



MR of Musculoskeletal Neoplasms

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Cystic Angiomas

Diagnostic imaging

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



MRI - Technique

- 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



Osteochondroma T1FSGd

MRI Contrast

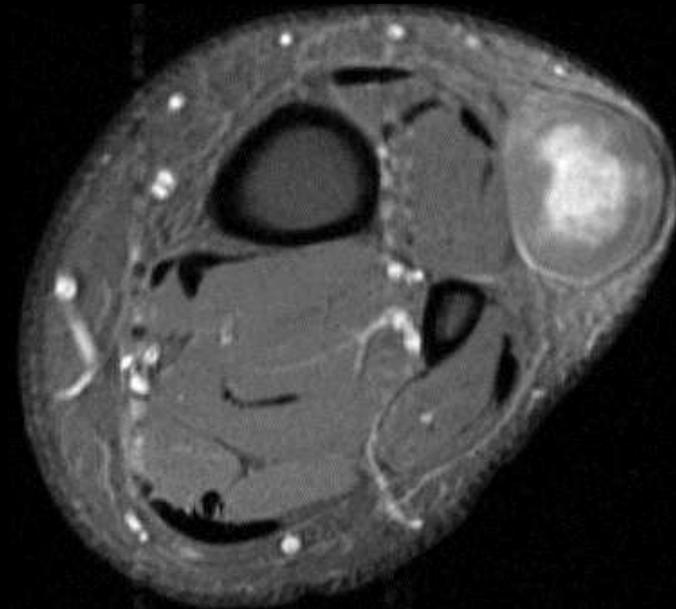
- May add a little to conspicuity
- Helps define
 - Tumour V's necrosis
 - Homogeneous solid vs cystic
 - Substitute ultrasound
 - Vascularity prior to biopsy
 - Tumor next to fluid
 - Epidural or intraarticular
- Greatly enhanced by T1FS
 - Same plane pre and post
 - Don't compare T1 pre with T1FS post.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



Sag T1FS post Gd

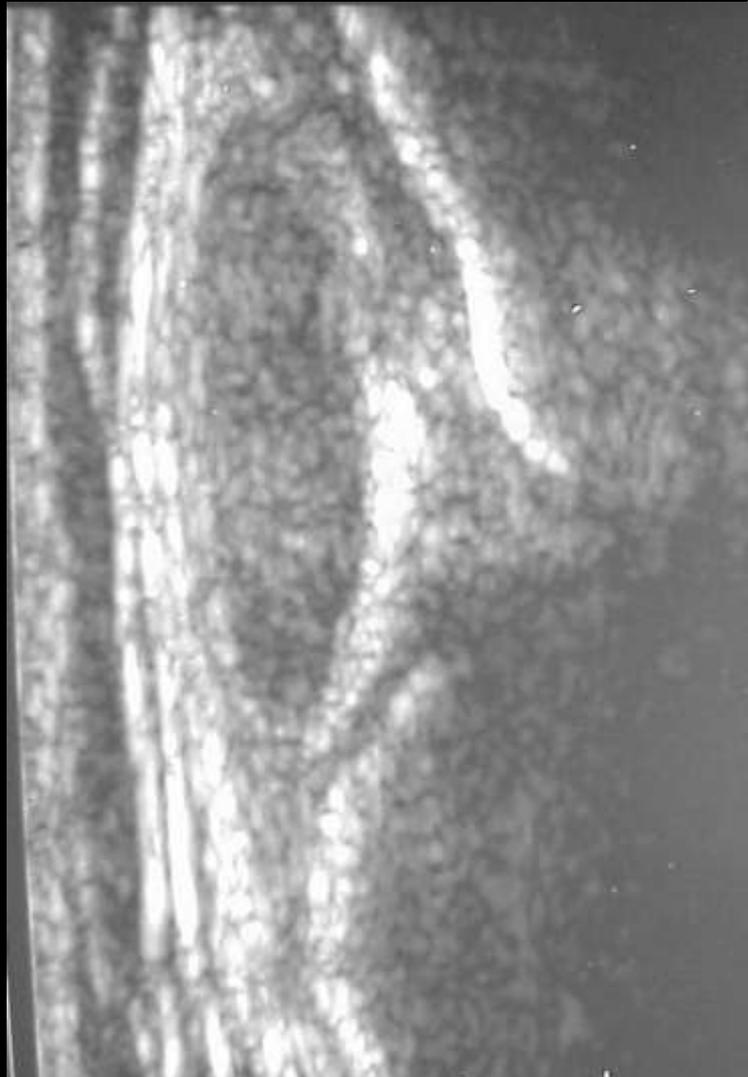
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Neurofibroma T1FSGd

No Gd-DTPA



Cor PDFS



Ax PDFS

Dynamic Enhancement



Cor T1

Cor T1Gd

Immediate

Cor T1Gd

15m delay

- 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

MR Angiography

- Defines anatomy of major vessels and their relation to neoplasms
- Differentiates masses from vascular pathology (eg. 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



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



Cor T2

Benign V's Malignant

- Zone of transition
- Margin
- Periosteal reaction
- Soft tissue spread
- Growth rate
- Tumor size
- Tumor location



FCD

Osteosarcoma

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



Benign V's Malignant

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



Histological Characterization

- Epidemiology

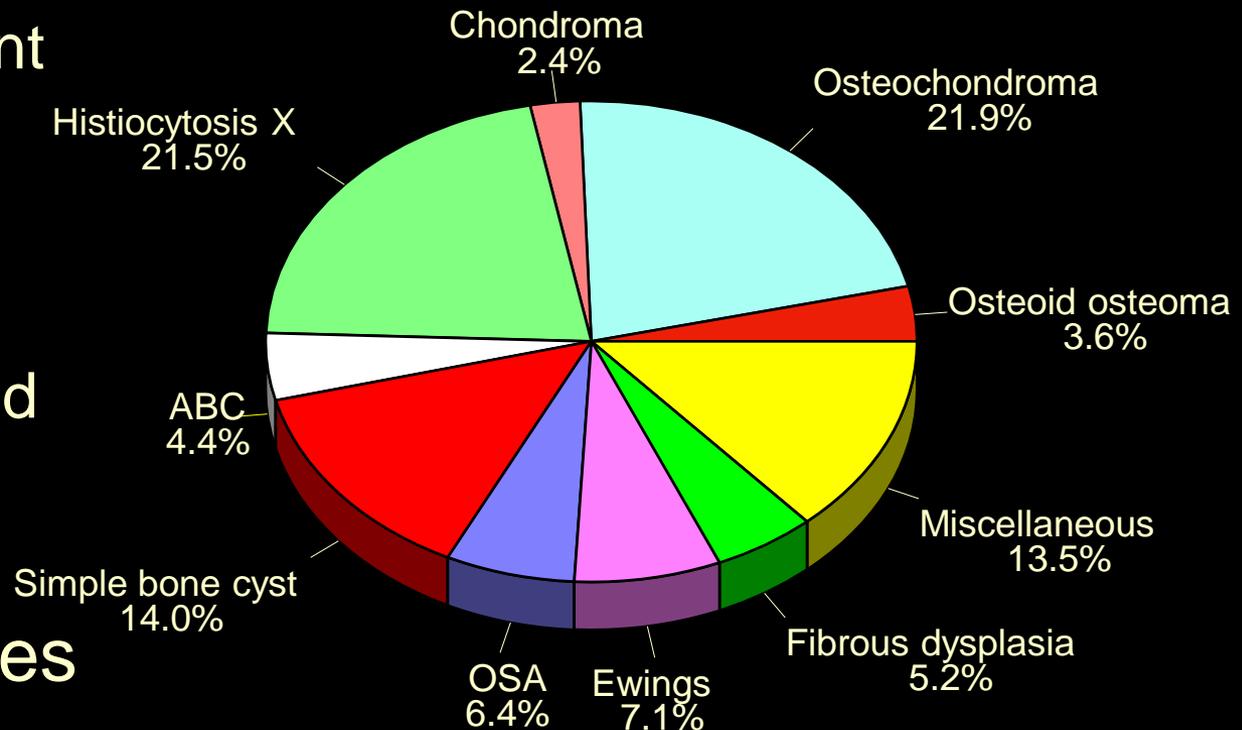
- Age of patient

- Distribution

- Diffuse
- Disseminated
- Solitary

- Tumor features

- Location
- Biologic activity
- Matrix



Distribution

- Diffuse
 - All bone is histologically abnormal
- Disseminated
 - Multiple distinct lesions
- Few
- Solitary



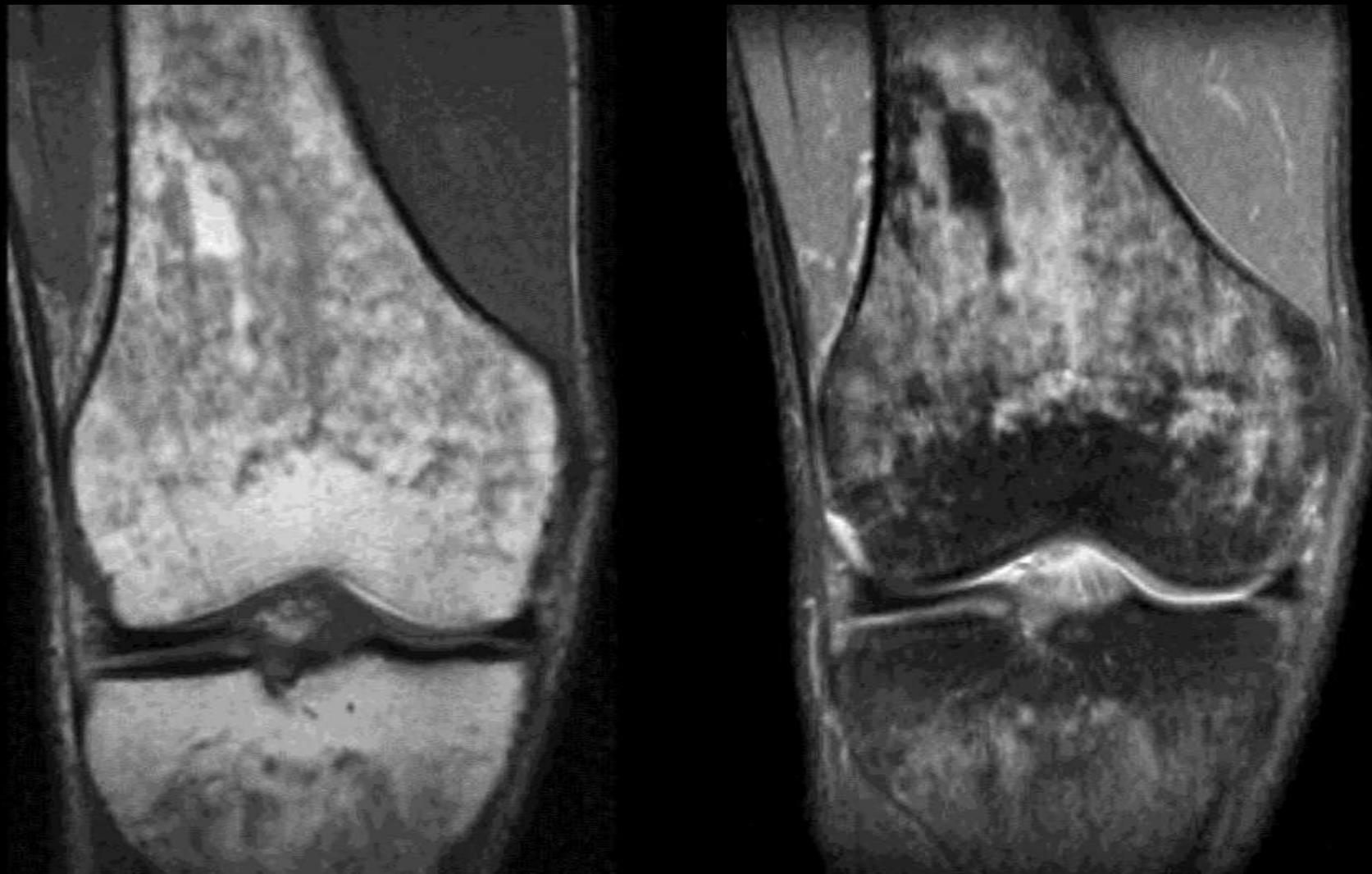
Diffuse Distribution

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



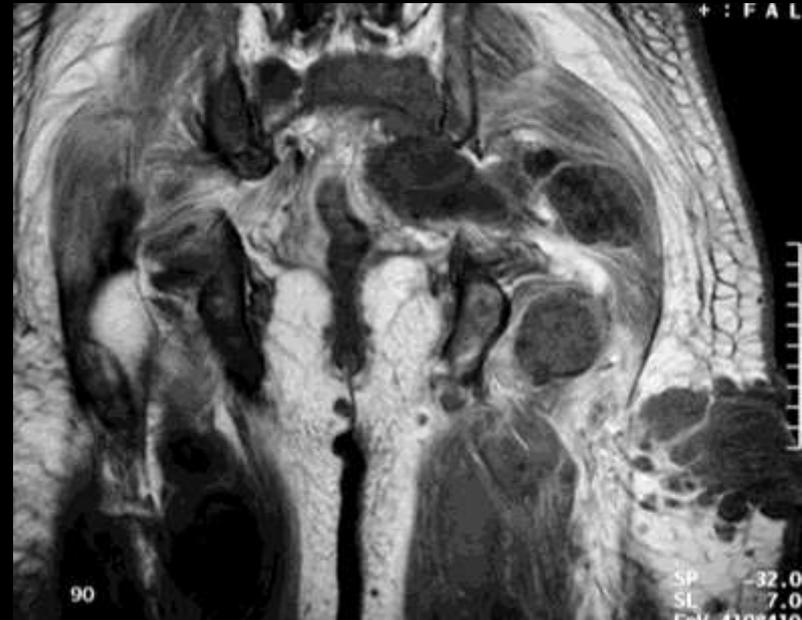
Sag T1

Diffuse Distribution

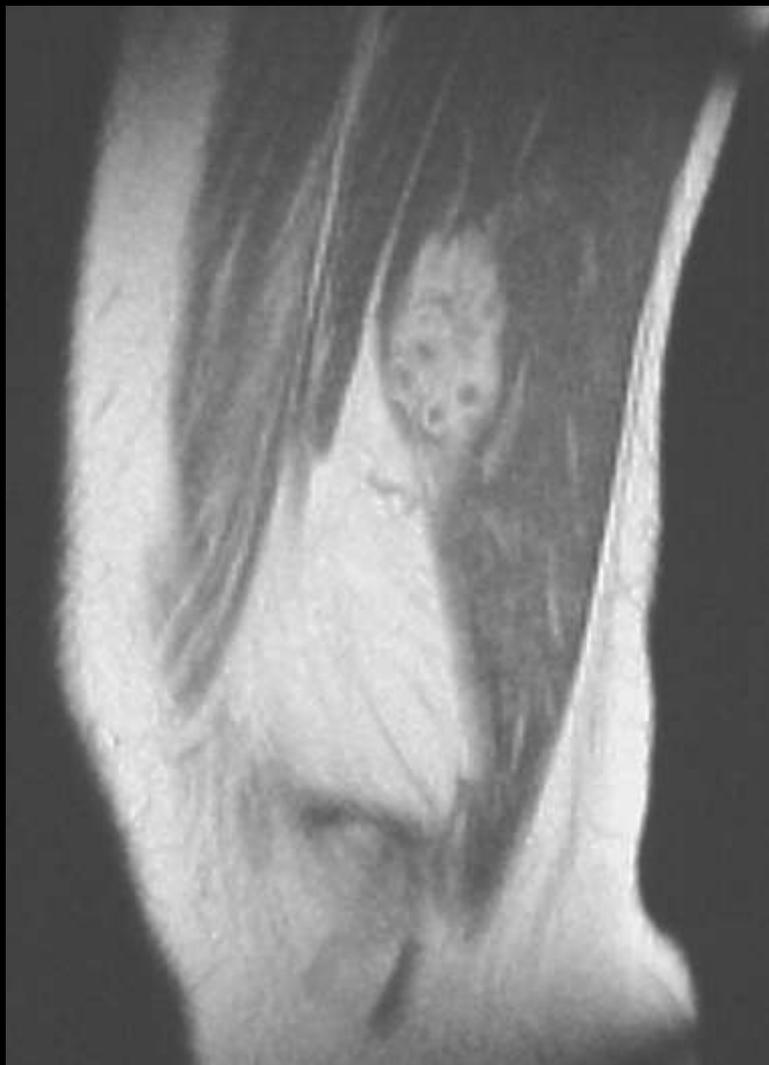


Disseminated Distribution

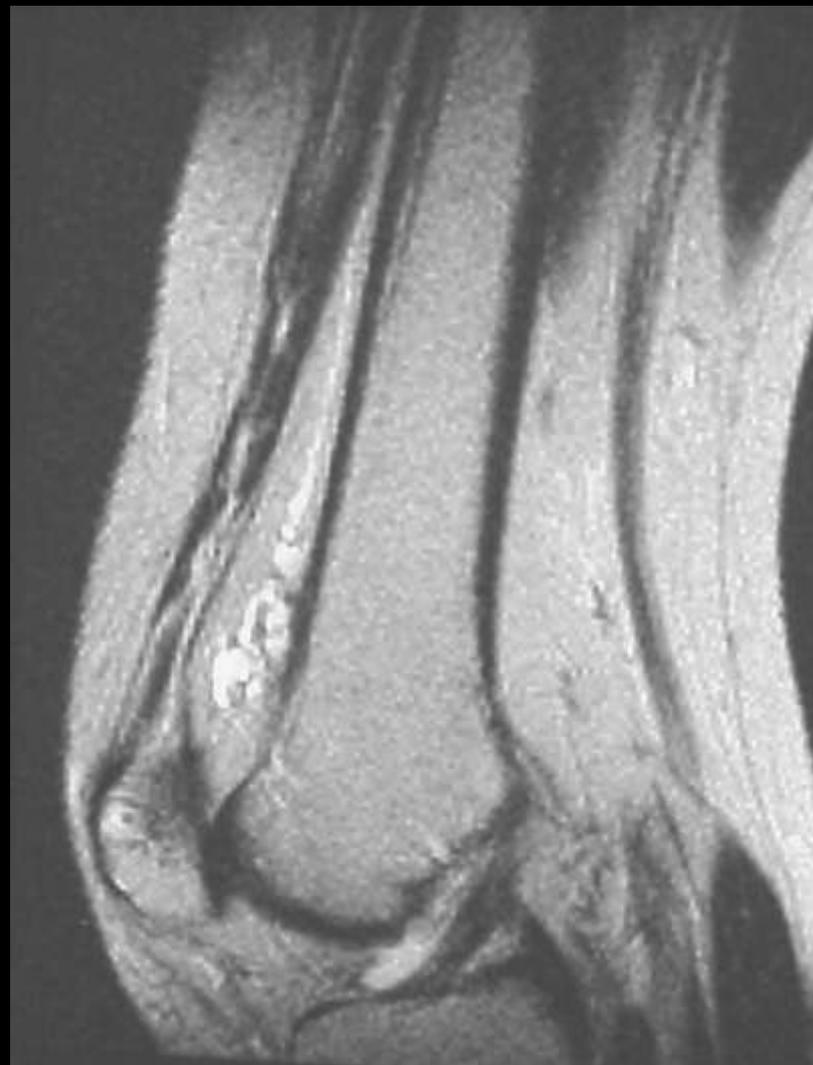
- Normal intervening bone
- Lesions may be synchronous or metachronous
- Not all lesions may be evident radiographically
- **Metastatic disease**
- Multiple myeloma
- Paget disease
- Eosinophilic granuloma
- Fibrous dysplasia
- Enchondromatosis
- Multiple osteochondromatosis



Distribution - Few



Sag PD



Heamangiomata of ST 49F

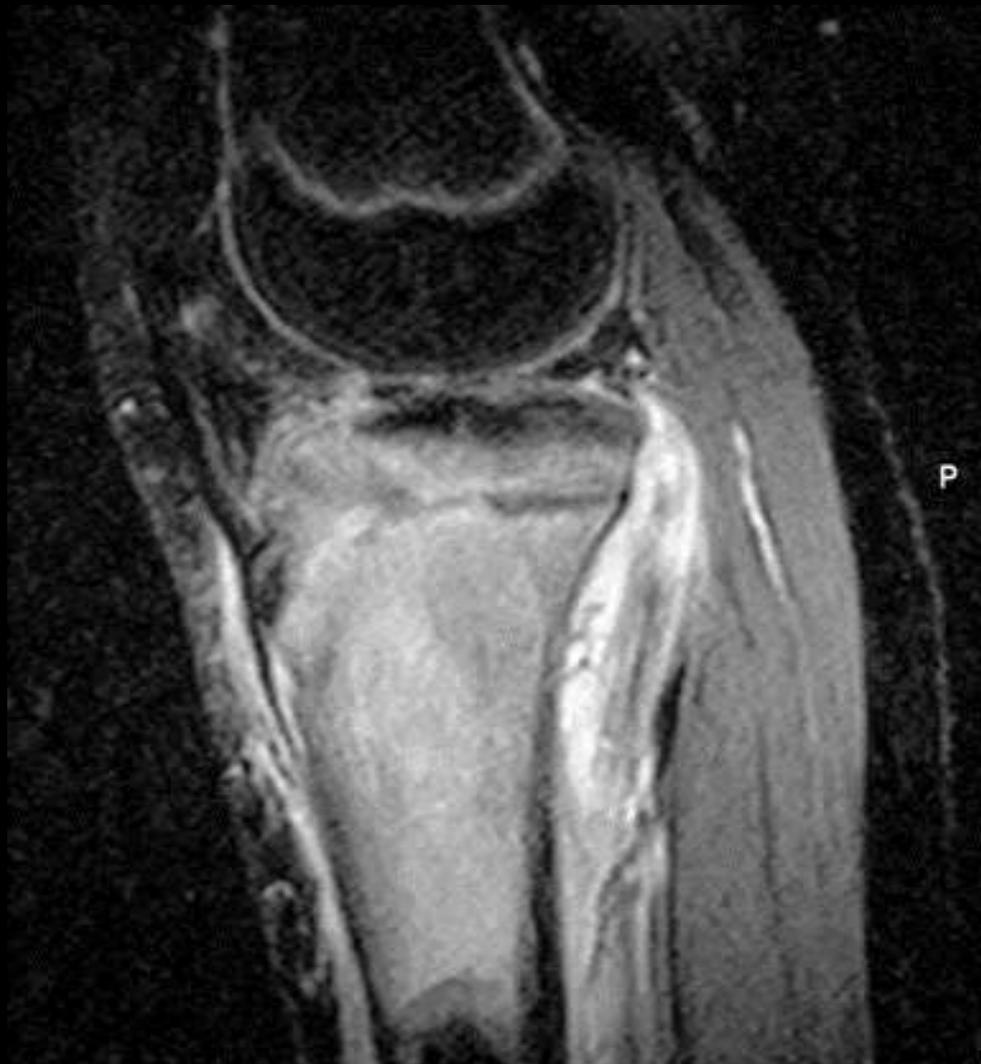
Distribution - Solitary lesion

- 10-15% of mets
- Ability to identify lesion radiographically depends on what it does to underlying osseous matrix



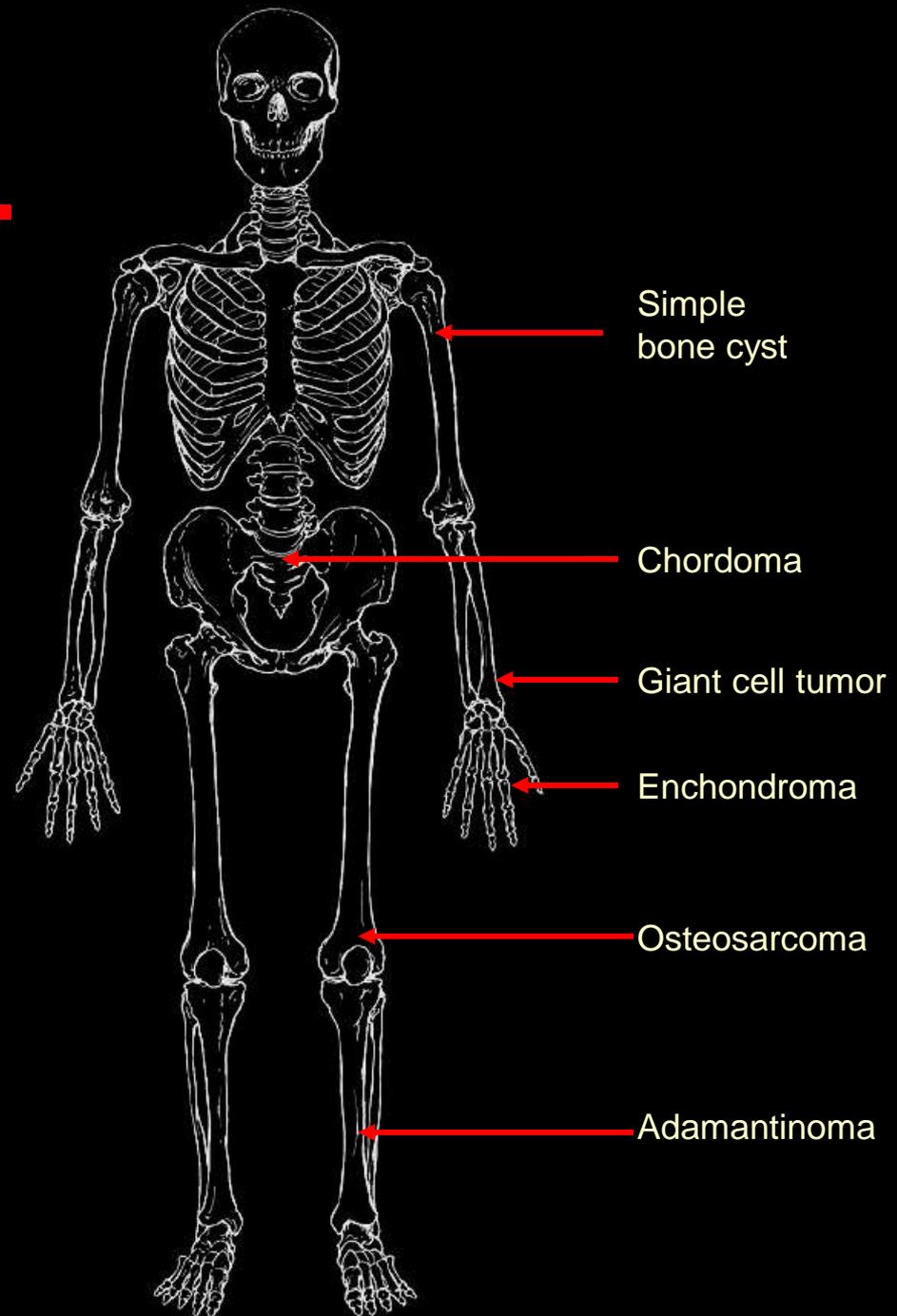
Location

- Osseous
- Soft tissue
- Intraarticular

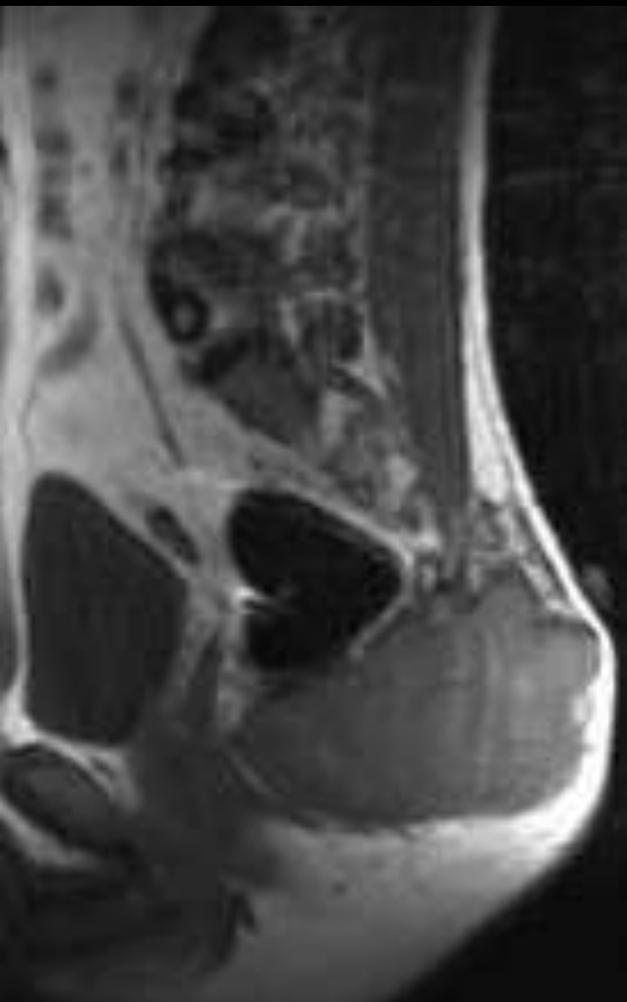


Location

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



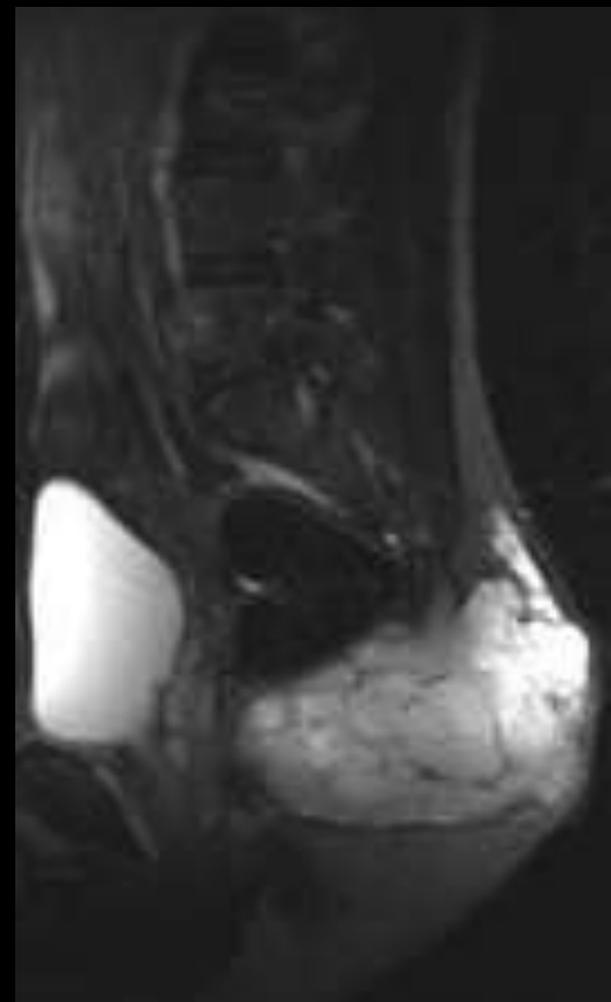
Location - Sacrum



Sag T1

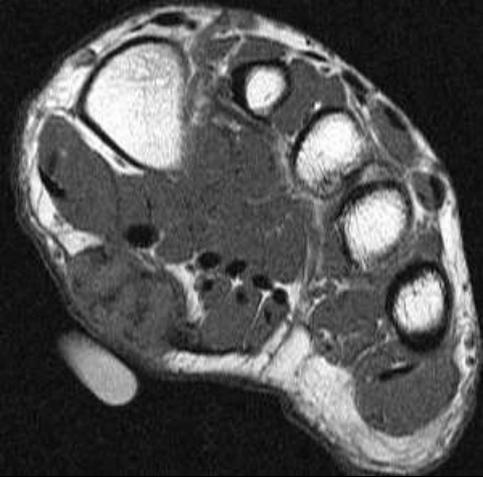


Sag T1FS IV Gd

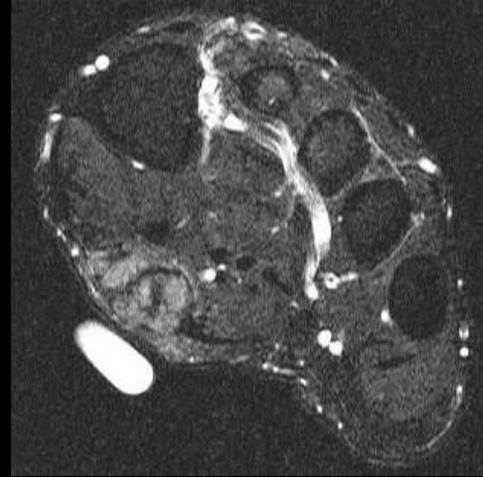


Sag T2FS

Location - Foot

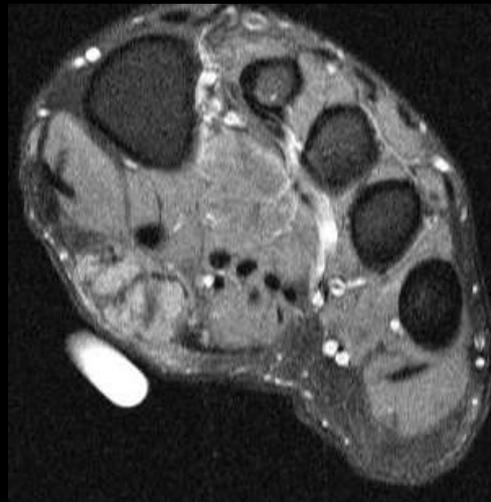


Cor T1

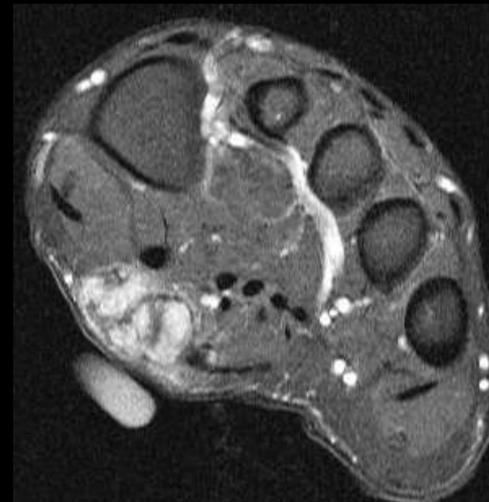


Cor T2FS

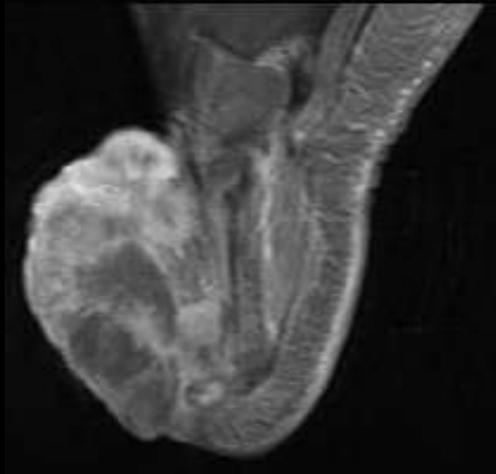
Cor PDFS



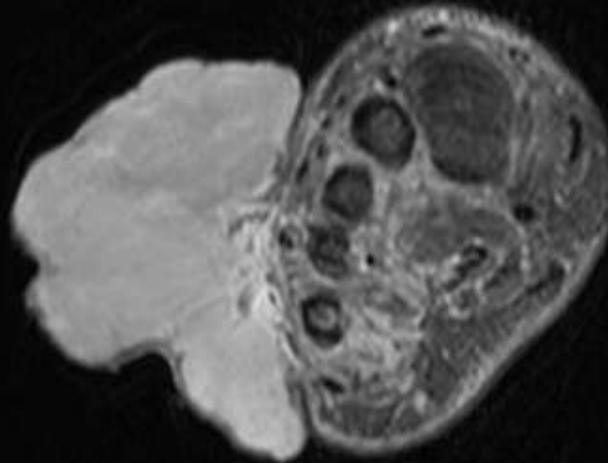
Cor T1FS IVGd



Location - Foot



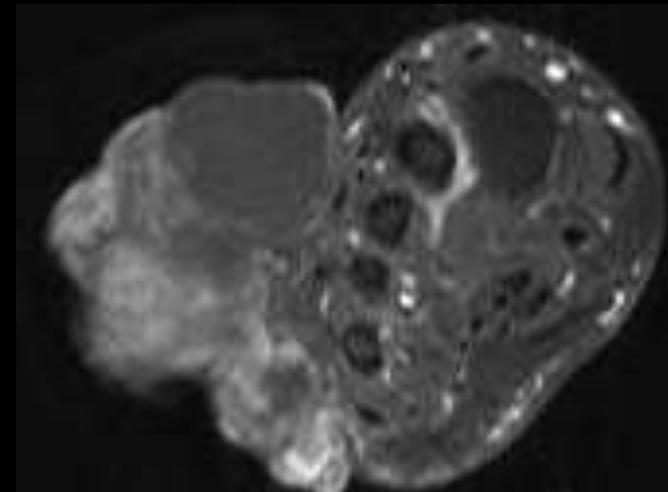
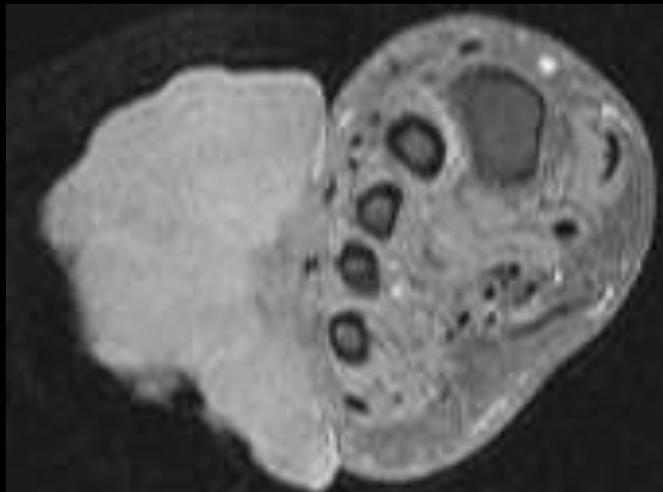
Sag T1FS IVGd



Cor T2FS

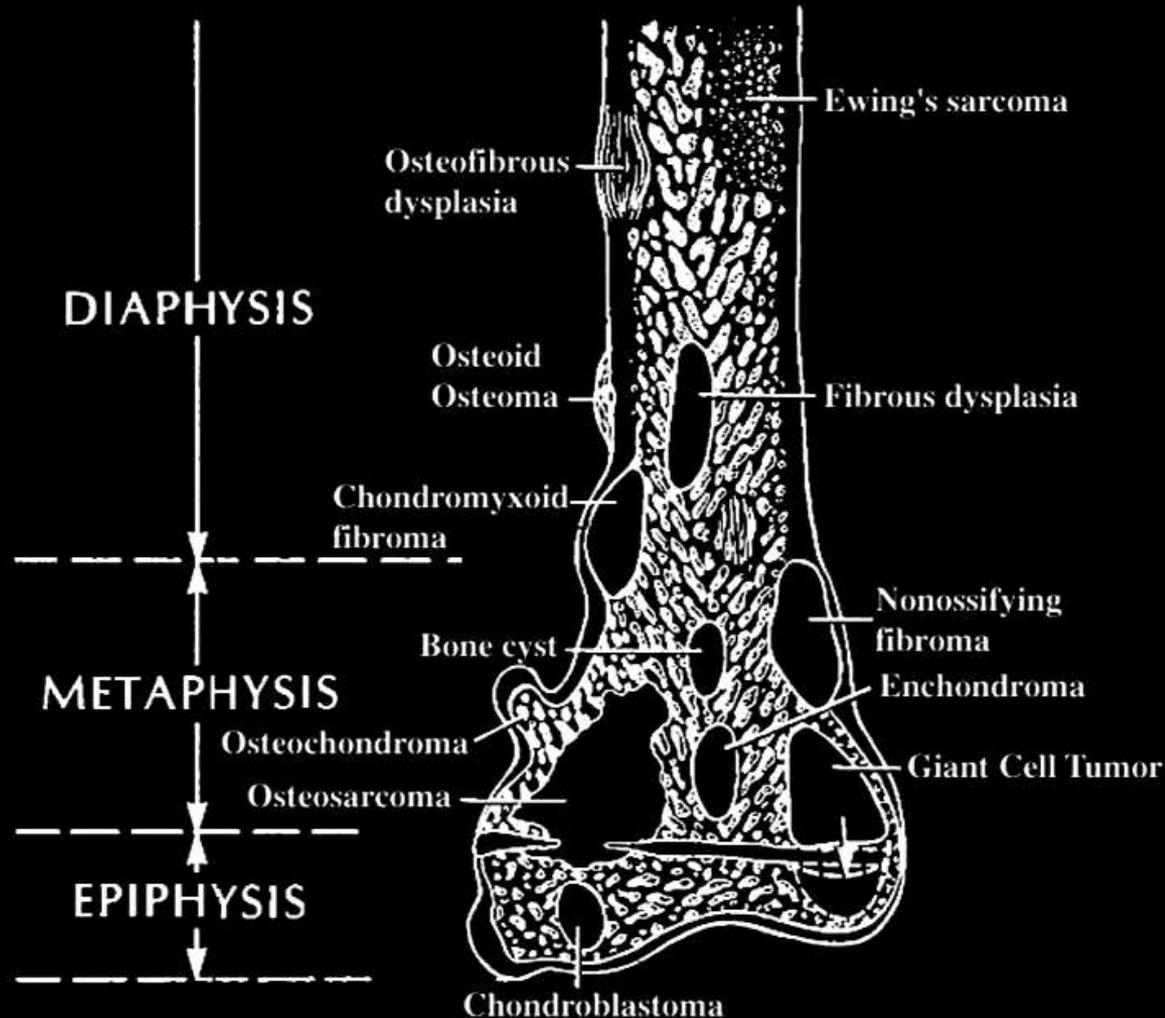
Cor PDFS

Cor T1FS IVGd

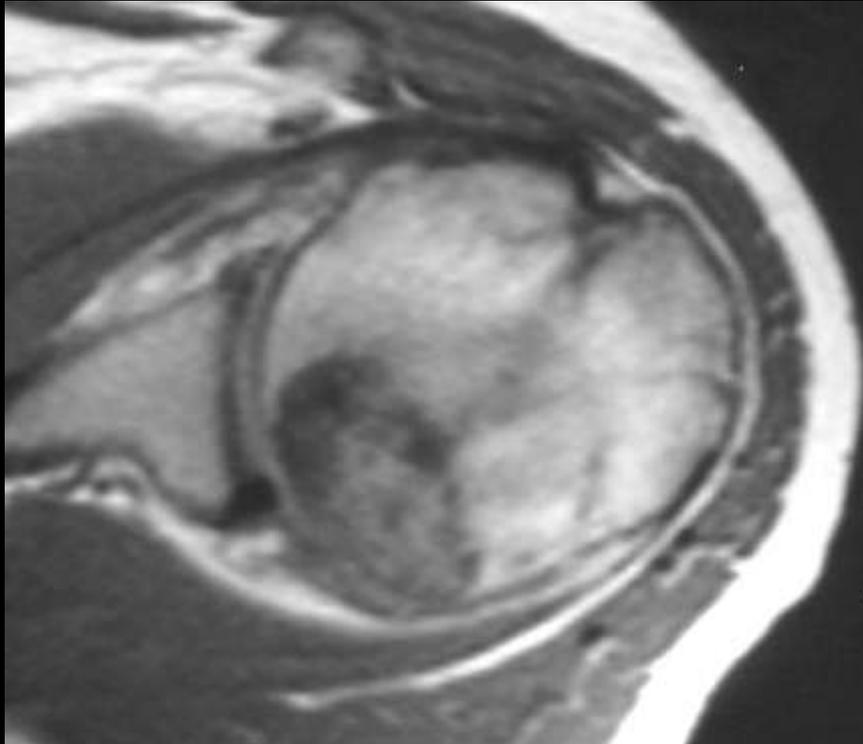


Location

- Longitudinal
 - Epiphysis
 - Metaphysis
 - Diaphysis
- Transverse
 - Central
 - Eccentric
 - Cortical
 - Surface



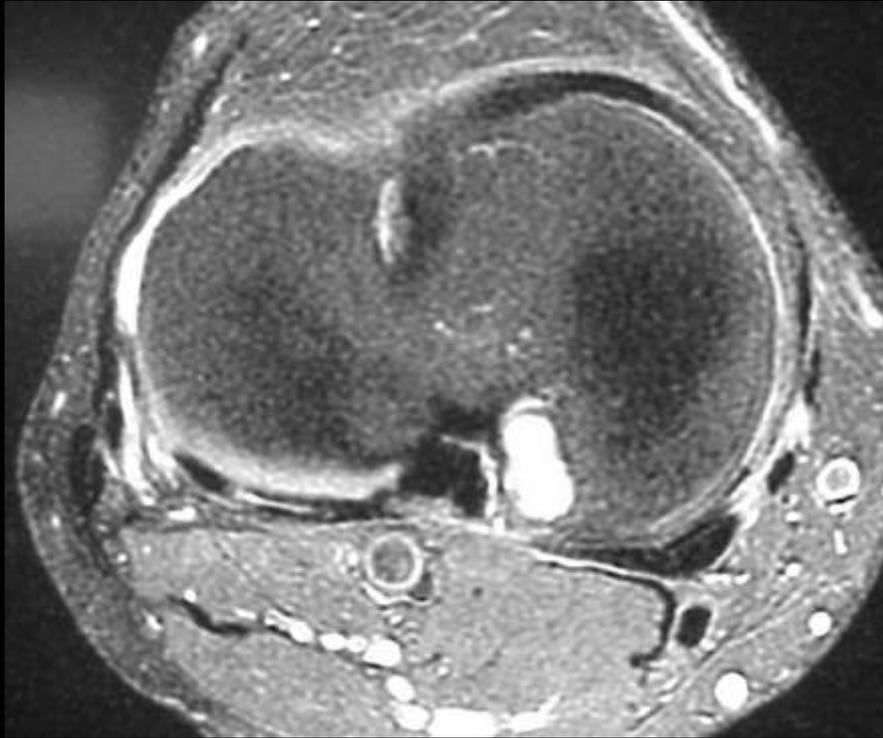
Location - Longitudinal - Epiphyseal



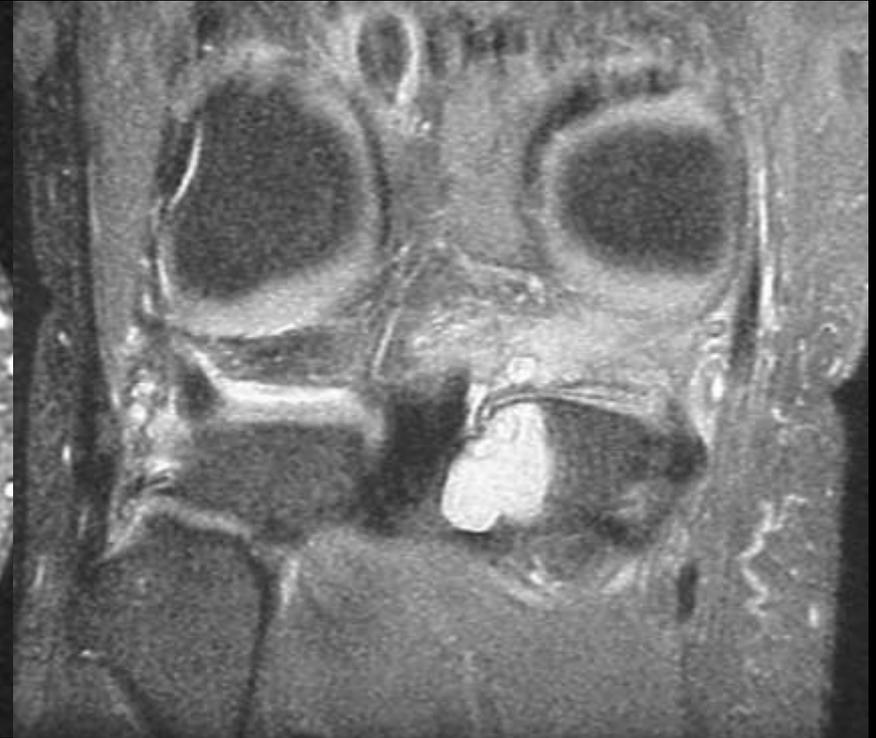
Ax T1



Location - Longitudinal - Epiphyseal



Ax PDFS



Cor PDFS

Technique

Detection

Histologic characterization

Anatomic staging

Biopsy

Follow-up

Location - Longitudinal - MetaEpiphyseal



AP



Cor T1

Location - Longitudinal - Metaphyseal



Sag T1



Sag PDFS



Sag T1FS IV Gd

Location - Longitudinal - Metaphyseal



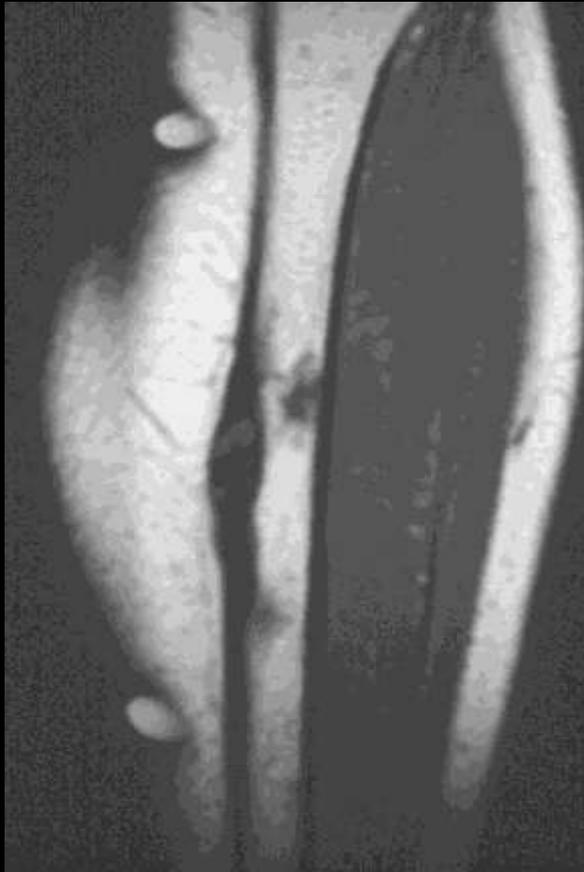
Cor T1



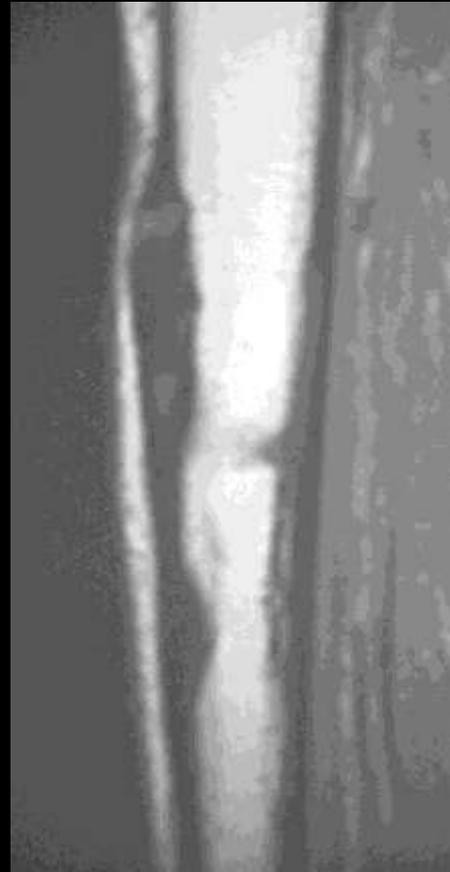
Ax GrT2

Osteochondroma

Location - Longitudinal - Diaphyseal



Cor T1



Sag T1



SagT2FS

Location – Transverse - Medullary



Cor T1



Cor PDFS

Location – Transverse - Medullary



Cor T1



Cor PDFS

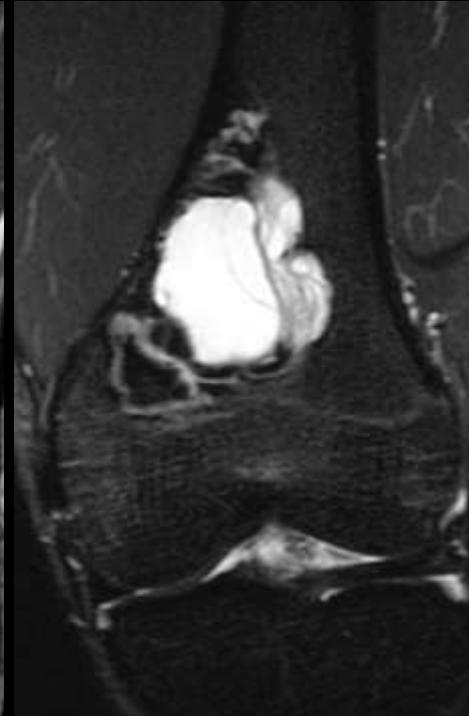
Location – Transverse - Eccentric



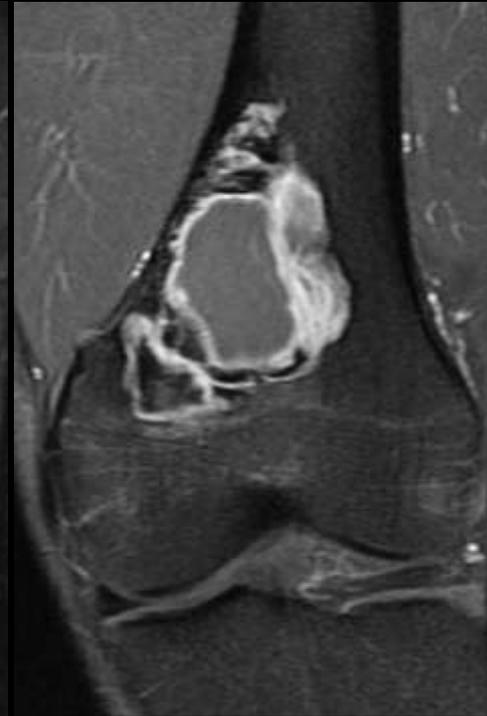
AP



Cor T1

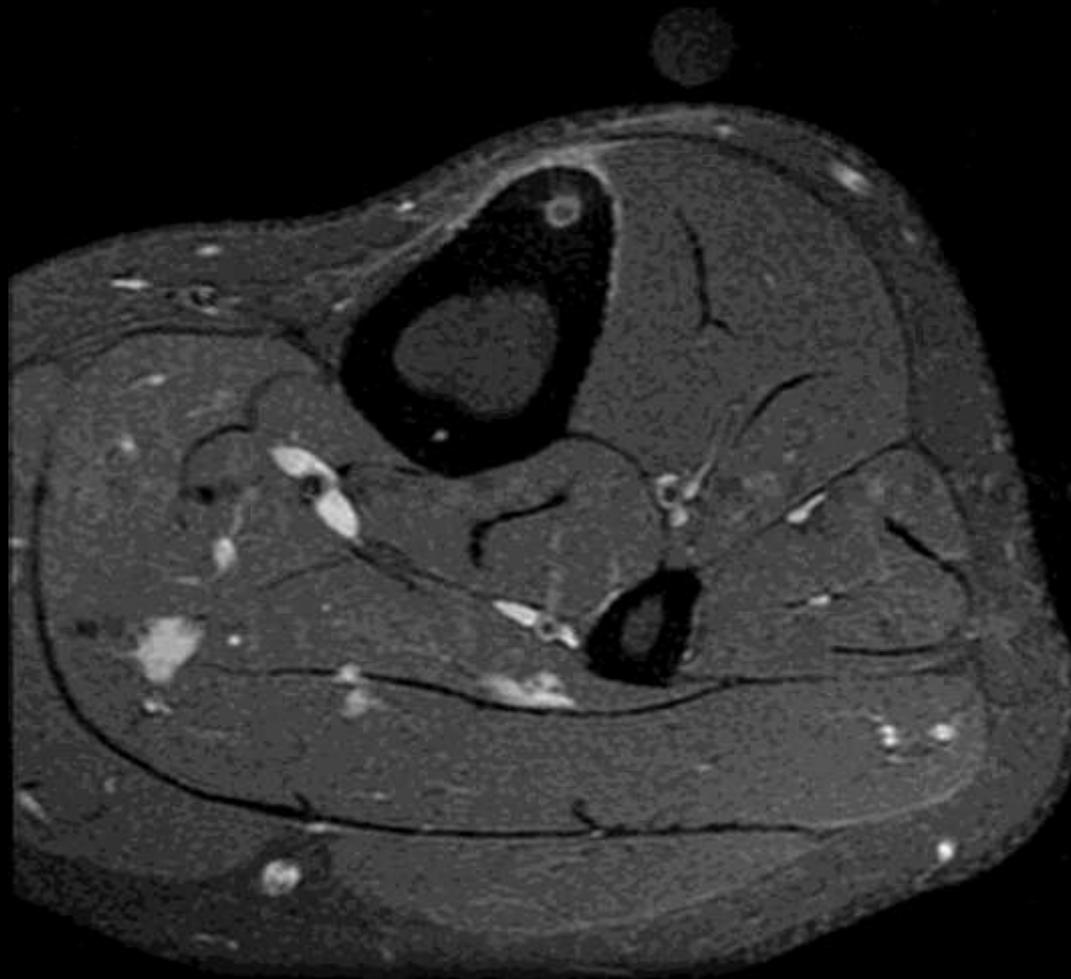


Cor PDFS

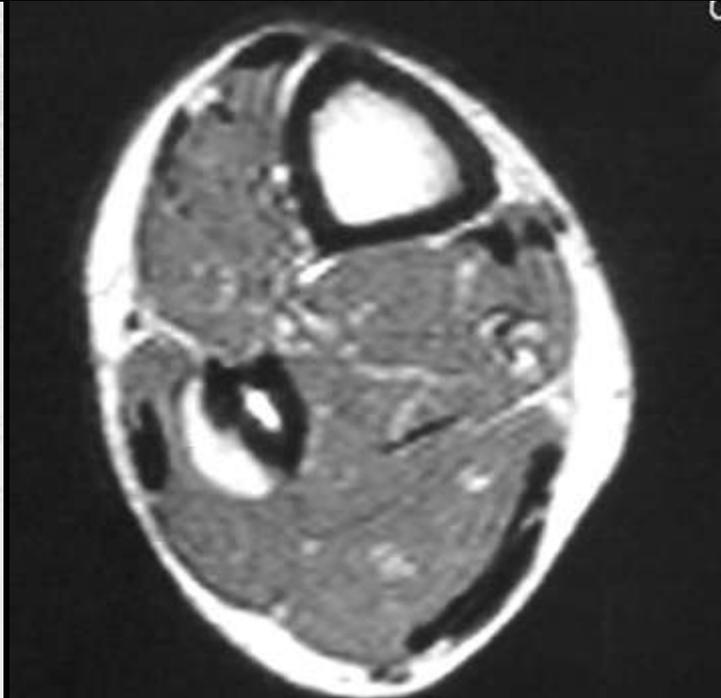


Cor T1FS IV Gd

Location – Transverse - Cortical



Location - Transverse - Periosteal



Ax T1



Sag T1 SPIR Gd

Location - Transverse - Juxtacortical



Cor T1



Cor T1Gd



Cor T2

Technique

Detection

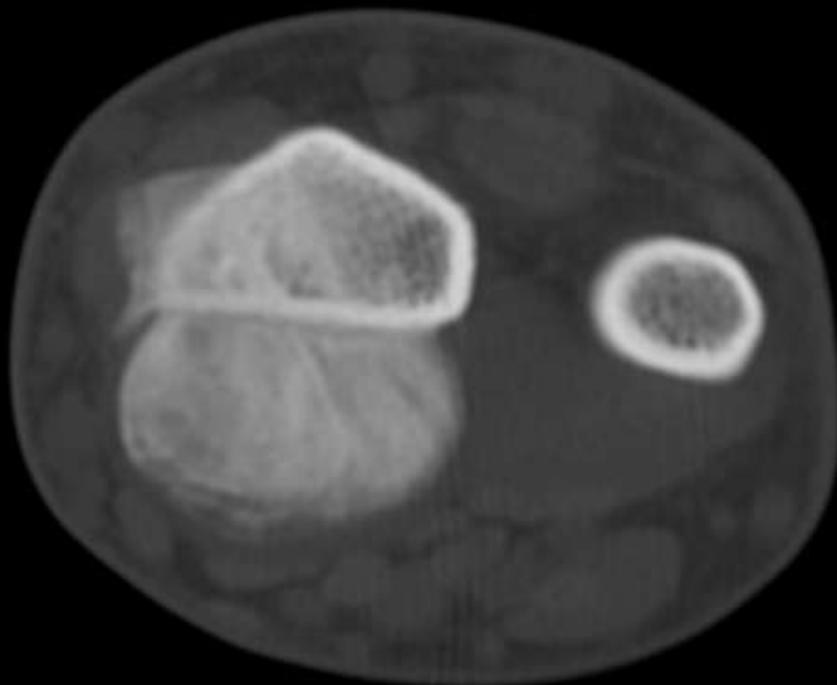
Histologic characterization

Anatomic staging

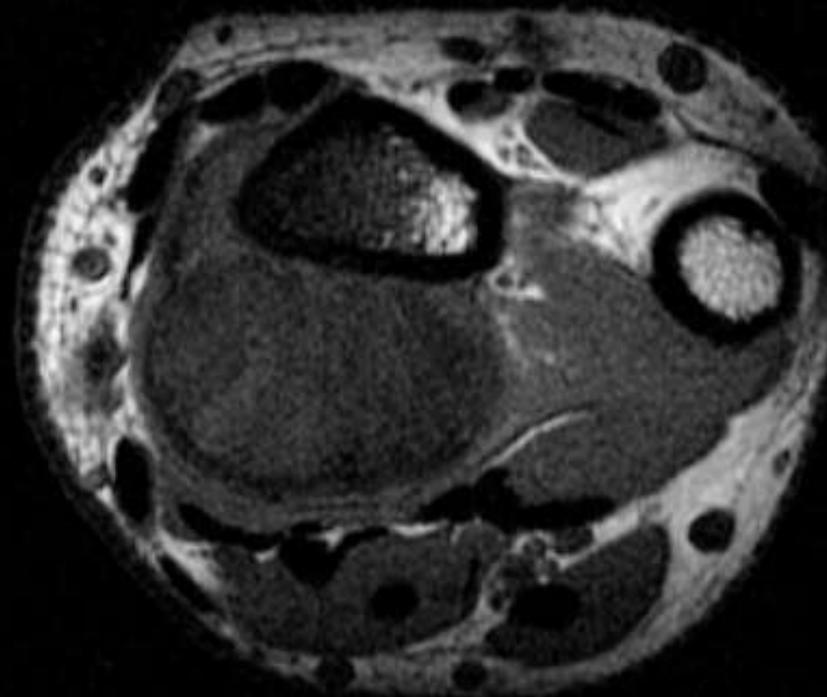
Biopsy

Follow-up

Location - Transverse - Parosteal



Axial CT

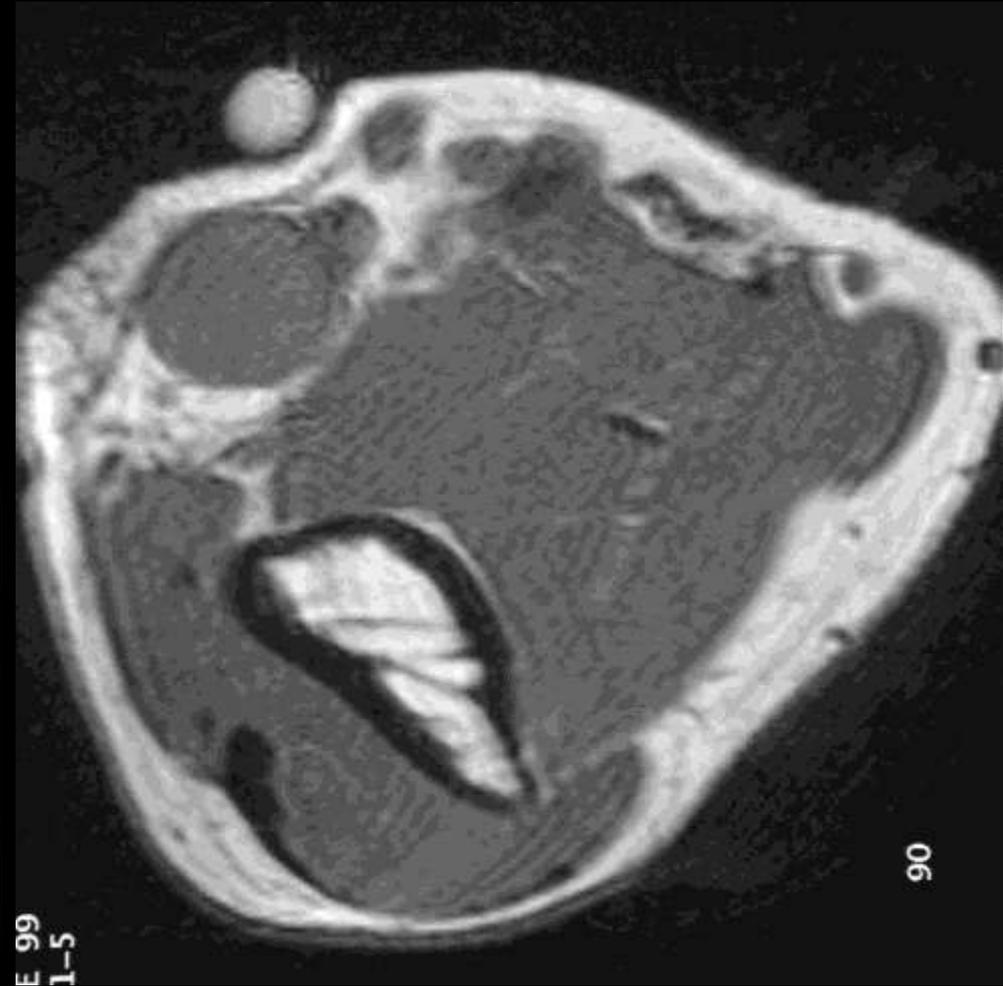


Axial T1

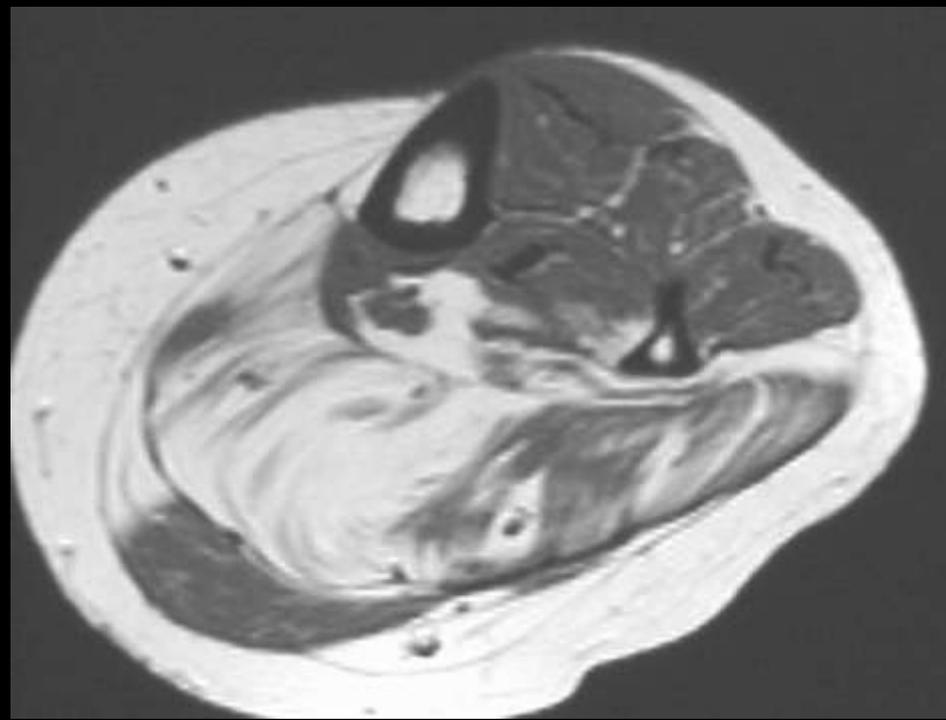
Lump on Forearm Parosteal osteosarcoma

Location – Soft tissues

- Not as helpful for soft tissue lesions



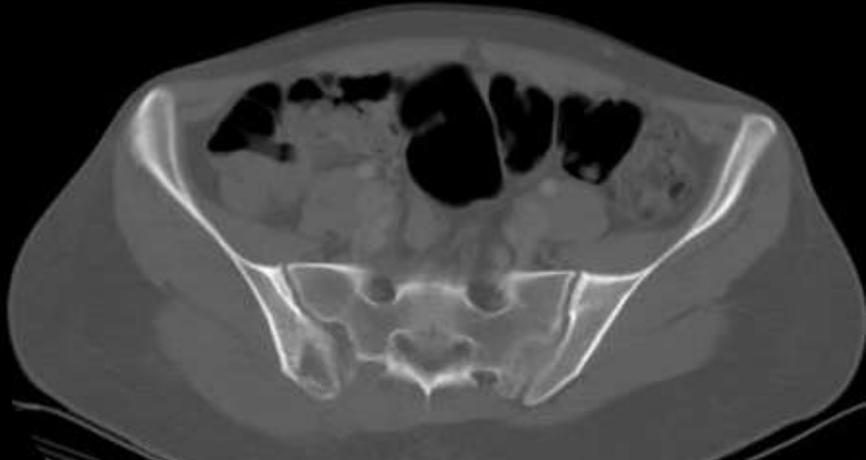
Location - Depth



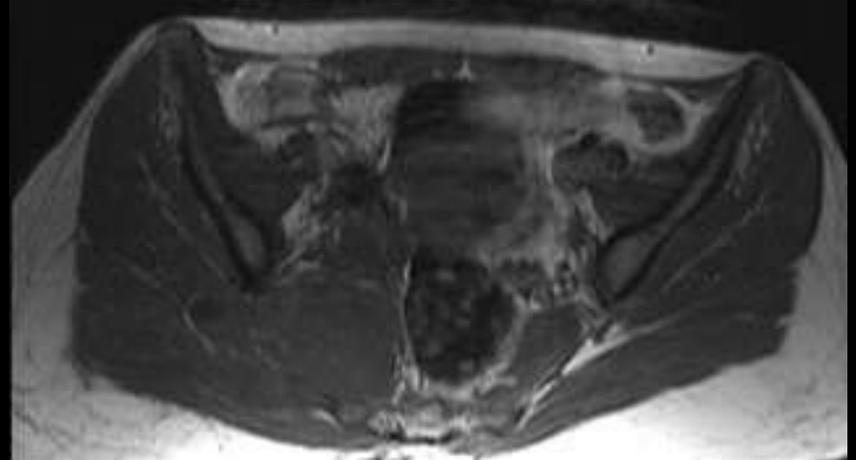
Intermuscular lipoma shoulder

Intramuscular lipoma soleus

Location – Soft tissues

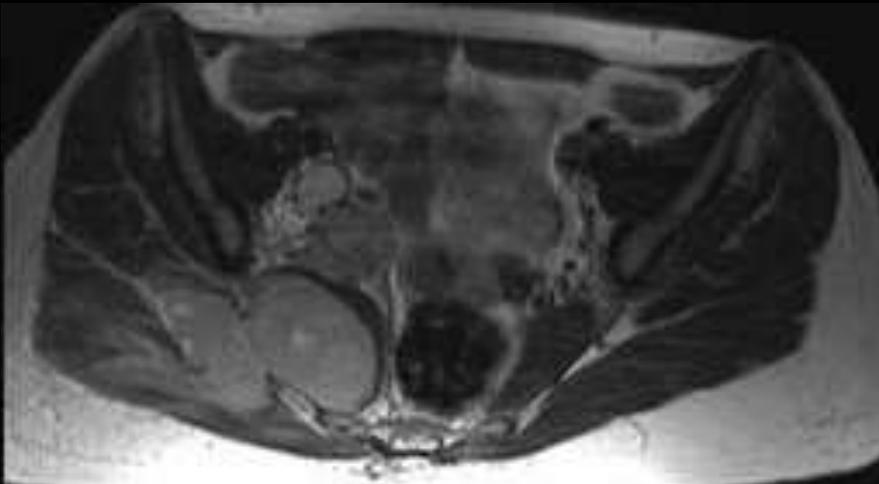


Ax CT

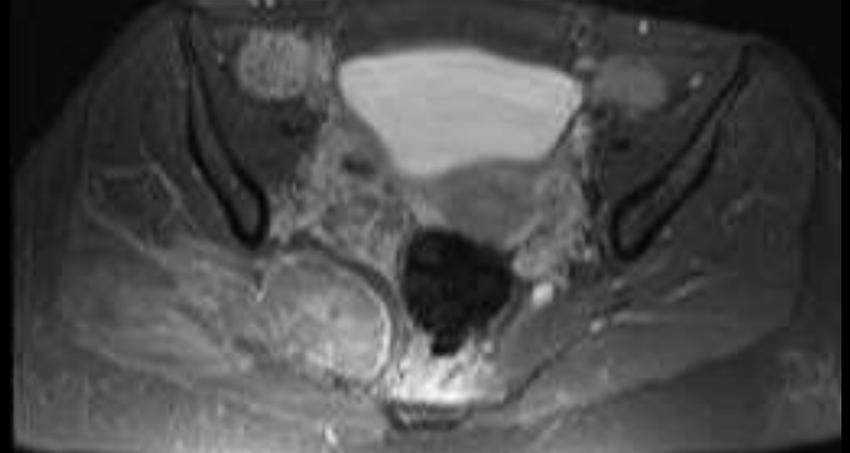


Ax T1

Ax T2



Ax T1FS IVGd



Location - Joint

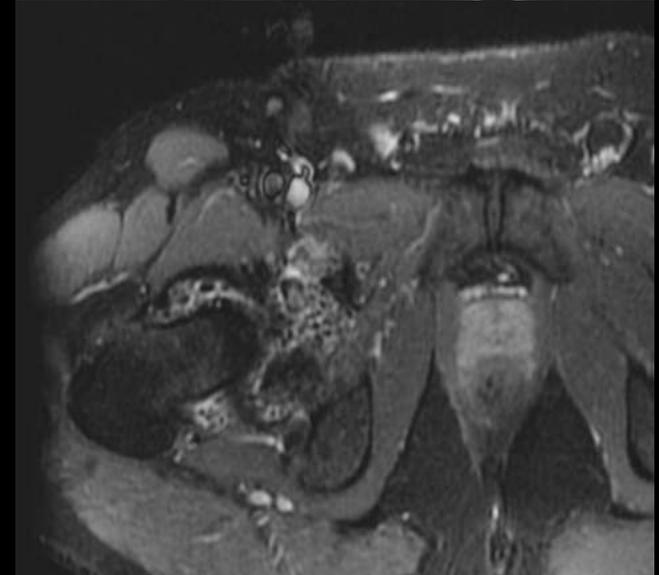
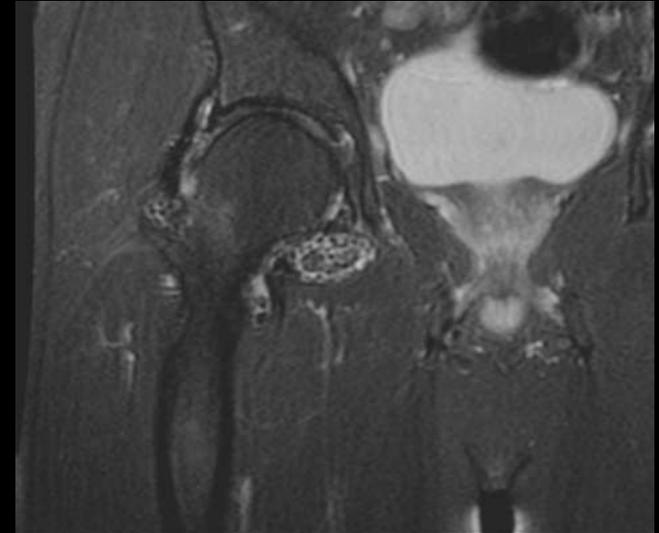
- PVNS
- Synovial osteochondromatosis
- Hemangioma
- Synovial sarcoma
- Intraarticular osteoid osteoma



Sag T1Gd

Location - Joint

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



Location - Joint

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Sag PDFS

Location - Joint

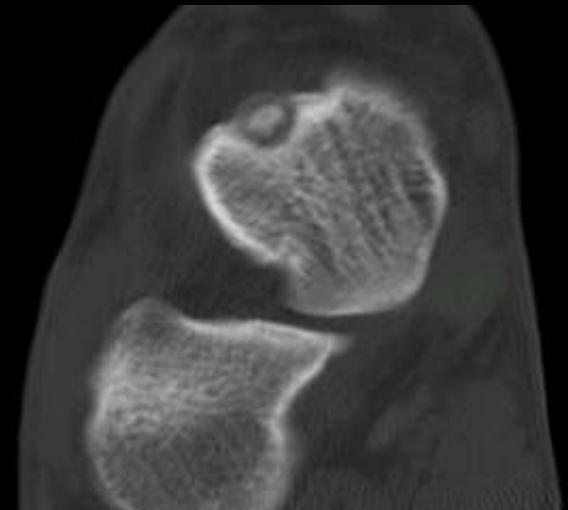
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Sag GE

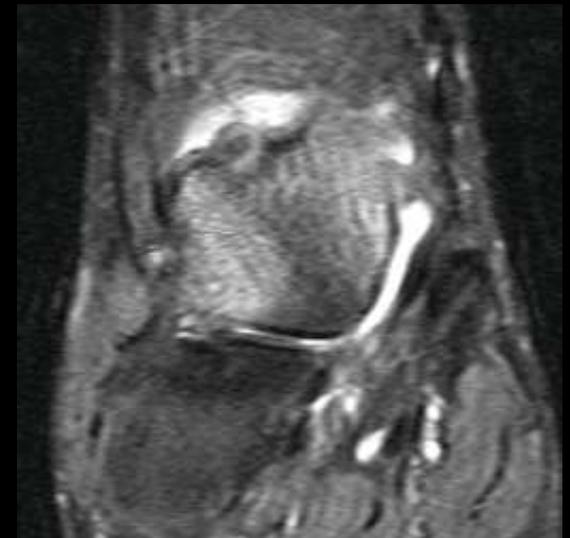
Location - Joint

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Cor CT

Cor T2FS



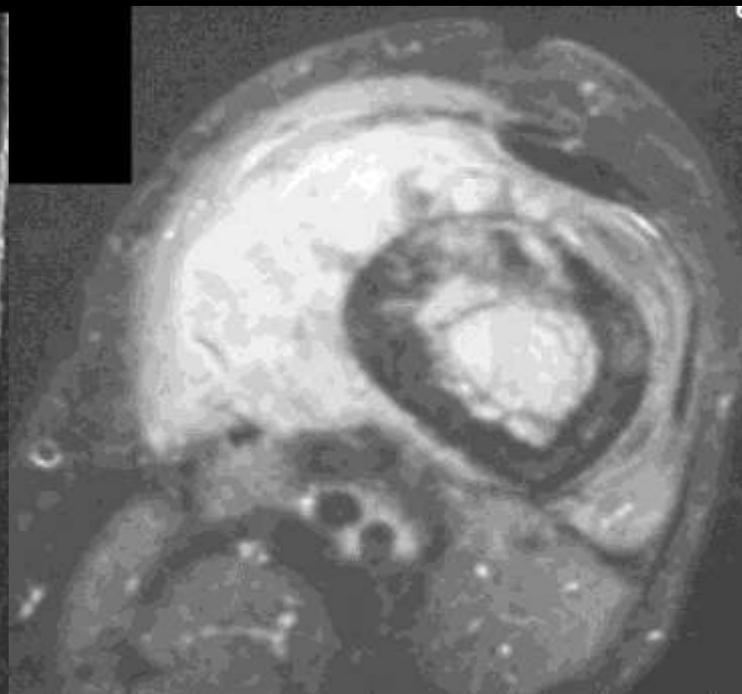
Osteoid-osteoma ankle

Location - Pre existing condition



Cor T1

Cor T2



Ax T2 STIR

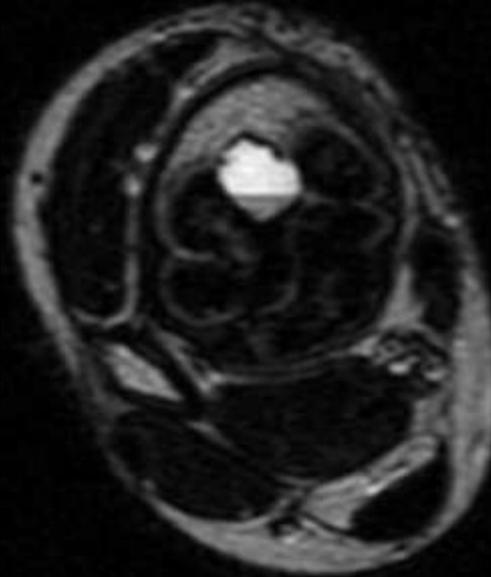
Location - Pre existing condition

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

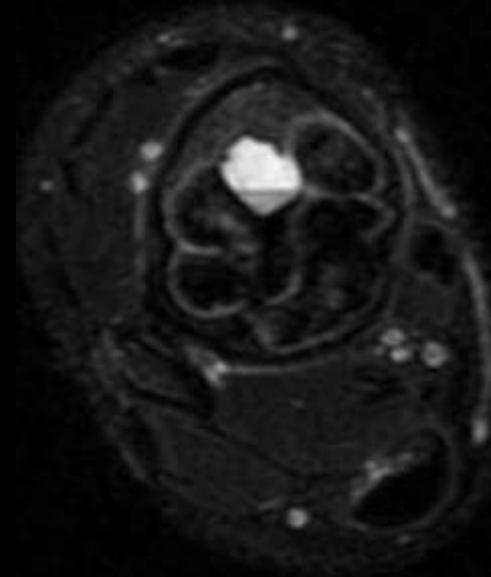


Location - Pre existing condition

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Ax T2



Ax T2 FS

Location - Pre existing condition

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



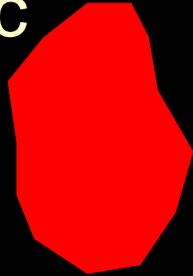
Location - Pre existing condition

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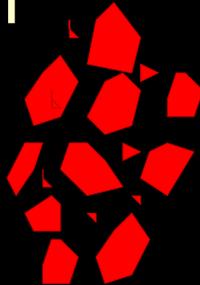


Biologic activity

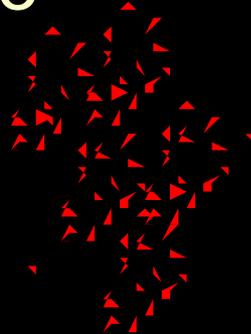
- Geographic



- Moth-eaten



- Permeative

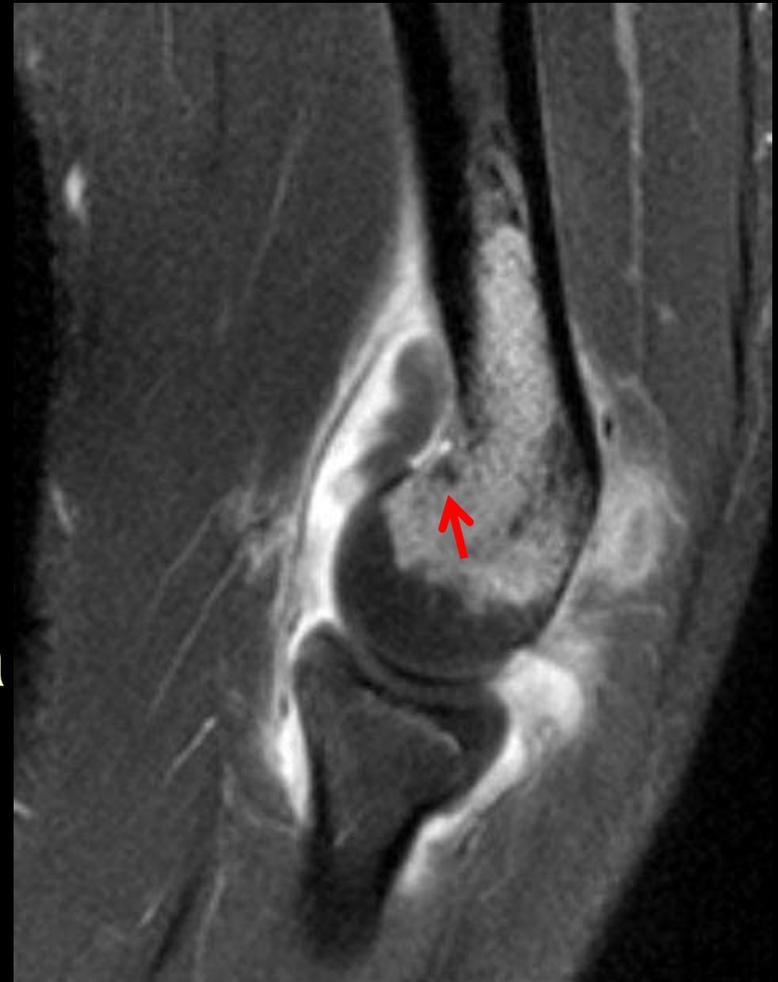


Margin

- 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

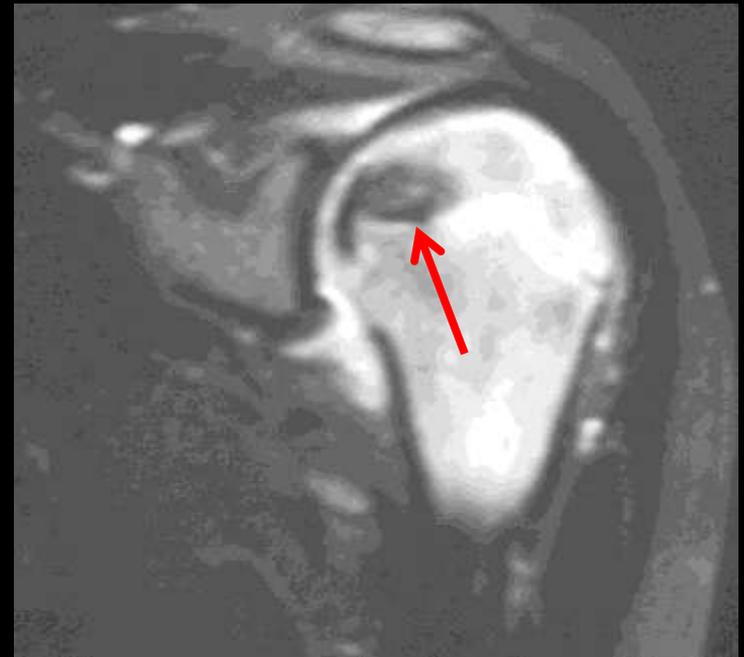
- Osteoid osteoma
- Chondroblastoma
- Eosinophilic granuloma



Sag T1FS IVGd

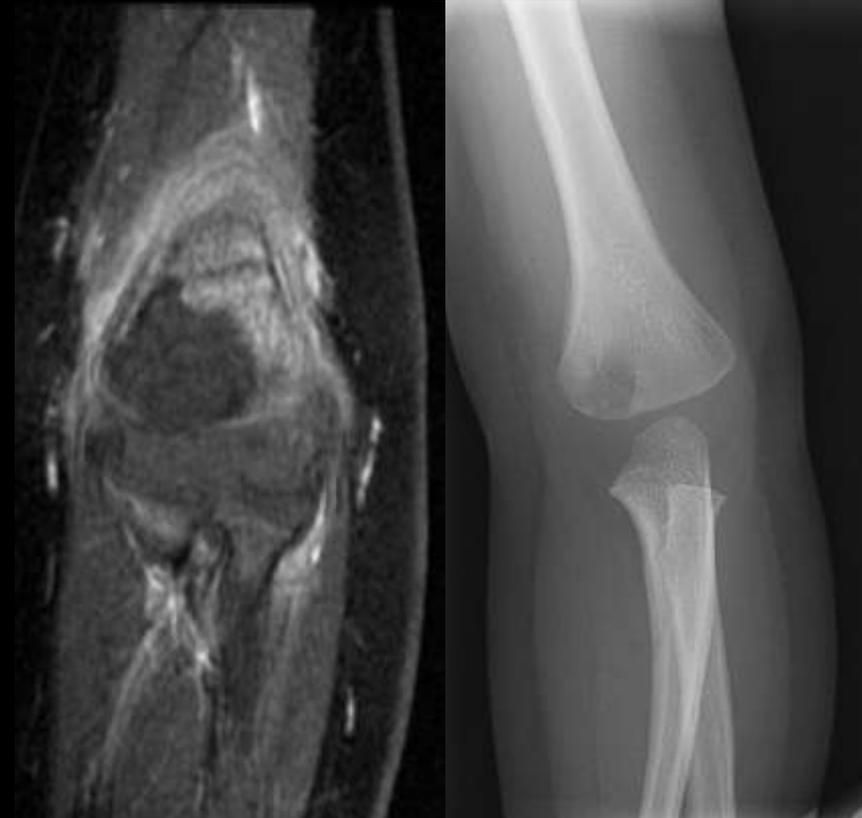
Peritumoral edema

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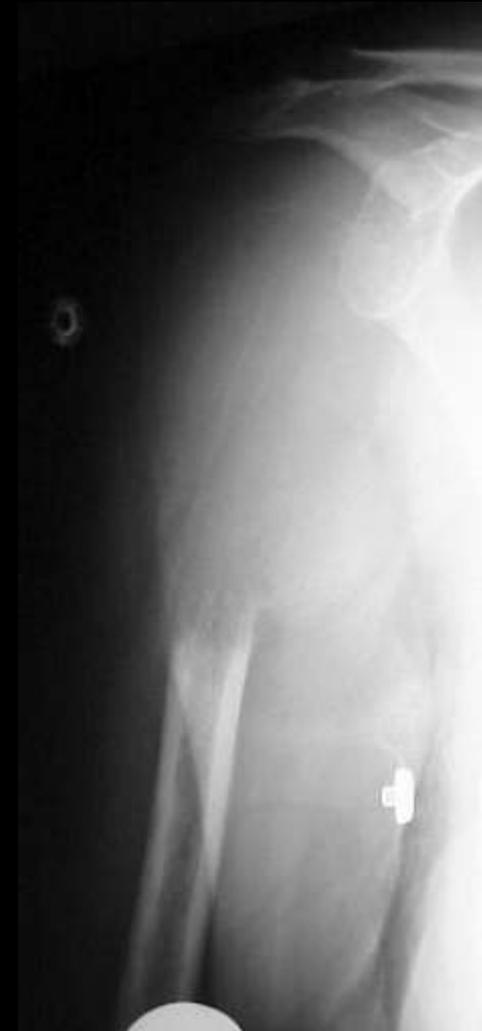
Peritumoral edema

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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

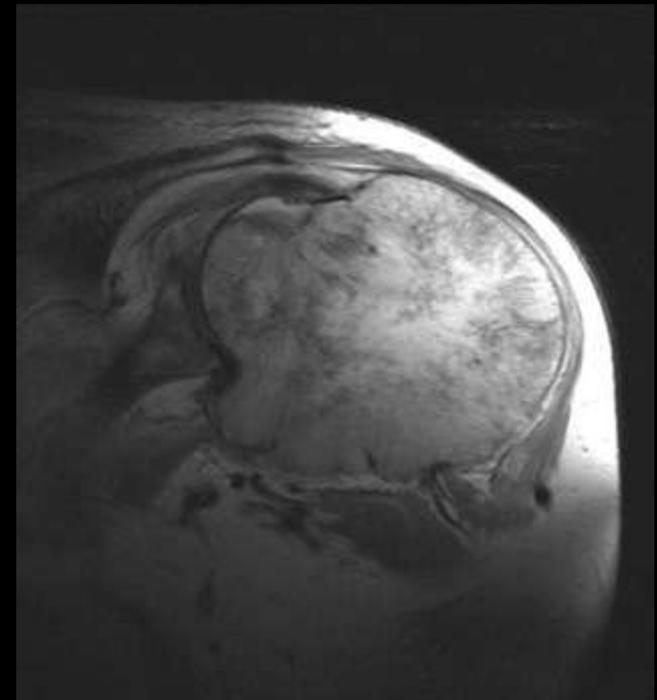
- Primary malignant

- Primary benign

-

- Non-neoplastic

-



Expansile lytic lesions of bone

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- Primary malignant

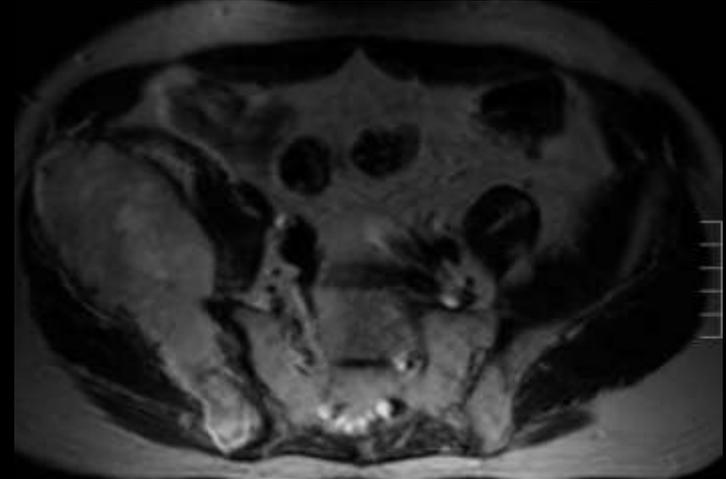
- Plasmacytoma

- Primary benign

-

- Non-neoplastic

-



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

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

- Primary malignant

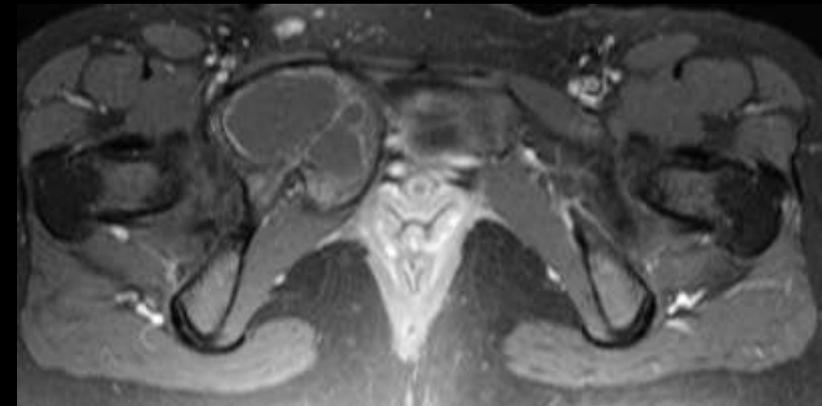
- Plasmacytoma

- Primary benign

- ABC, GCT, Enchondroma

- Non-neoplastic

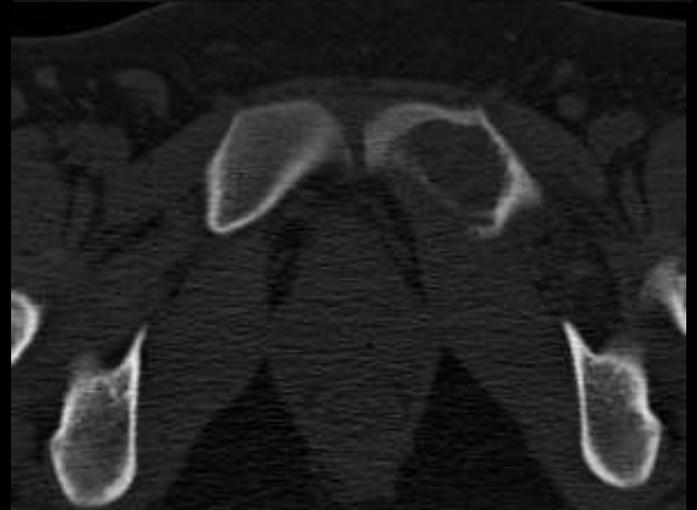
- Hemophilia, Brown, Hydatid, Fibrous dysplasia



Fluid fluid levels

Differential Diagnosis – fluid-fluid levels

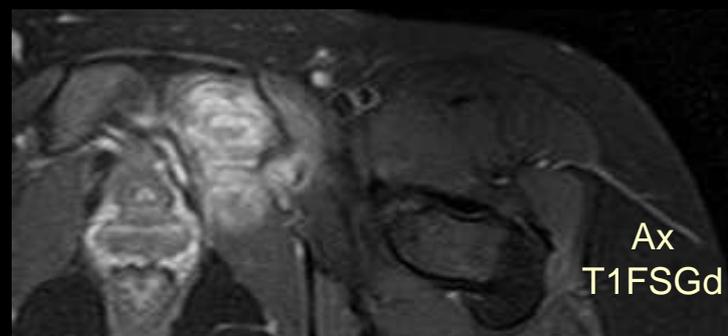
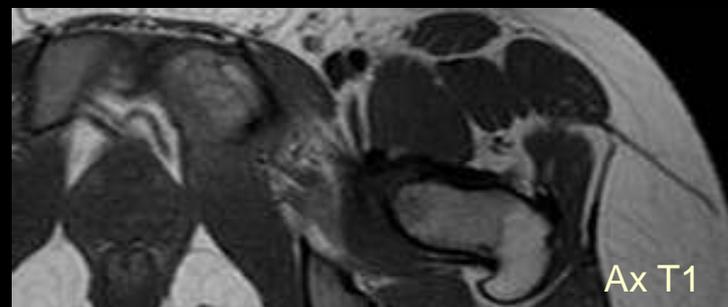
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- Telangiectatic osteosarcoma
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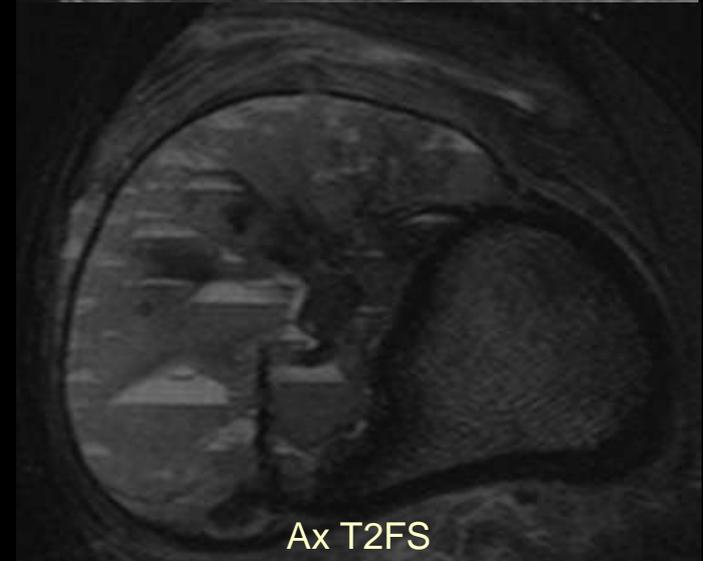


19 year old male with knee pain. Right distal femur: Osteosarcoma with telangiectatic features.

Fluid fluid levels

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 - NOF
 - Chondroblastoma
 - Osteoblastoma



Types of Periostitis

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



Solid



Onion-skin



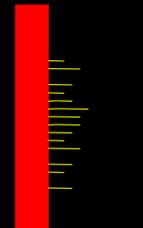
Sunburst



Linear



Codman's triangle

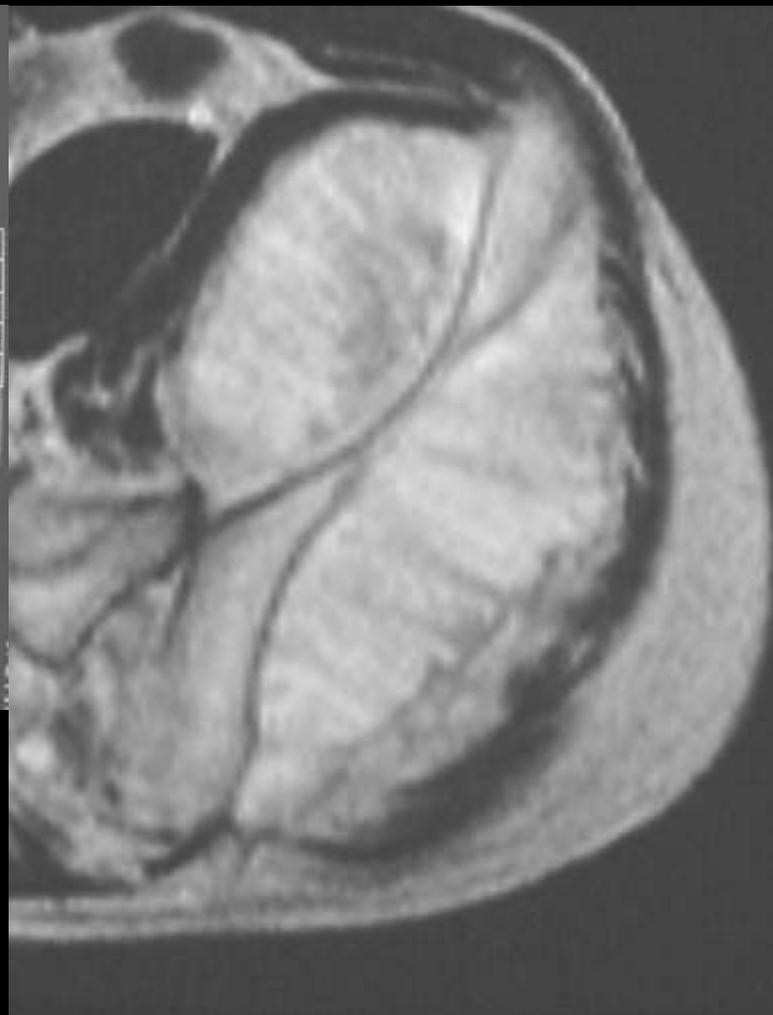


Hair-on-end

Types of Periostitis



Hair on end

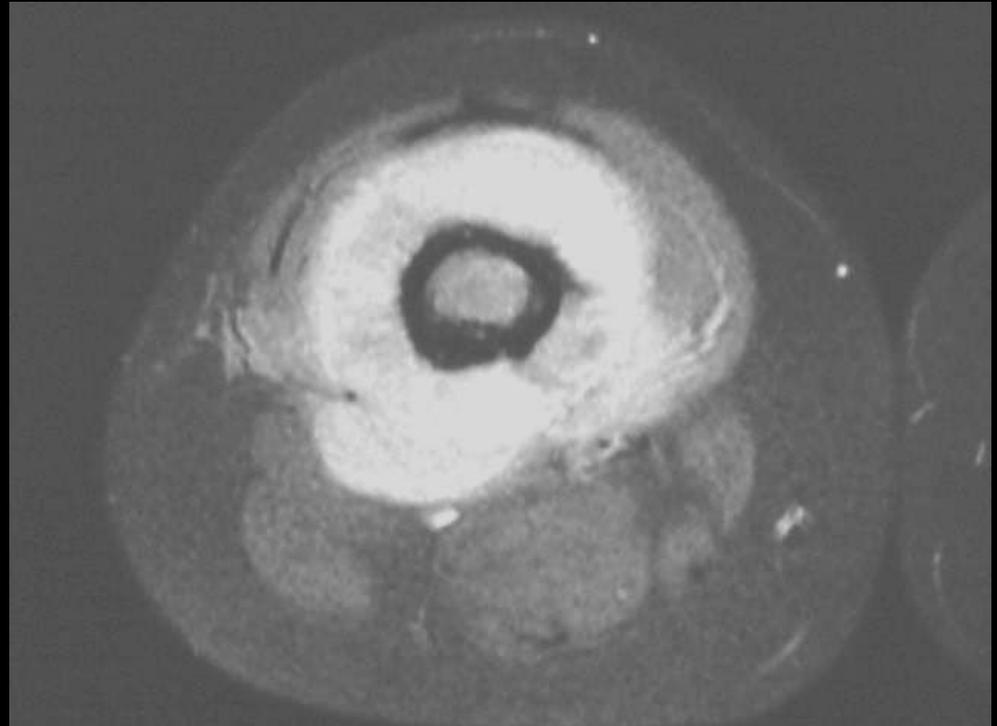


Ax T2

Types of Periostitis



Sag T1 SPIR Gd



Ax T1 SPIR Gd

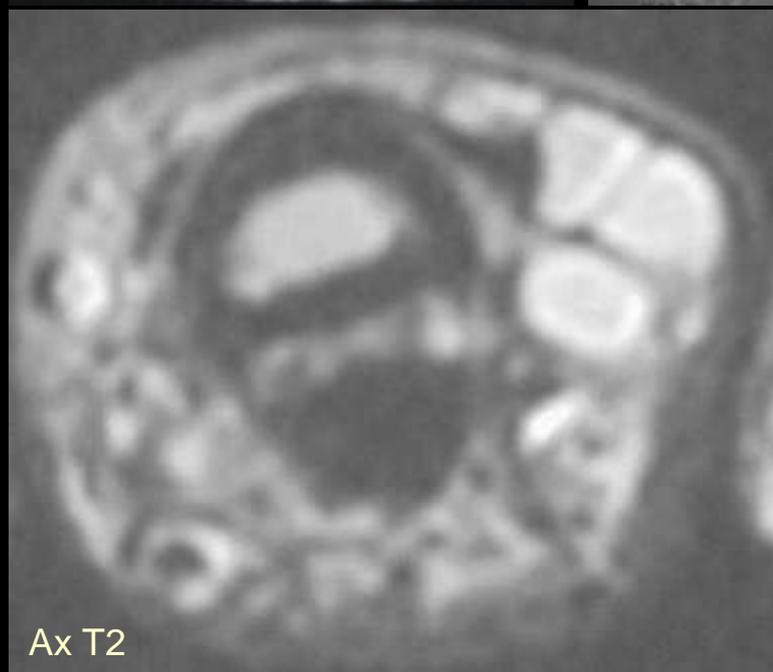
Hair on end / Sunburst

Soft Tissues

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



Soft Tissue Involvement

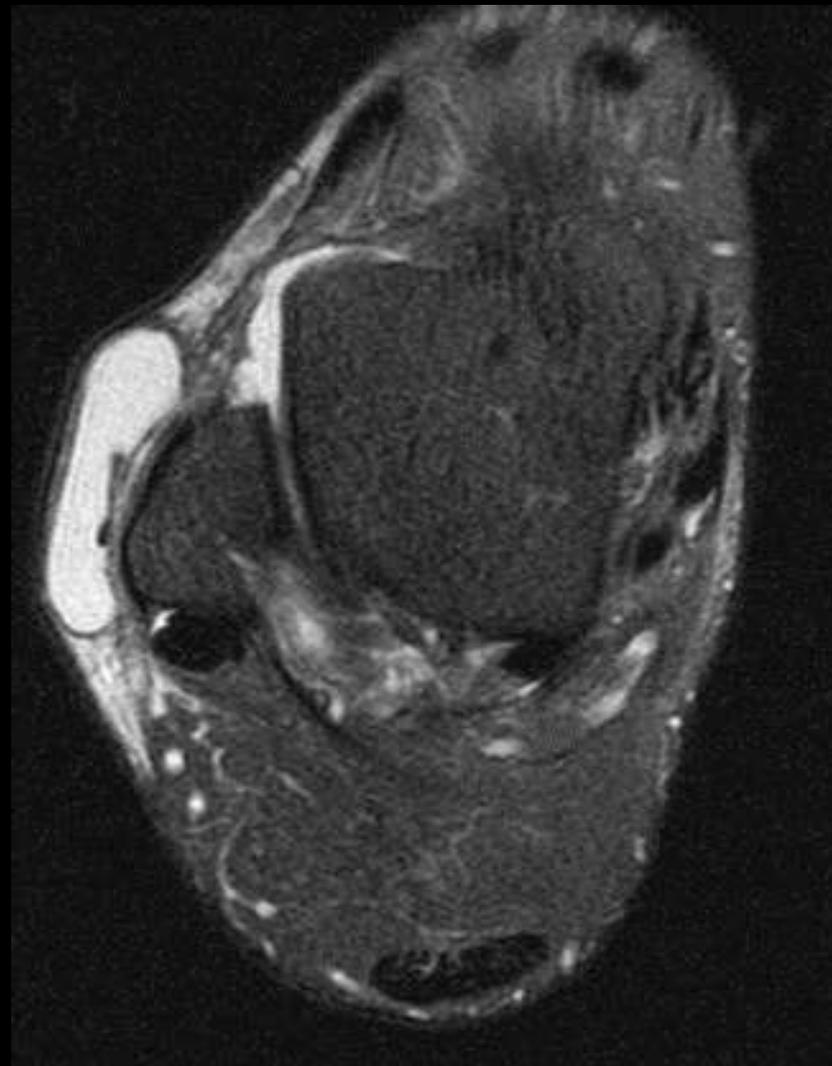
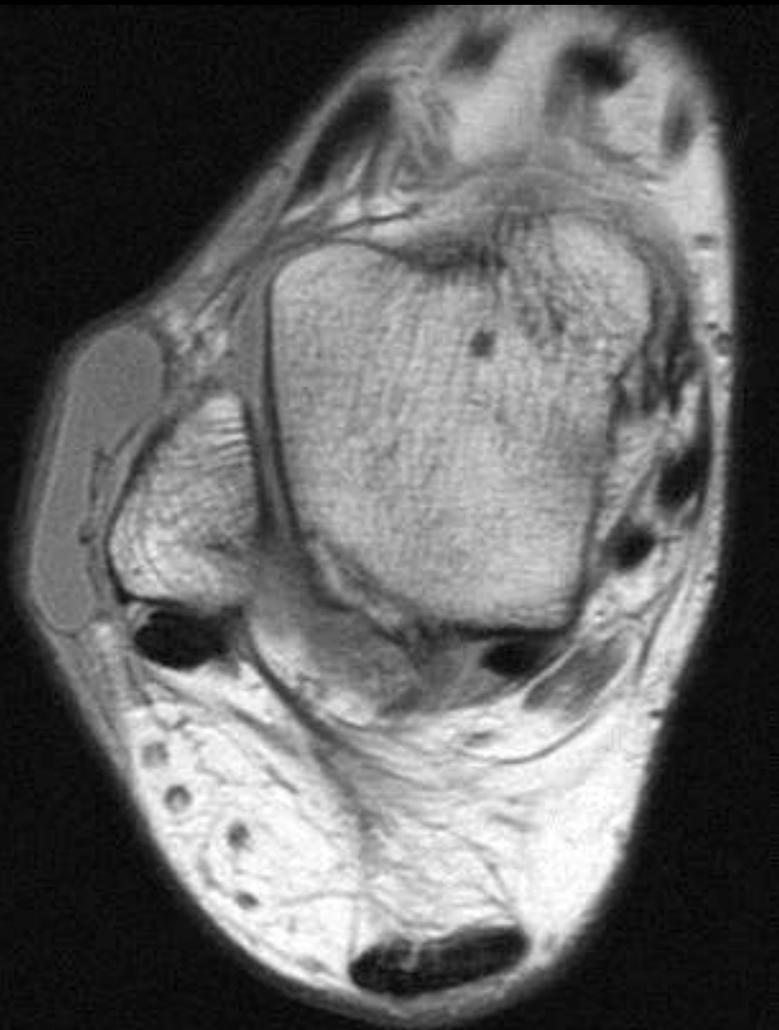


Histologic Characterization - Matrix

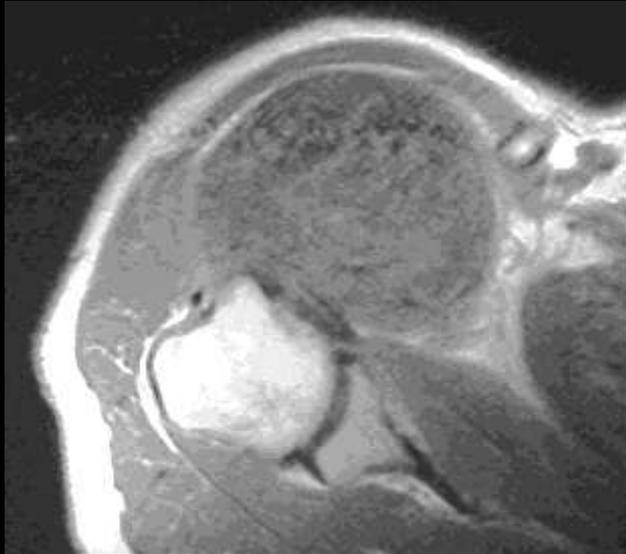
- Acellular substance produced by the lesion
- Helps define histology of lesion
 - Ossific
 - Chondroid
 - Lipoid
 - Myxoid
 - Collagenous



Matrix - None



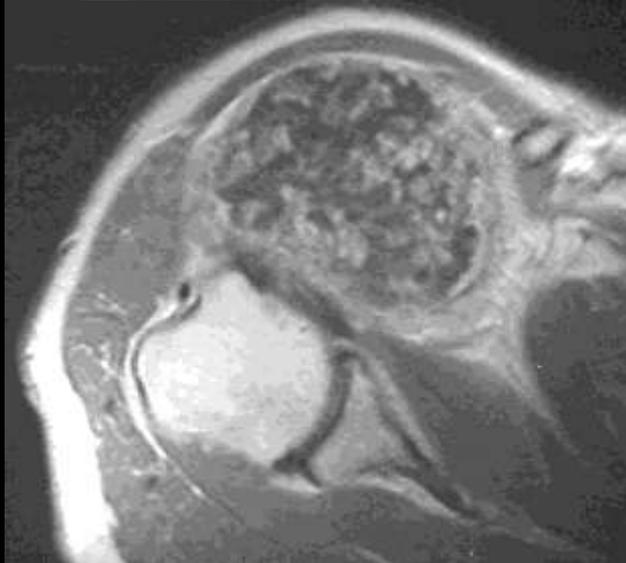
Matrix - Chondroid



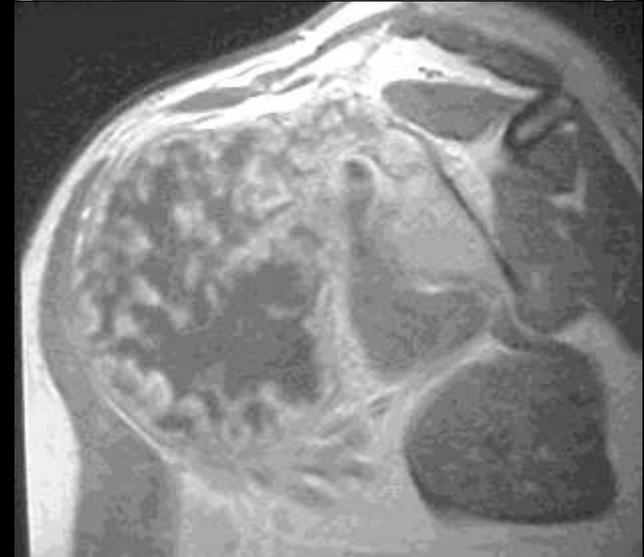
Ax T1



Sag T2

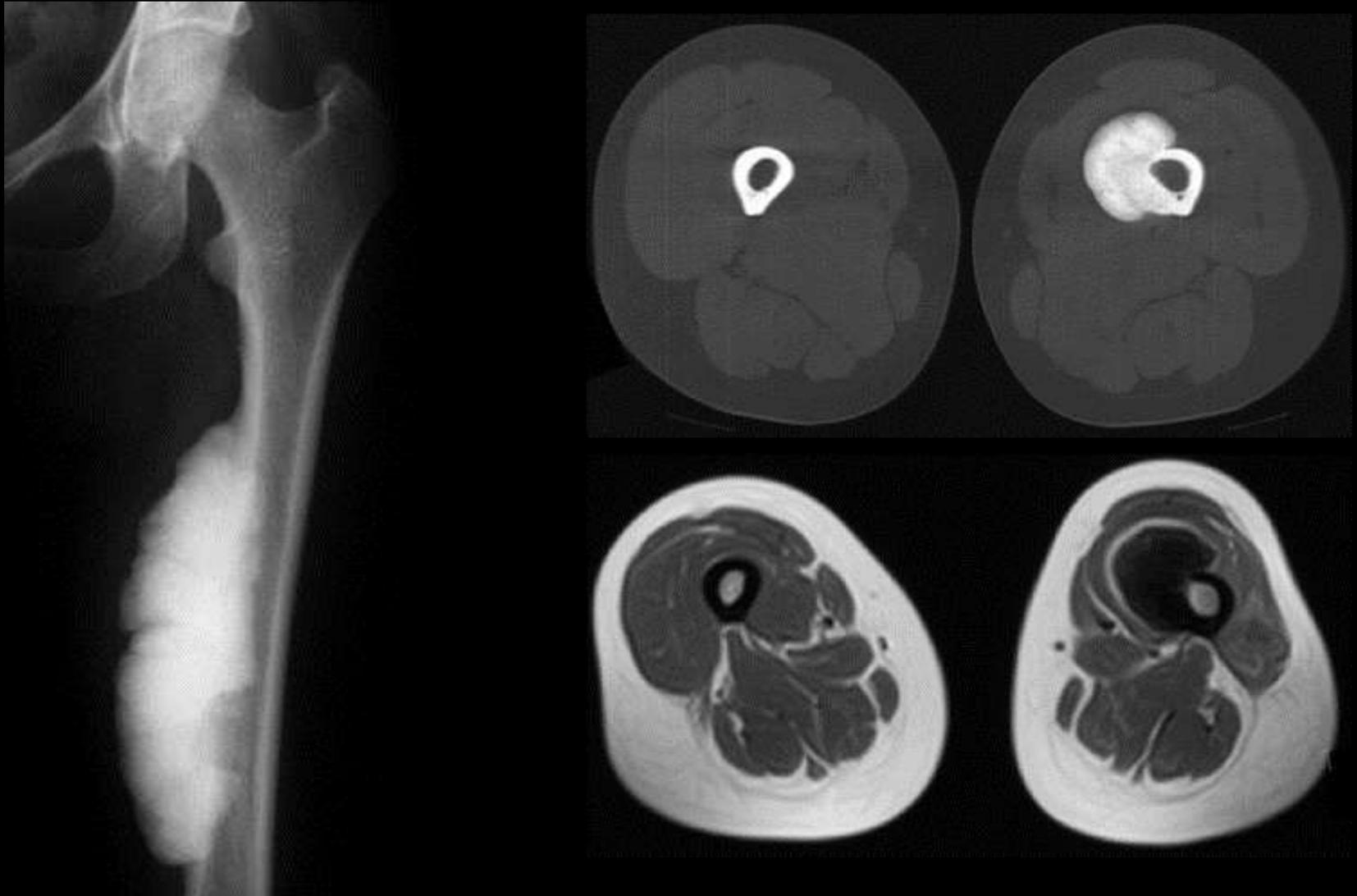


AxT1Gd



Sag T1Gd

Matrix - Ossific

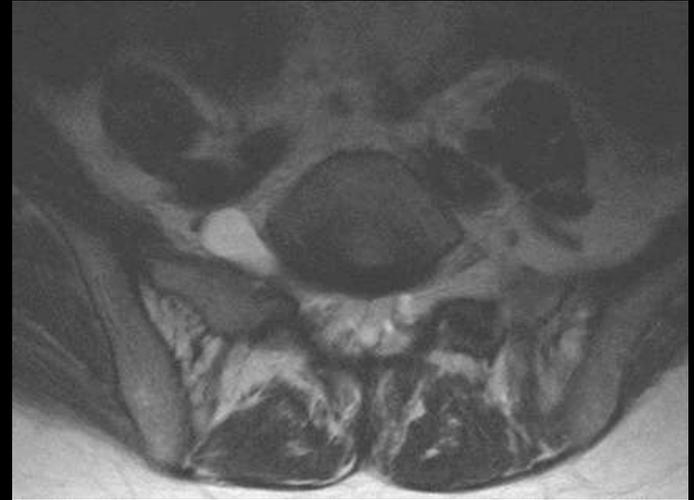


High-grade surface Osteosarcoma

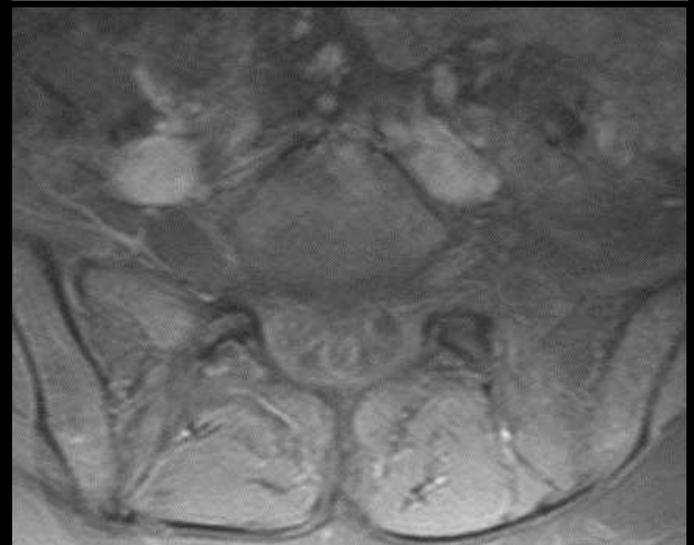
Matrix – MR signal - ↓T1, ↑T2

- Nonspecific
- Majority of benign and malignant lesions show this pattern
- History, location and configuration help establish differential diagnosis

AxT2

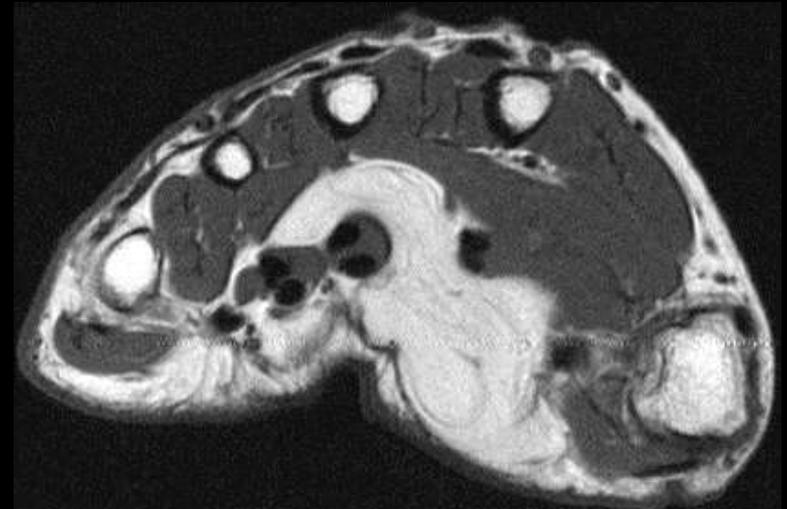


Ax T1FSGd



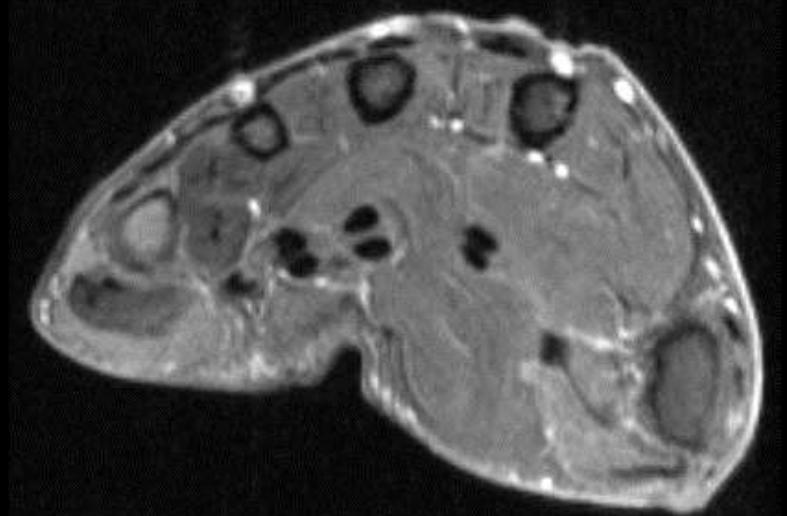
↑T1, ↑T2

- Fat
 - Lipoma
 - Well-differentiated liposarcoma
 - Hemangioma



T1 and T1 fatsat

- Subacute blood
- Paramagnetic substances



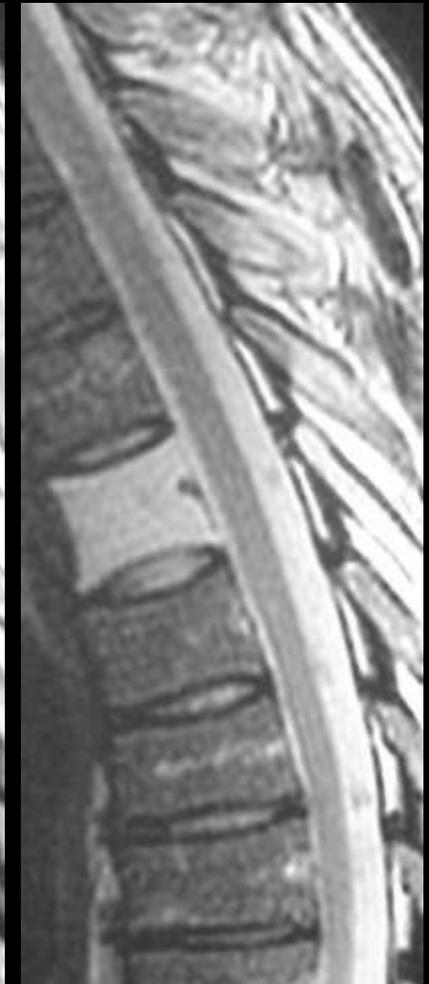
Lipoma

↑T1, ↑T2

- Fat
 - Lipoma
 - Well-differentiated liposarcoma
 - Hemangioma
- Subacute blood
- Paramagnetic substances



Sag T1



Sag T2

↑T1, ↑T2

- Fat
 - Lipoma
 - Well-differentiated liposarcoma
 - Hemangioma
- Subacute blood
- Paramagnetic substances



Cor T1

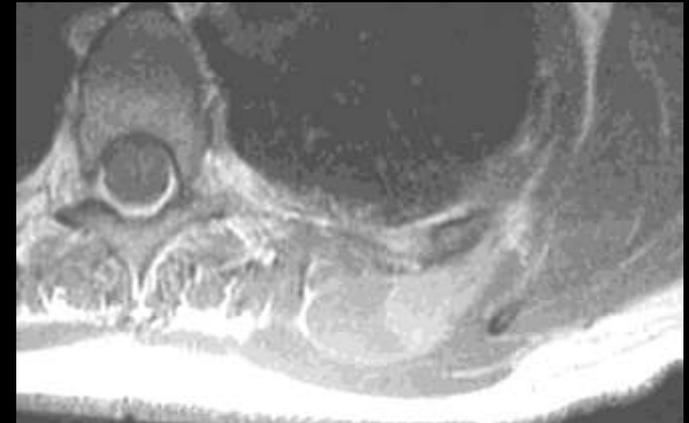
↑T1, ↑T2

- Fat
 - Lipoma
 - Well-differentiated liposarcoma
 - Hemangioma
- Subacute blood
- Paramagnetic substances



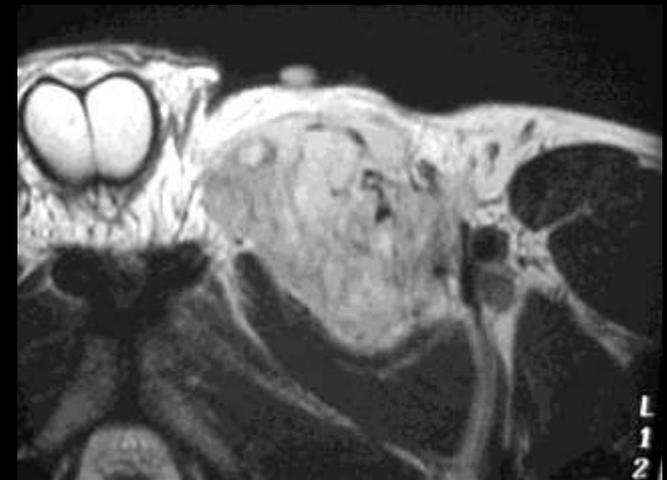
Ax T1

Ax T1Gd



↑T1, ↑T2

- Fat
 - Lipoma
 - Well-differentiated liposarcoma
 - Hemangioma

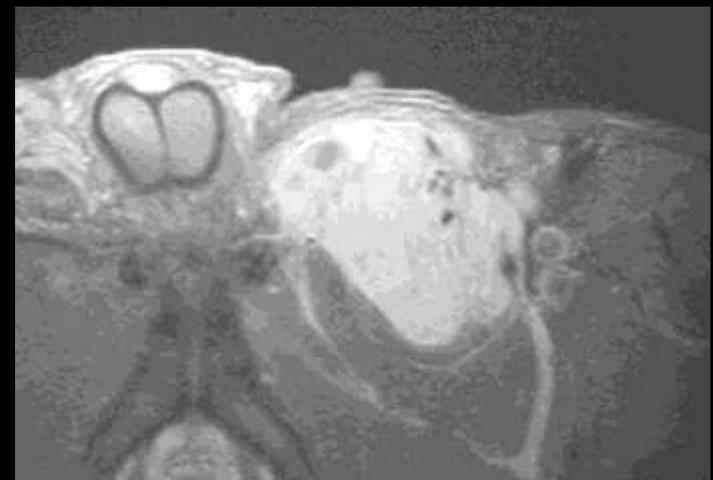


Ax T2

- Subacute blood

- Paramagnetic substances

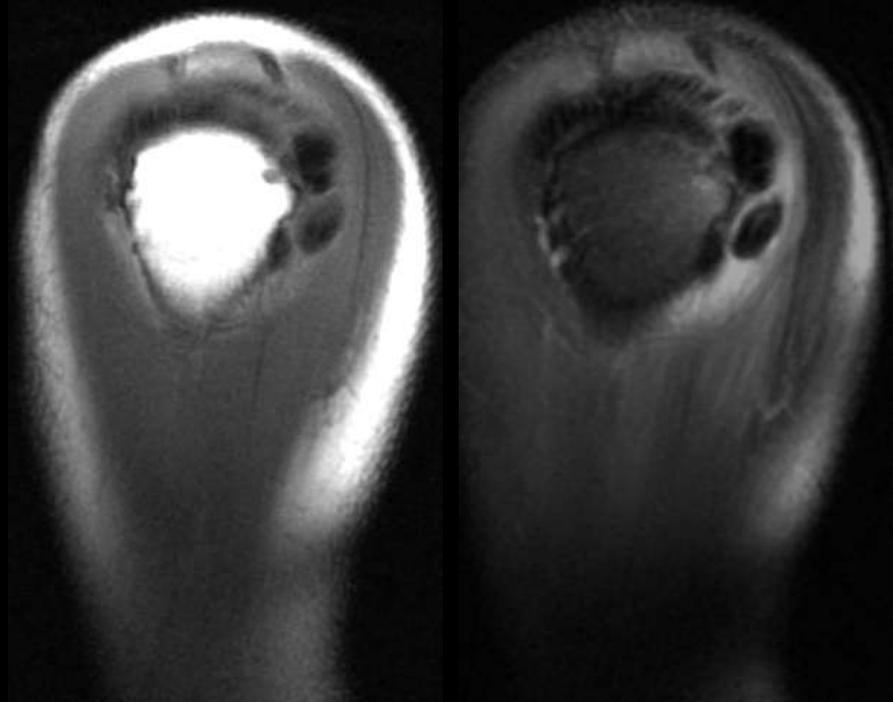
Ax T1FS IVGd



Solitary fibrous tumor of soft parts

↓T1, ↓T2

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



Sag T1

Sag PDFS

↓T1, ↓T2

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



↓T1, ↓T2

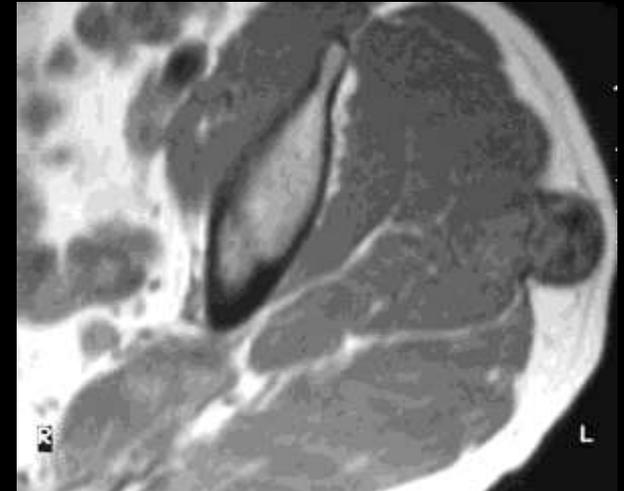
- Calcification
- Ossification
- Crystalline structures
- Dense fibrous tissues
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies



Fibrous dysplasia

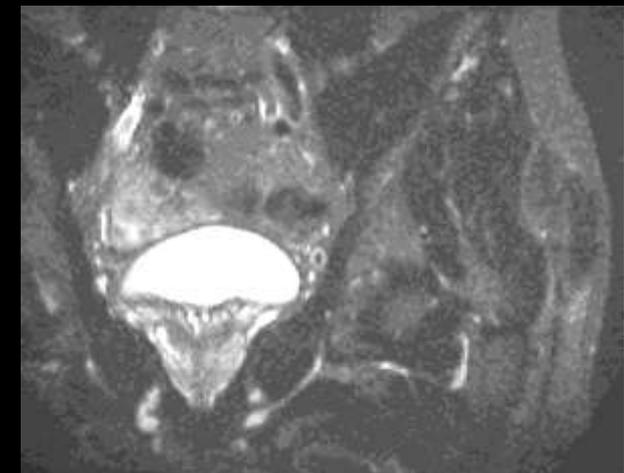
↓T1, ↓T2

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



Ax T1

Cor T2STIR



Desmoid Tumor 38M

↓T1, ↓T2

- Calcification
- Ossification
- Crystalline structures
- Dense fibrous tissues
- Hemosiderin
- Flowing blood
- Gas
- Foreign bodies



Sag PD



Sag GE

Paradoxical Signal Pattern



Ax T2



Ax T1Gd

Diagnostic imaging

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



Staging

- Assess anatomic extent of the lesion
- Guide treatment
- Provide prognosis
- Ultimately, improve longevity

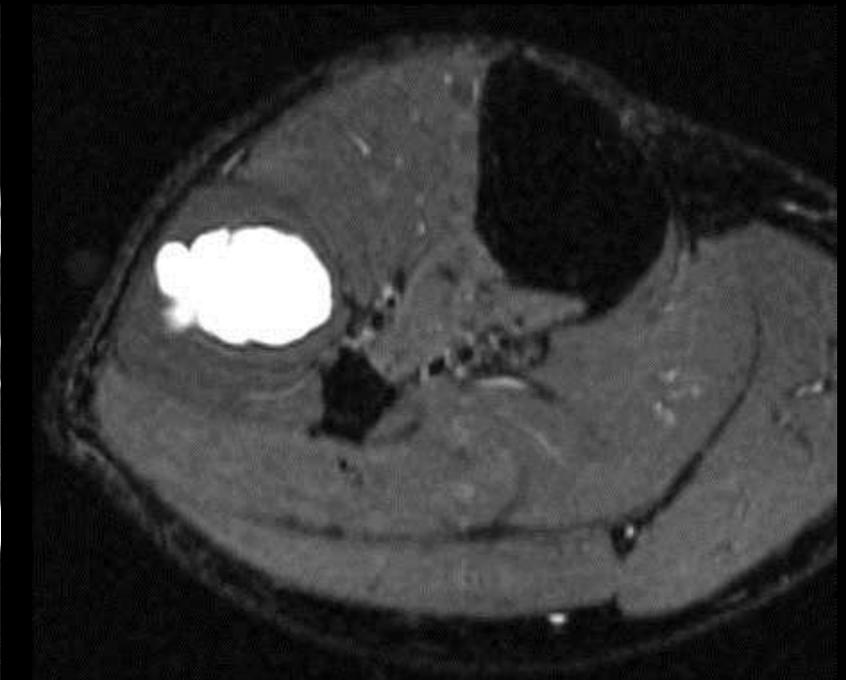
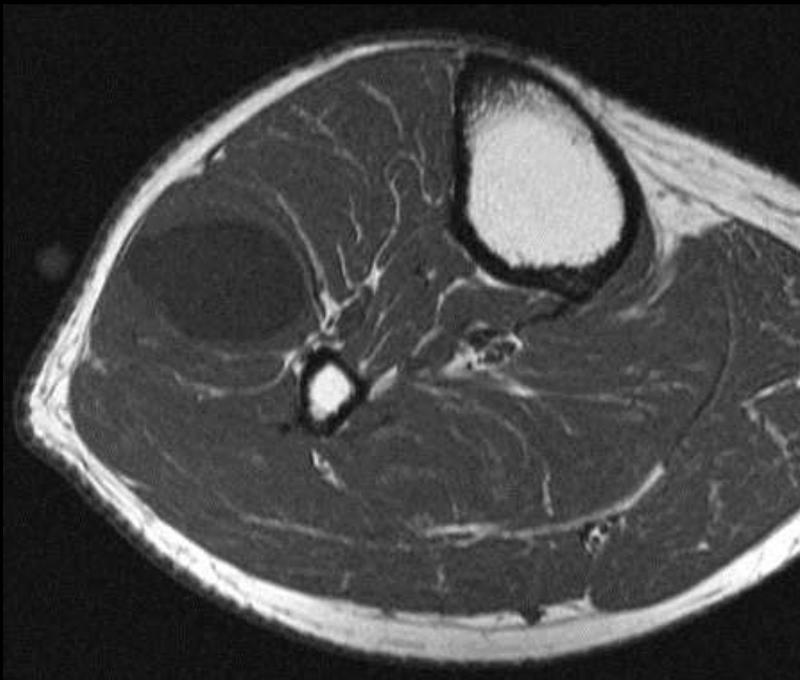


Staging

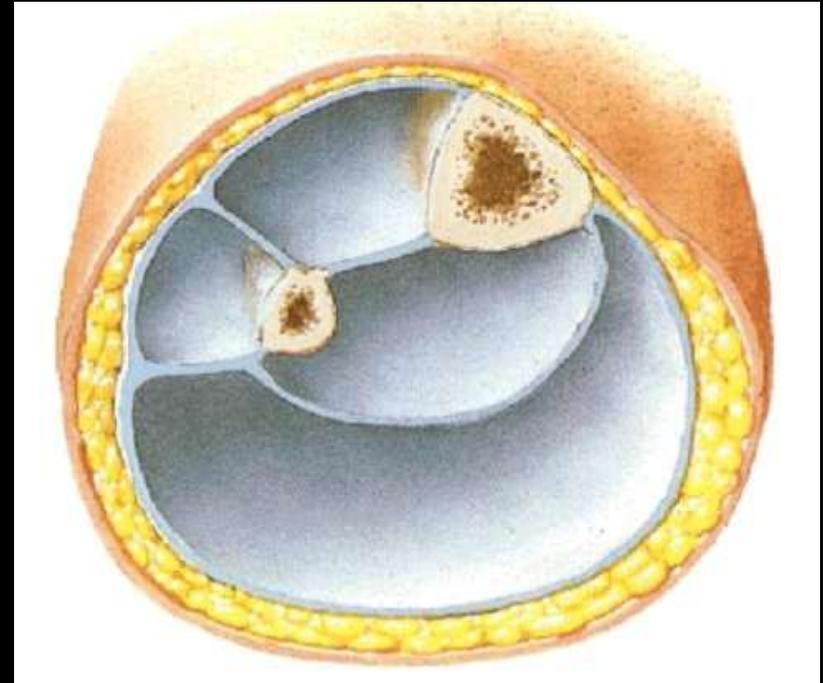
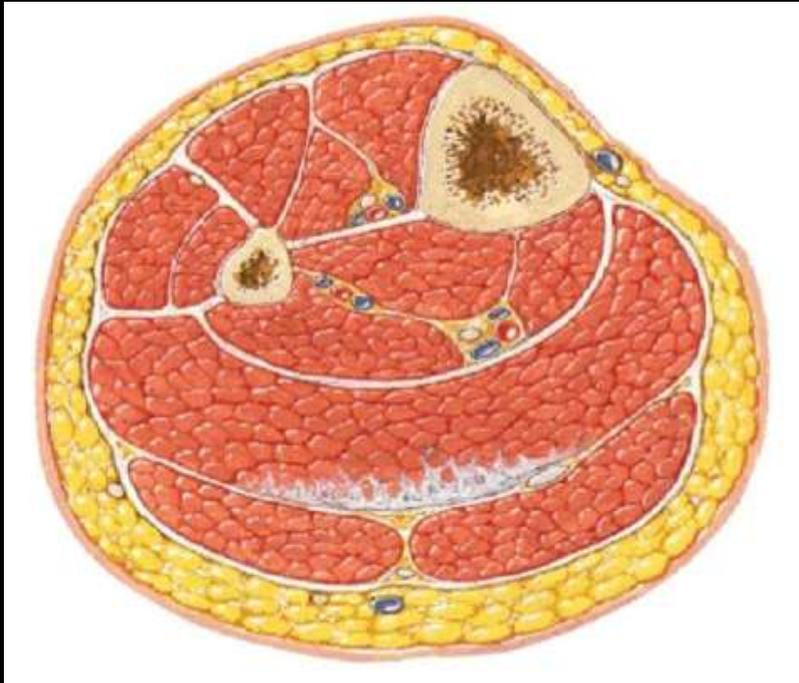
Surgical Staging System	American Joint Committee
Orthopedic surgeons	Oncologists
Benign and malignant lesions	Malignant lesions only
Bone and soft tissue	Soft tissue only
Compartmental anatomy important	Tumor size important
Nodal metastasis treated same as distant metastasis	Nodes are evaluated separately

SSS Tumor

T0	True capsule surrounds tumor
T1	Extracapsular, but still intracompartmental
T2	Extracapsular and extracompartmental Abutment of NV bundle



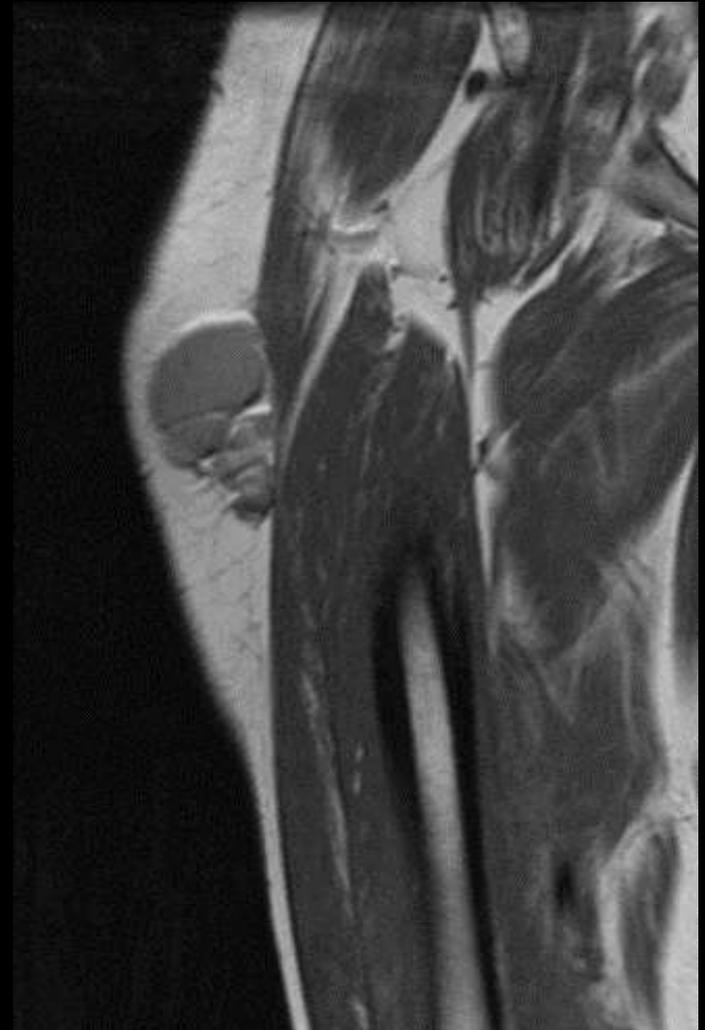
Compartment anatomy



- 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

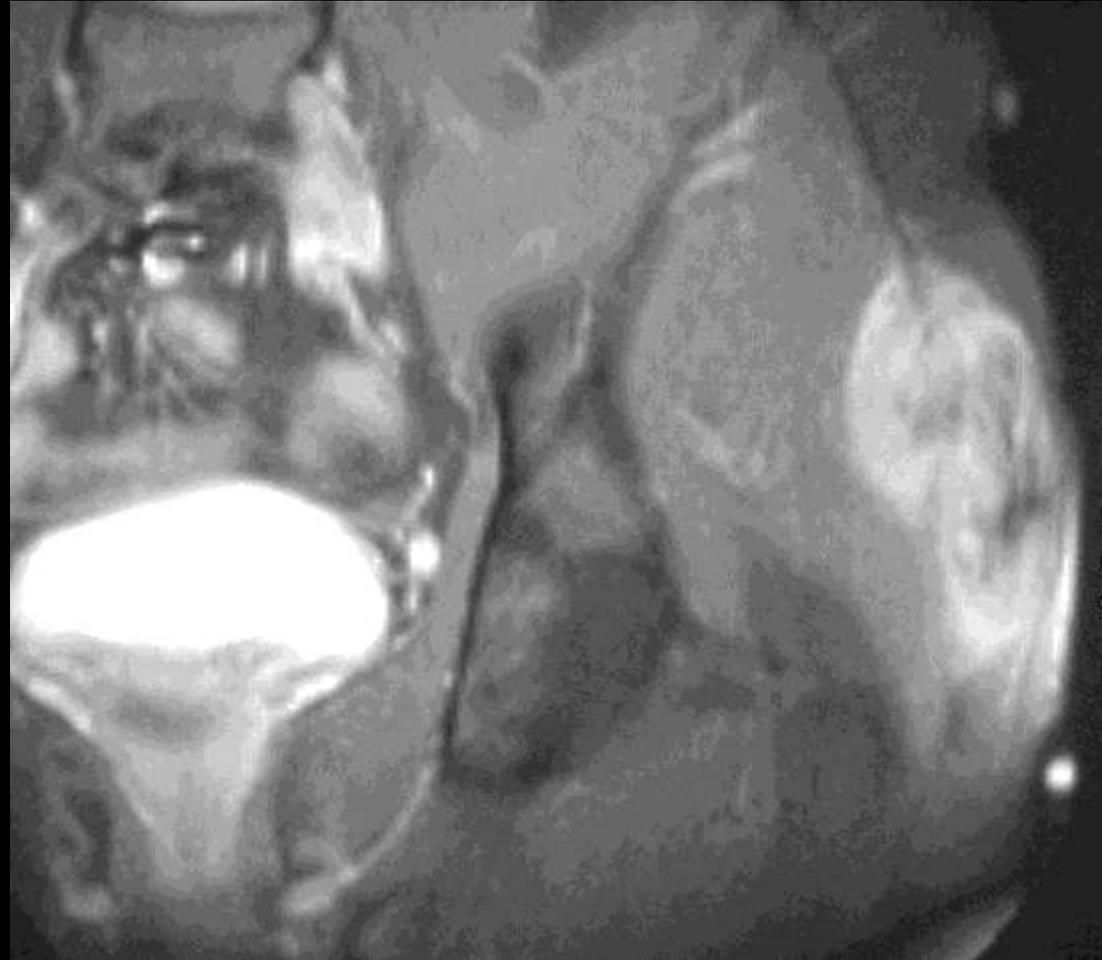
Stage - T1

- Extracapsular but intracompartmental
 - Skin and subcutaneous tissues
 - One muscle compartment
 - Intracortical
 - Paraosseous without muscle or bone invasion
 - Single ray of hand or foot



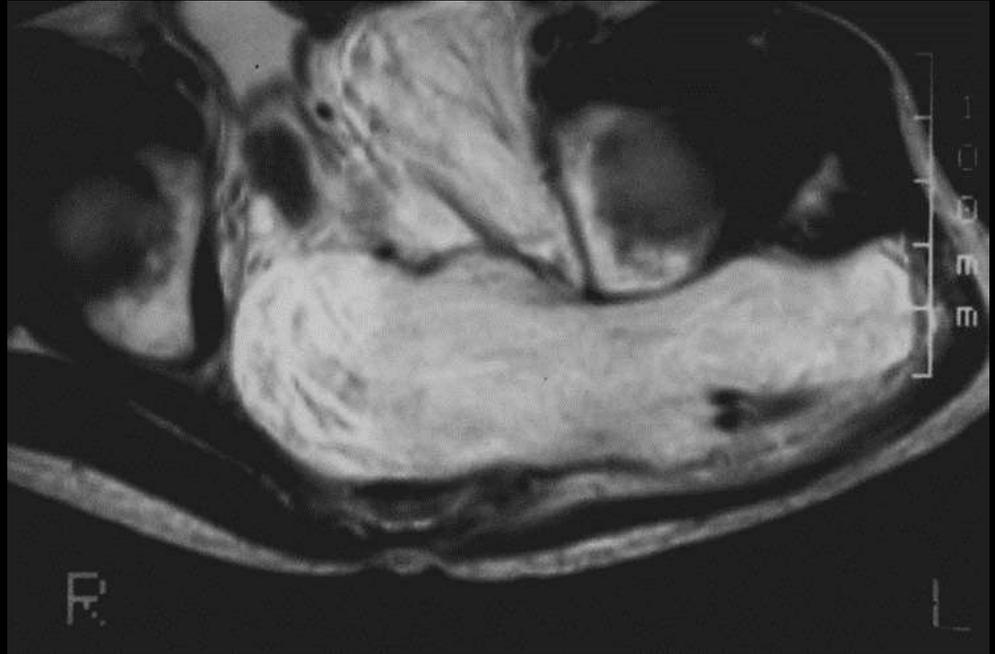
Stage - T2

- Extracapsular extracompartmental
- Lesion no longer confined by periosteum or fascia
- Increases risk of metastasis and recurrence



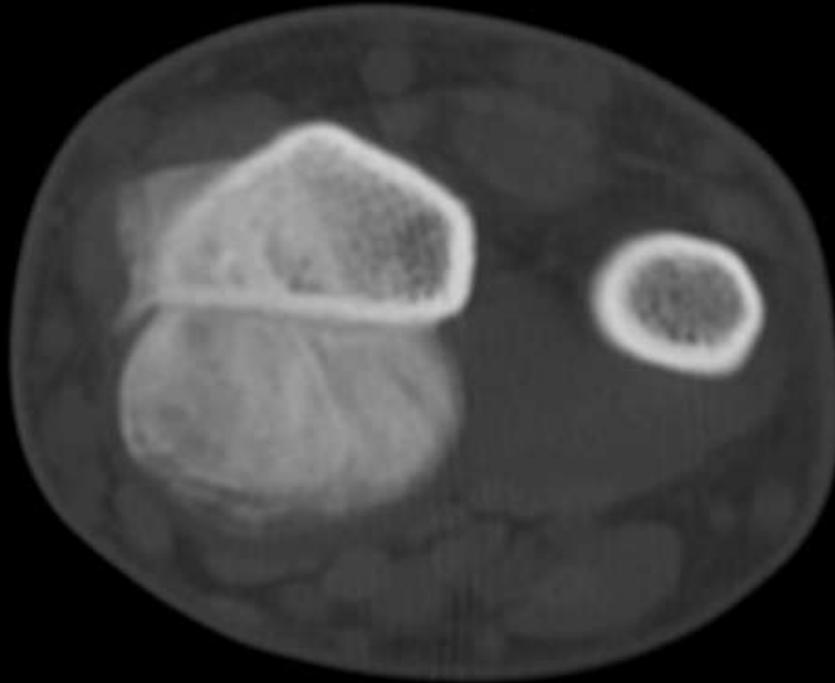
Stage - T2

- Extracapsular extracompartmental
- Lesion no longer confined by periosteum or fascia
- Increases risk of metastasis and recurrence

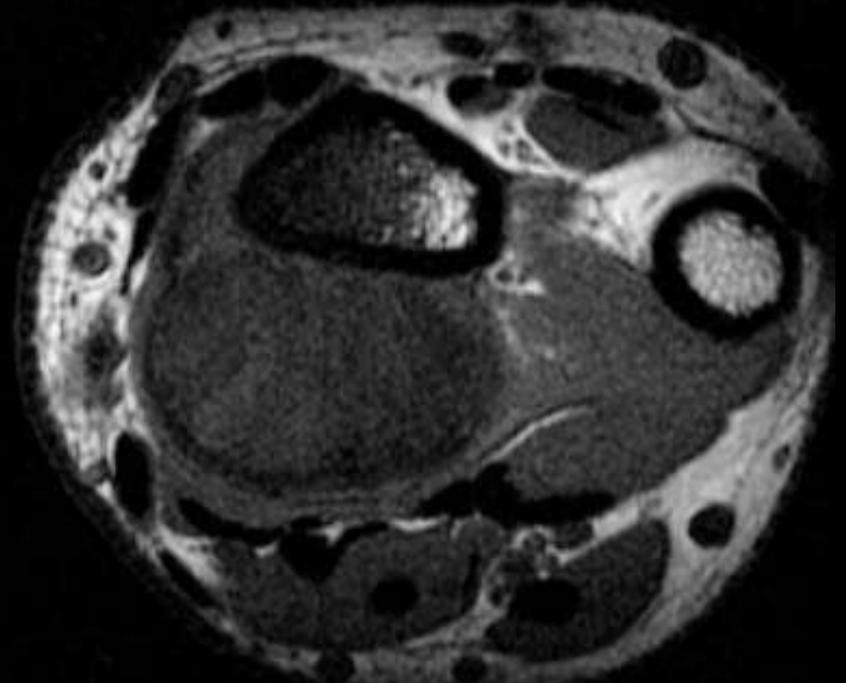


Sciatic invasion by liposarcoma- Stage T2

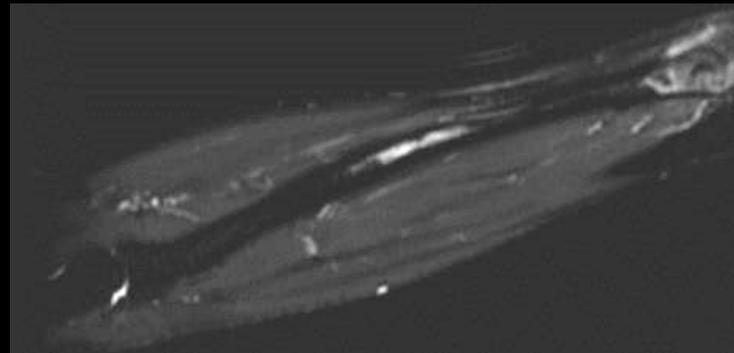
Stage - T2



Axial CT



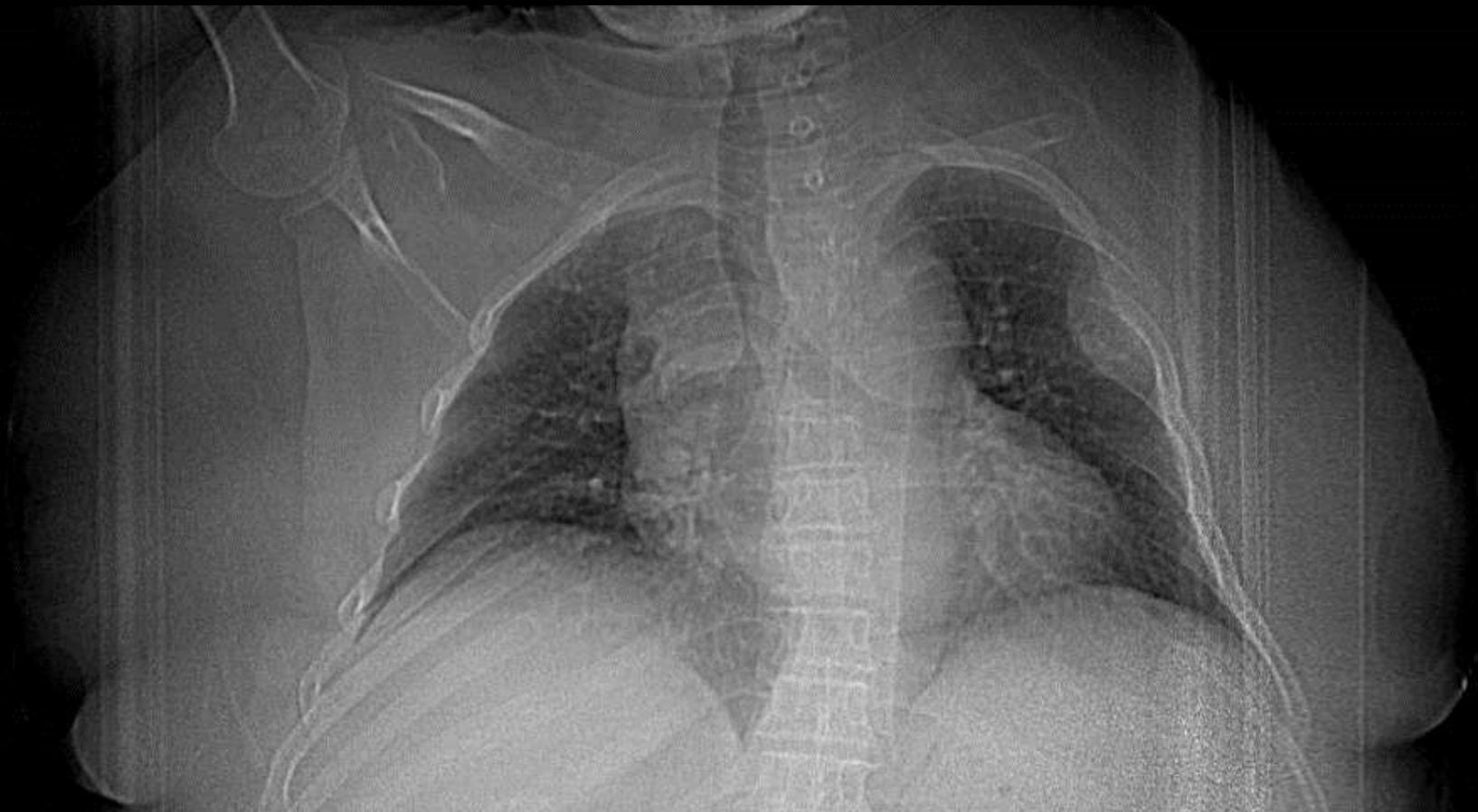
Axial T1



Lump on Forearm

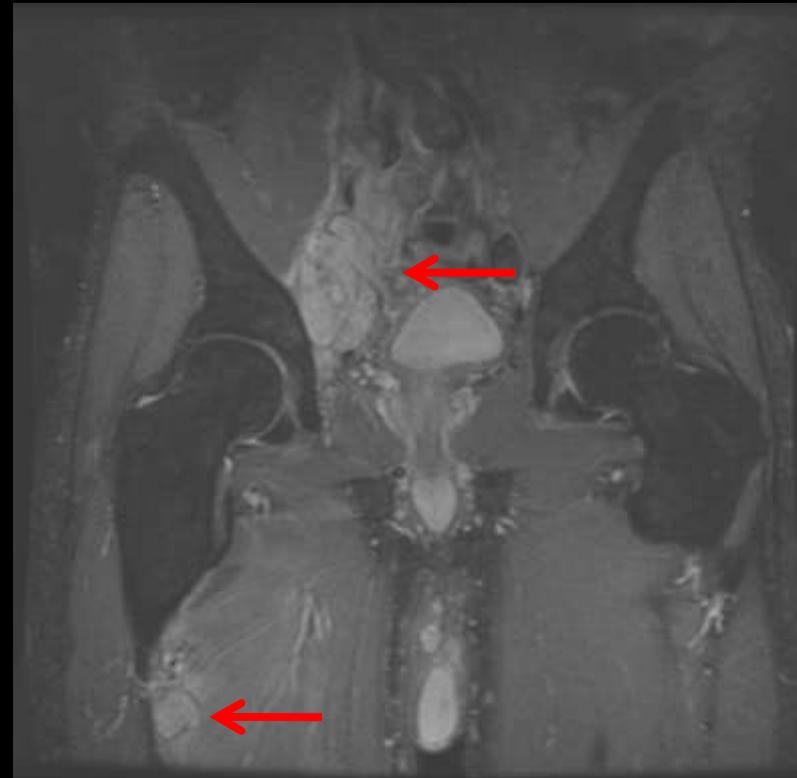
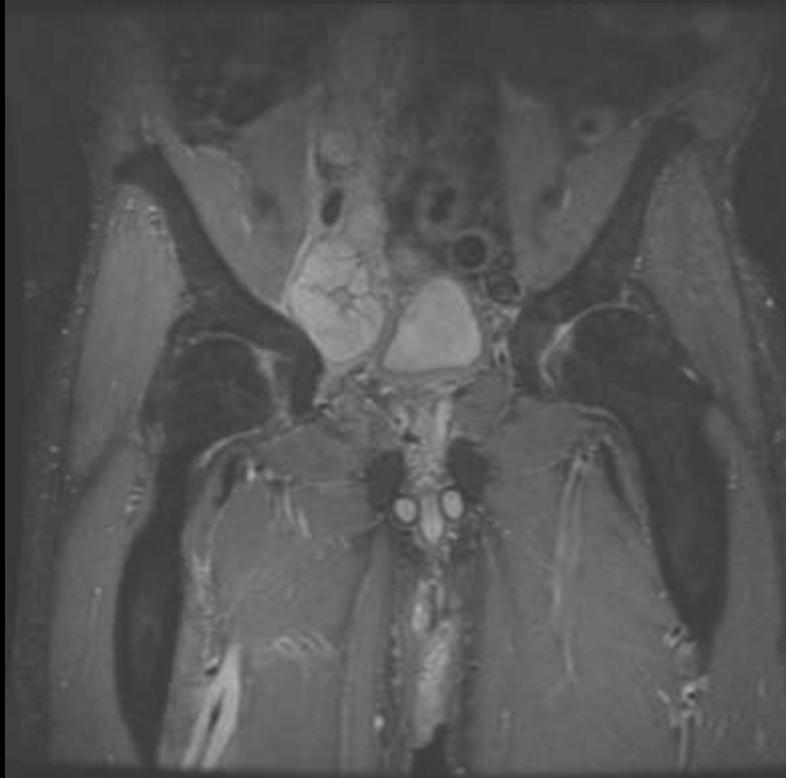
Parosteal osteosarcoma

Stage - M1



- Nodal and distal metastases are treated the same in SSS (no difference in prognosis)

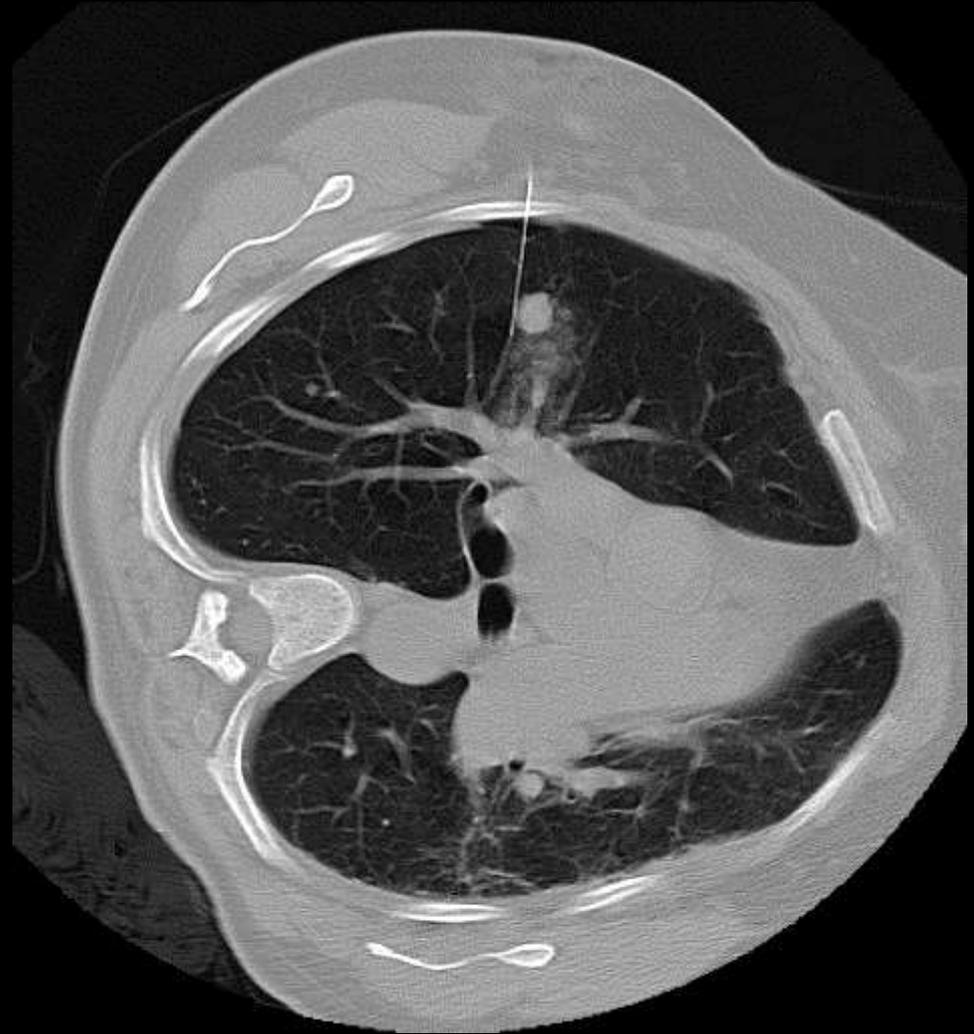
Stage - M1



- 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!



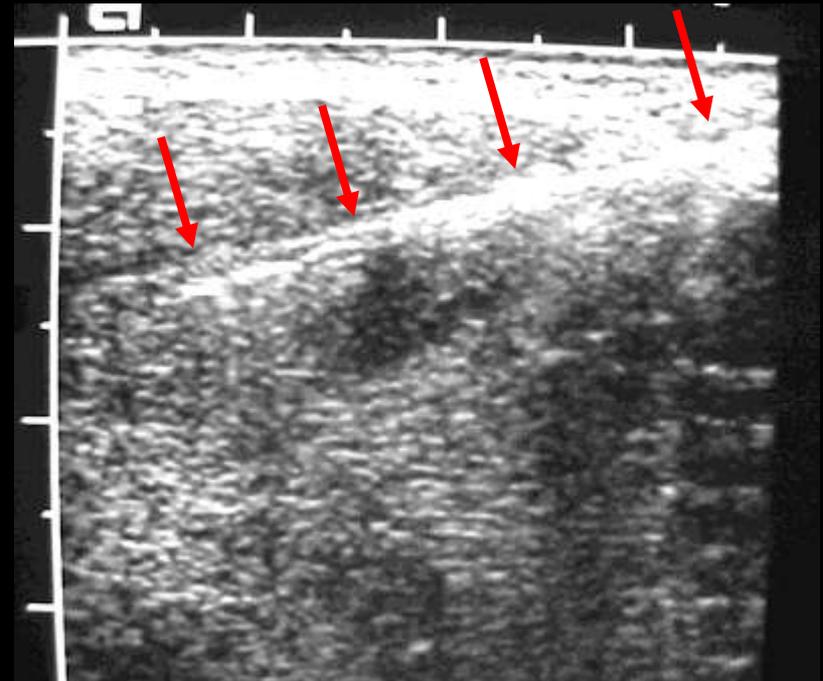
Diagnostic imaging

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



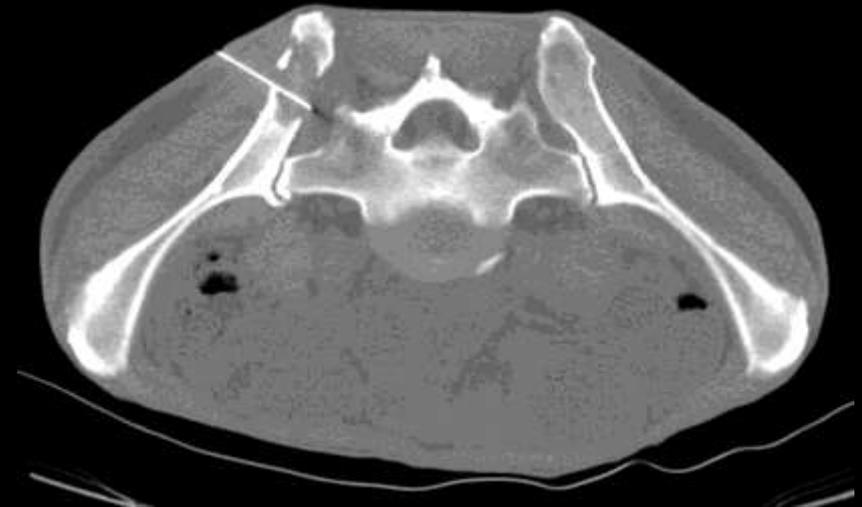
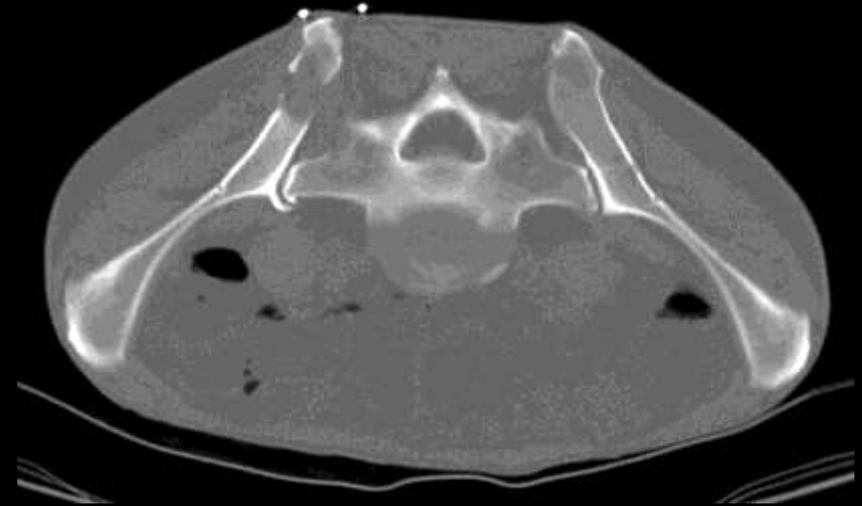
Biopsy

- 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



Biopsy

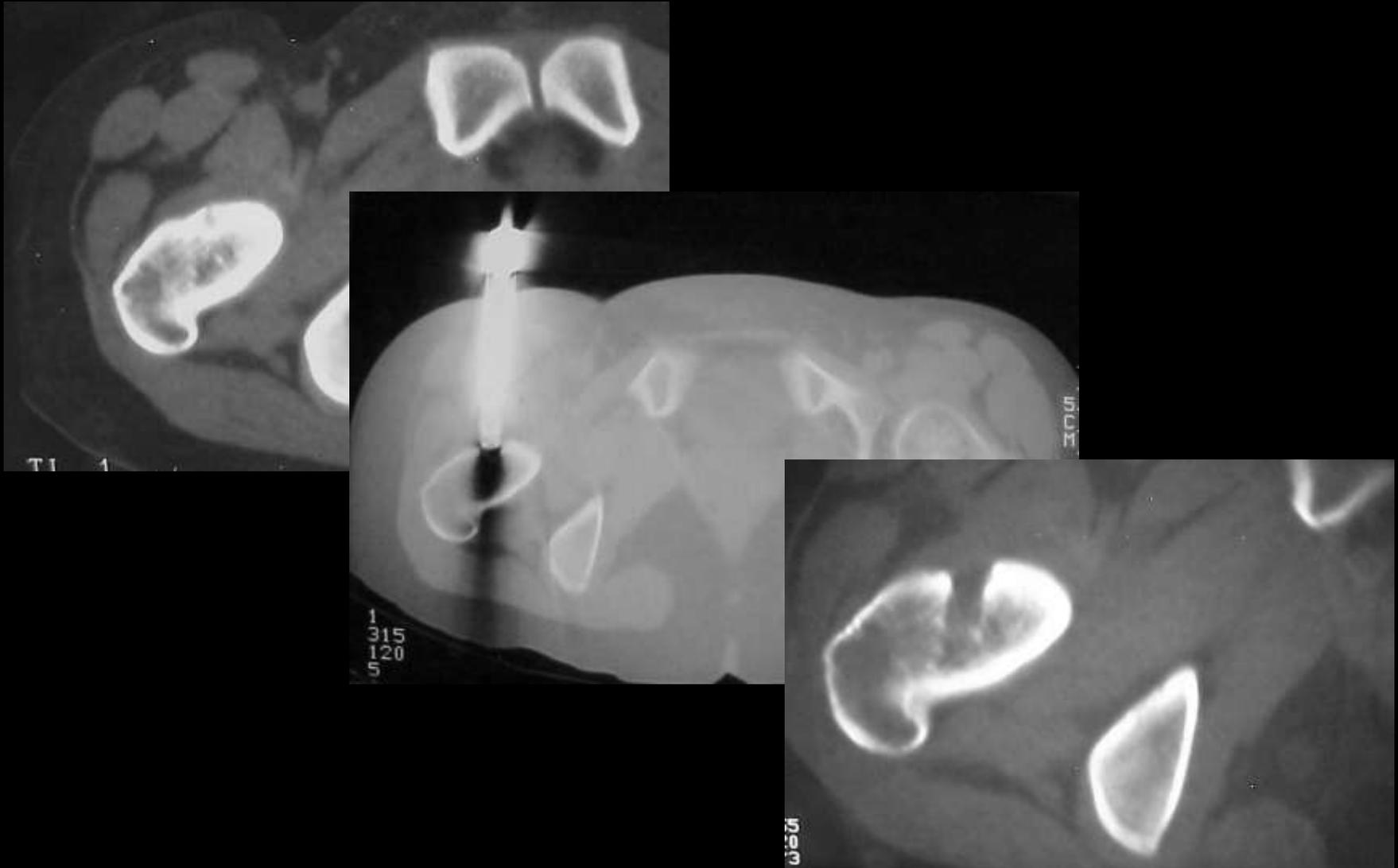
- Fluoroscopic
- US for soft tissue
- CT guidance for axial and deep lesions
- Fine needle aspiration
- Core biopsy with cutting needle or trephine



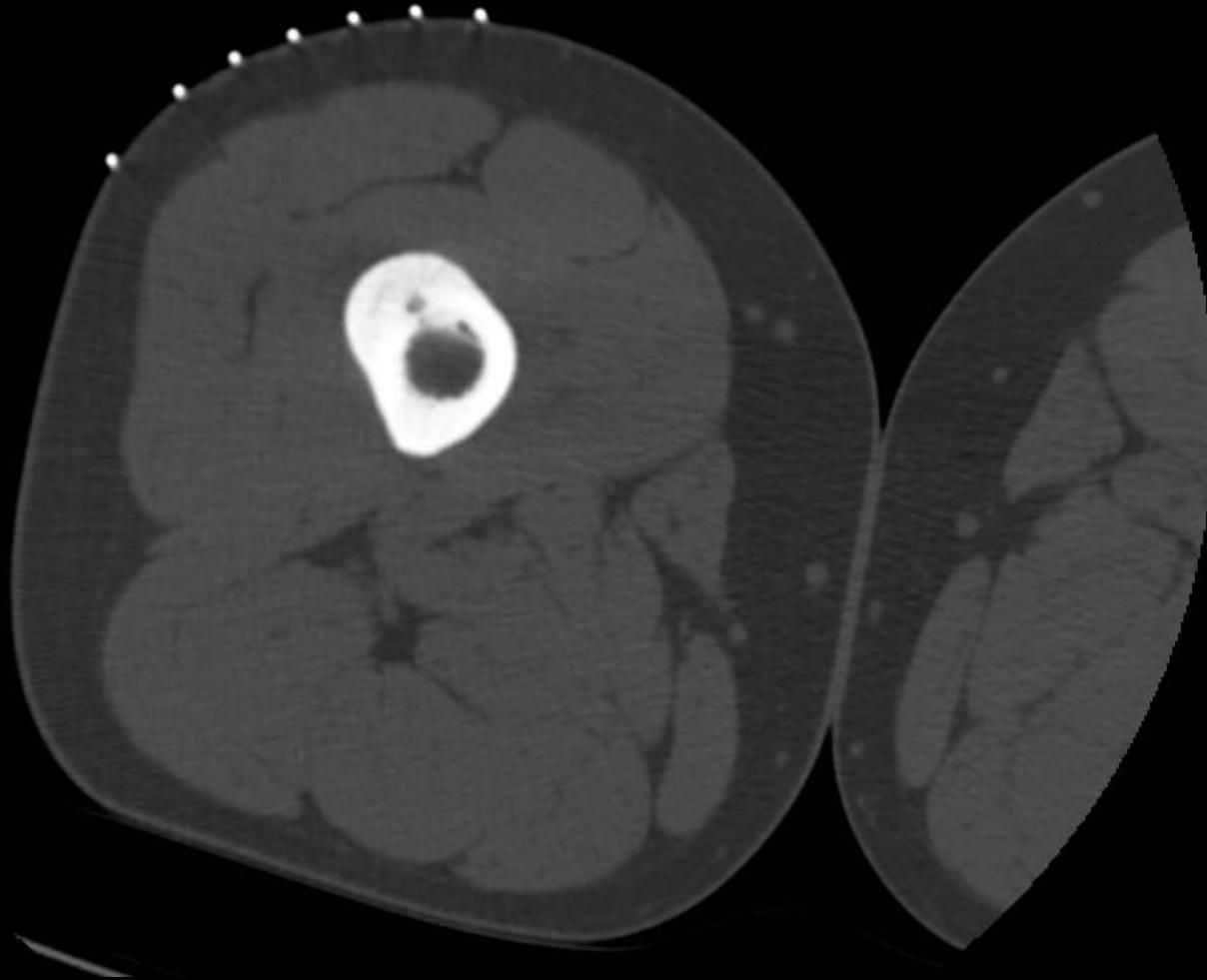
Percutaneous Biopsy



Definitive (excision) Biopsy



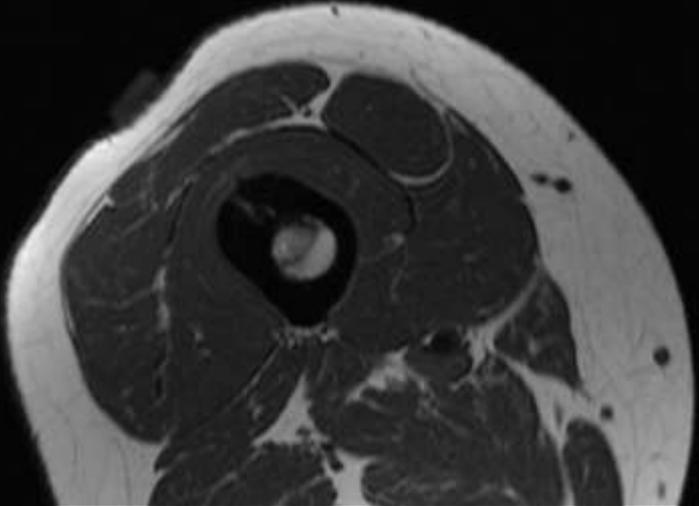
Radiofrequency ablation



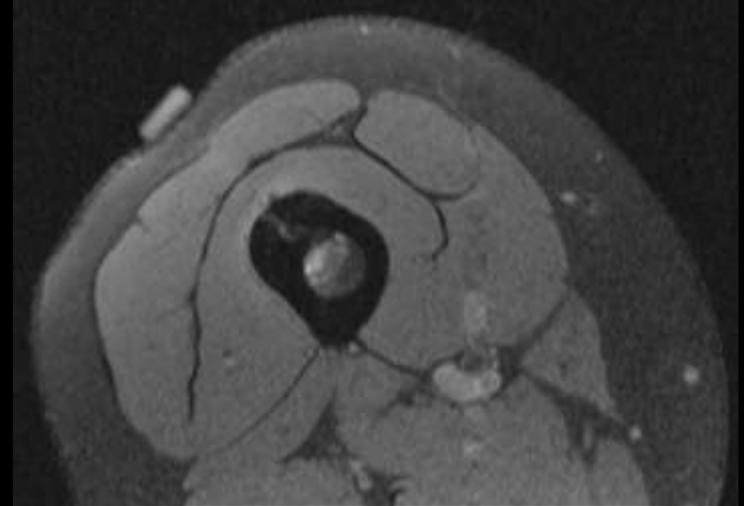
Radiofrequency ablation



Radiofrequency ablation

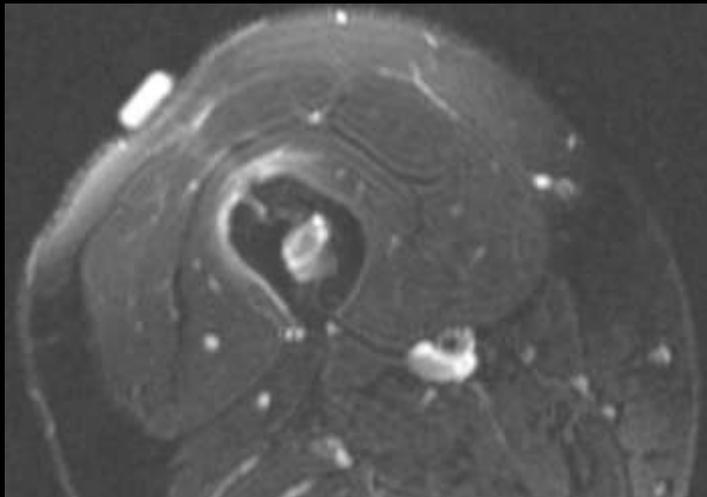


Ax T1

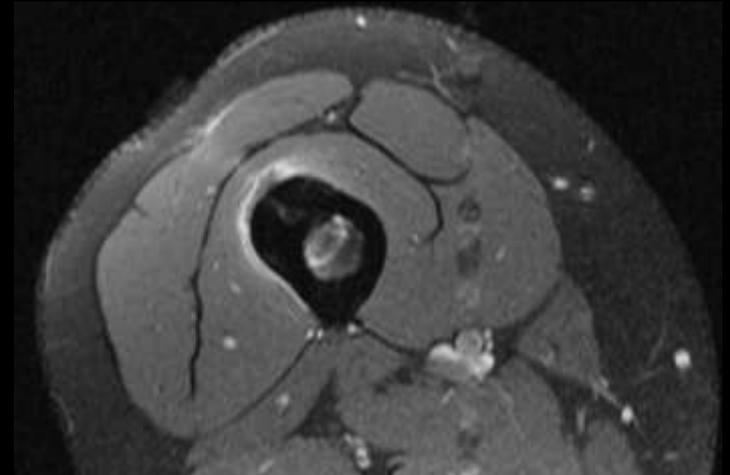


Ax T1FS

Ax T2FS



Ax T1FSGd



Follow up

OO 24F 2w post RFA

Diagnostic imaging

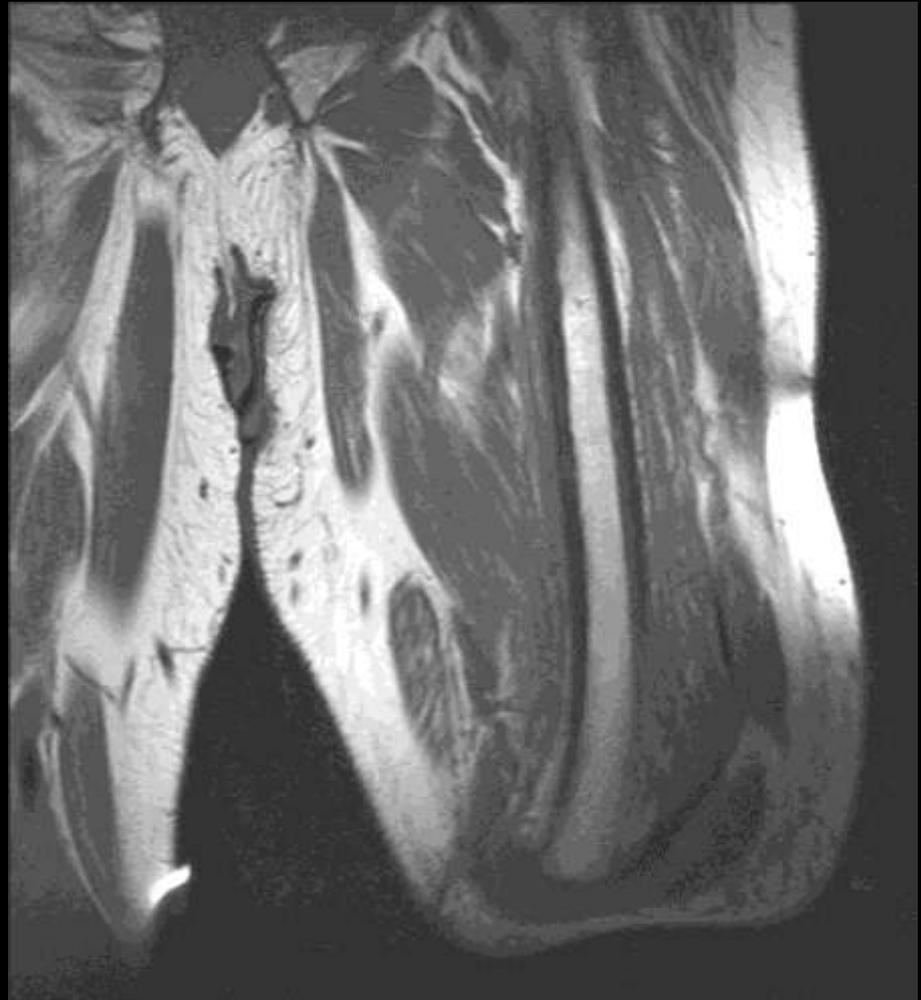
- Technique
- Detection
- Histologic characterization
- Anatomic staging
- Biopsy
- Follow-up



Neurofibromatosis

Follow-up

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



Follow-up

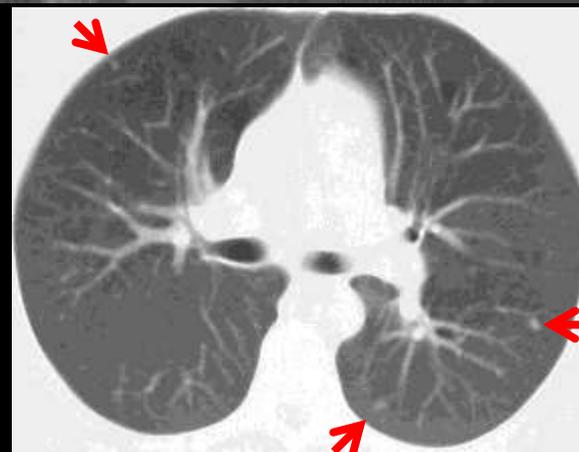
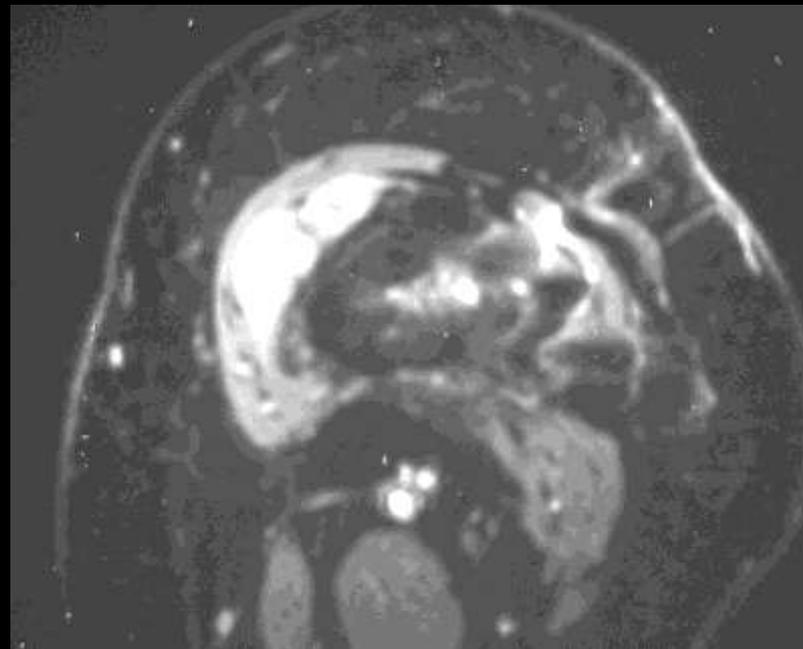
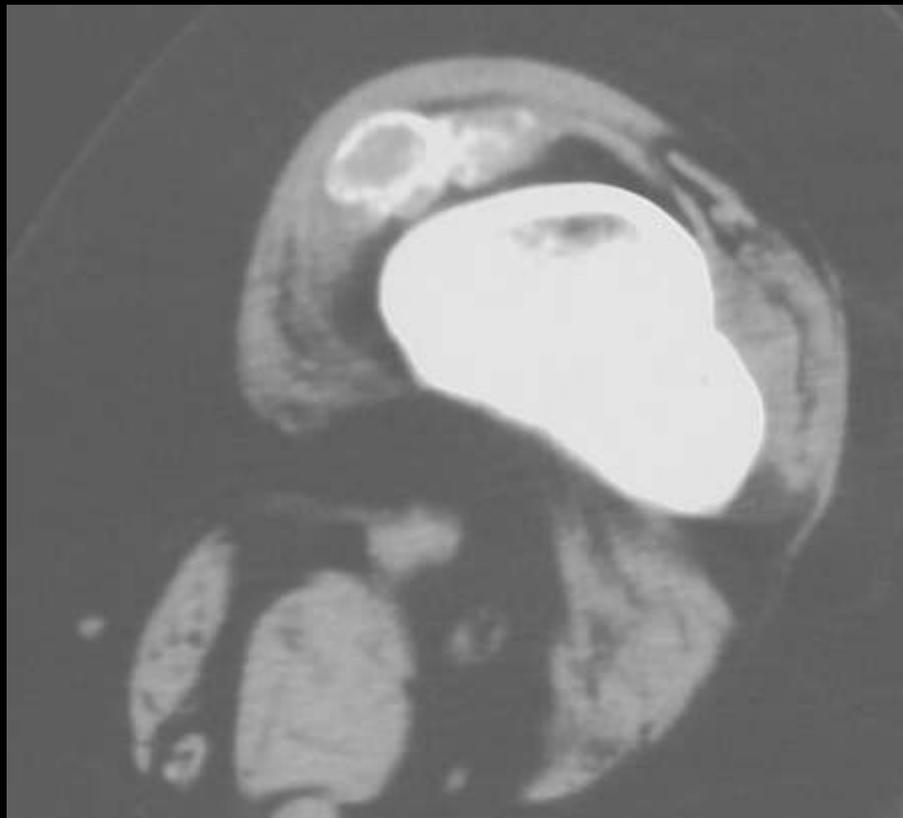
- Clinical assessment limited
- Laboratory indicators limited
- Diagnostic imaging
- Histology and pathology



MRI Follow Up

- Be cost effective
- Have baseline 12 week post op
- Often and Limited rather than 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



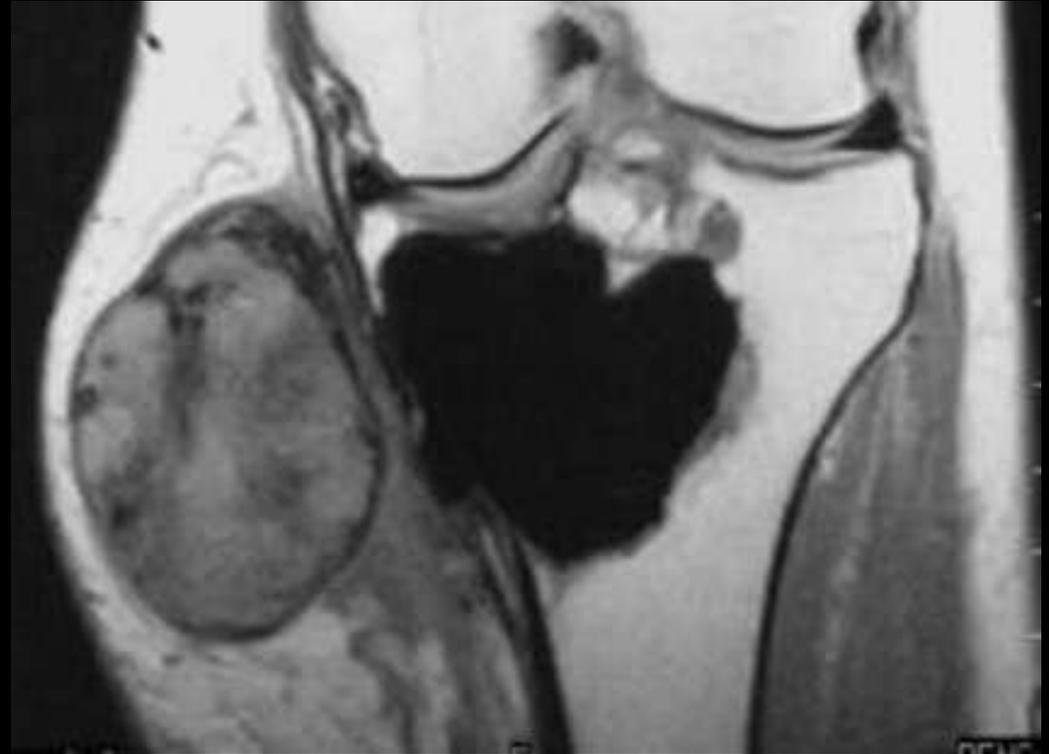
GCT femur 36F with ST and lung spread

Treatment

- Observation
- Intralesional injection / RFA / Cryo
- Intralesional 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



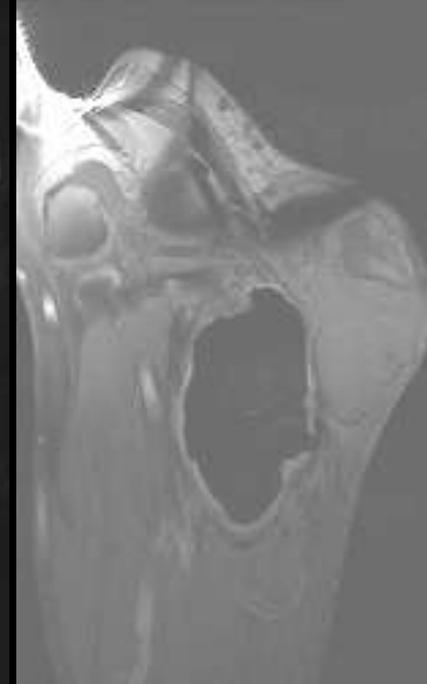
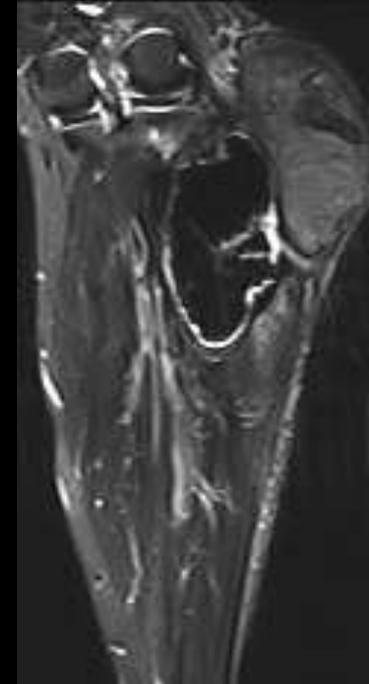
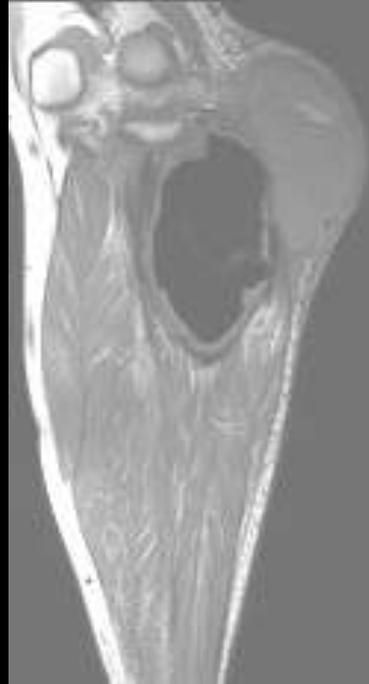
Recurrence of Musculoskeletal tumors

- Low grade
 - Rarely recur
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 - Local recurrence common
- High grade
 - Local recurrence and distant metastasis common



Recurrence of Musculoskeletal tumors

- Low grade
 - Rarely recur
- Moderate grade
 - Local recurrence common
- High grade
 - Local recurrence and distant metastasis common



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



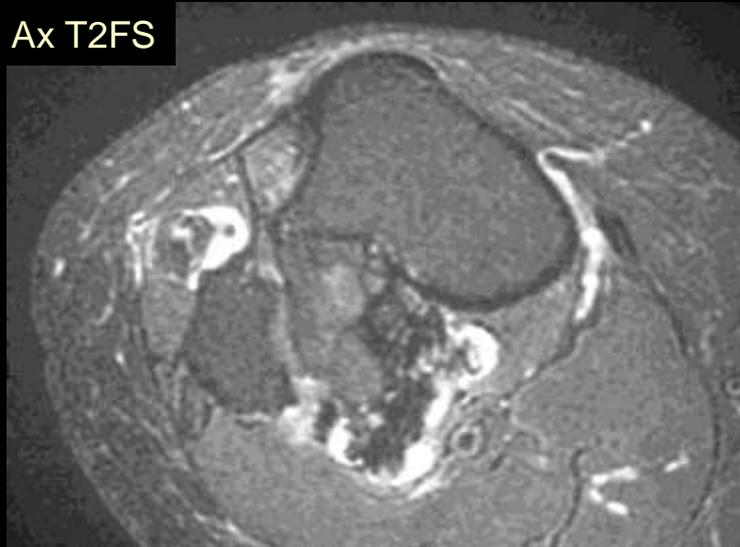
Cor T1Gd

Follow-up - Recurrence

Ax T1



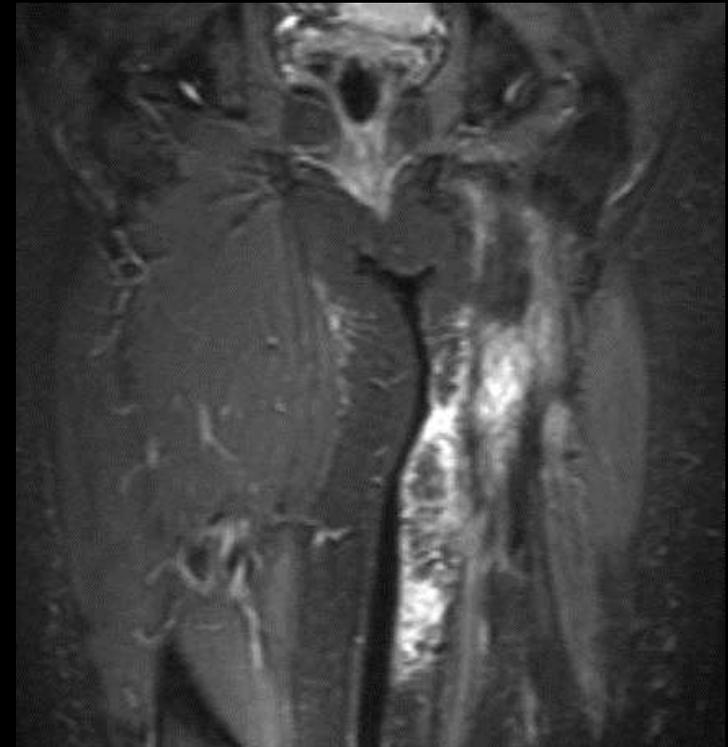
Ax T2FS



Cor T2FS

Increased signal post therapy

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



Cor T1FSGd

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