Imaging Osteosarcoma & Surgical Outcomes

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Patient 1: Clinical presentation

15 year old boy presents with…
“Pain in the upper part of my left knee”

The pain became progressively worse over 3 months

**He now reports…**
Moderate pain at rest
Severe pain when bearing weight
Frequent waking at night with knee pain

He works out “once in a while”
He denies a history of trauma and infection
He denies previous problems with his left knee
No significant past medical history or family history
No fever, chills, nausea, or vomiting
Patient 1: Clinical presentation

15 year old boy presents with…
“Pain in the upper part of my left knee”

**Physical Exam**
No evidence of injury
Marked tenderness to palpation
Diffuse swelling of the distal femur
Firm, circumferential, fixed mass

Limited range of motion (painful!)
Intact sensation & motor function
Strong pulses throughout extremity
No lymphadenopathy
Patient 1: Differential diagnosis:
Atraumatic knee pain in an adolescent

- Juvenile rheumatoid arthritis
- Reactive arthritis
- Infectious arthritis
- Osteomyelitis
- Osteochondritis dessicans
- Degenerative joint disease
- Tendonitis, bursitis
- Chondromalacia
- Referred pain

- Malignancy
  - Ewing’s sarcoma
  - Osteosarcoma
  - Rhabdomyosarcoma
  - Lymphoid neoplasm
  - Metastasis

Consider tumor, inflammation & infection

M. M. Reeder and B Felson, Gamuts in Radiology, Springer-Verlag Telos, 3rd edition, 1993
S. Kahan and E. G. Smith, Signs & Symptoms, Blackwell publishing, Massachusetts, 2004
Where to begin?
Menu of tests: Atraumatic knee pain in an adolescent

1. **Radiograph**
   - Anteroposterior (AP)
   - Lateral
   - Notch or tunnel view
   - Axial view
   - Ipsolateral hip films (AP/frog leg lateral)

   \{ “Mandatory workup”
   \}

   ACR guidelines

2. Nuclear study: radionuclide bone scan
3. Ultrasound (US)
4. Computed tomography (CT)
5. Magnetic resonance imaging (MRI)
6. Aspiration/arthrogram
7. CT postarthrogram

American College of Radiology, *ACR Appropriateness Criteria*,
Patient 1: Radiograph of the left knee – AP view

Soft tissue
1. Increased amorphous density
2. Diffuse spiculated mass
3. Continuous with metaphysis

Bone from far
4. Osteosclerotic distal femur
5. Highest density at the metaphysis
6. Wide zone of transition

Bone from near
7. Ill defined cortical/medullary border
8. Periosteal reaction: lamellar & spiculated
9. Physis open, difficult to assess

Joint
10. Difficult to assess

Image courtesy of Dr. Jim Wu
Patient 1: Radiograph of the left knee – AP view

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Image courtesy of Dr. Jim Wu
Patient 1: Radiograph of the left knee – AP view

- **Soft tissue**
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  8. Periosteal reaction: lamellar & spiculated
  9. Physis open, difficult to assess

- **Joint**
  10. Difficult to assess

*Image courtesy of Dr. Jim Wu*
Patient 1: Radiograph of the left knee – lateral view

Soft tissue
1. Amorphous & focal densities

Bone from far
2. Osteosclerotic distal femur with a wide zone of transition

Bone from near
3. Poor cortical/medullary border
4. Periosteal reaction: lamellar & spiculated
5. Classic “Codman triangle”

Joint
6. Well aligned

Image courtesy of Dr. Jim Wu
Radiologic criteria suggesting bone malignancy

- Codman triangle
- Irregular, ill defined margins “Wide zone of transition”
- Periosteal right angle spiculation “Sunburst”
- Periosteal lamellation “onion skin”
- Adjacent soft tissue mass
- Osteoid matrix

Bone destruction
Cortical erosion or destruction

Evidence of metastasis (?)


Image courtesy of Dr. Jim Wu
Patient 1: Narrowing the differential for...

“...an aggressive appearing, sclerotic bone lesion of the distal femur with a significant periosteal reaction”

Ranked differential diagnosis
1. Osteosarcoma (ages 10-25)
2. Ewing’s sarcoma (ages 5-20)
3. Metastasis

→ Plan
Magnetic Resonance Imaging
Radionuclide study
Chest radiograph
CT guided biopsy
Patient 1: MRI – Coronal STIR of the left knee

Extent of disease for surgical planning
Excellent marrow & soft tissue contrast
Detailed anatomy

STIR suppresses signal from fat
Sensitive to edema and bone pathology
Normal marrow and fat: dark
Fluid & edema: bright

Bone findings:
1. Increased signal in the medullary canal
2. Irregular pattern in the metaphysis
3. Ill defined cortical outline
4. Extension past the physis

Soft tissue findings:
5. High signal around distal femur, suggesting edema and growth into the surrounding tissue

Image courtesy of Dr. Jim Wu
Patient 1: MRI – Axial STIR of distal femur

High signal in the medullary canal (1) and soft tissue (2)

Image courtesy of Dr. Jim Wu
Companion patient 1, osteosarcoma: An example of bone scintigraphy

Evaluation of metabolic activity

Technetium, $^{99}$Tc$^m$, coupled to methylene diphosphate

IV administration

Radioactive decay yields a 142.7 keV $\gamma$-ray

2D projections constructed with a scintillation camera

Extent of disease & metastasis

“Hot spots” arise in fractures & tumors

Significant uptake in the distal femur

Osteosarcoma: CT guided bone biopsy

Histology confirmed radiological suspicion of osteosarcoma in the distal femur of patient 1

1. Formation of new, abnormal bone with a coarse lacelike architecture
2. Variable tumor cell size & shape, with hyperchromatic nuclei and mitoses

V. Kumar, A. K. Abbas, N. Fausto, Robbins and Cotran Pathologic Basis of Disease, 7th edition, Elsevier, 2005
Now for a brief discussion of osteosarcoma
What is osteosarcoma?

Definition: a tumor of the skeleton in which cancerous cells produce bone matrix

2nd most common primary malignant bone tumor
Peak incidence in males 10-20 years of age
3 cases/million population/year

Metaphysis of long bones: 60% about the knee

Older patients: associated with Paget’s disease, radiation, bone infarcts, or chondrosarcomas

Potential etiologies include viral, mutations (RB), p53, ionizing radiation

Clinical findings: Pain, soft tissue swelling, fracture

Hematogenous spread to the lungs, liver & brain

Osteosarcoma

Gross appearance

Large tumors
Gritty & grayish-white
Hemorrhage
Cystic degeneration
Cortical destruction
Spreads – medullary canal
Soft tissue masses


Courtesy of Dr. Jim Wu
Classification of osteosarcoma

Classic osteosarcoma (75%): Affects long tubular bones, particularly the metaphysis, with mixed osteolysis & osteosclerosis and marked periosteal reaction

Telangiectatic osteosarcoma (2.5-12.5%): Lytic tumors consisting of large cystic cavities filled with blood

Small cell osteosarcoma (1-4%): Similar to classic osteosarcoma, primarily osteolytic with a poor prognosis

Surface osteosarcoma (4-10%): Marrow is uninvolved, often low grade with a good prognosis

Tumor stage: Based on grade, extension, and metastases

Treatment options for classic osteosarcoma

Surgery alone: 20% cure rate
Surgery & chemotherapy: 60-80% cure rate
Radiation therapy, rarely

Radical surgical treatment
• Amputation
• Limb salvage (used in 80-90% of all cases)
  – Bone replaced with a bone allograft or a prosthesis
• Arthrodesis: joint fusion

Complete resection of pulmonary & other metastasis
Closely monitor primary and metastatic disease

“Bone Tumors: Surgical Options” from Children’s Hospital Boston
http://www.childrenshospital.org/az/Site646/mainpageS646P0.html
Now, returning to patient 1....
Patient 1, osteosarcoma – PA chest radiograph

10-20% of patients have pulmonary metastases at the time of diagnosis

Multiple focal densities in both lungs, more numerous and dense toward the bases

In those who die from the disease, most have metastases to the lung, bones, or brain

Unfortunately, patient 1 was unsuccessfully treated with chemotherapy & surgery

The following three slides show the progression of the lung metastases

Image courtesy of Dr. Jim Wu

Patient 1, osteosarcoma – Chest CT

Axial CT at the level of the carina, lung window

Multiple pulmonary nodules found at initial diagnosis of osteosarcoma

Image courtesy of Dr. Jim Wu
Patient 1, osteosarcoma – Chest CT

Several months after initial presentation

Growth of the metastases and formation of a pneumothorax (arrow)

Image courtesy of Dr. Jim Wu
Patient 1, osteosarcoma – Chest CT

Several months after initial presentation

Growth of the metastases and formation of a pneumothorax (arrow)

Image courtesy of Dr. Jim Wu
Next, we have a patient with osteosarcoma and a much better prognosis & surgical outcome
Patient 2, osteosarcoma

22 year old man with osteosarcoma of the proximal tibia
Initial clinical presentation: knee pain

Radiograph (AP) of left knee

T2 weighted MRI

PACS, BIDMC

PACS, BIDMC
Patient 2, osteosarcoma

22 year old man with osteosarcoma of the proximal tibia
Initial clinical presentation: knee pain

Radiograph (AP) of left knee

T2 weighted MRI

High density  Low density  PACS, BIDMC

Low Signal  Soft tissue changes  PACS, BIDMC
Patient 2, osteosarcoma – Limb salvage surgery

AP Lateral
Patient 2, osteosarcoma – Limb salvage surgery

**AP**

PACS, BIDMC

**Lateral**

PACS, BIDMC

Allograph
Finally, we have a patient with osteosarcoma with very interesting surgical outcome
**Patient 3, osteosarcoma – AP & lateral radiographs**

HPI: 13 year-old boy
On a skiing trip with his family
Swerved to miss a pole
Fractured left femur

No prior trauma
Previously healthy

“Occasional ache”
“I thought it was just a muscle”

Workup: Plain film, MRI, bone scintigraphy, and biopsy confirmed osteosarcoma

*Simple oblique fracture of the distal femur with anterior translation of proximal femur, pathologic*
Patient 3, osteosarcoma – Scintigraphy

After the bone was set, this radionuclide scan was obtained.

Increased uptake in the distal femur is consistent with bone tumor.
Patient 3, osteosarcoma – Saggital MRI T1W

MRI shows the location of the fracture, as well as the extent of disease along the medullary canal (arrows). Normal marrow is characterized by high signal, while the malignancy is characterized by low signal. Abnormal, weak cortex surrounds the pathologic marrow.
The tumor was resected...
Patient 3, osteosarcoma – Status post rotation-plasty
AP radiographs of left femur, tibia and fibula

Images courtesy of Anne C. Kim, M.D.
Rotation-plasty

- When limb-sparing not possible
- Most nervous function preserved
- Ankle joint functions as knee

Images from “Bone Tumors: Surgical Options” from Children’s Hospital Boston
http://www.childrenshospital.org/az/Site646/mainpageS646P0.html
Rotation-plasty – surgical incisions & resection

Patient 3, osteosarcoma – Rotation-plasty

Patient 3 outcome:
Oncologist: “He’s doing very well.”
Follow-up radiographs every 6 months

Higher function
Increased participation in hobbies/sports
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References


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