MR of Musculoskeletal Neoplasms

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San Diego, California
Diagnostic imaging

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Neurofibromatosis
## MRI - Technique

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- Obtain an adequate history
- Correlate with x-rays, CT and scintigraphy
- Always before biopsy (needle or open)
- Mark the lesion
- Make patient comfortable

Neurofibroma of median nerve 27F Sag T2FS
MRI - Technique

• High field strength helps - not essential
• T1 and T2 to characterize
• FS for sensitivity, cartilage, and fatty tumors
• Multiple planes

• Shaft
  • Axial,
    • Sagittal and Coronal
• Adjacent to Joint
  • Sagittal and Coronal
  • Axial
MRI Contrast

- May add a little to conspicuity
- Helps define
  - Tumour V's necrosis
  - Homogeneous solid vs cystic
    - Substitute ultrasound
  - Vascularity prior to biopsy
  - Tumor next to fluid
    - Epidural or intraarticular
- Greatly enhanced by T1FS
  - Same plane pre and post
  - Don’t compare T1 pre with T1FS post.
- Occasionally diagnostic
- Useful Post Chemotherapy/XRT

Sag T1FS post Gd
MRI Contrast

- May add a little to conspicuity
- Helps define
  - Tumour V’s necrosis
  - Homogeneous solid vs cystic
    - Substitute ultrasound
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Neurofibroma T1FSGd
Technique
Detection
Histologic characterization
Anatomic staging
Biopsy
Follow-up

No Gd-DTPA

Synovial sarcoma lateral knee, US no doppler called ganglion 13M
Technique

Dynamic Enhancement

- 84% of malignant tumors had contrast enhancement slopes >30%
- 72% of benign tumors had contrast enhancement slopes <30%
- Areas of necrosis and peritumoral edema enhanced significantly less and more slowly than viable tumor

Erlemann et al, Radiology 171:767,1989
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<td><strong>MR Angiography</strong></td>
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- Defines anatomy of major vessels and their relation to neoplasms
- Differentiates masses from vascular pathology (e.g. aneurysm or pseudoaneurysm)
Diagnostic Imaging

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up
Detection

- Initial examination conventional radiography

- **Bone neoplasms**
  Higher sensitivity with CT, scintigraphy and MR

- **Soft tissue neoplasms**
  Higher sensitivity with CT, ultrasound and MR
Diagnostic imaging

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Neurofibromatosis
Histological Characterization

- Benign tumors, metastases, round cell tumors and pseudotumors are managed differently than sarcoma.

- Management of sarcomas depends on grade and anatomic extent more than on histologic type.
Histologic Characterization

- Emphasis of radiology training

- Surgeon more interested in where it is than what it is

- Biopsy necessary in sarcoma for accurate diagnosis
Osseous Tumors

- Metastatic disease most common
- Primary benign tumors more common than primary malignant tumors
- Most common primary malignancies are myeloma, osteosarcoma and Ewing sarcoma
- Other primary skeletal malignancies rare
Benign V’s Malignant

- Zone of transition
- Margin
- Periosteal reaction
- Soft tissue spread
- Growth rate
- Tumor size
- Tumor location
Benign V’s Malignant

- Signal intensity
- Tumor margin
- Signal inhomogeneity
- Neurovascular invasion
- Growth rate
- Tumor size
- Tumor location
- Soft tissue extension
- Multicompartment involvement
- Bone destruction

Kransdorf, AJR 153:541, 1989

Post traumatic myositis ossificans
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**Benign V’s Malignant**

- Signal intensity
- Tumor margin
- Signal inhomogeneity
- Neurovascular invasion
- Growth rate
- Tumor size
- Tumor location
- Soft tissue extension
- Multicompartment involvement
- Bone destruction

Kransdorf, AJR 153:541, 1989
Post traumatic myositis ossificans
Histological Characterization

- **Epidemiology**
  - **Age** of patient

- **Distribution**
  - Diffuse
  - Disseminated
  - Solitary

- **Tumor features**
  - Location
  - Biologic activity
  - Matrix

**Primary Bone Tumors Age 0-10** from Senac et al, Radiology 160:491, 1986
Distribution

- **Diffuse**
  - All bone is histologically abnormal

- **Disseminated**
  - Multiple distinct lesions

- Few

- Solitary
## Diffuse Distribution

- Pattern seen with dysplastic, metabolic and endocrine disease
- Less commonly, seen with neoplastic infiltration
Diffuse Distribution
Disseminated Distribution

- Normal intervening bone
- Lesions may be synchronous or metachronous
- Not all lesions may be evident radiographically

- Metastatic disease
- Multiple myeloma

- Paget disease
- Eosinophilic granuloma
- Fibrous dysplasia
- Enchondromatosis
- Multiple osteochondromatosis
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<td>Distribution - Few</td>
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**Heamangioma of ST 49F**

Sag PD

Heamangioma of ST 49F
Distribution - Solitary lesion

- 10-15% of mets

- Ability to identify lesion radiographically depends on what it does to underlying osseous matrix

Sclerotic osteosarcoma Sag T1
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- Osseous
- Soft tissue
- Intraarticular

Osteosarcoma
Location

- Which bone is involved?
- Each neoplasm has a tendency to involve particular bones

Simple bone cyst
Chordoma
Giant cell tumor
Enchondroma
Osteosarcoma
Adamantinoma
Location - Sacrum

Technique Detection Histologic characterization Anatomic staging Biopsy Follow-up

Sag T1  Sag T1FS IV Gd  Sag T2FS

Chordoma 43F
Location - Foot

Cor T1
Cor T2FS
Cor PDFS
Cor T1FS IVGd

Plantar fibroma 27M
**Location - Foot**

**Dermatofibrosarcoma 50M**

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- Sag T1FS IVGd
- Cor PDFS
- Cor T2FS
- Cor T1FS IVGd
Location

- **Longitudinal**
  - Epiphysis
  - Metaphysis
  - Diaphysis

- **Transverse**
  - Central
  - Eccentric
  - Cortical
  - Surface

Additional Notes:

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Anatomical Locations:

- Ewing's sarcoma
- Osteofibrous dysplasia
- Fibrous dysplasia
- Chondromyxoid fibroma
- Bone cyst
- Nonossifying fibroma
- Enchondroma
- Giant Cell Tumor
- Chondroblastoma
Location - Longitudinal - Epiphyseal
Location - Longitudinal - Epiphyseal

Ax PDFS

Cor PDFS

Intraosseous ganglion of PCL
Giant Cell Tumor distal femur metaepiphysis 34M
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**Location - Longitudinal - Metaphyseal**

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**Enchondroma 41M**

Sag T1

Sag PDFS

Sag T1FS IV Gd
## Location - Longitudinal - Metaphyseal

### Ax GrT2

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<td>Osteochondroma</td>
<td>Cor T1</td>
<td>Ax GrT2</td>
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</table>
Location - Longitudinal - Diaphyseal

Cor T1  Sag T1  SagT2FS

Adamantinoma  46F
Location – Transverse - Medullary

Cor T1

Cor PDFS

Enchondroma
Location – Transverse - Medullary

Cor T1

Cor PDFS

Prostate mets to knee 50M
Location – Transverse - Eccentric

Technique | Detection | Histologic characterization | Anatomic staging | Biopsy | Follow-up

Location

- Transverse
- Eccentric

Location

- NOF femur 19M

AP

Cor T1

Cor PDFS

Cor T1FS IV Gd

NOF femur 19M
Location – Transverse - Cortical

Osteoid osteoma
**Location - Transverse - Periosteal**

- **Technique**
- **Detection**
- **Histologic characterization**
- **Anatomic staging**
- **Biopsy**
- **Follow-up**

*Ax T1*  
*Sag T1 SPIR Gd*  
*Periosteal lipoma*
Location - Transverse - Juxtacortical

Technique  Detection  Histologic characterization  Anatomic staging  Biopsy  Follow-up

Cor T1  Cor T1Gd  Cor T2

Juxtacortical chondroma 22M
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<tr>
<td>Location - Transverse - Parosteal</td>
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Axial CT

Axial T1

Lump on Forearm  Parosteal osteosarcoma
Location – Soft tissues

- Not as helpful for soft tissue lesions

Fibrolipomatous hamartoma of median nerve
Location - Depth

- Intramuscular lipoma soleus
- Intermuscular lipoma shoulder
**Location – Soft tissues**

- **Ax CT**
- **Ax T1**
- **Ax T2**
- **Ax T1FS IVGd**

26F Lump in bottom PNET
Location - Joint

- PVNS
- Synovial osteochondromatosis
- Hemangioma
- Synovial sarcoma
- Intraarticular osteoid osteoma
Technique | Detection | Histologic characterization | Anatomic staging | Biopsy | Follow-up
--- | --- | --- | --- | --- | ---

**Location - Joint**

- PVNS
- **Synovial osteochondromatosis**
- Hemangioma
- Synovial sarcoma
- Intraarticular osteoid osteoma

50 M Right Hip Pain  Several years of joint pain and swelling  Limited range of motion and occasional joint locking
Location - Joint

• PVNS
• Synovial osteochondromatosis
• Hemangioma
• Synovial sarcoma
• Intraarticular osteoid osteoma
Location - Joint

- PVNS
- Synovial osteochondromatosis
- Hemangioma
- Synovial sarcoma
- Intraarticular osteoid osteoma

66 years old man with right knee pain
Location - Joint

- PVNS
- Synovial osteochondromatosis
- Hemangioma
- Synovial sarcoma
- Intraarticular osteoid osteoma
Location - Pre existing condition

Paget's sarcoma 74M
• ABC’s can be 1° or 2°

• Secondary ABC’s

• Occur in:
  • Fibrous dysplasia
  • GCT
  • NOF.
  • Chondroblastoma
  • Osteoblastoma
Location - Pre-existing condition

- ABC’s can be 1° or 2°
- Secondary ABC’s
- Occur in:
  - Fibrous dysplasia
  - GCT
  - NOF.
  - Chondroblastoma
  - Osteoblastoma
Location - Pre existing condition

- ABC’s can be 1° or 2°
- Secondary ABC’s
- Occur in:
  - Fibrous dysplasia
  - GCT
  - NOF
  - Chondroblastoma.
  - Osteoblastoma

20F, surgery 1 year ago, known chondroblastoma, pain forefoot 3 months ago.
Location - Pre existing condition

- ABC’s can be 1° or 2°
- Secondary ABC’s
- Occur in:
  - Fibrous dysplasia
  - GCT
  - NOF
  - Chondroblastoma
  - Osteoblastoma

20F, surgery 1 year ago, known chondroblastoma, pain forefoot 3 months ago.
Biologic activity

- Geographic
- Moth-eaten
- Permeative
Margin

- Difficult to distinguish tumor from peritumoral edema
- Benign and malignant tumors can have peritumoral edema
- Tumor and edema enhance with Gd
- Gadolinium flow rate may be helpful
Peritumoral edema

- Osteoid osteoma
- Chondroblastoma
- Eosinophilic granuloma

Sag T1FS IVGd

Intraarticular Osteoid Osteoma elbow 8M
Peritumoral edema

- Osteoid osteoma
- Chondroblastoma
- Eosinophilic granuloma

Technique  Detection  Histologic characterization  Anatomic staging  Biopsy  Follow-up
Peritumoral edema

- Osteoid osteoma
- Chondroblastoma
- Eosinophilic granuloma

Expansion

- Deposition of solid periosteal layer around periphery of lesion
- Expansion implies loss of original cortex
- Generally seen in slowly growing lesions
- Does not mean that the lesion is benign
Expansile lytic lesions of bone

- Metastases
  - Renal, Thyroid, Breast, Lung, Melanoma, Phaeo

- Primary malignant

- Primary benign

- Non-neoplastic
Expansile lytic lesions of bone

- Metastases
  - Renal, Thyroid, Breast, Lung, Melanoma, Phaeo

- Primary malignant
  - Plasmacytoma

- Primary benign

- Non-neoplastic
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### Expansile lytic lesions of bone

- **Metastases**
  - Renal, Thyroid, Breast, Lung, Melanoma, Phaeo

- **Primary malignant**
  - Plasmacytoma

- **Primary benign**
  - ABC, GCT, Enchondroma

- **Non-neoplastic**
Expansile lytic lesions of bone

- **Metastases**
  - Renal, Thyroid, Breast, Lung, Melanoma, Phaeo

- **Primary malignant**
  - Plasmacytoma

- **Primary benign**
  - ABC, GCT, Enchondroma

- **Non-neoplastic**
  - Hemophilia, Brown, Hydatid, Fibrous dysplasia

21 yo woman with right hip pain
Differential Diagnosis – fluid-fluid levels

- ABC
- Telangiectatic osteosarcoma
- ABC’s can be 1° or 2°
- Secondary ABC’s are due to:
  - Fibrous dysplasia
  - GCT
  - NOF
  - Chondroblastoma
  - Osteoblastoma
Differential Diagnosis – fluid-fluid levels

- ABC
- Telangiectatic osteosarcoma
- ABC’s can be 1° or 2°
- Secondary ABC’s are due to:
  - Fibrous dysplasia
  - GCT
  - NOF
  - Chondroblastoma
  - Osteoblastoma

ABC 19M left groin pain

Ax T1
Ax T2
Ax T1FSGd
Differential Diagnosis – fluid-fluid levels

- ABC
- Telangiectatic osteosarcoma

ABC’s can be 1° or 2°
Secondary ABC’s are due to:
- Fibrous dysplasia
- GCT
- NOF
- Chondroblastoma
- Osteoblastoma

19 year old male with knee pain. Right distal femur: Osteosarcoma with telangiectatic features.
Fluid fluid levels

Differential Diagnosis – fluid-fluid levels

- ABC
- Telangiectatic osteosarcoma

ABC’s can be 1° or 2°
Secondary ABC’s are due to:
- Fibrous dysplasia
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19 year old male with knee pain. Right distal femur: Osteosarcoma with telangiectatic features.
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Secondary ABC’s are due to:
- Fibrous dysplasia
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- Osteoblastoma

19 year old male with knee pain. Right distal femur: Osteosarcoma with telangiectatic features.
Types of Periostitis

- Uninterrupted solid
- Uninterrupted single linear
- Interrupted "onion-skin"
- Interrupted "Codman's triangle"
- Perpendicular "sunburst"
- Perpendicular "hair-on-end"
Types of Periostitis

Chondroblastic high grade osteosarcoma 16M

Ax T2

Hair on end
Types of Periostitis

- **Ax T1 SPIR Gd**
  - Osteosarcoma femur

- **Sag T1 SPIR Gd**
  - Hair on end / Sunburst
Soft Tissues

- Soft tissue component
- Distortion of fat planes
- Soft tissue edema
- Matrix in soft tissue
Soft Tissue Involvement

- Technique: Cor MRA-MIP, Sag T2FS, Ax T2
- Detection: Hemangioma, AVM of finger 56M
- Histologic characterization: Cor T2
- Anatomic staging: Biopsy, Follow-up
Histologic Characterization - Matrix

- Acellular substance produced by the lesion
  - Helps define histology of lesion
    - Ossific
    - Chondroid
    - Lipoid
    - Myxoid
    - Collagenous

Enchondroma
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**Matrix** - None

**Ganglion**
Matrix - Chondroid

Technique | Detection | Histologic characterization | Anatomic staging | Biopsy | Follow-up
--- | --- | --- | --- | --- | ---

Chondrosarcoma coracoid 61M

Ax T1

Ax T1Gd

Sag T2

Sag T1Gd
High-grade surface Osteosarcoma
Matrix – MR signal - ↓T1, ↑T2

- Nonspecific

- Majority of benign and malignant lesions show this pattern

- History, location and configuration help establish differential diagnosis
• **Fat**
  - Lipoma
  - Well-differentiated liposarcoma
  - Hemangioma

• **Subacute blood**

• **Paramagnetic substances**
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**↑T1, ↑T2**

- **Fat**
  - Lipoma
  - Well-differentiated liposarcoma
  - Hemangioma

- **Subacute blood**

- **Paramagnetic substances**

![Sag T1](image1.png)  ![Sag T2](image2.png)
Fat
- Lipoma
- Well-differentiated liposarcoma
- Hemangioma

Subacute blood

Paramagnetic substances

Cor T1
Hematoma
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<td>Biopsy</td>
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<td>→ T1, → T2</td>
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- **Fat**
  - Lipoma
  - Well-differentiated liposarcoma
  - Hemangioma

- **Subacute blood**

- **Paramagnetic substances**
- **Fat**
  - Lipoma
  - Well-differentiated liposarcoma
  - Hemangioma

- **Subacute blood**

- **Paramagnetic substances**
- **Calcification**.
- Ossification
- Crystalline structures
- Dense fibrous tissues
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies
- Calcification
- Ossification
- Crystalline structures.
- Dense fibrous tissues
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- Calcification
- Ossification
- Crystalline structures
- **Dense fibrous tissues**
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies

**Fibrous dysplasia**
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- Calcification
- Ossification
- Crystalline structures
- Dense fibrous tissues.
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies

Ax T1
Cor T2STIR

Desmoid Tumor 38M
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- Calcification
- Ossification
- Crystalline structures
- Dense fibrous tissues
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies

†T1, †T2

PVNS

Sag PD

Sag GE
Paradoxical Signal Pattern

Technique  Detection  Histologic characterization  Anatomic staging  Biopsy  Follow-up

Paradoxical Signal Pattern

Ax T2

Ax T1Gd

Neurofibroma forearm

Staging
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**Diagnostic imaging**

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Neurofibromatosis
Staging

- Assess anatomic extent of the lesion
- Guide treatment
- Provide prognosis
- Ultimately, improve longevity
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<th>American Joint Committee</th>
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<td>Orthopedic surgeons</td>
<td>Oncologists</td>
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<tr>
<td>Benign and malignant lesions</td>
<td>Malignant lesions only</td>
</tr>
<tr>
<td>Bone and soft tissue</td>
<td>Soft tissue only</td>
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<tr>
<td>Compartmental anatomy important</td>
<td>Tumor size important</td>
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<tr>
<td>Nodal metastasis treated same as distant metastasis</td>
<td>Nodes are evaluated separately</td>
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<tr>
<td>T0</td>
<td>True capsule surrounds tumor</td>
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<tr>
<td>-----</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>T1</td>
<td>Extracapsular, but still intracompartmental</td>
</tr>
<tr>
<td>T2</td>
<td>Extracapsular and extracompartmental Abutment of NV bundle</td>
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Compartment anatomy

- All extremities contain compartments bounded by fascia
- Neurovascular bundles travel between compartments
- Soft tissue lesion is contained by fascia
- Osseous lesion is contained by periosteum
Technique       Detection       Histologic characterization       Anatomic staging       Biopsy       Follow-up

Stage - T1

- Extracapsular but intracompartmental

- Skin and subcutaneous tissues

- One muscle compartment

- Intracortical

- Paraosseous without muscle or bone invasion

- Single ray of hand or foot
Stage - T2

- Extracapsular extracompartmental

- Lesion no longer confined by periosteum or fascia

- Increases risk of metastasis and recurrence
Stage - T2

- Extracapsular extracompartmental

- Lesion no longer confined by periosteum or fascia

- Increases risk of metastasis and recurrence

Sciatic invasion by liposarcoma - Stage T2
<table>
<thead>
<tr>
<th>Technique</th>
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<td>Axial CT</td>
<td>Axial T1</td>
<td>Stage - T2</td>
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Lump on Forearm    Parosteal osteosarcoma
• Nodal and distal metastases are treated the same in SSS (no difference in prognosis)
Nodal and distal metastases are treated the same in SSS (no difference in prognosis)
Sarcoma Metastasis

- Most common site of sarcoma metastasis is lung

- Lung staging part of initial tumor workup for sarcoma

- CT scanning more sensitive than radiography

- CT used for staging, biopsy, and follow-up
Sarcoma Metastasis

• Next most common site is bone

• Axial and diaphyseal predominance

• Osteolytic in 88%, majority show moth-eaten pattern

• Cortical violation in 51%, high risk of pathologic fracture

• Bone scan has high false negative rate!
# Diagnostic imaging

- **Technique**
- **Detection**
- **Histologic characterization**
- **Anatomic staging**
- **Biopsy**
- **Follow-up**

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Neurofibromatosis
Biopsy

- Metastatic disease
- Round cell tumor
- Primary bone or soft tissue neoplasm only after consultation with orthopedic surgeon
- Local staging should be completed prior to biopsy

Fibrous tumor of soft tissue parts
Biopsy

- Fluoroscopic
- US for soft tissue
- CT guidance for axial and deep lesions
- Fine needle aspiration
- Core biopsy with cutting needle or trephine
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<td>Percutaneous Biopsy</td>
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![Percutaneous Biopsy Image]
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Osteoid Osteoma 14F
Radiofrequency ablation
Radiofrequency ablation

Technique       Detection       Histologic characterization       Anatomic staging       Biopsy       Follow-up
Radiofrequency ablation

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Ax T1

Ax T2FS

Ax T1FS

Ax T1FSGd

Follow up

OO 24F 2w post RFA
Diagnostic imaging

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Neurofibromatosis
Follow-up

- Monitor therapy
- Identify complications
- Detect recurrence
- Detect metastases
Follow-up

- Clinical assessment limited
- Laboratory indicators limited
- Diagnostic imaging
- Histology and pathology
MRI Follow Up

- Be cost effective
- Have baseline 12 week post op
- Often and Limited rather then Infrequent and Extensive
- Limit scans to useful plane
- Limit sequences to those previously shown to be Sensitive for the tumor
- Mainstay of follow up for low grade tumour
Follow-up

GCT femur 36F with ST and lung spread
Treatment

- Observation
- Intrallesional injection / RFA / Cryo
- Intrallesional curettage
  - With bone graft
  - With cement
- Marginal excision
- Wide resection
  - Allograft
  - Arthroplasty
- Radical amputation
- Chemotherapy
- Radiation therapy
Recurrence of Musculoskeletal tumors

- Low grade
  - Rarely recur

- Moderate grade
  - Local recurrence common

- High grade
  - Local recurrence and distant metastasis common
Recurrence of Musculoskeletal tumors

- Low grade
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GCT recurrence 28M fibula
Recurrence of Musculoskeletal tumors

- Low grade
  - Rarely recur

- Moderate grade
  - Local recurrence common

- High grade
  - Local recurrence and distant metastasis common

GCT recurrence 28M fibula
Local Recurrence

- Increased size of lesion
- Development of new areas of osteolysis
- Cortical thinning and destruction
- Resorption of graft
- Arrest or failure of healing
Local Recurrence

1Y earlier

Cor T1

Cor T1Gd

Recurrent CMF 13M
Follow-up - Recurrence

Ax T1

Ax T2FS

Cor T2FS

Recurrent osteochondroma 47F
Increased signal post therapy

- Residual or recurrent tumor
- Necrosis
- Lymphocele
- Seroma / Hemorrhage
- Edema
- Granulation tissue

Cor T1FSGd
Post liposarcoma resection and radiation therapy
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**Improved Prognosis**

- Earlier detection
- More accurate staging
- Adequate surgical resection
- Adjuvant radiation and/or chemotherapy
Diagnostic imaging

- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up

Neurofibromatosis