Radiologic Evaluation of Scoliosis in Young People

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Classification of Scoliosis

- Congenital
  - Failure of formation
  - Failure of segmentation
  - Mixed

- Neuromuscular
  - Myopathic
    - Arthrogryposis
    - Muscular dystrophy
  - Neuropathic
    - Upper motor neuron
    - Lower motor neuron
    - Dysautonomia (Riley-Day Syndrome)

- Idiopathic
  - Infantile (0-3 years)
  - Juvenile (3-10 years)
  - Adolescent (10+ years)

- Others
  - Neurofibromatosis
  - Mesenchymal (Marfan’s, Ehlers-Danlos)
  - Traumatic
  - Tumors
  - Osteochondrodystrophies
Definitions

- **Scoliosis**: Lateral curvature of the spine.
- **Non-Structural curve**: has no structural component, it corrects on supine side-bending films.
- **Non-Structural Scoliosis**: reversible lateral curvature without rotation.
- **Structural curve**: lacks normal flexibility.
- **Structural Scoliosis**: Irreversible lateral curvature of the spine with rotation of the vertebral bodies in the area of the major curve.
- **Major curve**: The largest structural curve.
- **Compensatory curve**: A curve that is above or below a major curve that serves to maintain normal body alignment.
Curves Patterns

- Most common is a right thoracic curve in adolescent females.

Images from the University of Iowa's Virtual Hospital at http://www.vh.org/Providers/Textbooks/AIS/02Curve.html
Physical Exam

- Evaluation of patient in standing and bending positions (forward and lateral)
- Tilt/asymmetry of shoulders and pelvis
- Lower leg length measurement to r/o leg length discrepancy
- Detailed neurologic exam
- Signs of syndromic or hereditary disorders
- Tanner staging to determine future growth
Role of radiography in scoliosis

• Document severity
• Determine skeletal maturity
• Monitor progression
• Evaluate for non-Idiopathic causes of scoliosis (spinal, soft tissue, systemic pathology).
• Ensure adequacy of bracing/surgery
Idiopathic Scoliosis

- One in 20 children have some degree of deformity of their spine
- Unknown etiology (multifactorial), but familial inheritance pattern of some sort is suspected
- Female predominance
- Not associated with back pain or fatigue
Plain-Film Technique

Radiation Reduction

• PA projections now used (AP was formerly the standard).
• Contoured filter used in order to balance the higher density of the abdomen and pelvis with the lower density of the thorax.
• High-speed film to reduce exposure time necessary.
• Intensifying screens (e.g. rare earth screen) to reduce exposure by converting x-ray photons to light.
• Breast and gonad shields
• Collimation
Plain Film Technique

continued

• All upright films taken at a distance of 6ft – standardizes exams.
• Initial evaluation: Standing PA and lateral films.
• Flexibility of the curve is evaluated with supine side-bending films (may only be needed preoperatively)
• Standing PA studies are used for follow-up
• Lateral films beyond initial evaluation are not necessary unless spondylolysis or spondylolisthesis is suspected.
• Traction is used in patients with neuromuscular disease with muscles weakness/paralysis that prevents active side-bending.
Plain Film Technique

continued

• By convention, all spinal films are viewed as if looking at the patient from the back – the patient’s right side is on the viewer’s right side.
Patient#1

- 15yo F with 4 year h/o Right thoracic deformity ("rib hump")
- No symptoms
**Cobb Method**

- Universal standard for measuring degree of curvature.
- Identify vertebrae at both ends of the curve (“end vertebrae”) – The pedicle levels with the greatest tilt from the horizontal plane.
- With use of a goniometer: – Construct lines along the superior endplate of highest vertebrae and inferior endplate of lowest vertebrae. – Draw lines perpendicular to those lines. – Determine angle.

Image courtesy of Children’s Hospital Boston, Teaching File
Vertebral Rotation

• As a curve increases, the vertebrae rotate.
• Spinous process deviates toward the concave side.
• The vertebral body rotates toward the convex side.
• Ribs become closer together on the concave side and separated on the convex side.
Vertebral Rotation
The Nash and Moe Method

- **Zero**: Pedicle shadows are equal distance from the sides of the vertebral body.
- **Grade I**: “pedicle shadow on the convexity has moved from the edge of the vertebral body.”
- **Grade II**: Intermediate between I and III.
- **Grade III**: Pedicle shadow is in middle of vertebral body.
- **Grade IV**: Pedicle shadow is past middle of the vertebral body.

Image from Moe’s Textbook of Scoliosis and Other Spinal Deformities.
Approximating Skeletal Age – Risser’s Sign

- Ossification of the iliac apophysis – begins laterally (at the anterior superior iliac spine) and progresses postero-medially (towards the posterior superior iliac spine) to eventually cap the entire iliac crest.

- Risser 1-5 used as measure of skeletal maturity and therefore to predict progressive of scoliosis.

- Incidence of curve progression is higher with Risser 0-1 compared to Risser 2 or more.

Image from Richardson, http://www.rad.washington.edu/mskbook/scoliosis.html
**Determining Skeletal Age – Hand Film**

- Compare plain film of the left hand and wrist with the standards of the “Radiographic Atlas of Skeletal Development of the Hand and Wrist” by Greulich and Pyle.
  - **Distal ends of radius and ulna**
  - **Carpals** (in the order that they appear: Capitate, Hamate, Triquetrum, Lunate, Scaphoid, Trapezium, Trapezoid, Pisiform)
  - **Metacarpals**
  - **Phalanges**
  - **Sesamoids**

Image from “Radiographic Atlas of Skeletal Development of the Hand and Wrist” by Greulich and Pyle
Patient#1
continued

• Original plain film revealed a curve with a Cobb angle measuring 55 degrees.
• Within a few months, the curve had progressed to greater than 60 degrees.
• Based on degree of curvature and continued progression, surgery was determined to be treatment of choice.
• Cotrel-Dubousset instrumentation was placed from T5-T12 and the spine was fused posteriorly.
• Subsequent radiograph confirmed correct placement of instrumentation and satisfactory correction of the curve.
Treatment for Idiopathic Scoliosis

- **Observation** for curves less than 25 degrees.
- **Bracing** to halt progression of curvature (not correct) above 25 degrees.
- **Surgical fusion** of the spine with curve greater than 40-50 degrees after the growth spurt.
- Untreated scoliosis can lead to variety of problems including chronic back pain and compromise of cardiopulmonary function.
Patient #2

- 14yo F with known scoliosis with double curve of lumbar and thoracic area.
- Noted to have progression of curves, referred to Orthopaedic Surgeon for evaluation.
- Suspician while taking history and conducting physical exam leads Surgeon to check for additional signs…exam reveals findings similar to the following:
Physical Exam findings

Physical findings suggest...

Images from Moe’s Textbook of Scoliosis and Other Spinal Deformities, 3rd edition.
Marfan’s Syndrome

- Scoliosis occurs in 40-70% of patients with Marfan’s.
- Tendency is for curvature to progress - Surgical correction is treatment of choice.
- Can be painful.
- Thoracic curves are usually to the Right.
- Lumbar curves are usually to the Left.
- Double major curves are frequent.
- Thoracic lordosis is very common and it is often associated with a lumbar or thoracolumbar kyphosis.
- Associated with high grade spondylolisthesis

Image from http://www.scoliosisrx.com/
When plain films are not enough...
Patient #3

• 16yo M with back pain in low thoracic/upper lumbar region.
• Pain is worse at night and is partially relieved by Aspirin.
• No h/o trauma.
• No neurologic deficits.
• Original plain film x-ray revealed a very mild thoracolumbar scoliosis to the right side.

History suggestive of...
Osteoid Osteoma

- Unknown etiology.
- Pain is the presenting symptom
- 2-3 times more common in males
- Highest incidence in second decade of life (with range of 5-40 years old).
- Preference is for the long bones (50% in femur and tibia, 20% in hands or feet, vertebral involvement is rarer).
- Lesions usually in posterior elements of the vertebra.
- Lumbar > Cervical > Thoracic
Radiologic Findings in Osteoid Osteoma

- Lesion usually on concave side of the curvature and is often in the apical posterior elements.
- Minimal correction with side bending.
- Lesions on plain film are an area of lucency with a central nidus and a sclerotic rim. They have variable amounts of calcifications.
- Bone scintigraphy demonstrates well-defined area of increased tracer uptake by the osteoma. This is surrounded by an wider zone of more diffuse increased activity “Double density sign”
- CT will show a central nidus with low attenuation, surrounded by variable amounts of dense sclerosis.
Osteoid Osteoma: Bone Scintigraphy

Increased radiotracer uptake in the posterior elements of the T10 vertebral body (left side)

Images courtesy of Children’s Hospital Boston – Teaching File
CT Imaging of T10

- Well circumscribed, lucent lesion
- Involving the lamina and pedicle of the left side of T10.
- Calcifications
- Mildly sclerotic rim

Image courtesy of Children’s Hospital Boston, Teaching File
Patient # 4

• 10yo F
• p/w scoliosis
• Found to have asymmetric reflexes on exam
• Plain film evaluation reveals 43° thoracic curve.

A spinal MRI revealed...

Photo from Meyer JS, Radiologic Clinics of North America: Pediatric Musculoskeletal Radiology, July 2001
Syrinx

- MRI of cervicothoracic spine revealed a Syrinx from C5-T2.
- Syrinx was decompressed and the curve reduced to 12°.

Photo from Meyer JS, Radiologic Clinics of North America: Pediatric Musculoskeletal Radiology, July 2001
Patient #5

- 43yo F who presented for unrelated reason.
- CXR was obtained and Radiologist noted scoliosis of the thoracic spine.
- Consulted with patient’s clinical physician for further history – patient recalled having some “skin tumors” removed from chest area as a child.
- Radiologist was first to suggest diagnosis of Neurofibromatosis in this patient.

Image courtesy of Dr. Ferris Hall, BIDMC Dept of Radiology.
Plain Film Findings in Neurofibromatosis

- Short segment, usually thoracic
- Said to have sharp angulation with associated kyphosis
- Paravertebral soft tissue mass.
- Deformed transverse processes
- Enlarged vertebral foramina.
- Marked rotation of spinal curvature.
- Coarsened and sclerotic trabecular pattern.
- Rib penciling
- Vertebral body scalloping
- Dural ectasia
Neurofibromatosis

- Scoliosis is the most common skeletal abnormality in patients with NF-1.
- CT used to evaluate the anatomic connections between the heads of the ribs in order to r/o dislocation that could cause cord compression.
- MRI used to evaluate for intraspinal lesions.
MRI Images of Neurofibromas
from different patients

Image from ACR Radiological Learning Laboratory

Image from http://www.yoursurgery.com
In Conclusion...
Plain film

• Indication:
  – Used in every patient with scoliosis

• Technique:
  – Standing PA (+/- lateral, +/- supine side-bending films)
  – Taken at a distance of 6 feet with utilization of a variety of methods to reduce a patient’s exposure to radiation

• Purpose:
  – Document severity – curvature and rotation
  – Determine skeletal maturity – Risser’s Sign, hand films compared to Greulich and Pyle Atlas
  – Structural vs. non-structural (with supine side-bending films)
  – Evaluate for associated kyphosis, lordosis, spondylolysis, spondylolisthesis.
  – Monitor progression
  – Ensure adequacy of bracing/surgery
Nuclear Scintigraphy  
(“Bone Scan”)

• Indication:
  – Pain

• Technique:
  – Use of radionuclides (such as technitium-99m-labeled polyphosphate) to demonstrate changes in local blood flow and degree of metabolic activity. Serves to locate a “hot spot”.

• Purpose:
  – Identification of benign tumors (e.g. osteoid osteomas, osteoblastomas), primary malignant tumors, metastases to bone, osteomyelitis and stress fractures.
CT

- **Indication:**
  - Known/suspected vertebral pathology
- **Purpose:**
  - Useful in bone tumor cases – localize lesion in order to plan surgical approach.
  - Used for preoperative evaluation of vertebral deformities that are associated with:
    - Congenital scoliosis
    - Diastematomyelia
    - Dysraphism
    - Meningomyelocele
**MRI**

- **Indications:**
  - Routine imaging in evaluation of children less than 11 years old (to r/o intraspinal pathology)
  - Should be done in every patient with:
    - Very rapid curve progression
    - Unusual curve pattern
    - Back pain
    - Neurologic deficiency
    - Neck stiffness
    - Headache
MRI

• Technique:
  – Image from brainstem to sacrum
  – T1 weighted images +/- Gadolinium (use when examining for cord neoplasms)

• Purpose:
  – Test of choice for assessment of spinal canal contents and evaluation of soft tissue in the paraspinal area.
    • Tumor, syrinx, neurofibromatosis, cord compression, atrophy, chiari malformations, cord tethering, syringomyelia, diastematomyelia, spinal dysraphism, etc.
References

- Blackman R. Scoliosis Treatment [http://www.scoliosisrx.com/]
- Richardson ML. “Scoliosis” in Approaches To Differential Diagnosis In Musculoskeletal Imaging [http://www.rad.washington.edu/mskbook/scoliosis.html]
- Spine Tumor Surgery. [http://www.yoursurgery.com]
Acknowledgements

Thanks to all the people who were willing to take a moment or two to answer questions...

- Michael Larson, the man who can scan
- Pamela Lepkowski
- Ferris Hall, MD
- Lawrence Karlin, MD
- Joseph Makris, MD
- Wendy Dole, MD
- Gillian Lieberman, MD
- The staff at the Children’s Hospital Film Library
- M.R. Geller at the Children’s Hospital Library
- Larry Barbaras and Cara Lyn D’amour, the Webmasters
- My classmates, whom I thank for their friendship, inspiration, tasty snacks, and the infamous black eye.

Image from “Textbook of Disorders and Injuries of the Musculoskeletal System” by RB Salter
A common cause of scoliosis in the past that we, thankfully, don’t see much of anymore.