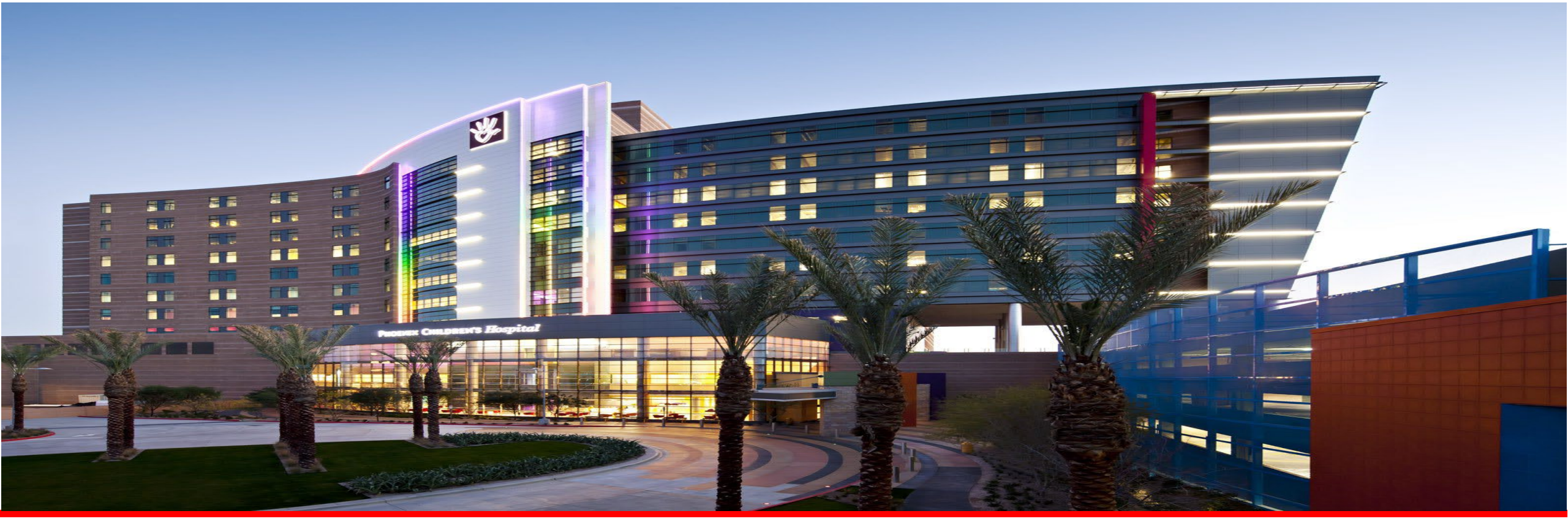
Phoenix Children's®
Center for Trauma Care



100% FOR CHILDREN℠

Mechanisms of Injury in Pediatric Trauma – Does It Make a Difference?

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Objectives

- Discuss the epidemiology of pediatric trauma
- Discuss common mechanisms of injury seen in children
- Discuss important differences between pediatric and adult patients
- Discuss the initial stabilization of a child during a traumatic event, including primary survey interventions and case presentation
- Discuss pain assessment and management for the pediatric patient

Epidemiology

- Pediatric Trauma:
  - Boys>Girls
  - For head trauma:
    - Falls are the most common injury in infants
    - Abuse is the most common cause of severe head trauma
  - MVC's, suicides, and assaults are top 3 for adolescents
  - Mechanism of Injury: >90% Blunt force trauma

10 Leading Causes of Death, United States
2020, All Races, Both Sexes

y colored box for detailed causes and ICD codes.

Click on any age group for percentag

	Age Groups										
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	All Ages
1	Congenital Anomalies 4,043	Unintentional Injury 1,153	Unintentional Injury 685	Unintentional Injury 881	Unintentional Injury 15,117	Unintentional Injury 31,315	Unintentional Injury 31,057	Malignant Neoplasms 34,589	Malignant Neoplasms 110,243	Heart Disease 556,665	Heart Disease 696,962
2	Short Gestation 3,141	Congenital Anomalies 382	Malignant Neoplasms 382	Suicide 581	Homicide 6,466	Suicide 8,454	Heart Disease 12,177	Heart Disease 34,169	Heart Disease 88,551	Malignant Neoplasms 440,753	Malignant Neoplasms 602,350
3	SIDS 1,389	Homicide 311	Congenital Anomalies 171	Malignant Neoplasms 410	Suicide 6,062	Homicide 7,125	Malignant Neoplasms 10,730	Unintentional Injury 27,819	COVID-19 42,090	COVID-19 282,836	COVID-19 350,831
4	Unintentional Injury 1,194	Malignant Neoplasms 307	Homicide 169	Homicide 285	Malignant Neoplasms 1,306	Heart Disease 3,984	Suicide 7,314	COVID-19 16,964	Unintentional Injury 28,915	Cerebro-vascular 137,392	Unintentional Injury 200,955
5	Maternal Pregnancy Comp. 1,116	Heart Disease 112	Heart Disease 56	Congenital Anomalies 150	Heart Disease 870	Malignant Neoplasms 3,573	COVID-19 6,079	Liver Disease 9,503	Chronic Low. Respiratory Disease 18,816	Alzheimer's Disease 132,741	Cerebro-vascular 160,264
6	Placenta Cord Membranes 700	Influenza & Pneumonia 84	Influenza & Pneumonia 55	Heart Disease 111	COVID-19 501	COVID-19 2,254	Liver Disease 4,938	Diabetes Mellitus 7,546	Diabetes Mellitus 18,002	Chronic Low. Respiratory Disease 128,712	Chronic Low. Respiratory Disease 152,657
7	Bacterial Sepsis 542	Cerebro-vascular 55	Chronic Low. Respiratory Disease 54	Chronic Low. Respiratory Disease 93	Congenital Anomalies 384	Liver Disease 1,631	Homicide 4,482	Suicide 7,249	Liver Disease 16,151	Diabetes Mellitus 72,194	Alzheimer's Disease 134,242
8	Respiratory Distress 388	Perinatal Period 54	Cerebro-vascular 32	Diabetes Mellitus 50	Diabetes Mellitus 312	Diabetes Mellitus 1,168	Diabetes Mellitus 2,904	Cerebro-vascular 5,686	Cerebro-vascular 14,153	Unintentional Injury 62,796	Diabetes Mellitus 102,188
9	Circulatory System Disease 386	Septicemia 43	Benign Neoplasms 28	Influenza & Pneumonia 50	Chronic Low. Respiratory Disease 220	Cerebro-vascular 600	Cerebro-vascular 2,008	Chronic Low. Respiratory Disease 3,538	Suicide 7,160	Nephritis 42,675	Influenza & Pneumonia 53,544
10	Neonatal Hemorrhage 317	Benign Neoplasms 35	Suicide 20	Cerebro-vascular 44	Complicated Pregnancy 191	Complicated Pregnancy 594	Influenza & Pneumonia 1,148	Homicide 2,542	Influenza & Pneumonia 6,295	Influenza & Pneumonia 42,511	Nephritis 52,547

Produced By: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention

Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System

Accidental Injury Deaths

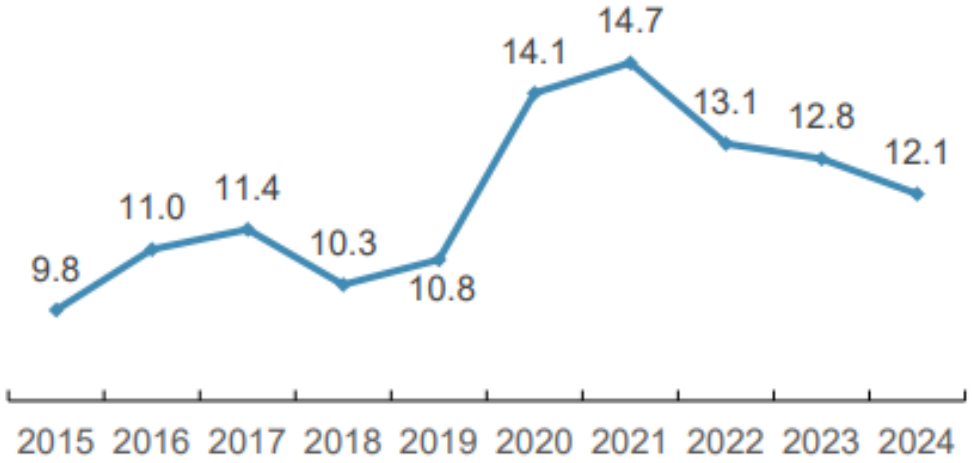
An injury that occurred when there was no intent to cause harm or death is an unintentional injury. See the Glossary for further explanation.

Total Accidental Injury Deaths
202
(26% of all child deaths)

5.4% decrease
in mortality rate from 2023
(12.1 deaths per 100,000 children in 2024)

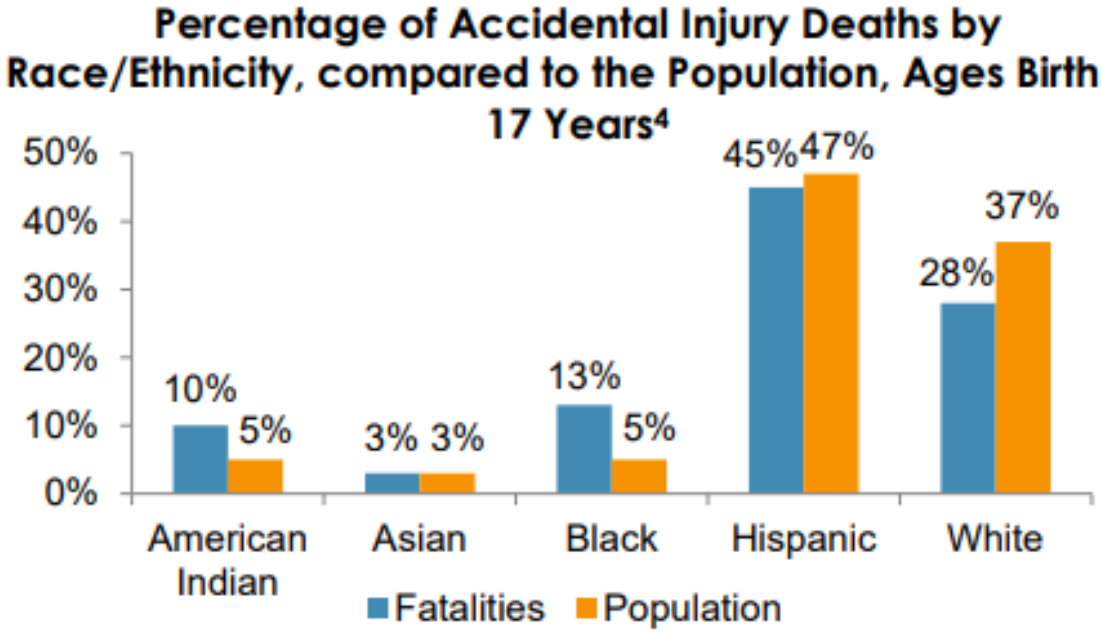
100%
of Accidental Injury Deaths were Preventable

Mortality Rate per 100,000 Children Due to Accidental Injury, Ages Birth to 17 Years[4-13]



Top Causes of Accidental Injury Deaths:

MVC	Suffocation	Drowning	Poisoning	Environmental Heat Exposure
39% (78 deaths)	27% (54 deaths)	17% (35 deaths)	6% (12 deaths)	3% (7 deaths)



31% of accidental injury deaths occurred in **infants (less than one year of age)**

63% of accidental injury deaths were among **males**

Leading Risk Factors of Accidental Injury Deaths*:

CPS History with Family	Parental Substance Use History	Poverty	Lack of Supervision	Substance Use
47%	40%	38%	35%	29%

*More than one risk factor may have been identified for each death.

Top MOI at Phoenix Children's in 2025

1. Falls (794)
   >10 ft or 2-3 times the child's height
2. MVC/MPC (325)
   Unrestrained or improperly restrained (275)
   Struck by motor vehicle (50)
3. Electric bike/scooter (106)
4. Dog Bite (95)
5. Cut/Pierce (95)
6. Bike/Pedal (73)
7. ATV (65
8. Firearm (40)

Basic Concepts

- The mechanics of injury are related to the type of injuring force and the subsequent tissue response
- Damage occurs to an object when the force is greater than the object can tolerate
  - Damage can occur to connective, muscle, epithelial, and nerve tissues

Mechanism of Injury: Does it place the Pediatric Patient at Risk?

- High-risk MVC
  - Roll-over
  - Head-on collision
  - Ejection of patient
  - Death in same vehicle
  - Speeds > 55 mph
- Axial loads – big heads on small bodies
- Acceleration/deceleration injuries
- Lateral bending forces to neck/torso
- Violent impact – properly restrained???

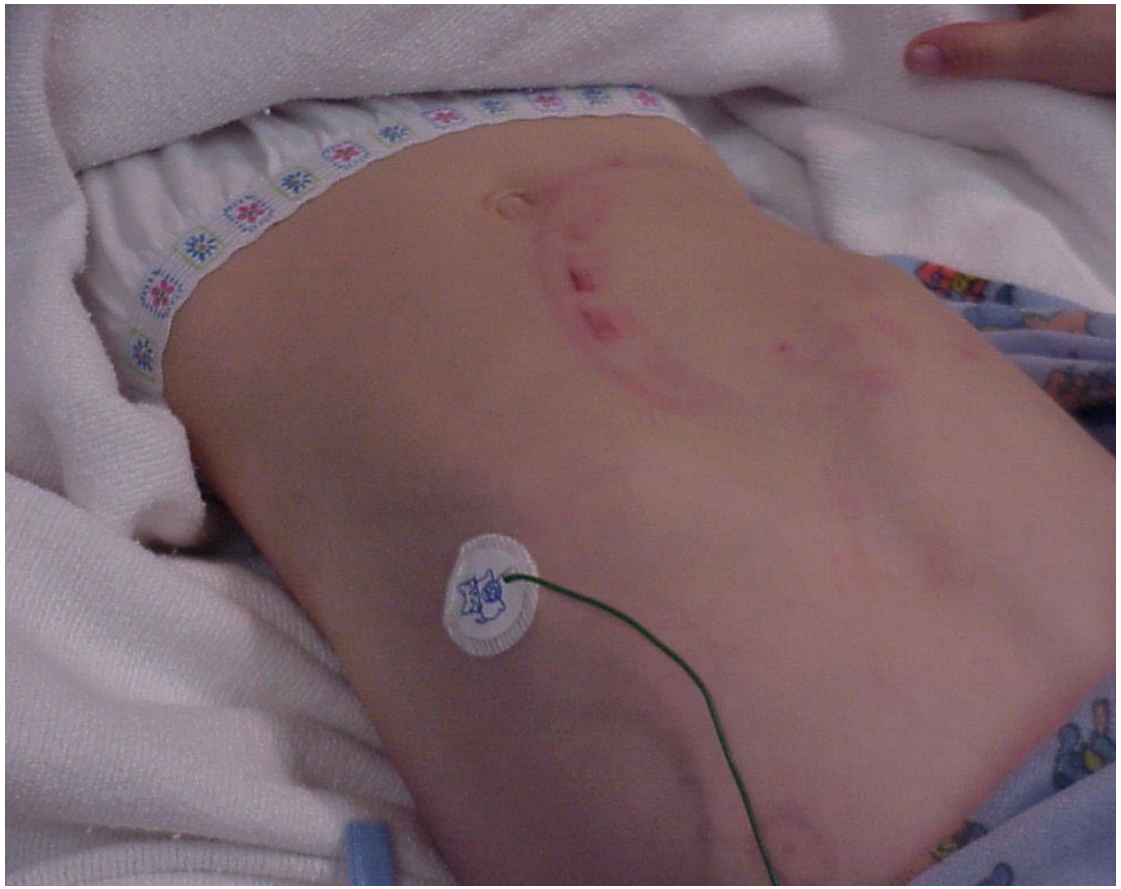
Mechanism of Injury
Blunt vs Penetrating

- Blunt = forces do not penetrate the body
  - Multiple occult injuries – difficult to detect
  - Diagnosis can be complicated
  - MVC, MPC, assault, sports
- Penetrating = object penetrates tissue
  - Injuries isolated to dissipated energy
  - GSW, stab wound, animal bites

Blunt Injuries in Children

90% of Injuries in Children

MOI – Often no obvious external signs

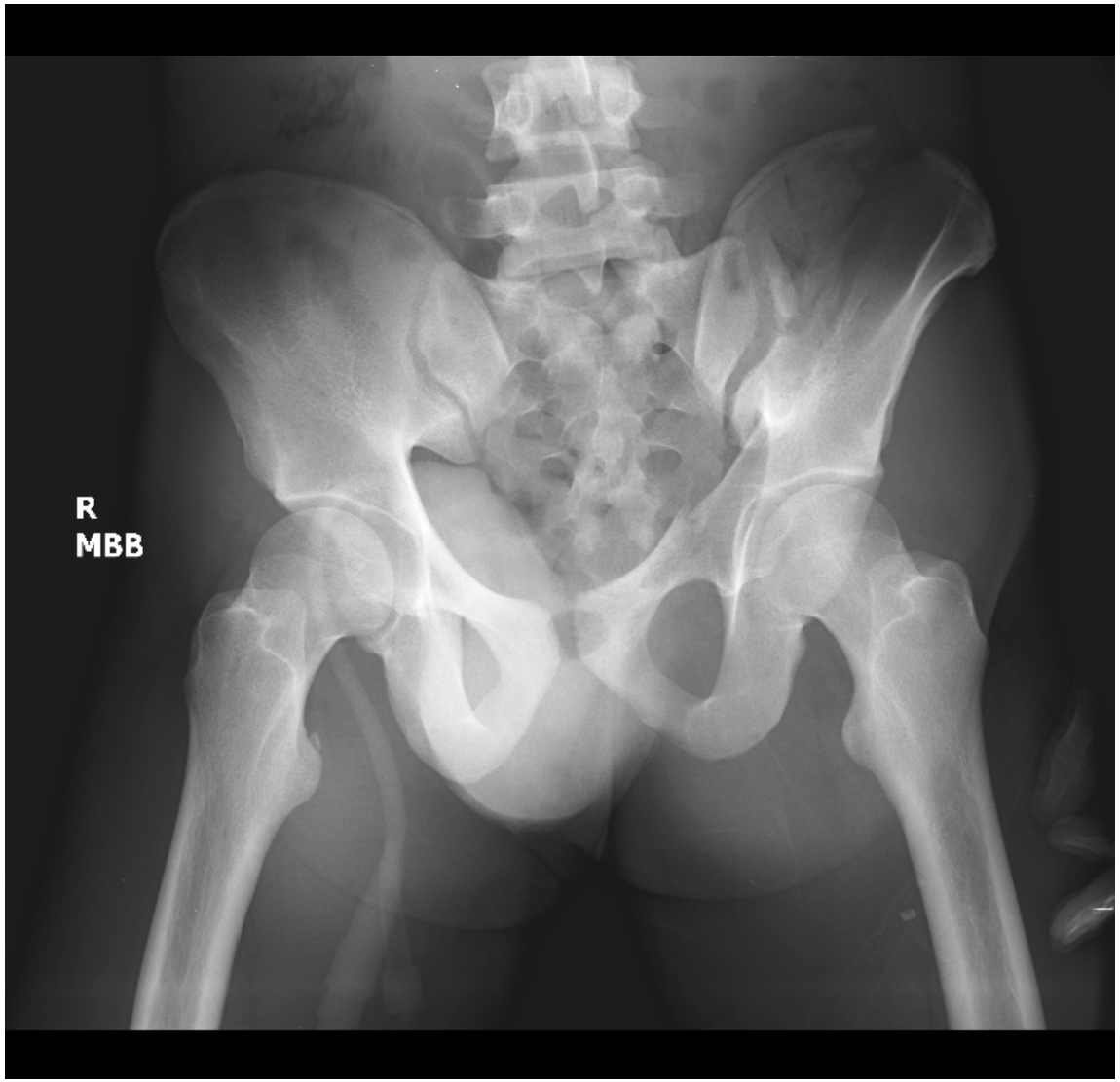


MVC

- Frontal – impact
  - Was the steering wheel bent?
  - Was the windshield broken?
  - Were there knee imprints on the dashboard?
- Injuries
  - Head, neck and spine injuries
  - Hemo/pneumothorax
  - Spleen/liver injury
  - Patella Injury
  - Femur fractures
  - Aortic rupture

MVC

- Side - impact
  - Contralateral neck injuries
  - C-spine fractures
  - Rib/clavicle fractures
  - Abdominal injuries on side of impact
  - Pelvic/Acetabular fractures



MVC

- Rear - impact
  - Hyperextension neck injuries
  - Similar to front-impact

MVC

- Restraint Injuries
  - 3-point restraints
    R/O Bowel Injury
  - Lap belts
  - Air bag deployment

Anatomic & Physiologic Differences
Abdomen

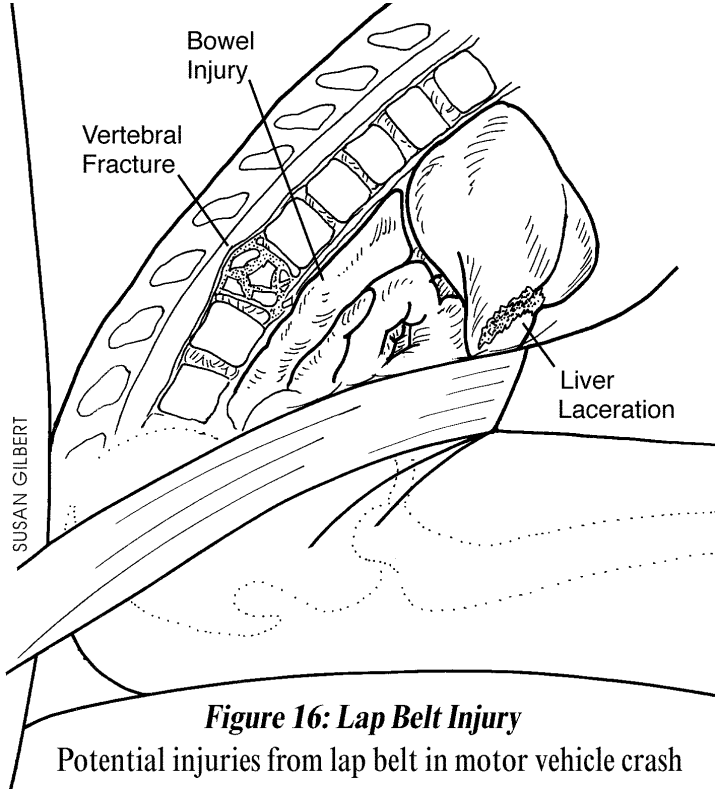
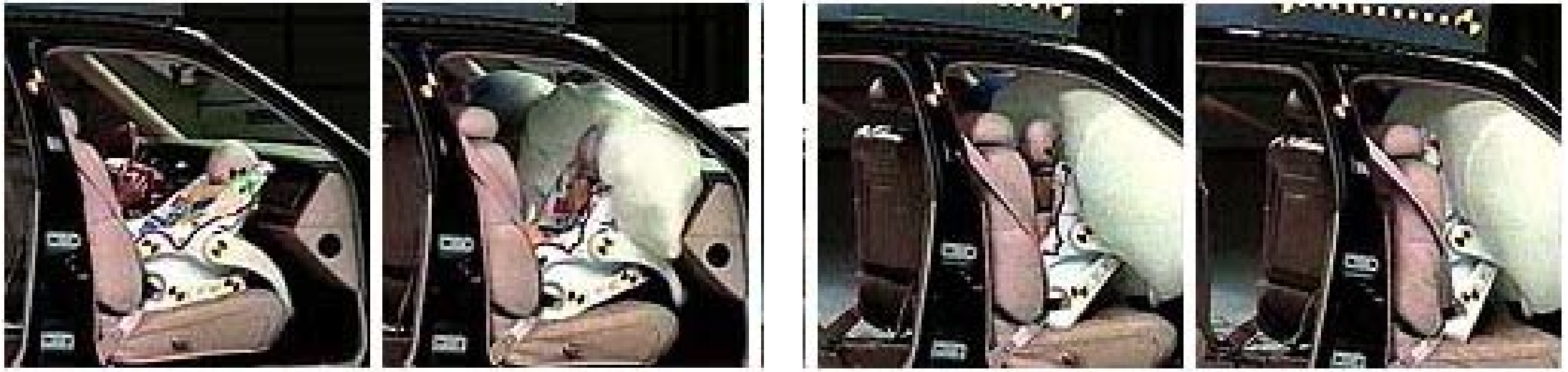


Figure 16: Lap Belt Injury
Potential injuries from lap belt in motor vehicle crash

- Bowel Injury
- Lumbar Vertebral Fractures
  - Paralysis
- Liver Laceration



MVC - Airbags

There are contraindications to airbags…

Motorcycle Crash (MCC) and Bicycle Crashes

- MCC/Bicycle
  - Helmet
  - Protective clothing
  - Speed
  - Single or Multiple Impact

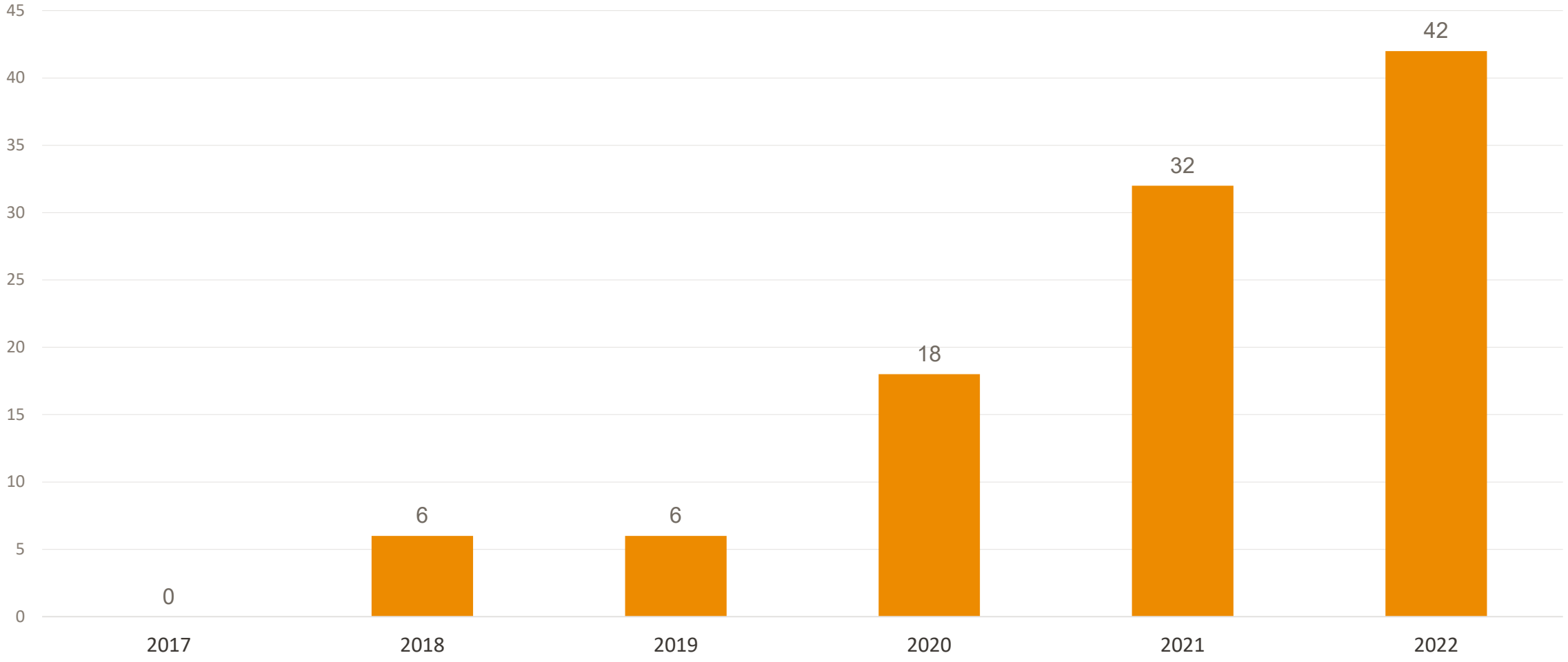
MCC

- MCC/Bicycle
  - Injury Patterns
    - Head injuries
    - Long bone fractures
    - Pelvic fractures
    - Soft tissue injury

Accelerating Risk: The Growing E-bike Trauma Crisis

Phoenix Children's

Number of Reported Fatalities in the US Associated with E-bikes from 2017 to 2022. All Ages.



Note: Reporting for 2021-2022 is ongoing. Counts may change in future reports. Source: CPSRMS, NEISS, U.S. Consumer Product Safety Commission, 2017-2022.

E-bike Traumas at Phoenix Children's

	2021	2022	2023	2024	2025
Level 1	0	0	1	3	4
Level 2	1	0	7	23	46
Level 3	1	0	3	3	5
Other	1	1	4	5	9
Total	3	1	15	34	64

Electric Scooters & Bikes – Patterns of Injury

- Head Injuries – lack of helmet use
  - Traumatic Brain Injuries
  - Cervical Spine Injuries
  - Chest/Abdomen/Pelvis
    - Blunt force injuries
    - Handlebars – Abdominal Injuries
      - Can be penetrating
  - Extremity Injuries
    - Upper & Lower Extremity fractures
      - Open fractures – need antibiotic therapy in the first hour

Motor Pedestrian Collision

- Auto v. pedestrian
- Children typically hit the bumper and are thrown upward
- Triad of Injuries
  - Head Injury (head hitting the ground)
  - Intra-abdominal injuries (hood)
  - Lower extremity injury (bumper)

Waddel's Triad

Falls

The leading cause of injury in children

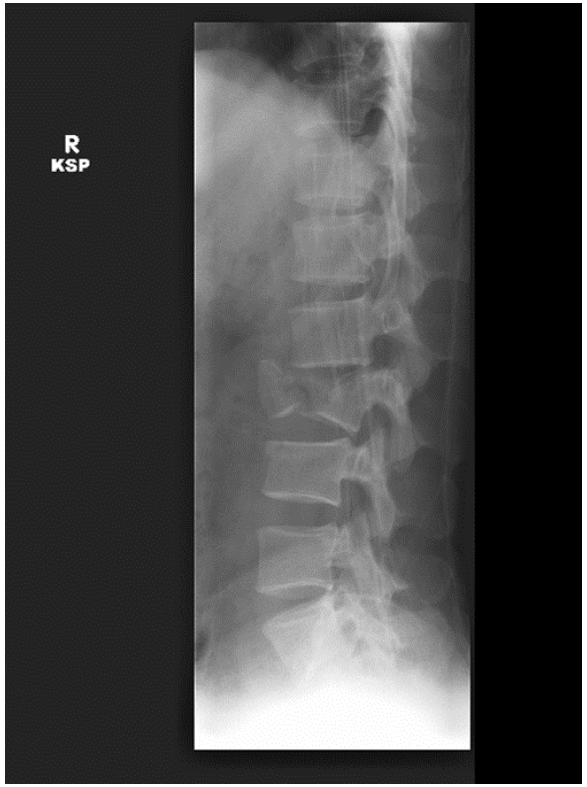
Over 50% of injured patients seen at PCH have fallen

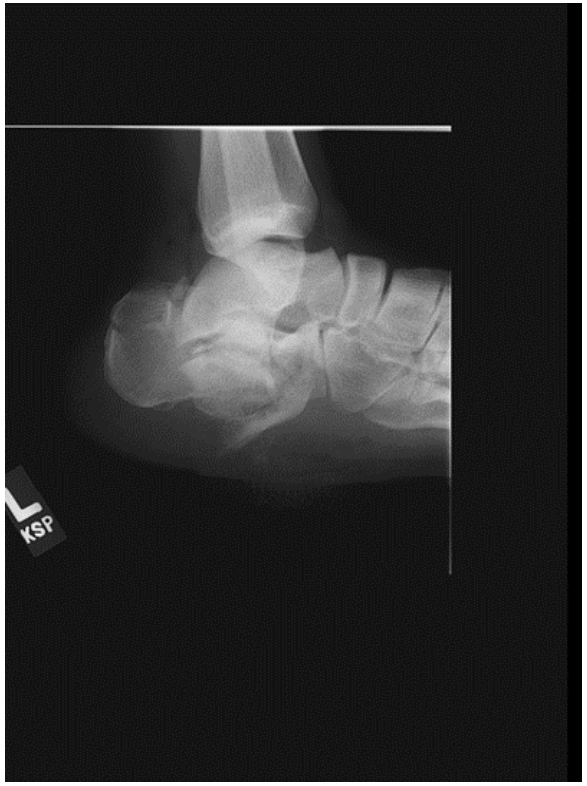
What do children fall from:

- Highchairs
- Shopping carts
- Beds
- Tables
- Countertops
- Changing tables
- Stairs
- Windows
- Balconies
- Sports
- Tree climbing
- Skating
- Playground equipment

Just About Anything!

Falls – Distance and Landing Surface





- Falling or jumping from a height that results in the victim landing on his or her feet or head is termed ***AXIAL LOADING*** - the energy on impact is applied to the axial skeleton
- Remember 2-3x child's height is significant

Skateboarding and Scooters

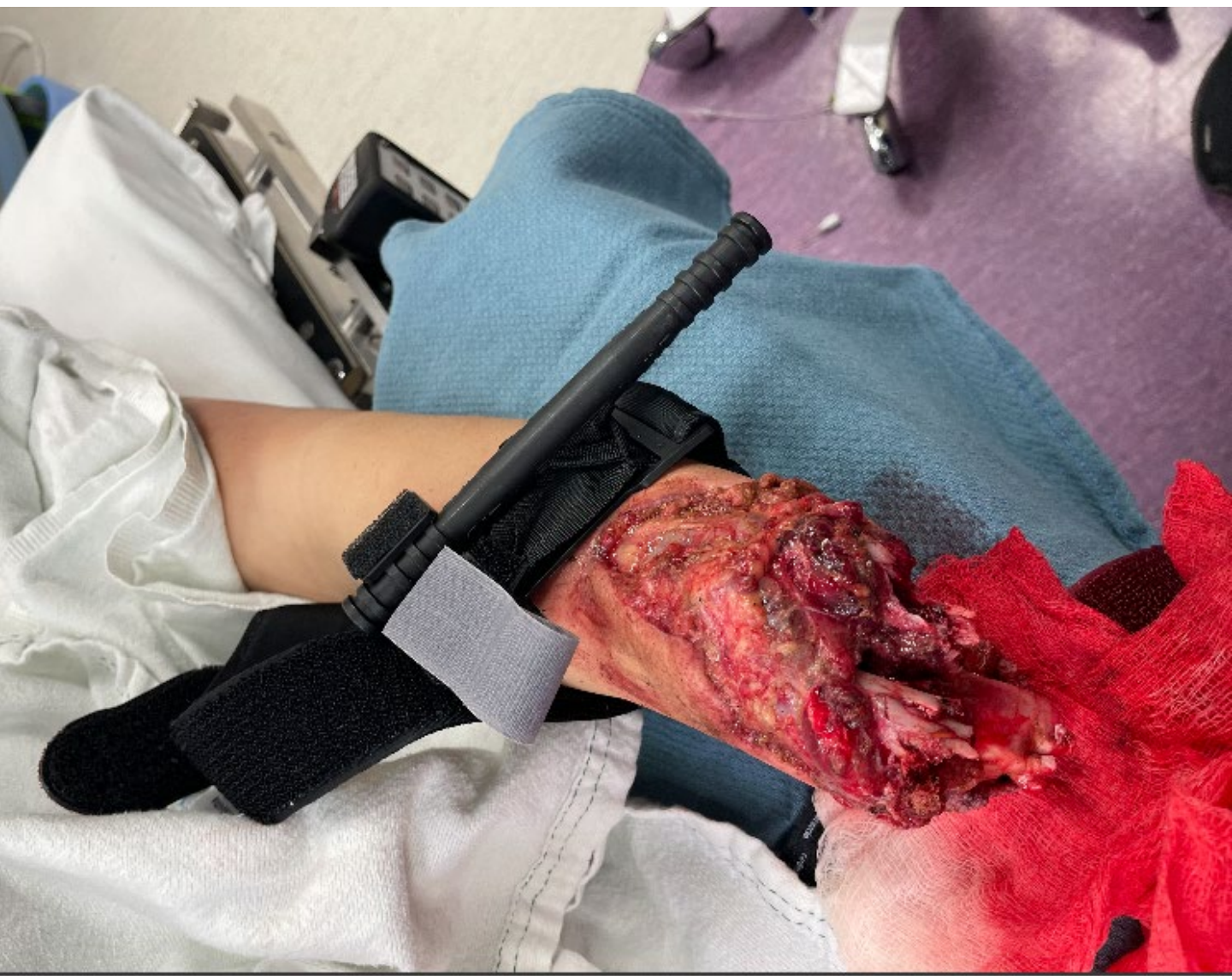
- Falls common
- Collisions with motor vehicles
- Head injuries due to poor compliance with helmet use
- Extremity fractures
- 90% of injuries seen in males

ATV Injuries

- In the top 5 MOI seen at Phoenix Children's
- Extremity Injuries
  - Partial Amputations of arms, legs, hands, feet
  - Tourniquet use – time of application is very important
- Cervical/Spinal Injuries – C-spine & SMR
- Head Injuries

Tourniquets

- At least 2-3 inches above injury
- Thigh placement may require more than one to stop bleeding.
- <u>Consider Wound Packing</u>
  Hemostatic agents require up to 5 minutes of significant direct pressure to be effective. Ideally they are packed into the wound.



Assaults

- Abuse
  - Patterned injuries
  - Inconsistent stories
  - Injuries do not match history
  - Hidden injuries
  - Various stages of injury

Other blunt injuries

Penetrating trauma

- Penetrating trauma
  - Intentional vs. Unintentional
    - Type of weapon
    - Distance from victim
    - Stance of assault
    - Number of wounds
    - Energy dissipated

Penetrating- Low Velocity

- Low Velocity
  - Stab wounds
    - Local injury
  - Shot-gun wounds
    - Pellets released
    - Tissue damage

    can be great depending

    on the range from the target
  - Impalements
    - Do not remove the object until surgery

Shotgun injury

Penetrating- High Velocity

- GSW
  - Rifles
    - Highest velocity
    - Single shot
    - Semi to fully automatic
  - Handguns
    - Revolvers
    - Auto loading pistols
    - Medium velocity

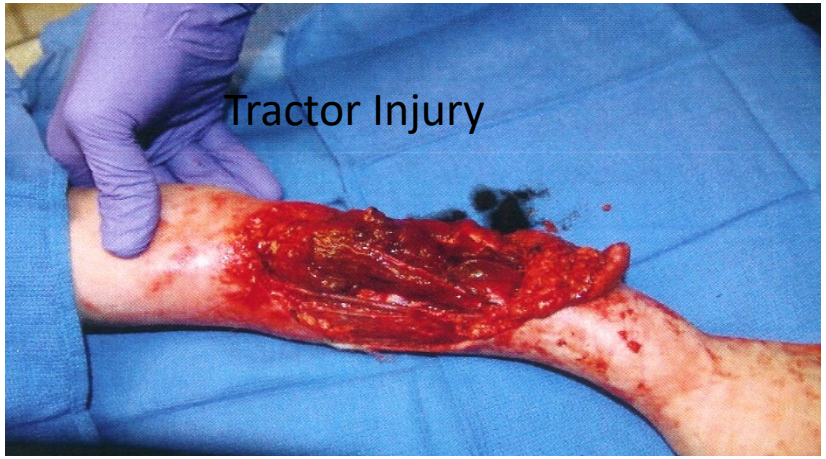
GSW

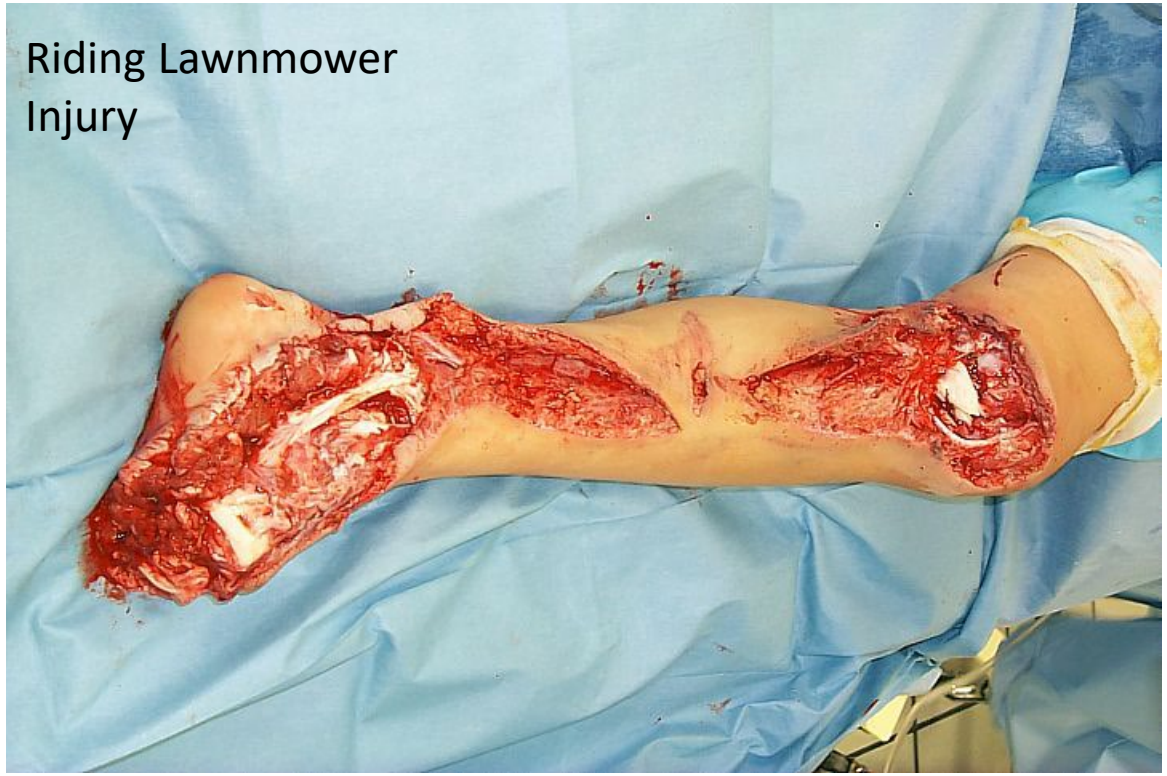
- Bullet produces energy
- The greater the energy/velocity the greater the damage
- Cavitation- penetration of the bullet
  - Bullet causes direct damage but also causes indirect damage to other surrounding areas related to shock and shear waves produced
  - This is called the blast effect

Other penetrating injuries

On the rise in the pediatric population

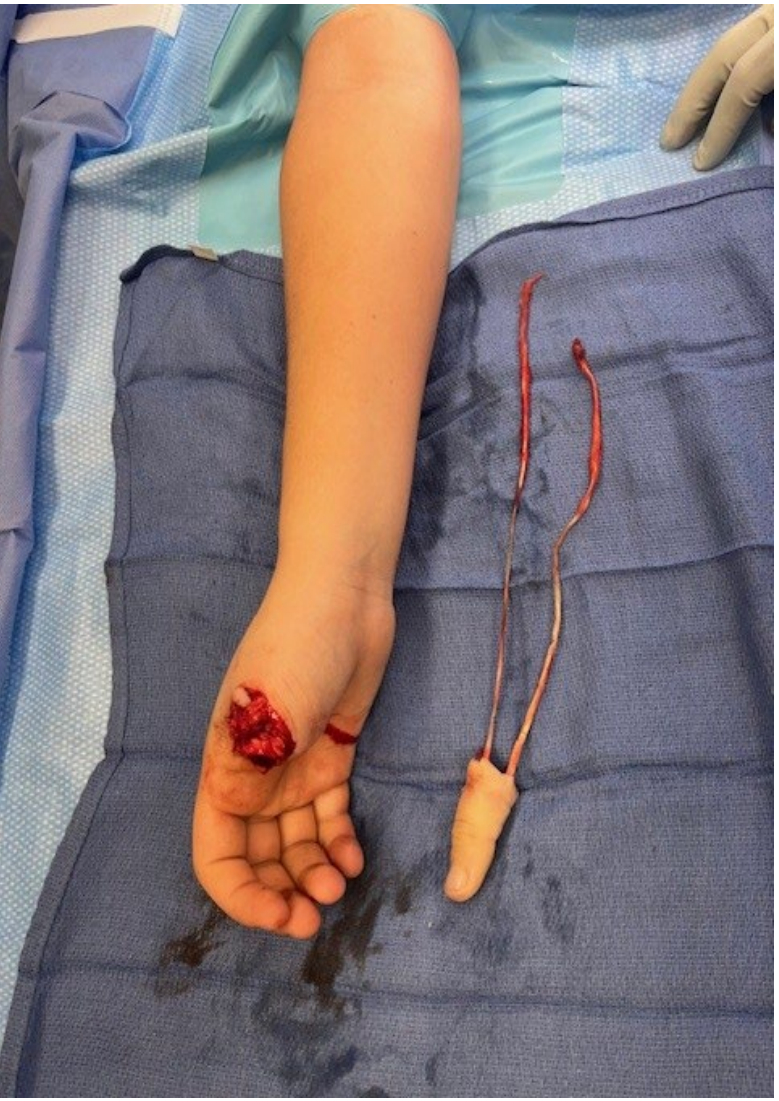
Include:
- dog bites
- farming injuries
- lawnmowers
- firearms
- stabbings
- blasting
- sharp objects
- impaled objects secondary to falls





Crush Injuries

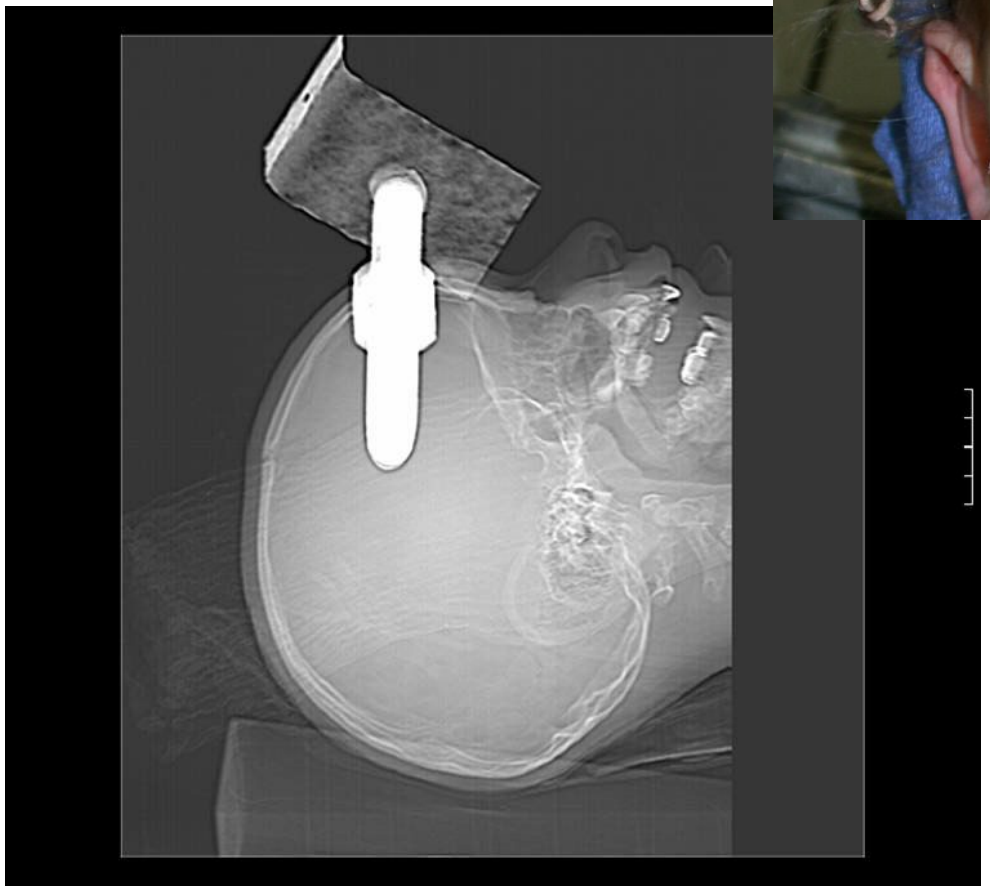
- Injuries dependent on length of compression, force applied, and type of tissue compressed
- Tissue can suffer ischemia due to increase in compartment pressure



Bites

- Dogs account for approximately 90% of animal bites in children
- Infection causes complications
- Rabies concern
- May or may not be sutured depending on depth

The Unknown…



- Children are not “small adults”. There are several differences between children and adults that effect assessment and management.

Pediatric Patients: What makes them unique?

- Size
- Developmental stages
- Musculoskeletal immaturity
- Larger head to body ratio
- Shorter necks
- Hypotension is a pre-terminal event
- Different Injury Patterns

Anatomic and Physiologic Differences in Children:

AHHHH, there is a formula for everything!

- Minimum Systolic Blood Pressure

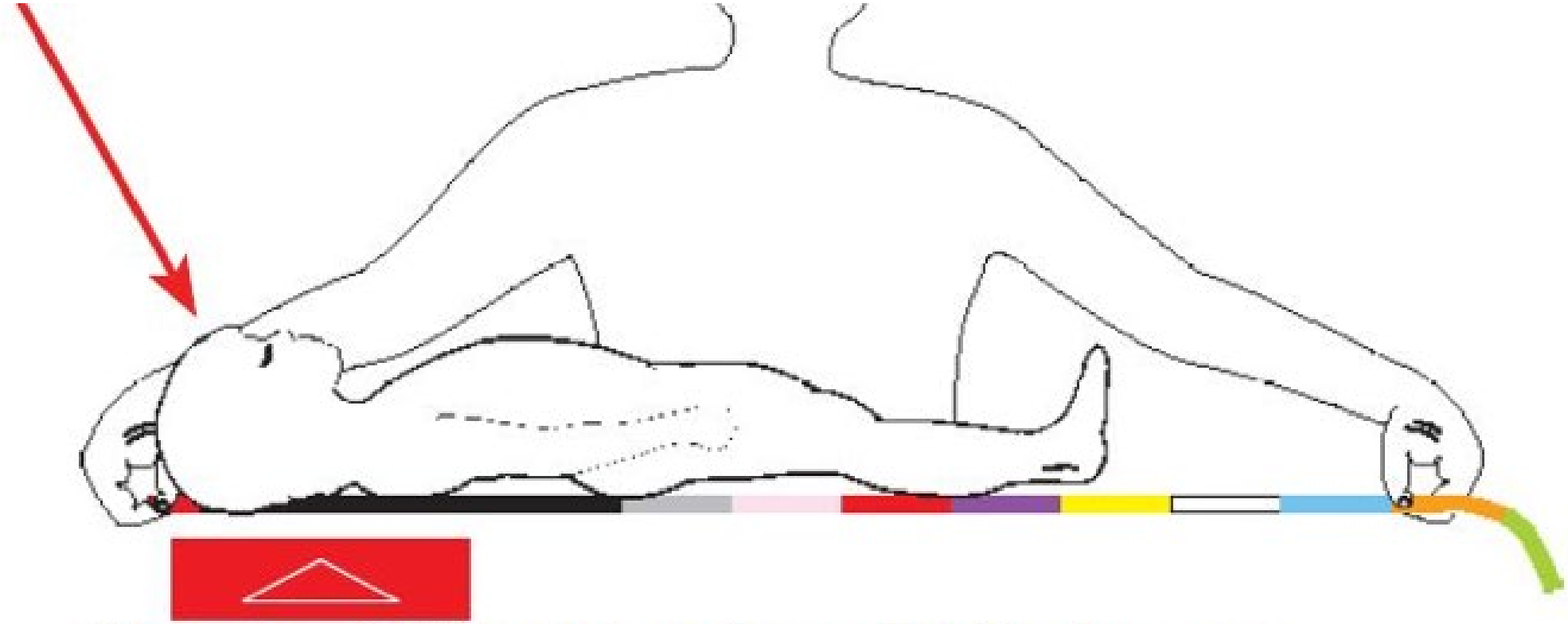
  [2 x age (in years)]+70= systolic

- ETT size

  16 + age in years/4

- ETT depth

  3x ETT size



Measure child to determine weight/color zone.
If a child appears overweight consider utilizing one zone higher for

Anatomic and Physiologic Differences in Children:

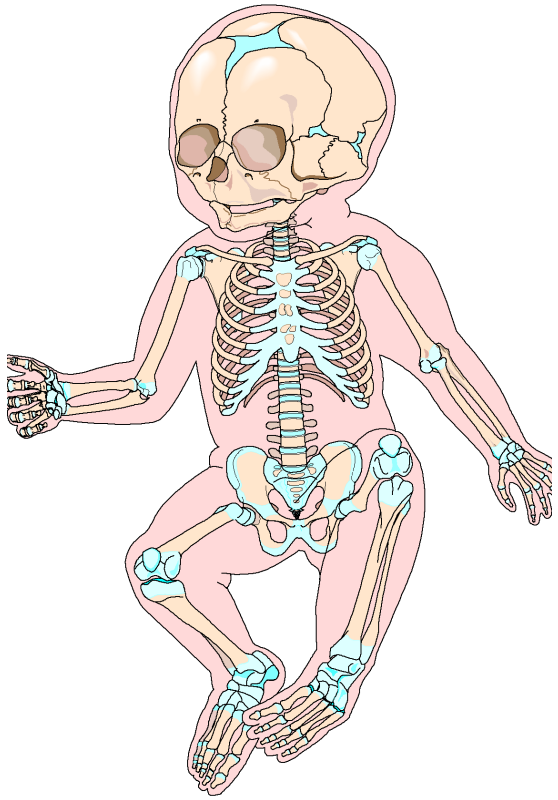
Always estimate weight in kilograms

HANDTEVY™

Pediatric Emergency Standards

Anatomic & Physiologic Differences
Head

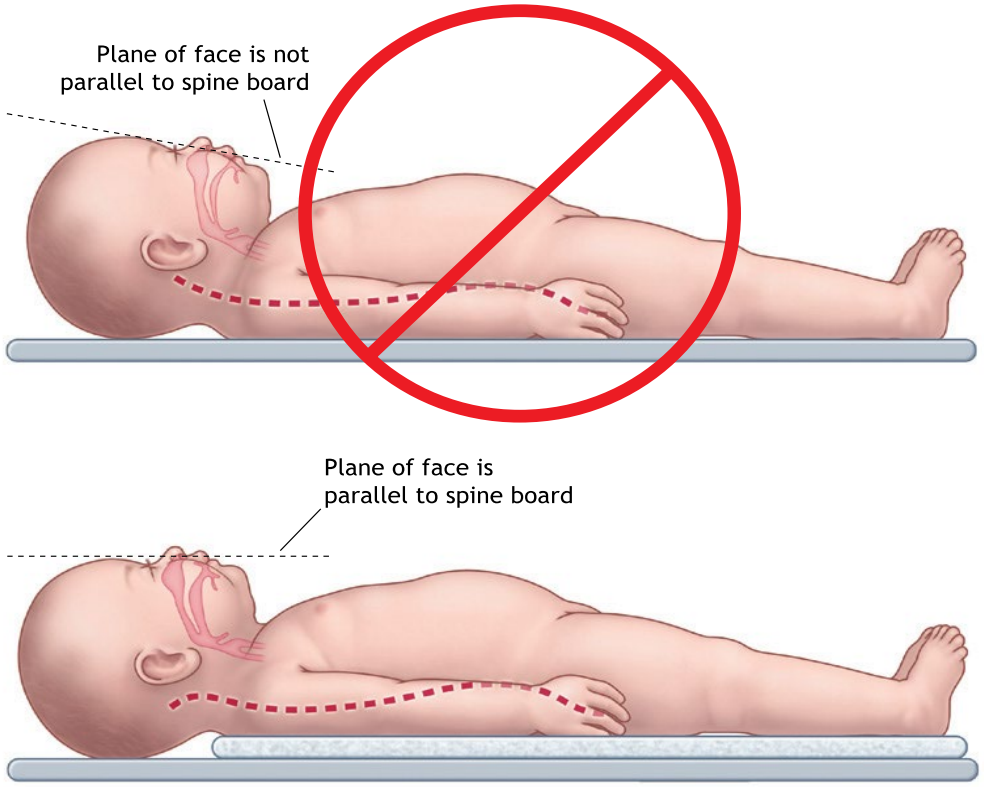
- The head is larger in proportion to the body
- Large occiput
- Large tongue
- Smaller jaw
- Shorter, narrower, funnel-shaped airway



Anatomic & Physiologic Differences
Head

Prominent occiput in younger child

1” pad under torso for neutral position

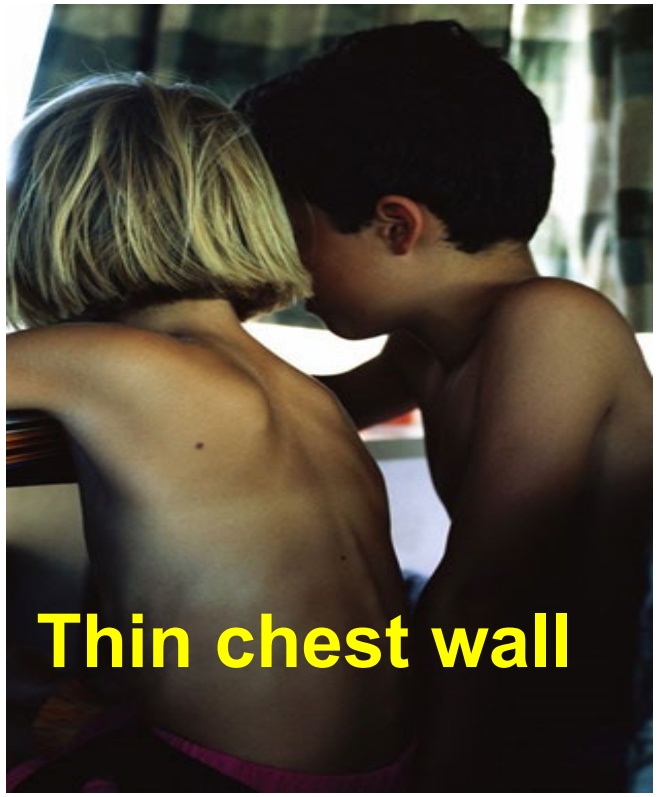


Anatomic & Physiologic Differences
Cervical Spine

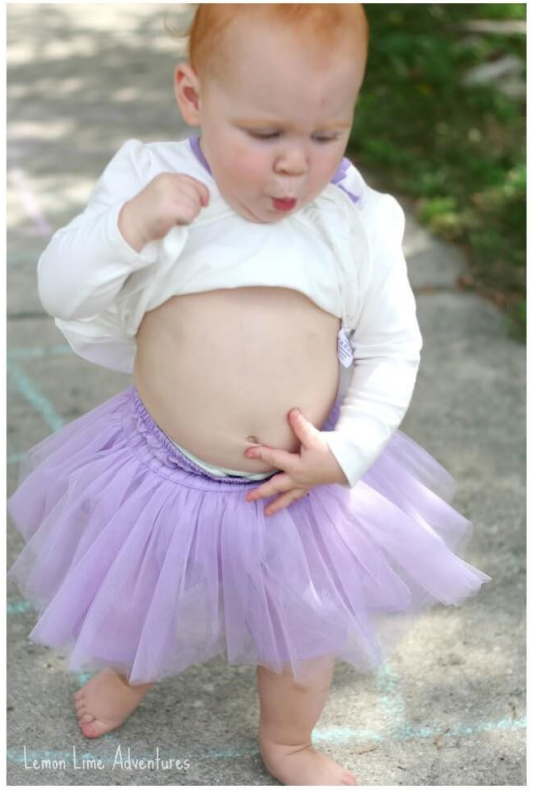
- Flexible spinal ligaments
- Anteriorly wedged vertebrae
- Flat facet joints
- Angular momentum
- Pseudo subluxation
- SCIWORA

Anatomic & Physiologic Differences
Chest & Lungs

- Chest wall composed of more cartilage than bone
  - Pliable
  - Less protection to underlying organs
  - Significant internal injury can be present without external signs
  - Thin chest wall
    - Allows for easily transmitted breath sounds
    - Easy to miss a pneumothorax or misplaced ETT



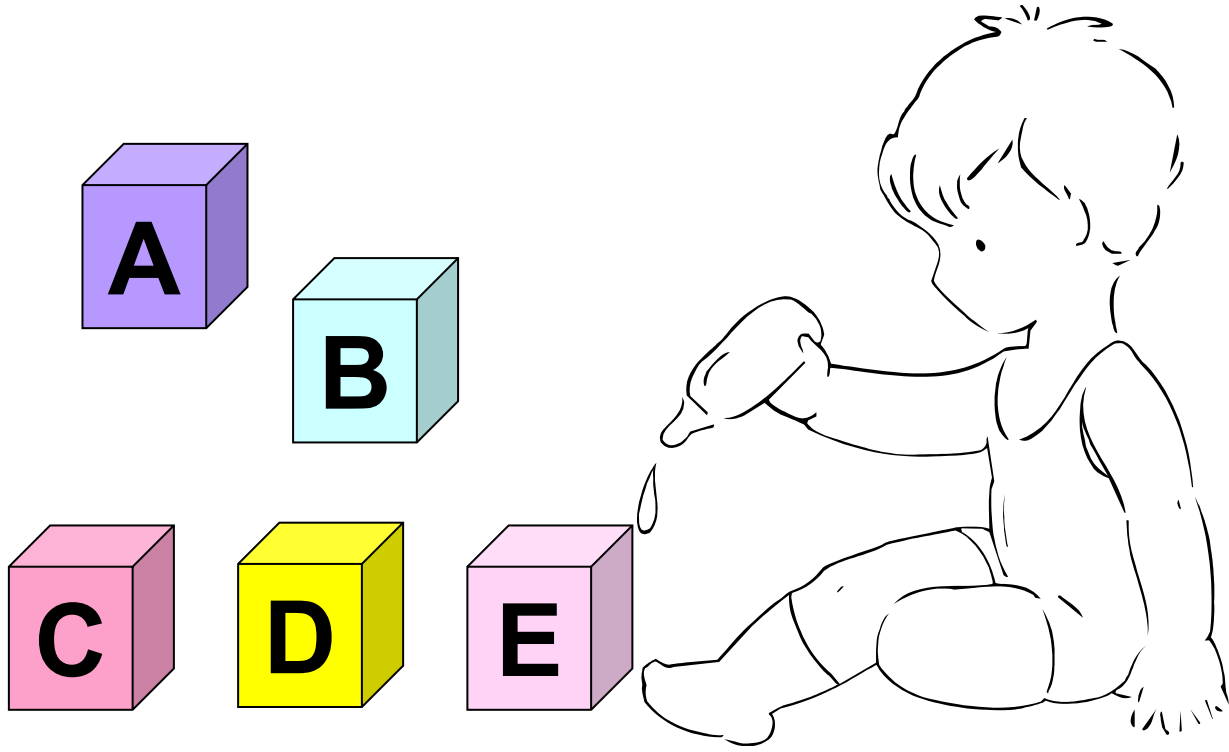
Anatomic & Physiologic Differences
Abdomen



- Softer, thinner, muscular wall
- Lower-riding liver, spleen
- Bladder is an intra-abdominal organ in young children

Initial Stabilization

- Primary Survey
  - X- Check for external bleeding
  - A- Airway and C-spine immobilization
  - B- Breathing and ventilation
  - C- Circulation and hemorrhage control
  - D- Disability assessment (Neuro exam)
  - E- Exposure/Environment control



Initial Stabilization
Primary Survey

- ASK THEM THEIR NAME!!
- Are They Crying or screaming?
  - Airway patency
  - Breathing
  - Circulation
    - Appropriate response demonstrates cerebral perfusion
  - Disability
    - GCS

Initial Stabilization
Airway Issues

- Airway patency: Use jaw thrust & provide 100% Oxygen
- Stabilize C-spine
  - Have a high index of suspicion for cervical cord injuries
- OGT if patient is being ventilated – nothing in the nose
- Maxillofacial injury: Clear airway of debris
- Cricothyroidotomy as a last resort

Indications for Intubation

- GCS < 8 or absent gag
- Inability to ventilate w/ BVM
  - Consider SGA
  - Use video laryngoscopy
  - ETT size important – limit number of attempts
- Hypotension resistant to fluid resuscitation
- Flail chest – maybe….
- **Always maintain C-spine** during intubation attempts

Initial Stabilization
Breathing

Observation

- Bruising, Subcutaneous air, penetrating trauma, symmetry, tracheal deviation, distended neck veins

Auscultation

- Symmetric, absent, muffled, bowel sounds

Palpation/Percussion

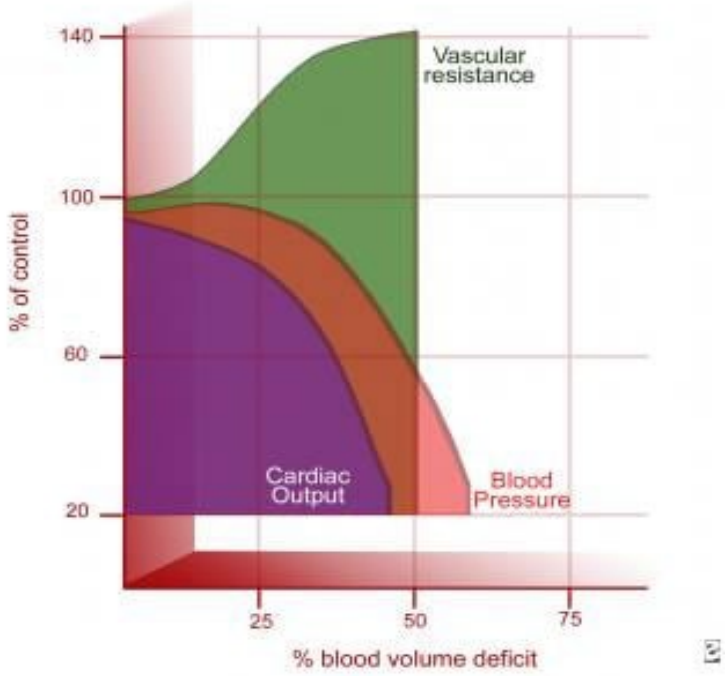
- Subcutaneous air, flail segments

Initial Stabilization
Circulation

- Assess a combination of factors:
  - Pulse: presence of peripheral pulses
    - Indicates a systolic BP of ≥ 80 mm Hg or normal SBP for age
  - Skin color
  - Level of consciousness
  - Capillary refill
  - Blood Pressure
    - Manual BP vs NIBP
    - Hypotension is a pre-terminal event in children

Effects of Shock

- Cells can no longer produce energy
- Cells die
- Organ tissue dies
- Organ Failure/Death
- Kids compensate until they don't!



Why is Pre-Hospital so Important in Managing Shock?

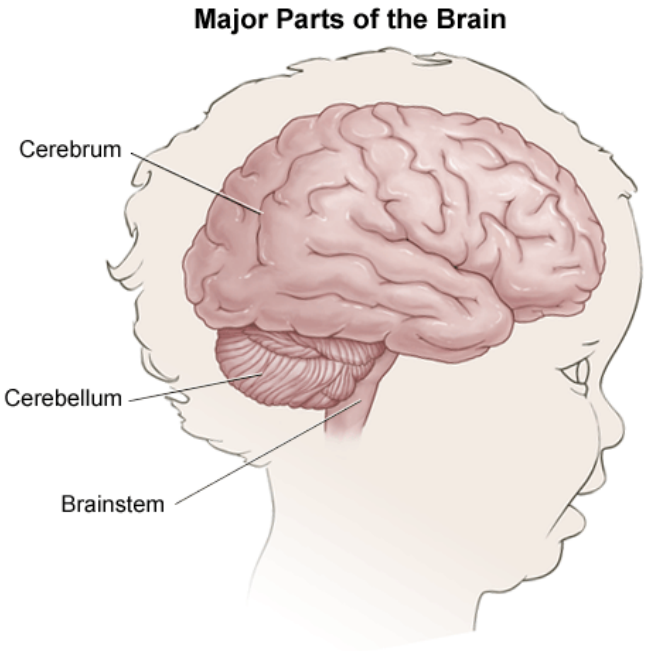
- Damage starts within 4-6 minutes of hypoxia
- Hypoxia and hypoperfusion can ultimately result in the patient's death.
- Therefore, it is critical that the pre-hospital provider prevent hypoxia and hypoperfusion

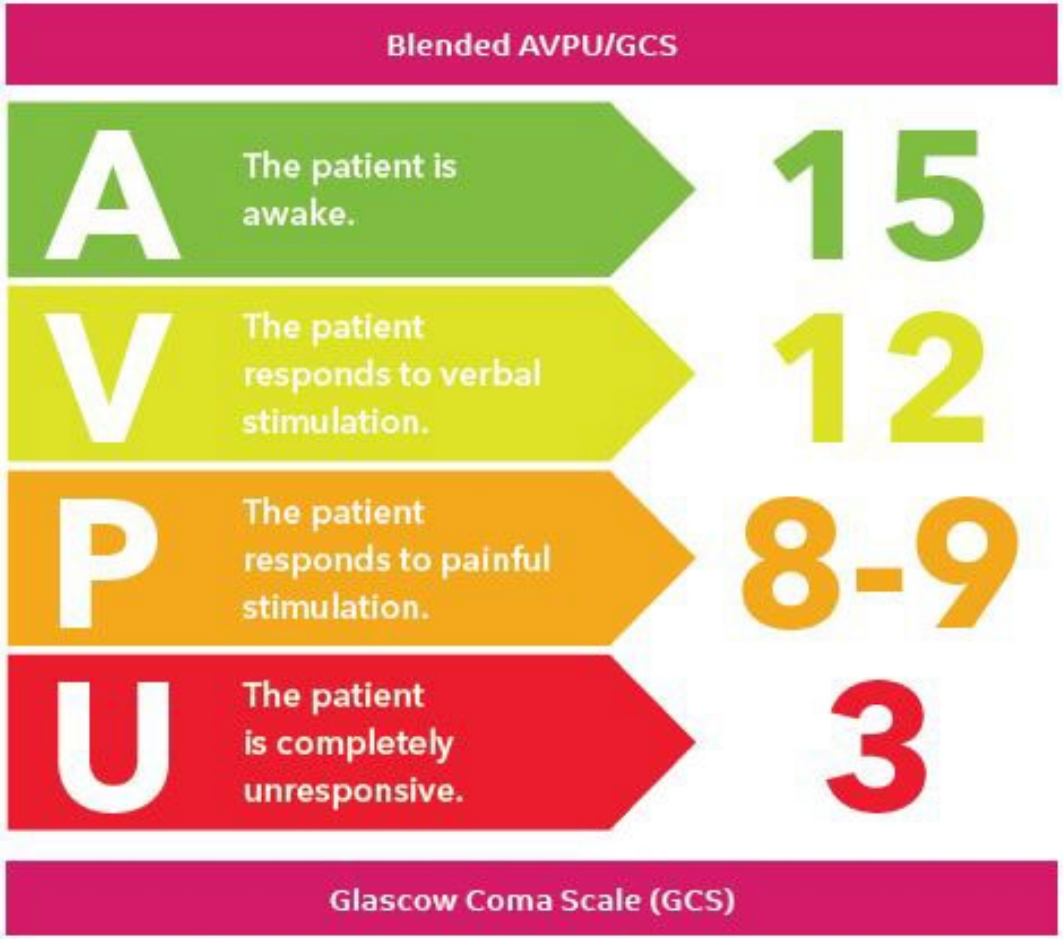
Initial Stabilization
Circulation

- Cardiac monitoring and oximetry
- Vitals signs q 5 mins at least
- 2 large bore PIVs – preferred
  - What is large bore for pediatrics?
  - Consider IO
- Control all hemorrhage
- Bolus 20ml/kg Isotonic Crystalloid (warm if possible)
  - Administer blood products early – Start MTP
  - Remember to administer CaCl after transfusions

Initial Stabilization
Disability

Index	High index of suspicion for Intracranial Hemorrhage (ICH) with alterations of GCS
Transport	Transport to Level 1 Trauma Center or refer early if suspicious and no Pediatric neurosurgeon available – Time is brain!
Know	Know what specialists will be available to care for this patient at the location of transport; don't waste time
PROTECT	PROTECT THAT C-SPINE




Blended AVPU/GCS
A
The patient is awake.
15
V
The patient responds to verbal stimulation.
12
P
The patient responds to painful stimulation.
8-9
U
The patient is completely unresponsive.
3
Glascow Coma Scale (GCS)

AVOID THE "Three H-Bombs"

- **Hyperventilation**
  - Monitor ETCO2
  - Recommended ETCO2 – 35-45 mmHg
- **Hypoxia**
  - Utilize high-flow O2
  - Recommend O2 Sats 95-99%
- **Hypotension**
  - Careful use of pain medications and sedatives
  - Normal BP for age
  - 20ml/kg NS to keep normotensive

Other Considerations for C-spine Injuries

- Altered level of consciousness
- Neck pain
- Abnormal neurological exam
- Findings of neck trauma on physical exam
- Substance abuse
- Inconsolable


MIAMI Jr®

Initial Stabilization
Exposure/Environment

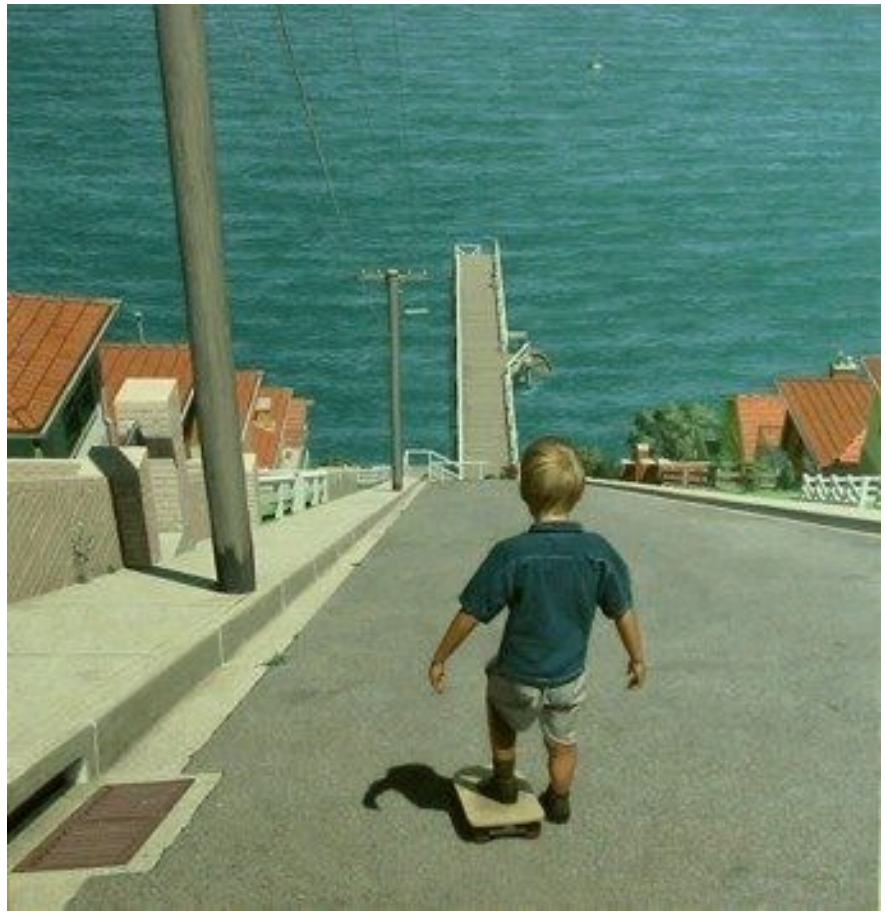
- Children have a larger Body Surface Area
  - Heat loss occurs rapidly
  - Hypothermia can occur quickly
  - Consider warming fluids if large amounts of IVF or blood products are used

- Make sure children are covered
  - Prevents heat loss
  - Less frightening for the child – respect their modesty

- Expose to examine for hidden injuries

Extremity Injuries

- Femur fractures-most common injury (pedestrian MVC) can result in major blood loss
- Palpate extremity for deformity, pain, edema, asymmetry
- Assess circulation distal to injury
- Assess joints above and below injury
- Immobilize extremity above and below injury
- Assess and treat pain
- Antibiotics for open fractures
  - Cefazolin or Ceftriaxone



Pediatric Pain Management

- Weight based dosing
  - [Age in years x 2] + 8 = KG
- Vascular access or not?
  - Intranasal route
- Pain tool
  - FLACC/Wong-Baker Faces
- Blood pressure
  - Normotensive?

EMS Treatment Priorities

- Control hemorrhage
- C-spine/SMR
- TBI Management
  - Avoid the “H-Bombs”
    - **Hyperventilation** – Keep ETCO2 35-45 mmHg
    - **Hypoxia** – Keep O2Sats 95-99%
    - **Hypotension** – Normal SPB for age (70 + (2x age in yrs) or presence of distal pulses
    - Give 20ml/kg NS to keep patient normotensive until blood can be given
- Seizure Management – watch for posturing, eye deviation – treat w/ benzos
- Hypothermia – Large BSA- Keep kids warm
- Pain management – only if patient’s BP is normal

Patient outcome is related to
time from injury ***to*** properly
delivered
definitive care

Questions?

Lisa Dowrick: ldowrick@phoenixchildrens.com

Brief Case Summary/Mechanism

8y M MVC restrained back seat passenger on driver side. Damage to R front of vehicle.

Timeline: EMS

SUMMARY
• 8y M involved in a MVC, restrained back seat passenger • Asystole on scene – parent did CPR • ROSC achieved by EMS • C-spine/SMR • IO L femur • I-gel with BVM

Timeline: Hospital Course

Phoenix Children's

SUMMARY

- Patient admitted to PICU
- Patient non-responsive – vent dependent, paralyzed
- Injuries
  - AOD dislocation
  - Spinal cord severely damaged at C1
  - Moderate to severe TBI – cerebral edema, axonal injuries, hypoxic ischemic injuries
  - R femur fracture

Timeline: Hospital Course

SUMMARY
• Patient required a trach and G-tube for long-term care • Cervical spine fusion needed to stabilize neck prior to trach placement • Ethics called – case of futility • Compassionate withdrawal of life support