“...to the informed physician, the bones tell a story the child is too young or too frightened to tell.”
Kempe 1962
Overview

• The Skeletal Survey
  – 2011 ACR Guidelines
  – Can we limit the images?

• 3D cranial CT model

• Bone Scintigraphy – F-18 PET

• MRI, CT and US – Problem solving tools

• Reporting – Standardized templates
Use of Skeletal Surveys to Evaluate for Physical Abuse: Analysis of 703 Consecutive Skeletal Surveys

AUTHORS: Shanna O. Duffy, BS,a Janet Squires, MD,b Janet B. Fromkin, MD,b and Rachel P. Berger, MD, MPHb

aBoonshoft School of Medicine, Wright State University, Dayton, Ohio; and bDepartment of Pediatrics, Children’s Hospital of Pittsburgh of UPMC, Pittsburgh, Pennsylvania

RESULTS: Of the 703 SSs, 10.8% yielded positive results. Children <6 months of age, children with an apparent life-threatening event or seizure, and children with suspected abusive head trauma had the highest rates of positive SS results. Of children with positive SS results, 79% had ≥1 healing fracture.

CONCLUSIONS: This is the largest study to date to describe the use of the SS. Almost 11% of SS results were positive. The SS results influenced directly the decision to make a diagnosis of abuse for 50% of children with positive SS results. These data, combined with the high morbidity rates for missed abuse and the large proportion of children with healing fractures detected through SS, suggest that broader use of SS, particularly for high-risk populations, may be warranted. Pediatrics 2011;127:e47–e52
Imaging the Skeleton in Suspected Abuse

• < 2 yo
  – Mandatory skeletal survey - using ACR standards
  – 2 wk follow up skeletal survey or bone scan

• 2-5 yo
  – Skeletal survey or bone scan

• >5 yo
  – Little value in skeletal survey and bone scan
  – Image areas of clinical concern

Imaging the Skeleton

• Other considerations
  – MRI and US in selected cases
  – Image twin of abused infant
  – Fractures in neglected or sexually assaulted child is low, do skeletal survey in selected cases

AAP: Admit child to the hospital for safety until adequate studies performed
ACR Standards

- Adequate spatial resolution
- High signal to noise, sufficient mAs (dose)
- Low kVp 50-70 for high contrast
- Monitored by radiologist
- Cone to anatomic region
- Injuries viewed in at least two planes

NEW: OBLIQUE VIEWS OF THE CHEST
Follow-Up Skeletal Survey

• Adds information in 14-61% cases
• Identifies new fractures
  – 62-91% Ribs and CMLs
• Confirms suspected fracture
• Clarifies a finding, normal variant
• Aids dating injuries

In patients with normal initial skeletal survey, the follow up study can show additional information in 8-12% of the cases

Kleinman. AJR 1996;167:893-896
Bennett. BMC Research Notes 2011;4:354
Sonik. Child Abuse Negl 2010;804-806
Harlan. Pediatr Radiol 2009;962-968
Can we Decrease the Images in the Skeletal Survey?
Follow-up skeletal surveys for nonaccidental trauma: can a more limited survey be performed?

Routine Protocol

• Initial: 21 views
• Follow-up: 17 views
• New information in 37%

Limited 15-Views

1. AP bilateral oblique chest
2. AP humeri
3. AP forearms
4. AP hands
5. AP femurs
6. AP tib/fib
7. AP feet

No pelvis or lateral spine
Although the medical diagnosis is not altered, there may be an impact on child protection proceedings and legal outcomes if all the fractures not documented
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Head Trauma
AP, Townes, Both Laterals
CHB: 3D Cranial Models

• 3D models changed the initial CT interpretation in 38% (10) cases
  – Identified additional fractures
  – confirmed a suspicious fracture or normal variants

• Protocol:
  – Non-contrast contiguous 5 mm thick axial images
  – Reconstruct 0.63 mm axial images bone algorithm, generate 3 mm coronal and sagittal reformats.
  – 3D model performed in Vitrea or Voxar

CHB: 3D models routinely performed in all infants
Skeletal survey rarely adds additional information beyond the clinical history and physical findings.
Use of Skeletal Surveys to Evaluate for Physical Abuse: Analysis of 703 Consecutive Skeletal Surveys

Duffy. Pediatrics 2011;127:e47-e52

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aBoonshoft School of Medicine, Wright State University, Dayton, Ohio; and bDepartment of Pediatrics, Children’s Hospital of Pittsburgh of UPMC, Pittsburgh, Pennsylvania

3 infants with isolated skull fractures had additional findings in the skeletal survey that influenced the diagnosis of abuse.
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Role of Bone Scan

- High suspicion of abuse, equivocal or normal skeletal survey
- Child will not be in a safe environment without further abuse documentation
F-18 NaF PET

- Higher resolution
- Multiplanar imaging
- Rapid scanning after administration
- Dose comparable to $^{99m}$Tc MDP: total effective dose of 0.3 rads for 10 kg patient
- Dose 10x higher than skeletal survey
- Requires sedation
  - Better sensitivity than skeletal survey for all fractures and chest/posterior rib fractures (SS:152 vs F-18:200)
  - Lower sensitivity for CMLs

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Ultrasound

- Epiphyseal displacement
- Fracture extension into unossified epiphysis especially in the elbow
- Evaluation of joint effusions
Wootton-Gorges et al Child Abuse Negl 2008, 32:659-663
Whole Body MRI

- Joint effusions
- Muscle hematomas
- Subcutaneous/Muscle edema
- Salter II/Epiphyseal separation

- WB-MRI insensitive to the high specificity indicators of abuse and currently cannot replace the skeletal survey

Perez-Rossello. AJR 2010;195:744-750
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Standardized Reporting

- Radiologist:
  - “A check-list” to assure completeness
  - Helps meet accreditation requirements
  - Improves reimbursements
  - Use of radiology terms RadLex
  - Report search for research, categorize data

- Referring Physician
  - Improves clarity of communication
HISTORY: The patient is a [#] year(s) and [#] month old [male|female] with []

COMPARISON: [None*]

TECHNIQUE: Frontal and lateral views of the skull, chest, abdomen, and spine, bilateral oblique views of the ribs, and frontal views of the upper and lower extremities obtained according to the guidelines for the American College of Radiology for the investigation of possible child abuse are submitted for interpretation.

FINDINGS: [There is no evidence of fracture]. [There is no bony abnormality]. [The soft tissues, including the chest and abdomen appear normal].

[Definite | probable | possible] fractures are noted with an estimation of their approximate age [acute | early healing | advanced healing] as follows:

Head and neck: [none*]
Chest and ribs: [none*]
Right ribs: [none*]
Left ribs: [none*]
Pelvis: [none*]
Long bones: [none*]
Hands and feet: [none*]

The bone density appears [normal | decreased].
The bone age is [approximately | normal | delayed | advanced] for age according to the standards of Greulich and Pyle.

This report has been called to the [Emergency Department staff | Forensic pediatrics staff | Other] at <time> on <date> by Dr. [].

IMPRESSION:
[Normal | Abnormal] skeletal survey.
[Further radiographs to better visualize these findings include: ]
[Follow up skeletal survey/selected radiographs are recommended in 10-14 days].
Take Home Points

- Skeletal surveys now include oblique images of the ribs
- Multicenter studies are needed to determine if the initial and follow up skeletal surveys can be performed with less images
- Other imaging tools
  - F-18 PET for equivocal skeletal survey finding
  - 3D CT for evaluation of skull
  - MRI and US for evaluation of soft tissue injuries and epiphyseal separation
  - CT to confirm rib fractures or further evaluate complex fractures
- Standardized reporting and data entry tools