufficient to damage the intestine as it presses against the spine (**Fig. 15**).

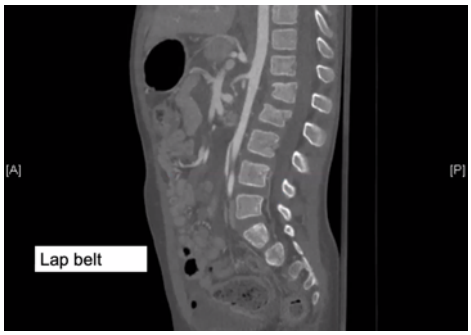

Fig. 15. Lap belt trauma

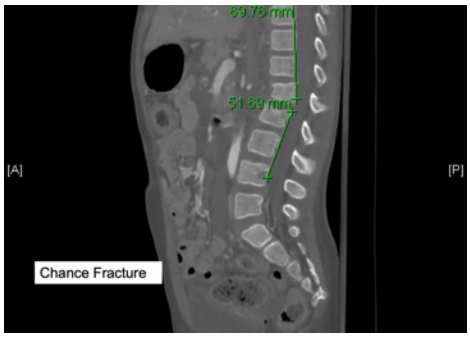

Fig. 16. A Chance fracture of the spine

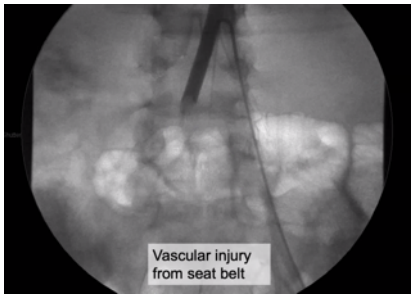

Fig. 17. Vascular injury resulting from a lap belt in a motor vehicle collision.

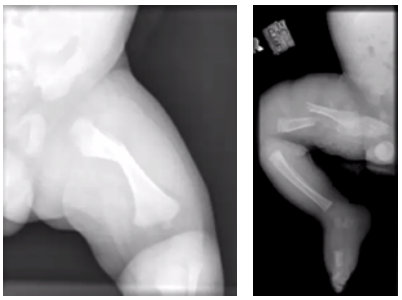

Fig 18. Femur fractures in an infant

Fig. 19. Abuse-related hand burns

In this case, the collision pressure injured the spine itself (a Chance fracture—**Fig. 16**, p. 10), a hyperextension. On impact, a child restrained by only a lap belt basically folds in half—posterior distraction, anterior compression. It usually does not cause spinal cord injury but in this case the iliac artery was torn (**Fig. 17**, next page**)**. Surgeons were unable to revascularize the leg, which had to be amputated.

The classic CT finding is "free fluid in the absence of solid organ injury." Free air (pneumoperitoneum) is seldom seen. Diagnosis can be delayed because some bowel injuries do not cause pneumoperitoneum, or the patient may present in septic shock attributed to another cause (i.e. meningococcemia). For some mechanisms (such as child abuse) presentation to the ED may be delayed.

Child Abuse

Child abuse occurs in every socioeconomic strata in society and mostly in children under age 3. Tragically, it can be hard to detect. At my institution, Epic's EHR automatically sends a referral to the child abuse team if an injured child < age 5 is brought in. Bleeding disorders in children are relatively rare and bruises are usually traumatic.

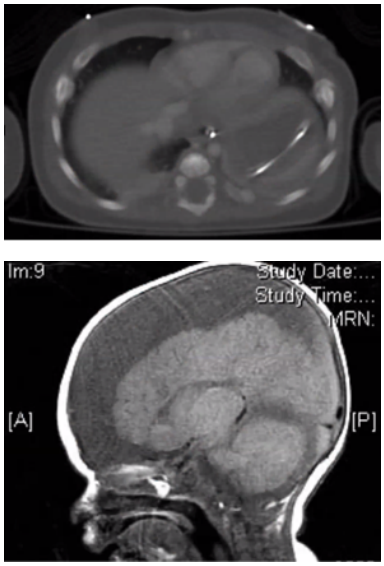

Fig. 20. 12-week-old infant with seizures

Femur fractures are common in abused infants and toddlers (**Fig. 18**).

Fig. 19 shows the classic glove pattern of hands that have n=been abused (by burning, in this case). **Fig. 20** shows studies of a 12-week-old 12 week old infant with seizures.

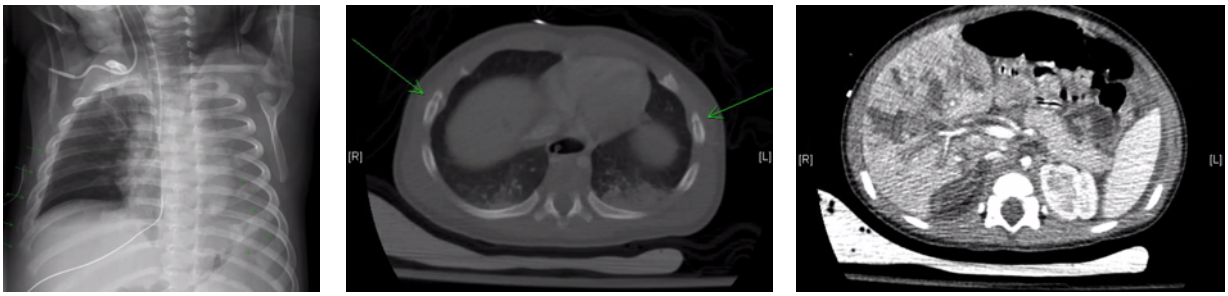

Fig. 21. Images from Case Study #7.

Case Study #7
A 7 month old was brought to the ED for medical evaluation following seizures. The child had gone full term and had no past medical history. EMS personnel witnessed a seizure and the patient responded to rectal diazepam.

The image on the left in **Fig. 21**) shows obvious rib fractures but injury to solid organs is not so clear and easily missed. To avoid missing child abuse the physician must:

- Assume that any toddler with new onset seizures might be injured.
- Assume that any toddler < age 5 injured in the home was injured intentionally.
- Assume that if the diagnosis is missed, the child will die.

The more times a child goes to the ER with abuse injuries (and typically, their abusers will take them to different ERs to avoid detection) the more likely they are to die before they ever get to a children's hospital.

Conclusions

Missing injuries can usually be avoided by:

- Recognizing the provider's natural propensity toward cognitive bias and implicit bias;
- Remembering pediatric-specific injuries like child abuse and seat belt trauma;
- Adopting a standard approach in which every major trauma patient has a primary, secondary, and tertiary survey;
- Trusting one's instruments—they are usually right; and
- Trusting one's allied health professional colleagues—they are also usually right. Remember "deference to expertise".

* * *