Non-Accidental Trauma (NAT) in Pediatric Patients

Ryan E. Fitzgerald, MD
Riley Children’s Hospital
Indiana University
Disclaimer

• All clinical and radiographic images provided are used with permission of Ryan Fitzgerald, MD and Chris Souder, MD, unless otherwise specified
Overview

- Definitions
- History
- Epidemiology
- Evaluation
- Imaging

- Differential Diagnosis
- Clinical Features
  - Nonorthopaedic Features
  - Orthopaedic Features
- Management
- Summary
 Definitions

• Federal law identifies a minimum set of acts that characterize maltreatment

• Defines child abuse and neglect as:
  • Imminent risk of serious harm
  • Death
  • Serious physical or emotional harm
  • Sexual abuse
  • Exploitation
Definitions

• 4 Types of abuse
  – Physical abuse
    • Harming a child with or without intention of injury
  – Neglect
    • Failing to provide a child’s basic needs
      • Physical, medical, educational and emotional
  – Sexual abuse
  – Emotional abuse
History

• Writings from 1st and 2nd century A.D. describe afflictions of children who may have been stricken intentionally

• Ambrois Tardieu, 1860 (Paris) – Professor of Legal Medicine
  – Published 1st article on maltreatment of children
  – Detailed clinical findings, including description of fractures
  – Described parental collusion and response to removal of children

• Ingraham & Matson, 1944
  – Suggested traumatic origin for subdural hematomas in infants, rather than infectious etiology
History

- **Caffey, 1946 (NY)**
  - 6 children with chronic subduralas and 23 long bone fractures
  - Described metaphyseal fragmentation, cortical thickening, fractures in many stages of healing

- **Kempe, 1962**
  - Coined term ‘Battered Child Syndrome’
  - Constellation of physical findings of children who have been abused with discrepancy in reported history
    - Failure to thrive
    - Subdural hematomas
    - Multiple soft-tissue and bony injuries
    - Poor hygiene
  - Greatly increased public awareness, leading to improved legislation
  - The Child Abuse Prevention and Treatment Act - 1974
Epidemiology

- Difficult to determine prevalence and track trends
  - Inconsistencies in reporting
  - Variation in definitions

- The number of children who received child protective services (CPS) investigation increased 8.4% from 2014 to 2018.

- In 2018, 4.3 million referrals to CPS
  - 7.8 million children
  - 678,000 known cases
  - 1,770 deaths
Epidemiology

• In 2018:
  • 84.5% of abused children suffered a single type of abuse
    • 15.5% suffered from 2 or more types
  • Neglect is most common
    • 10.3% physically abused

• Rate of death from abuse is 2.39 per 100,000 children in the US

• Estimated only 50-60% of cases of death due to neglect or abuse are recorded
### Epidemiology
National Child Abuse and Neglect Data System (NCANDS) 2018

#### Exhibit 4–E Maltreatment Types of Child Fatalities, 2018

<table>
<thead>
<tr>
<th>Maltreatment Type</th>
<th>Child Fatalities</th>
<th>Maltreatment Types</th>
<th>Maltreatment Types Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Neglect</td>
<td>-</td>
<td>120</td>
<td>8.1</td>
</tr>
<tr>
<td>Neglect</td>
<td>-</td>
<td>1,081</td>
<td>72.8</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>116</td>
<td>7.8</td>
</tr>
<tr>
<td>Physical Abuse</td>
<td>-</td>
<td>684</td>
<td>46.1</td>
</tr>
<tr>
<td>Psychological Abuse</td>
<td>-</td>
<td>17</td>
<td>1.1</td>
</tr>
<tr>
<td>Sexual Abuse</td>
<td>-</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>Sex Trafficking</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unknown</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>National</strong></td>
<td>1,485</td>
<td>2,027</td>
<td>-</td>
</tr>
</tbody>
</table>

*Based on data from 44 states. Data are from the Child File. A child may have suffered from more than one type of maltreatment and therefore, the total number of reported maltreatments exceeds the number of fatalities, and the total percentage of reported maltreatments exceeds 100.0 percent. The percentages are calculated against the number of child fatalities in the reporting states. Dashes are inserted into cells without any data.*
Epidemiology
National Child Abuse and Neglect Data System (NCANDS) 2018

• 546,365 perpetrators in 2018

• Demographics
  • Age: 83.3% of perpetrators – 18-44 y/o
  • Sex: 53.8% - Female
  • Relationship: 77.5% were parents of the victim
**NAT in a Pandemic**

- During a pandemic mass closures are necessary to mitigate transmission of disease

- Secondary effects of social distancing are present

- In a level 1 pediatric trauma center the total number of trauma patients due to physical child abuse (PCA) were analyzed
  - 13% during the pandemic
  - 4% the year prior to the pandemic (P<0.05)

- Most patients had public health insurance (75%)

- Awareness of this and strategies to mitigate this secondary effect should be implemented

Physical Abuse

• Among infants and young children represent 12-20% of fractures

• **Fractures** are *2nd most common* presentation of physical abuse
  • Found in 25-50% of cases
  • ~20% involve burns

• The youngest patients are most affected and vulnerable
  • Unable to report
  • <1 year → MUCH higher rate of abuse
Exhibit 3–D Victims by Age, 2018
The youngest children were the most vulnerable to maltreatment

Exhibit 4–B Child Fatality by Age, 2018
Children <1 year old died from abuse and neglect at 3.6 times the rate of children who were 1 year old.

Based on data from 32 states. See table 3–5. Percentages do not sum to 100.0 due to rounding.

Based on data from 44 states. See table 4–3
Physical Abuse

**IMPORTANT**

- Second leading cause of mortality in infants and children
- Orthopedic surgeons often first to diagnose NAT victims
- *Unrecognized NAT returned to home:*
  - 30-50% repeat trauma
  - 5-10% risk of death
Risk Factors for NAT

Children of all ages, socioeconomic backgrounds & family types are victims: ANYONE
Risk Factors for NAT

Child factors
- Young (age < 3 yr)
- First born children
- Unplanned children
- Premature infants
- Disabled children
- Psychosocial comorbidities
- Stepchildren
- Single-parent homes

Parental Factors
- Substance abuse
  - 50-80% involve some degree of substance abuse
- Families with low income
  - < $15k were 25x more likely than > $30k
- Unemployed parents
- Children of parents with psychosocial comorbidities
- Children of parents who were abused
Evaluation

• A thorough history and physical exam are essential

• Diagnosis is difficult
  • Must include sociobehavioral factors
  • Clinical findings
Evaluation

• Team approach
  • Pediatrician
  • ER physician
  • Medical social worker
  • Government child protection agencies
  • Law enforcement

• BUT the orthopedic surgeon may be alone in recognition
Myth

It is easy to recognize child with NAT
Evaluation

• Age of Patient

• History

• Social situation

• Other specific injuries/ fractures
History

- Has there been a **delay** in seeking medical treatment?
- Is the **parent reluctant** to give an explanation?
- Is the **injury consistent** with the explanation given?
- Does the story **change**?
History

- The abused child may be overly compliant and passive or extremely aggressive.

- Is the affect appropriate between the child and the parents?
Social Situation

• Families under stress (loss of job, etc.)?

• Drug or alcohol abuse?

• Parents in abusive relationships
Social Situation

• Poor compliance with past medical treatment?

• Children born to adolescent parents?

• Children who suffer from colic?
Other Injuries

• Soft tissue injuries - bruising, burns

• Intraabdominal injuries

• Intracranial injuries

• Multiple fractures in different stages of healing
Physical Examination

Undress the child!
Physical Examination

Careful search for signs of acute or chronic trauma

- **Skin** - bruises, abrasions, burns
- **Head** - examine for skull trauma, palpate, fontanelles if open, consider funduscopic exam for retinal hemorrhage
- **Trunk** - palpate rib cage, abdomen
- **Extremities** - careful palpation
Abusive vs Accidental BRUISING

Redrawn from original courtesy of Samir Abedin, MD.
Radiographic Evaluation

- Skeletal survey for children with suspicion of NAT
  - Highly detailed radiographs that follow guidelines set for by the American College of Radiology are necessary

- “Babygram” is unacceptable - does not provide necessary detail to identify fractures
Radiographic Evaluation

- AAP Section on Radiology:
  - *Mandatory survey in all cases of suspected abuse in children less than 2*
  - Individualized use of survey in children 2-5 yr
  - Not useful in children over 5 yr (exam more specific)
<table>
<thead>
<tr>
<th>Advanced Imaging Modality</th>
<th>American College of Radiology Recommendations</th>
<th>American Academy of Pediatrics Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc-99m whole-body bone scan</td>
<td>Use when skeletal survey is negative with a high clinical concern as an adjunctive exam. <strong>Not</strong> a alternative skeletal survey. Used as a problem solving study not first line.</td>
<td>In setting of a fracture can be used to complement a skeletal survey, <strong>not</strong> substitute for one. Less sensitive than skeletal survey for classic metaphyseal lesions.</td>
</tr>
<tr>
<td>CT head without contrast</td>
<td>Exam of choice in suspected abusive head trauma (AHT). Emergent in setting of head trauma, neurologic changes &lt;24 months. 3-D volume rendering increases sensitivity.</td>
<td>Emergent in setting of head trauma. Study of choice</td>
</tr>
<tr>
<td>MRI Head without contrast</td>
<td>Non-emergent cases.</td>
<td>Non-emergent cases</td>
</tr>
<tr>
<td>Advanced Imaging Modality</td>
<td>American College of Radiology Recommendations</td>
<td>American Academy of Pediatrics Recommendations</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>MRI Spine</td>
<td>Non-emergent cases when imaging head may be considered – presence of spine fracture is almost 10% when positive skeletal survey.</td>
<td>Non-emergent cases when imaging the head to diagnose occult injury</td>
</tr>
<tr>
<td>CT Abd/Pelvis with contrast</td>
<td>Emergent in setting of abdominal trauma. CT Abd/Pelvis without contrast not recommended.</td>
<td>Emergent in setting of abdominal trauma.</td>
</tr>
<tr>
<td>Ultrasonography</td>
<td></td>
<td>Head: Via the anterior fontanelle helps to clarify the nature of extra-axial fluid collections. In conjunction with CT or MRI.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appendicular Skeleton: US may be indicated in epiphyseal separations.</td>
</tr>
</tbody>
</table>
### Utilization of Imaging Modalities in Suspected NAT

<table>
<thead>
<tr>
<th>Advanced Imaging Modality</th>
<th>American College of Radiology Recommendations</th>
<th>American Academy of Pediatrics Recommendations</th>
</tr>
</thead>
</table>
| Skeletal Survey           | • Primary imaging for detecting fractures. Initial imaging for pts <24 months old  
• Signs of intrathoracic or intra-abdominal visceral injury  
• Child with neurologic signs/symptoms, complex skull fracture, apnea, multiple fractures, spine trauma, and facial injury  
• Older children >2: skeletal survey is low yield, targeted imaging in suspected injury based off patient report of pain  
• *Not part of guidelines:*  
• Lateral radiographs of long bones increases detection of metaphyseal lesions by 50%.  
• A repeat performed 2 weeks after initial exam can provide additional information about presence and age of NAT – many perform | • Non-ambulatory infants with bruising  
• Ambulatory infants and toddlers with suspicious bruising  
• Children <2 years old with abdominal trauma  
• Children <3 with fracture concerning for NAT due to pattern, historical inconsistency or other red flag history  
• Little value in children older than 5.  
• Children with head trauma |
Radiographic Work-Up

Skeletal Survey

- AP/LAT skull
- AP/LAT axial skeleton and trunk
- AP bilateral arms, forearms, hands, thighs, legs, feet
Bone Scan

- Usually reserved for highly suspicious cases with negative skeletal survey
- Good at picking up rib and vertebral fractures

Imaging

• Skeletal Survey includes AP/LAT of skull & spine
• MRI of the spine is obtained on a case-by-case basis
• Consider if already obtaining an MRI to evaluate for traumatic brain injury from suspected NAT
• This may help evaluate for ligamentous injury
Fractures

• 2nd most common presentation of NAT
  • **Bruising is most common injury**

• Fracture pattern is typically similar to accidental trauma

• More common in younger children (demanding, nonverbal, defenseless)
  • Children < 1 yr, up to 70% associated NAT
  • Children < 3 yr, 40% w/ NAT
Fractures

• 65% of abused children present with a single long bone fracture

• Long bone fractures in pre-ambulatory infants in absence of bone disease = NAT(until proven otherwise)
Fractures

• Fracture pattern is not specific (spiral, transverse, etc.)
  • Transverse fractures are more common than spiral fractures in NAT

• Multiple fractures at different stages of healing is highly specific
Specificity of Radiologic Findings in NAT

• High Specificity:
  • Metaphyseal corner lesions, posterior rib fractures, scapular fractures, spinous process fractures, sternal fractures

• Moderate Specificity:
  • Multiple fractures, fractures of different ages, epiphyseal separations, vertebral body fractures, digital fractures, complex skull fractures

• Common in NAT but Low Specificity:
  • Clavicular fractures, long bone shaft fractures, linear skull fractures

Kocher & Kasser. JAAOS 2000
Fractures in Different Stages of Healing

- Present in 70% of physically abused children < 1 yr
- Present in 50% of all abused children

Fractures of NAT - High Specificity

- Classic metaphyseal lesions (CML)
  - Formerly known as a metaphyseal corner fracture or bucket-handle fracture
- Femur: < 1-year-old (any pattern)
- Humeral shaft: < 3-year-old
- Sternal fractures
- Posterior rib
- Digit fractures in non-ambulatory
Myths

• **Myth:** Spiral fractures have a high association with NAT

• **TRUTH:** Both transverse and spiral fractures are seen in NAT
  - Transverse is more common in NAT cases
  - Spiral fractures are common in accidental trauma
    - Bone is weakest in tension/torsion failure mechanism
    - Fracture configuration is **NOT** specific for NAT
Facts

- Spiral fractures can occur accidentally
- Spiral only 8-36% of fractures in NAT
- Toddlers fx of tibia common accidental injury
Femur Fractures

- Femur fractures in children < 1 year
  - NAT (60-70%)

- Femur fractures in children > 1 year
  - Accidental (60-70%)
• **Strong evidence** supports that children younger than 36 months with a **diaphyseal femur** fracture be evaluated for child abuse.
  
  • Level 2 evidence – Strong recommendation
  • Based on 3 large population-based studies
     • 2 reported: 14% and 12% of fractures were result of abuse in children zero to 12 months, and zero to 3 years, respectively
2009 AAOS Clinical Practice Guidelines
Treatment of Pediatric Diaphyseal Femur Fractures
(updated 2015)

• Emphasis on history and physical in evaluation

• Selective use of a skeletal survey

• Despite this, Oetgen et al. showed poor utilization of this guideline with only 48% of this population being evaluated for NAT
Classic Metaphyseal Lesion (CML)

- Pathognomonic of NAT
- Less common than diaphyseal fractures
- More specific for NAT
CML

- Traction/rotation mechanism of injury

- Planar fracture through the primary spongiosa
Fractures in Unusual Locations

- Requires a violent blow or traction injury
  - Distal clavicle
  - Transphyseal Distal humerus
  - Scapula
  - Acromial tip
  - Proximal humeral metaphysis

Abzug JM et al. JAAOS 2016
Distal Humeral Transphyseal Fractures

• Typically seen in children <3

• A result of birth trauma, accidental trauma or NAT
  • A detailed history - high index of suspicion for NAT

• Often will be reported as an elbow dislocation

• Supakul et al reported >50% were missed by initial radiology
Distal Humeral Transphyseal Fractures

- Usually unstable fractures that require operative care

- Arthrogram with percutaneous vs. open pinning may be required

- With prompt recognition and management, outcomes are generally excellent
Humerus Fractures

• Diaphyseal fractures in children < 3 yr

• Highly suggestive of NAT
• As high as 18% has been reported
Rib Fractures

- Secondary to AP or lateral compressive forces
  - Squeezing, direct impact, shaking
- Present in 5-25% of abused children
- Posterior & posterolateral fractures most common and highly specific
Rib Fractures

- Indicator of severe trauma due to relative compliance of rib cage
  - Associated with high risk of mortality
- Up to 50% of all postmortem fractures are rib fractures
- Only 35% of rib fractures are visible on skeletal survey
Spine Fractures

• Only 0-3% of fractures

• Most asymptomatic compression fractures detected on skeletal survey

• Fracture or avulsion of spinous processes is fairly specific to abuse
  – Most in lower thoracic and upper lumbar spine
  – May be multiple levels
  – Secondary to hyperflexion and hyperextension with shaking
Spine Fractures

• Knox et al, 2014
  • 726 cases of NAT – Spine injury present in 1.5%
  • 11/342 spine injuries were NAT – 3.2%
    • All patients were under 2 years
    • Average age of 7 months
  
  • Of patient under 2 years, NAT was the most common mechanism of injury (38%)

  • 8/11 patients had injuries to the patients were cervical
    • 7 of the 8 were atlantoaxial or atlanto-occipital
Management - NAT Suspected

- Professional, tactful, nonjudgmental approach
- Explain workup to parents as standard approach to specific ages/injury patterns
- Early involvement of child protection team if available
- Early contact/involvement of child’s primary care physician
Management - Documentation

• Medical records are part of a legal record
• Carefully document history, physical exam and radiographic findings
• Document evidence supporting physical abuse
• Document statement regarding level of certainty of abuse
Legal Aspects of NAT

• All states require reporting of suspected cases of abuse by medical professionals

• Need only reasonable suspicion to report suspected maltreatment

• Law affords immunity from civil or criminal liability for reporting in good faith
## Differential Diagnosis of Non-Accidental Trauma

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidental Injury</td>
<td>Age, mechanism of injury, no bruising and associated injuries, no delay in presentation, no fractures in other stages of healing</td>
</tr>
<tr>
<td>Normal radiographic variants</td>
<td>Angulation of ossifying metaphysis, cortical irregularity, spurring, juxtaphyseal variants</td>
</tr>
<tr>
<td>Birth Trauma</td>
<td>Obstetric history, callus within 2 weeks of birth, humeral and clavicular fracture common, distal humeral physeal separation can occur</td>
</tr>
<tr>
<td>Osteogenesis Imperfecta</td>
<td>Family history, short trunk, marked deformities of lower extremities, triangular facies, thin skin, muscle atrophy, osteopenia, blue sclera, poor dentition (dentinogenesis imperfecta), wormian bones</td>
</tr>
<tr>
<td>Rickets</td>
<td>Potentially family history, potentially exclusively bottle fed, physeal widening, metabolic abnormalities, deformity or deviation from mechanical axis LE, osteopenia, Looser’s lines, laboratory anomalies</td>
</tr>
</tbody>
</table>
## Differential Diagnosis of Non-Accidental Trauma

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffey Disease</td>
<td>Family history, diffuse periosteal elevation, mandibular radiographic changes, irritability, inflammation and swelling, stiffness of joints</td>
</tr>
<tr>
<td>Leukemia</td>
<td>Metaphyseal lucencies, diffuse osteopenia most common radiographic finding, sclerotic bands in older children, systemic findings, laboratory abnormalities, bone-marrow biopsy findings</td>
</tr>
<tr>
<td>Congenital syphilis</td>
<td>Metaphyseal erosions, periosteal bone formation, serologic tests, pseudoparalysis</td>
</tr>
<tr>
<td>Congenital insensitivity to pain</td>
<td>Infection, joint destruction, neurologic abnormalities, family history</td>
</tr>
<tr>
<td>Coagulation disorders</td>
<td>Bruising, coagulopathy, laboratory abnormalities</td>
</tr>
</tbody>
</table>
Summary

- Child abuse is pervasive

- Major cause of disability and death among children

- Diagnosis involves careful consideration of
  - Sociobehavioral factors
  - Clinical findings
  - Radiographs
Summary

• Fractures are second most common presentation of physical abuse, after skin lesions
• No pathognomonic fracture pattern of abuse
• Suggestive findings include
  – Certain metaphyseal lesions
  – Multiple fractures in various stages of healing
  – Posterior rib fractures
  – Long-bone fractures in children less than 3 years old
Summary

• Management should be multidisciplinary

• Risk of repeated abuse and death are substantial
References

References


References

• Hansen KK, Prince JS, Nixon GW. Oblique chest views as a routine part of skeletal surveys performed for possible physical abuse--is this practice worthwhile? Child Abuse Negl. 2008;32(1):155-159.