Radiographic Evaluation of Musculoskeletal Tumors

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Staging Studies

- Plain Radiograph
- MRI
- CT scan
- Chest CT
- Bone Scan
Plain Radiographs

- **Evaluate:**
  - Rate of tumor growth
  - Tumor interaction with surrounding non-neoplastic tissue
  - Internal composition of tumor
MRI

- Visualize entire bone and adjacent joint
- Best test for intraosseous extent and soft tissue extent
- Identify skip metastases
- Tumor proximity to neurovascular structures
- Occasionally helpful in diagnosis of bone or soft tissue tumors (experienced radiologist)
## MRI Signal Intensities of Various Tissues

<table>
<thead>
<tr>
<th>Tissue</th>
<th>T-1 Weighted</th>
<th>T-2 Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematoma</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Fat, Fatty marrow</td>
<td>High</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Muscle, nerves, Hyaline Cartilage</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Cortical bone, tendons, ligaments, fibrocartilage, scar tissue, air</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Hyaline Cartilage</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Red (Hematopoietic marrow)</td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Fluid</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Tumors (General)</td>
<td>Intermediate-to-Low</td>
<td>High</td>
</tr>
<tr>
<td>Lipoma</td>
<td>High</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Hemangioma</td>
<td>Intermediate</td>
<td>High</td>
</tr>
</tbody>
</table>
CT

- Good for evaluating cortical details and destruction
- Subtle cortical erosions (endosteal; periosteal) not detectable on plain x-ray or MRI
- Subtle calcifications / ossification (Visible tumor matrix mineralization)
Plain Radiographs

- The next three slides demonstrate how plain radiographs should be utilized to evaluate a bone tumor.
- There are specific characteristics that should be identified on plain radiographs that aid in the differential diagnosis of a bone tumor.
Plain Radiographs

- Bone involved
- Is involved bone normal?
- What part of the bone?
- Open or closed growth plate
- Epicenter of lesion (cortex or medullary canal)
- Tumor contour and zone of transition between tumor and host bone
Plain Radiographs

- Mineralized matrix?
- Cortical destruction?
- Periosteal reaction? What type
- Involvement of joint space?
- Tumor multifocal?
- Is tumor of uniform appearance or does it have several different components?
Radiographic Evaluation

- Bone Involved and Position in the Bone
- Pattern of Bone Destruction
  - Geographic, Permeative, Moth Eaten
- Margin of the Lesion
- Presence of Visible Tumor Matrix
  (Calcification/Ossification)
- Internal Trabeculations
- Cortical Erosion, Penetration, Cortical Expansion
- Periosteal Response
  - Continuous or Interrupted
Sharp, Narrow Zone Of Transition

Calcifications

Geographic Bone Destruction

Solid Periosteal Rxn

Permeative Bone Destruction

Interrupted Periosteal Rxn

Epiphysis

Metaphysis

Diaphysis

Moth Eaten Appearance

Soft Tissue Mass

Multiplicity
Patterns of Bone Destruction

- Geographic
- Motheaten
- Permeative
Benign Mass
(Geographic Bone Destruction)

Possible Malignant Mass
(Moth Eaten Pattern of Destruction)

Malignant Mass
(Aggressive with Permeative Ill Defined Margins)
Geographic Bone Destruction

- Least Aggressive Pattern
- Slow Growing Lesion—Usually Benign
- Clearly Demarcated Lesion
  - Clearly Delineated Borders of Lesion
- Narrow Zone of Transition between Tumor and Normal Bone
- May have Sclerotic Margin
- Thicker Sclerotic Margin is Less Aggressive
- No Surrounding Sclerosis means more Aggressive/Faster Growing
- Usually Benign; also Myeloma, Mets, Osteomyelitis (Especially Granulomatous) can be Geographic
Geographic Bone Destruction
Giant Cell Tumor
Giant Cell Tumor
Geographic Bone Destruction
Chondroblastoma
Geographic Bone Destruction
Geographic Bone Destruction
Geographic Bone Destruction
Geographic Bone Destruction
ABC - Aneurysmal Bone Cyst
Geographic Bone Destruction
Fluid-Fluid Levels on MRI
ABC
Geographic Bone Destruction
Giant Cell Tumor
Geographic Bone Destruction

• Types of Margins Around Lesion
  • **IA** (Thick Complete Sclerotic Margin)
    - Indolent Lesion
  • **IB** (Thin and Incomplete)
    - Active Lesion
  • **IC** (No Sclerotic Margin)
    - Aggressive Lesion
Malignant

Ill Defined

Wide Zone of Transition

Benign

Well Defined Border

Narrow Zone of Transition
IA-Non Ossifying Fibroma
IB—Giant Cell Tumor
IC—Giant Cell Tumor
IC—CT Demonstration
Motheaten Bone Destruction

- More Aggressive Bone Destruction
- Less Well Defined Margins
- Larger Zone of Transition From Normal to Abnormal (Tumor)
- Multiple Punched Out Holes in the Bone
- Malignant Bone Tumors, Osteomyelitis, Eosinophilic Granuloma
Motheaten Bone Destruction
Permeative Bone Destruction

- Aggressive Lesion
- Rapid Growth Potential
- Poorly Demarcated and May Merge Imperceptibly with Uninvolved Bone
- Can Not Delineate Where Tumor Begins and Ends
- Tumor Not Clearly Demarcated From Normal Bone
- Malignant Bone Tumors (Ewings sarcoma; Osteosarcoma), Osteomyelitis, Osteoporosis
Permeative Bone Destruction
Lymphoma
Permeative
Permeative--Osteosarcoma
Permeative--Osteosarcoma
Permeative--Lymphoma
Permeative
Permeative
Permeative—MRI Shows Extent
Permeative Lesion Barely Perceptible on X-Ray
Permeative—MRI Demonstrates Tumor Extent Better
Permeative—CT Example

The Tumor is Not Clearly Demarcated
Permeative
Permeative
Visible Tumor Matrix

- Calcification
  - Stippled, Flocculent, Rings and Arcs
- Ossification
  - Solid, Cloud-Like, Ivory-Like
- Must Differentiate Mineralization from Calcification Due to Dead or Necrotic Tissue, Fracture Callus (Pathologic Fracture), Sclerotic Response of Non-Neoplastic Bone to Adjacent Tumor Deposit
Visible Tumor Matrix

• Calcification
  • Rings, Arcs, Flocculent, Fleck-like
• Cartilage Tumors
  • Enchondroma
  • Chondrosarcoma
  • Chondroblastoma
  • Chondromyxofibroma
Visible Tumor Matrix

• Cartilage grows in a lobular manner or in a ball like manner
• Calcification occurs around the periphery of these lobules
• If the calcification occurs completely around the periphery (circumference) it forms a circle or a Ring of calcification that is detectable on the Xray
• If the calcification occurs only partially around the lobule, it forms only part of a circle or an Arc that is detectable on the Xray
Cartilage Matrix

- Stippled
- Flocculent
- Rings and Arcs
Enchondroma or Low Grade Chondrosarcoma
Enchondroma
Chondrosarcoma
Intraosseous Lipoma
Chondrosarcoma
Osteochondroma
Dedifferentiated Chondrosarcoma

- Rings andArcs
- Calcifications
- Lytic Destruction by Dedifferentiated Component
Rings and Arcs
Rings and Arcs - Calcifications
Cartilage Tumor
Visible Tumor Matrix

- Ossification
  - Cloudlike, Fluffy, Marble-like
    - Osteosarcoma
    - Parosteal Osteosarcoma
    - Osteoblastoma
    - Osteoma
Osteosarcoma
Osteosarcoma
Periosteal Osteosarcoma
Periosteal Osteosarcoma CT Scan
Conventional Intramedullary Osteosarcoma
Marble-Like Ossification
Osteosarcoma
Parosteal Osteosarcoma
Parosteal Osteosarcoma
Parosteal Osteosarcoma
Parosteal Osteosarcoma CT Scan
Internal Trabeculations

- Residual Trabeculae or New Bone Formation Due to Adjacent Tumor

**Differential Diagnosis:**
- Giant Cell Tumor
- Chondromyxofibroma
- Desmoplastic Fibroma
- Nonossifying Fibroma
- Aneurysmal Bone Cyst
- Hemangioma
Giant Cell Tumor
Desmoplastic Fibroma
Chondromyxofibroma
Nonossifying Fibroma
Hemangioma
Continuous

Interrupted

- Solid Buttress
- Solid Longitudinal
- Solid Undulated
- Perpendicular (Sunburst)
- Perpendicular (Velvet)
- Lamellated (Onion-Skin)
- Codman Triangle
Periosteal Response

• **Benign:** Buttressing Pattern; Single Lamellar; Cortical Thickening; Bony Expansion
  - Endosteal Erosion Leads to Periosteal Proliferation
  - Can Be Same or Diminished Thickness Compared to Normal Cortex
  - Buttressing: Interface Between Normal and Expanded Cortex is Filled In with Bone
Buttressing
Periosteal Response

- **Malignant Tumors**: Rapid Tumor Growth May Lead to Single or Multiple Concentric Layers
- **Types of Malignant Periosteal Reactions:**
  - **Onion Skin**: Multiple Concentric layers
  - **Codman’s Triangle**: Occurs at the Periphery of a Lesion or Infective Focus
  - **Sun Burst**: Delicate Rays that Extend Away from the Bone (Angled with Bone)
  - **Hair On End**: Rays are Perpendicular to Bone
Onion Skin Appearance
Onion Skin
Codman’s Triangle
CODMAN’S TRIANGLE
CT Scan of Codman’s triangle
Sunburst Pattern
Hair On End Periosteal Reaction

Hair On End

Hair On End
**Benign**
- Geographic Bone Destruction
- Unified Periosteal Reaction
- Well Defined Border

**Malignancy**
- Ill-defined Border
- Permeative Bone Destruction
- Soft Tissue Extension
- Non-Unified Periosteal Rxn
Soft Tissue Mass

- Primary Malignant Bone Tumors
- Benign Aggressive Bone Tumors
- Mets
- Osteomyelitis
Cortical Erosion, Expansion, Penetration

- Bone Cortex Can Be an Effective Barrier To Tumor Growth of Certain Tumors
- Certain Tumors Penetrate the Cortex Partially or Completely (Benign and Malignant)
- Progressive Endosteal Erosion that is Accompanied by a Periosteal Reaction Leads to an Expanded Bony Contour (Like an ABC)
- Aggressive lesion that Penetrates the entire Cortex or Penetrates Haversian Canals will Elevate the Periosteum and Lead to a Periosteal Reaction
Cortical Erosion, Expansion, Penetration

- It is important to understand that both benign and malignant tumors can penetrate the cortical bone and form a soft tissue mass. The fact that there is a soft tissue mass does not automatically confer that the tumor is malignant. Certain benign tumors can also form a soft tissue mass. The peristeme usually remains intact around a benign soft tissue mass. This may only be detectable on a CT scan demonstrating an “Egg-Shell” rim of calcification around the periphery of the mass. The peristeme is usually destroyed by malignant tumors and does not remain intact around the soft tissue component of a malignant tumor.
Intact Cortex
Entire Cortex Destroyed
Scallopining Cortex
Dumbbell Configuration
Malignant:
Extension Through Periosteum into Soft Tissue

Benign:
Contained Lesion By Shell of Periosteum
Benign Aggressive Tumor
Periosteum Intact Around Periphery of Soft Tissue Mass
Benign Aggressive Giant Cell Tumor
Periosteum Intact Around Periphery
Malignant-- Osteosarcoma
Periosteum Not Intact Around Soft Tissue Mass
MRI of Osteosarcoma
Periosteum Not Intact Around Soft Tissue Mass
Distribution in Bone

- **Position in Transverse Plain**
  - Central
  - Eccentric
  - Cortical
  - Juxtacortical (Periosteal/Parosteal)
- **Soft Tissue Location**
Central Axis

- Enchondromas
- Fibrous Dysplasia
- Simple Bone Cysts
Fibrous Dysplasia
Fibrous Dysplasia
Fibrous Dysplasia
Enchondroma
Eccentric Lesions

- Giant Cell Tumor
- Osteosarcoma
- Chondrosarcoma
- Chondromyxofibroma
GCT
Osteosarcoma
Osteosarcoma
Osteosarcoma
Chondrosarcoma
Chondromyxofibroma
Cortical Lesions

- Nonossifying Fibromas
- Osteoid Osteomas
Nonossifying Fibroma
Osteoid Osteoma
Osteoid Osteoma
Osteoid Osteoma
Osteoid Osteoma
Osteoid Osteoma
Osteoid Osteoma
Brodie’s Abscess
Brodie’s Abscess
Juxtacortical Lesions

- Juxtacortical Chondroma
- Periosteal Osteosarcoma/Chondrosarcoma
- Parosteal Osteosarcoma
Periosteal Chondroma
Periosteal Chondrosarcoma
Periosteal Osteosarcoma
Periosteal Osteosarcoma
Periosteal/High Grade Surface Osteosarcoma
Periosteal/HGS Osteosarcoma
Periosteal/HGS Osteosarcoma
Periosteal/HGS Osteosarcoma
Parosteal Osteosarcoma
Parosteal Osteosarcoma
Osteochondroma
Osteochondroma
Cortico-Medullary Continuity
Surface Osteoma
Myositis Ossificans
Myositis Ossificans
Zonal Phenomenon—Central Lucency
Melorrheostosis

“Candle Wax Drippings”
Position of Lesion in Longitudinal Plane

- Epiphysis
- Metaphysis
- Diaphysis
Epiphyseal Lesions

- Adults:
  - Clear Cell Chondrosarcoma
  - Metastasis, Myeloma, Lymphoma
  - Lipoma
  - Intraosseous Ganglion
Epiphyseal Lesions

• **Children:**
  - Chondroblastoma
  - Osteomyelitis
  - Osteoid Osteoma
  - Enchondroma
  - Eosinophilic Granuloma
Metaphyseal Lesions

- GCT (extends to epiphysis)
- Nonossifying Fibroma
- Chondromyxoid Fibroma
- Simple Bone Cyst (Unicameral Bone Cyst)
- Osteochondroma
- Brodie’s Abscess
- Osteosarcoma
- Chondrosarcoma
- MFH/Fibrosarcoma
Diaphyseal Lesions

- Ewing’s Sarcoma
- Nonossifying fibroma
- Simple Bone Cysts
- Aneurysmal Bone Cysts
- Enchondromas
- Osteoblastomas
- Fibrous Dysplasia
- Adamantinoma
- Osteofibrous Dysplasia
Epiphyseal Equivalent Areas

- Subchondral Regions of Acetabulum and Scapula
- Tarsal Bones
- Calcaneus, Talus
Growth Plate

- Tumors Usually Do Not Cross Growth Plate
- Think Infection
Centrally Located Lesions

- Bone Cyst
- Enchondroma
- Fibrous Dysplasia

Eccentrically Located Lesions

- Fibrous Cortical Defect
- Non Ossifying Fibroma
- ABC
- Chondromyxoid Fibroma
- Osteoma

GCT
Skeletally Mature

- GCT
- MFH
- Intraosseous Ganglion
- Closed Growth Plate
- Myeloma
- Cortical Metastases (possibly lung and breast)
- Fibrosarcoma
- Adamantinoma
- Metastasis
- Lymphoma
## Common Spine Tumors with Their Location

<table>
<thead>
<tr>
<th>Malignant - Anterior</th>
<th>Benign - Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lymphoma</td>
<td>Osteoblastoma</td>
</tr>
<tr>
<td>Hodgkin</td>
<td>Osteoid Osteoma</td>
</tr>
<tr>
<td>Myeloma</td>
<td>ABC</td>
</tr>
<tr>
<td>Ewing</td>
<td>Osteochondroma</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>Chondromyxoid Fibroma</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td></td>
</tr>
<tr>
<td>Metastasis</td>
<td></td>
</tr>
</tbody>
</table>

**Exceptions:**
- Hemangioma
- Langerhans-cell Granuloma
- Fibrous Dysplasia
Specific Bones

• Heamatopoietic Marrow—predilection for sites with red marrow; rich sinusoidal vasculature

• Axial and Appendicular Skeleton in Children

• Axial Skeleton in Adults
  • Metastatic Disease
  • Myeloma
  • Ewing’s Sarcoma
  • Histiocytic Lymphoma
Specific Bones

- **Areas of Rapid Growth**
- **Primary Bone Tumors**
  - Distal Femur
  - Proximal Tibia
  - Proximal Humerus
Specific Bones

- **Vertebrae (Adults)**
  - Skeletal Mets
  - Myeloma
  - Hemangioma
  - Lymphoma
  - Osteomyelitis
- **Vertebrae (Children)**
  - Eosinophilic Granuloma
  - ABC
  - Osteoblastoma
  - Osteoid Osteoma
  - Lymphoma
  - Leukemia
  - Osteomyelitis

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<td>Osteosarcoma</td>
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<td>Chondrosarcoma</td>
<td></td>
</tr>
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<td>Metastasis</td>
<td></td>
</tr>
</tbody>
</table>

**Exceptions:**
- Hemangioma
- Langerhans-cell Granuloma
- Fibrous Dysplasia
Specific Bones

- Sacrum
  - Chordoma
  - Myeloma/Plasmacytoma
  - Giant Cell Tumor
  - Mets
  - Simple Cysts
  - Neurogenic Tumors /Schwannoma
Specific Bones

- Ribs
  - Mets
  - Fibrous Dysplasia
  - Enchondroma
Specific Bones

- **Metacarpals and Phalanges**
  - Giant Cell Tumor
  - Giant Cell Reparative Granuloma
  - Sarcoidosis
  - ABC
  - Fibrous Dysplasia
  - Enchondroma
Specific Bones

• **Terminal Phalanges**
  • Inclusion Cyst
  • Glomus Tumor
  • Mets (Lung)
# Tumors with Predilection for Certain Sites

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Bone</th>
<th>Site</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoid Osteoma</td>
<td>Femur</td>
<td>Neck of Femur</td>
<td>Cortically</td>
</tr>
<tr>
<td></td>
<td>Tibia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chondroblastoma</td>
<td>Tibia</td>
<td>Epiphysis</td>
<td>Eccentric</td>
</tr>
<tr>
<td>Chordoma</td>
<td>Clivus C-2 Sacrum</td>
<td>Posterior Aspect, Distal End</td>
<td>Central</td>
</tr>
<tr>
<td>Parosteal Osteosarcoma</td>
<td>Femur</td>
<td>Posterior Aspect, Distal End</td>
<td>Juxtacortically</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteofibrous Dysplasia</td>
<td>Tibia</td>
<td>Anterior Aspect</td>
<td>Cortically</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cortically</td>
</tr>
<tr>
<td>Adamantinoma</td>
<td>Tibia</td>
<td>Anterior Aspect</td>
<td>Cortically</td>
</tr>
<tr>
<td>Giant Cell Tumor</td>
<td>Femur</td>
<td>Articular End</td>
<td>Eccentric</td>
</tr>
<tr>
<td></td>
<td>Tibia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radius</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABC</td>
<td>Tibia</td>
<td>Metaphysis</td>
<td>Eccentric</td>
</tr>
<tr>
<td></td>
<td>Humerus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Bone Cyst</td>
<td>Humerus</td>
<td>Metaphysis</td>
<td>Central</td>
</tr>
<tr>
<td></td>
<td>Femur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chondromyxoid Fibroma</td>
<td>Tibia</td>
<td>Metaphysis</td>
<td>Eccentric</td>
</tr>
</tbody>
</table>
Unknown Examples
Unknown #1
Unknown #1

- Epiphyseal Lesion with Geographic Pattern of Bone Destruction (Probably Benign)
- Eccentric
- Internal Mineralization/Calcifications (indicates most likely cartilaginous nature)
- Sclerotic IA/IB Margin
Chondroblastoma
Unknown #2
Unknown #2

- Spine Lesion
- Posterior Elements
- Geographic Pattern of Bone Destruction (Probably benign)
- Internal Mineralization indicative of bone producing or cartilage producing tumor
Osteoblastoma
Unknown #3
Unknown #3

- Small Cortical Lesion
- Geographic pattern of Bone Destruction
- Extensive Surrounding Sclerosis
- Buttressing Periosteal Reaction (Benign Periosteal Reaction)
- Internal Mineralization
Osteoid Osteoma
Unknown #4
Unknown #4

- Central, Diaphyseal Lesion
- No Periosteal Reaction
- No Cortical destruction
- Calcifications in a Ring and Arc Like Manner
Enchondroma
Unknown #5

- Metaphyseal Eccentric Lesion
- Permeative Lesion (Malignant)
- Cortical Destruction
- Calcifications in a Ring and Arc Manner indicative of a cartilage tumor
Dedifferentiated Chondrosarcoma
Unknown #6

• Permeative Pattern of Bone Destruction
• Diaphyseal
• Cortical penetration
• Hair on End Periosteal Reaction
• No Internal Mineralization (probably not bone or cartilage producing)
• Malignant Appearing
Ewing’s Sarcoma
Unknown #7

- Metaphyseal, Central lesion
- Permeative Pattern of Bone Destruction (malignant)
- No Internal Mineralization (probably not cartilage or bone producing—no visible matrix)
- No Periosteal Reaction
- Malignant Appearing
Fibrosarcoma of Bone
Unknown #8

- Central Lesion
- Geographic Pattern of Bone Destruction (Benign Appearing)
- Metadiaphyseal
- Bone is Expanded (Benign Periosteal reaction)
- No Internal Mineralization (Probably not Cartilaginous or Bone Producing)
- Ground Glass Appearance
Fibrous Dysplasia
Unknown #9

- Eccentric Lesion
- Metaphyseal with Epiphyseal Extension
- No Internal Mineralization
- Cortex is Thinned and Slightly Expanded
- Thin, Incomplete Sclerotic Margin (Type IB)
- Benign Appearing
Giant Cell Tumor
Unknown #10

- Metadiaphyseal Lesion
- Motheaten and Permeative (Malignant Appearing)
- No Internal Mineralization
- Cortical Destruction
- No Periosteal Reaction
Malignant Fibrous Histiocytoma of Bone
Unknown #11

- Central Location
- Metaphyseal
- Multiloculated
- Geographic
- Bone is Expanded
- Skeletally Immature
- No Mineralization
- Benign Appearing
Unicameral Bone Cyst
Unknown #12

- Eccentric/Cortical Lesion
- Metaphyseal
- Geographic pattern of Bone Destruction
- Well Circumscribed (Type IA Margin: Indolent)
- No Internal Mineralization
- Bone has Expanded Contour
- Benign Appearing
Nonossifying Fibroma
Unknown #13

- Geographic, Central Lesion in a Phalange
- Lobular Growth Contour with Endosteal Erosion
- Punctate calcifications (arrows)—Cartilaginous
- Appears Benign
Enchondroma
Unknown #14

- Cortical based, Geographic Lesion in Tibia
- Extensive Sclerotic Margin
- Tibial bowing
Osteofibrous Dysplasia
Unknown #15
Unknown #15

- Permeative/Moth Eaten Lesion (Malignant)
- Eccentric, Metaphyseal
- Ossification Present within Neoplasm
- Codman’s Triangle
- Skeletally Immature; Spares Growth Plate
- Cortical Destruction
- Appears Malignant and is Producing Osteoid
Osteosarcoma
Thank You!