

IMAGING OF BONE TUMORS

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LEARNING OBJECTIVES

- Provide a logical framework in radiologic evaluation of bone tumors
- To recognize the importance and use of radiographs in evaluation of bone tumors in differential diagnosis
- To recognize the importance and use of CT/MR in evaluation of bone tumors in differential diagnosis and staging
- To recognize various pattern of bone destruction and matrix mineralization

P. Dan
Bizarro
8-31-11
w/ Wayno®

BIZARROCOMICS.COM

I'm serious. I literally
cannot hold my liquor.



Dist. by Kone Features

SOLITARY BONE LESION ANALYSIS

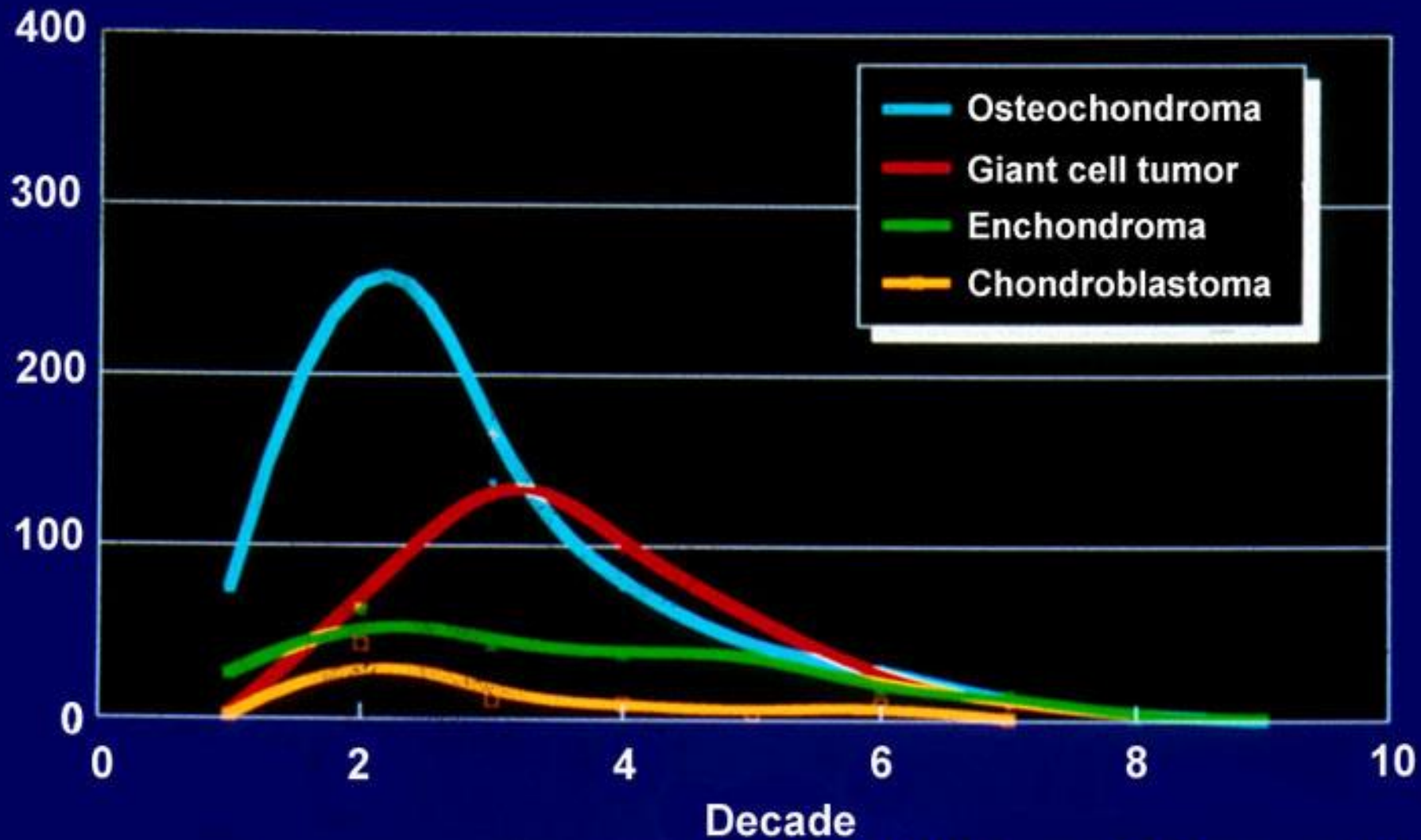
- Patient age/sex
- Bone involved and location – any
- Lesion margins – Radiographs > CT > MRI
- Matrix formation
 - Mineralized: CT > Radiographs > MRI
 - Nonmineralized: MRI > CT > Radiographs
- Periosteal reaction – Radiographs > CT > MRI
- Preoperative staging – MRI > CT > Radiographs
 - Lesion extent/affect on adjacent structures

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Primary Benign Bone Tumors

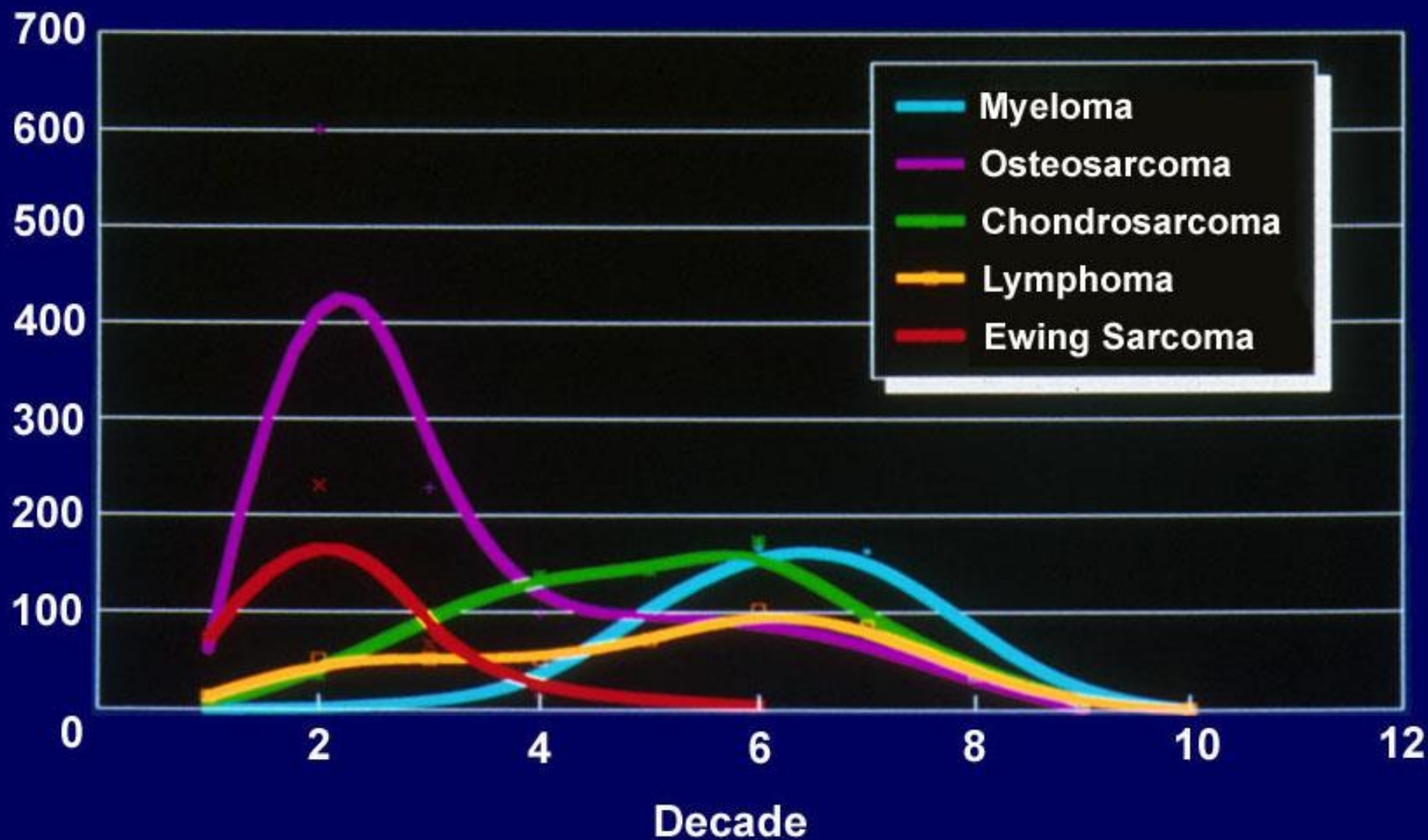
Age Distribution by Decade



Dahlin DC. Data on 8542 cases. 1986

Primary Malignant Bone Tumors

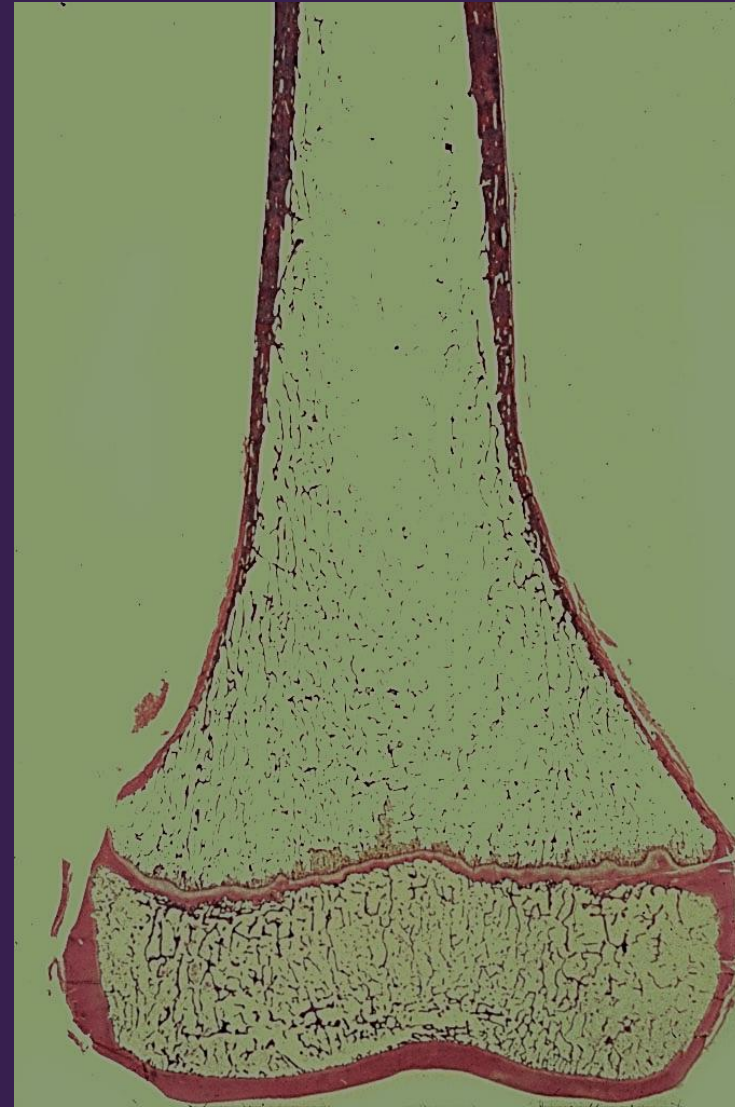
Age Distribution by Decade



Dahlin DC. Data on 8542 cases. 1986

LOCATION IN BONE: LONGITUDINAL

- Epiphysis
- Metaphysis
- Diaphysis



BONE LOCATION: LONGITUDINAL

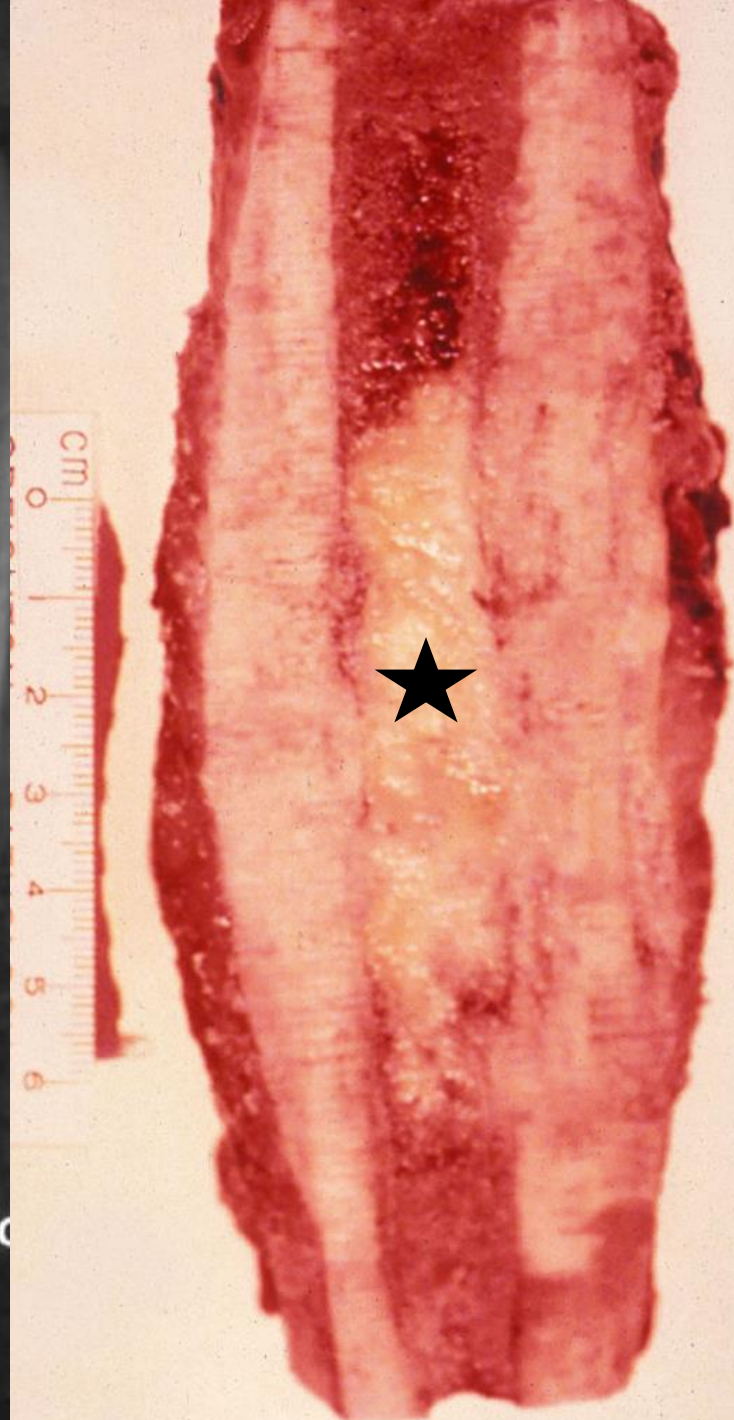
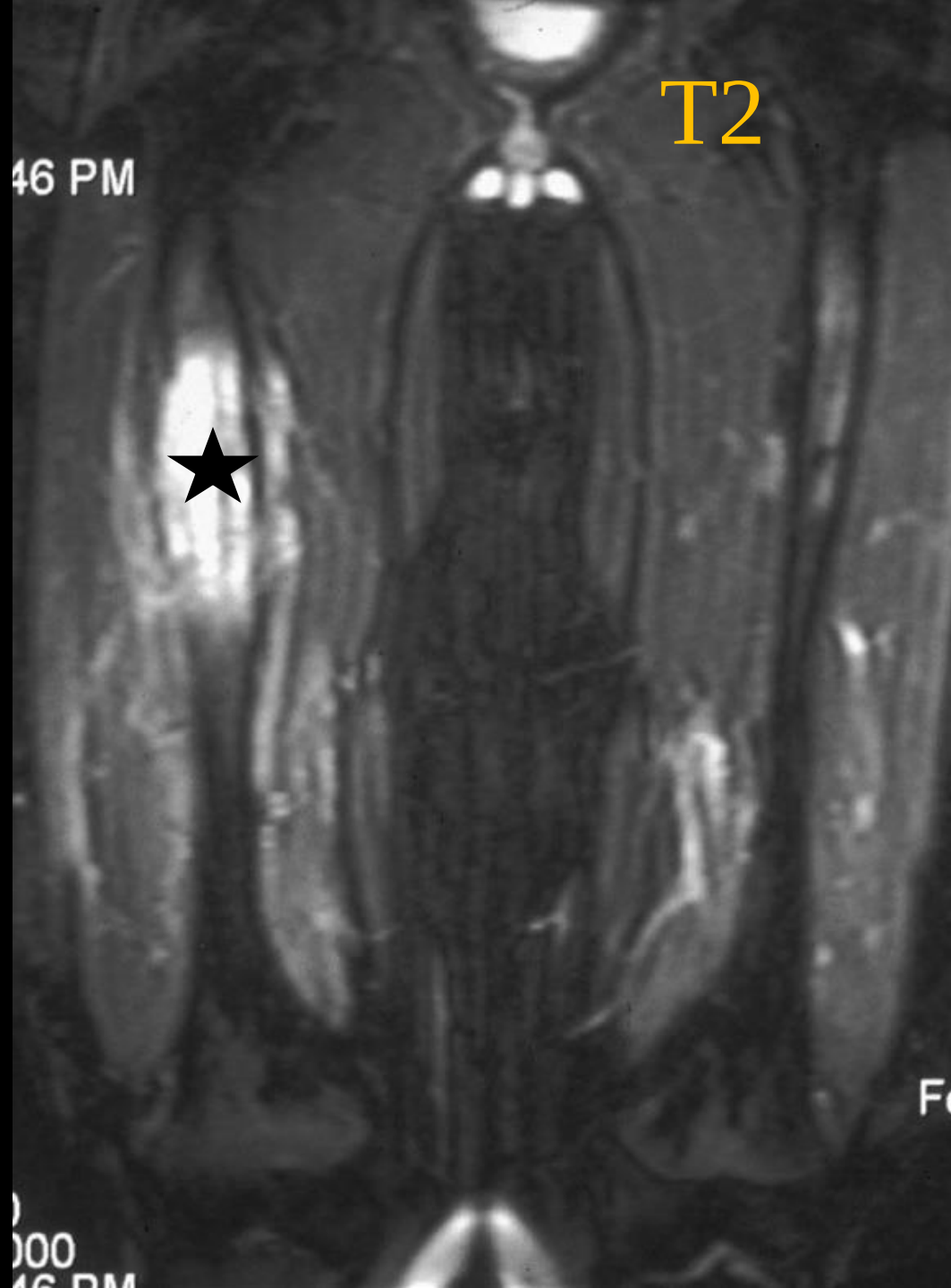
- Epiphyseal - Chondroblastoma, GCT, infection, LCH, subchondral cyst/ganglion
- Metaphyseal - most lesions
- Diaphyseal - Ewing sarcoma, leukemia, lymphoma, myeloma, adamantinoma, metastases, fibrous dysplasia, UBC, osteonecrosis, brown tumor





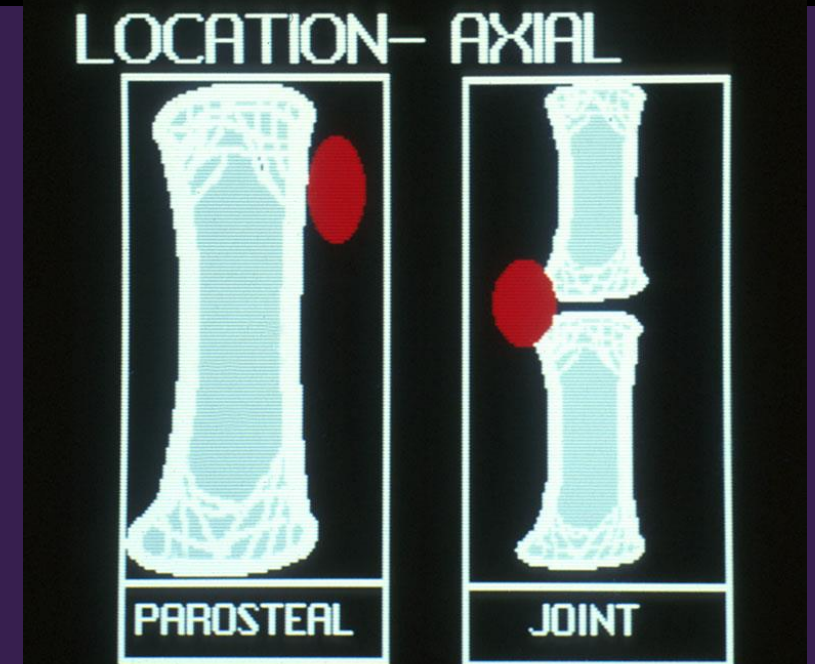
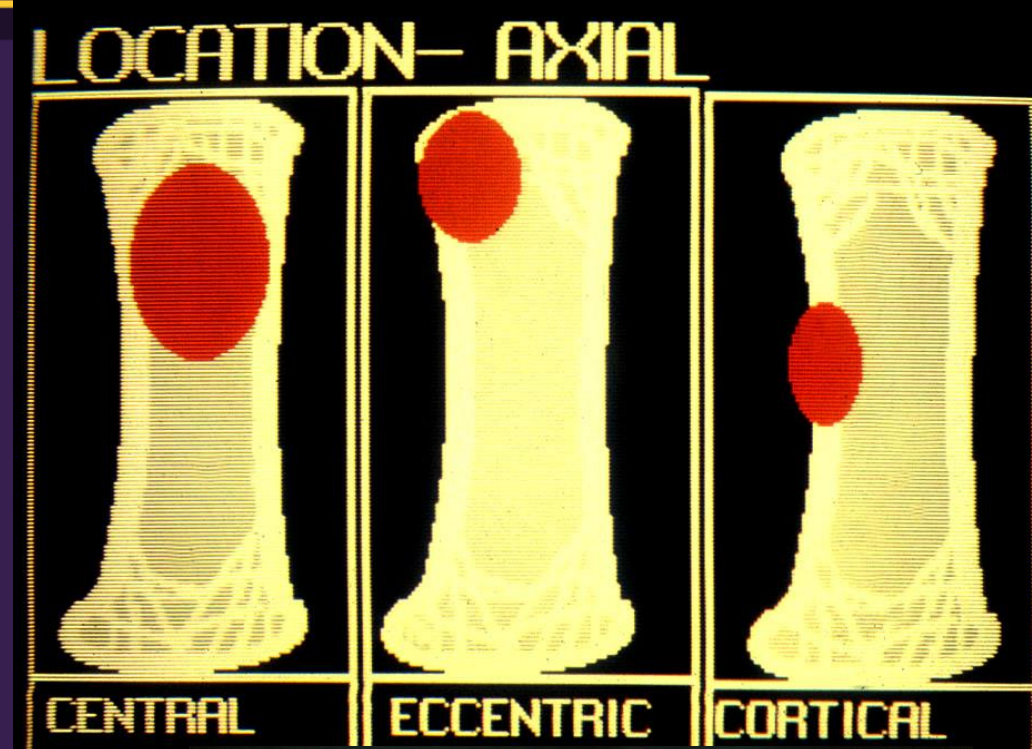






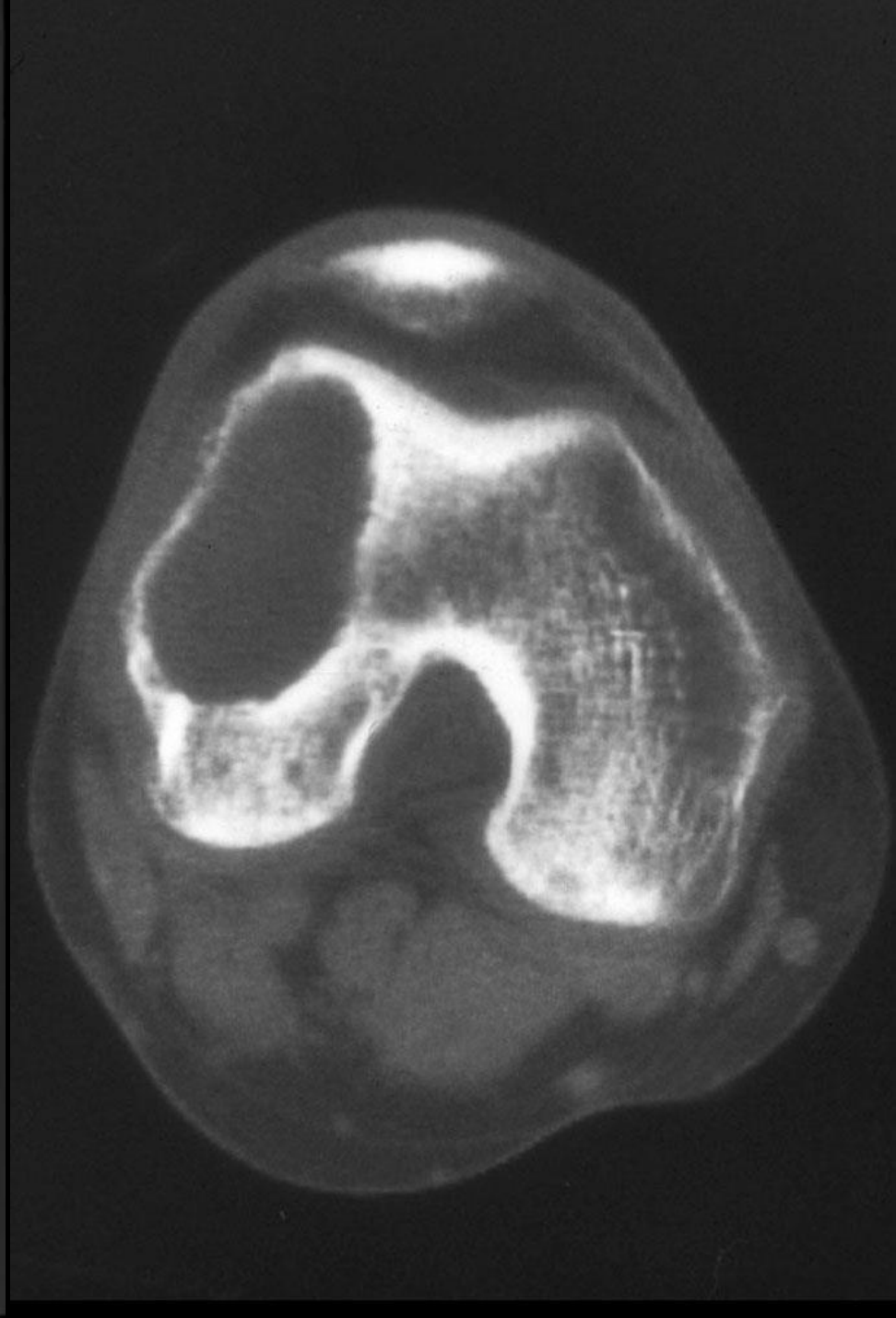
LOCATION IN BONE: AXIAL

- Central
- Eccentric
- Cortical
- Juxtacortical
- Soft tissue

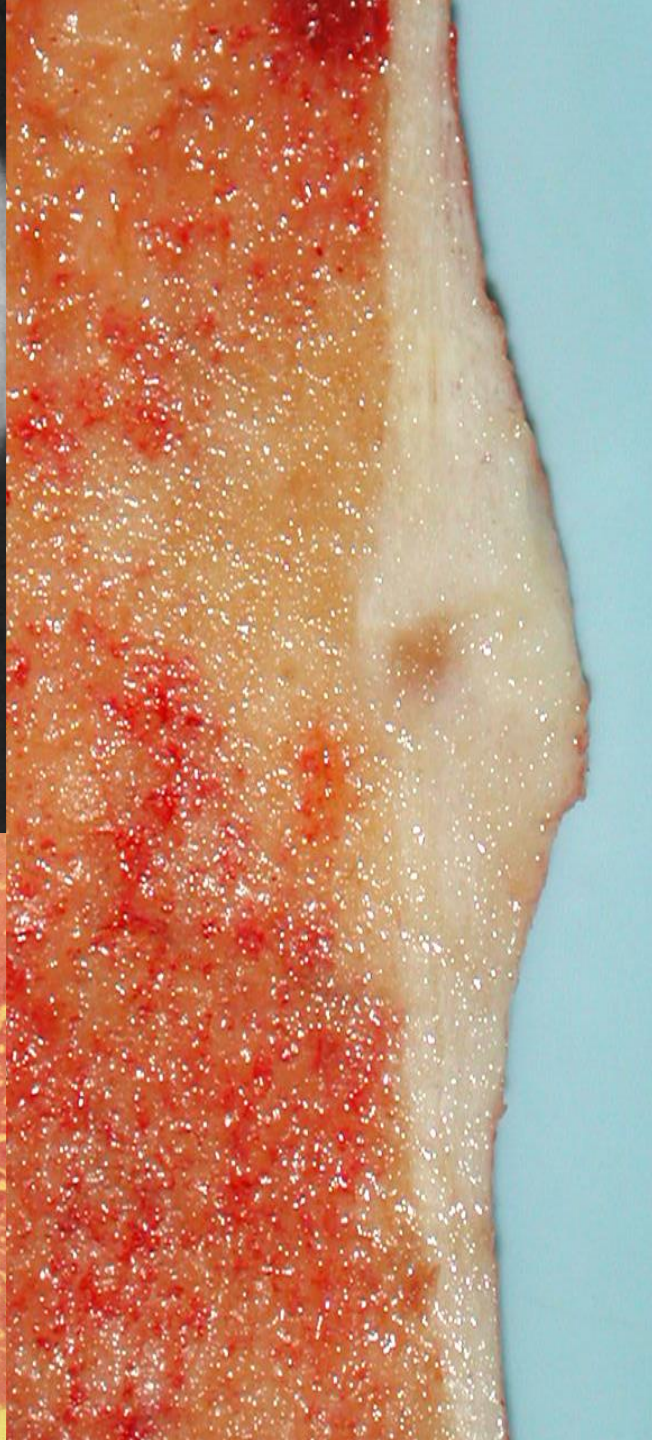
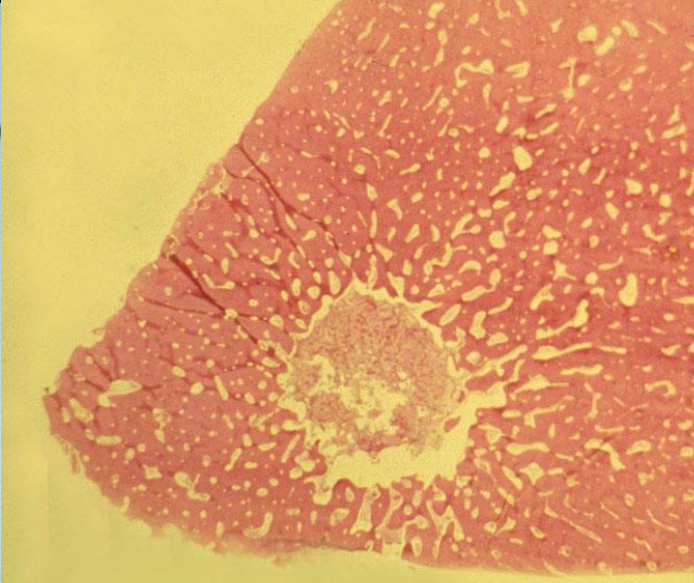
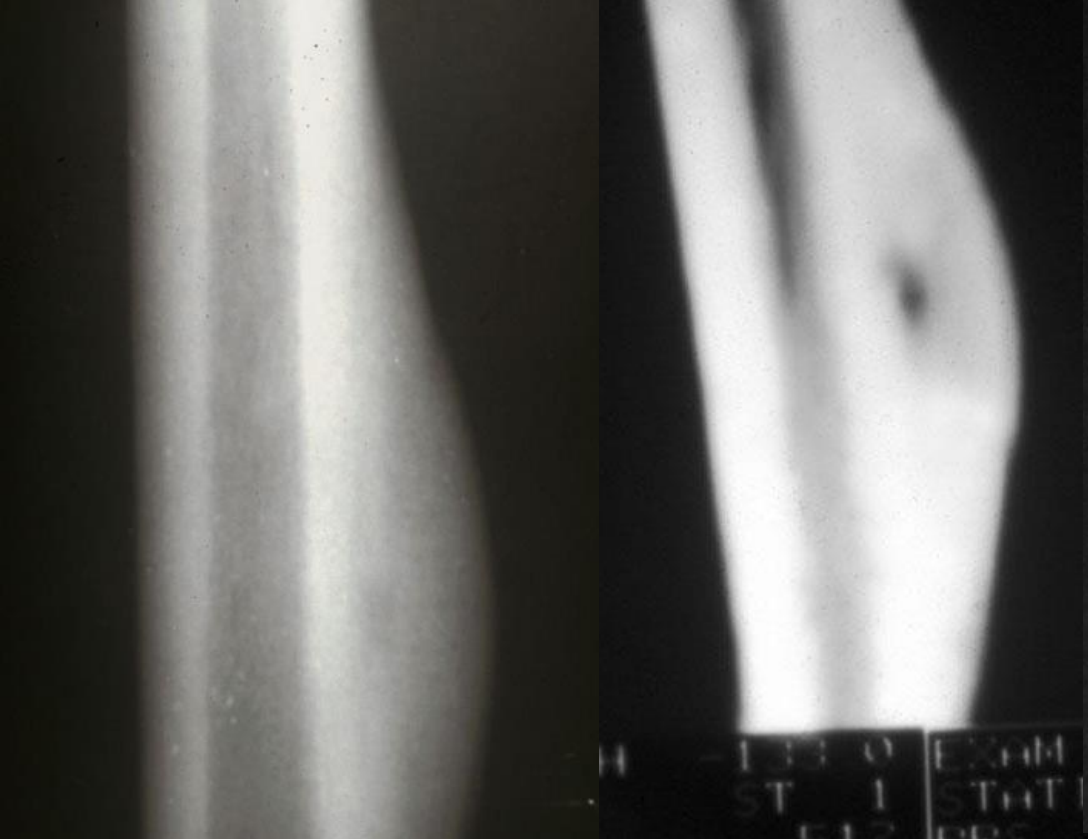


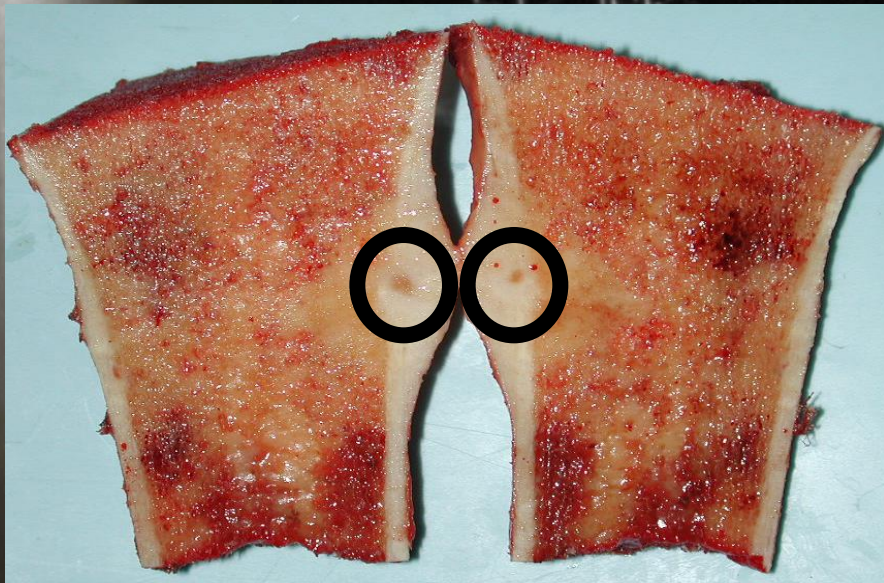
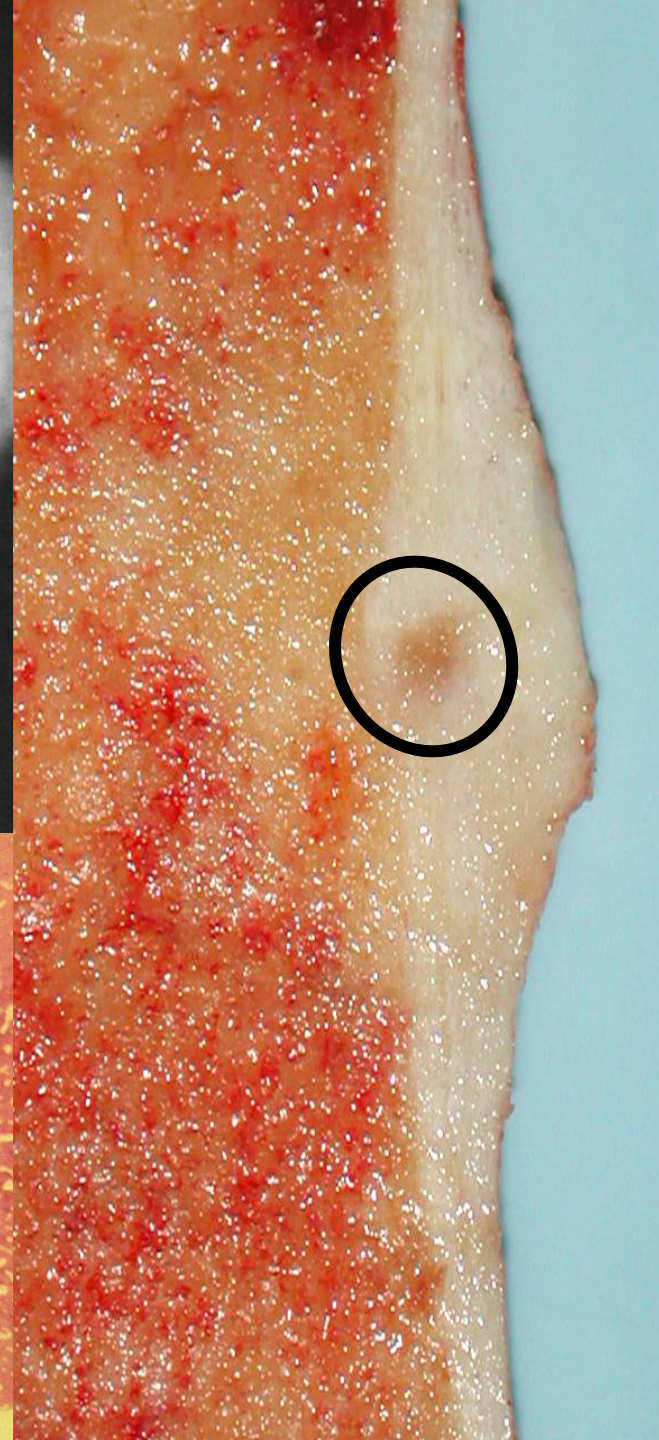
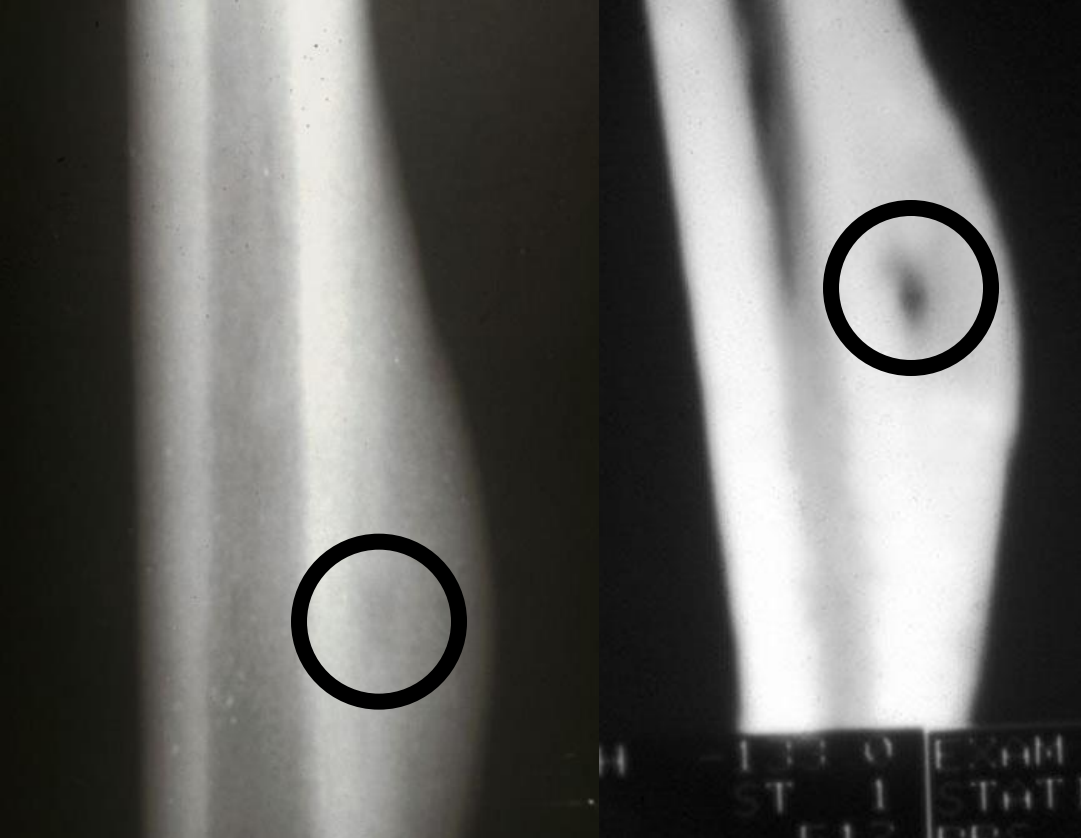
BONE LOCATION: AXIAL (long bones)

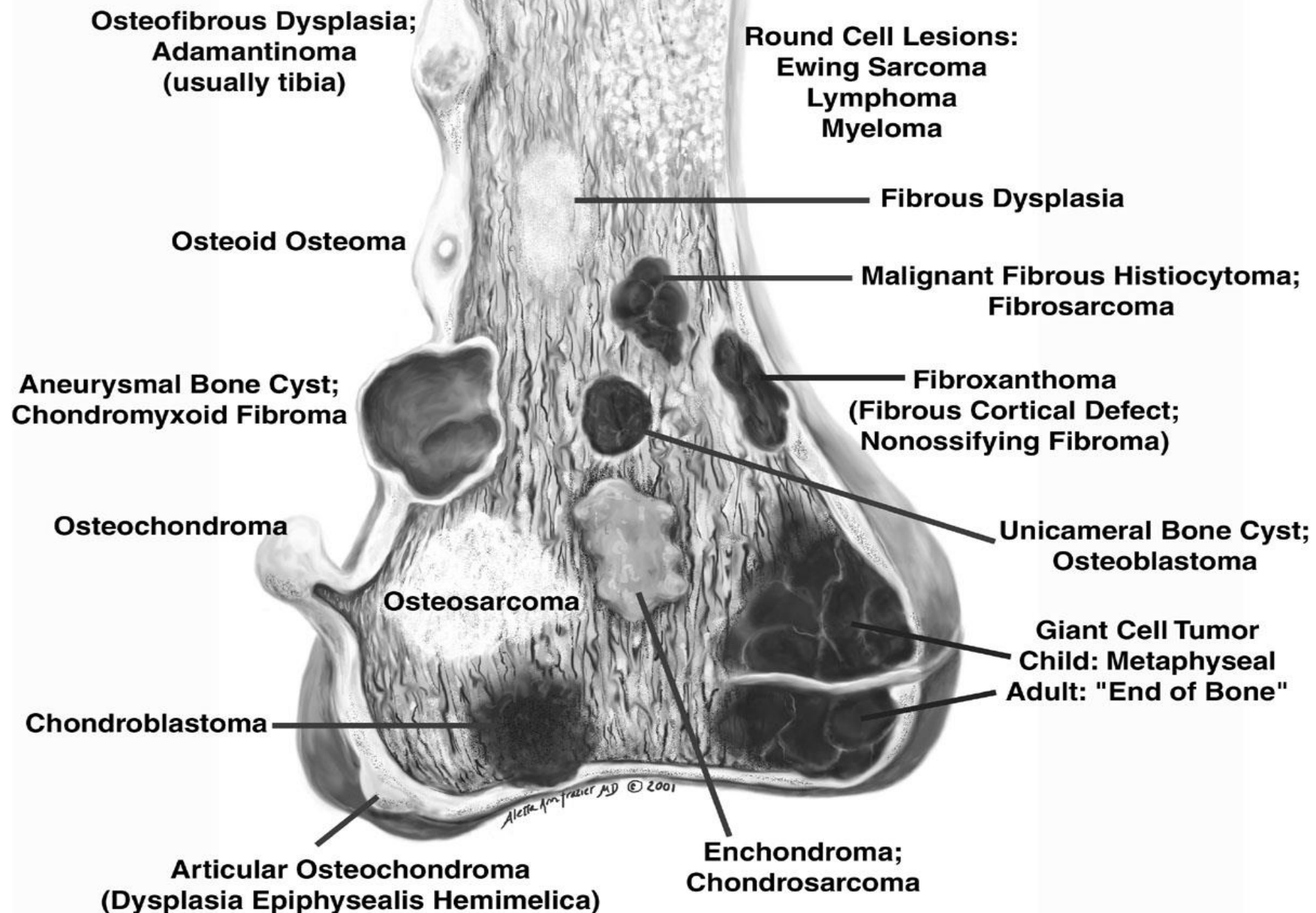
- Central - UBC, enchondroma, fibrous dysplasia, osteosarcoma, MFH, Ewing sarcoma, leukemia, lymphoma, myeloma, chondrosarcoma
- Eccentric - ABC, GCT, enchondroma, CMF, osteosarcoma, UPS/MFH, brown tumor
- Intracortical - NOF, osteoid osteoma, LCH, Brodie abscess, osteofibrous dysplasia, adamantinoma, Brown tumor
- Juxtacortical - Cortical desmoid, surface osteosarcoma, juxtacortical chondroma/chondrosarcoma, ABC, osteoid osteoma, osteochondroma









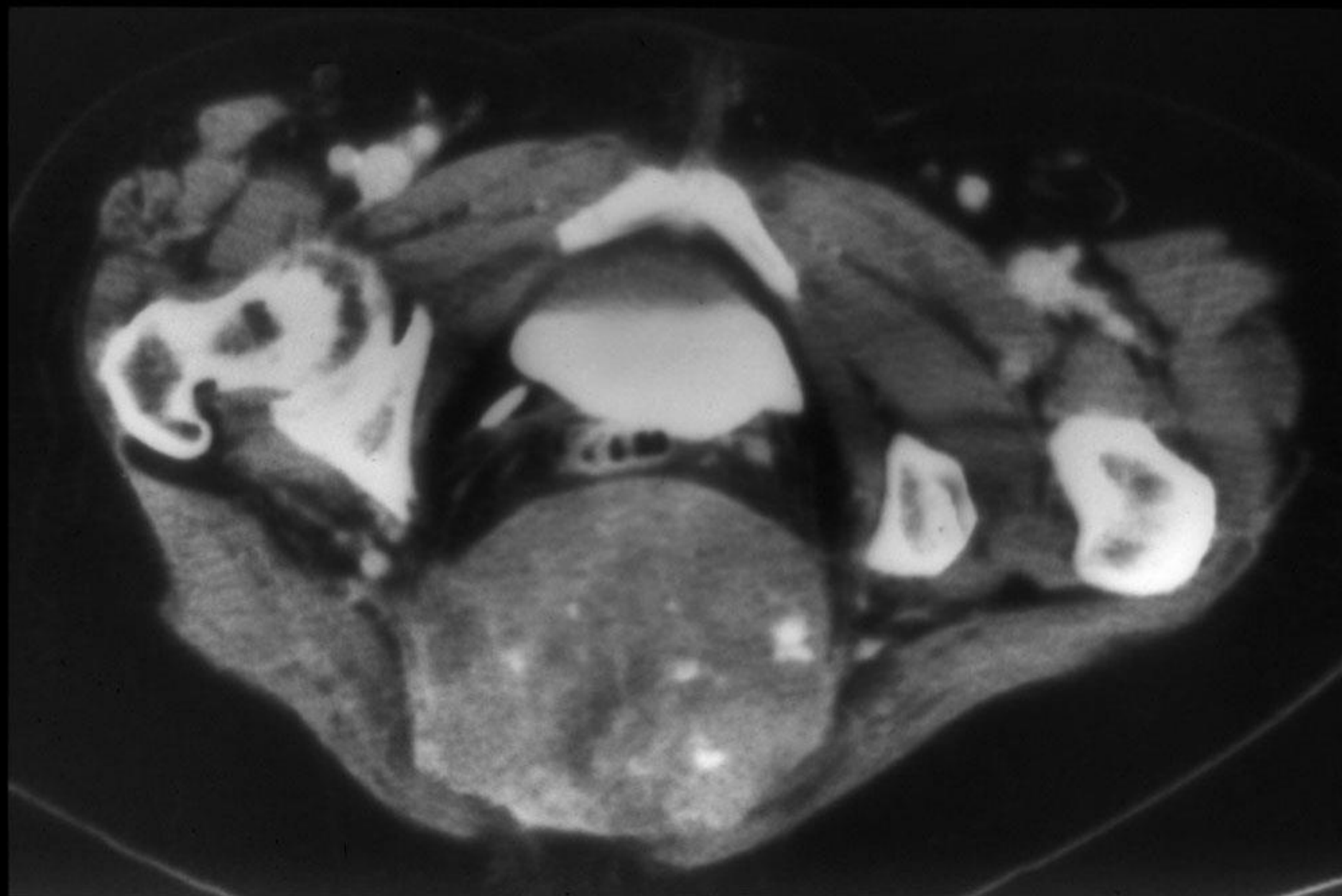


SPECIFIC BONE LOCATION DIFFERENTIAL DIAGNOSIS

- Sacrum - GCT, ABC, chordoma, neurogenic neoplasm, metastases, myeloma, insufficiency fractures
- Spine - Posterior elements: Osteoblastoma, ABC, metastases, myeloma, chondrosarcoma
 - Vertebral body: Hemangioma, GCT, LCH, metastases, myeloma, Ewing sarcoma, chondrosarcoma, chordoma







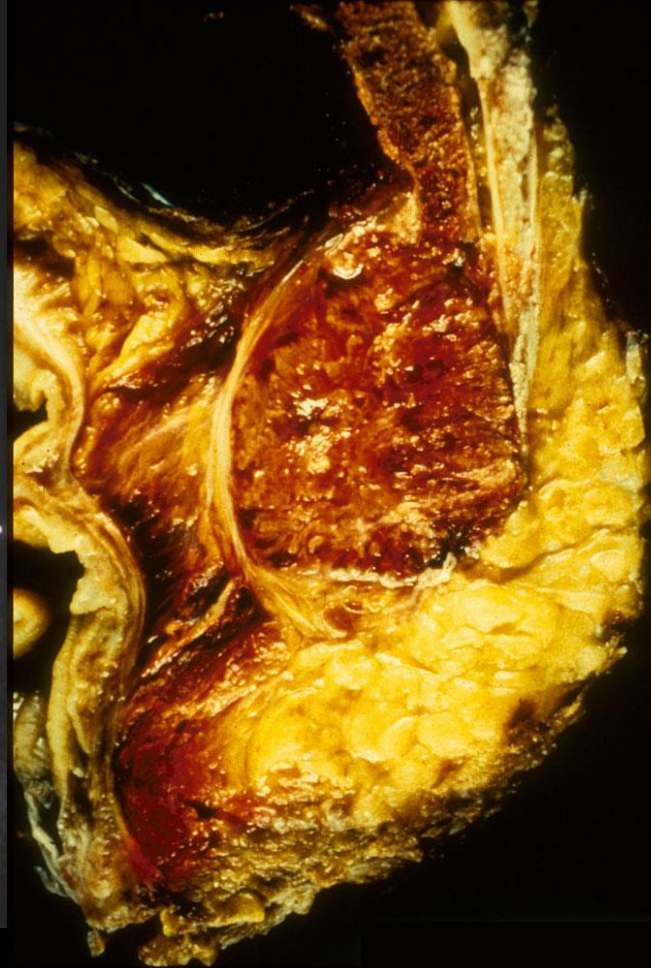




T1



T2

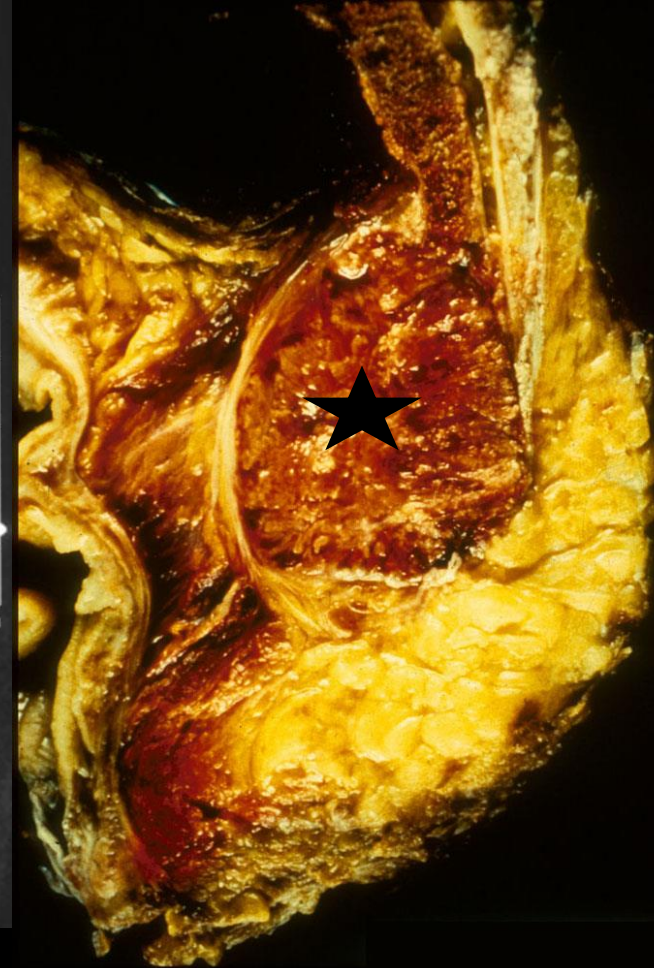




T1

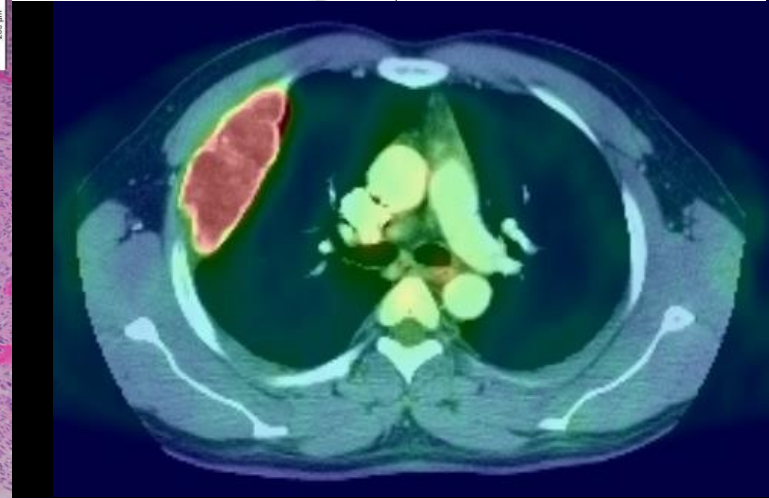
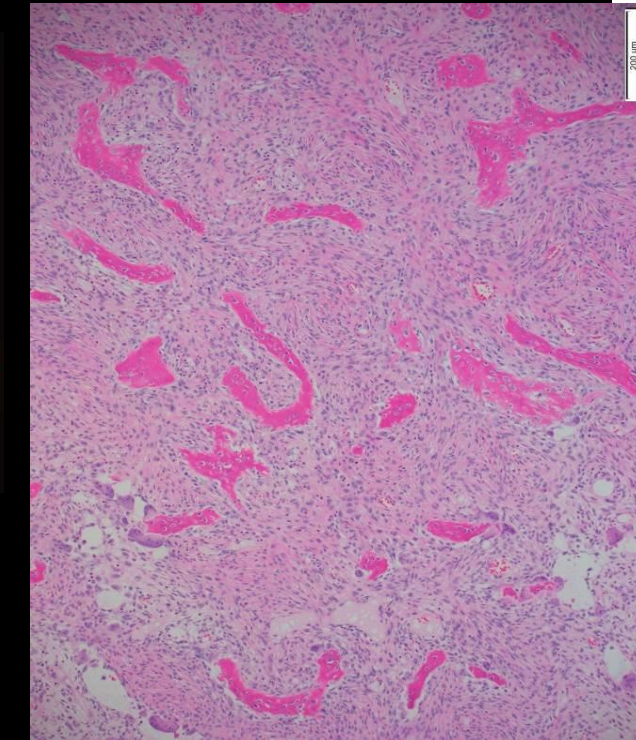
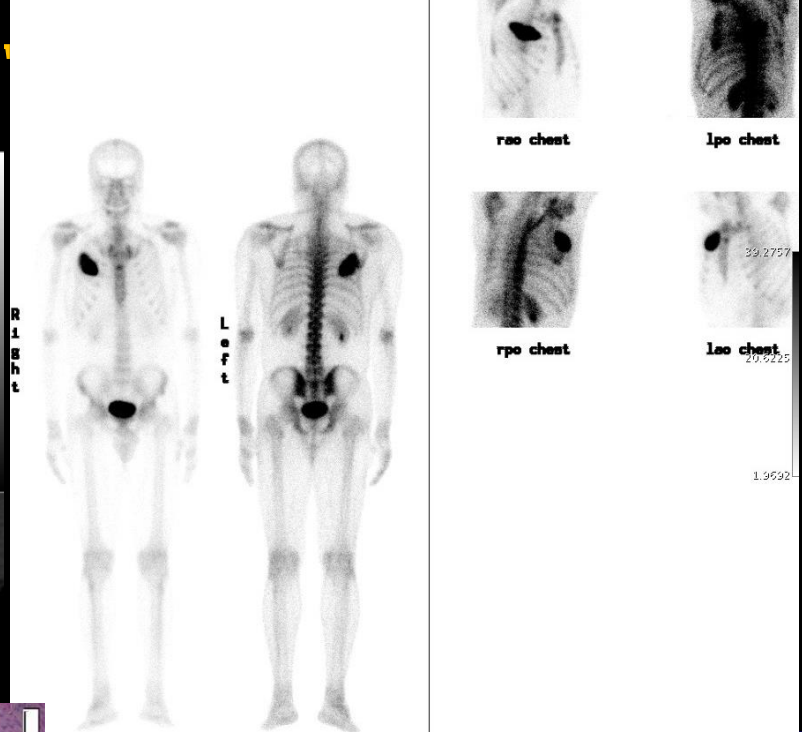
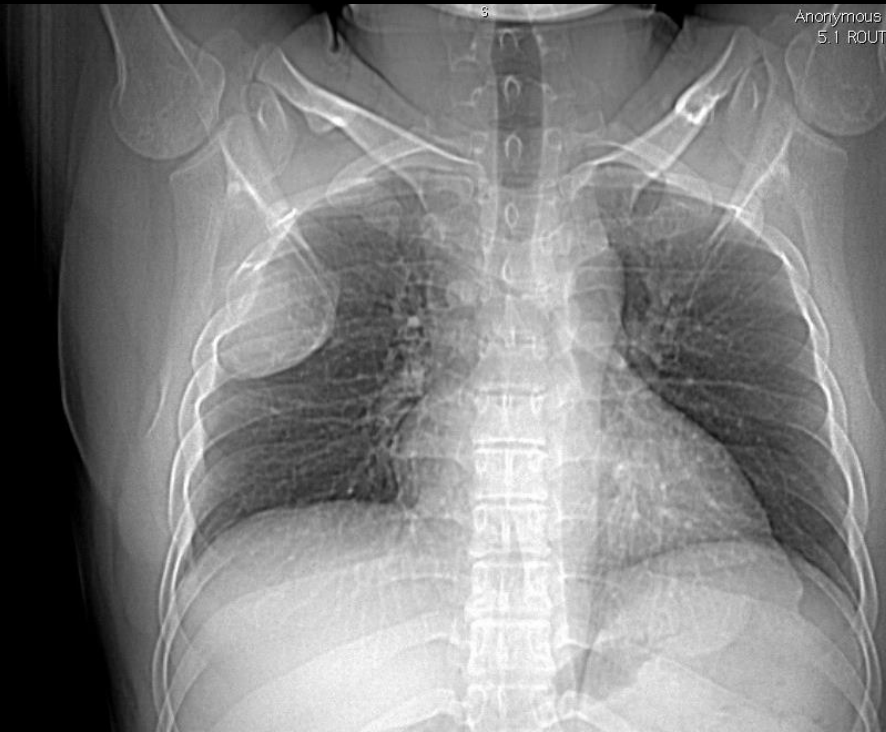


T2



SPECIFIC BONE LOCATION DIFFERENTIAL DIAGNOSIS

- Rib - Fibrous dysplasia, LCH, metastases, myeloma, chondrosarcoma
- Tibia (cortex) - Adamantinoma, osteofibrous dysplasia, hemangioma
- Skull - Metastases, myeloma, Paget disease, hemangioma, LCH, epidermoid cyst, leptomeningeal cyst, NF1



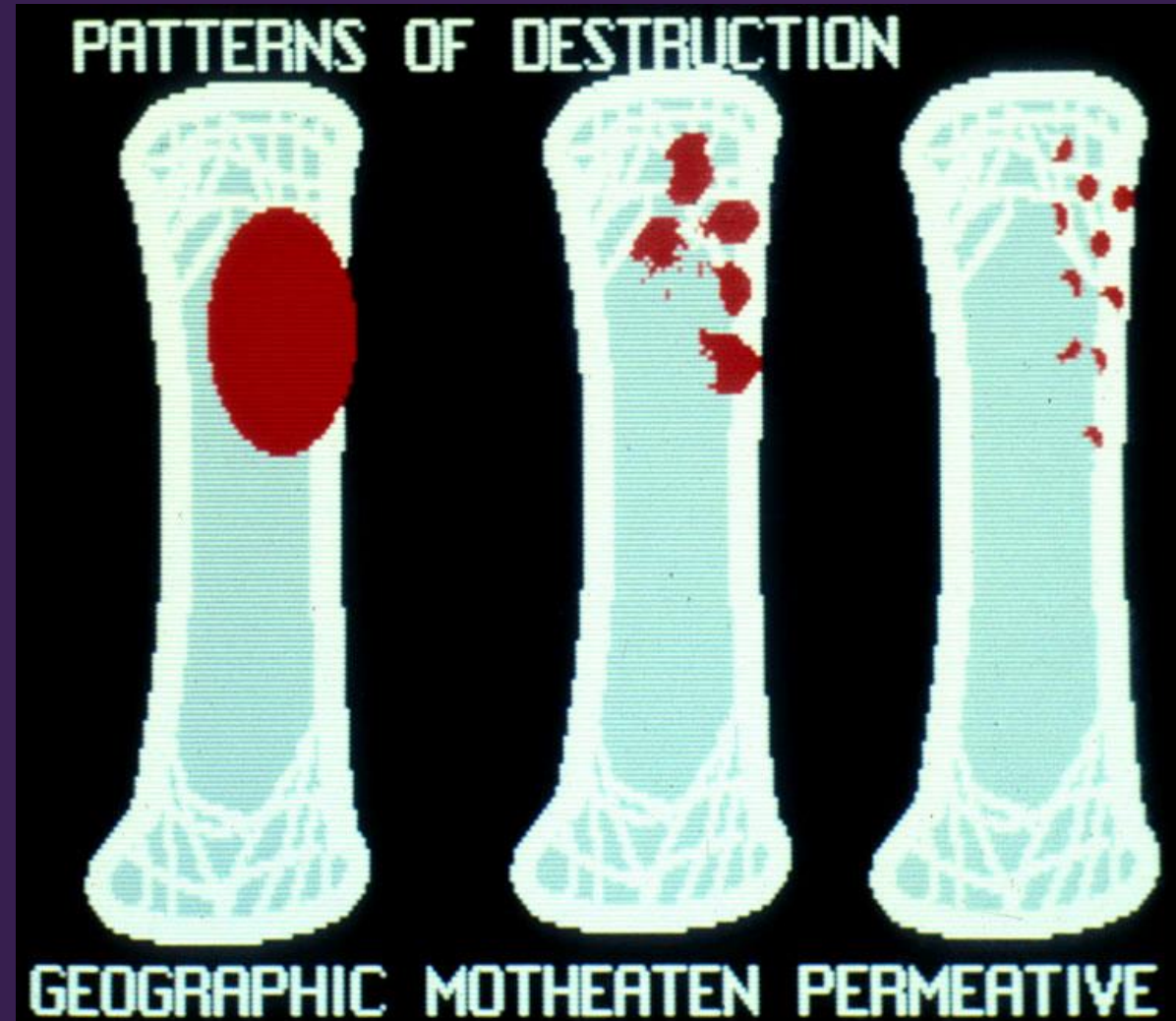
35M

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PATTERN OF BONE DESTRUCTION AND LESION MARGIN

- Type I: Geographic
 - A: Well-defined, sclerosis
 - B: Well-defined, no sclerosis
 - C: Ill-defined
- Type II: Motheaten
- Type III: Permeative
- Transition zone



BIOLOGIC ACTIVITY

MARGIN

GEOGRAPHIC

IA

IB

IC

MOTHEATEN

PERMEATIVE

GROWTH RATE

SLOW

SLOW TO INTERMEDIATE

INTERMEDIATE

INTERMEDIATE

FAST

FAST

AGGRESSIVE VS. NONAGGRESSIVE

Lodwick Grading System

IA

IB

IC

93% Benign

56% Benign

42% Benign

100% Malignant

II-III

***Test Library
223 Cases***

***IA-IC 73% Benign
II-III 100% Malignant***

Lodwick-Madewell Grading System

IA

99+% Benign

IB

94% Benign

IC

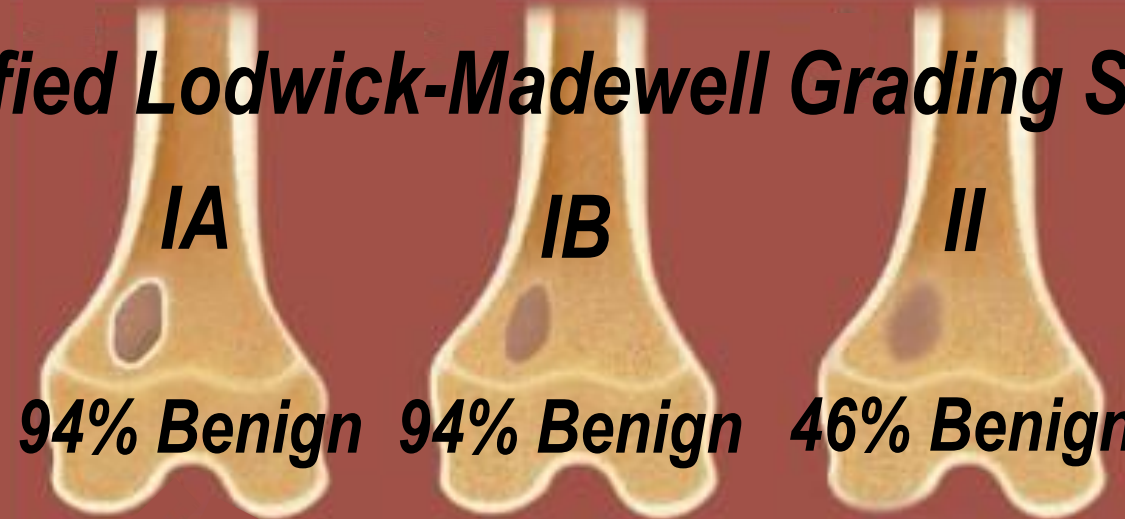
78% Benign

Erlemann et al. Radiologe 1994;34:53 (1154 long bone lesions)

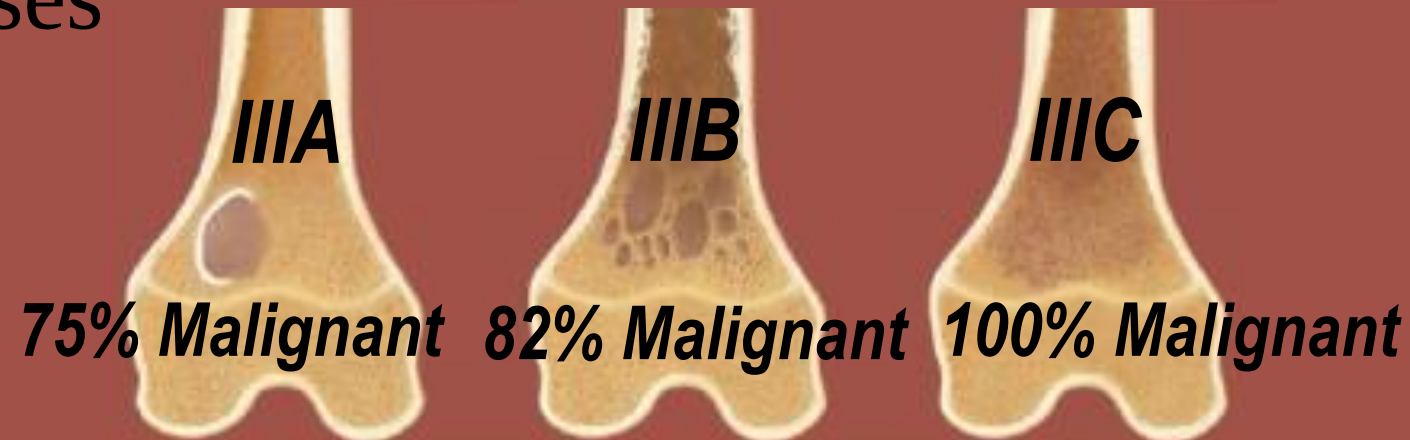
II-III

90% & 100% Malignant

Modified Lodwick-Madewell Grading System



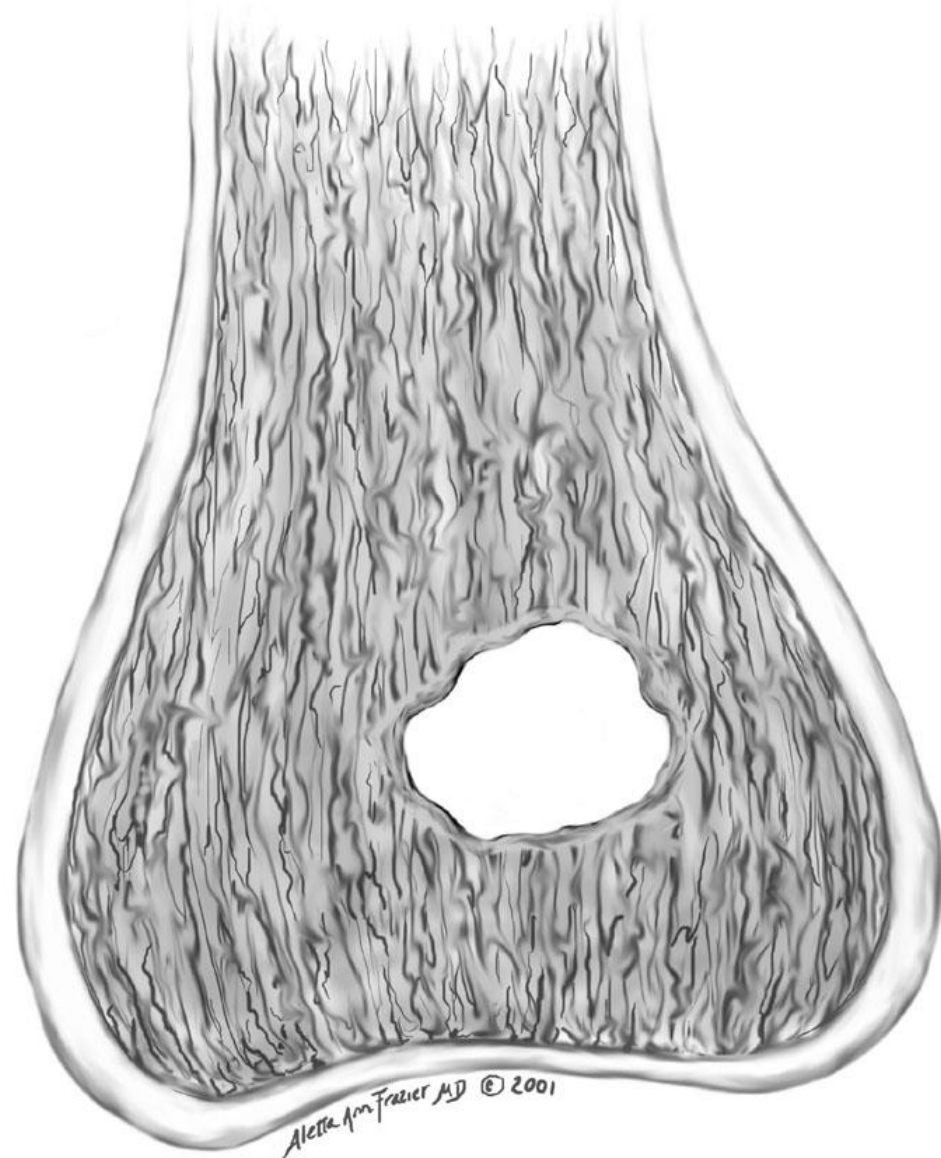
183 cases



Caracciolo JT et al. AJR 2016;207: 150–156

1A Margin

Geographic
Well-defined
Sclerosis



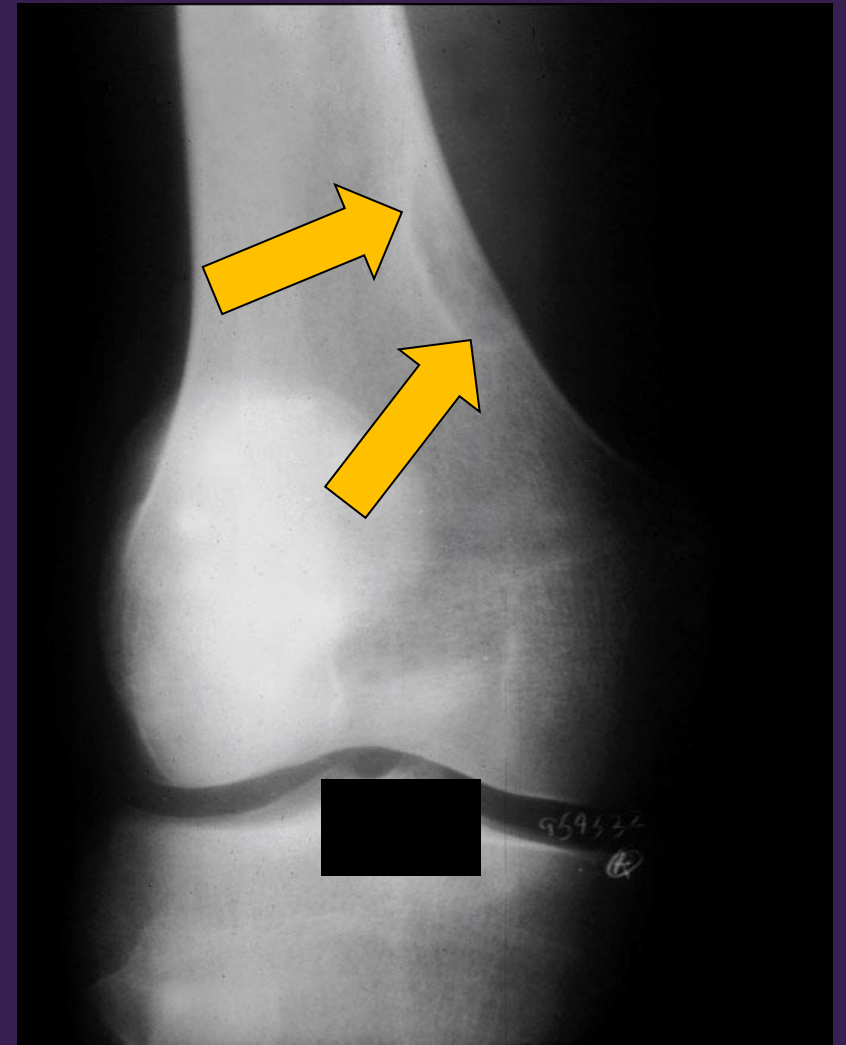
GEOGRAPHIC IA: DIFFERENTIAL DIAGNOSIS

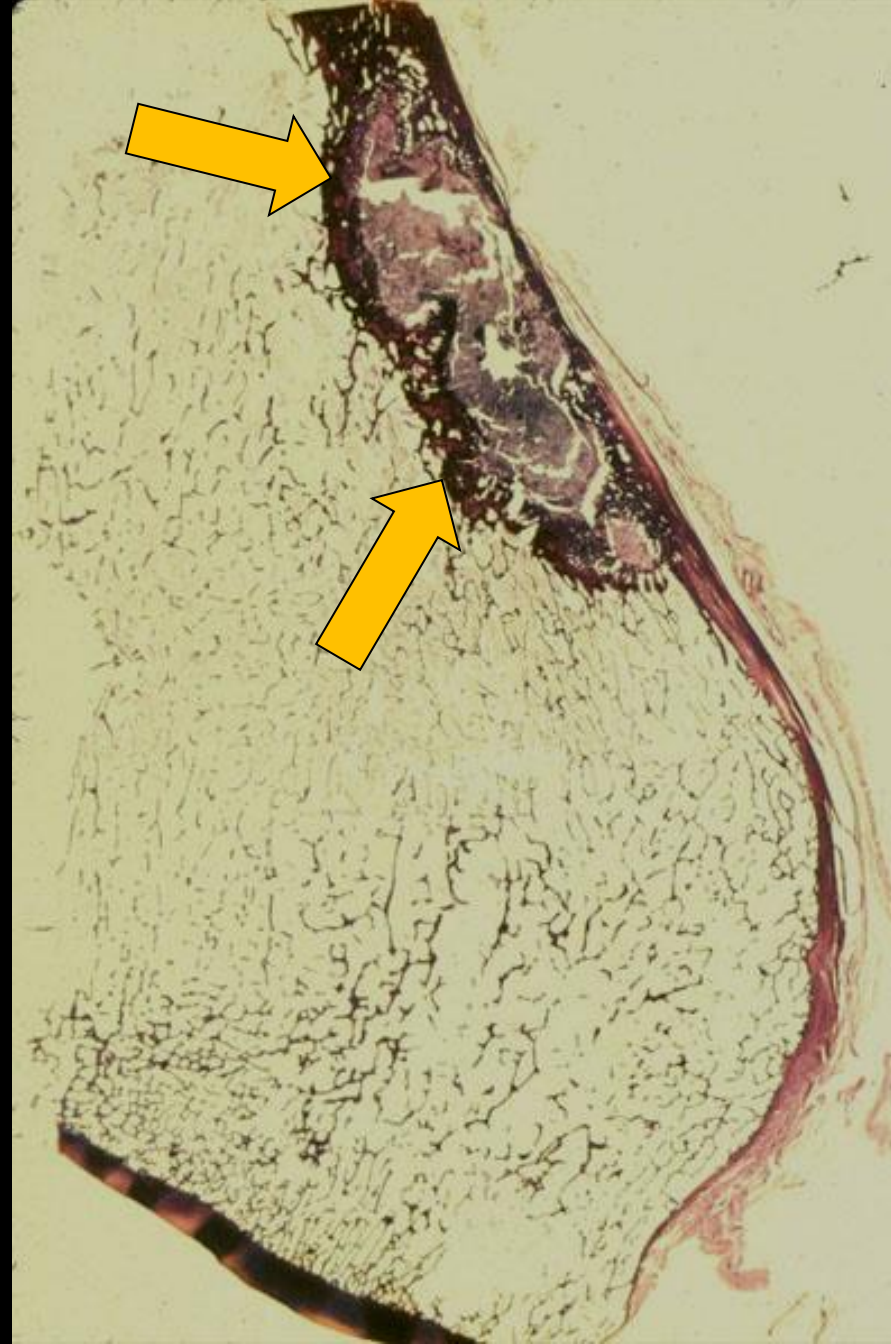
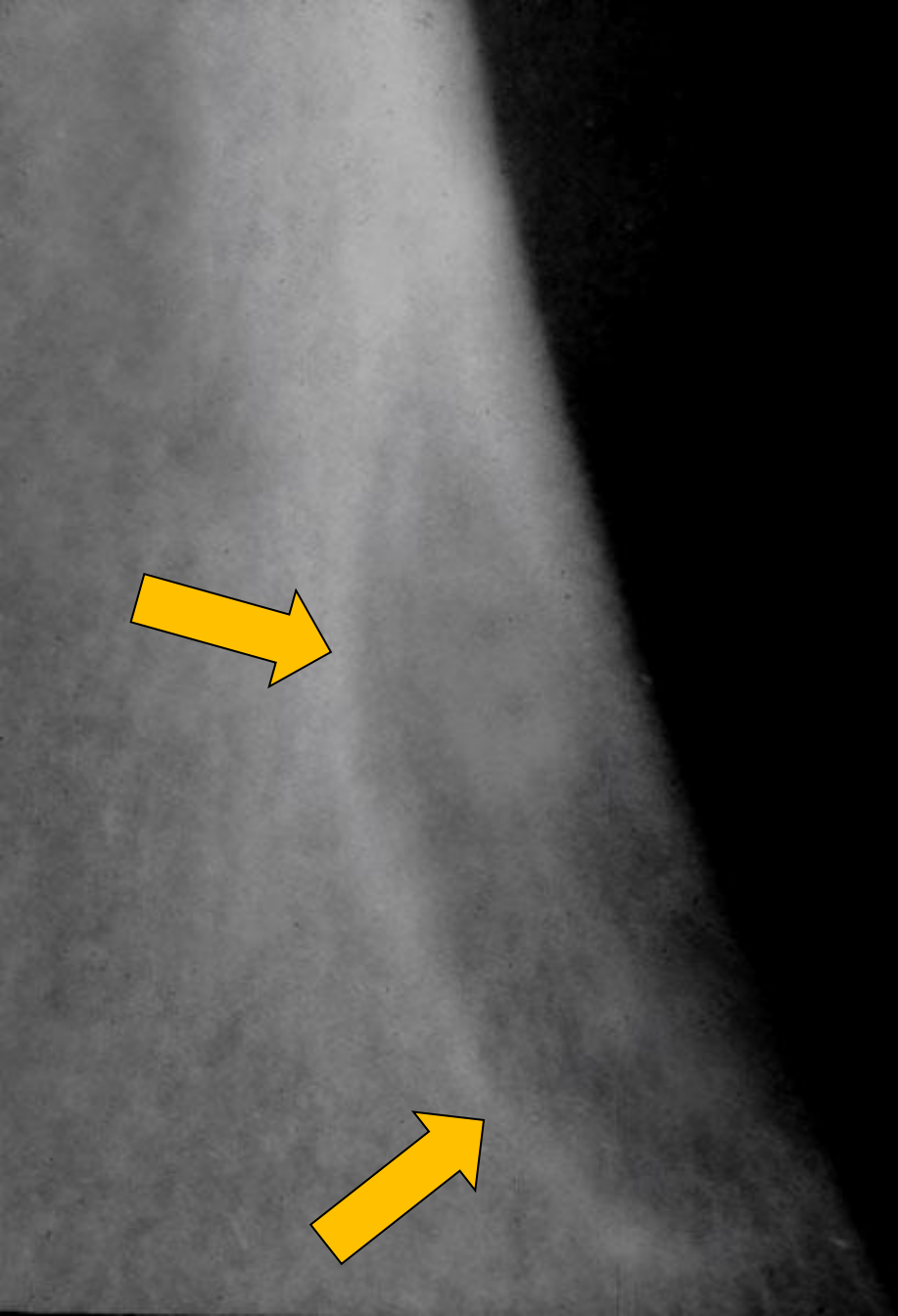
- Bone cyst
- Brodie abscess
- Cartilage lesions
 - Chondroblastoma
 - Chondromyxoid fibroma
 - Enchondroma
- Fibroxanthoma
- Fibrous dysplasia

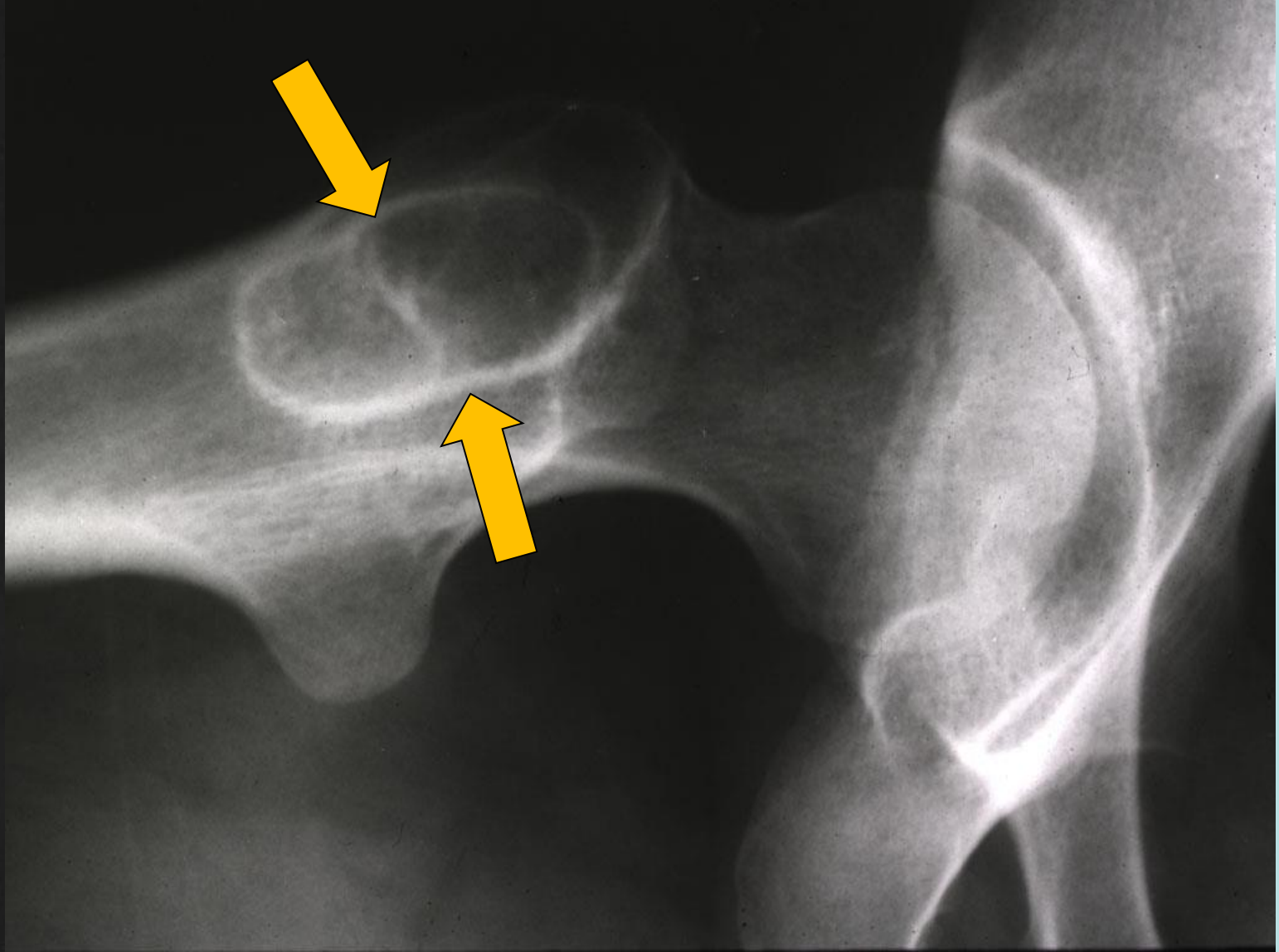


GEOGRAPHIC IA: DIFFERENTIAL DIAGNOSIS

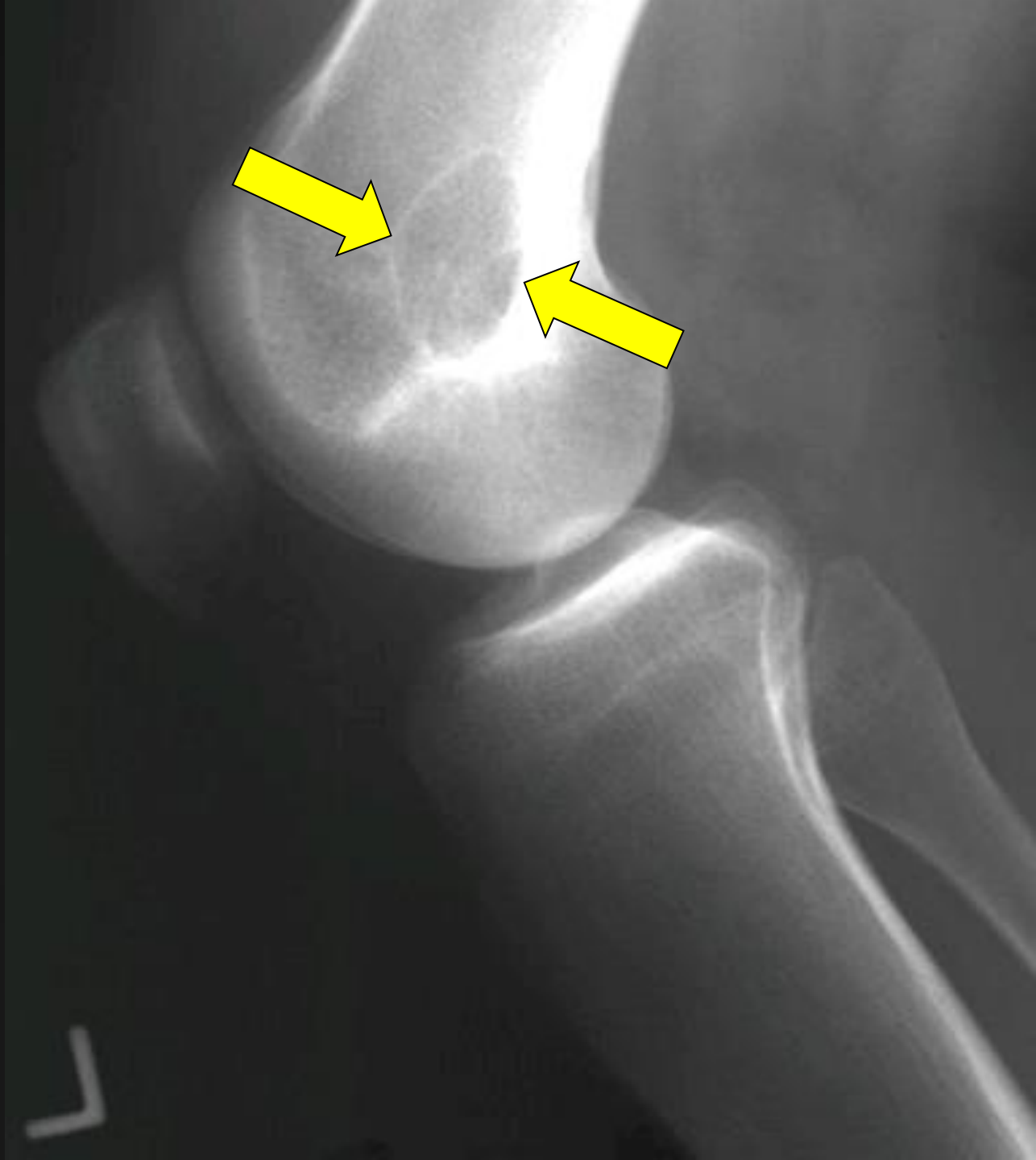
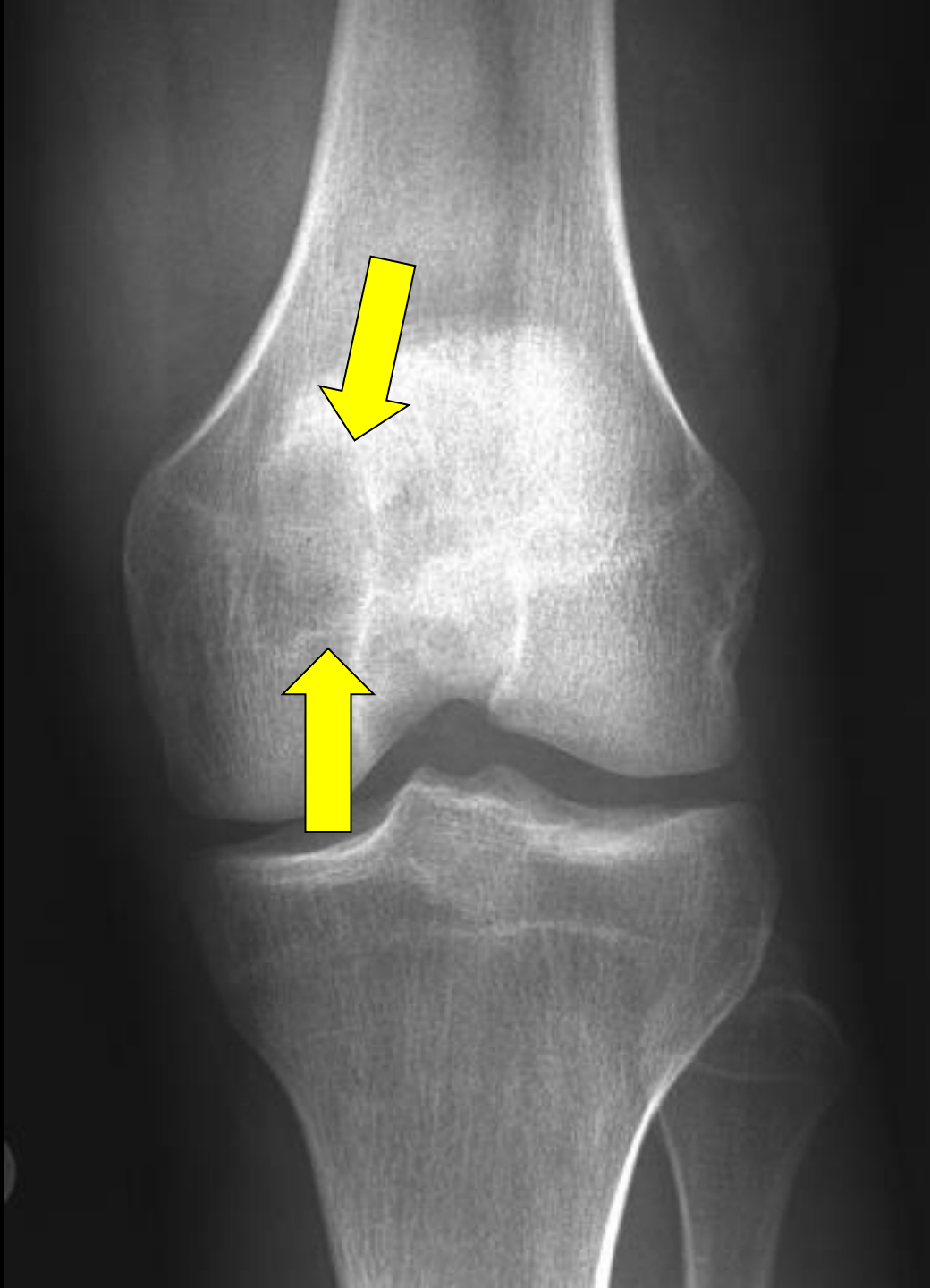
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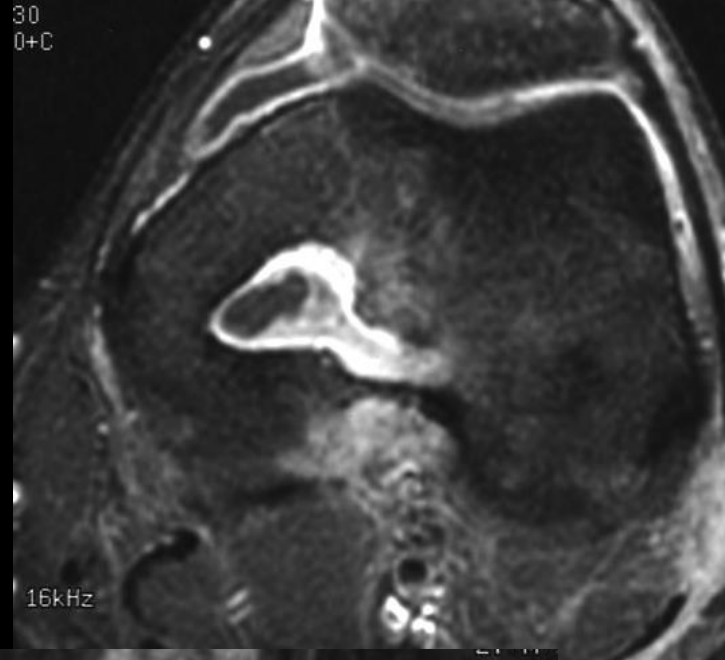
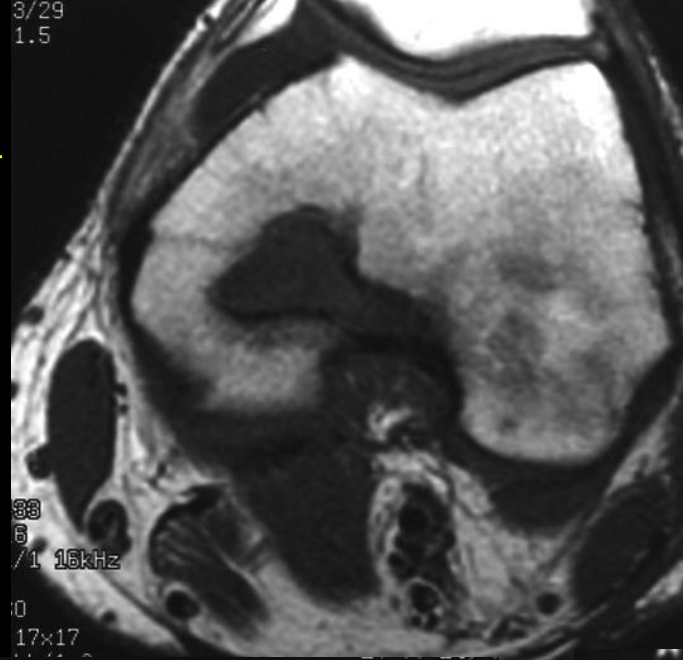






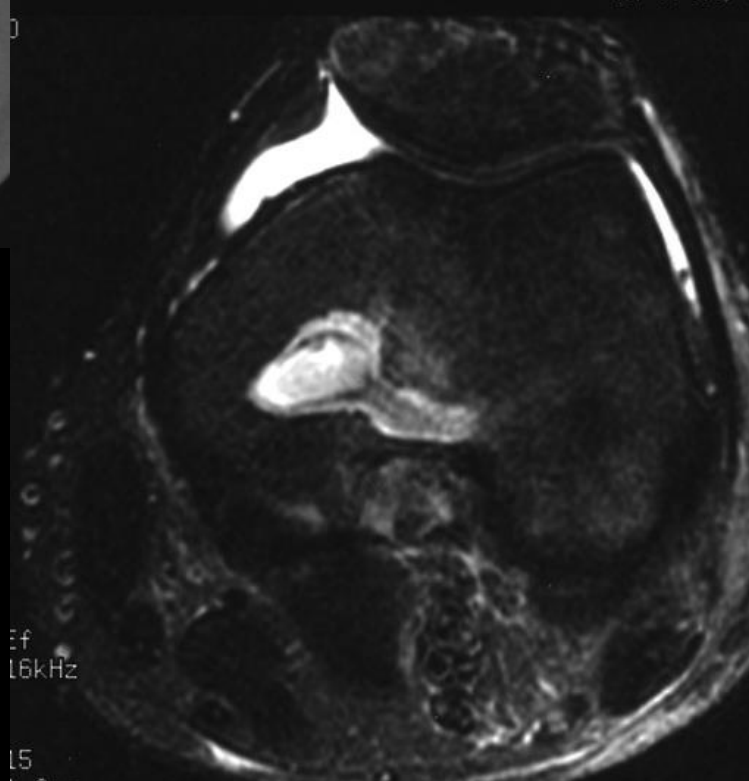


T1



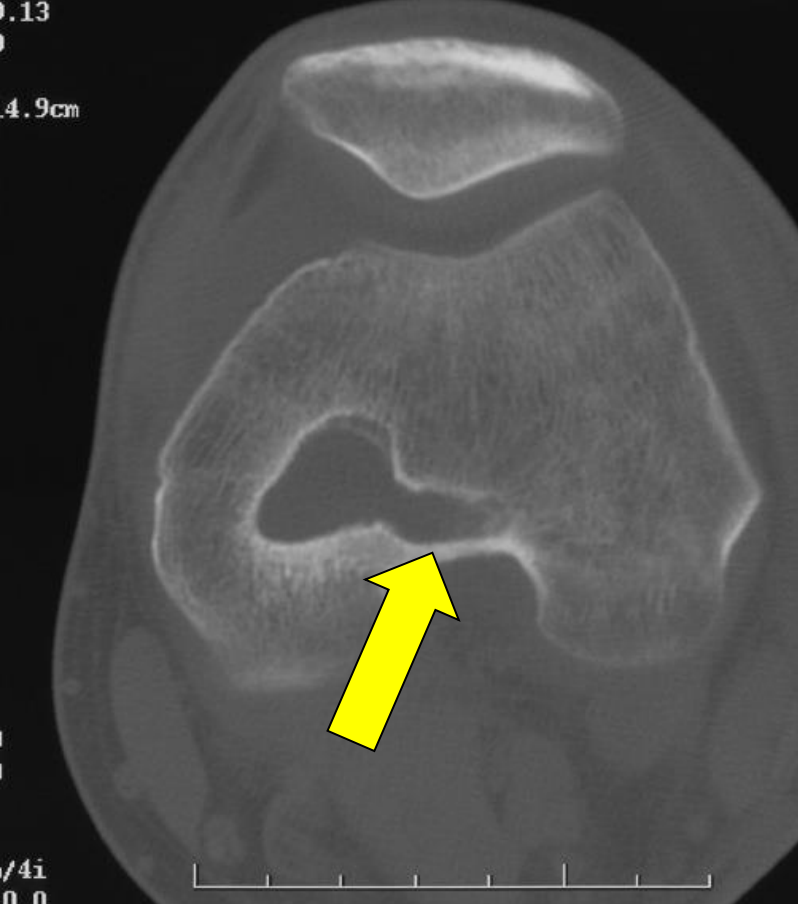
Gad

STIR

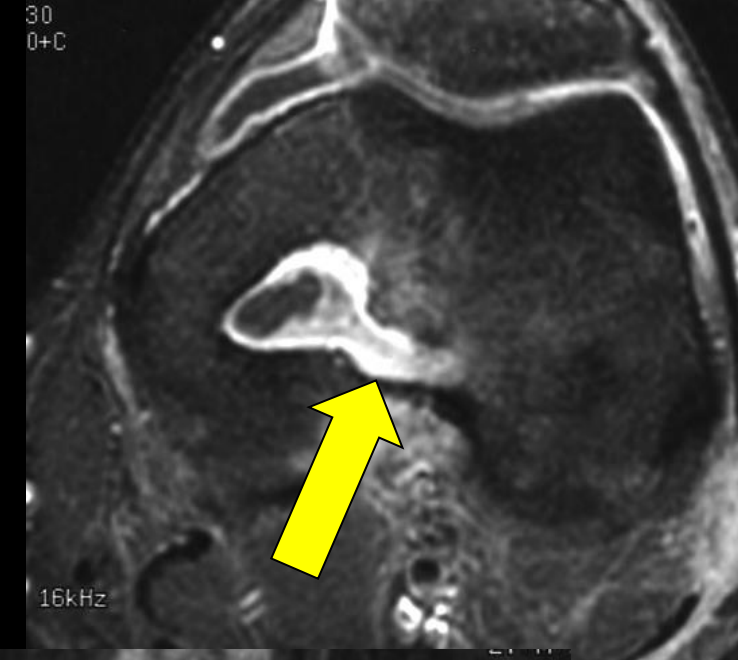
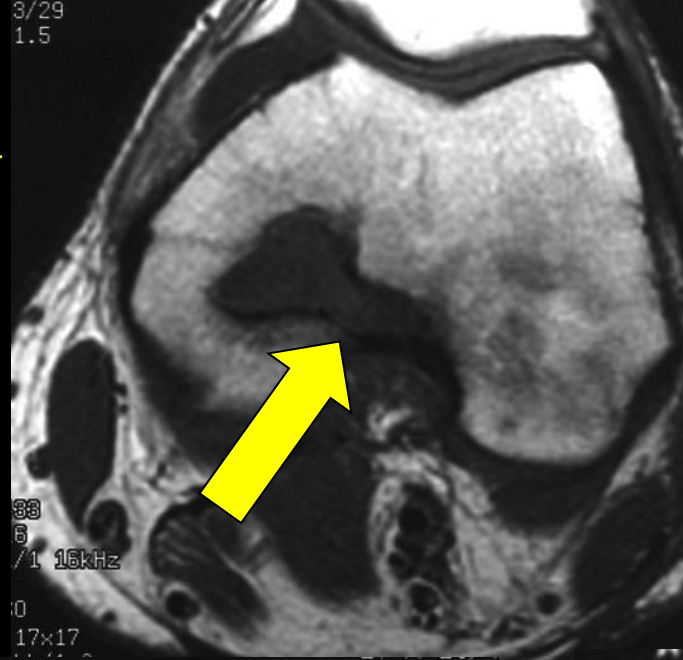


STIR



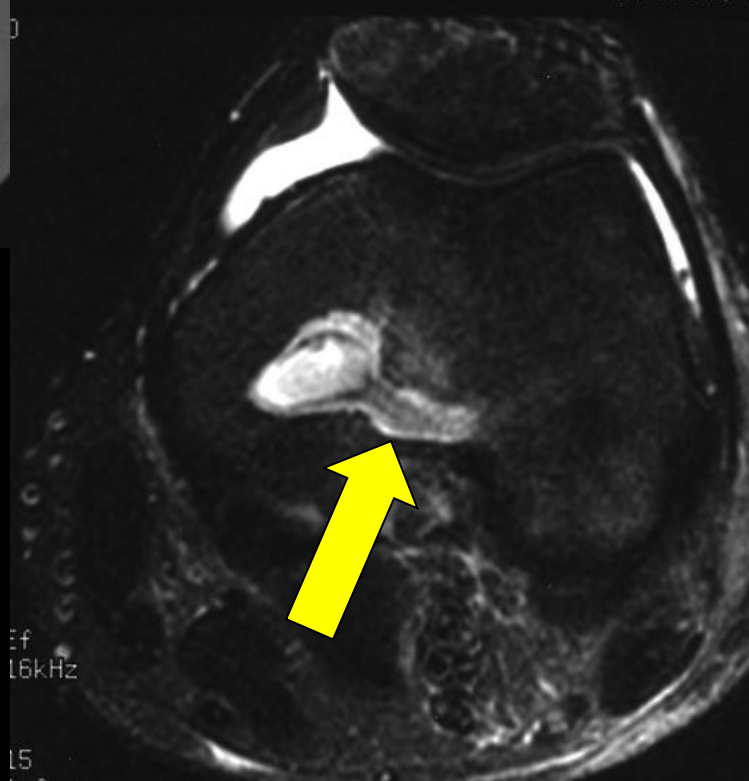


T1



Gad

STIR

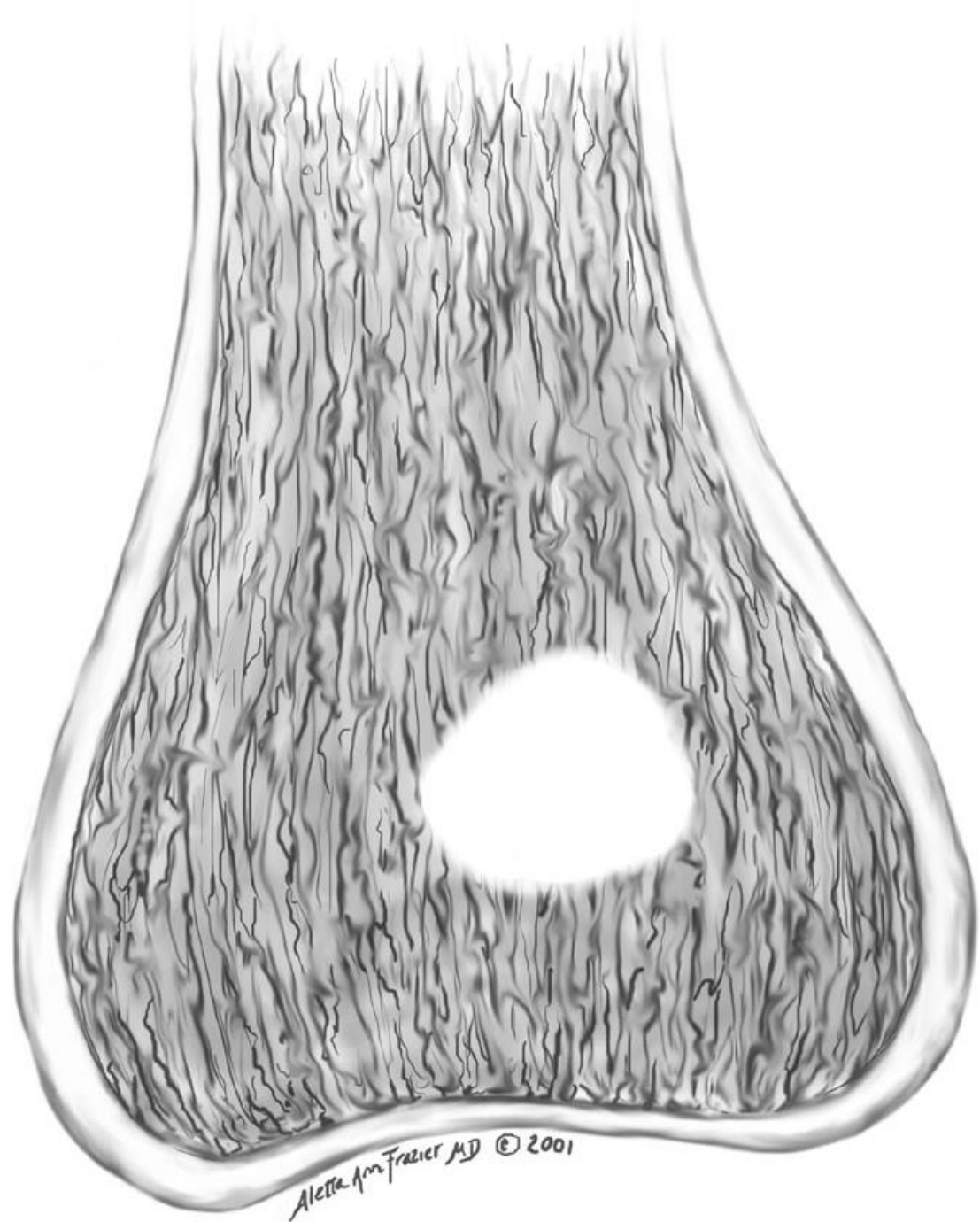


STIR



1B Margin

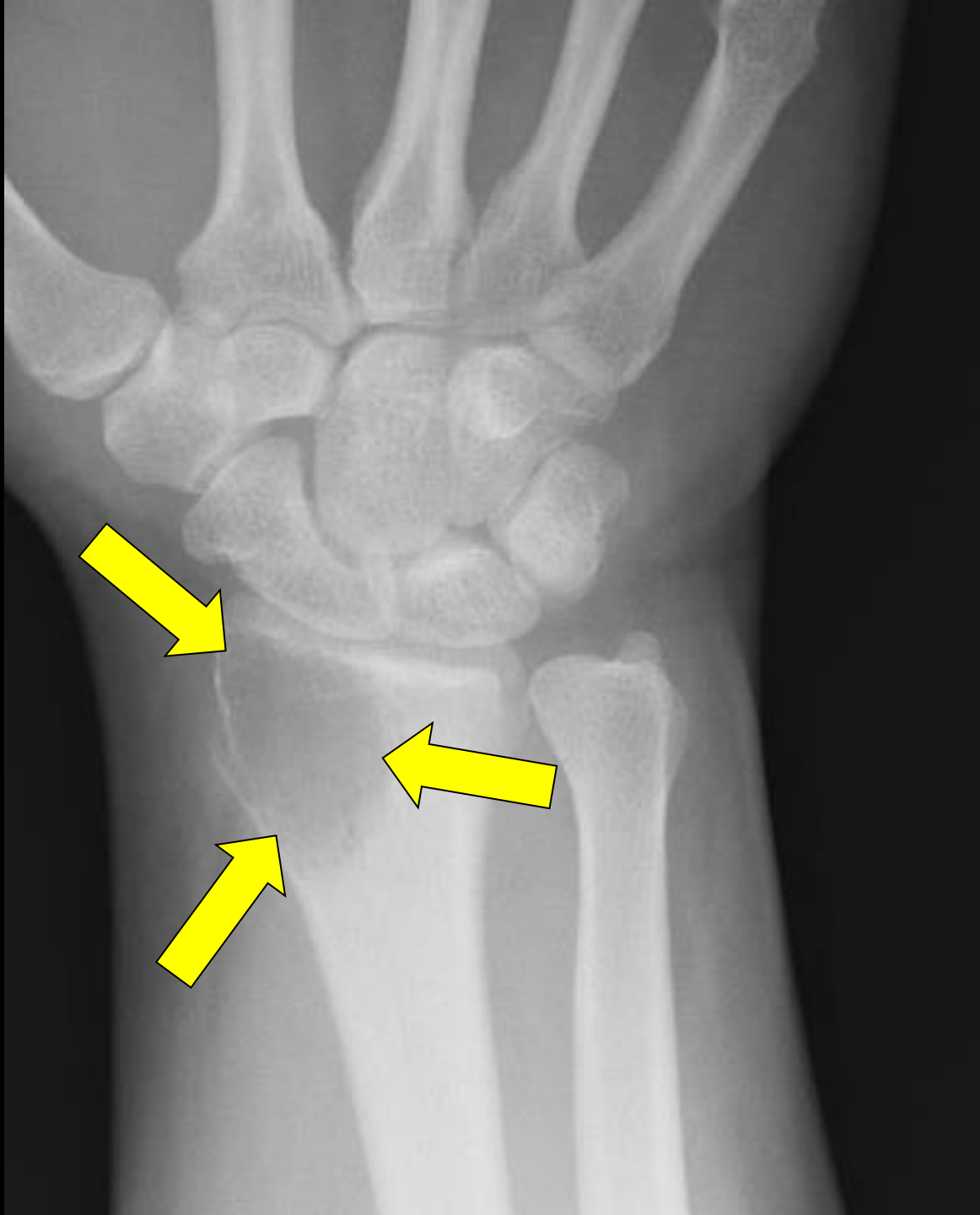
Geographic
Well-defined
No sclerosis

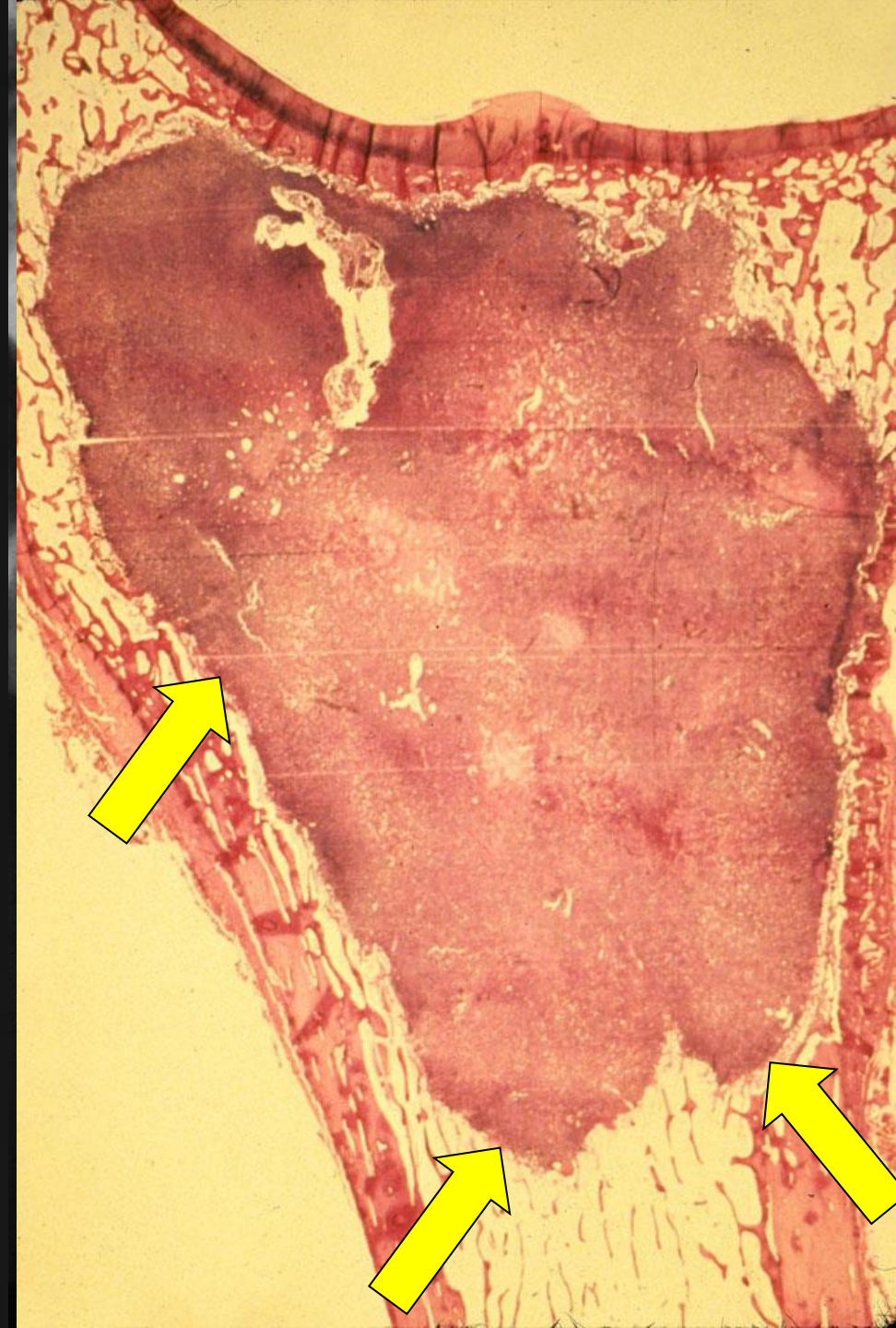


GEOGRAPHIC IB: DIFFERENTIAL DIAGNOSIS

- Giant cell tumor
- Bone cyst
- Cartilage lesions
 - Chondroblastoma
 - Chondromyxoid fibroma
 - Enchondroma
- Fibrous dysplasia
- Myeloma/metastasis













1C MARGIN

GEOGRAPHIC
ILL-DEFINED

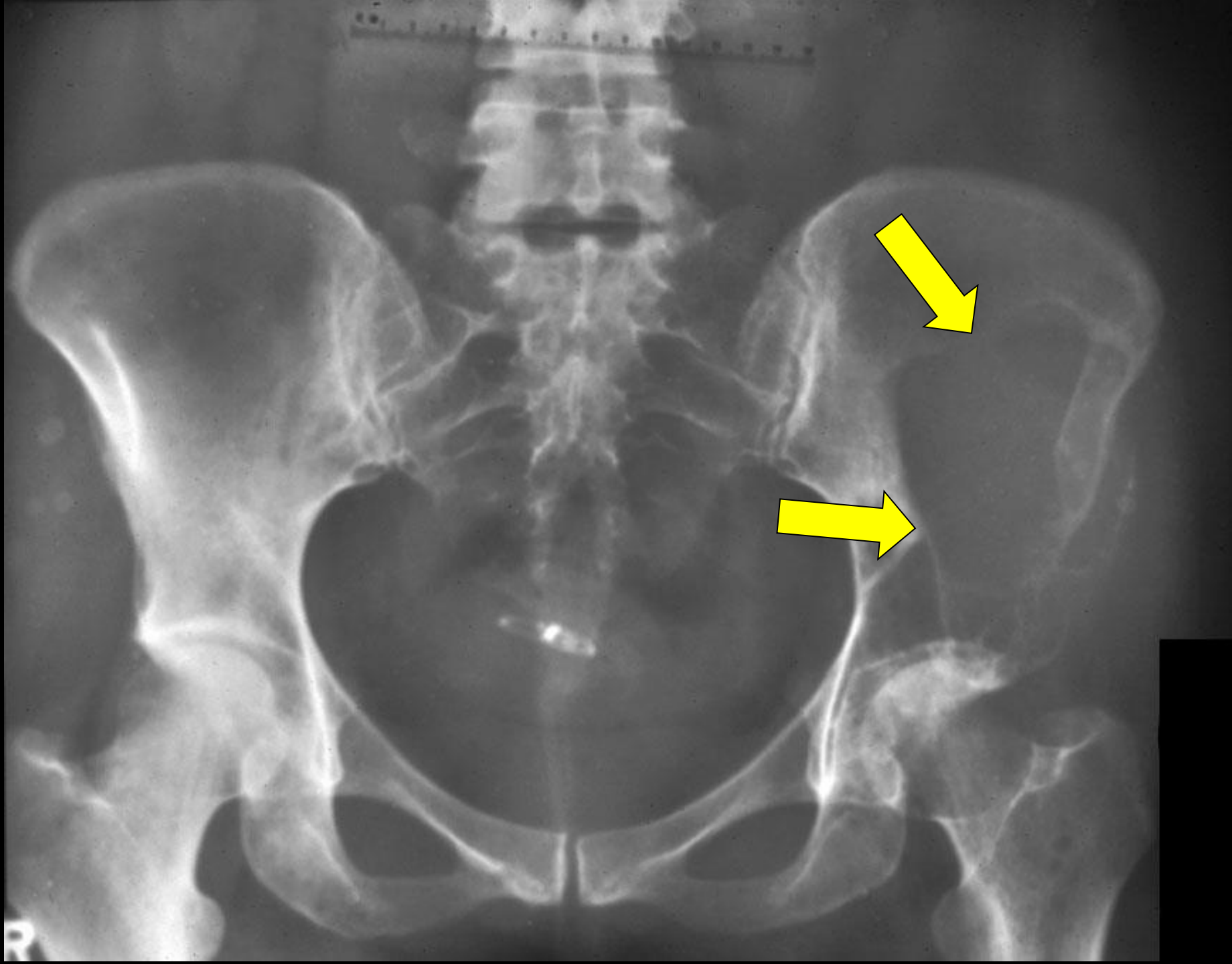


GEOGRAPHIC IC: DIFFERENTIAL DIAGNOSIS

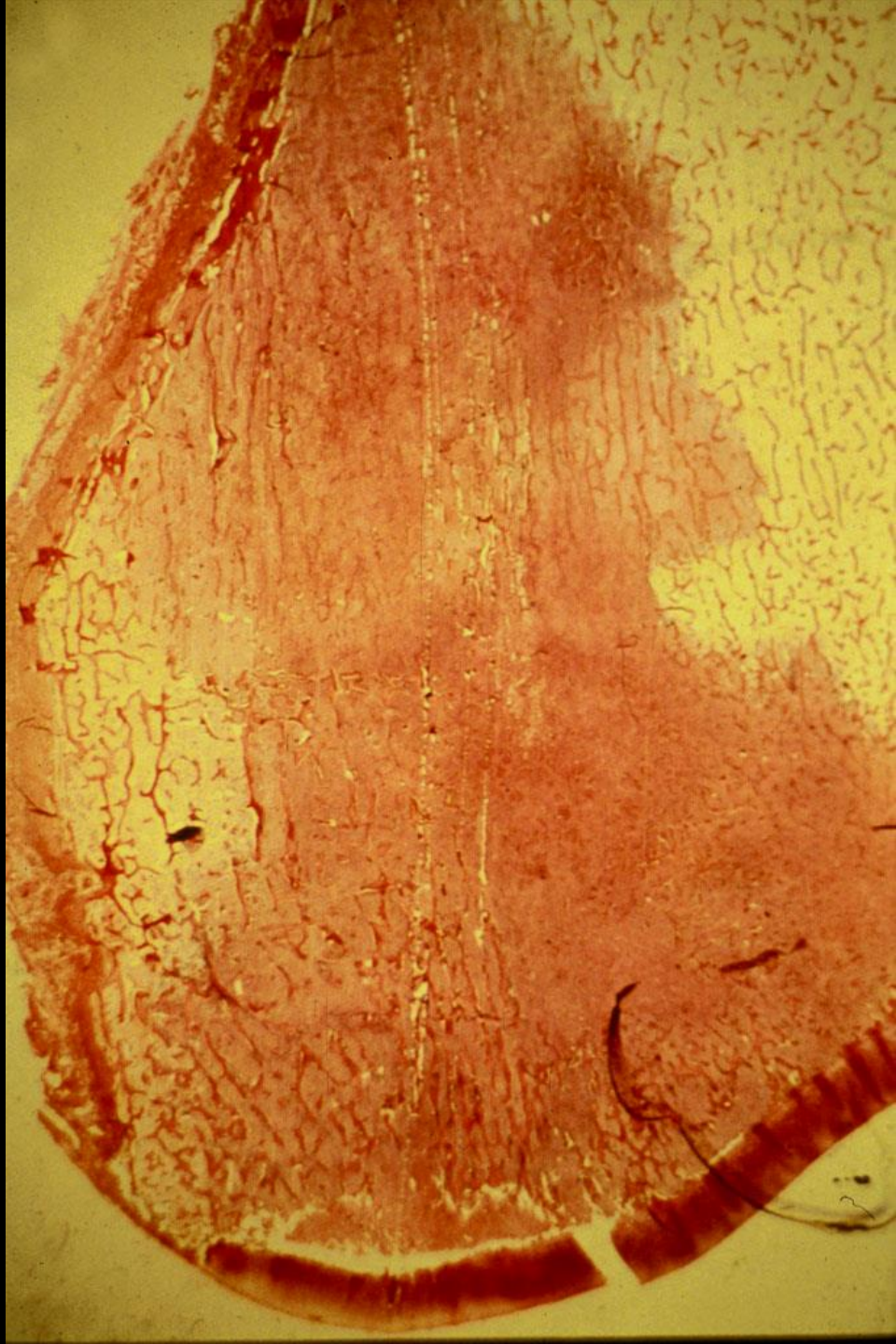
- Chondrosarcoma
- UPS (MFH)/Fibrosarcoma
- Giant cell tumor/ABC/CMF
- Osteosarcoma
- Metastasis/Myeloma/Lymphoma

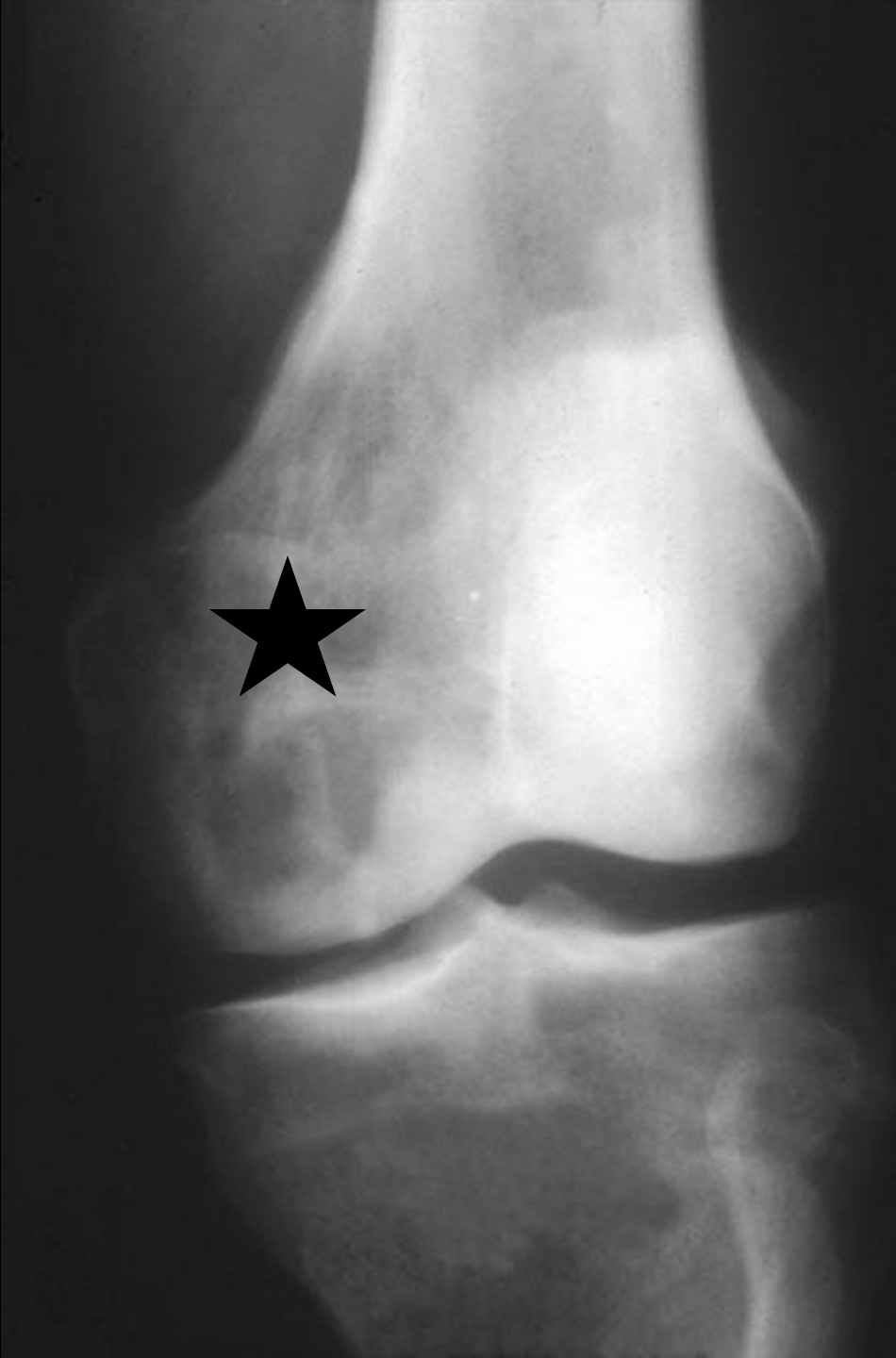


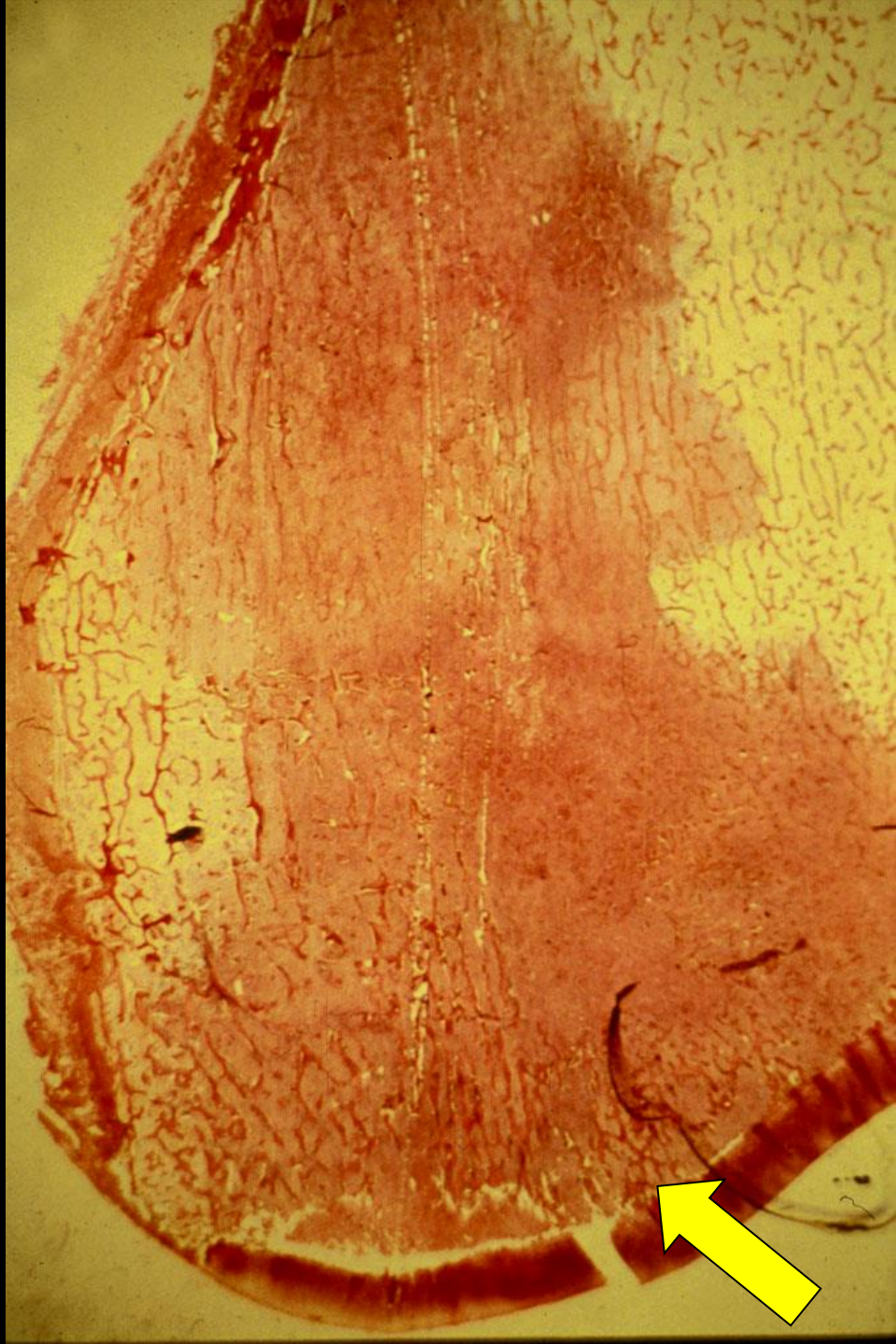
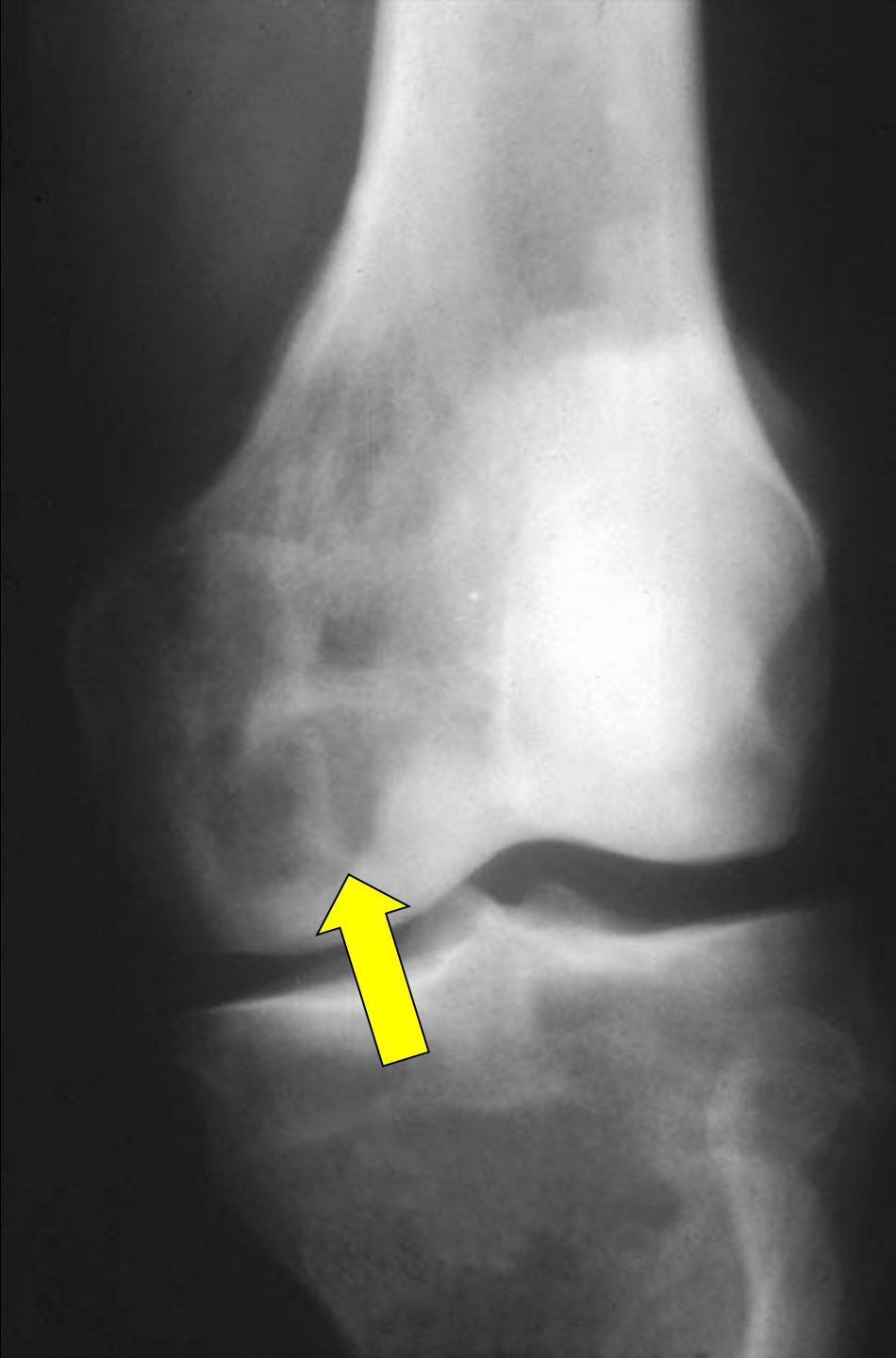


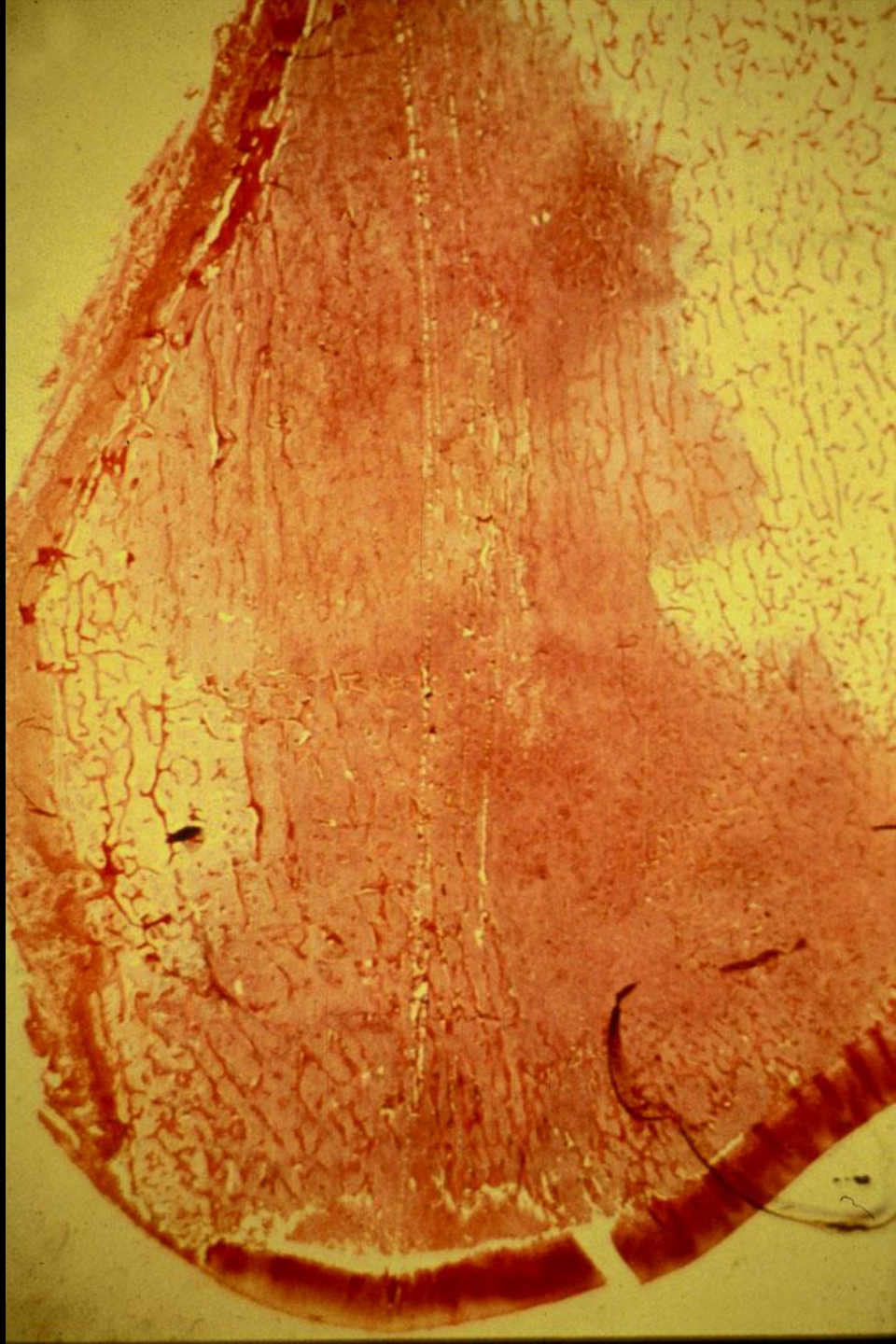
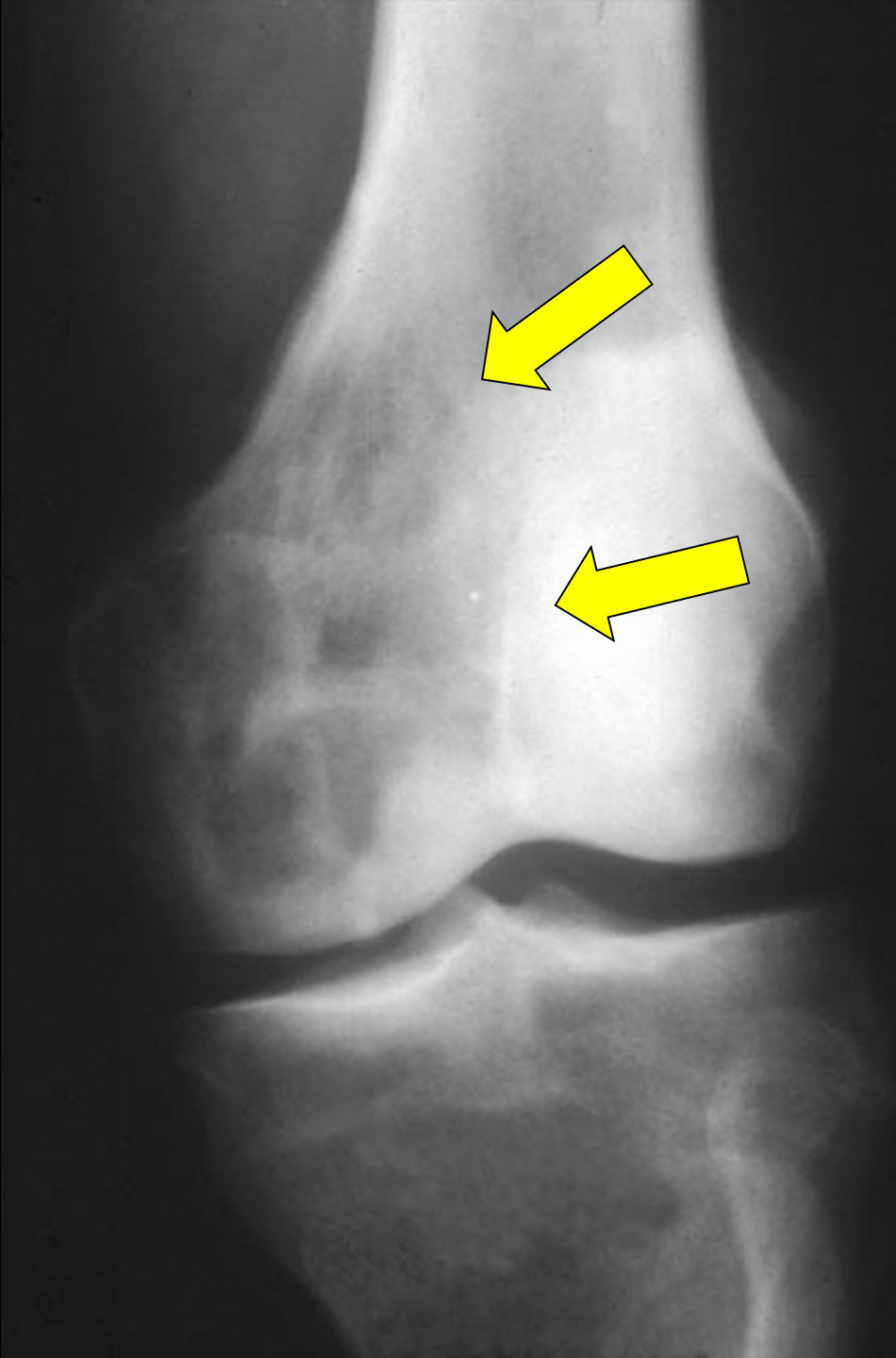


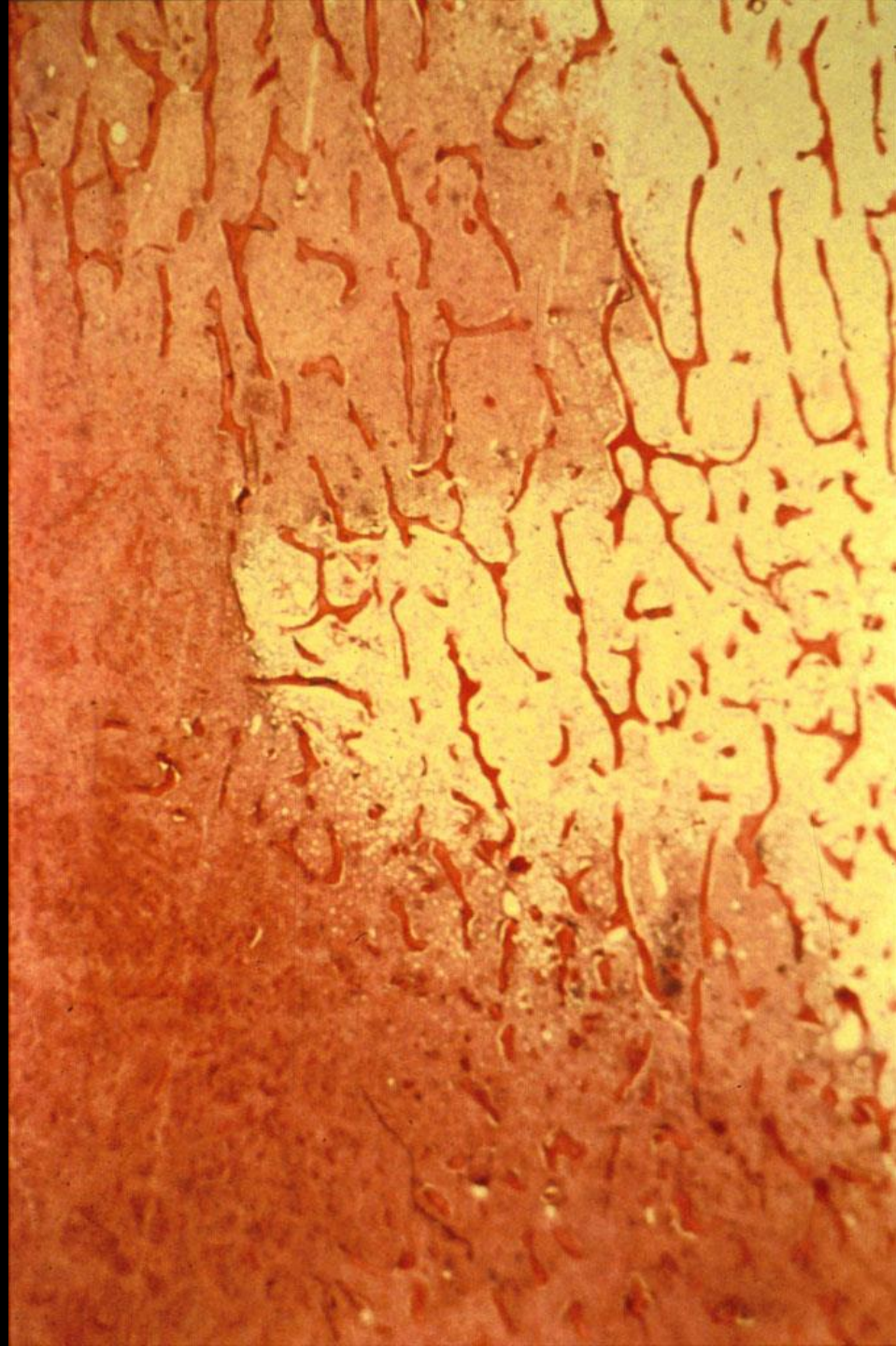




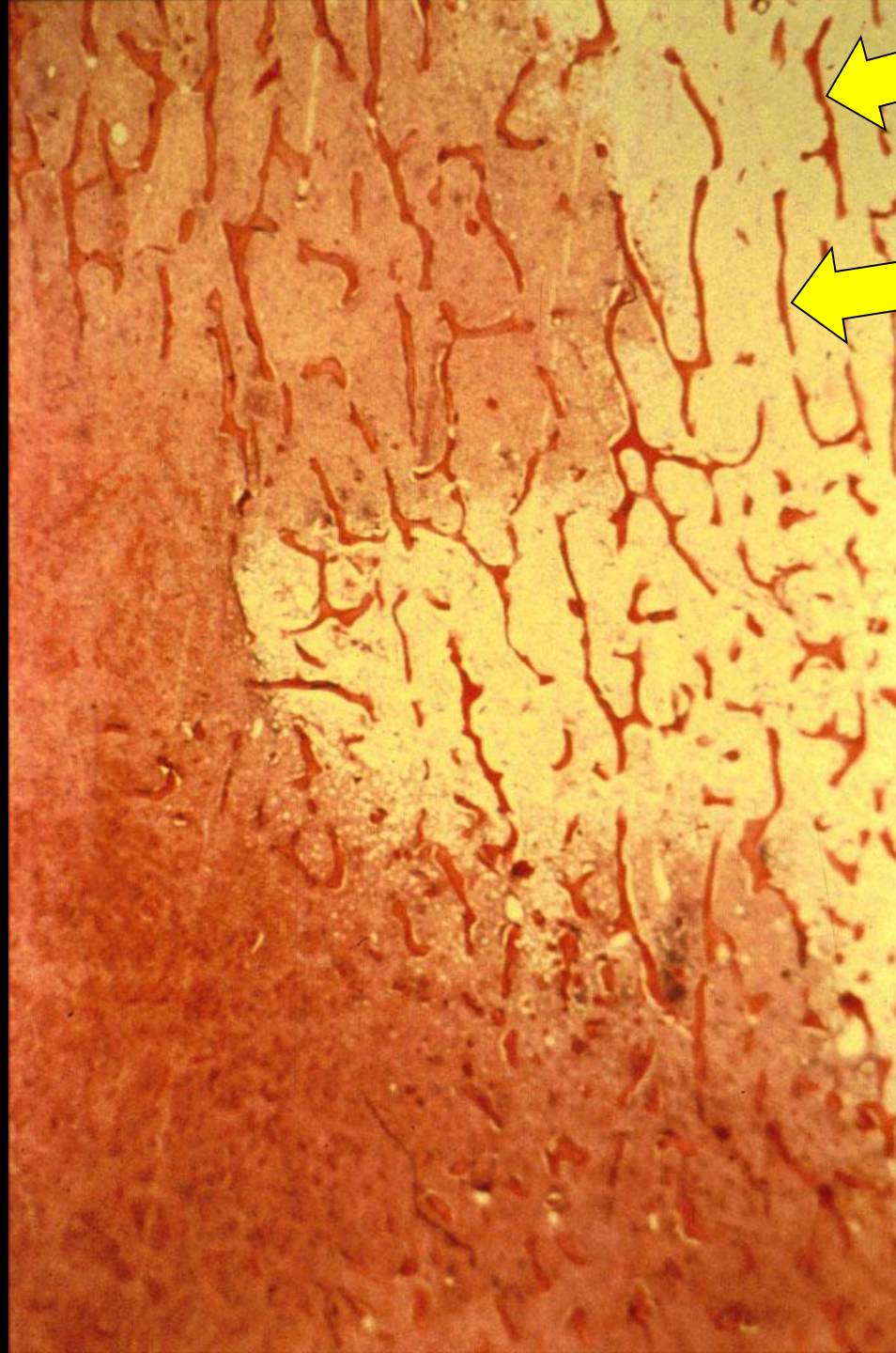










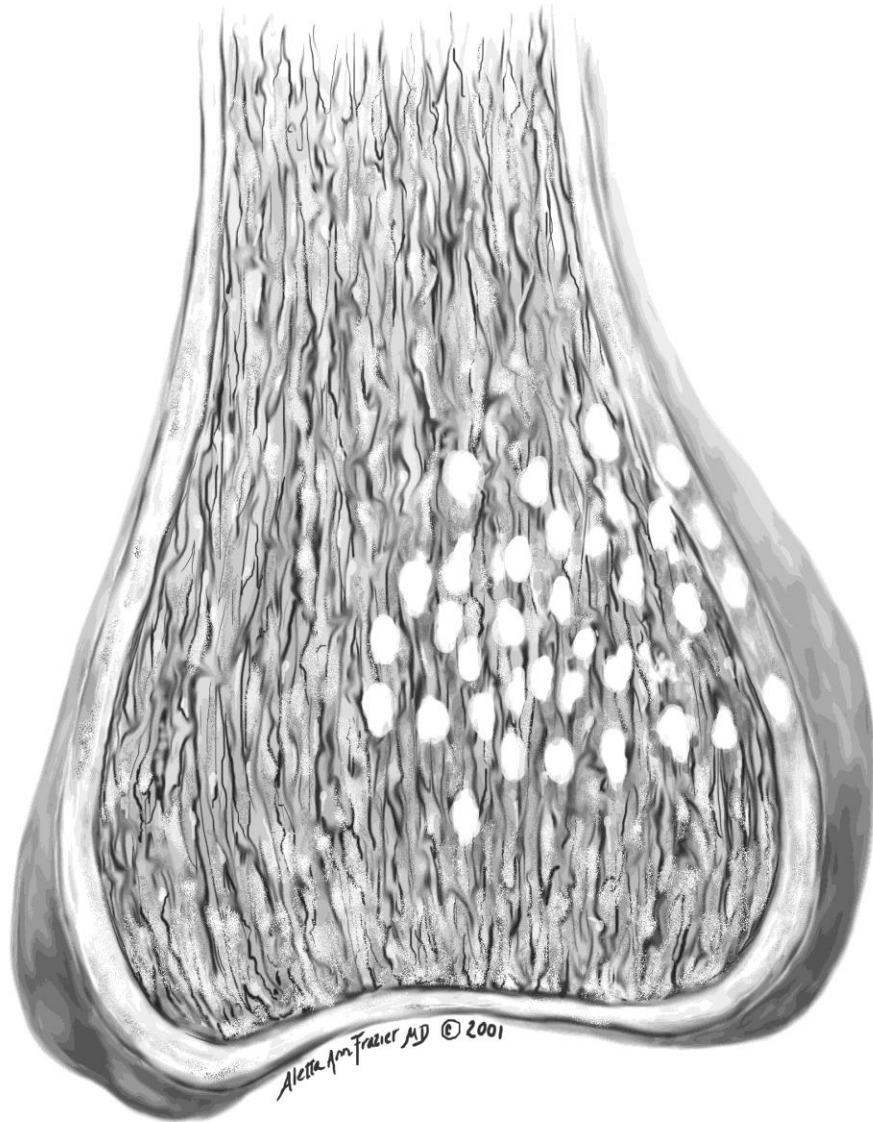




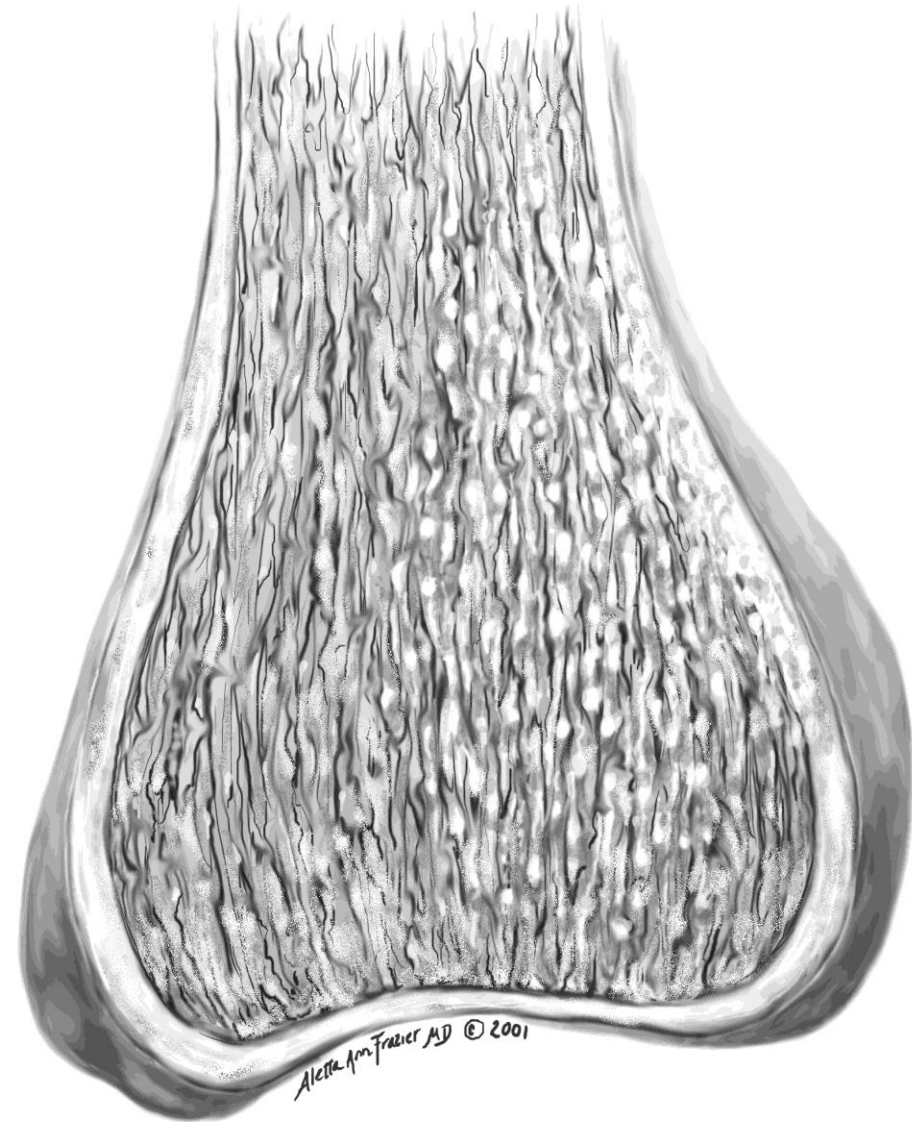




Motheaten



Permeative



TUMOR MARGIN

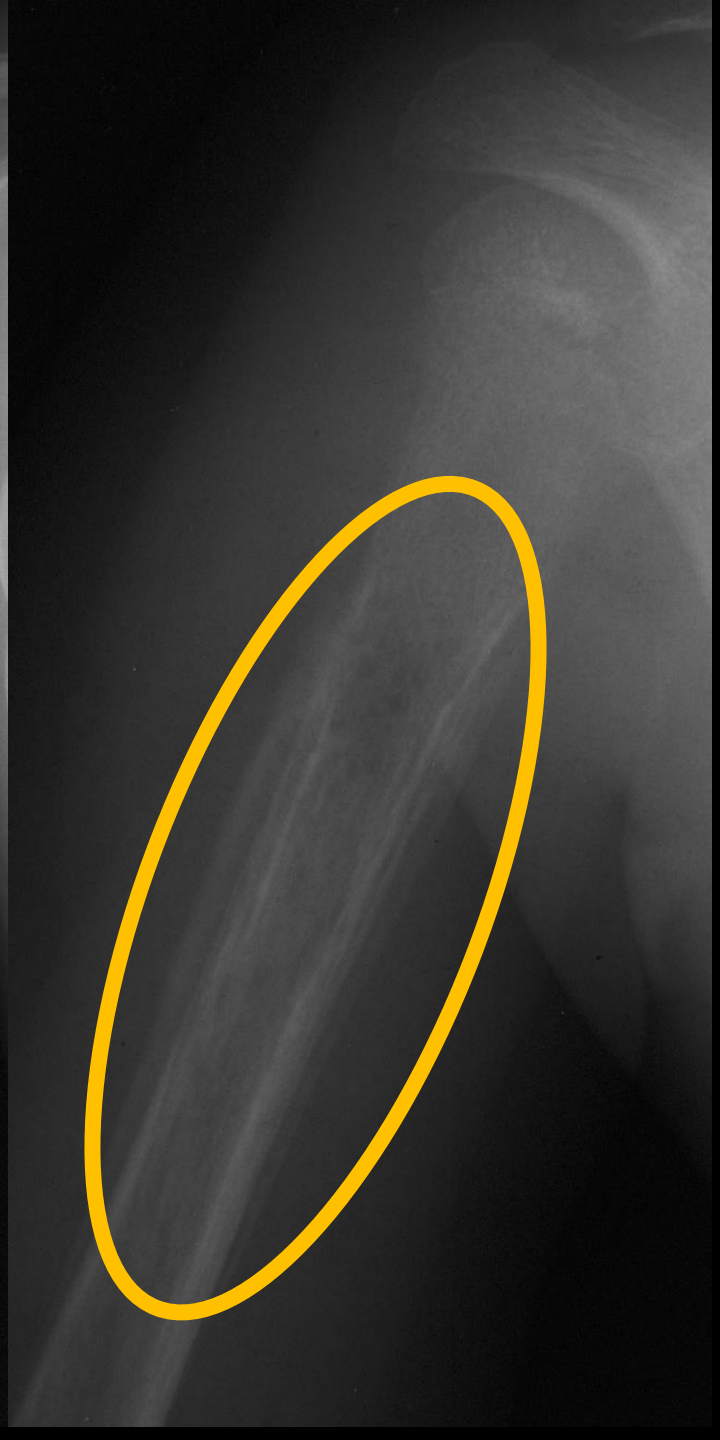
PERMEATIVE



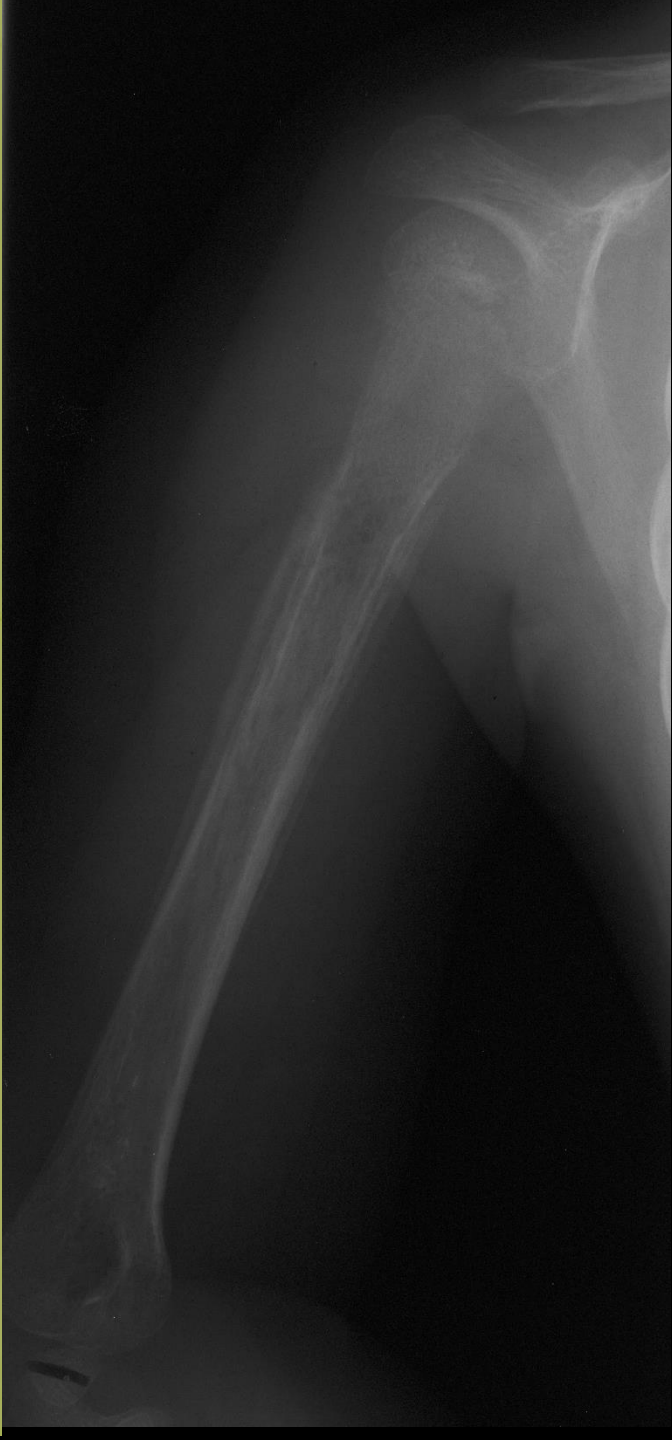
MOTHEATEN AND PERMEATIVE BONE DESTRUCTION: DIFFERENTIAL DIAGNOSIS

- Langerhans cell histiocytosis
- Acute bacterial osteomyelitis
- Metabolic disorders
- Small round cell tumors (Ewing, lymphoma, leukemia)
- Osteosarcoma
- Chondrosarcoma
- UPS (MFH)/fibrosarcoma
- Multiple myeloma





647



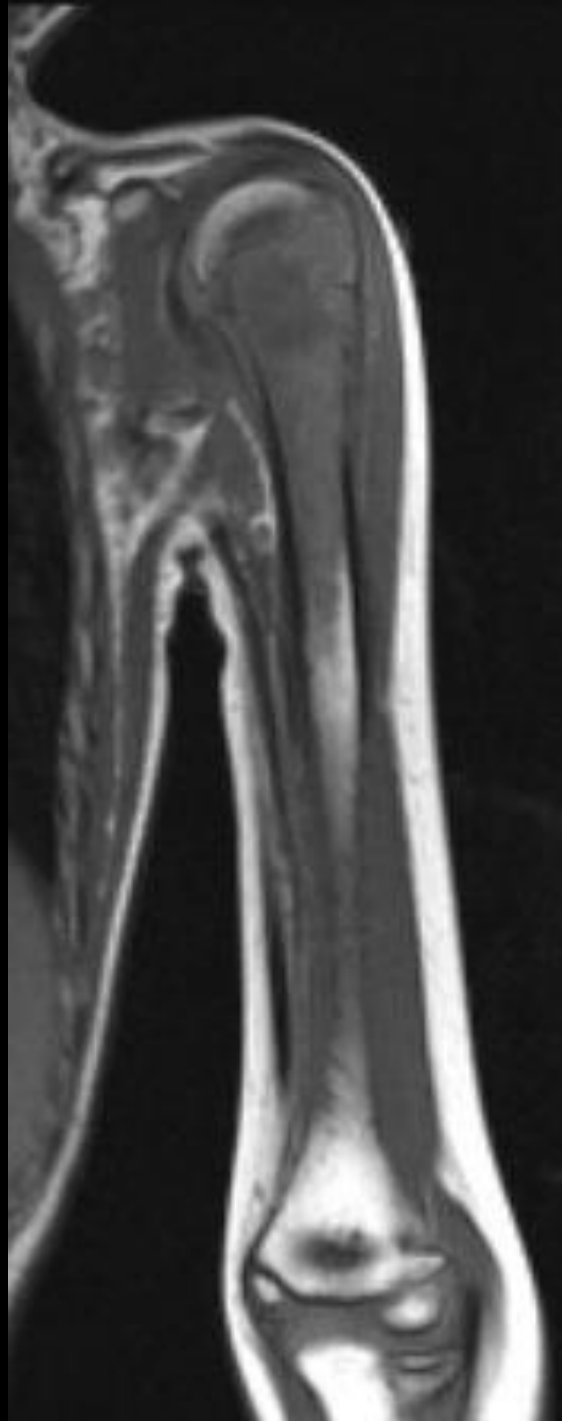








T1



T2



IA IB IC II III

Lytic Patterns

← Round Cell →

← Chondrosarcoma →

← Enchon →

← CMF →

← Fibrosarcoma/MFH →

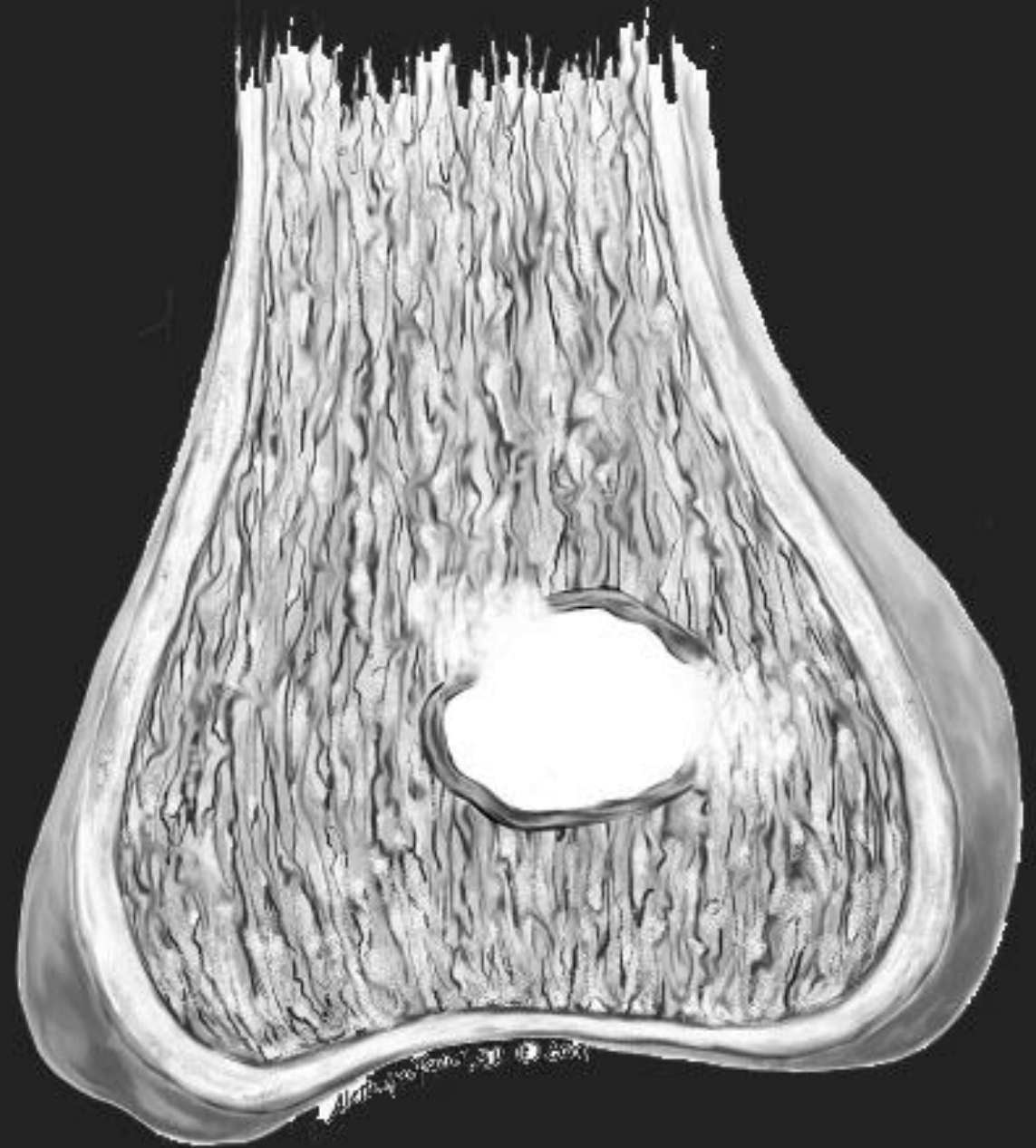
← NOF →

← Osteosarcoma →

← GCT →

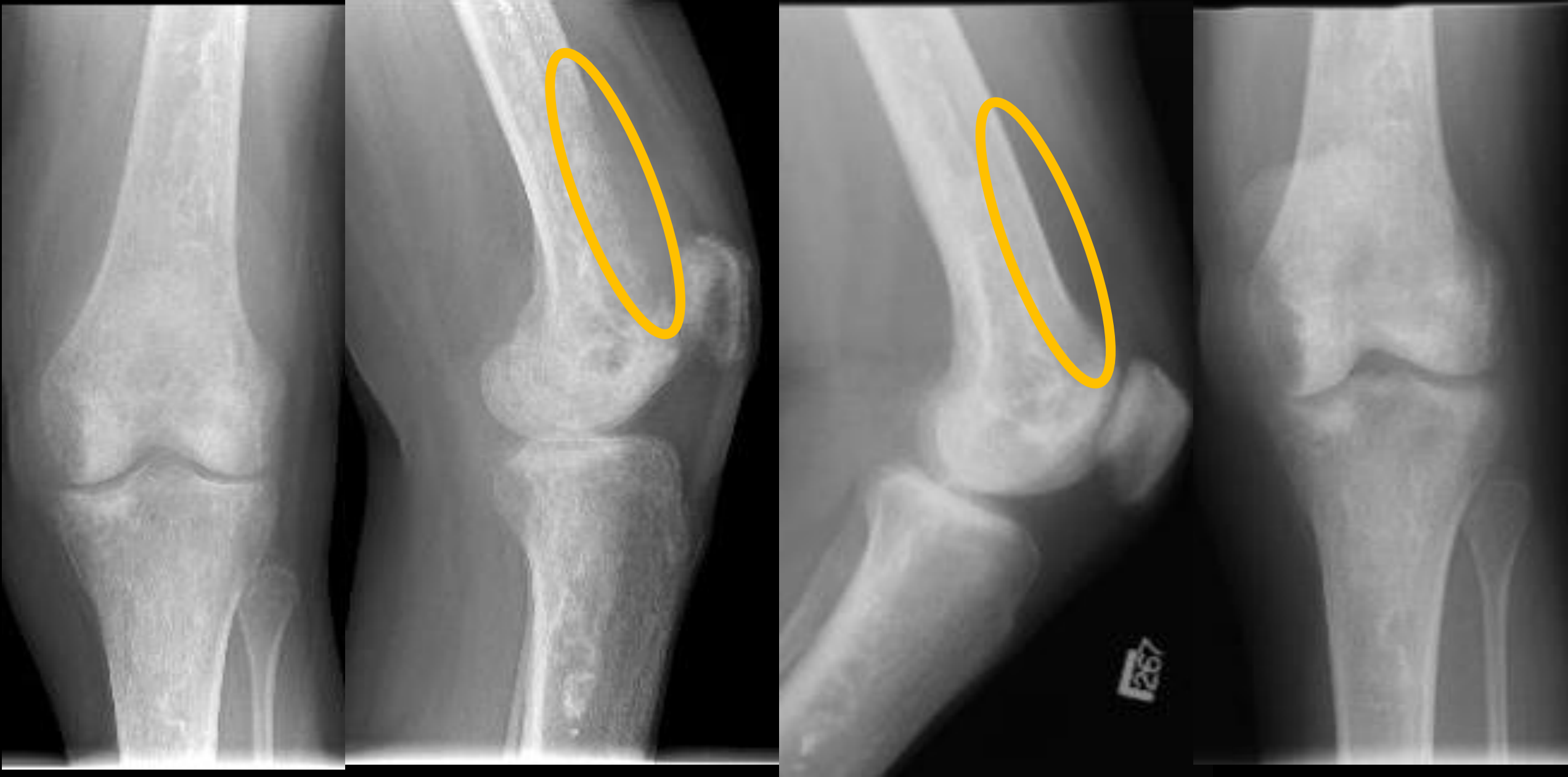
Changing Margin

Increased
Biologic
Activity



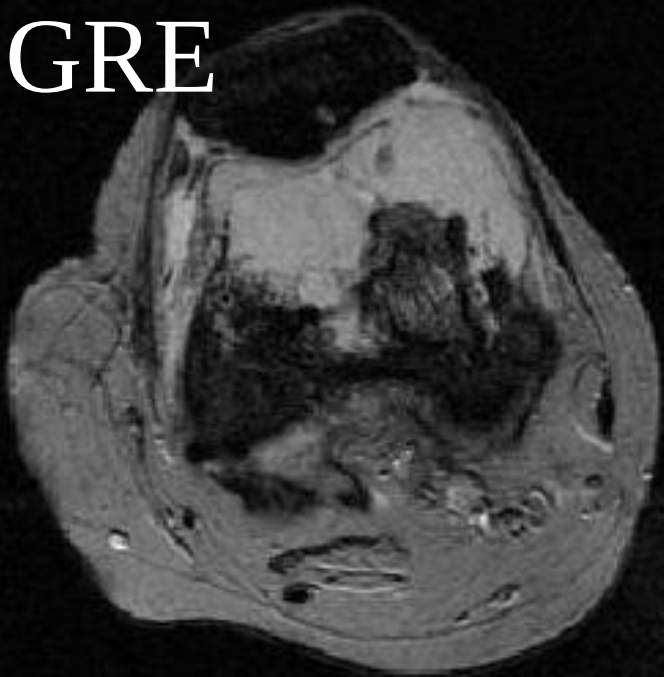


One year earlier



One year earlier

GRE



PD



PD



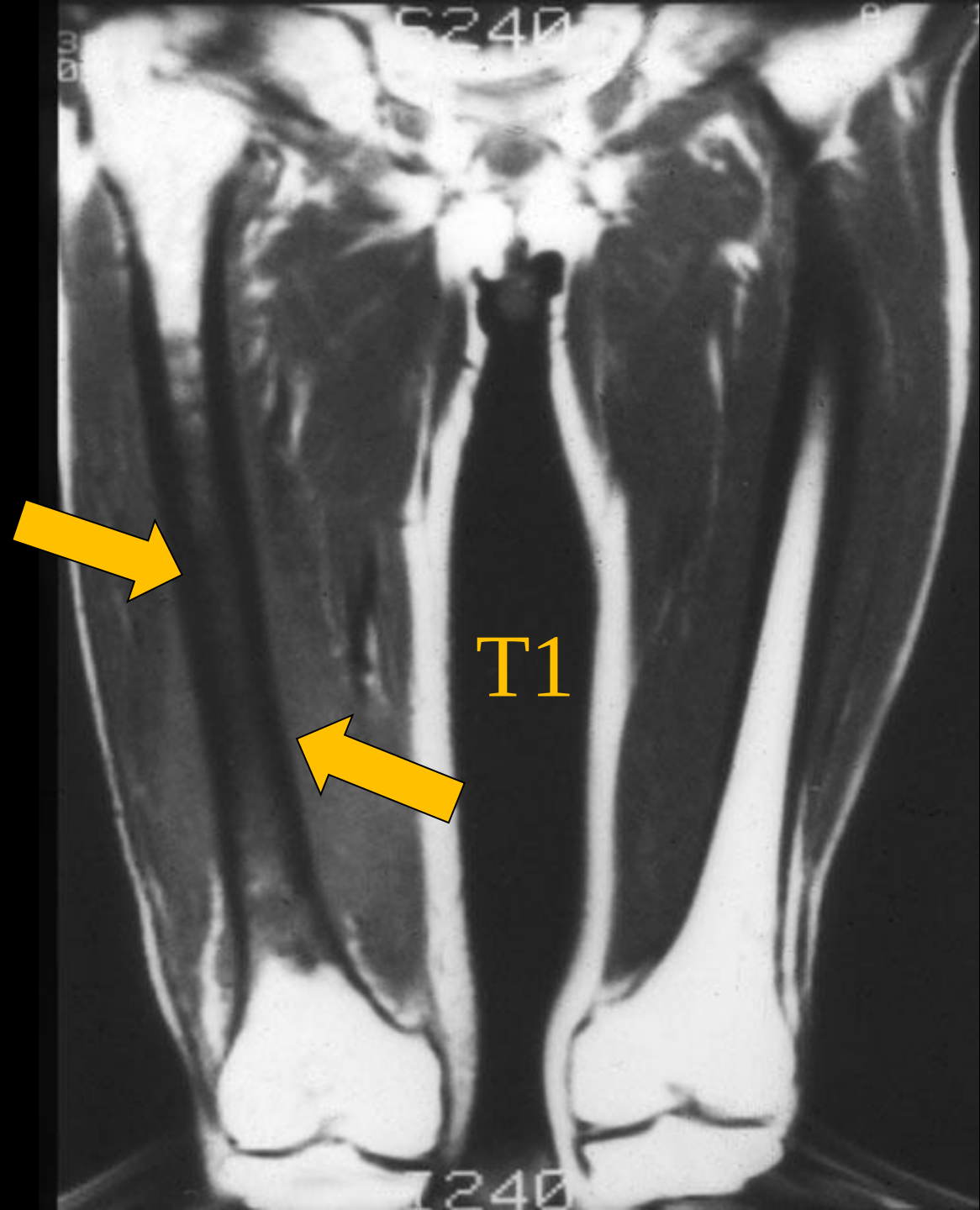
STIR



“INVISIBLE MARGIN”











SOLITARY BONE LESION ANALYSIS

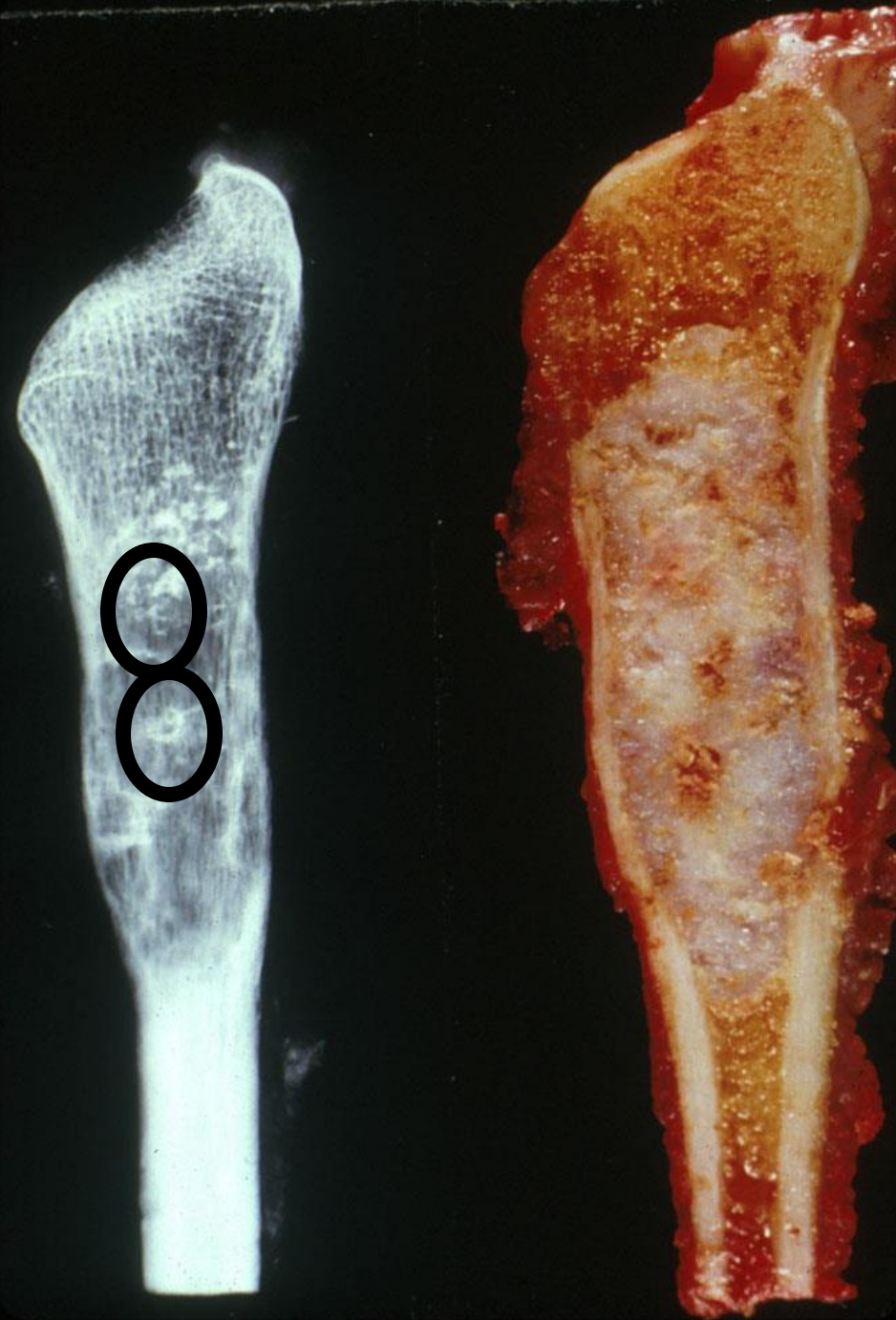
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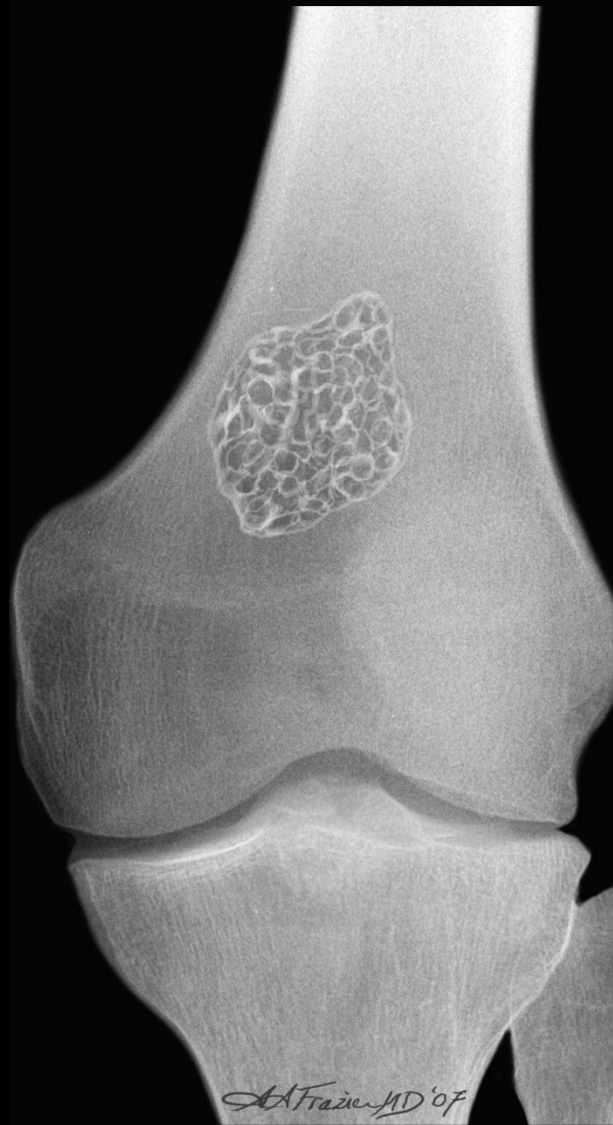
SOLITARY BONE LESIONS WITH PROMINENT SCLEROSIS

ALWAYS DUE TO MINERALIZED MATRIX WHEN WITHIN
THE LESION!

- Radiographs usually adequate
- CT best modality if subtle or complex anatomy







RINGS/ARCS



FLOCCULENT



STIPPLED

CHONDROID MATRIX

MINERALIZED MATRIX

- Chondroid - rings, arcs, honeycomb
 - Enchondroma, chondroblastoma, CMF, osteochondroma, chondrosarcoma
 - Osteonecrosis may simulate chondroid matrix (look for serpentine calcific rim)

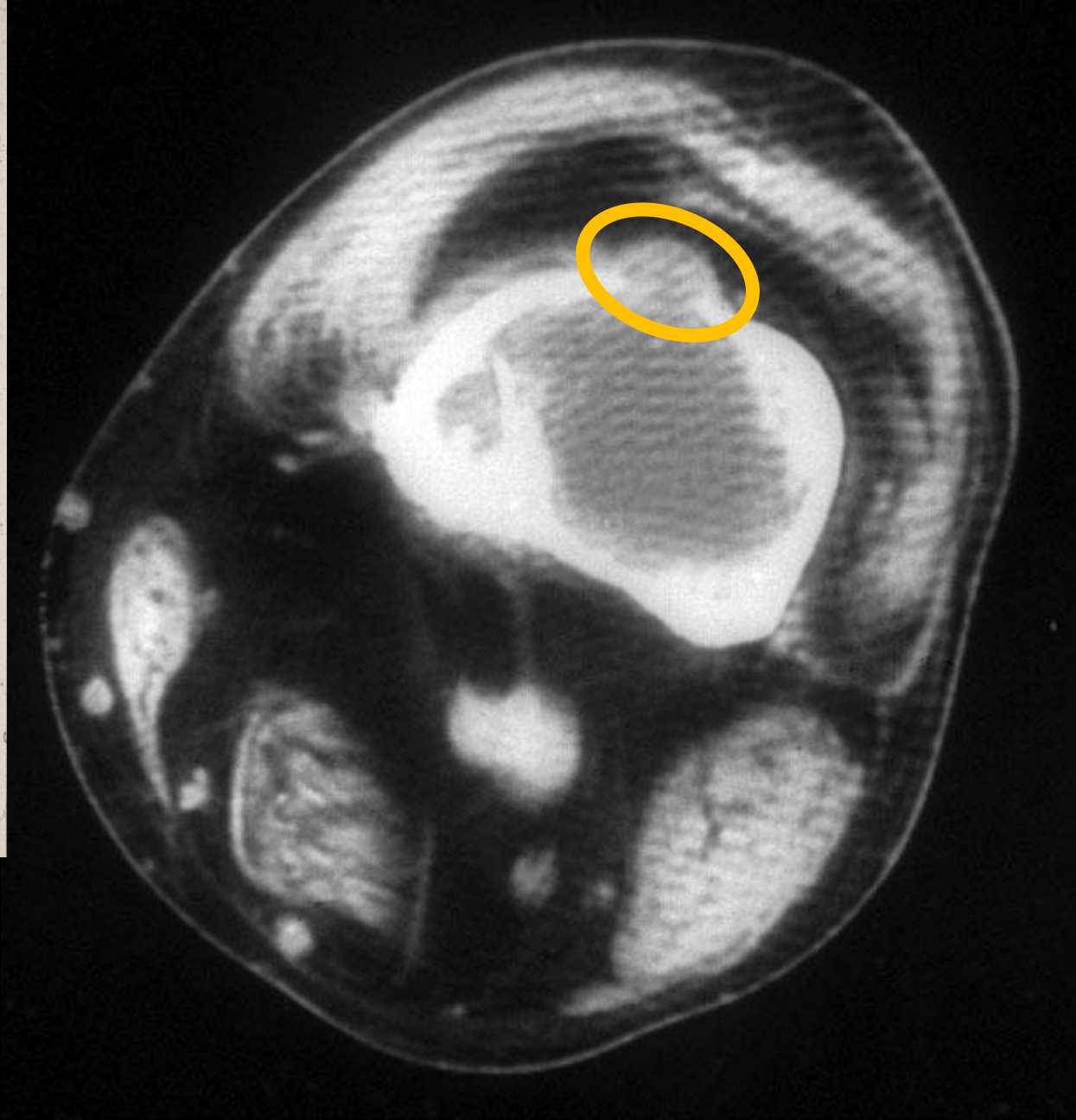




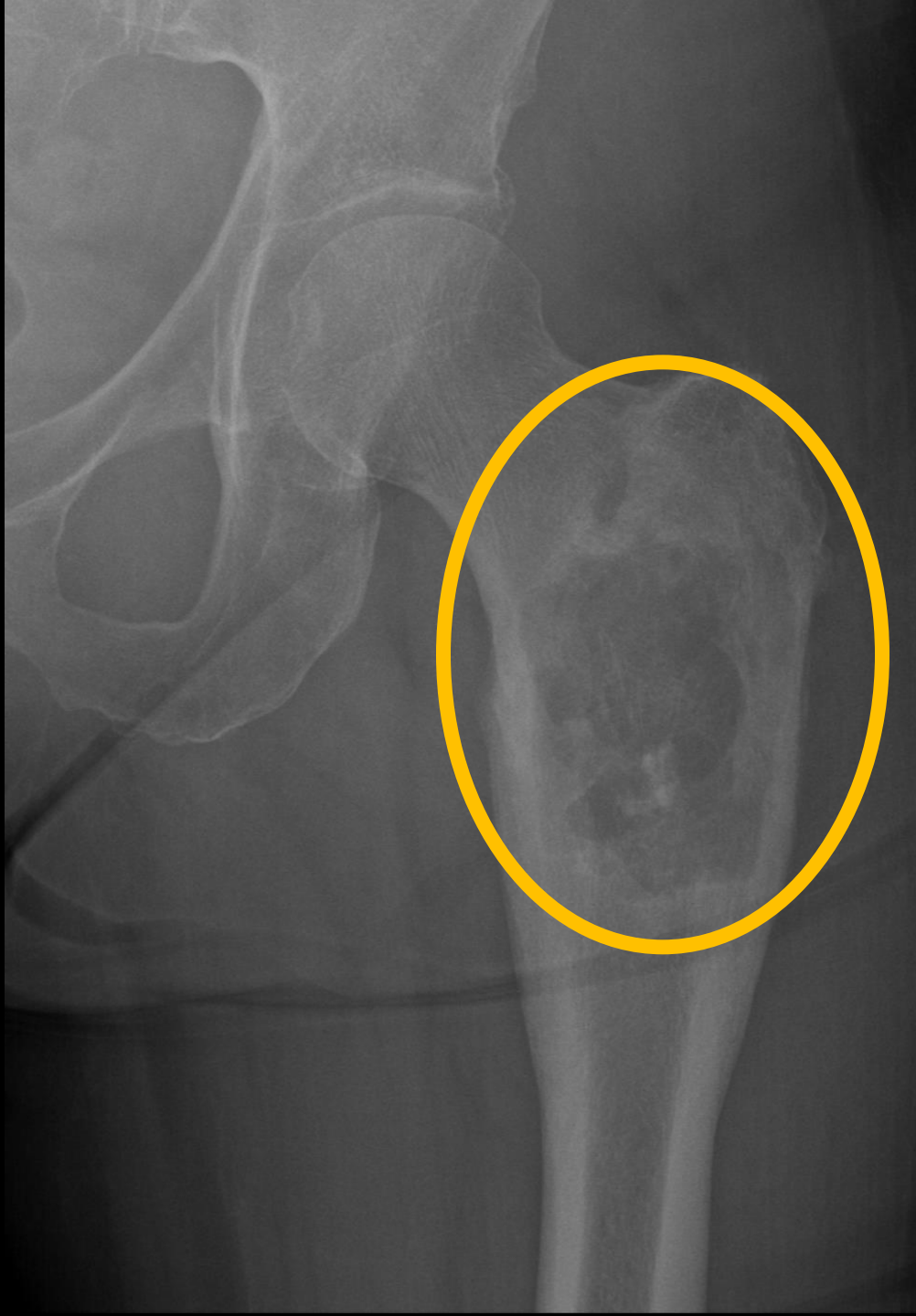


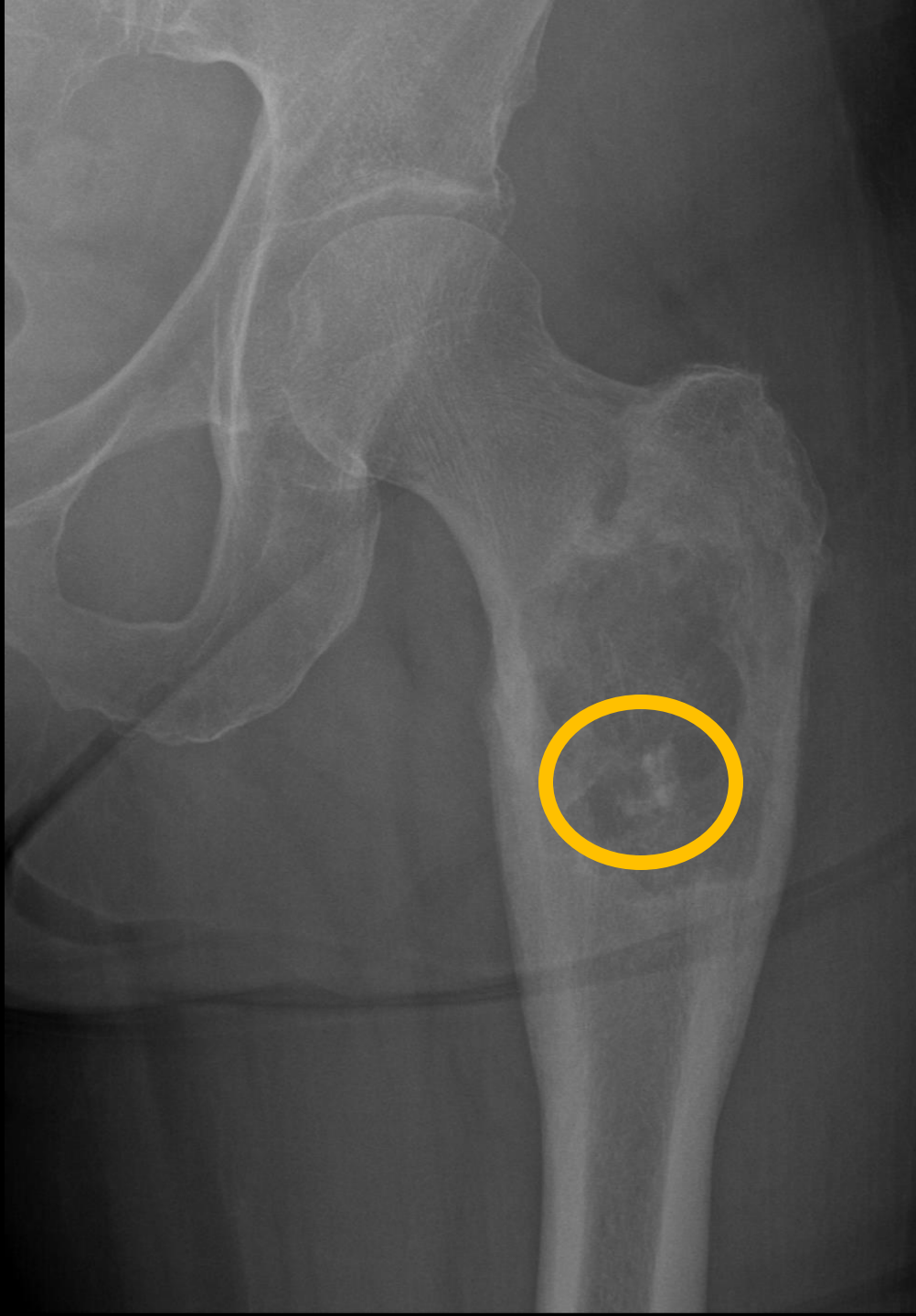


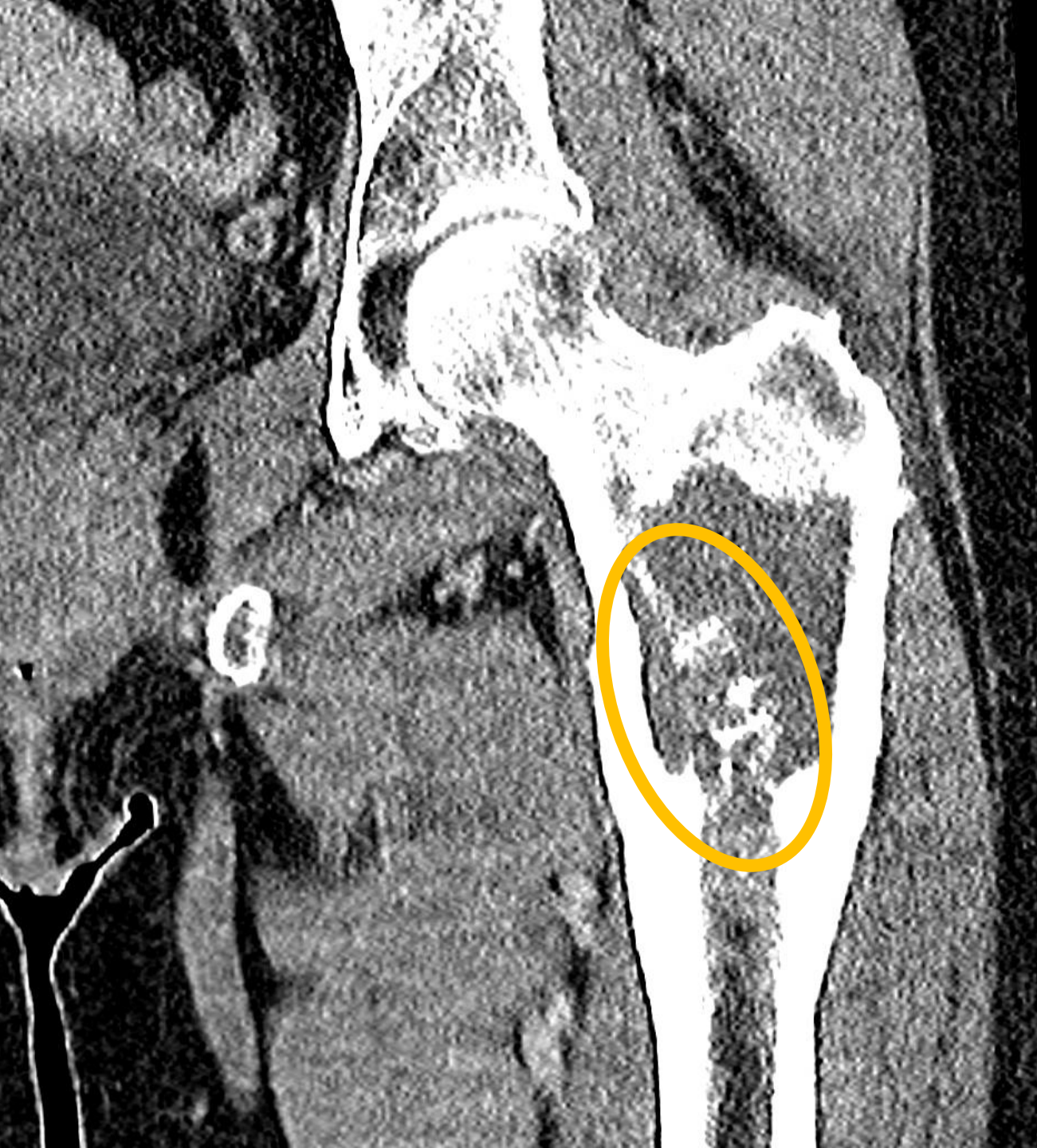


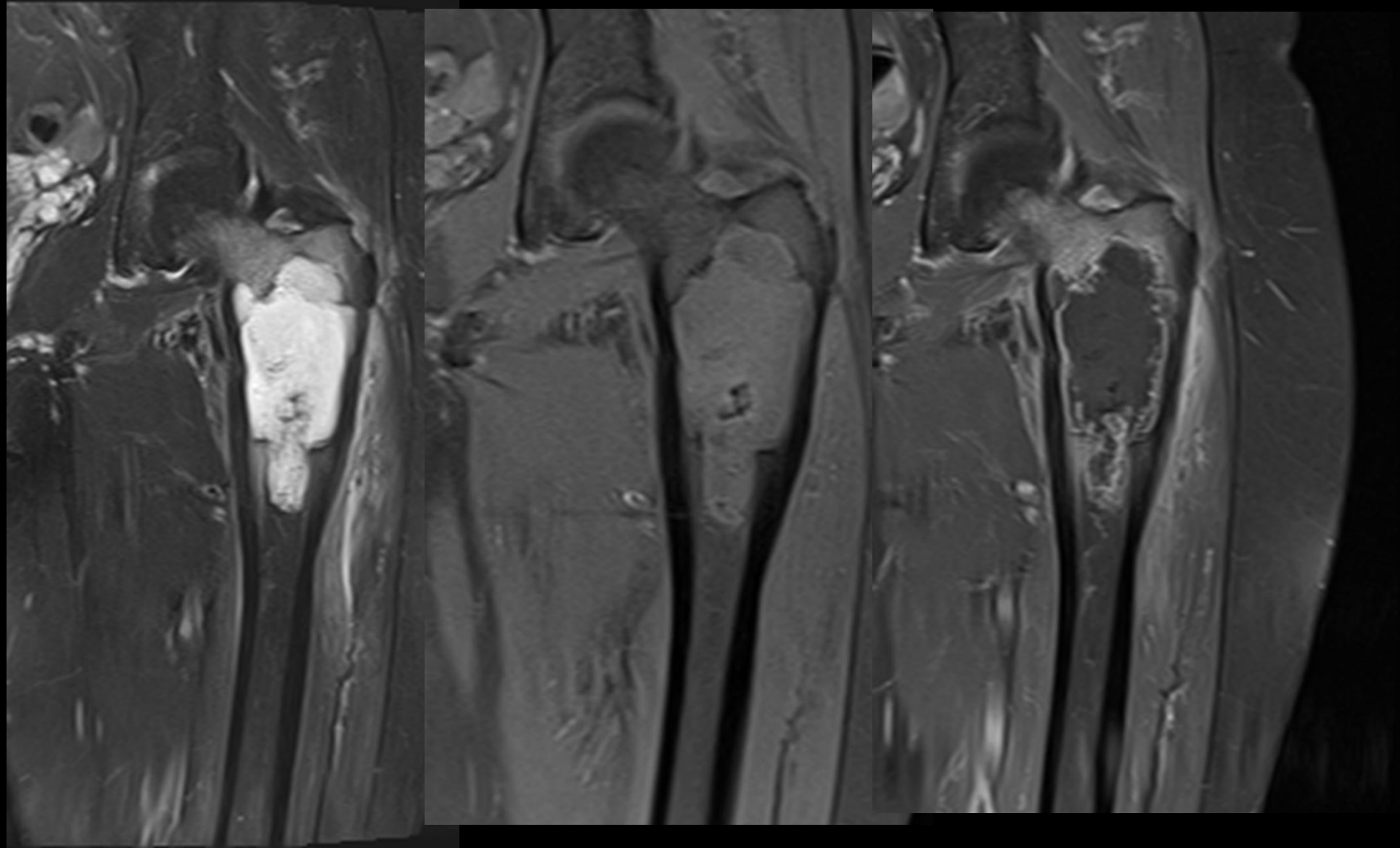




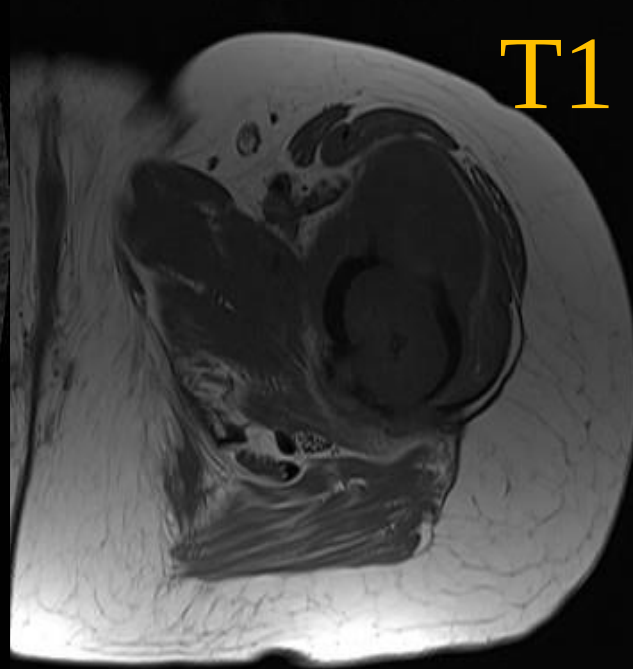
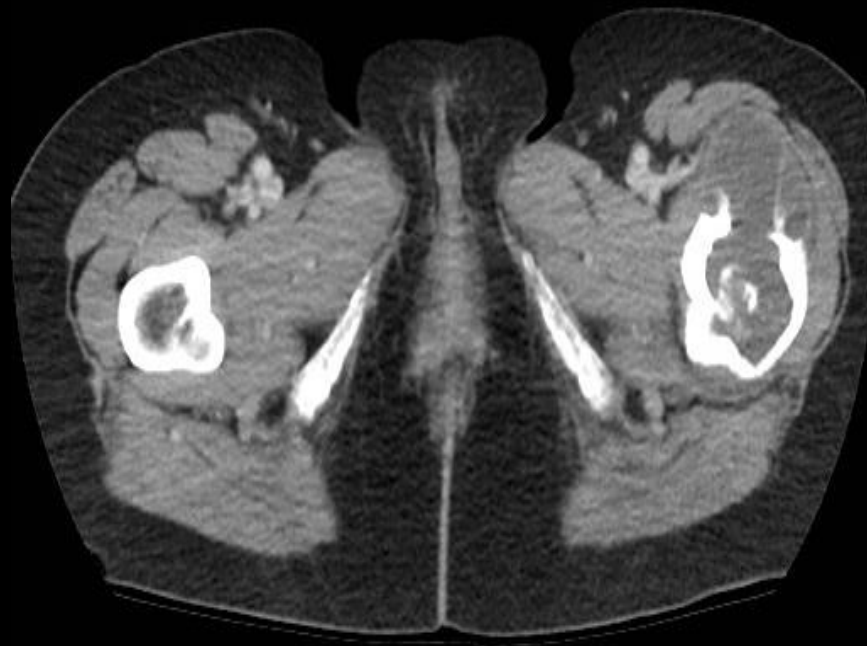




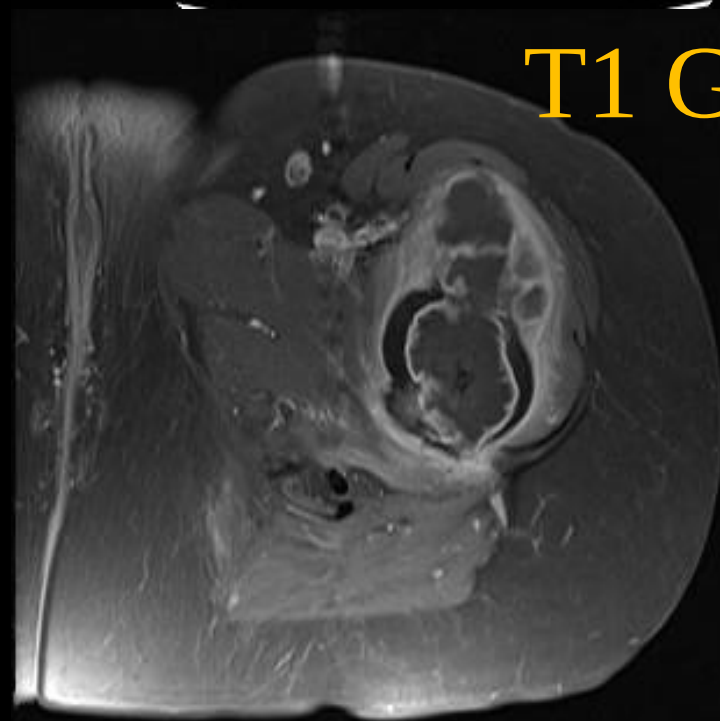




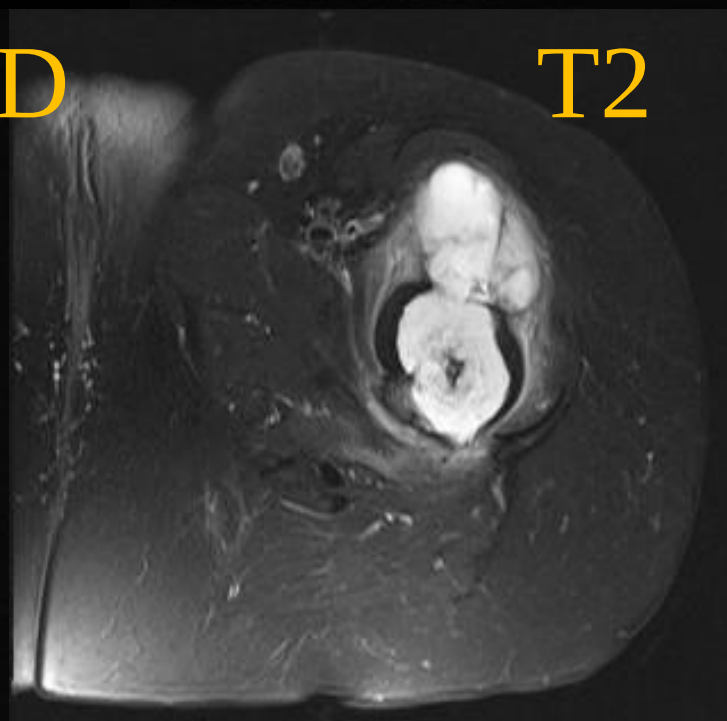
Coronal T2 FS, Coronal T1 pre and post



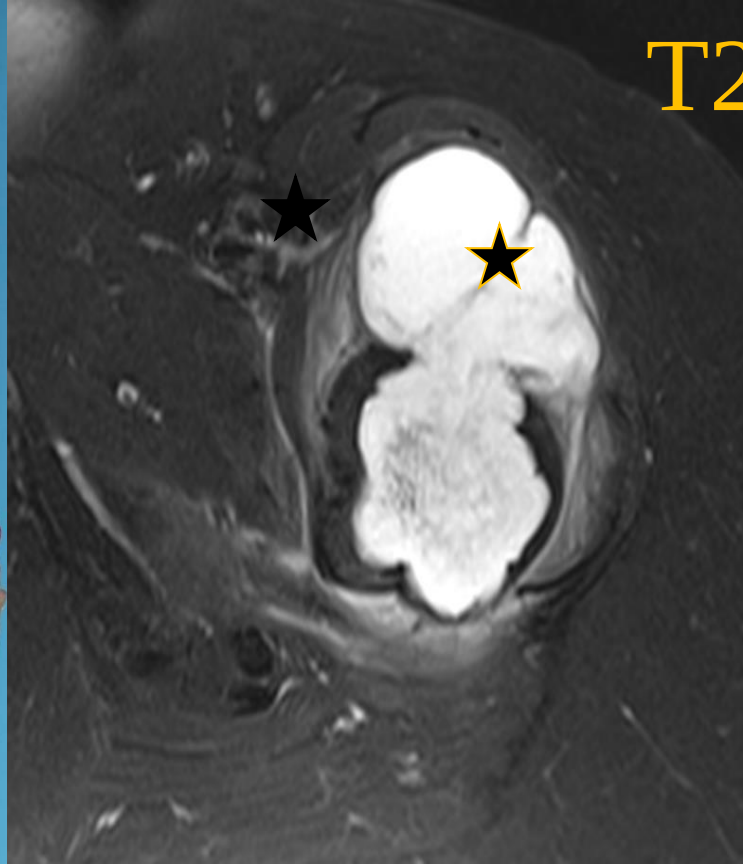
T1



T1 GD



T2



T2

T2 FS and matched gross photograph

MINERALIZED MATRIX

- **Osteoid** - ivory/cloud-like
 - **Neoplastic**: Enostosis, osteoma
osteoid osteoma, osteochondroma, osteoblastoma, osteosarcoma
 - **Reactive**: infection (chronic), LCH, Ewing sarcoma (flat bones), lymphoma, metastases, Paget disease, fibrous dysplasia, NOF, hemangioma, mastocytosis

OSTEOID MATRIX

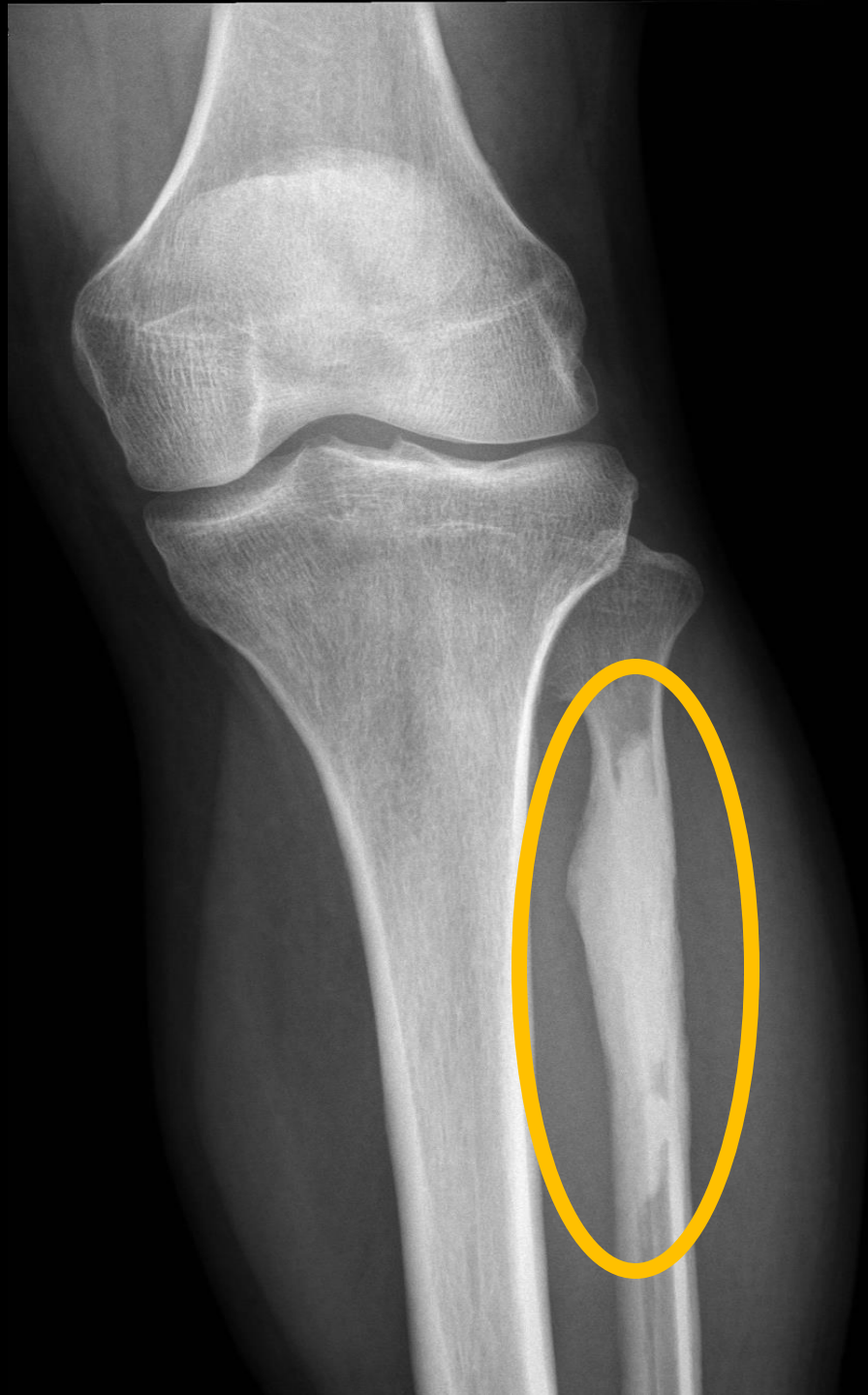


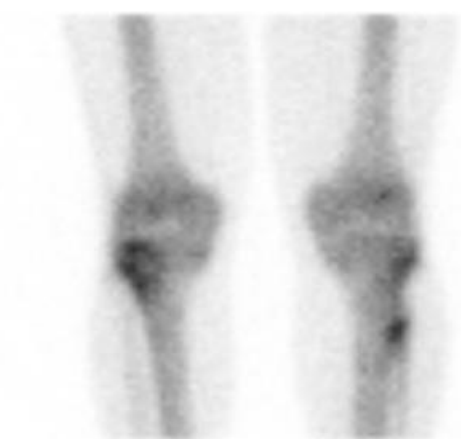
AA Frazier MD '07



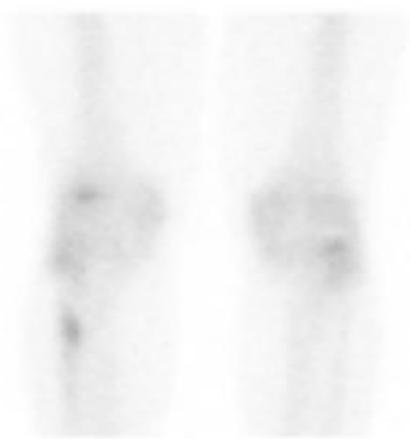
AA Frazier MD '07



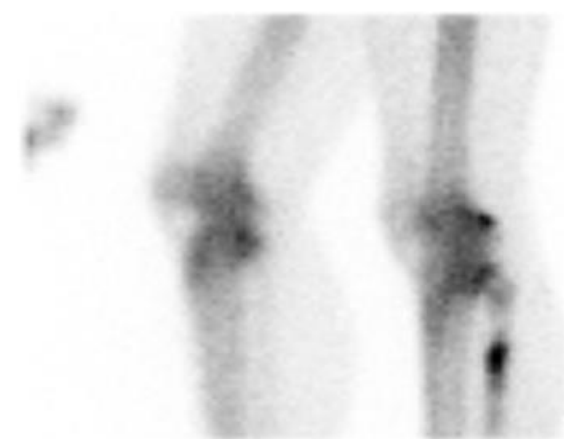




Select ☒



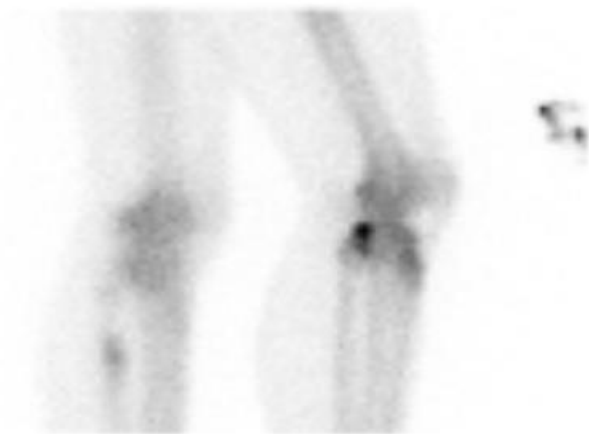
Select ☒



Select ☒

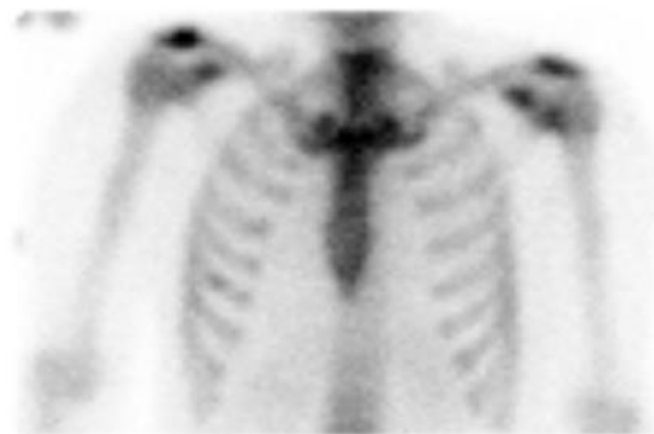
9

LT MED RT LAT



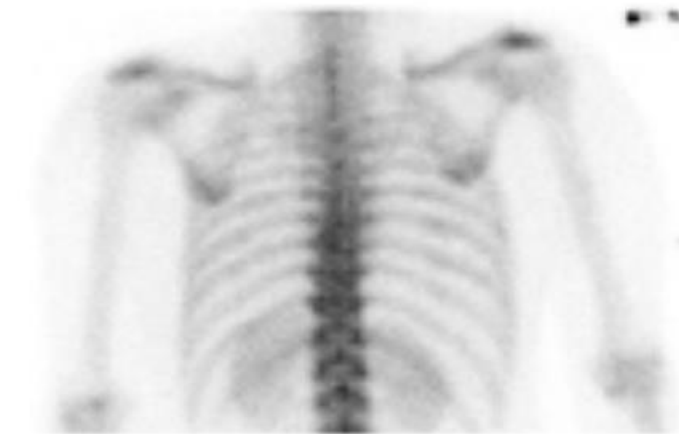
Thu Oct 12 2017 11:46:11
RT ANT LT 5
Duration: 300.00 sec

RT ANT LT



Thu Oct 12 2017 11:46:11
LT POST RT 6
Duration: 300.00 sec

LT POST RT



RT ANT LT



TC99M HDP/ SYMBIA T-6/ AG

LT POST RT



WB DELAY

125
62%

RT ANT LT



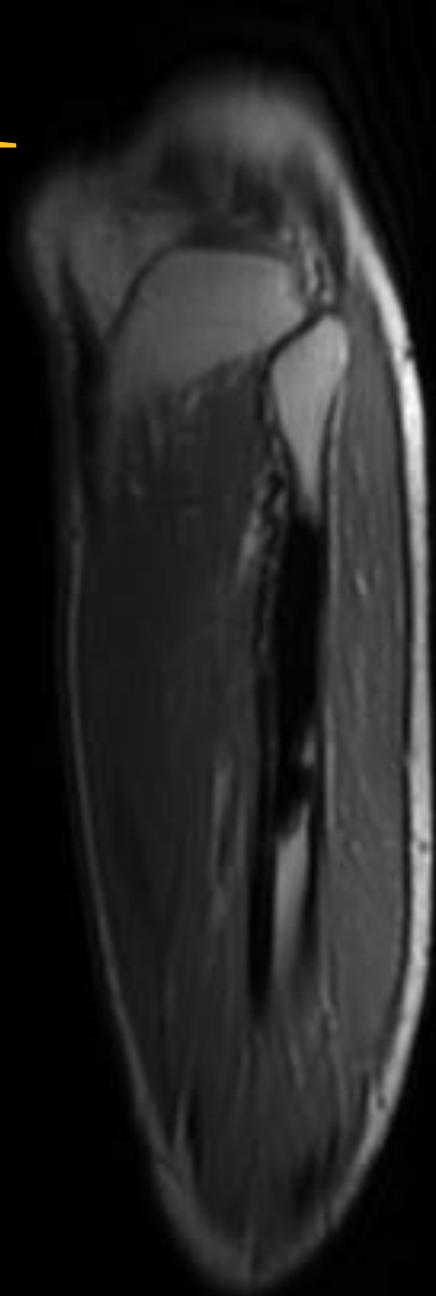
TC99M HDP/ SYMBIA T-6/ AG

LT POST RT

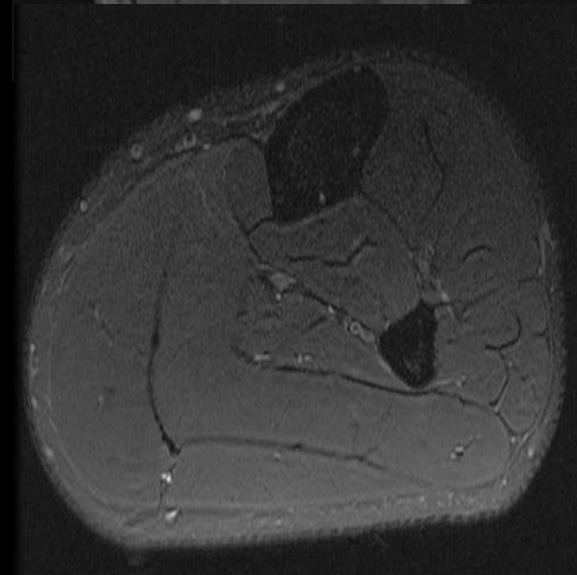
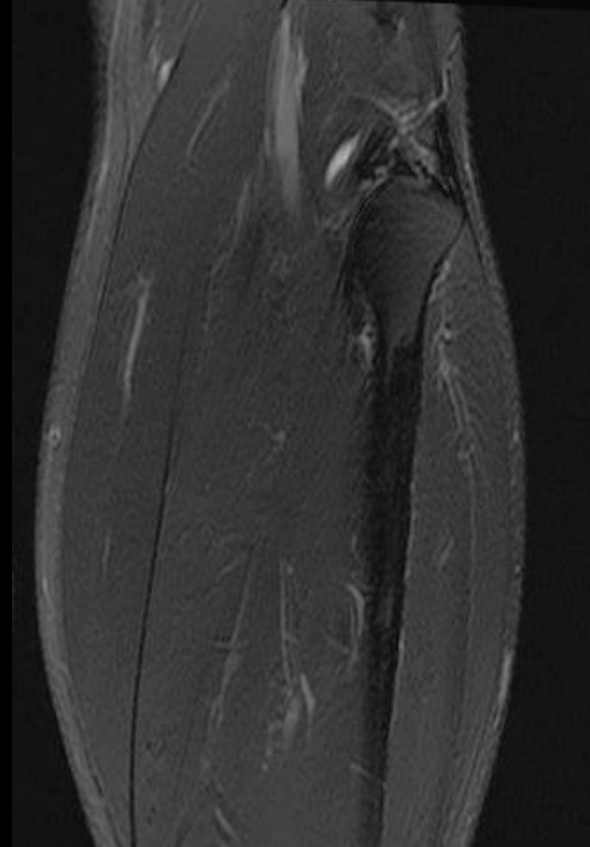
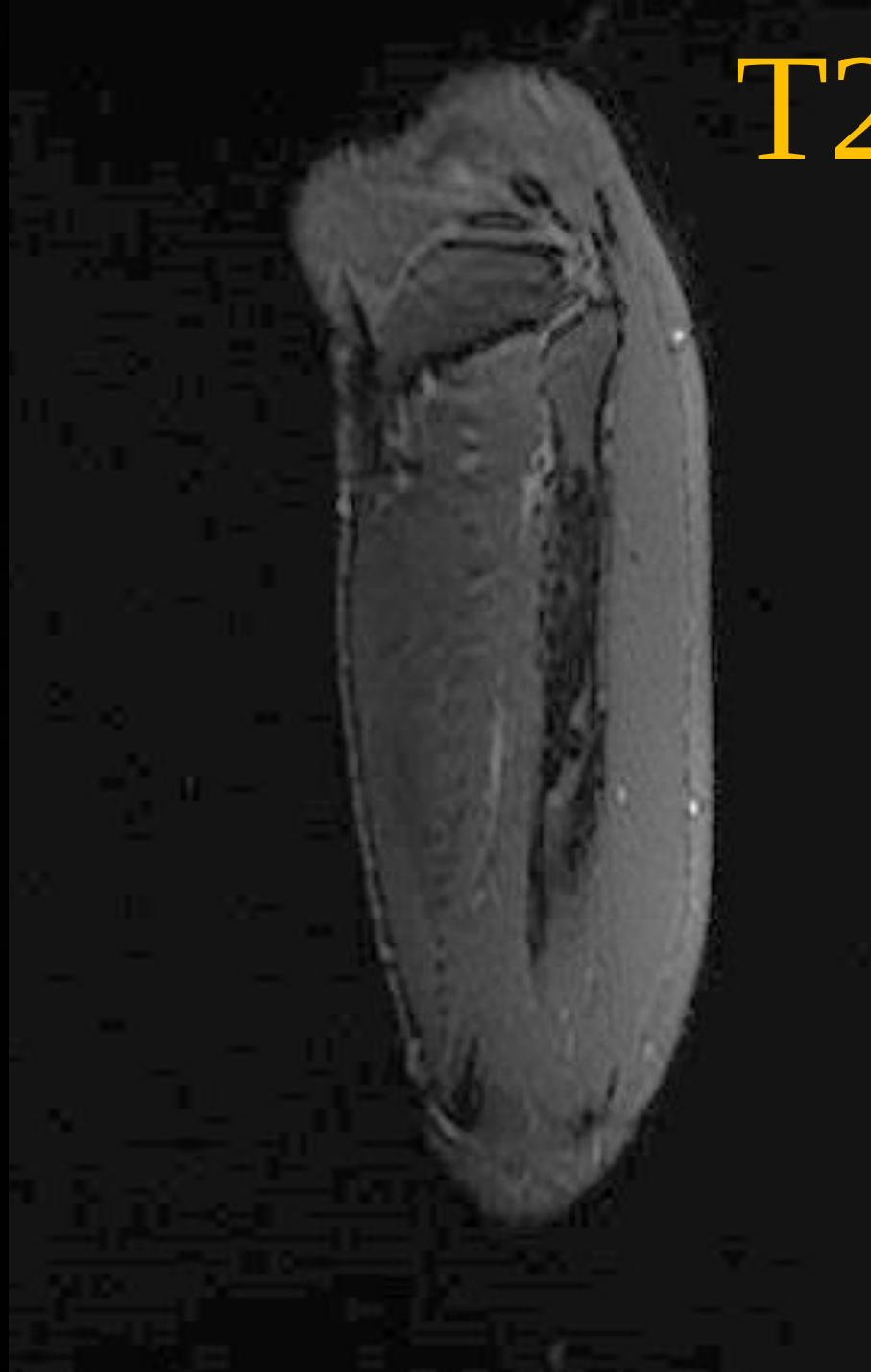


WB DELAY

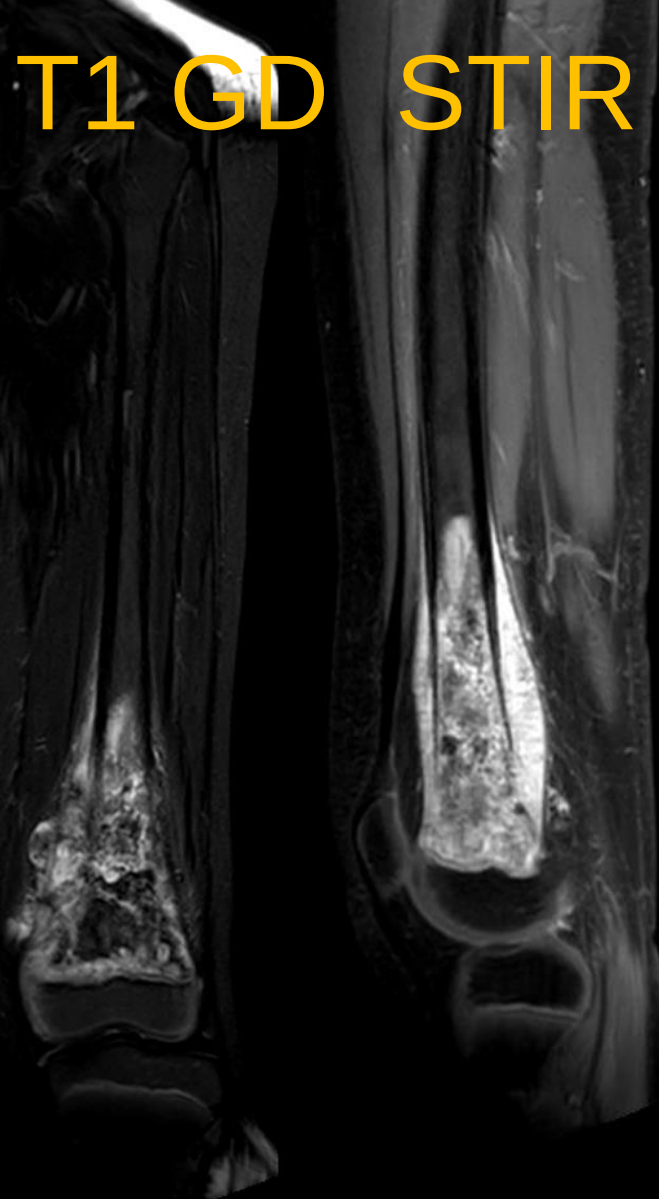
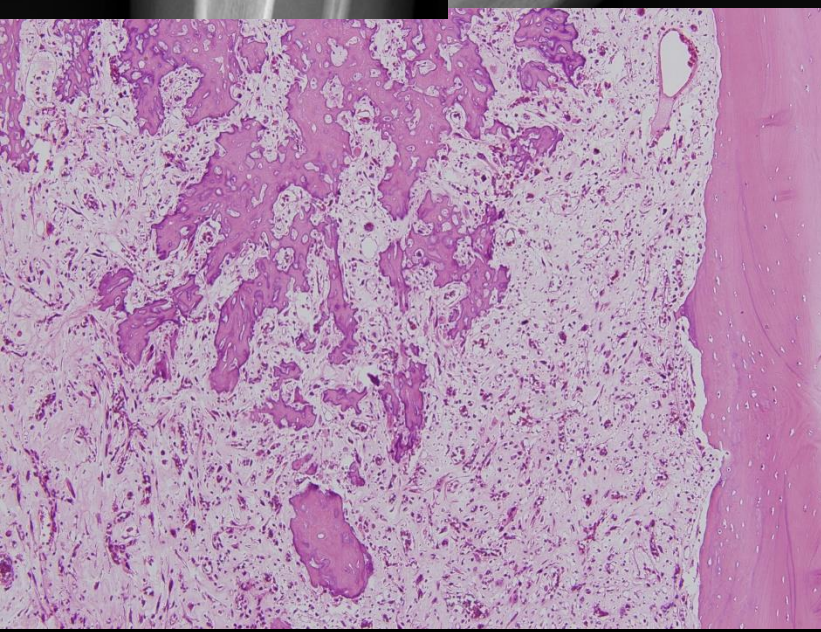
T1

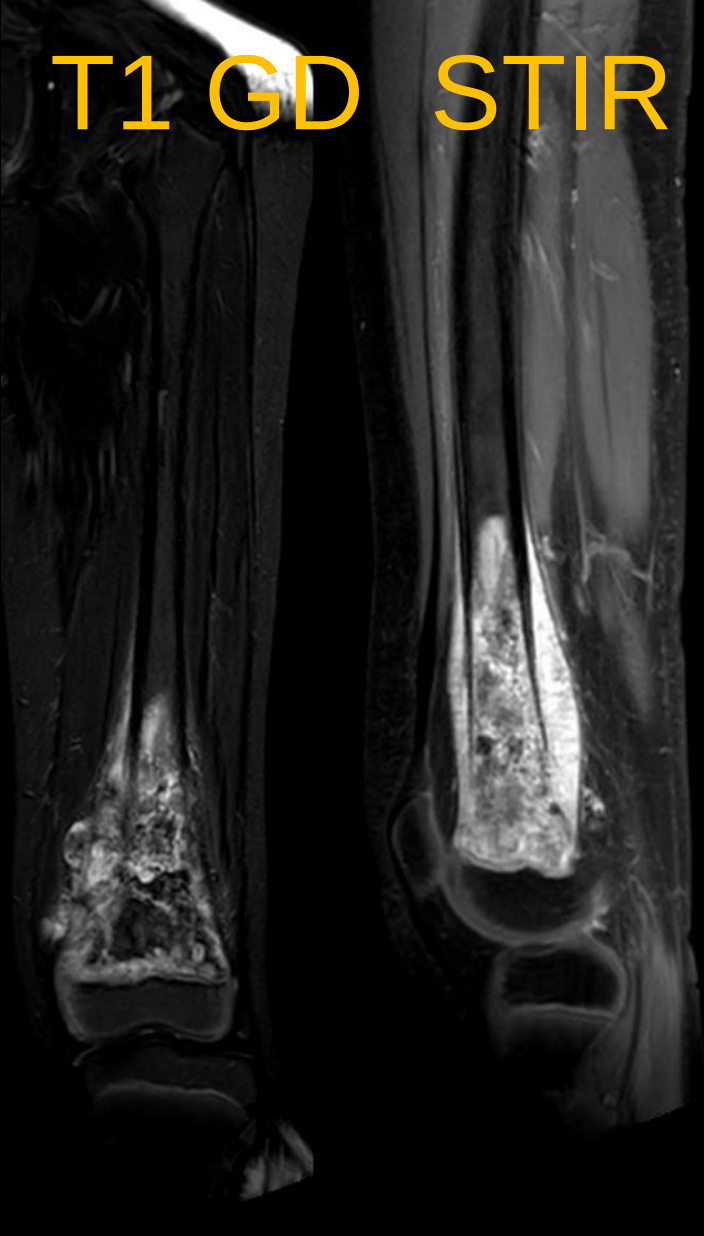
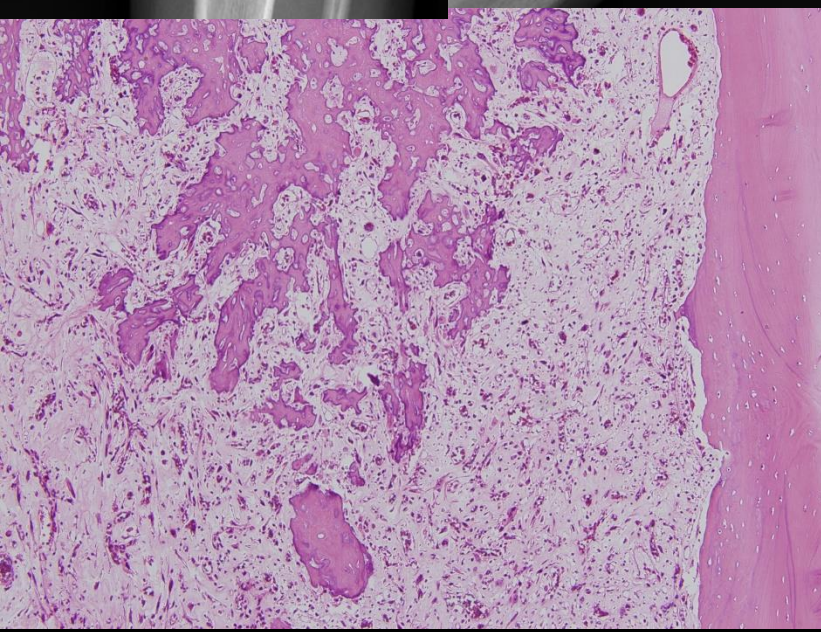


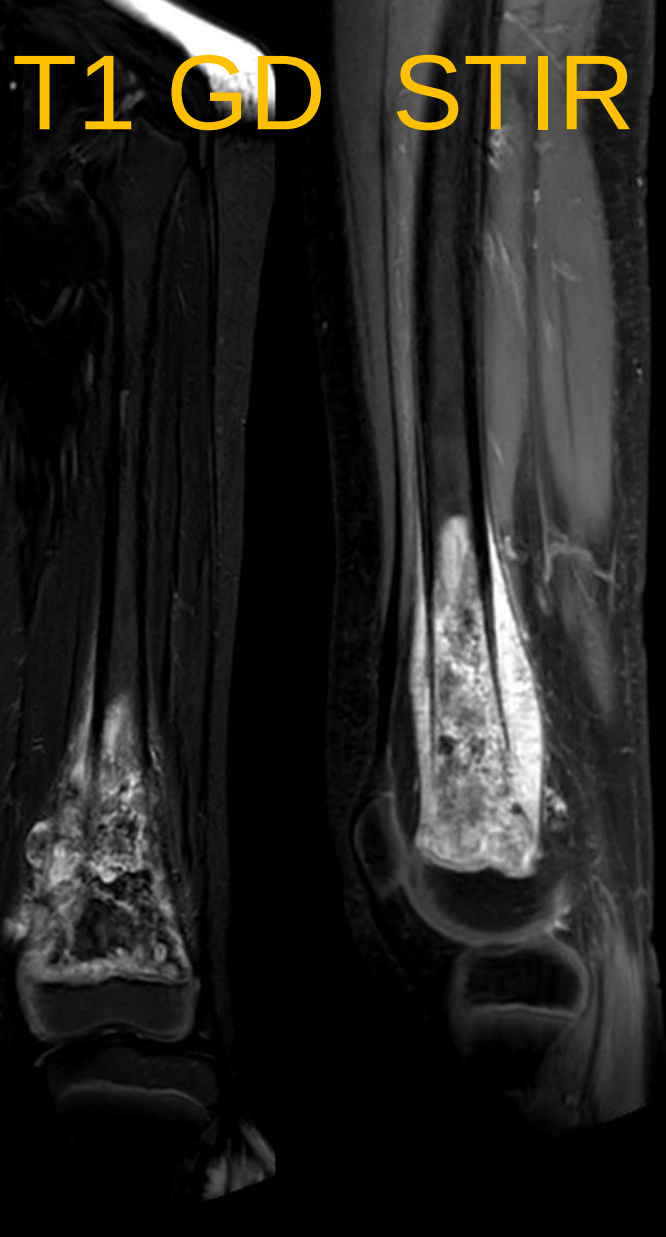
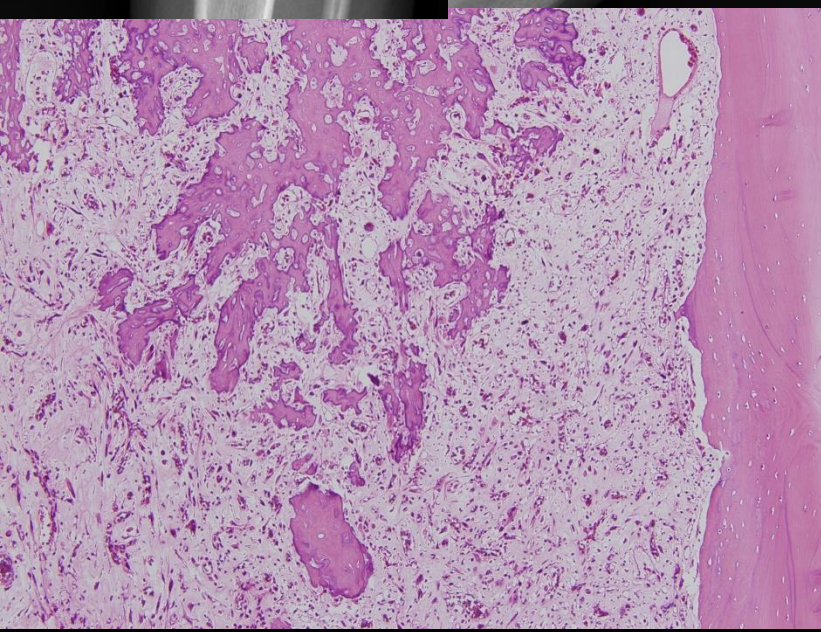
T2



T2





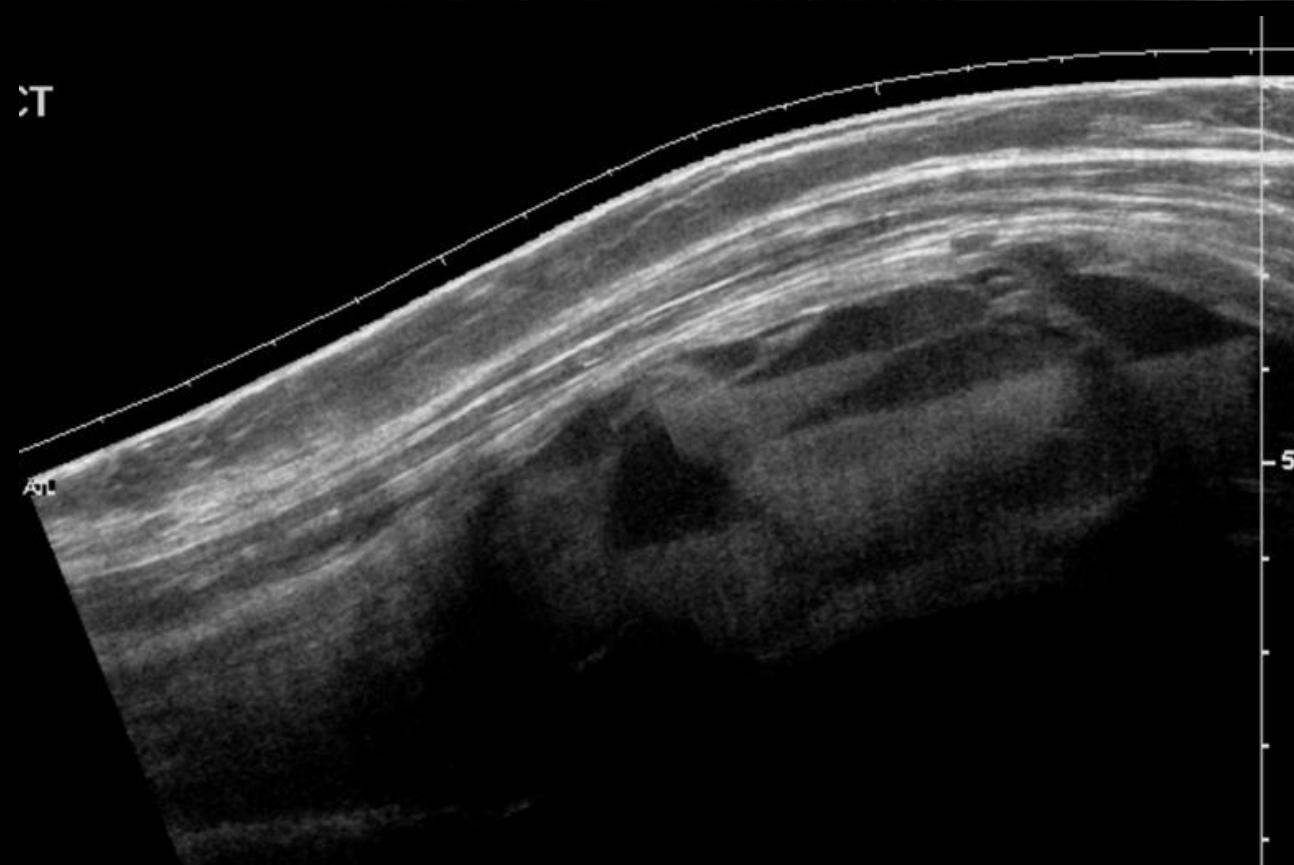
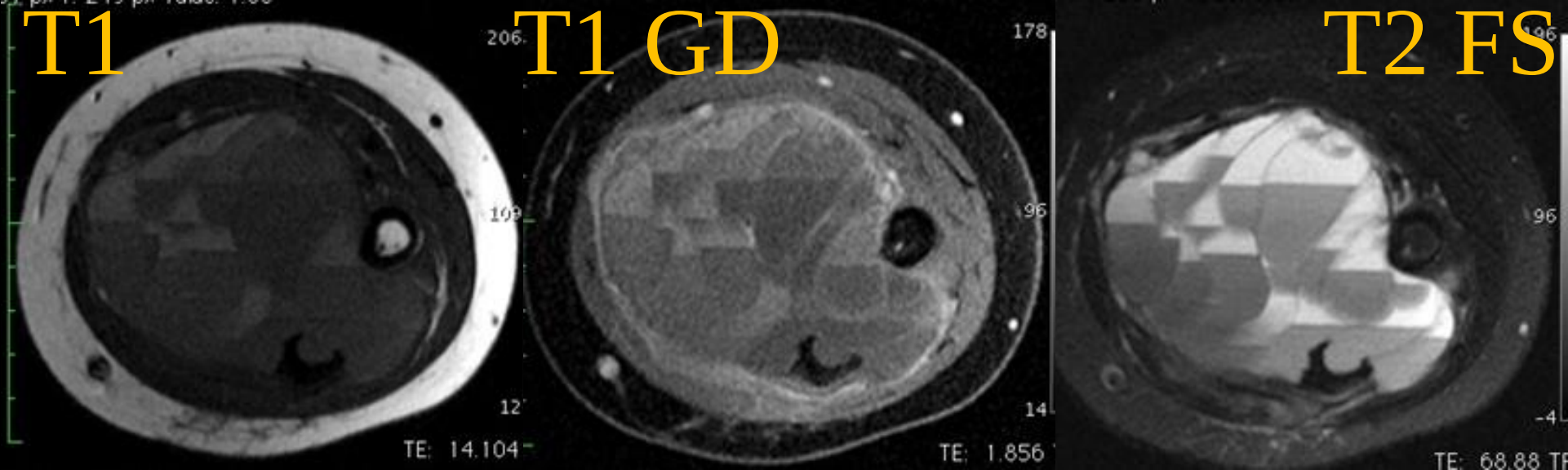


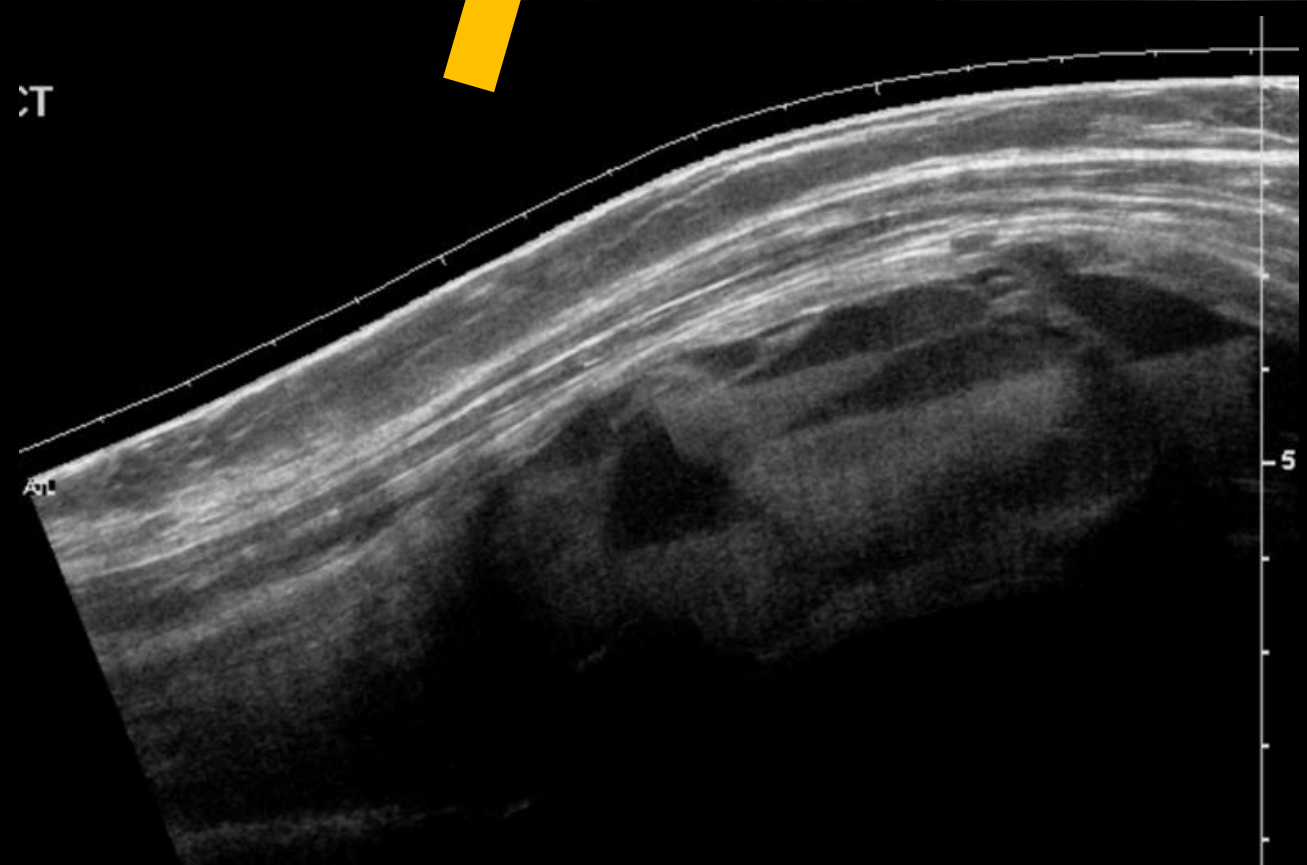
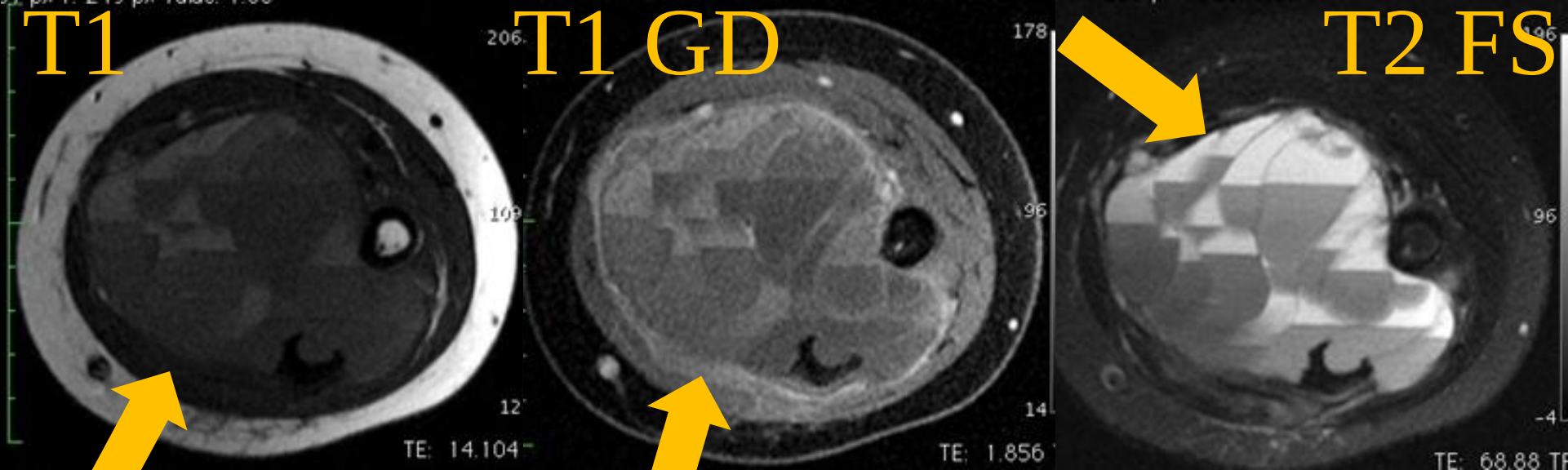
MATRIX FORMATION NONMINERALIZED (MRI > CT > Radiographs)

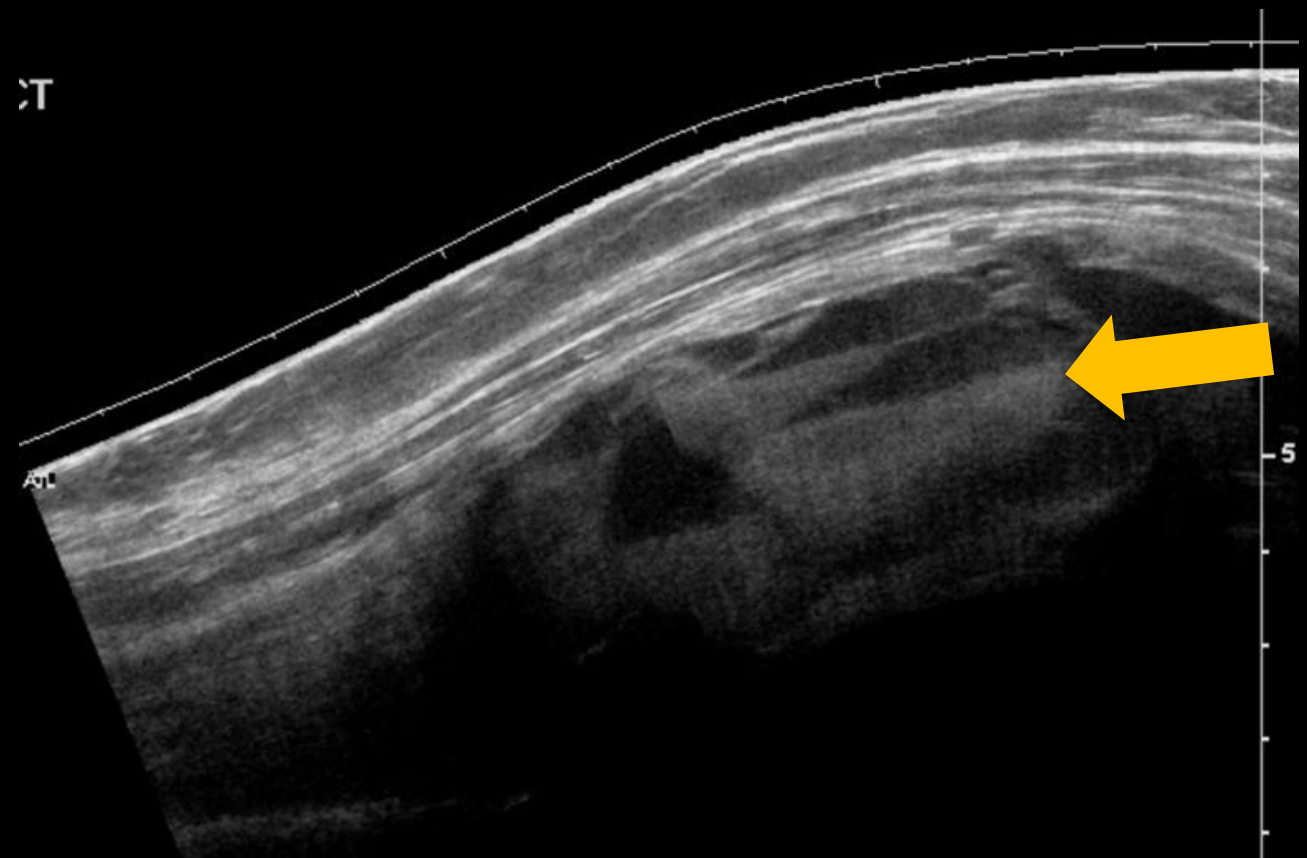
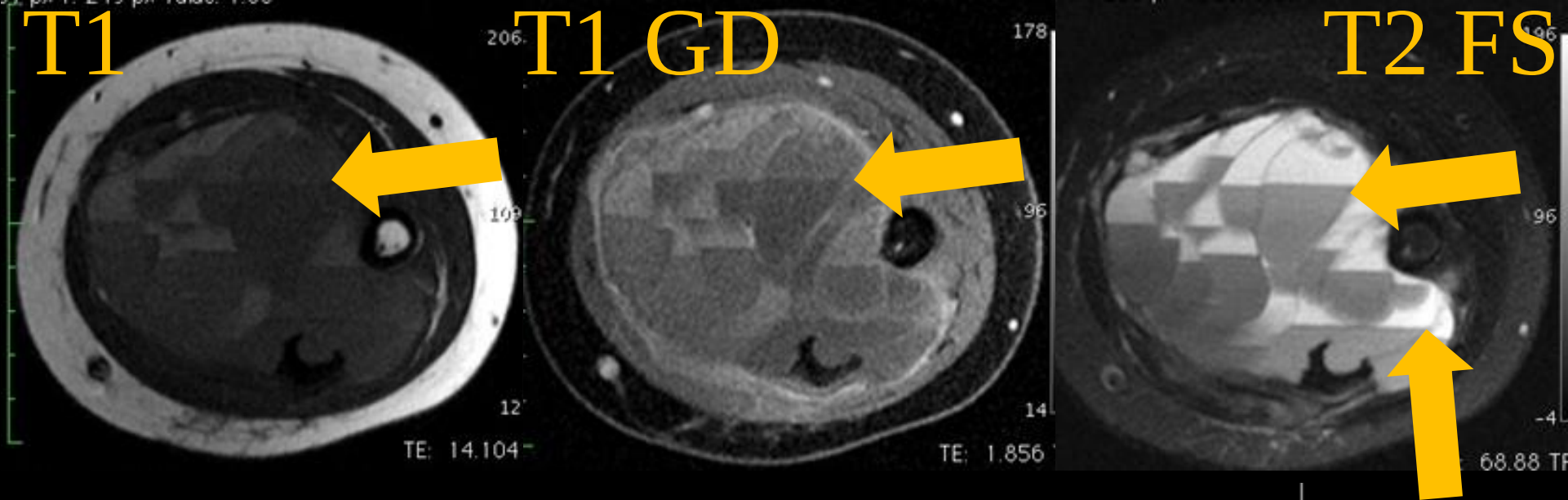
- Fluid-rim enhancement
 - Simple fluid: SBC, ABC, intraosseous ganglion, subchondral cyst, Brodie abscess
 - Complex fluid (fluid levels) from hemorrhage: ABC, GCT, chondroblastoma, osteoblastoma, telangiectatic osteosarcoma

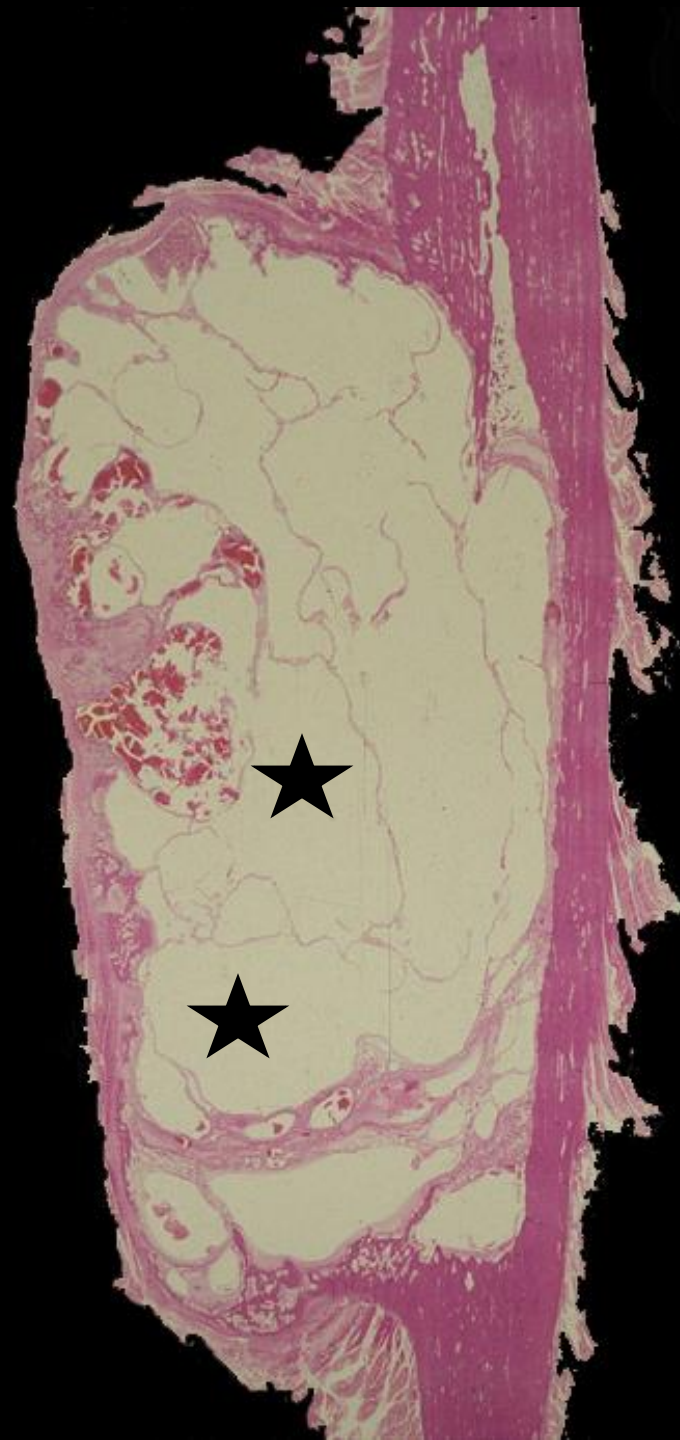


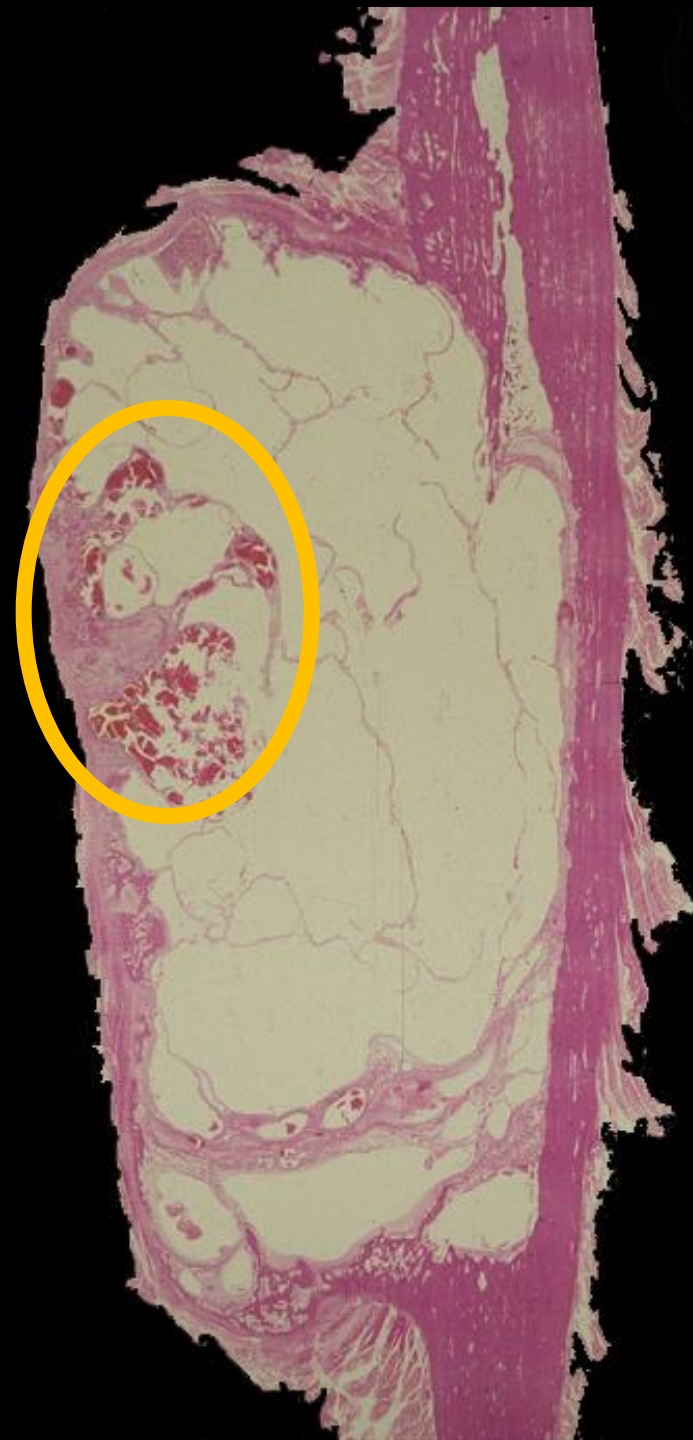


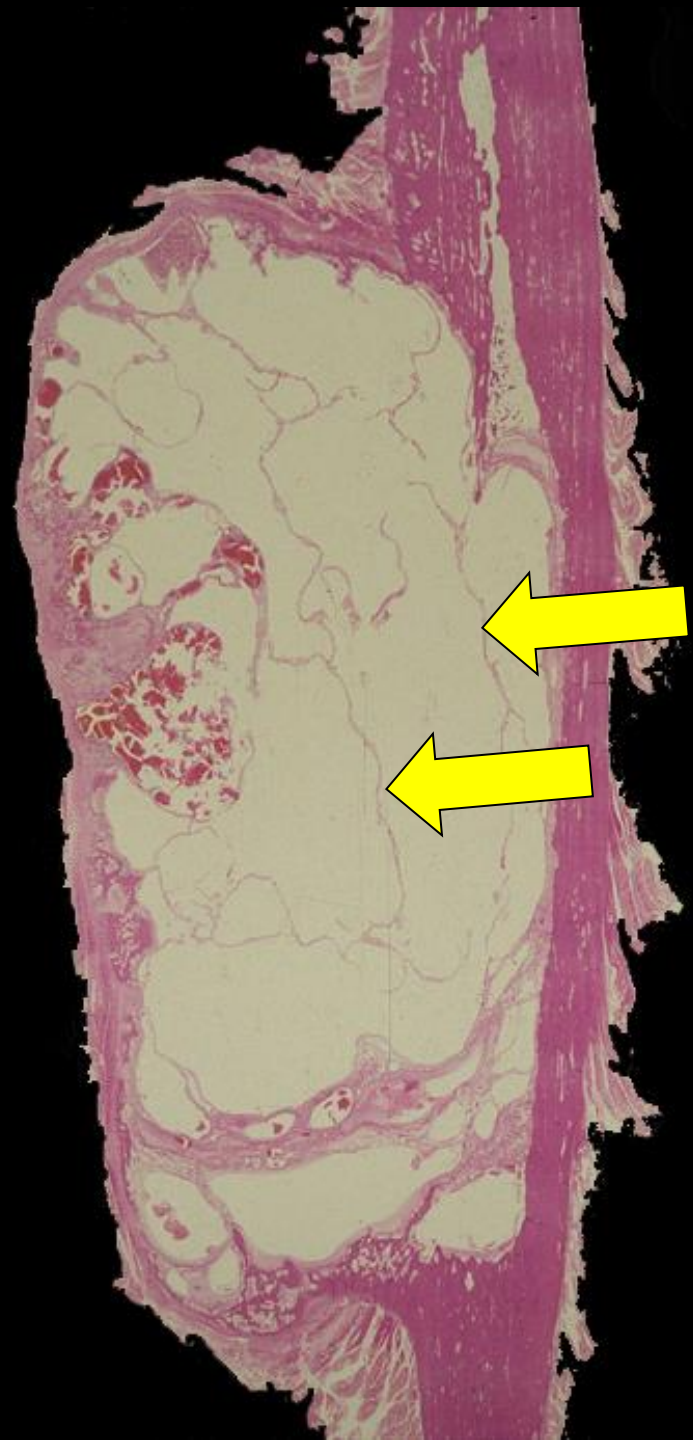
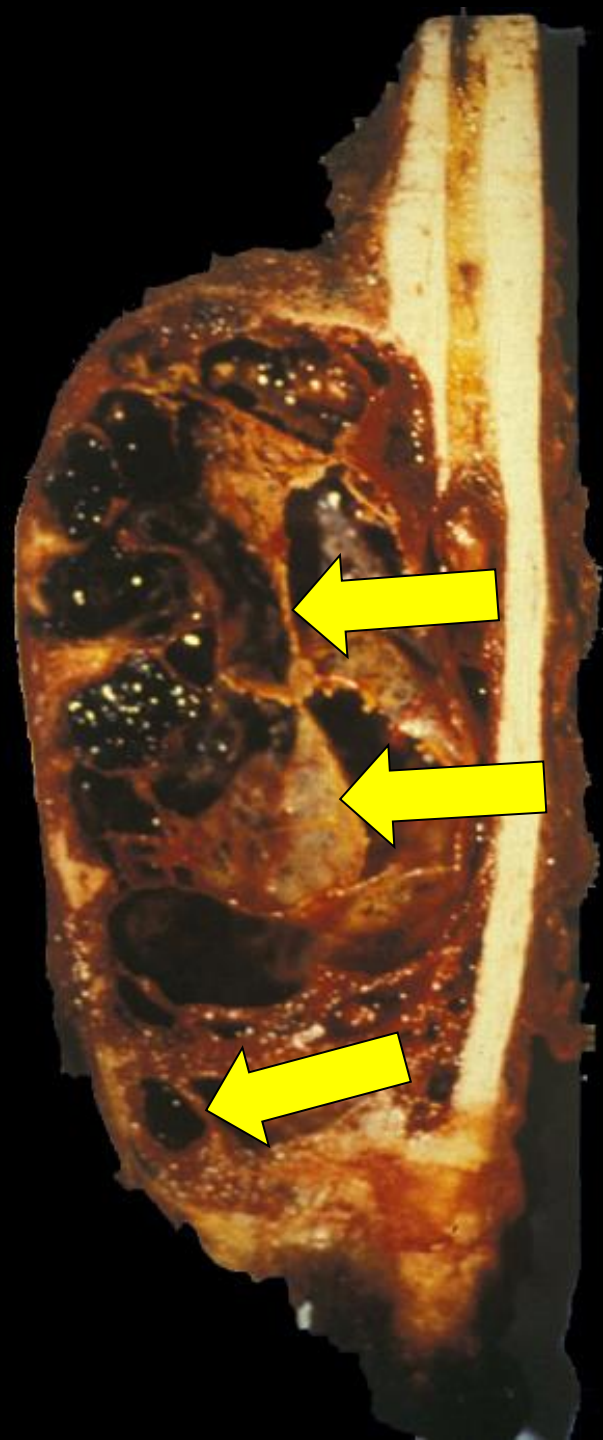








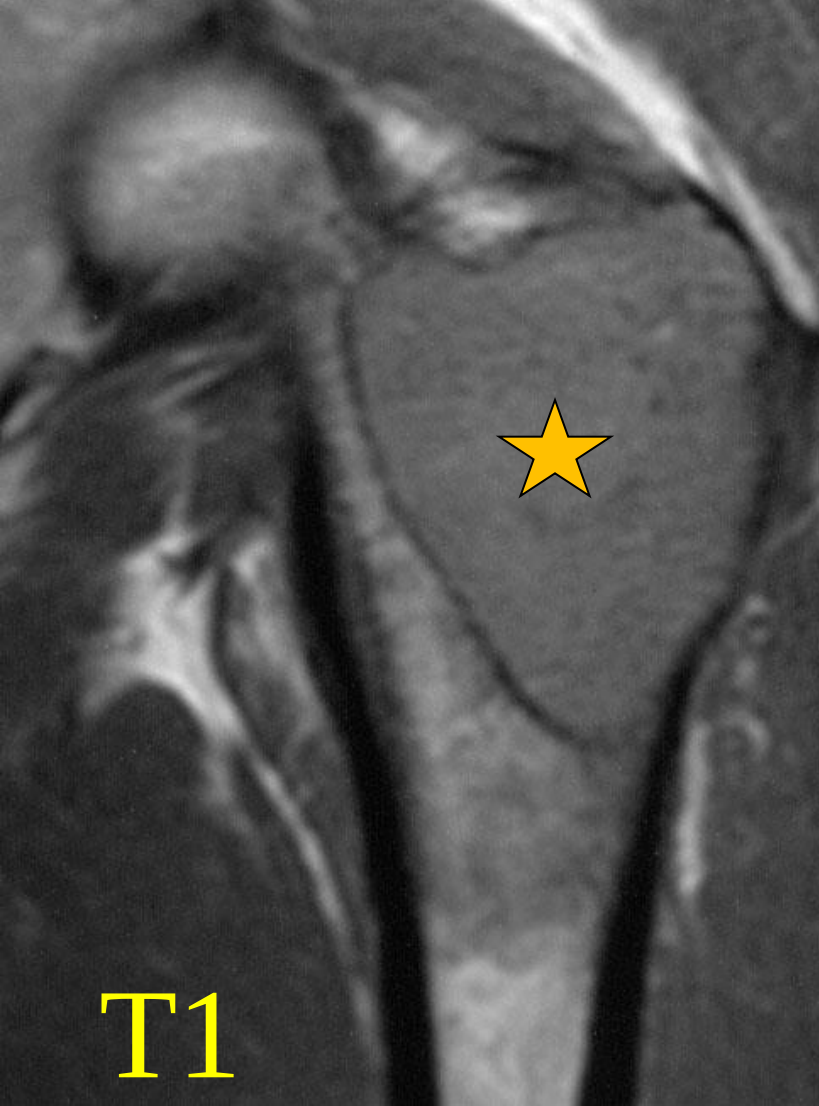


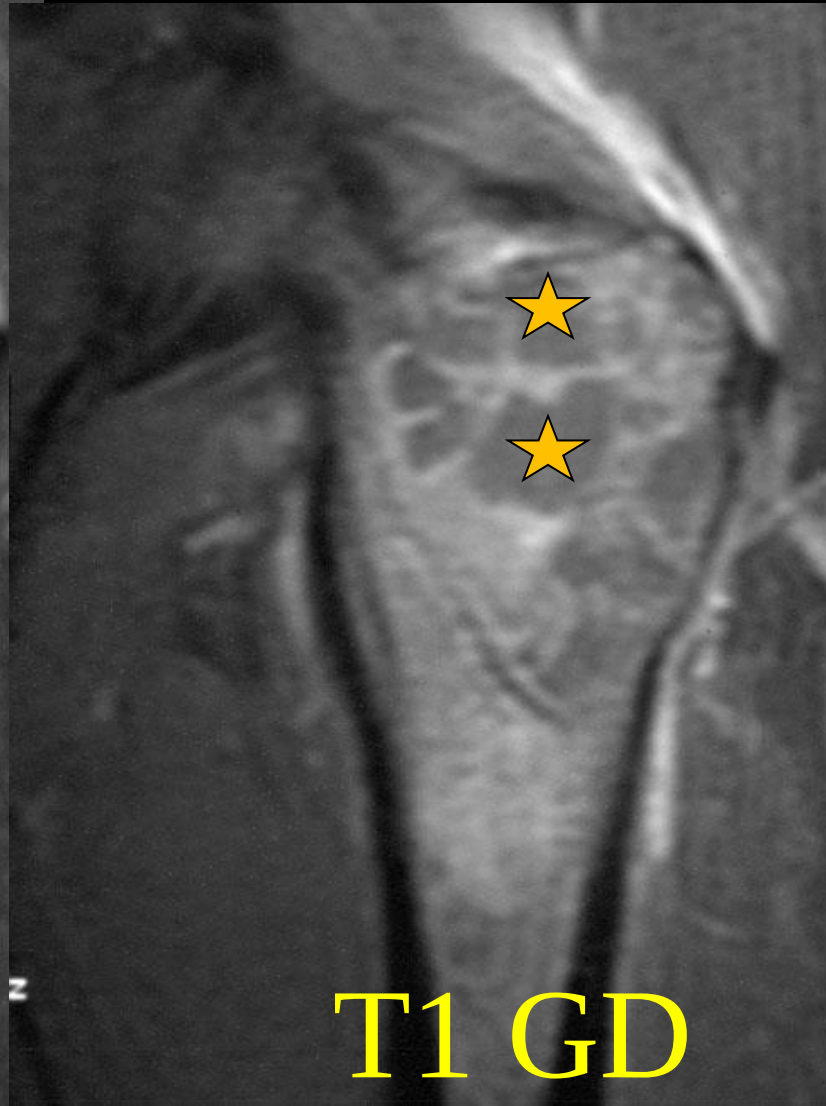


OSSEOUS LESIONS WITH PROMINENT FLUID LEVELS DIFFERENTIAL DIAGNOSIS

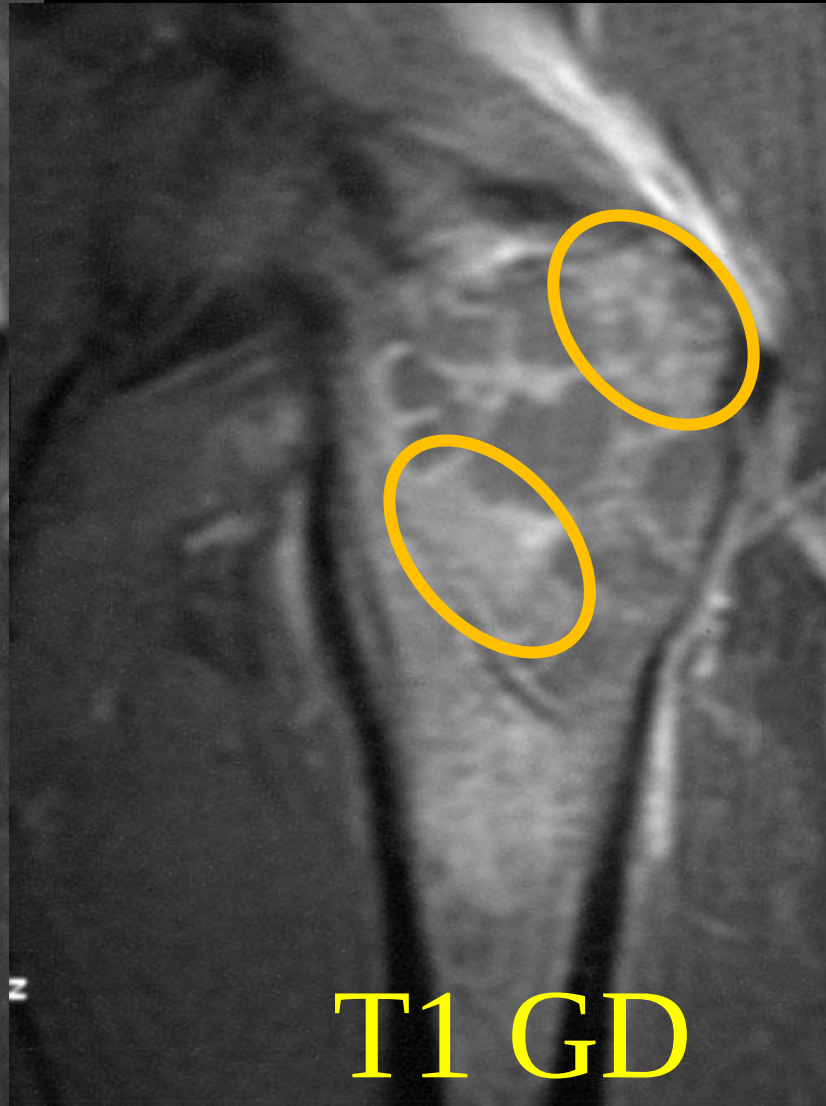
- Aneurysmal bone cyst (only fluid levels)
- Giant cell tumor (to bone end, metaphyseal center)
- Chondroblastoma (epiphyseal center)
- Osteoblastoma (posterior elements spine)
- Telangiectatic Osteosarcoma (thick walls, osteoid CT)
- Fibrous dysplasia (diaphysis, “ground glass”)







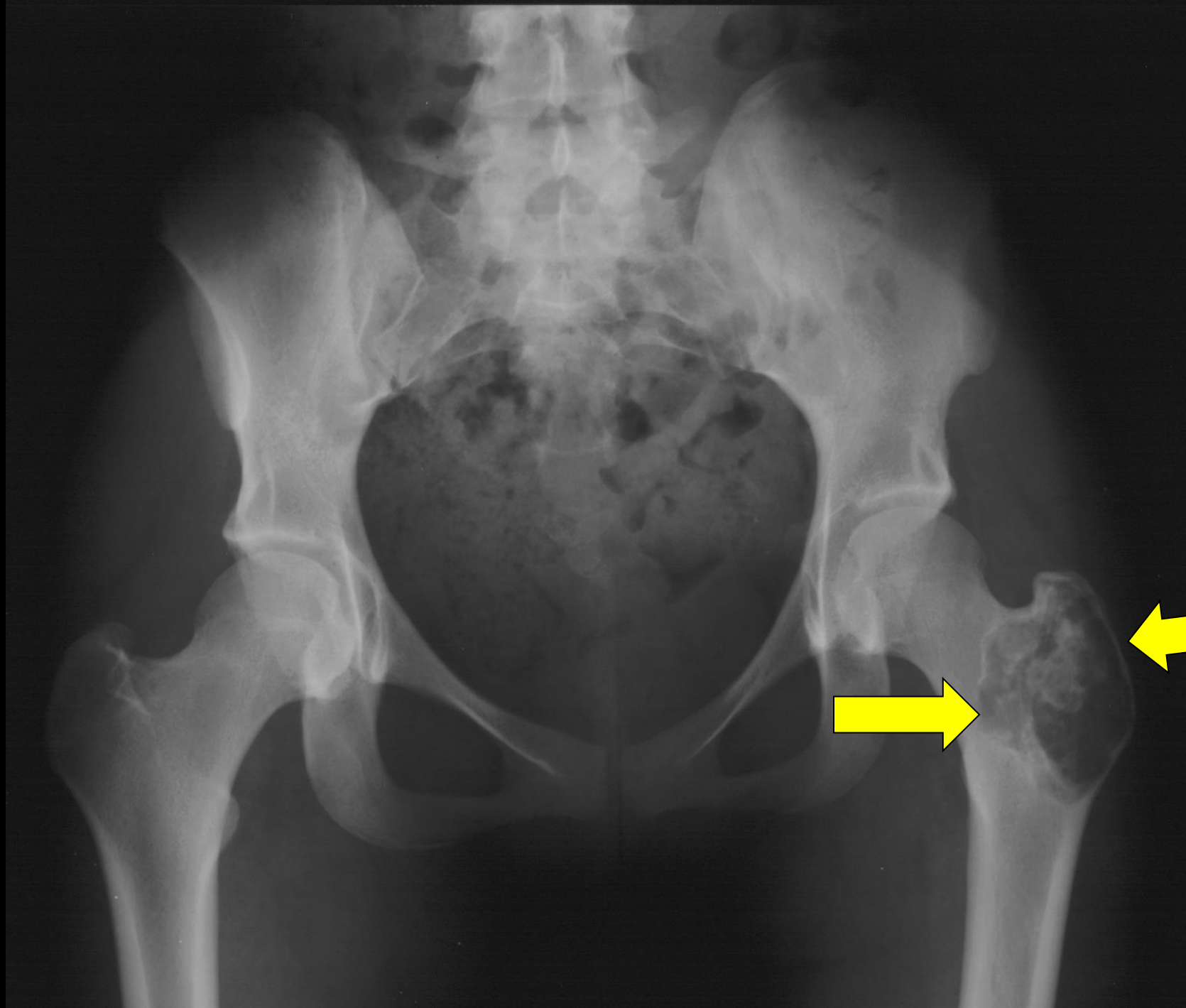


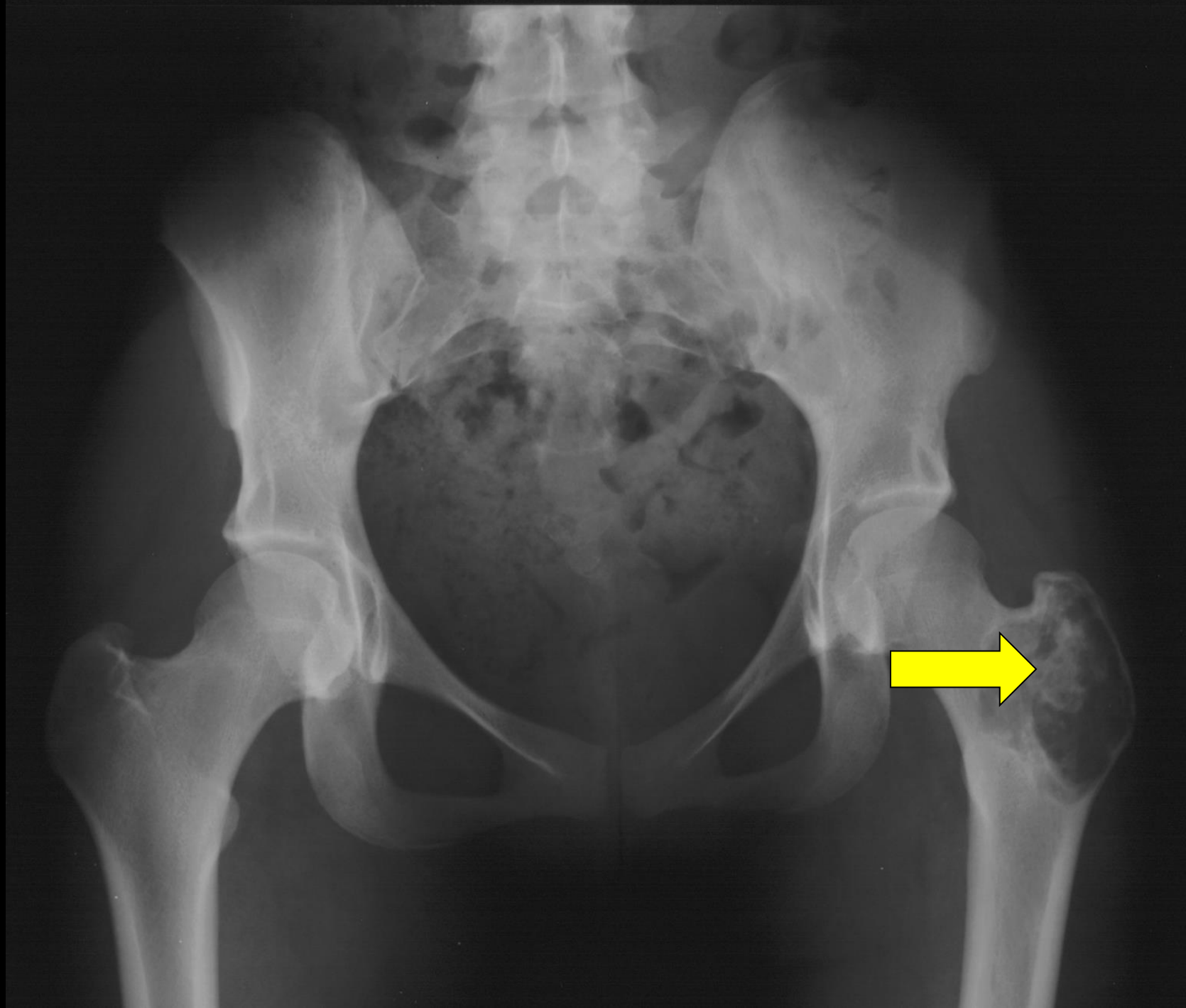




INTRAOSSSEOUS MASS PROMINENT EDEMA

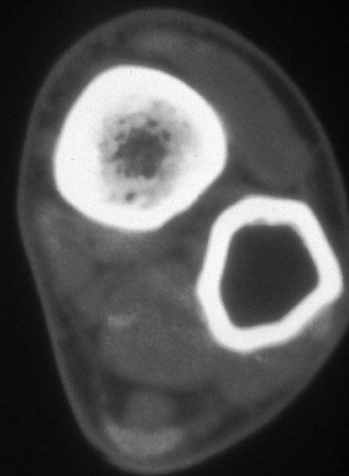
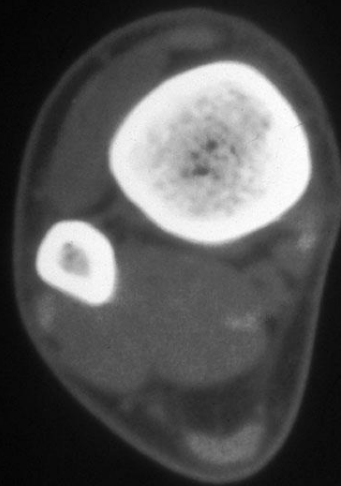
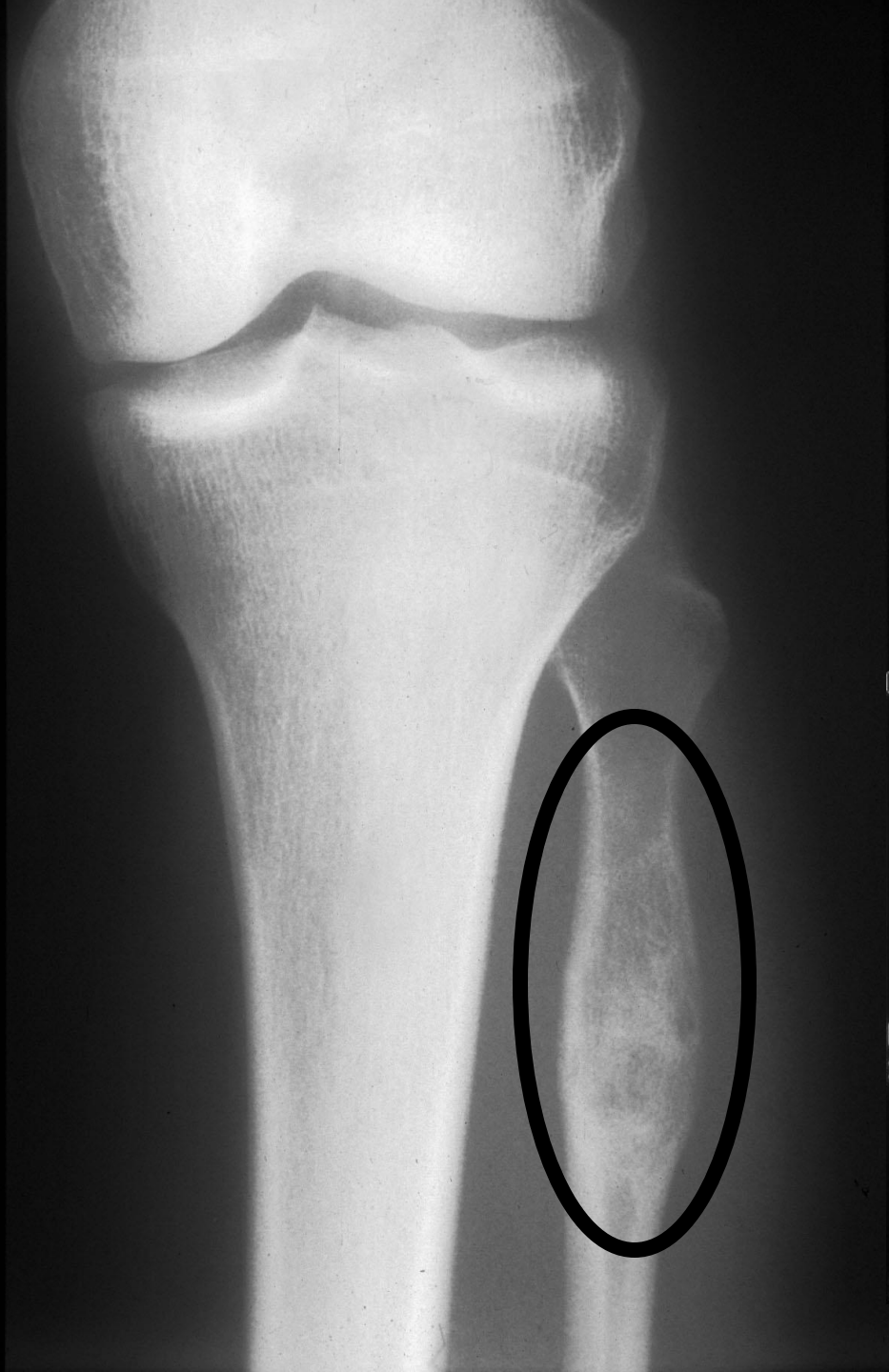
- Differential Diagnosis
 - osteoid osteoma, osteoblastoma, chondroblastoma, Langerhans cell histiocytosis, Brodie abscess, lymphoma, any lesion with associated fracture





MATRIX FORMATION NONMINERALIZED (MRI > CT > Radiographs)

- Fat: Intraosseous lipoma
- Soft tissue: nonspecific with GCT, UPS (MFH)/fibrosarcoma, metastases, lymphoma, Ewing sarcoma, osteomyelitis

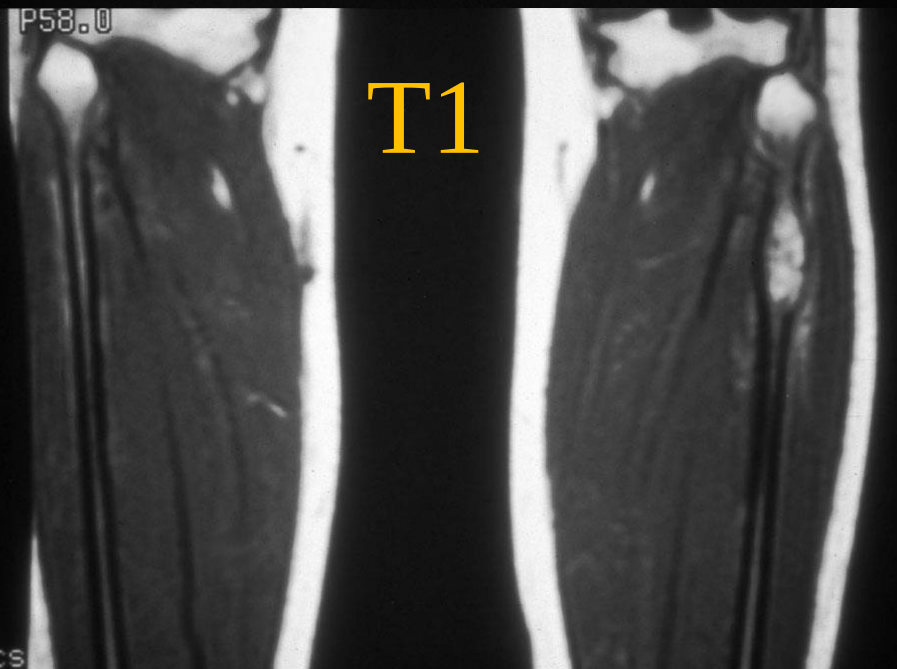


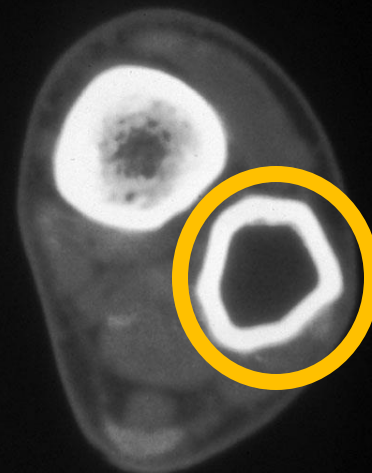
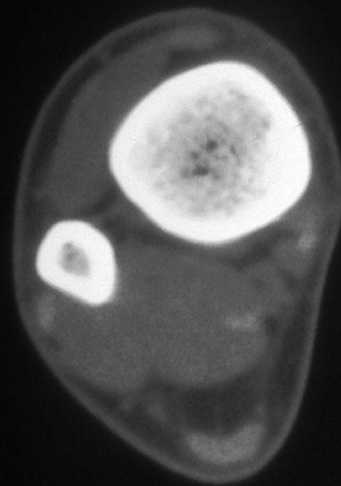
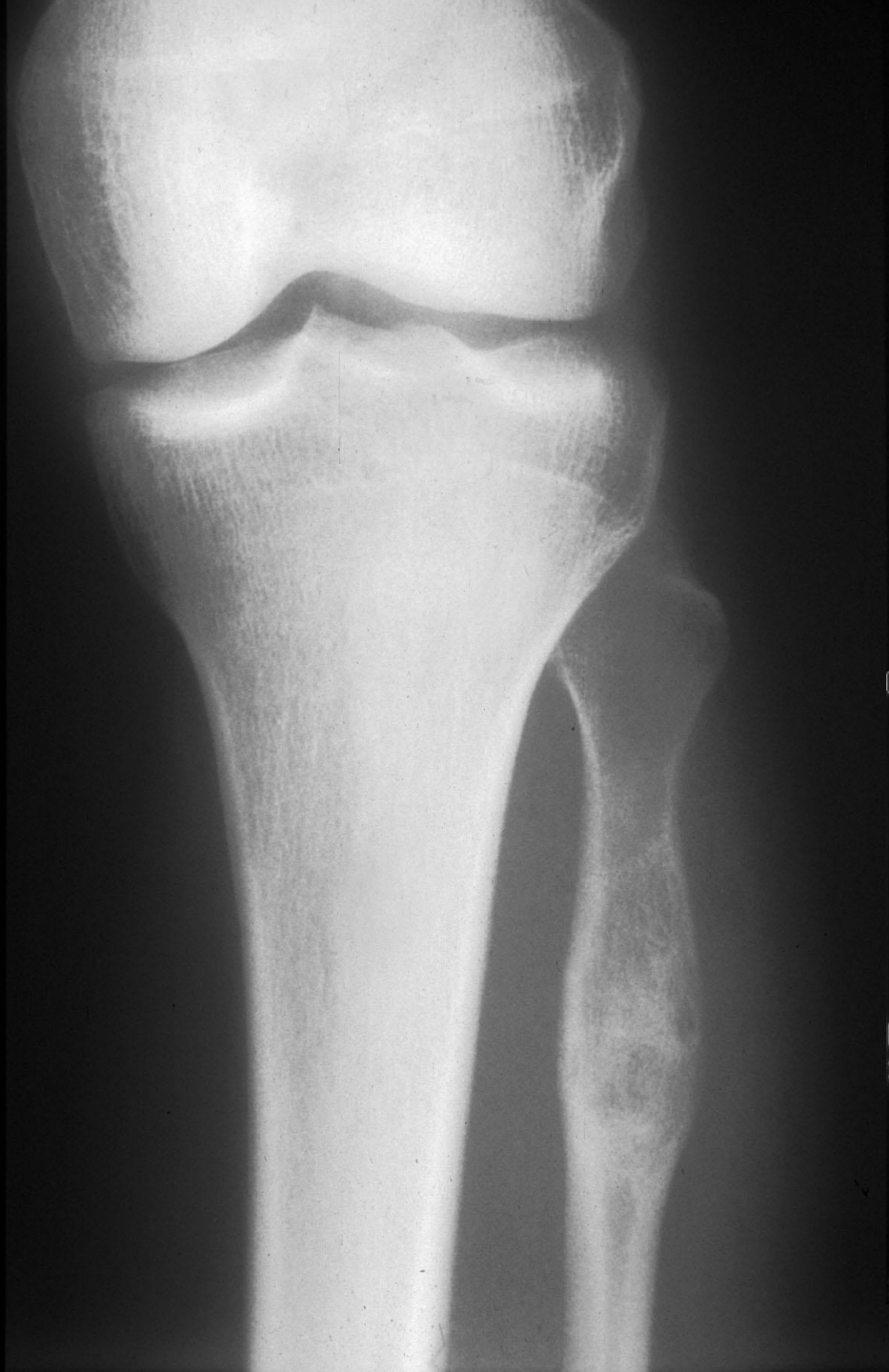
0Cor P58.0

R
S

SE/cs

T1





0Cor P58.0

R
S

SE/cs

T1



SOLITARY BONE LESION ANALYSIS

- Patient age/sex
- Bone involved and location – any
- Lesion margins – Radiographs > CT > MRI
- Matrix formation
 - Mineralized: CT > Radiographs > MRI
 - Nonmineralized: MRI > CT > Radiographs
- Periosteal reaction – Radiographs > CT > MRI
- Preoperative staging – MRI > CT > Radiographs
 - Lesion extent/affect on adjacent structures

PERIOSTEAL REACTION NONAGGRESSIVE

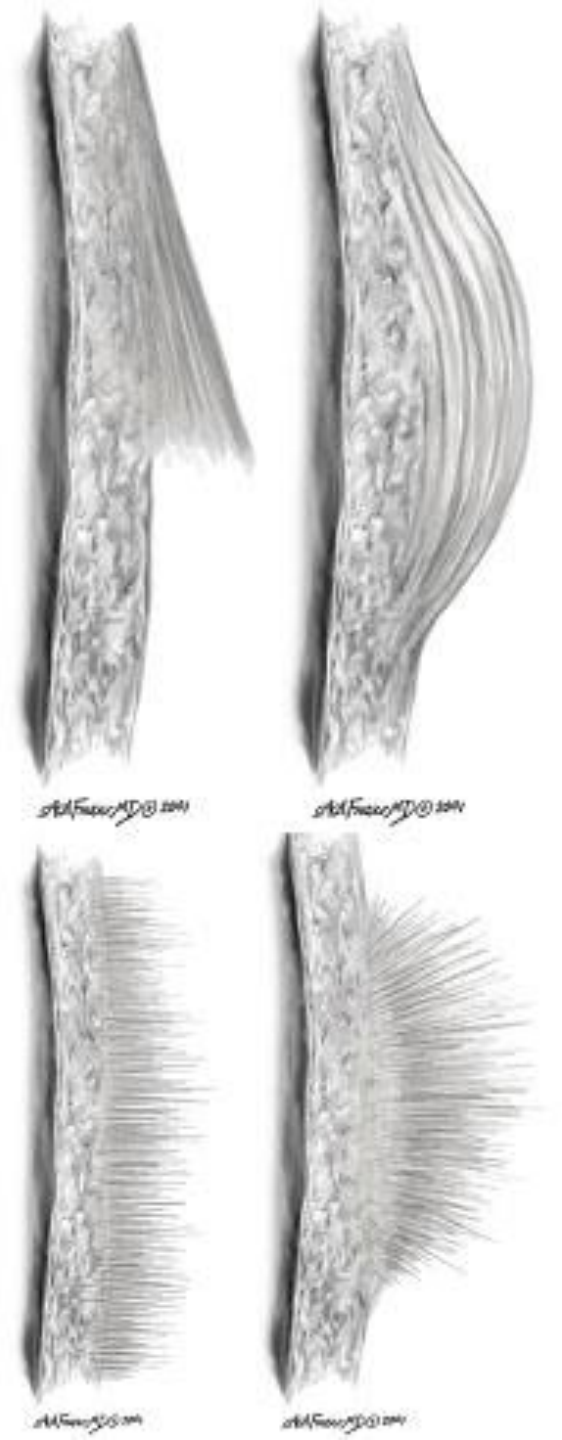
- SOLID
- BUTTRESSING
- EXPANSION
- SEPTATION

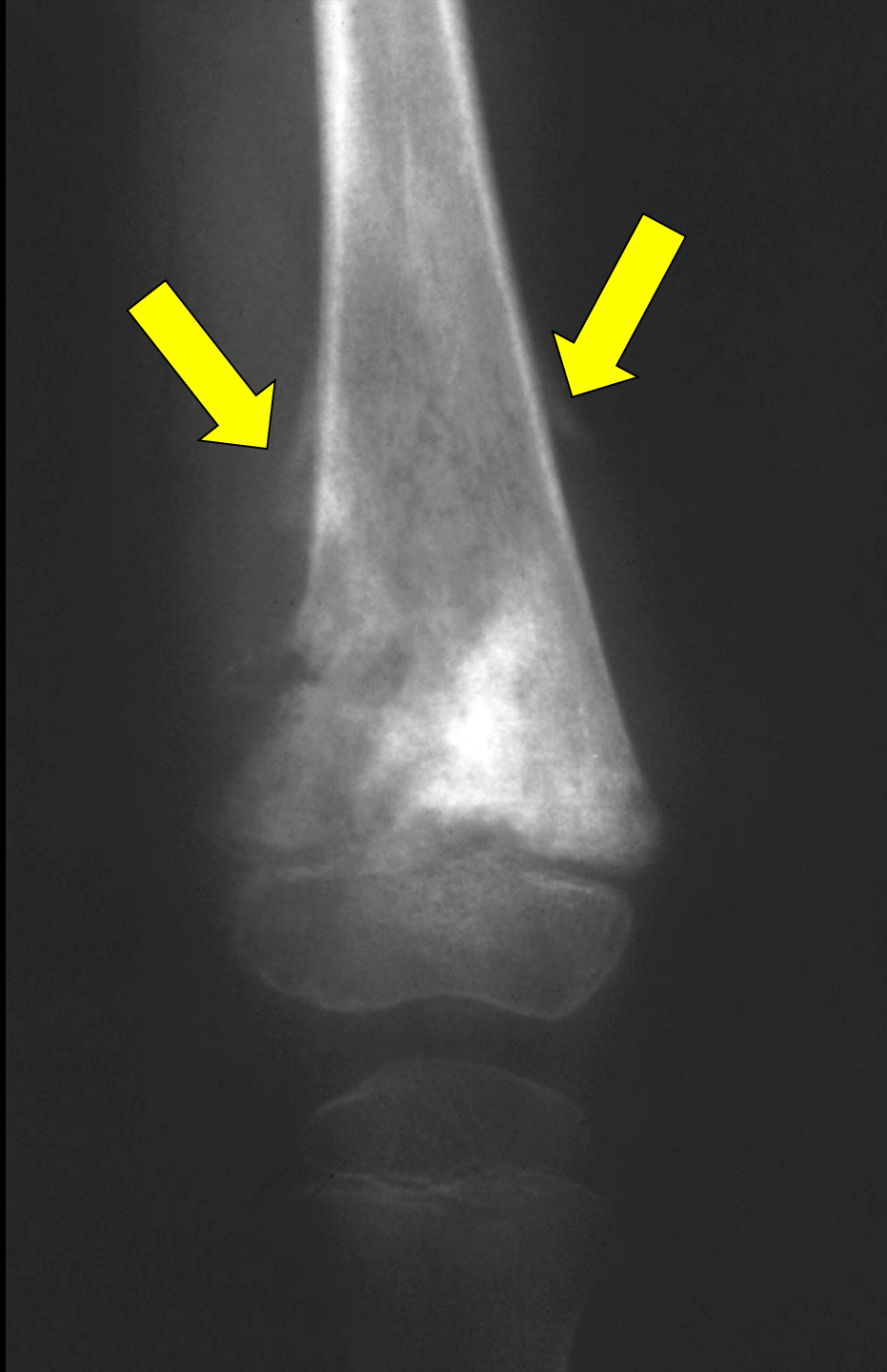


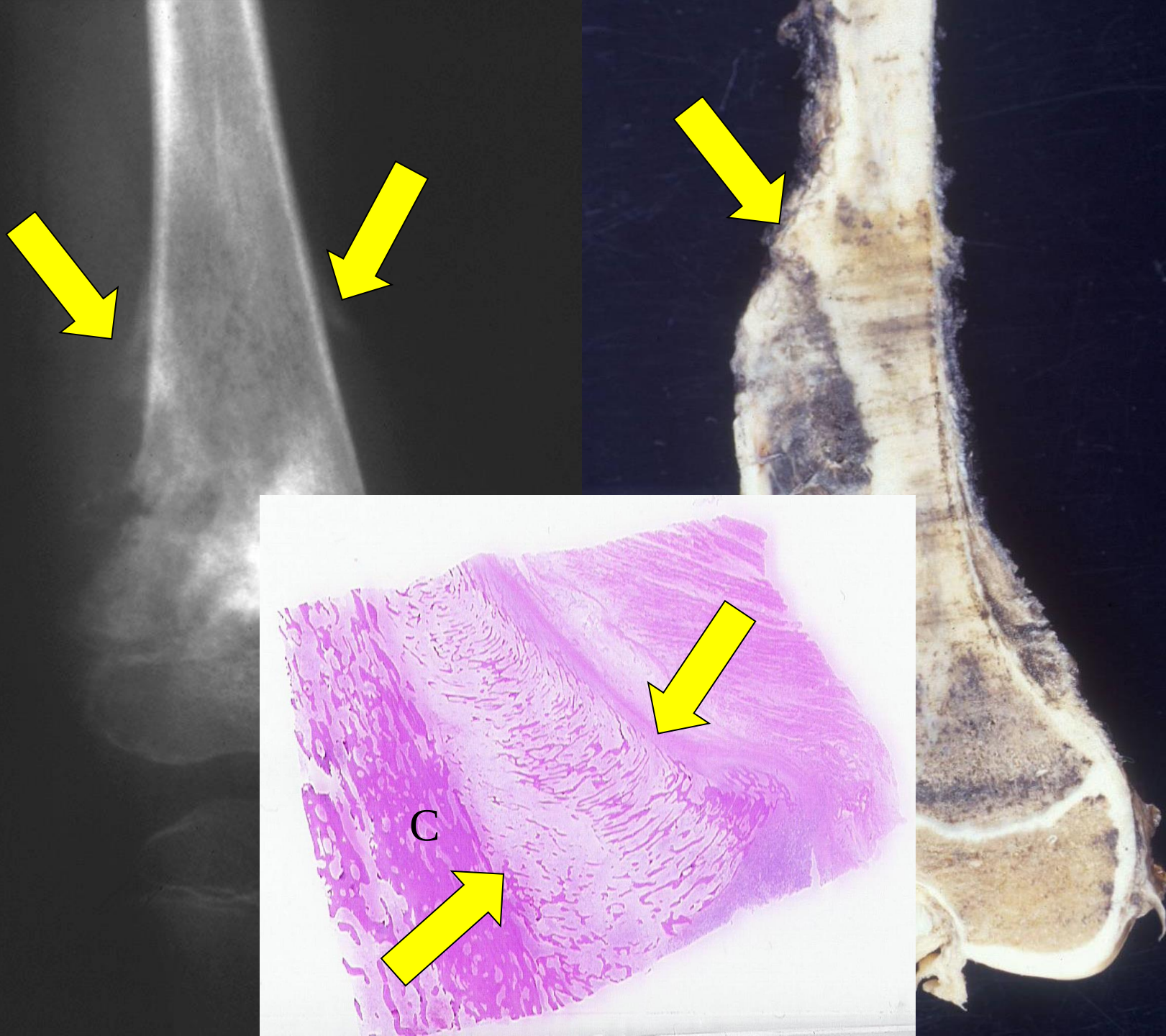


PERIOSTEAL REACTION AGGRESSIVE

- CODMAN TRIANGLE
- HAIR-ON-END
- SUNBURST
- LAMINATED

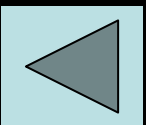








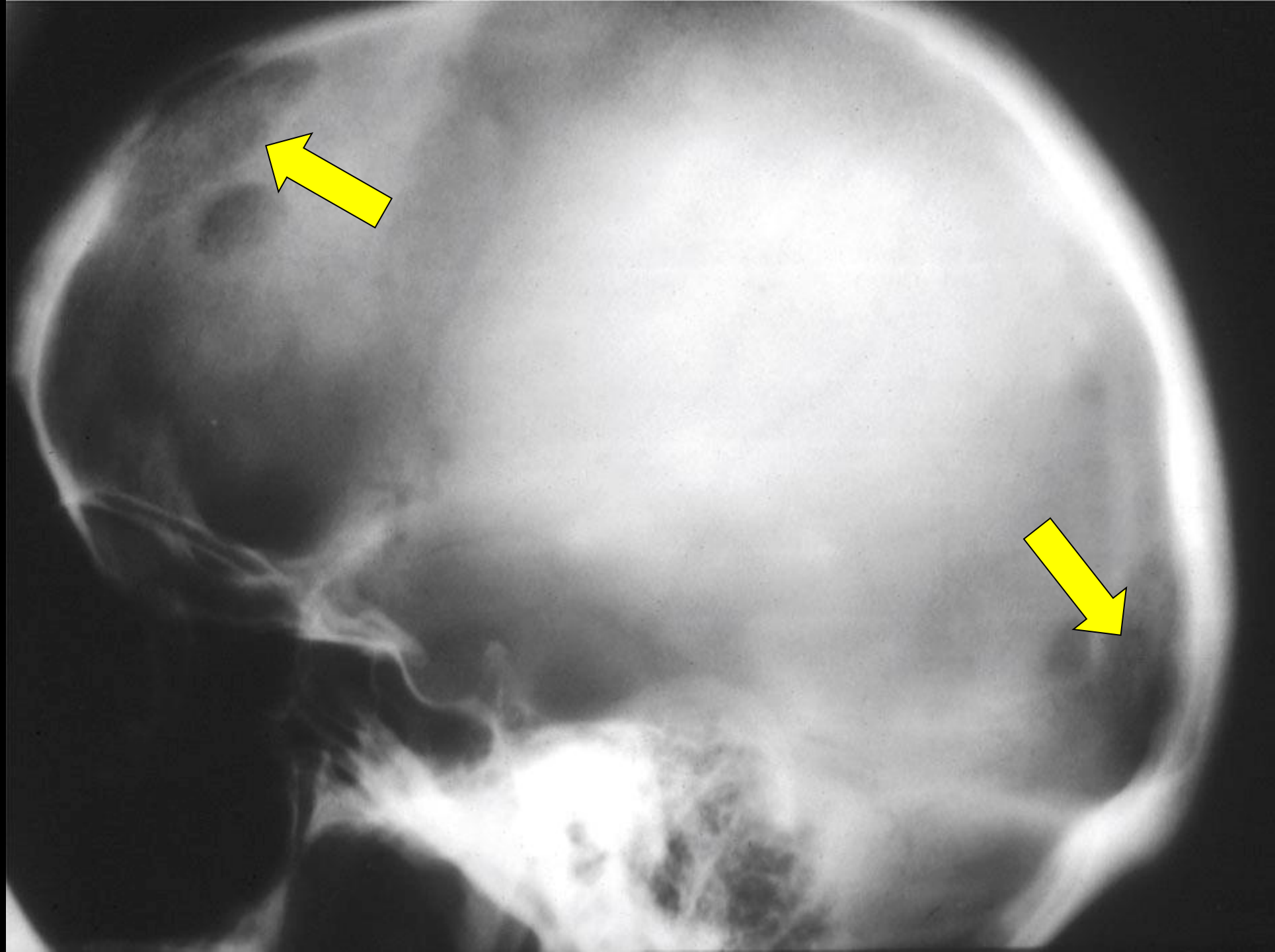




POLYOSTOTIC LESIONS

BENIGN

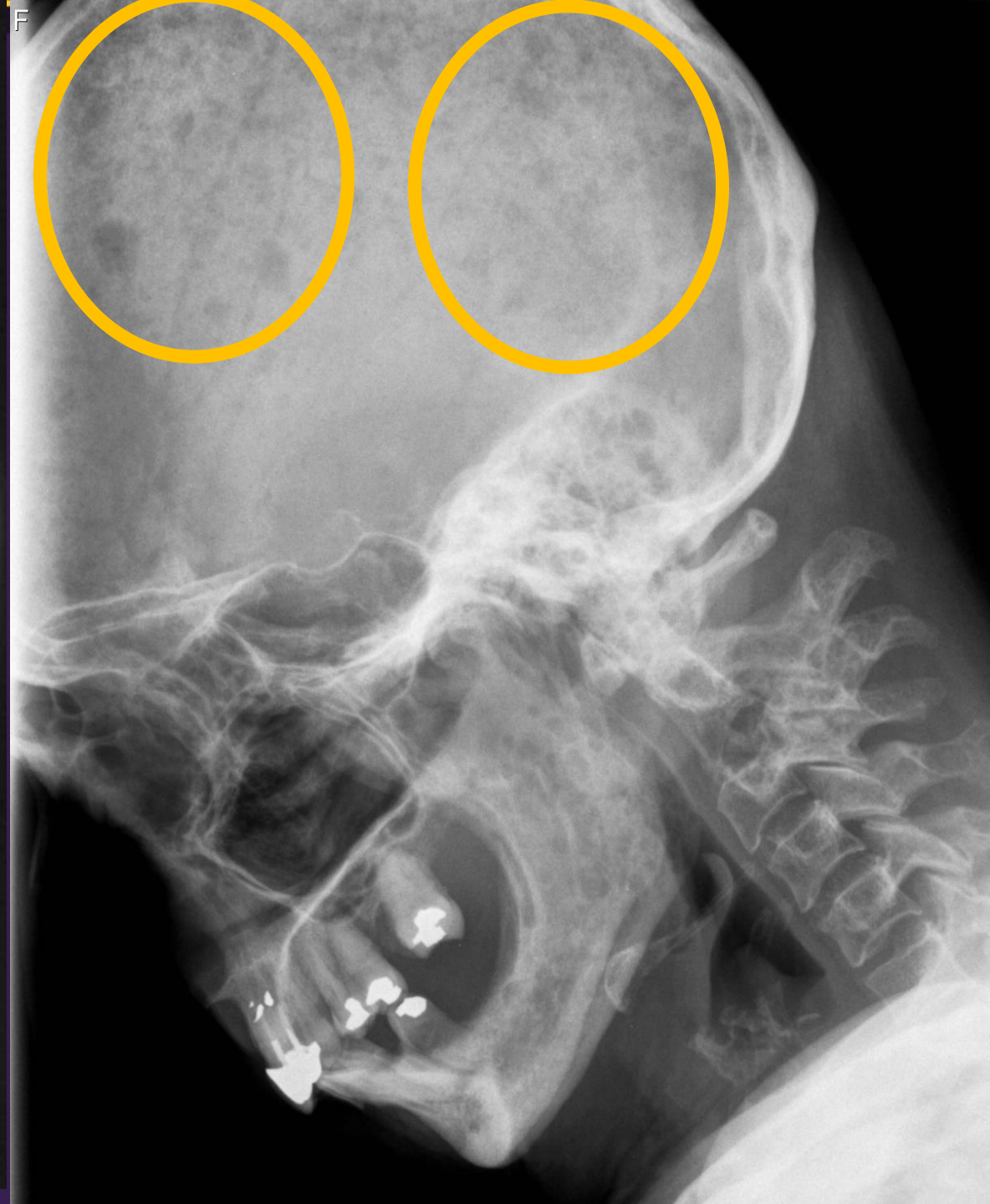
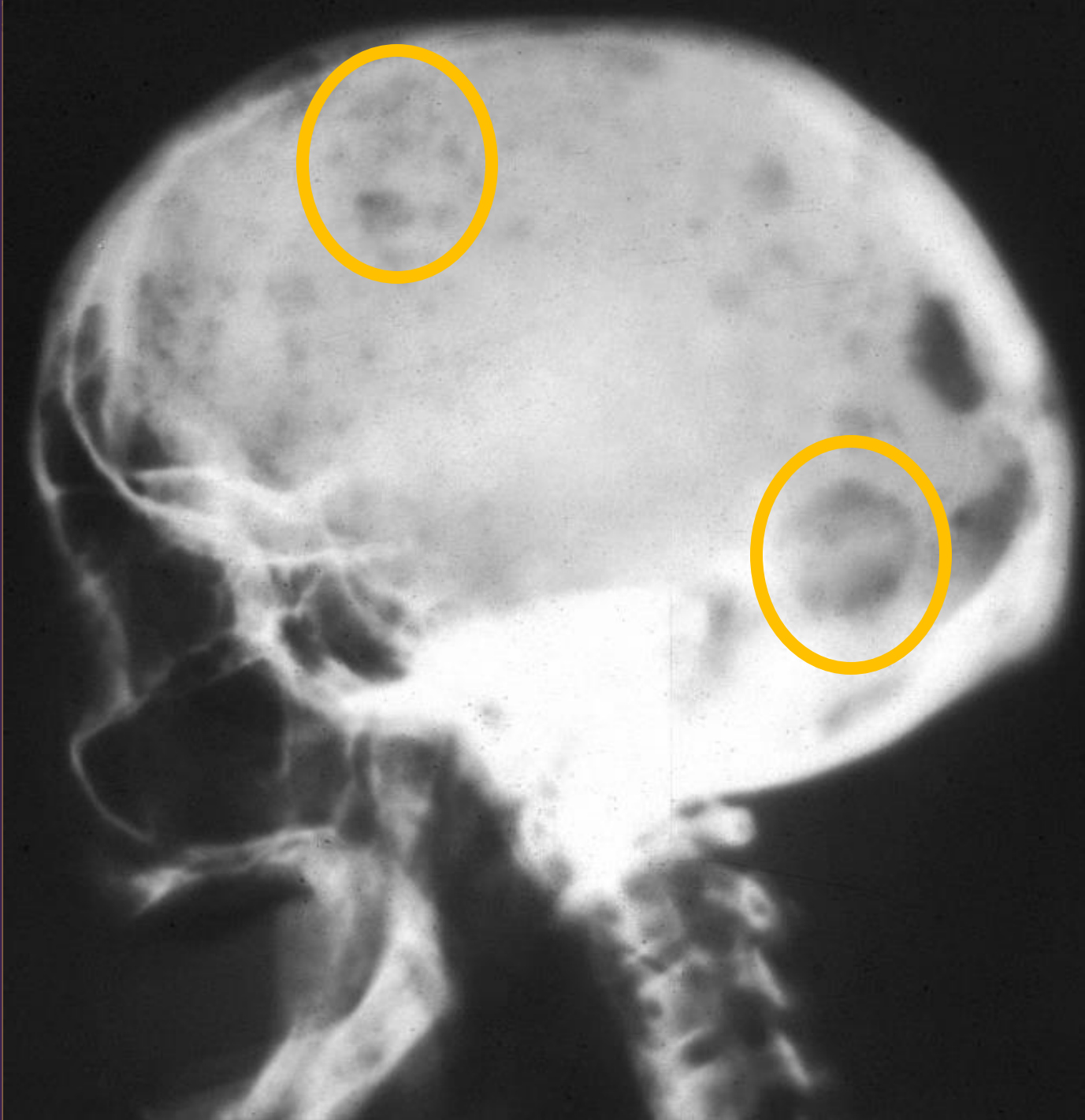
- LANGERHANS CELL HISTIOCYTOSIS (LCH)
- ENCHONDROMATOSIS
- FIBROUS DYSPLASIA
- HEREDITARY MULTIPLE EXOSTOSES (HME)
- OSTEOMYELITIS
- PAGET DISEASE
- NEUROFIBROMATOSIS (TYPE 1)
- ANGIOMATOUS LESIONS

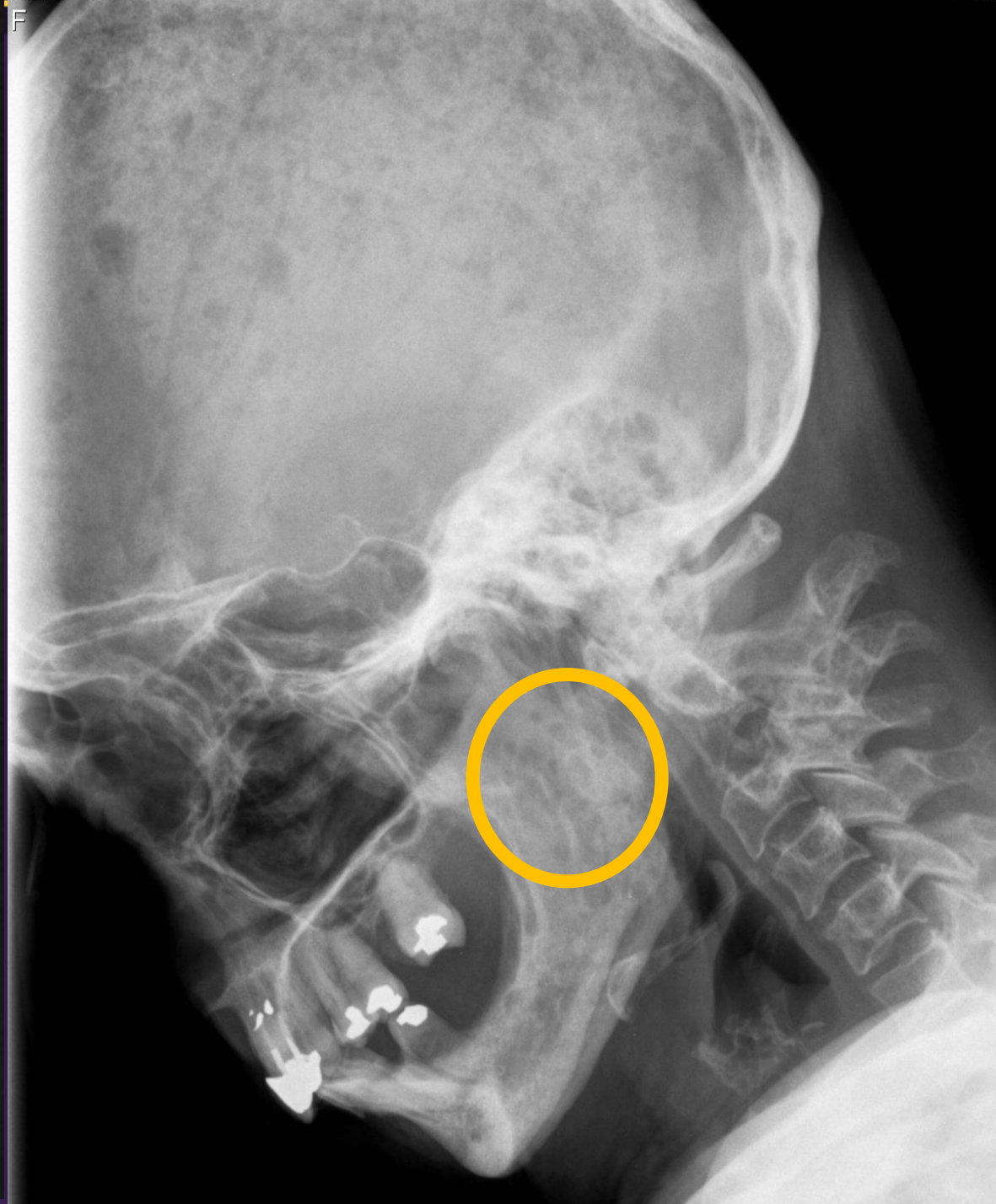


POLYOSTOTIC BONE LESIONS

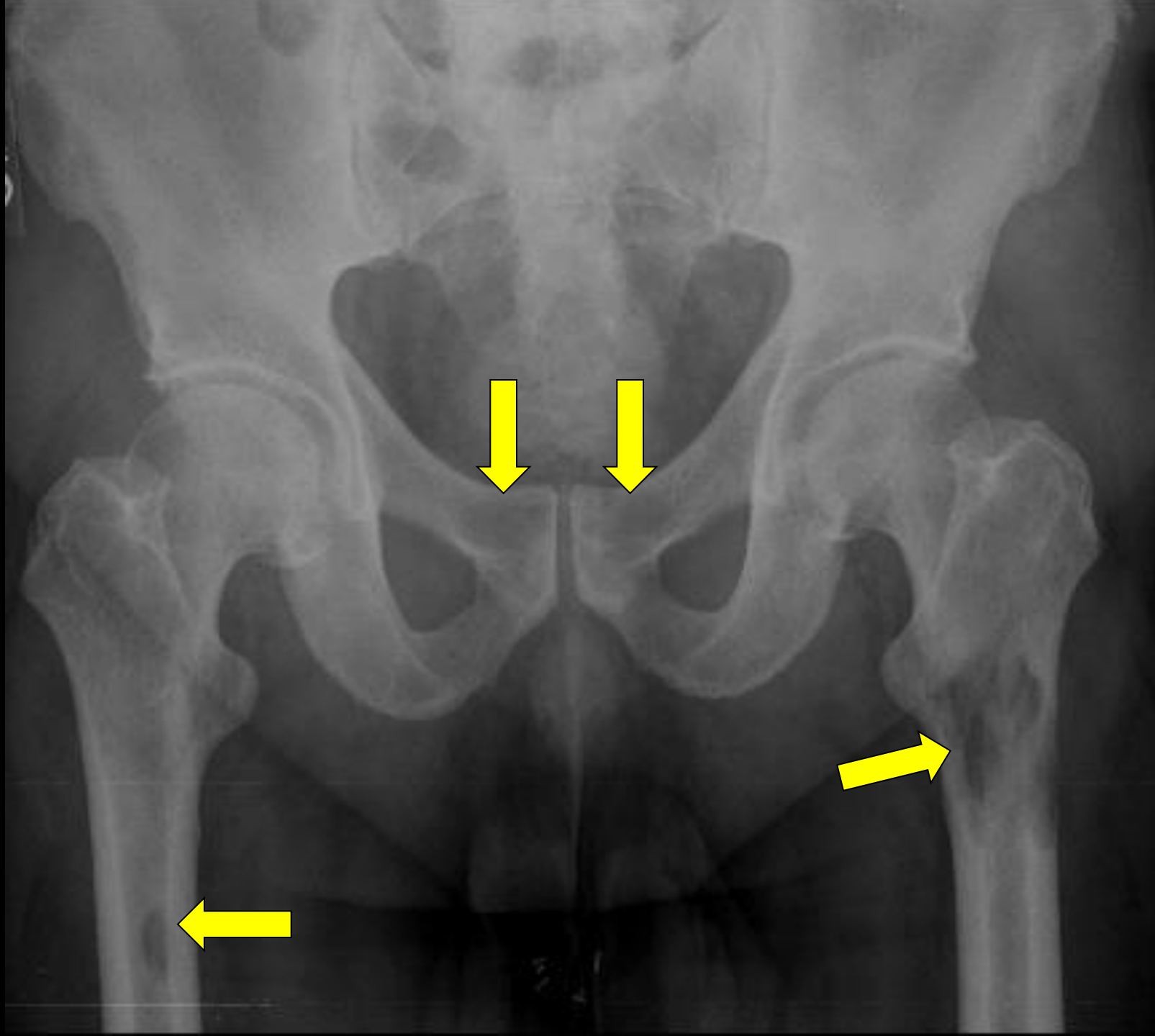
LYTIC: MALIGNANT

- Metastases
- Multiple Myeloma
- Lymphoma
- Angiomatous lesions







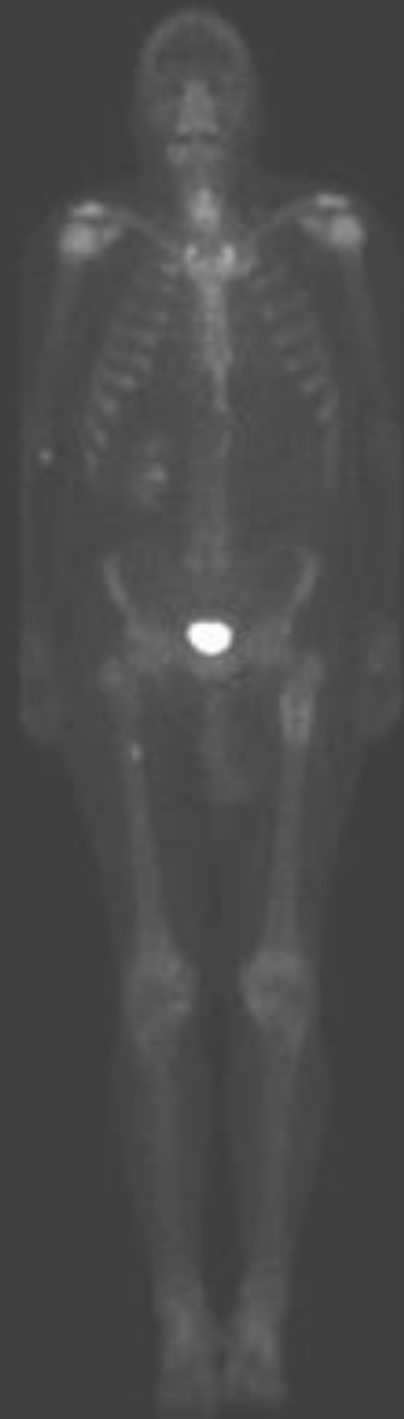
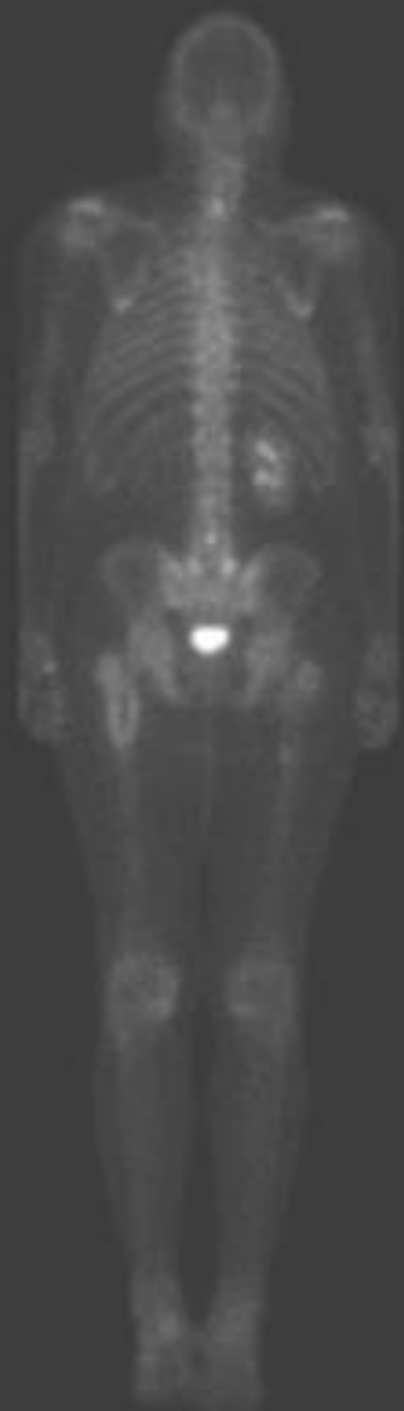






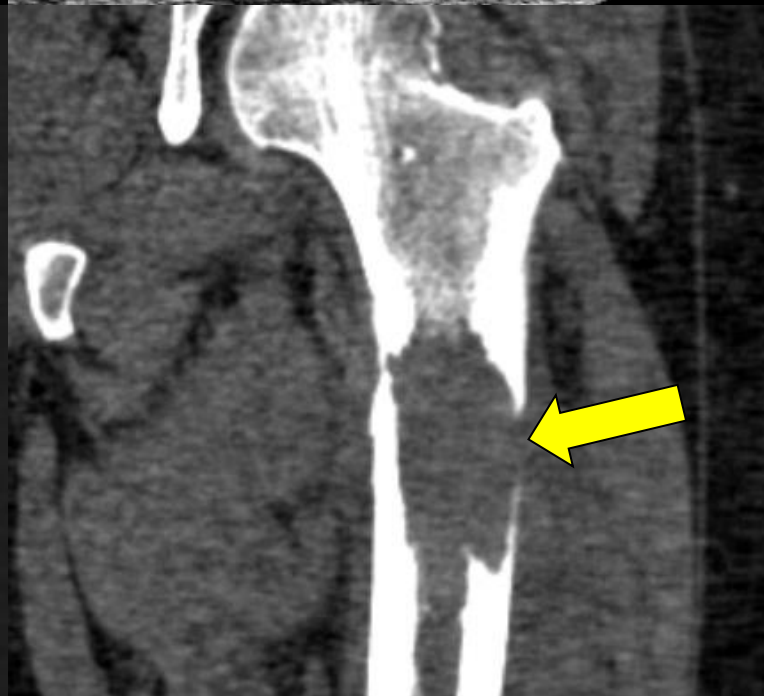
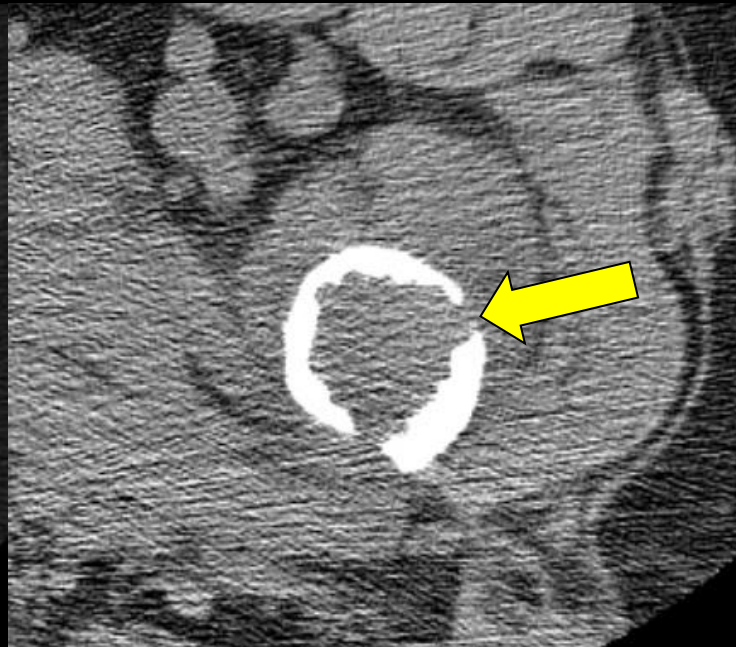
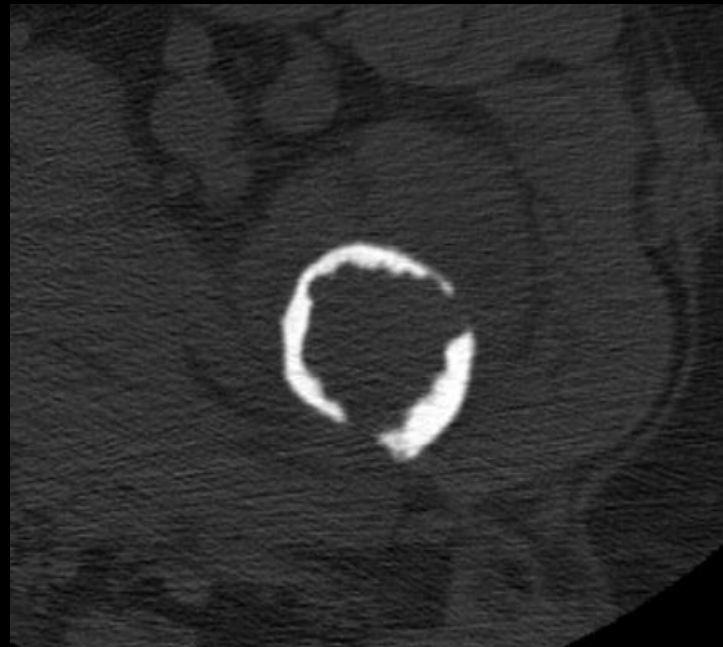
This patient is on your X-ray or MR/CT table. What do you do next?

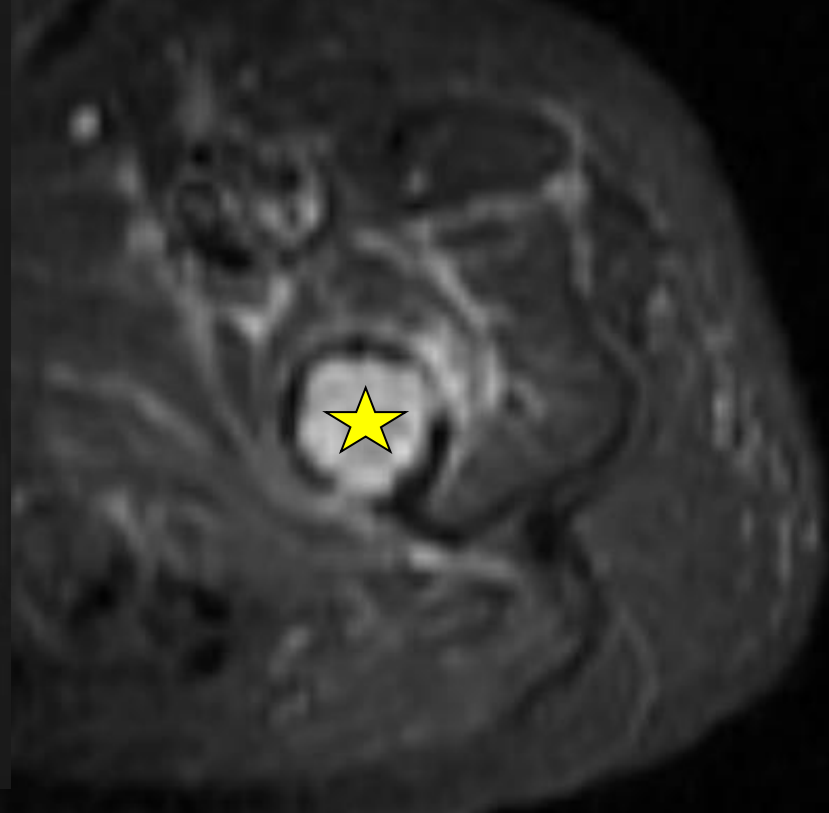
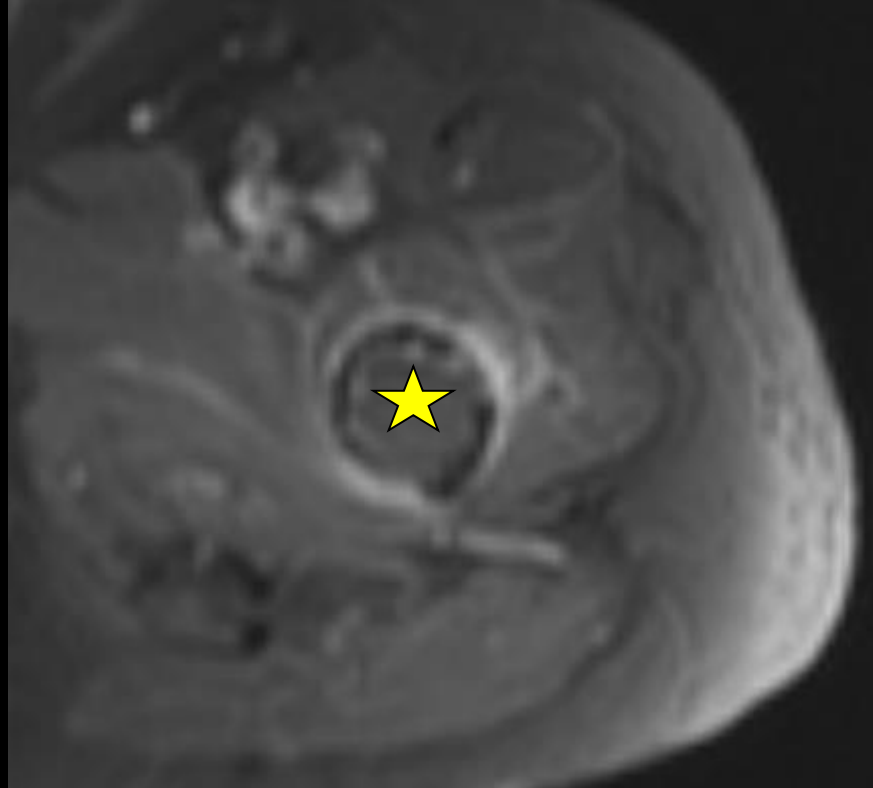
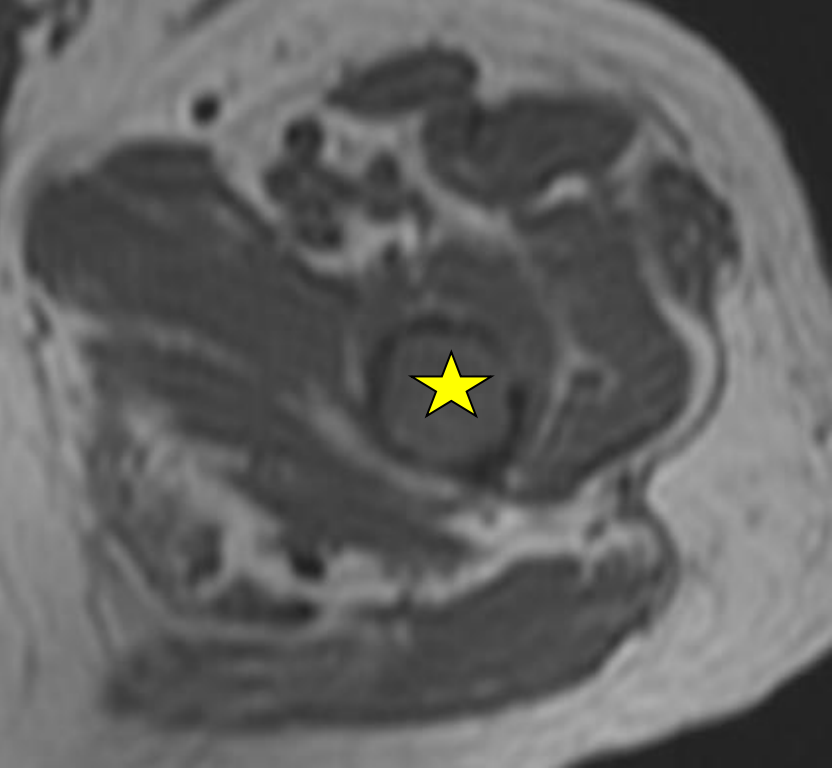
1. Read the study as mets/myeloma and move on
2. Ask for additional studies
3. Read the study as impending pathologic fracture
4. Not let the patient leave radiology weight-bearing



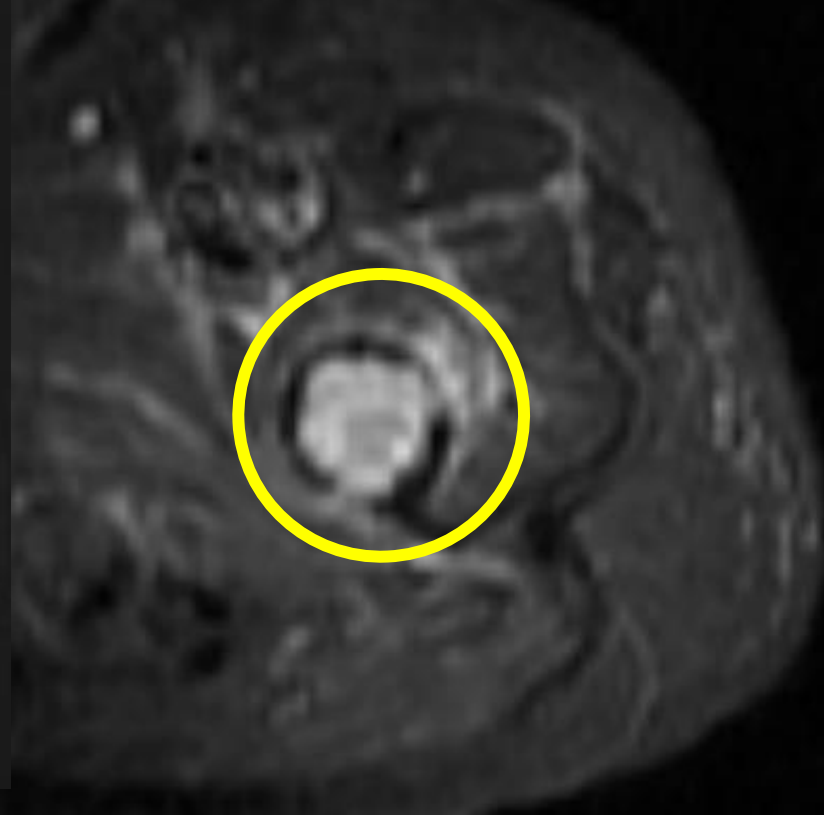
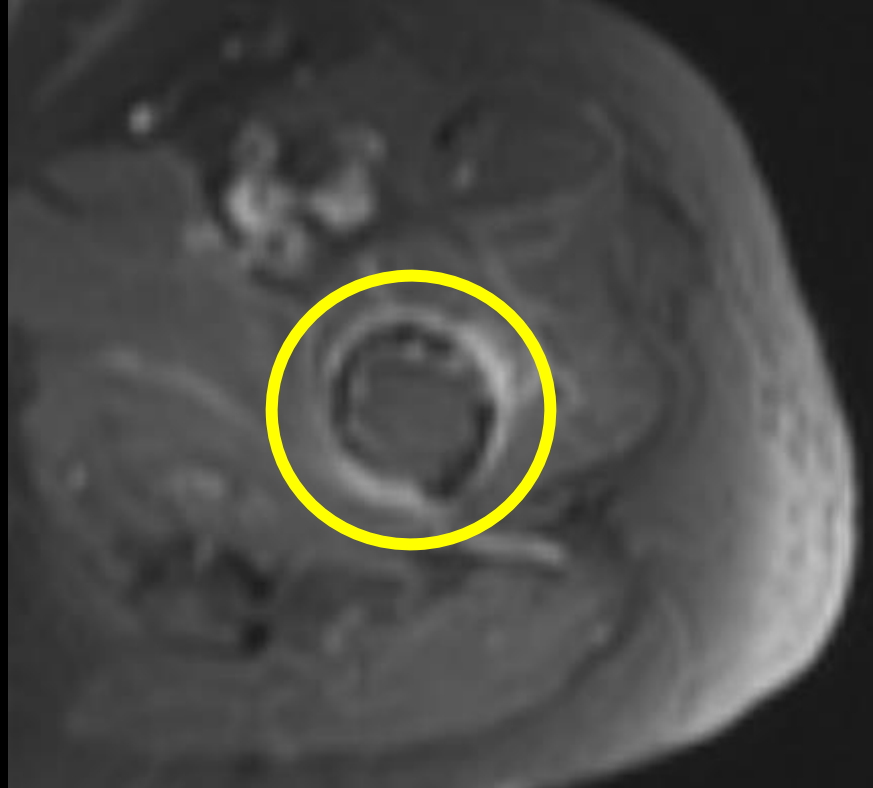
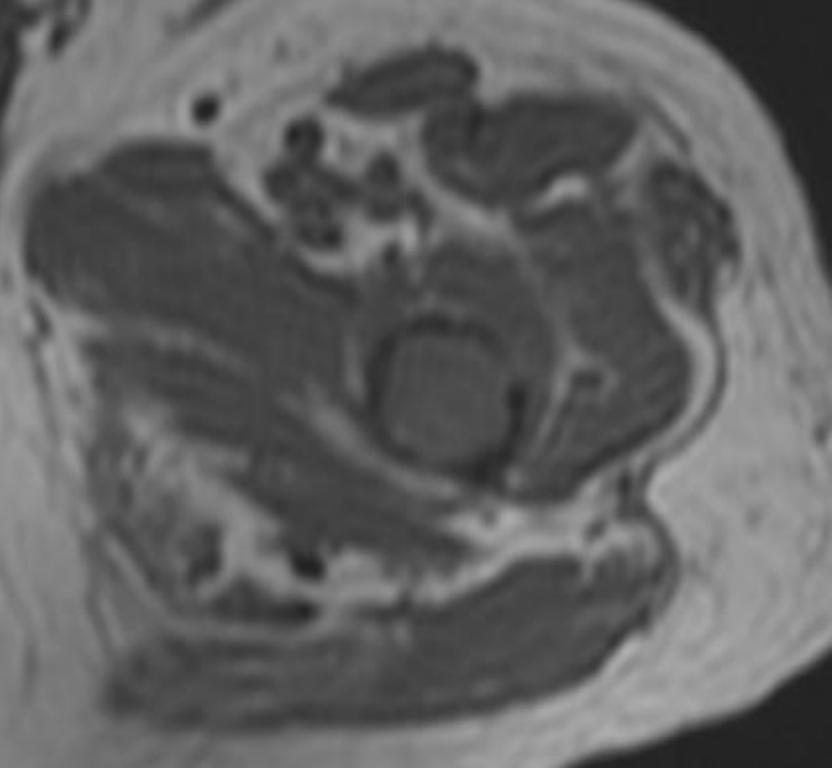
MIRELS CRITERIA

- Score of 1: upper extremity; blastic; $<1/3$ rd bone width; mild pain
- Score of 2: lower extremity; mixed sclerosis/lysis; $1/3$ - $2/3$ ds bone width; moderate pain
- Score of 3: peritrochanteric; lytic; $>2/3$ ds bone width; functional pain
- Total score ≥ 9 : Impending pathologic fracture treated with prophylactic stabilization
- Total score 8: Borderline consider prophylactic stabilization
- Total score ≤ 7 : Nonoperative care

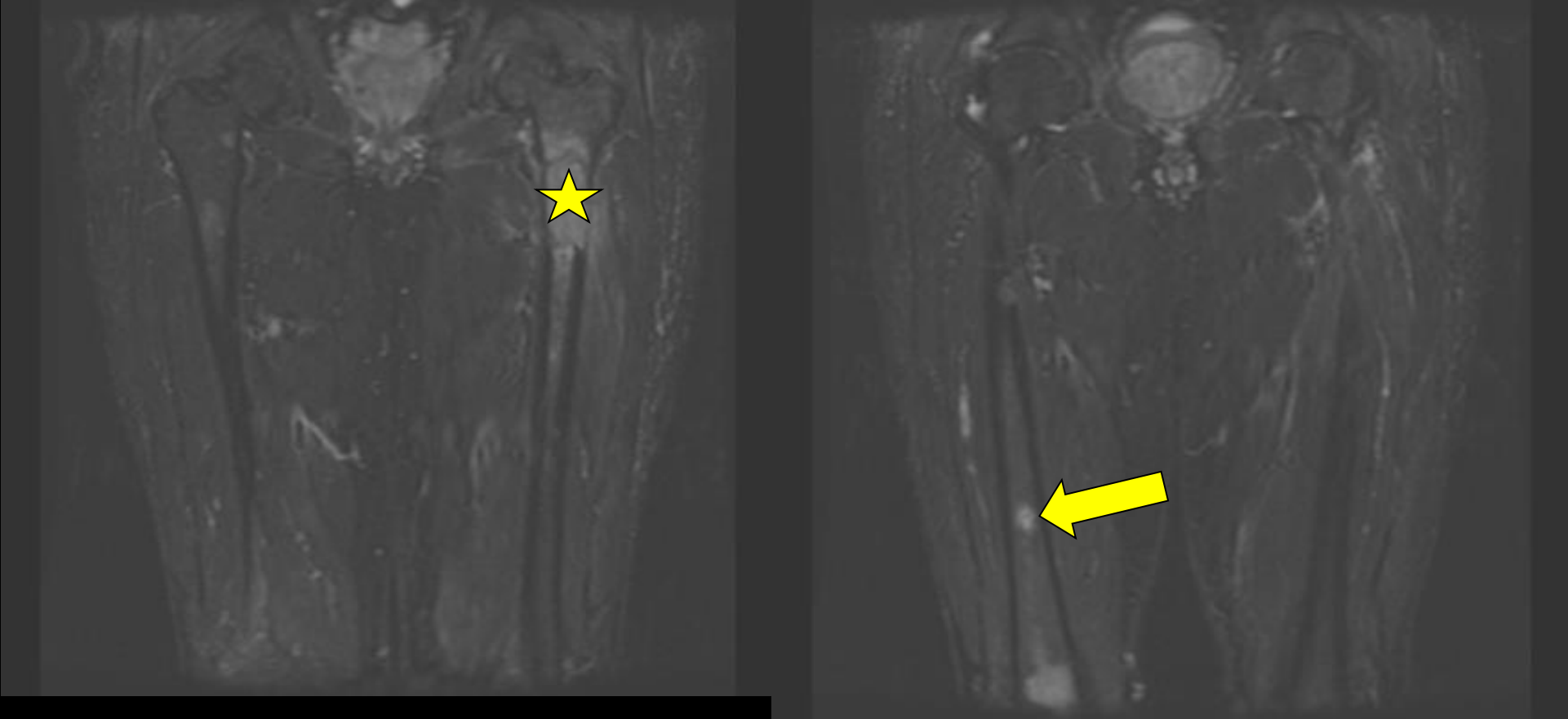




T1, T1 GD, T2 FS



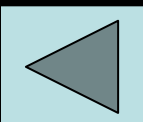
T1, T1 GD, T2 FS



Coronal STIR

POLYOSTOTIC BONE LESIONS: SCLEROTIC

- **Metastases** - prostate, breast, carcinoid, mucinous GI, transitional cell CA, lymphoma
- **Multiple fractures / Osteonecrosis**
- **Infection** - unusual organism/chronic
- **Paget** disease
- Mastocytosis / Myeloma (POEMS)
- Fibrous dysplasia
- **Osteopoikilosis**
- Sarcoid / Tuberous sclerosis



SOLITARY BONE LESION ANALYSIS

- Patient age/sex
- Bone involved and location – any
- Lesion margins – Radiographs > CT > MRI
- Matrix formation
 - Mineralized: CT > Radiographs > MRI
 - Nonmineralized: MRI > CT > Radiographs
- Periosteal reaction – Radiographs > CT > MRI
- Preoperative staging – MRI > CT > Radiographs
 - Lesion extent/affect on adjacent structures

Enneking MSK Tumor Society (MSTS)

Staging of Musculoskeletal Tumors

Stages 1–3. Histologically benign (G_0); variable clinical course and biologic behavior

Benign

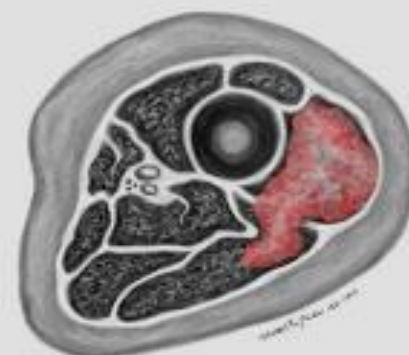
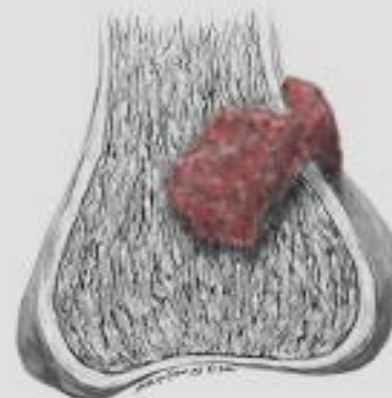
Stage 1. Remains static or heals spontaneously with indolent clinical course. Well encapsulated



Stage 2. Active; progressive, symptomatic growth. Remains intracapsular. Limited by natural boundaries but may often deform them



Stage 3. Aggressive; locally aggressive but not limited by capsule or natural boundaries. May penetrate cortex or compartment boundaries. Higher rate of recurrence



Stage III. Metastases;
regional or remote
(visceral, lymphatic,
or osseous)

CT chest
PET/CT



AMERICAN JOINT COMMISSION STAGING PROTOCOL FOR SARCOMA OF BONE* (2017)

- **Histologic grade (G)**
 - G1 low grade (well differentiated)
 - G2 high grade (moderately differentiated)
 - G3 high grade (poorly differentiated)
- **Primary Tumor (T)**
 - T1 tumor 8cm or less in greatest dimension
 - T2 tumor more than 8cm in greatest dimension
 - T3 discontinuous tumor in the primary site
- **Regional lymph nodes (N)**
 - N0 no regional lymph node metastasis; N1 regional lymph node metastasis
- **Distant metastasis (M)**
 - M0 no distant metastasis
 - M1 (a) metastasis to lung; (b) metastasis to bone or other distant sites

AMERICAN JOINT COMMITTEE ON CANCER STAGING FOR PRIMARY MALIGNANT TUMORS OF APPENDICULAR SKELETON* (2017)

Stage	Tumor	Lymph Node	Metastases	Grade
IA	T1	N0	M0	G1 or GX
IB	T2/T3	N0	M0	G1 or GX
IIA	T1	N0	M0	G2 or G3
IIB	T2	N0	M0	G2 or G3
III	T3	N0	M0	G2 or G3
IVA	Any T	N0	M1a	Any G
IVB	Any T	N1	Any M	Any G
IVB	Any T	Any N	M1b	Any G

LESION EXTENT OSSEOUS NEOPLASM

- Important/vital for staging
- Intramedullary/S.T. extent - MRI > CT > Radiographs
- Cortical Involvement/location
 - MRI=CT (current literature)
 - CT > MRI (my opinion)
- Neurovascular involvement - MRI > CT
- Joint involvement - MRI > CT

INTRAMEDULLARY/SOFT TISSUE EXTENT MUSCULOSKELETAL NEOPLASM

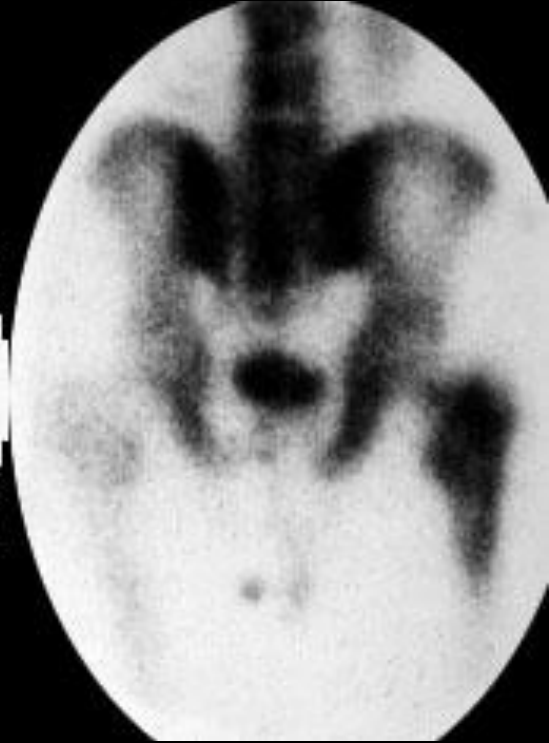
- MRI superior to CT
 - Superior contrast resolution
 - Multiplanar imaging capability
- Regional metastases-osseous/lymph node
- Can be helpful to direct biopsy
 - Always perform in consultation with orthoped
 - Done in institution of definitive procedure
- Give orthoped anatomic landmarks!!!



ANT



POST





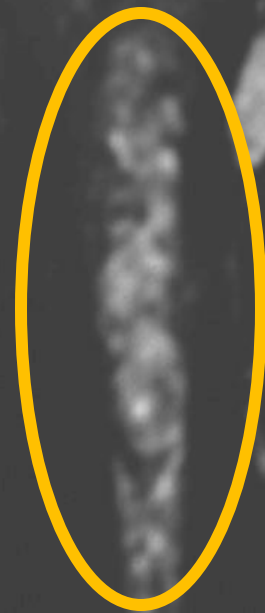
T1

S160

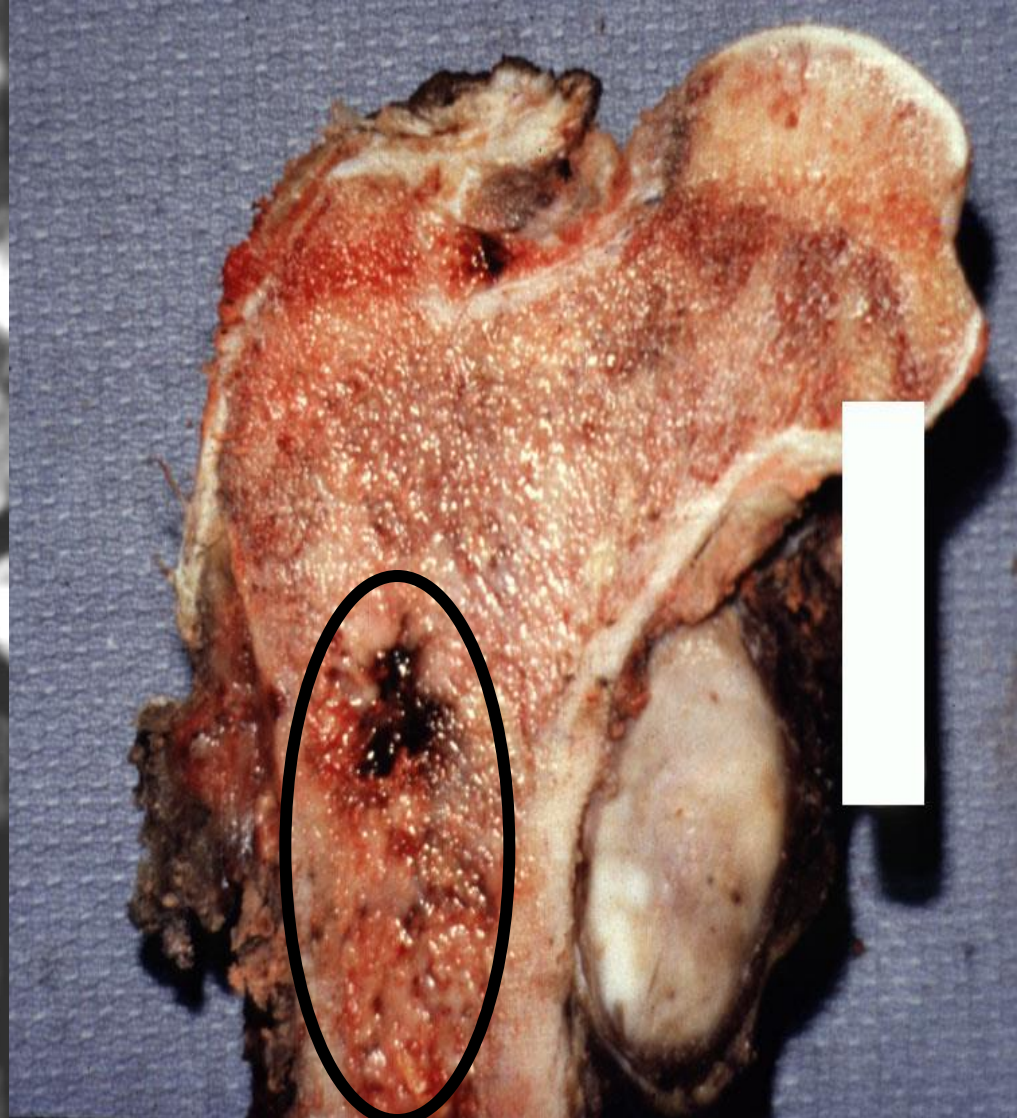


T160

T2

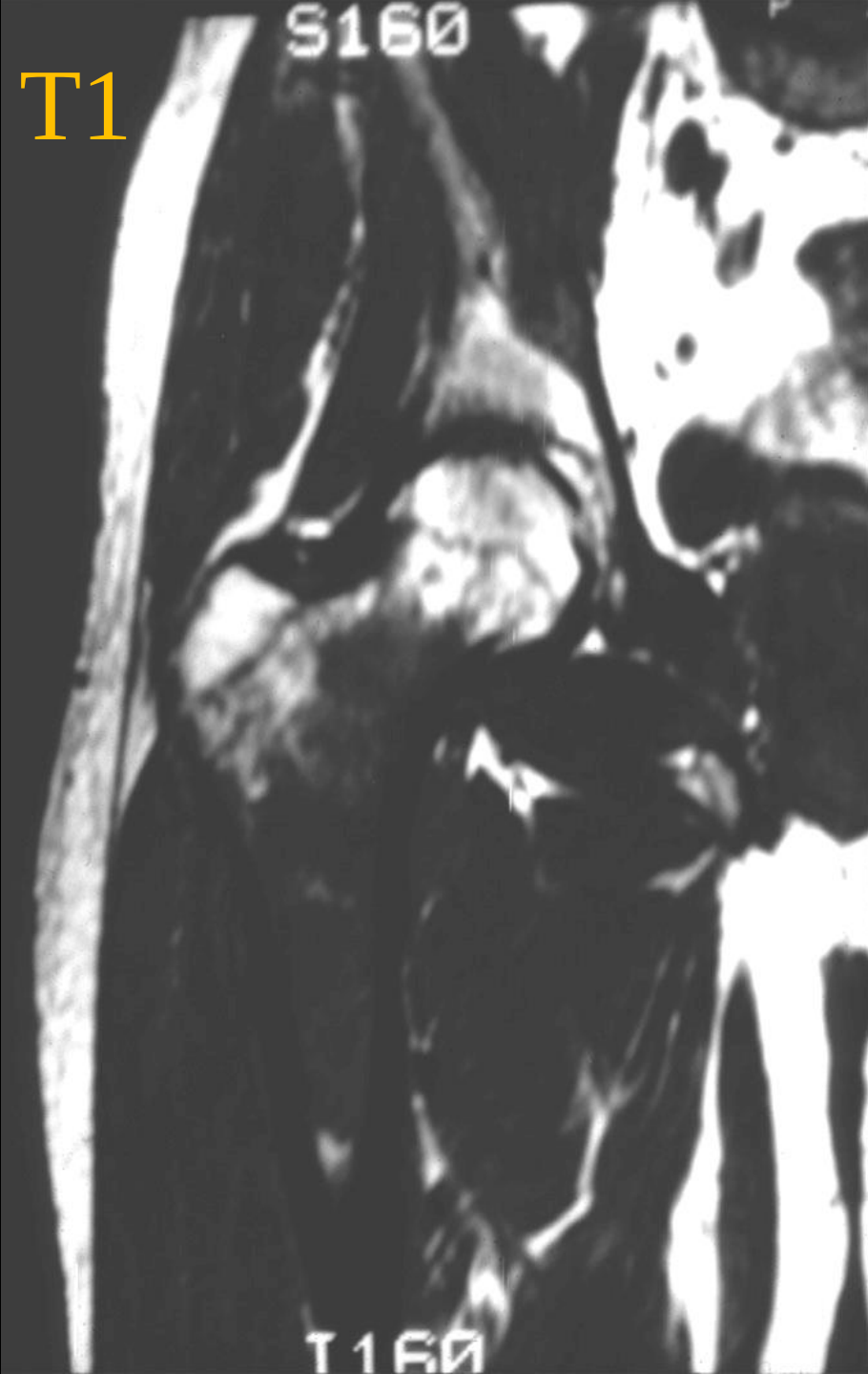


I160

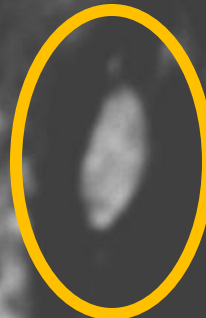


T1

S160

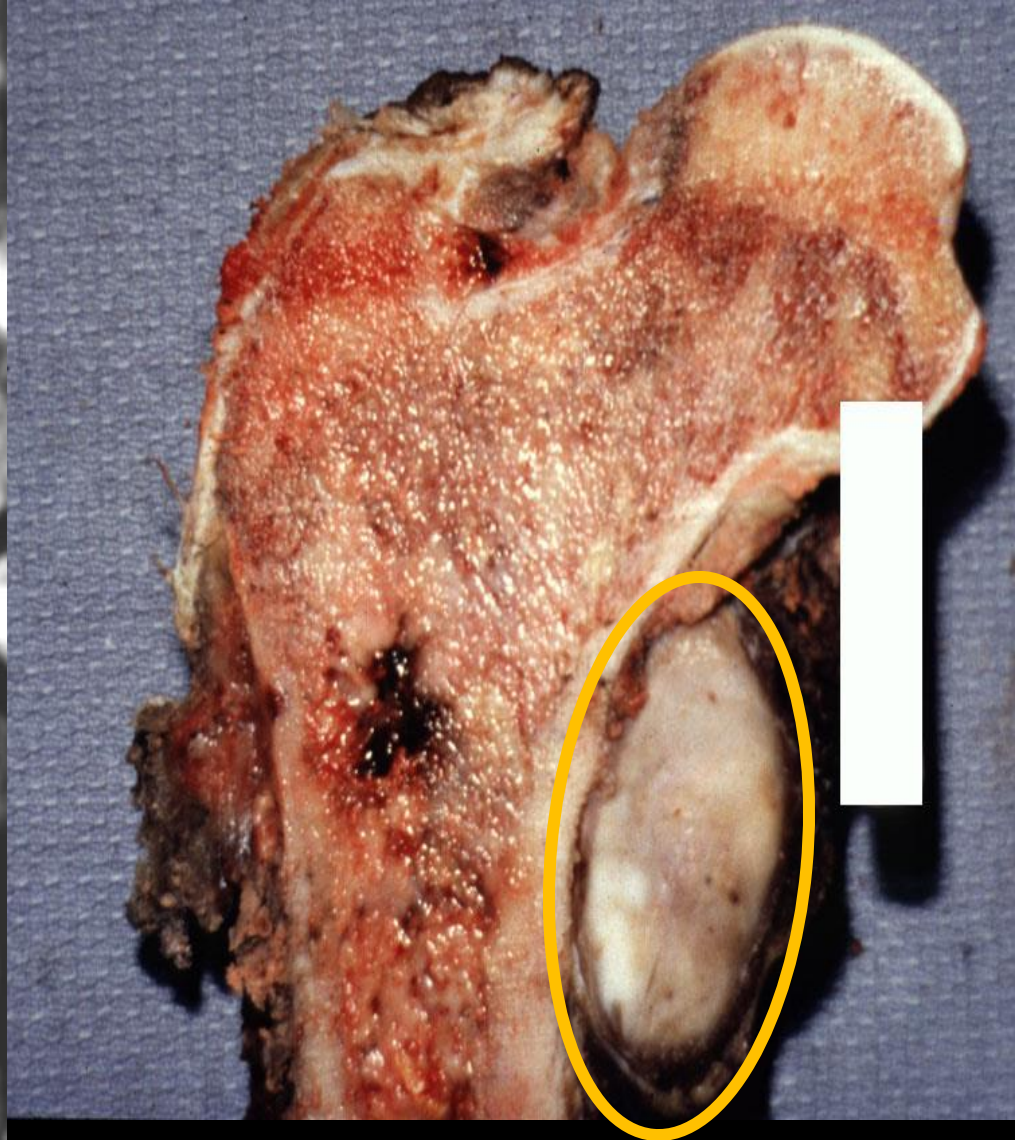


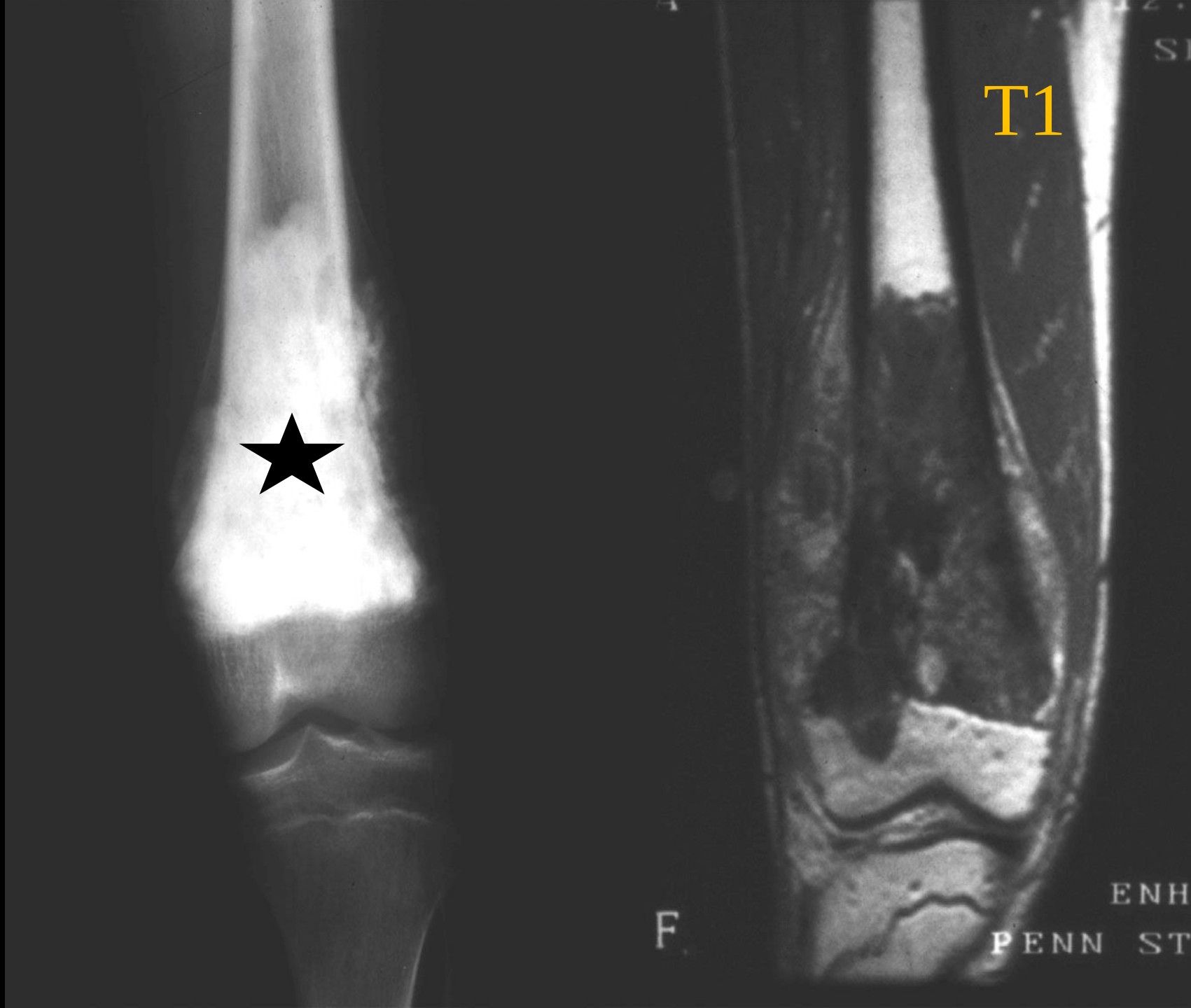
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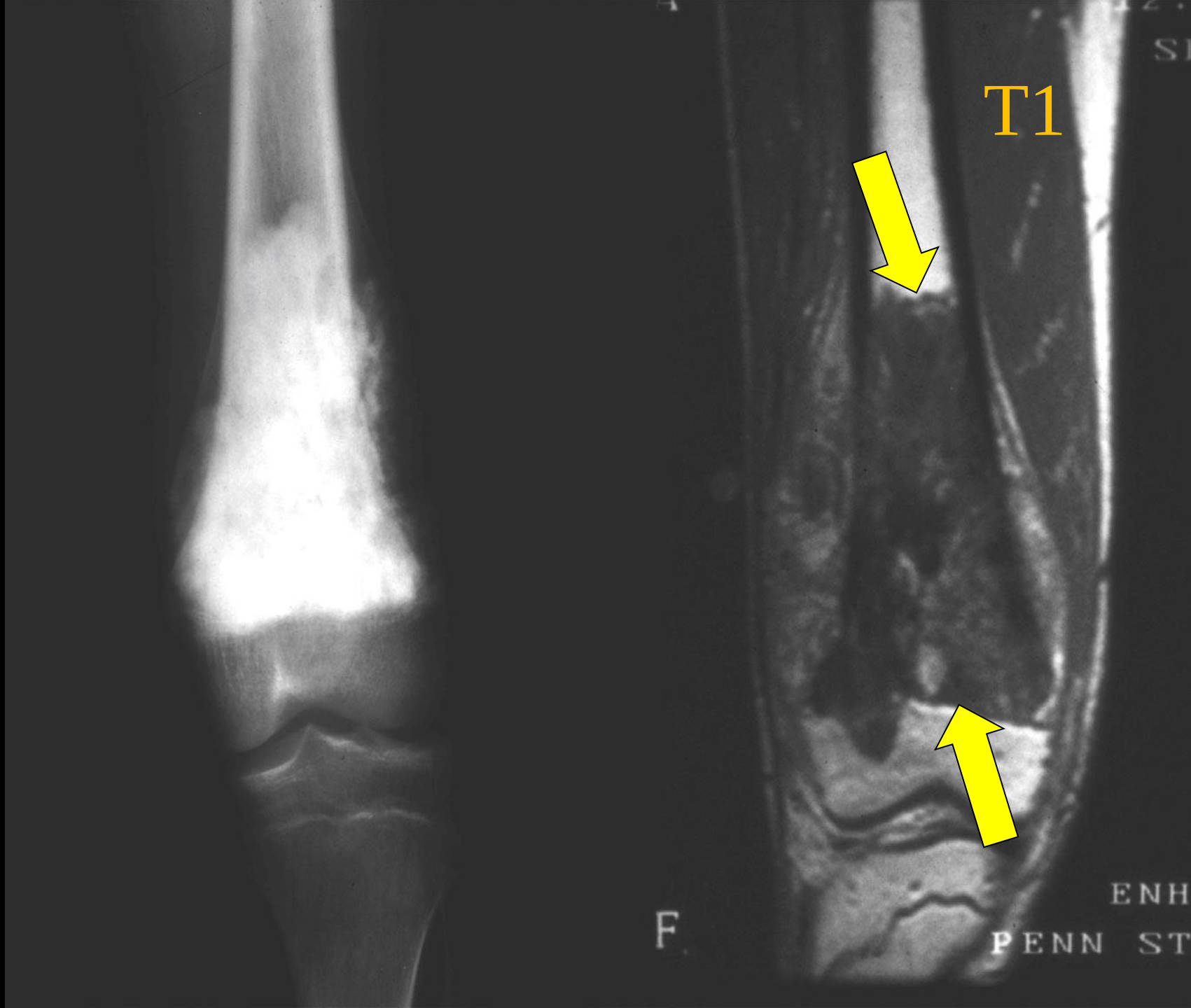


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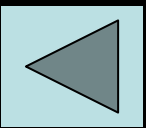












MUSCULOSKELETAL NEOPLASM NEUROVASCULAR INVOLVEMENT

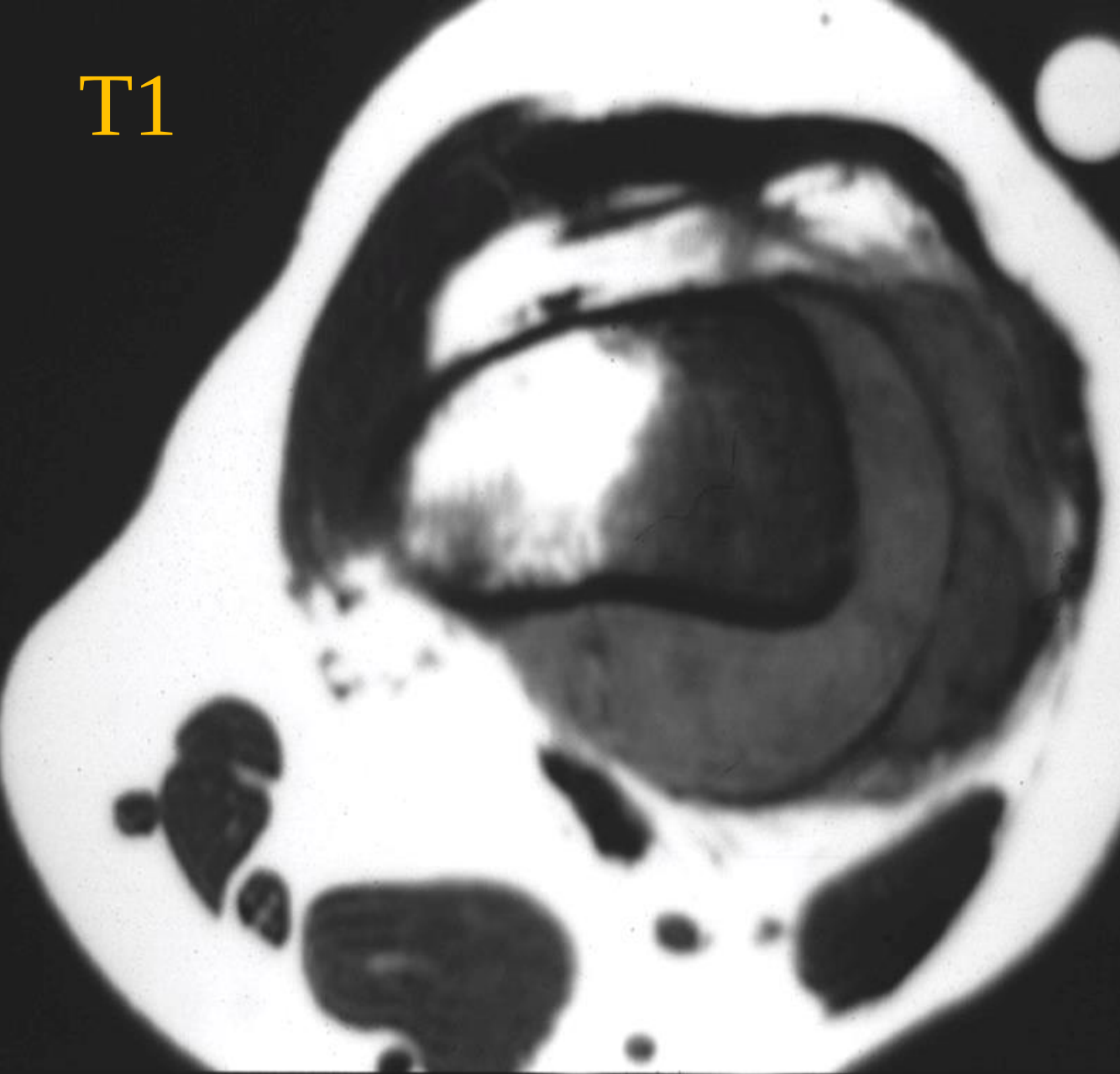
- Vital information for surgical resection
- MRI > CT (post-contrast if use CT-CTA)
- Improved contrast resolution
- Multiplanar MR images and MRA findings of stenosis highly specific/sensitive with accuracy of 84% for both
- 9% in soft tissue sarcomas; 3.3% of primary bone tumors

MUSCULOSKELETAL NEOPLASM NEUROVASCULAR INVOLVEMENT

- Axial plane usually best
- Look for intact fat plane
 - Best on T1W images
- If fat plane lost cannot exclude involvement
- Soft tissue mass encase vessels - definite involvement

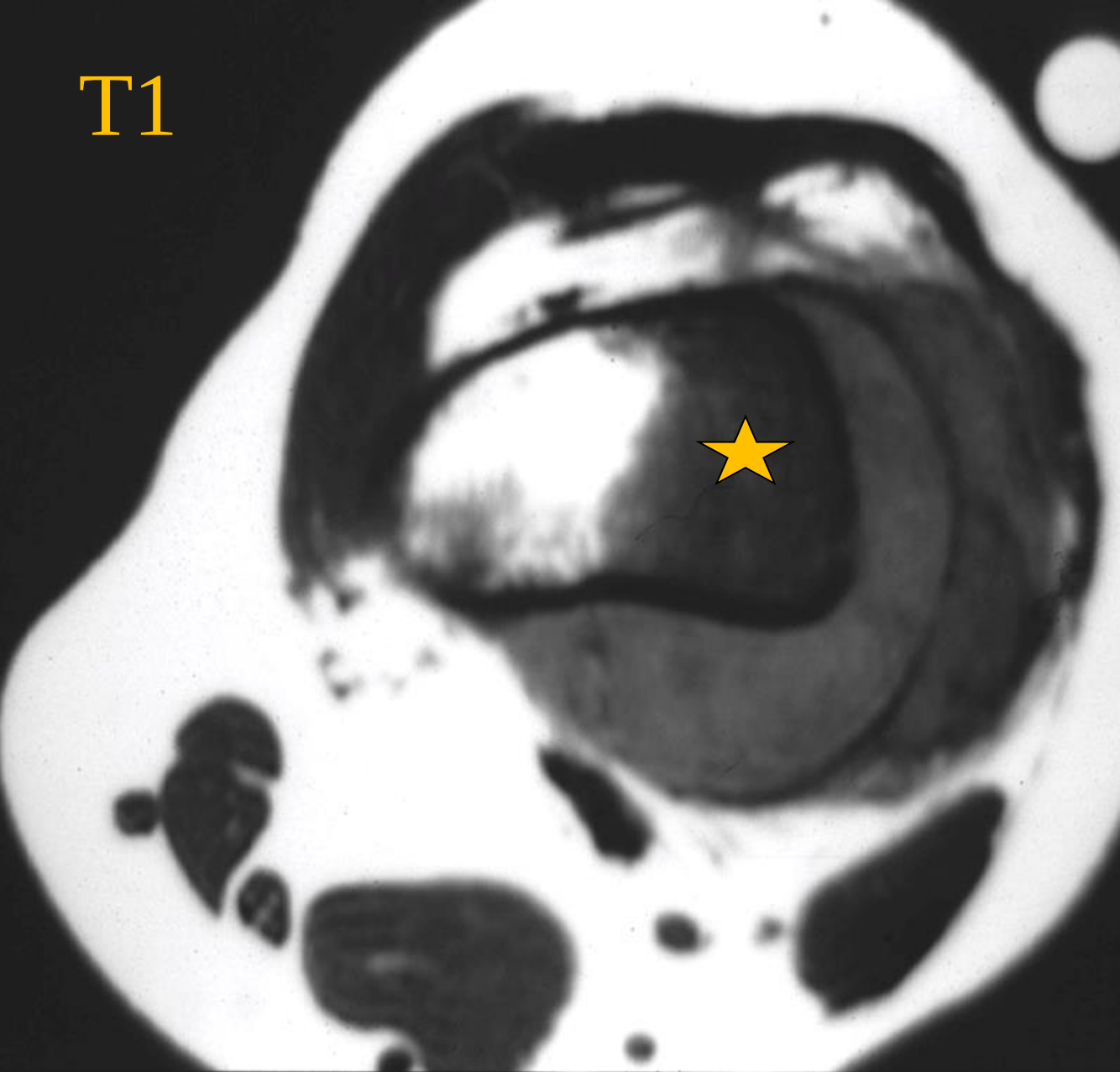


T1



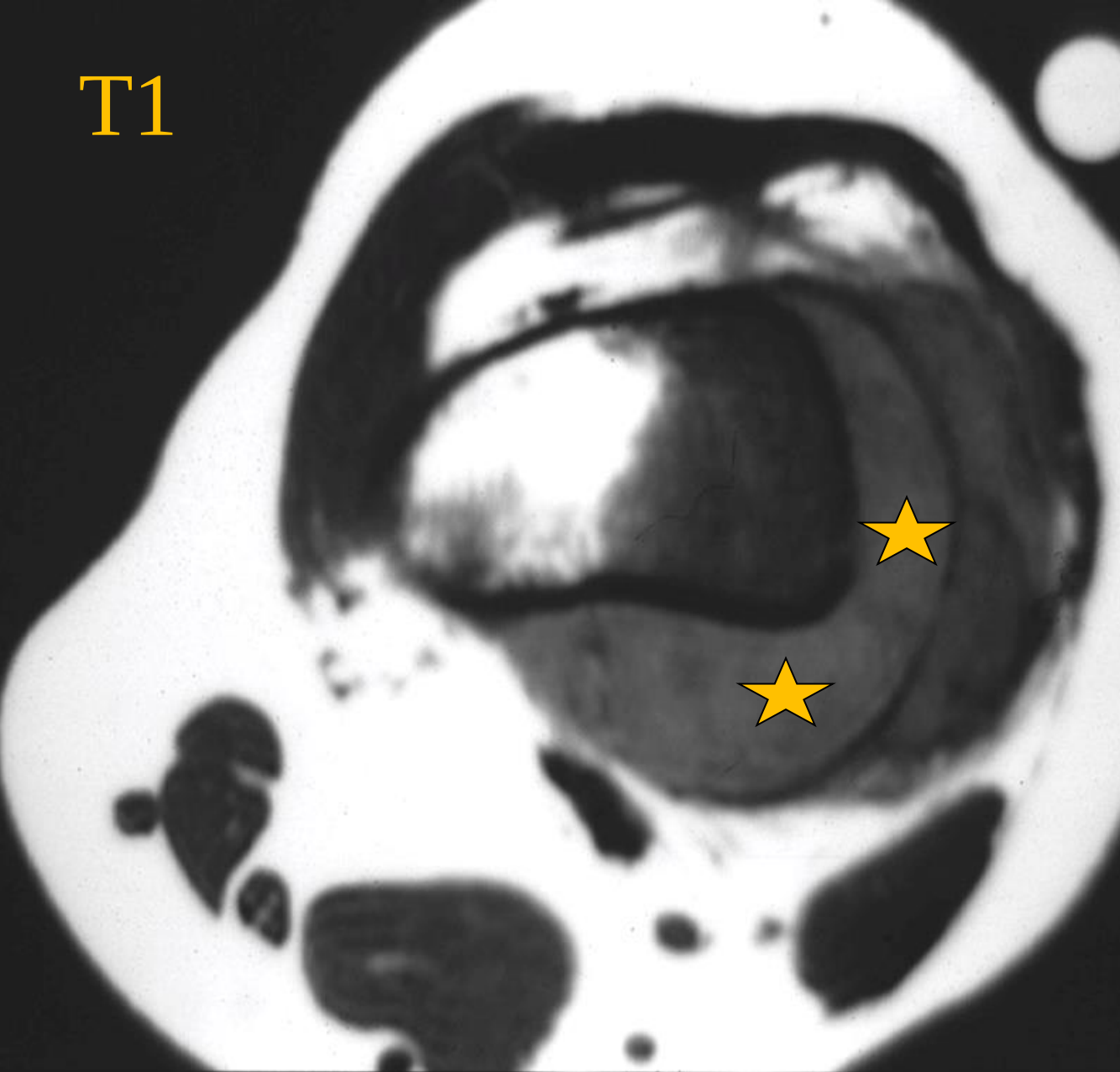
Alta Am Frazin MD

T1



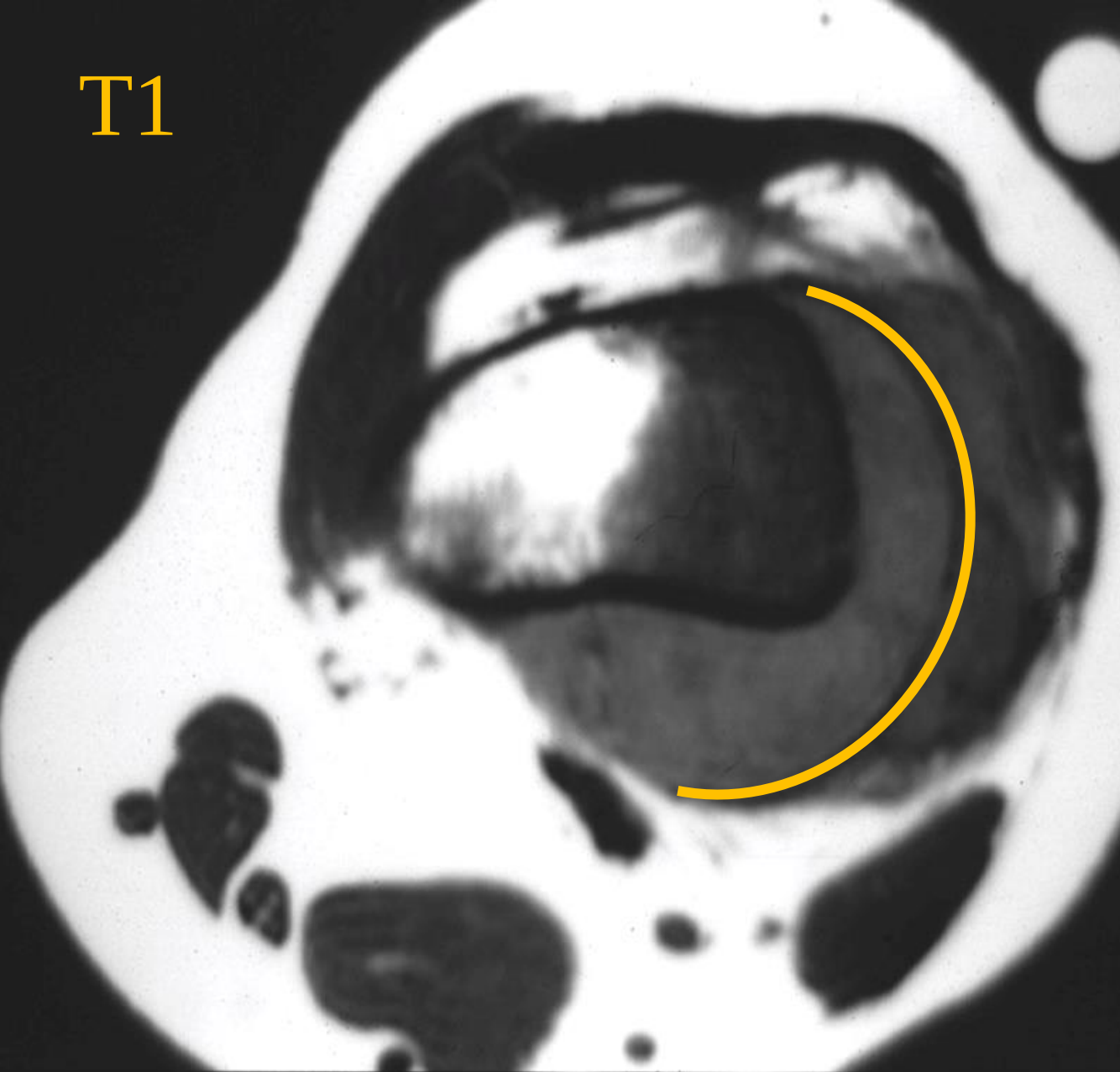
Alta Ann Frazier MD

T1



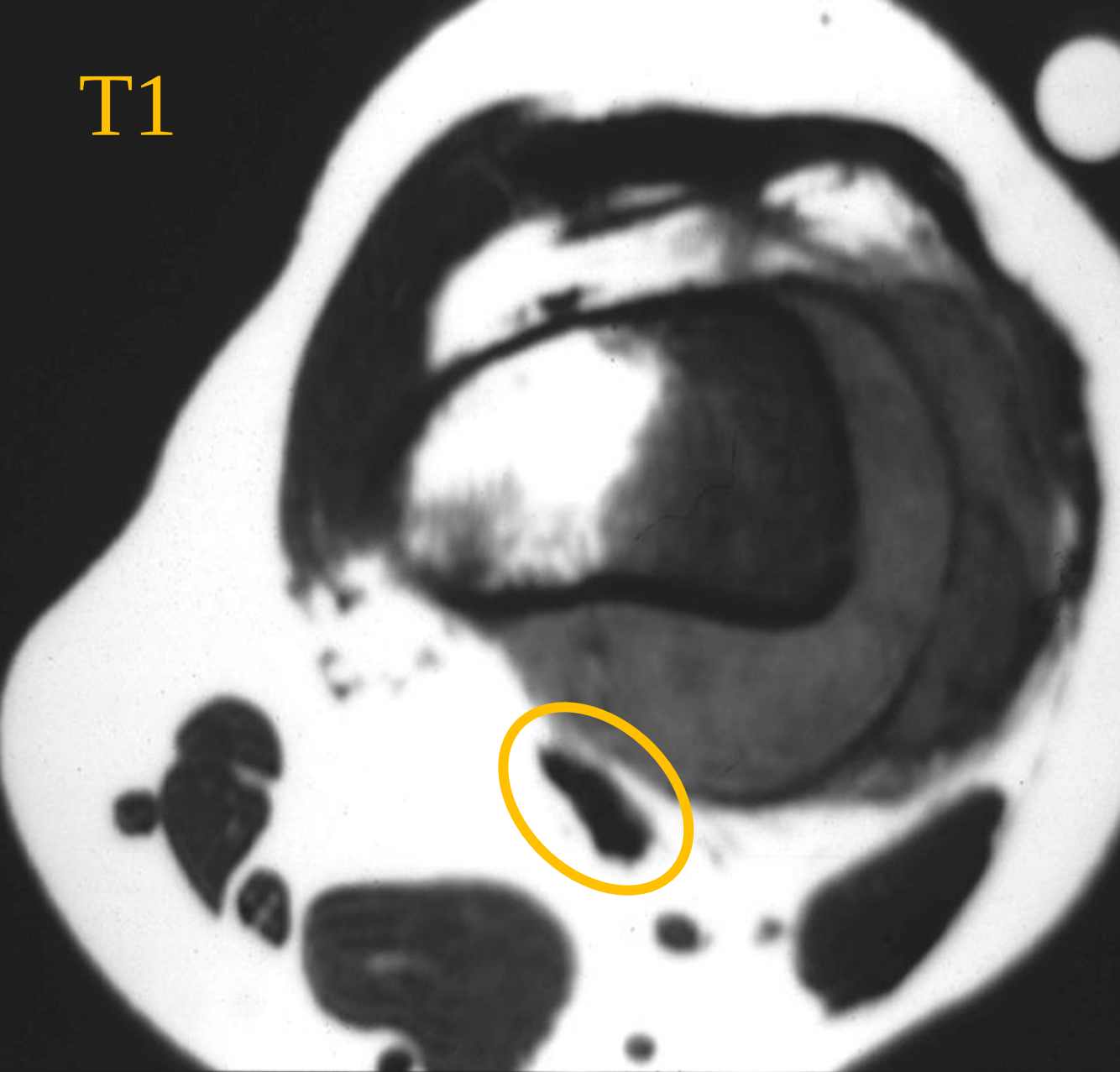
Alta Ann Frazin MD

T1



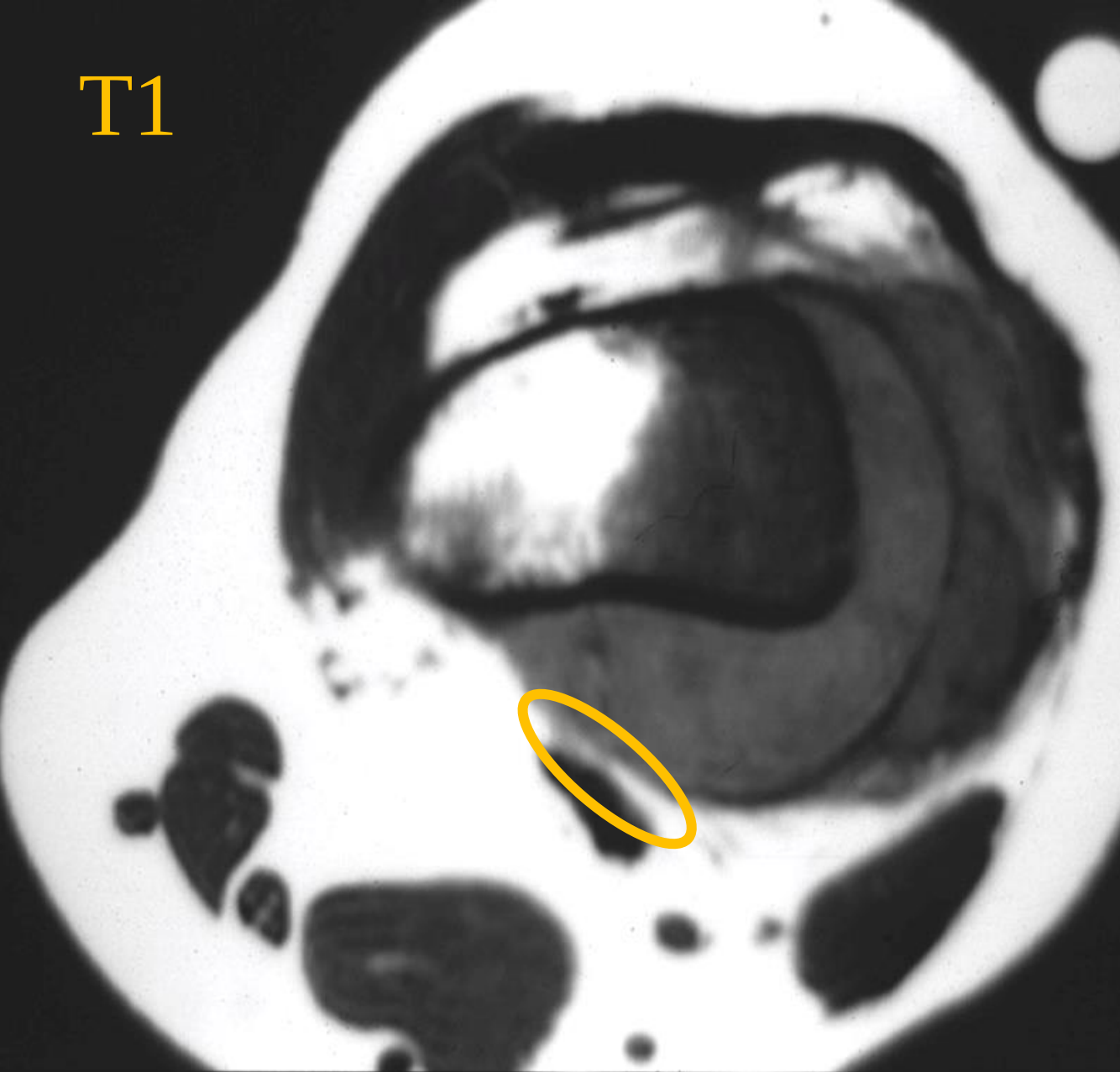
Alta Am Frazin MD

T1



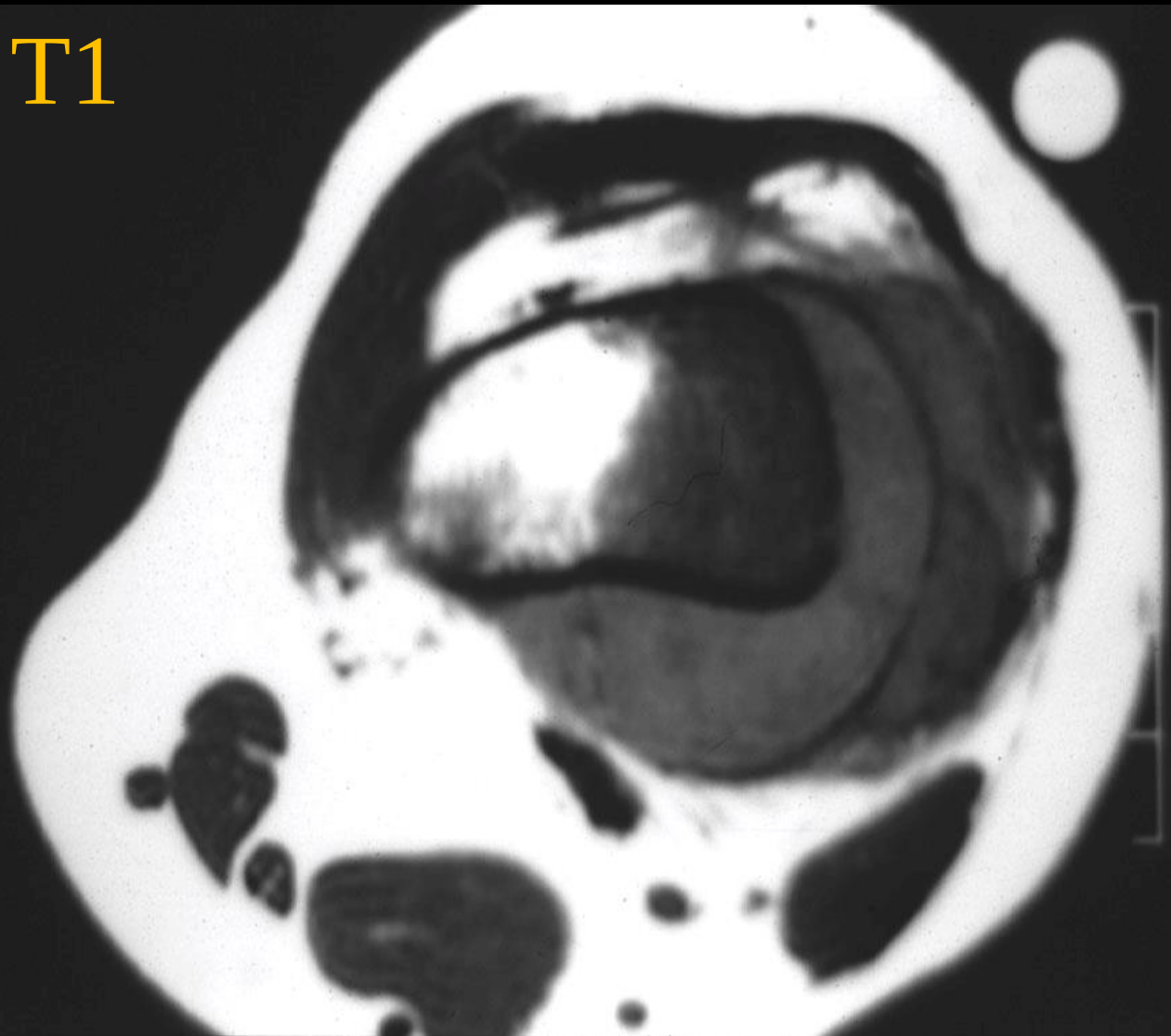
Alta Am Frazin MD

T1



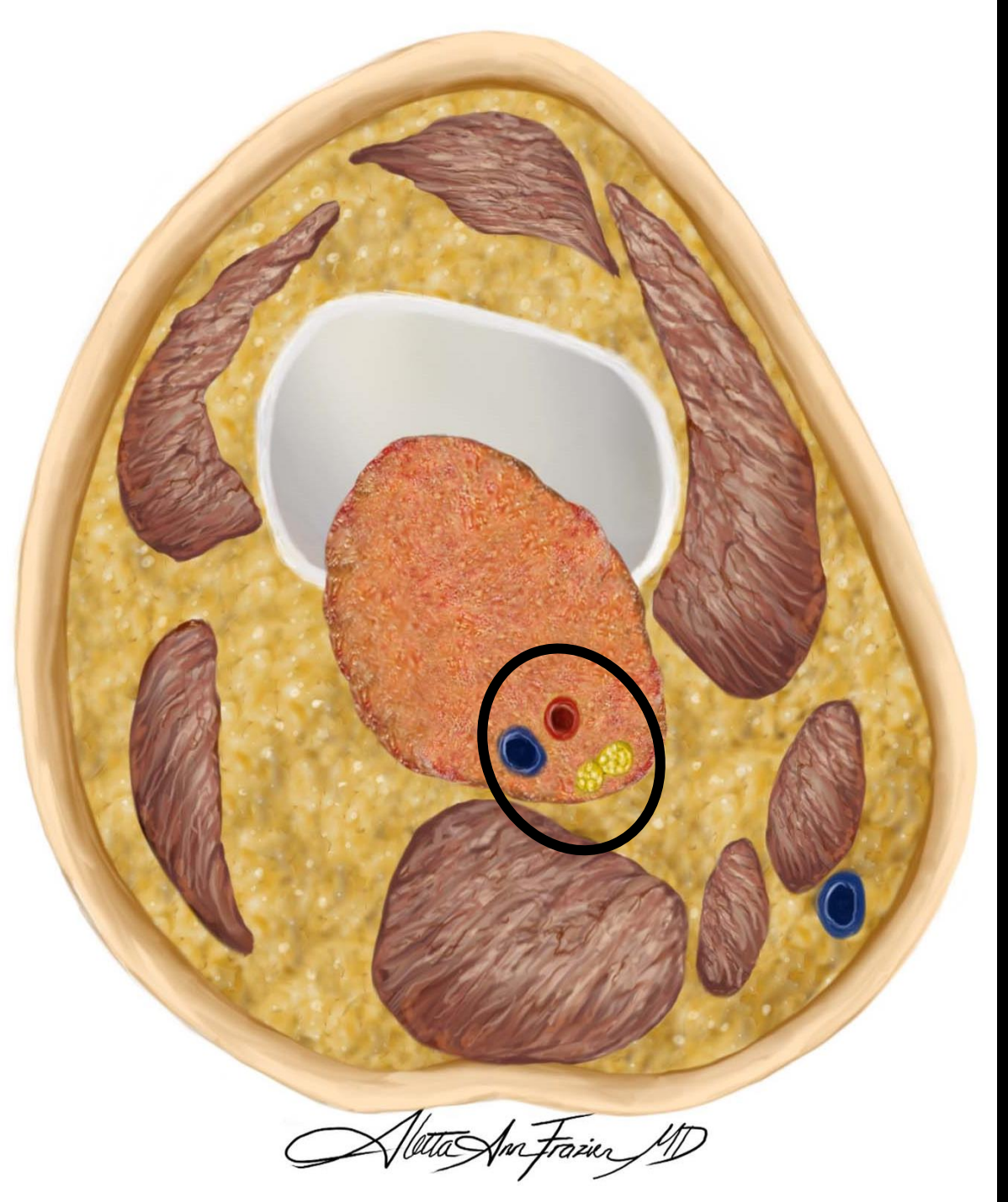
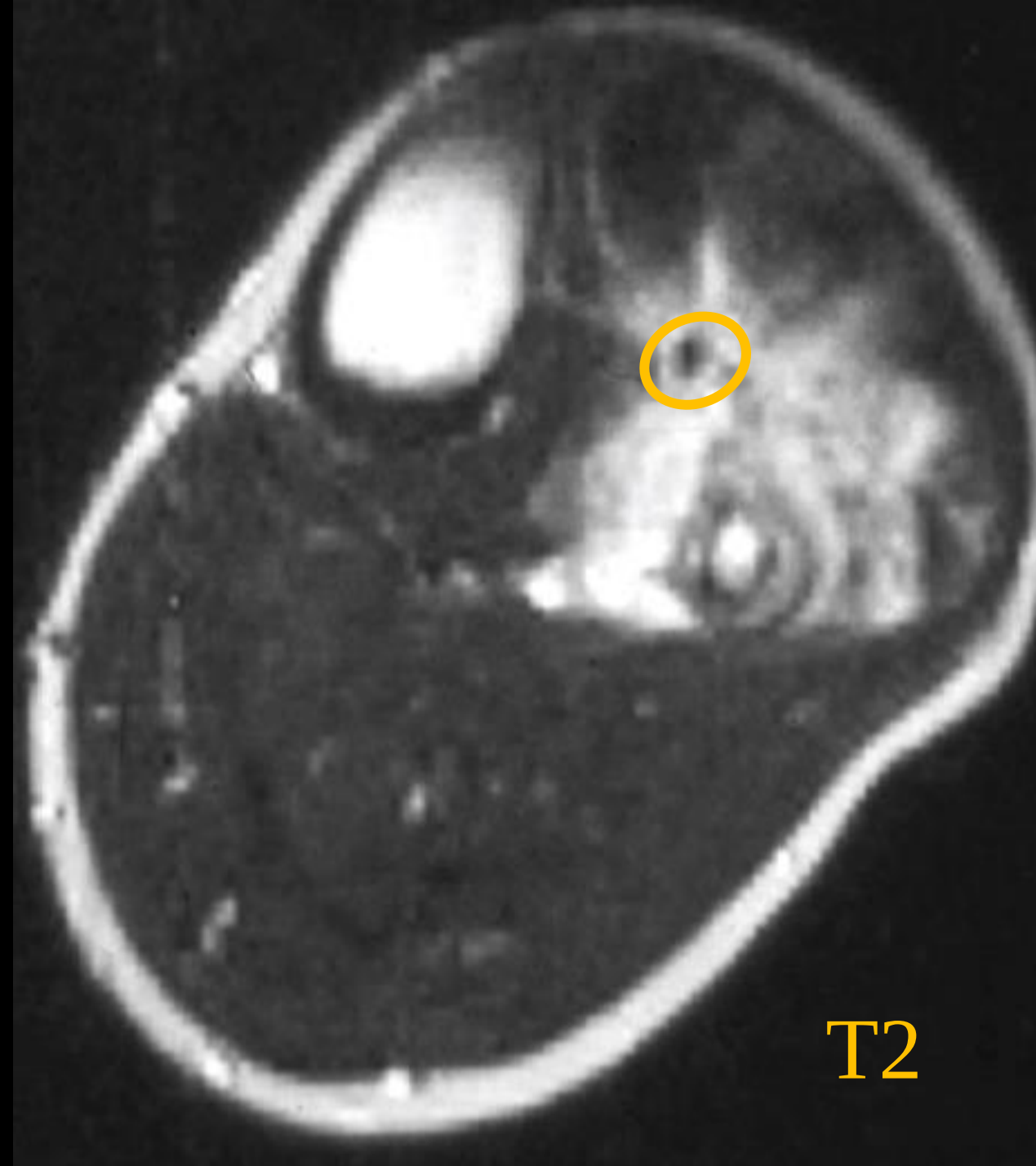
Alta Am Frazin MD

T1

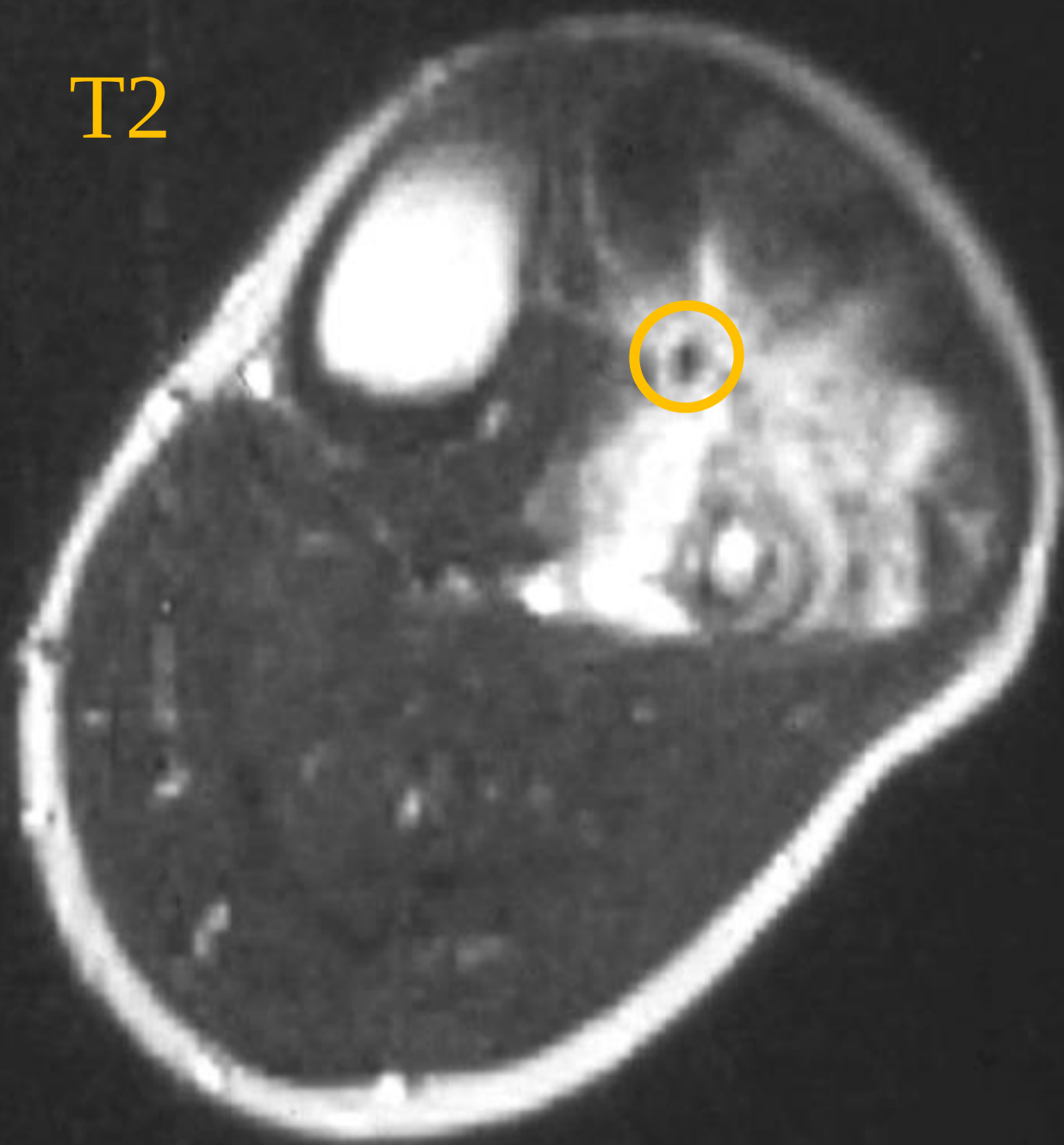


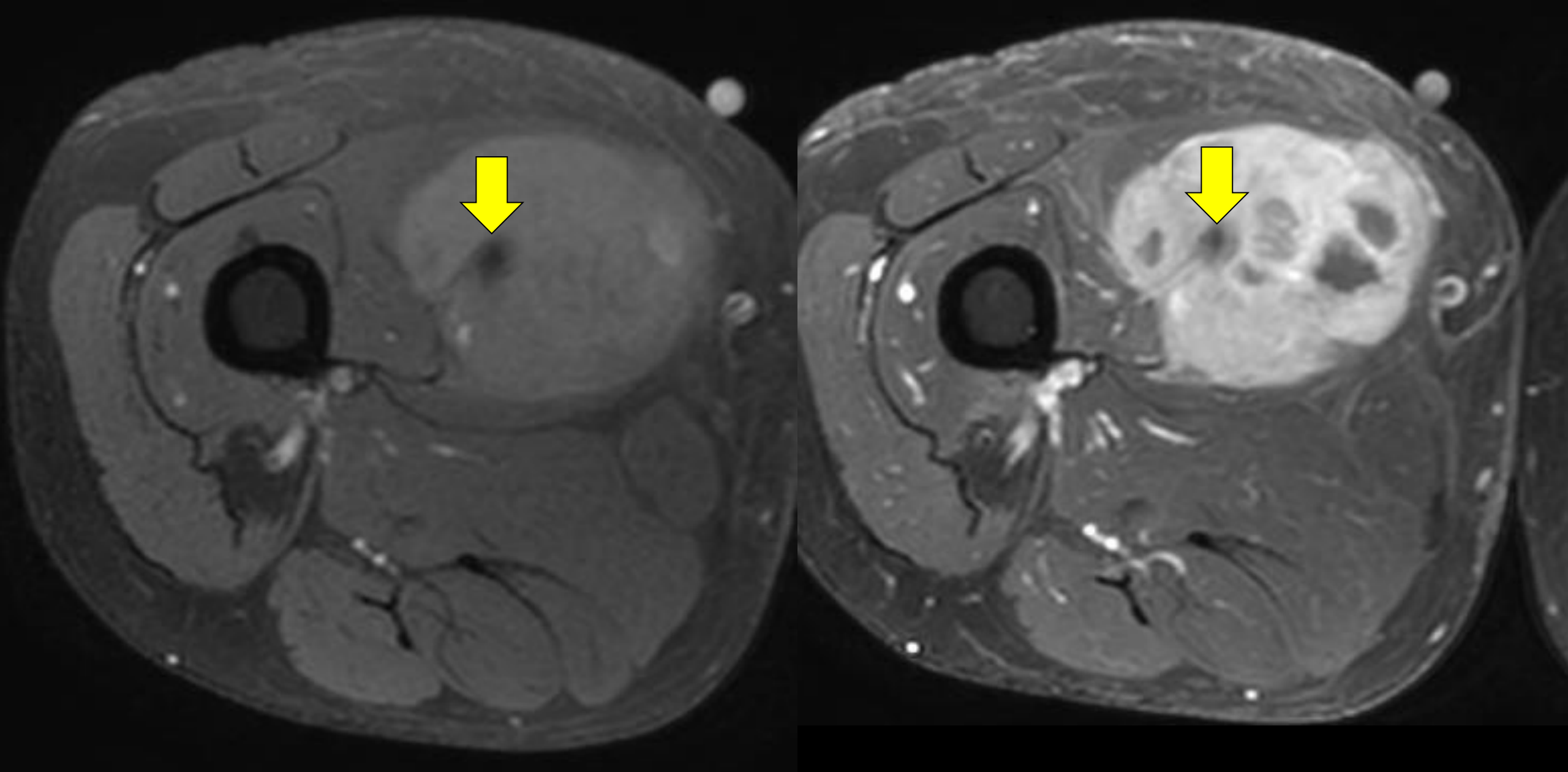
T2



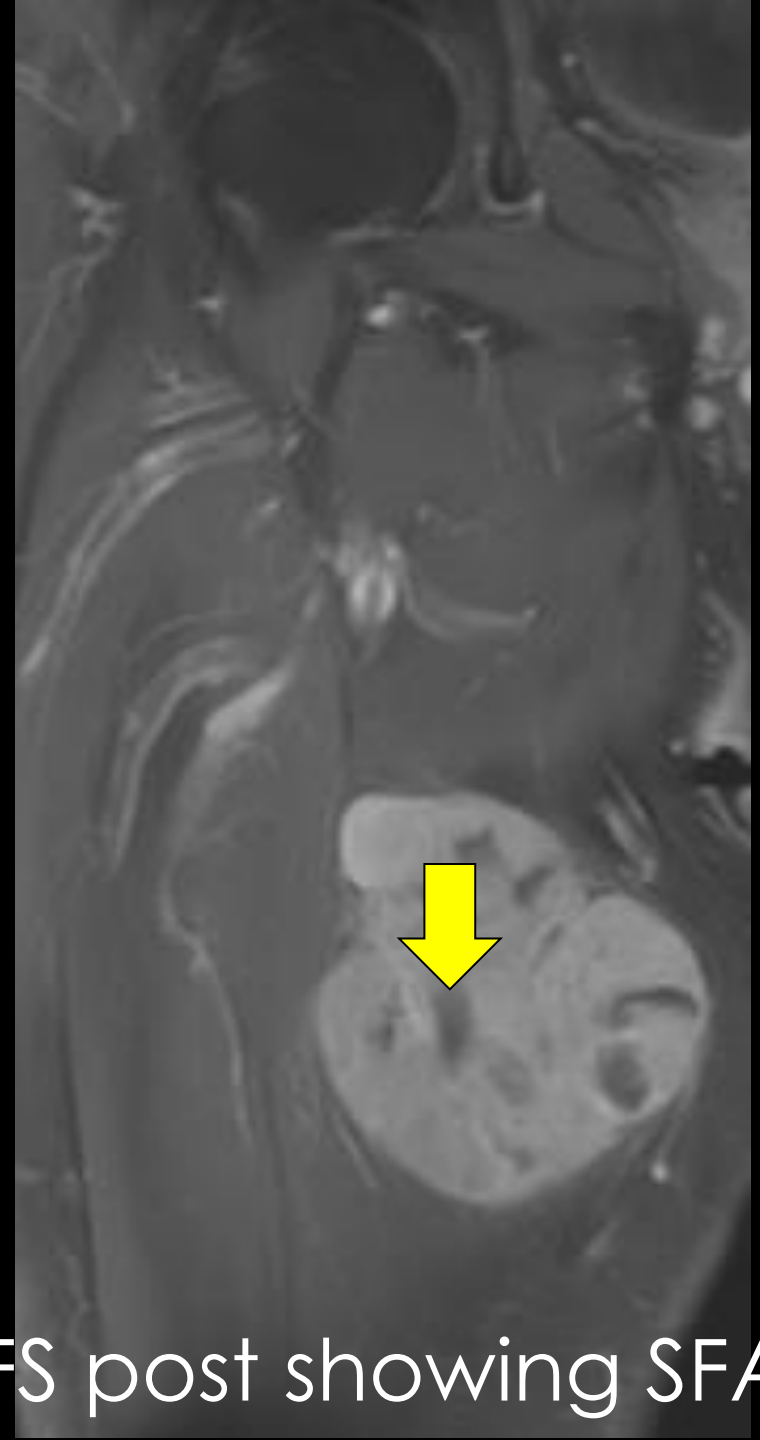
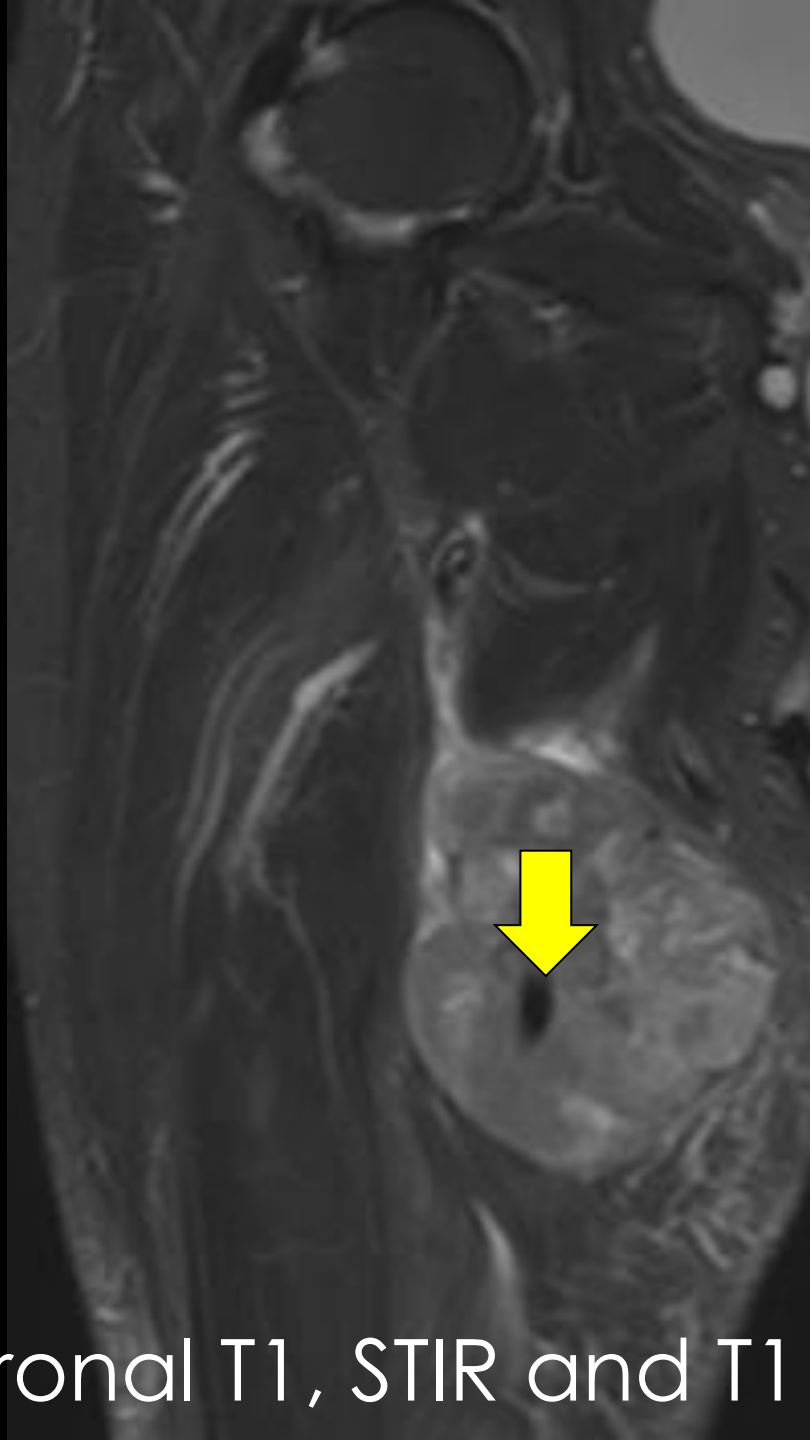
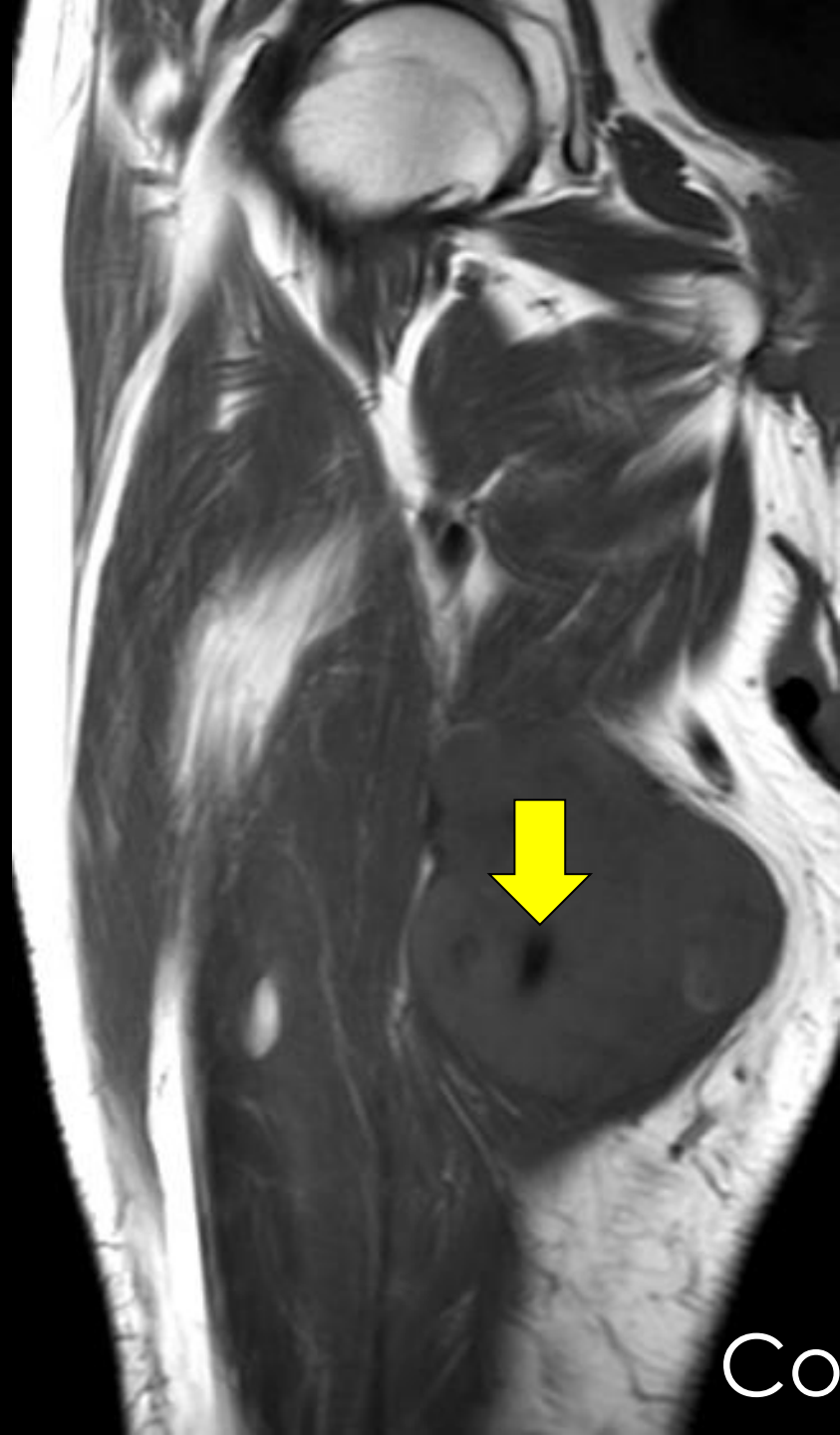


T2



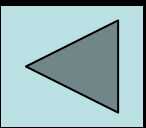
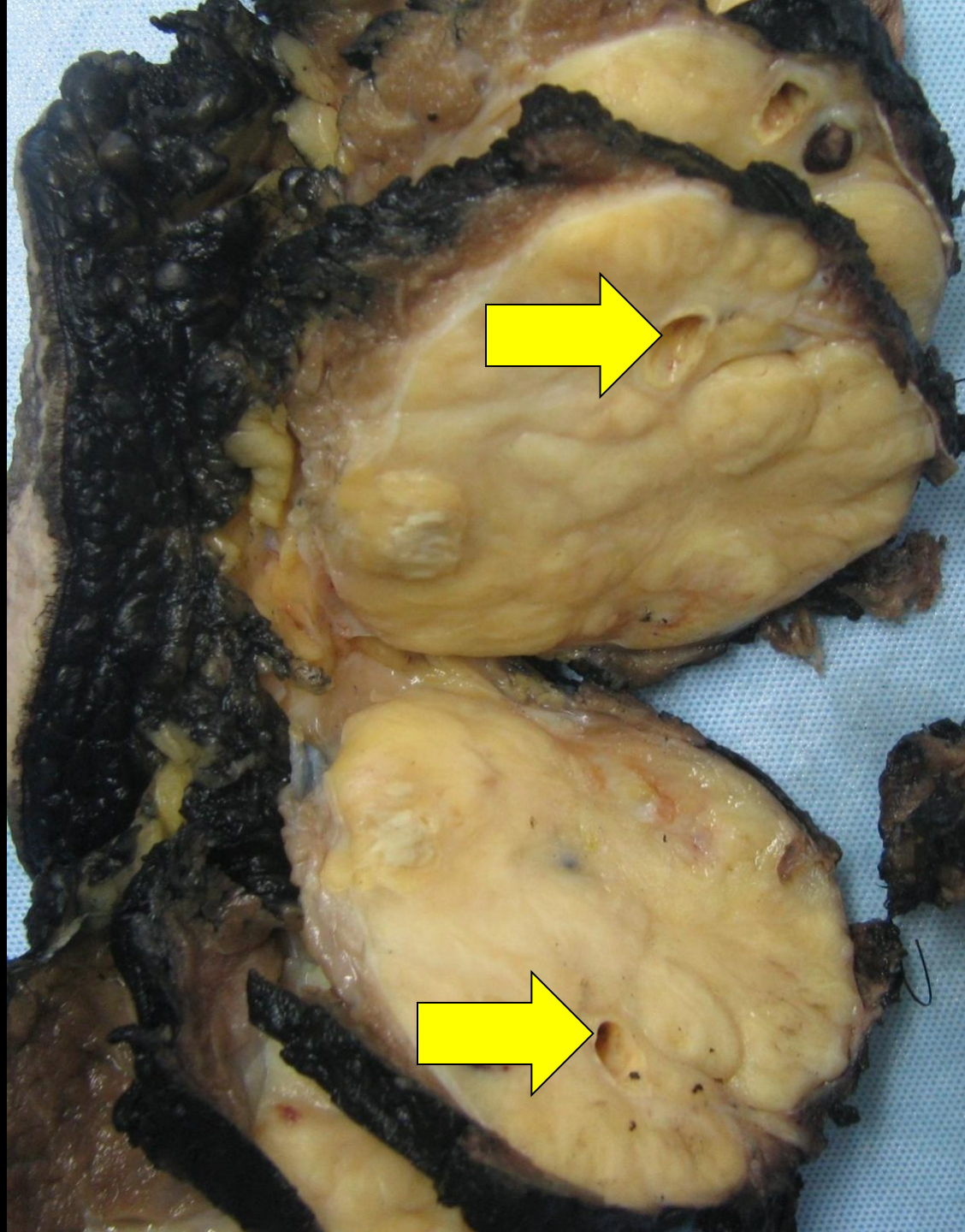


Axial T1 FS Pre and Axial T1 FS Post showing SFA



Coronal T1, STIR and T1 FS post showing SFA

Gross picture
showing SFA



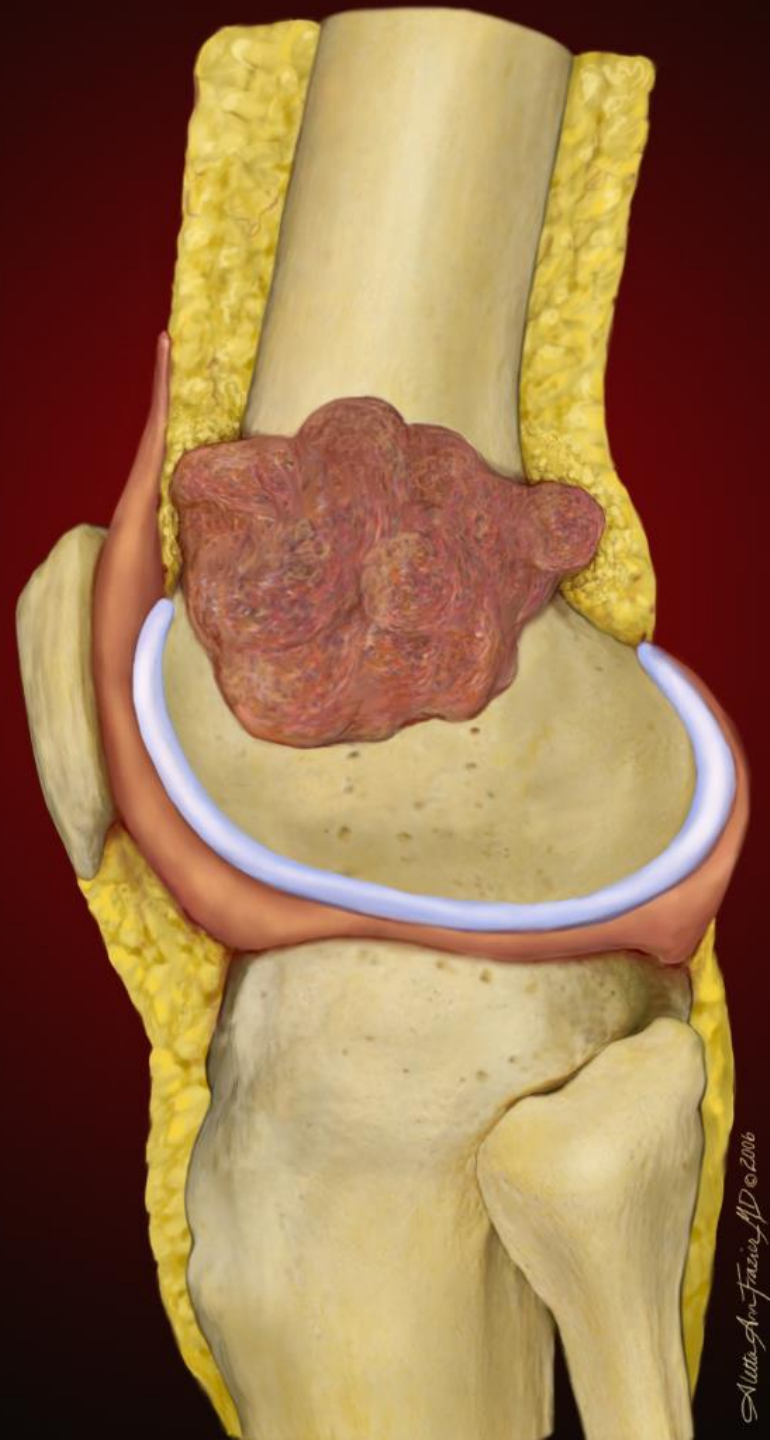
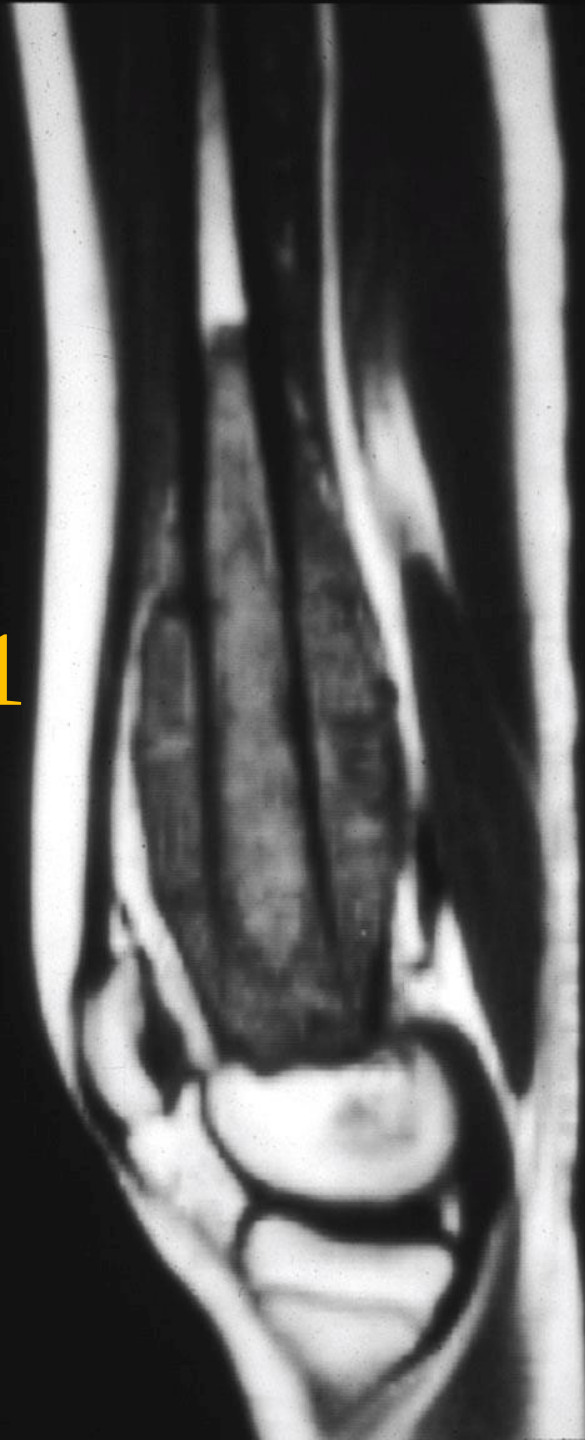
MUSCULOSKELETAL NEOPLASM JOINT INVOLVEMENT

- Dramatically changes surgery from:
 - Limb salvage; intraarticular resection
 - Extraarticular limb salvage/amputation
- MRI superior to CT - multiplanar imaging
 - Coronal or sagittal plane best

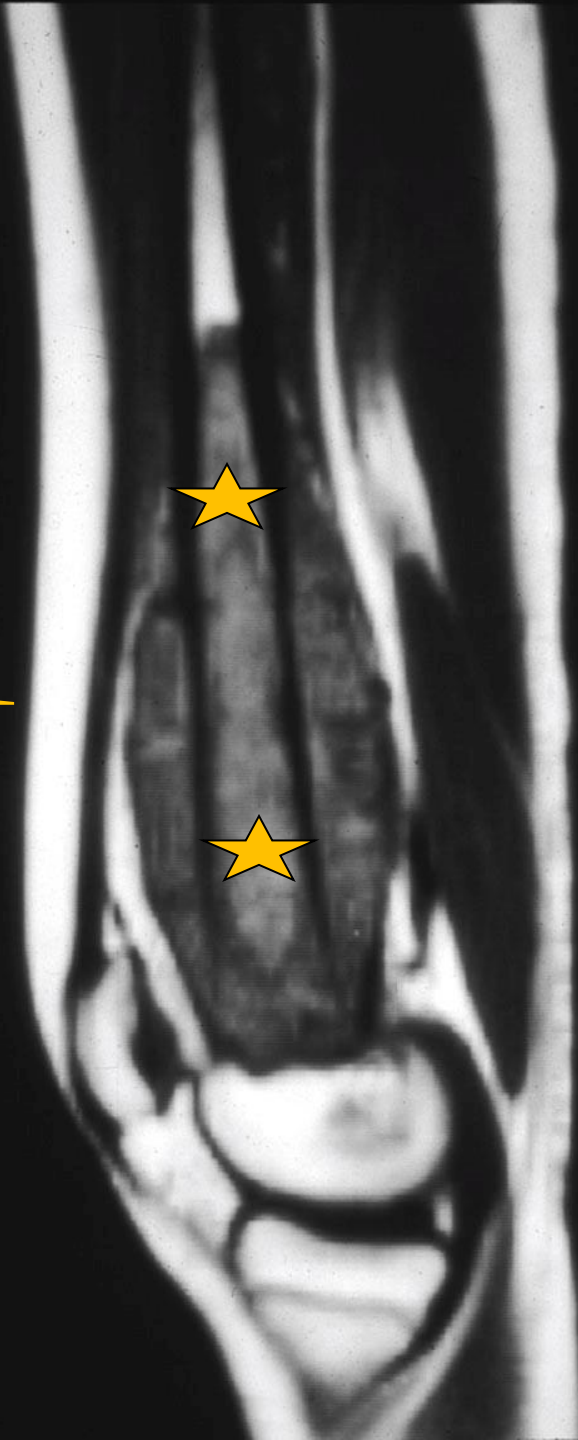
MUSCULOSKELETAL NEOPLASM JOINT INVOLVEMENT

- Three routes of spread into joint
 - Through bone/cartilage (transarticular)
 - Around joint margin (periarticular)
 - Along ligaments/tendons, or hematogenous
- Presence of joint effusion - suggestive
- Absence of joint effusion - excludes

T1

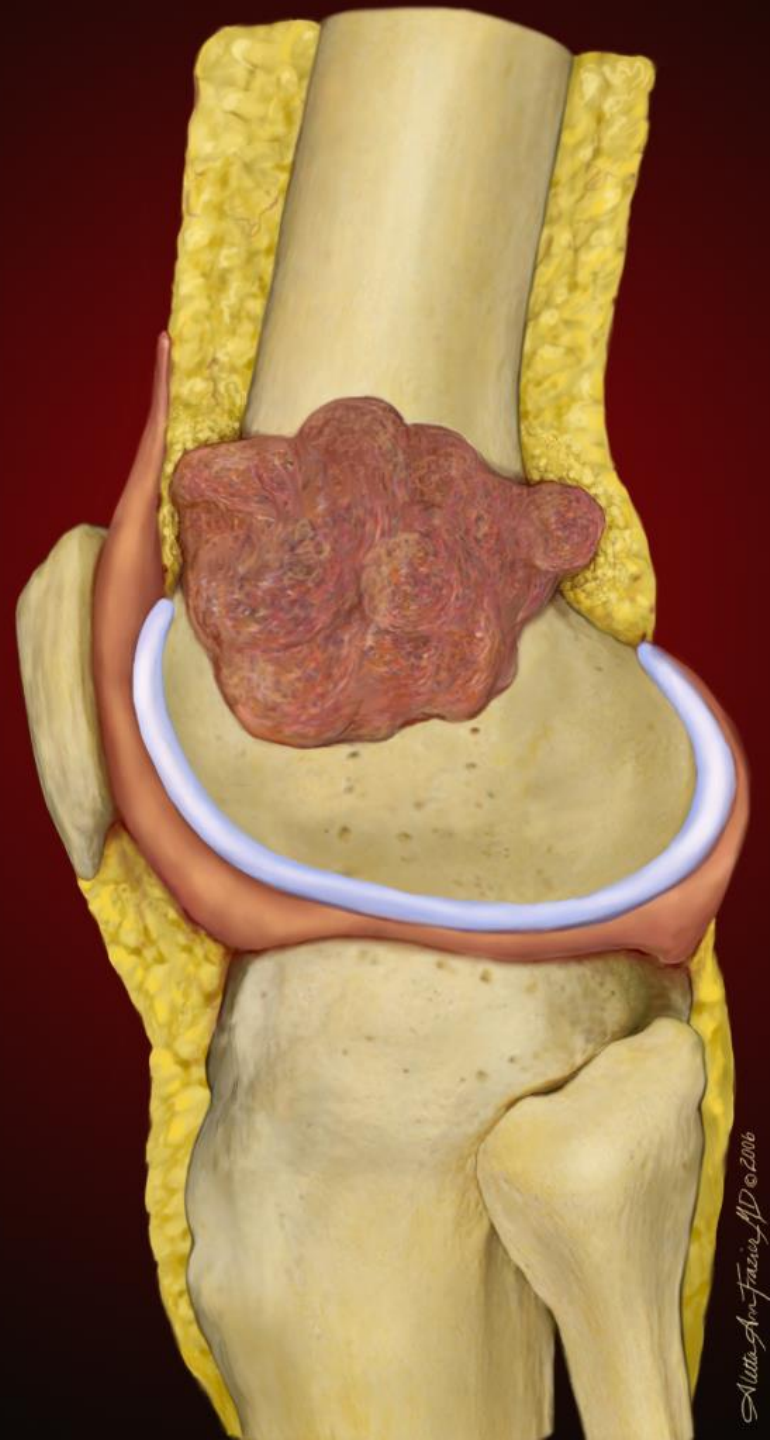


T1



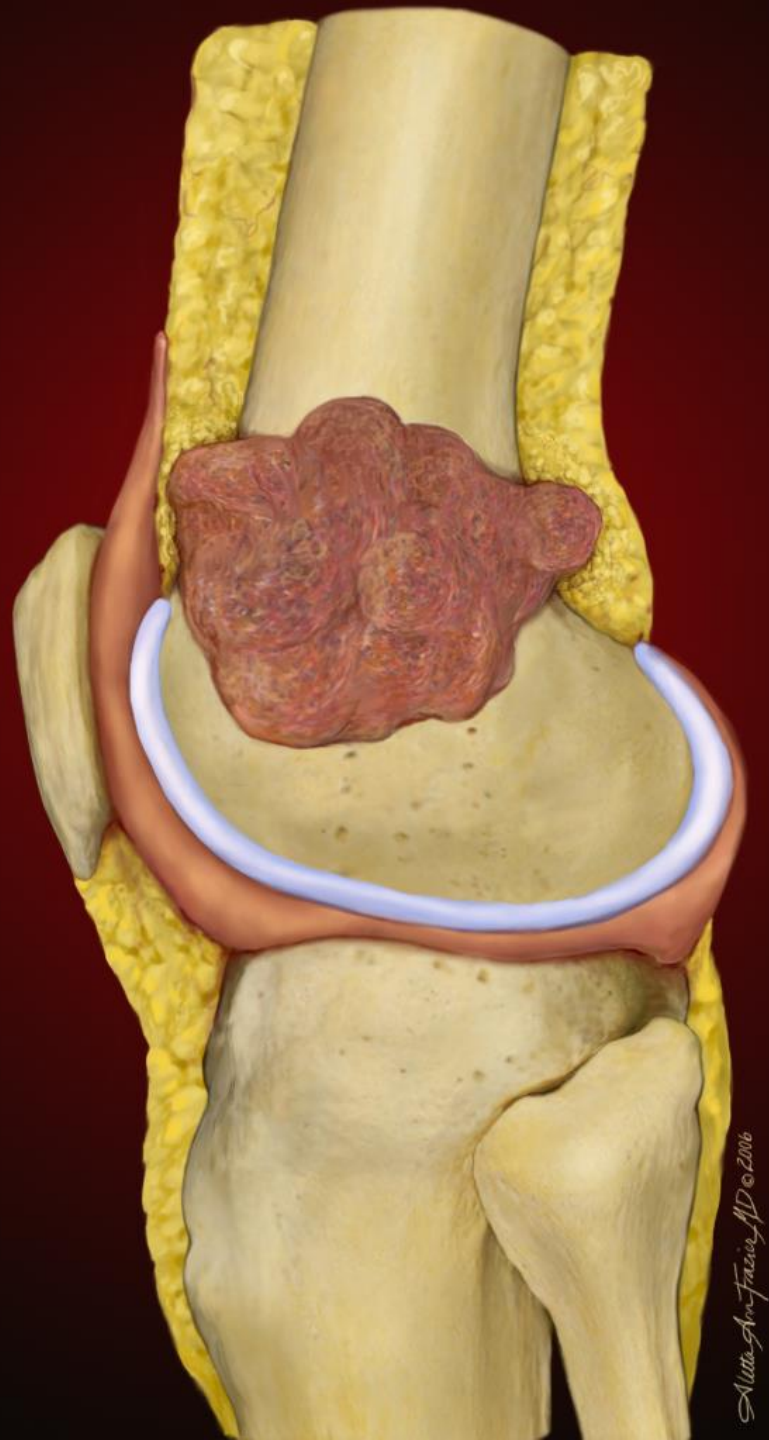
Alta AmFaire, MD © 2006

T1



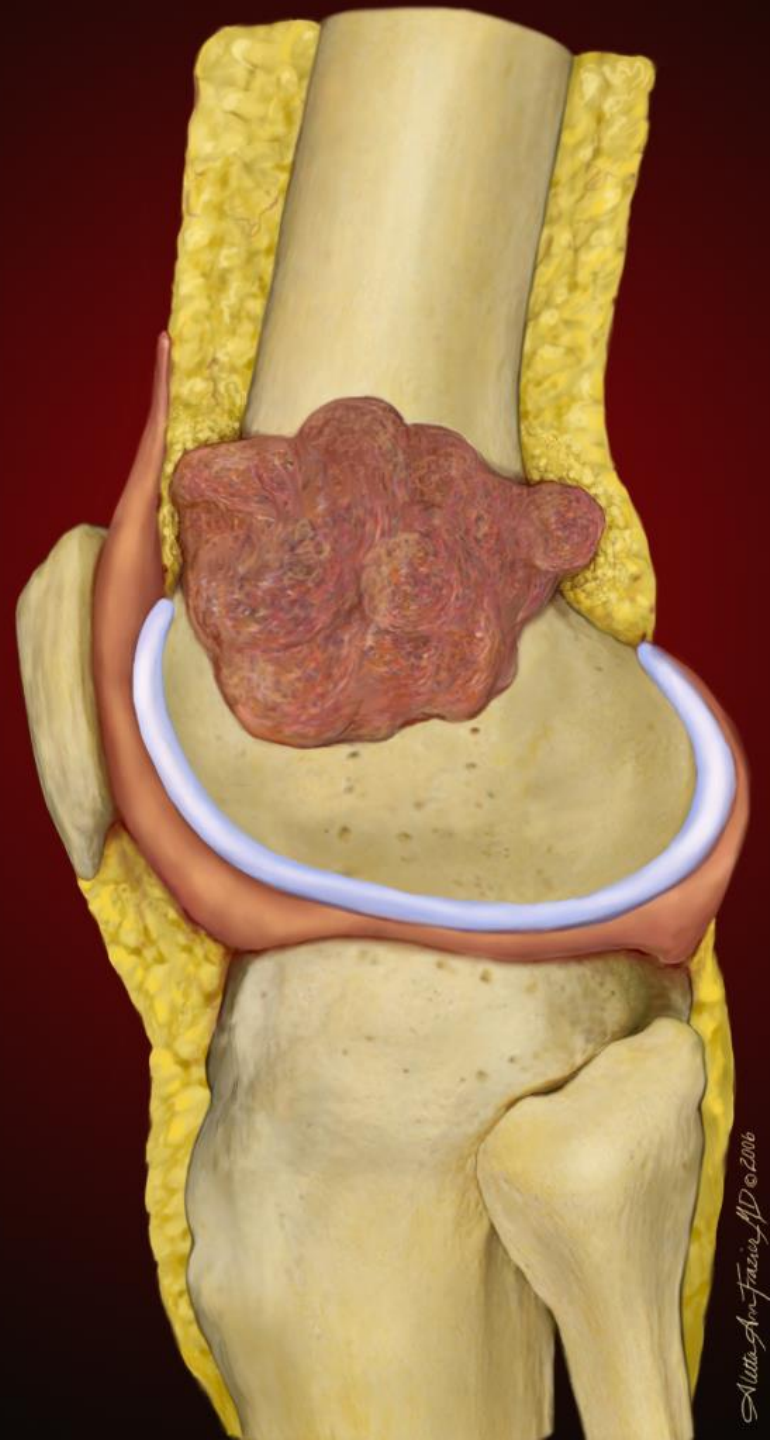
Alta AmFaire, MD © 2006

T1

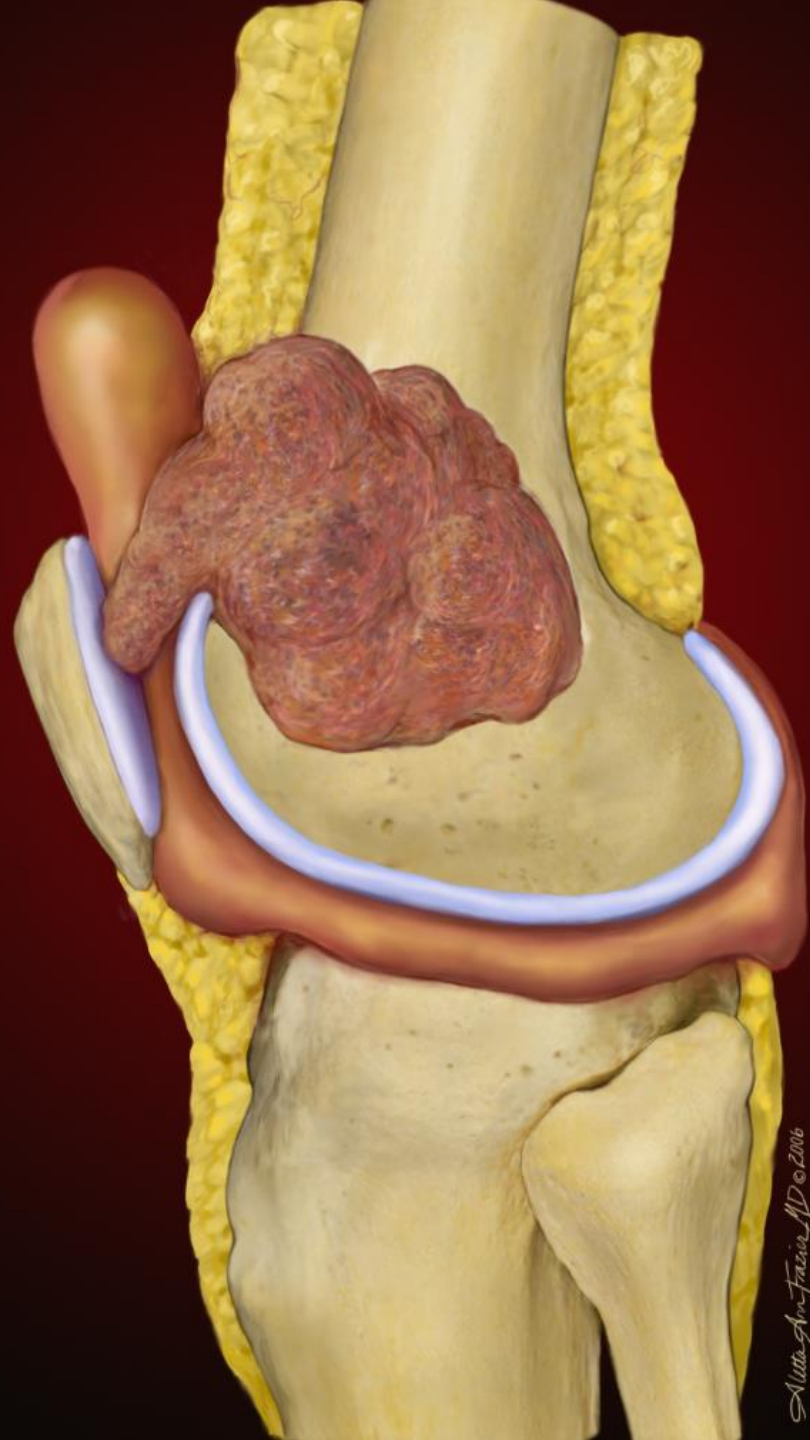


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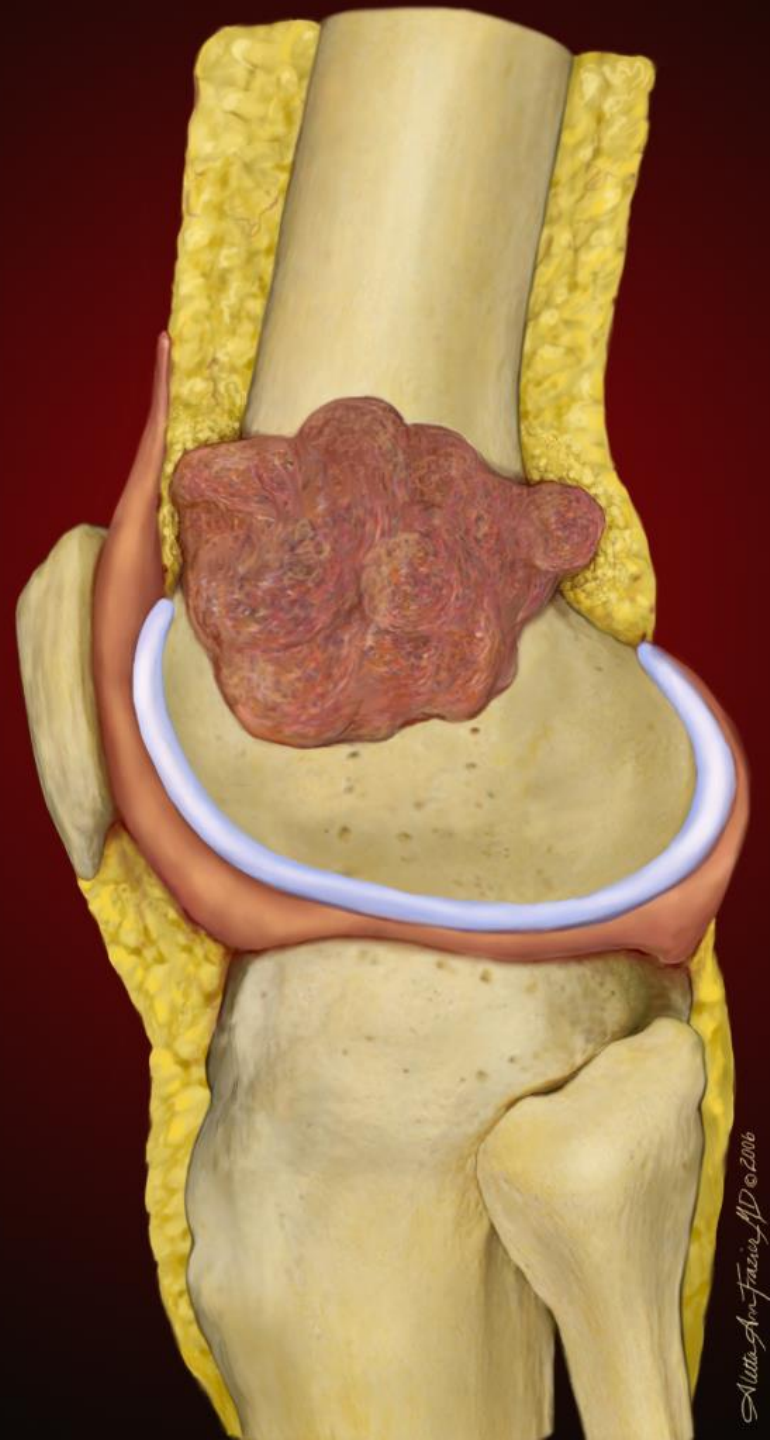
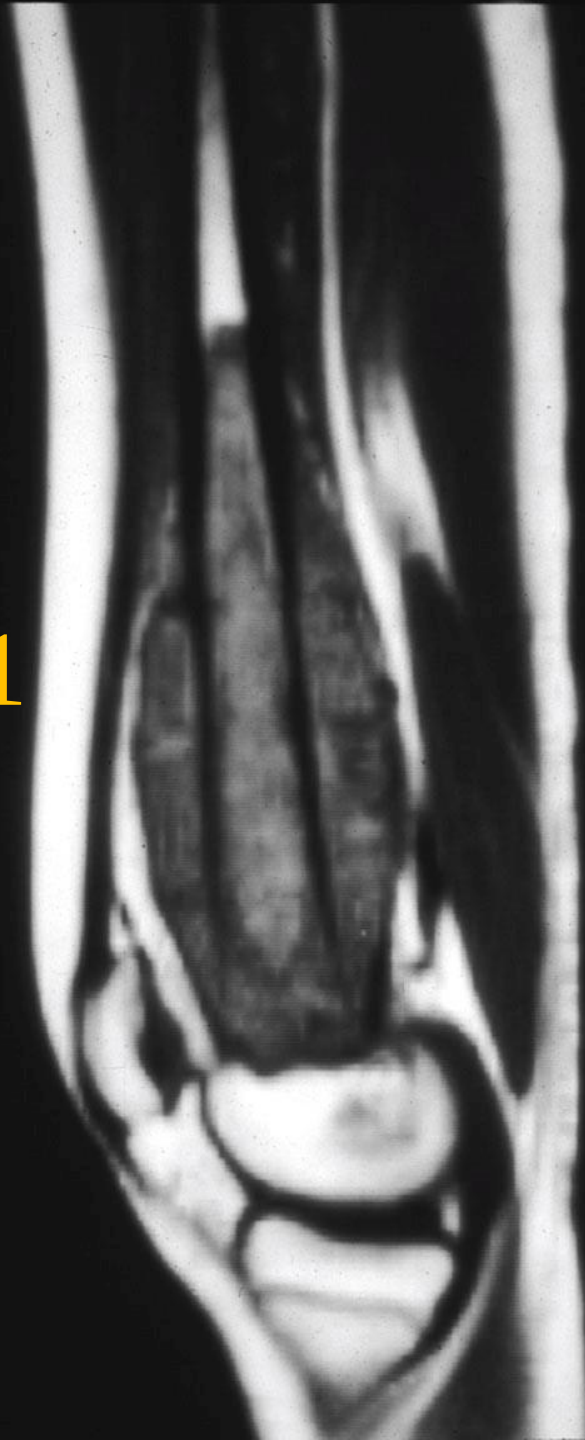
T1



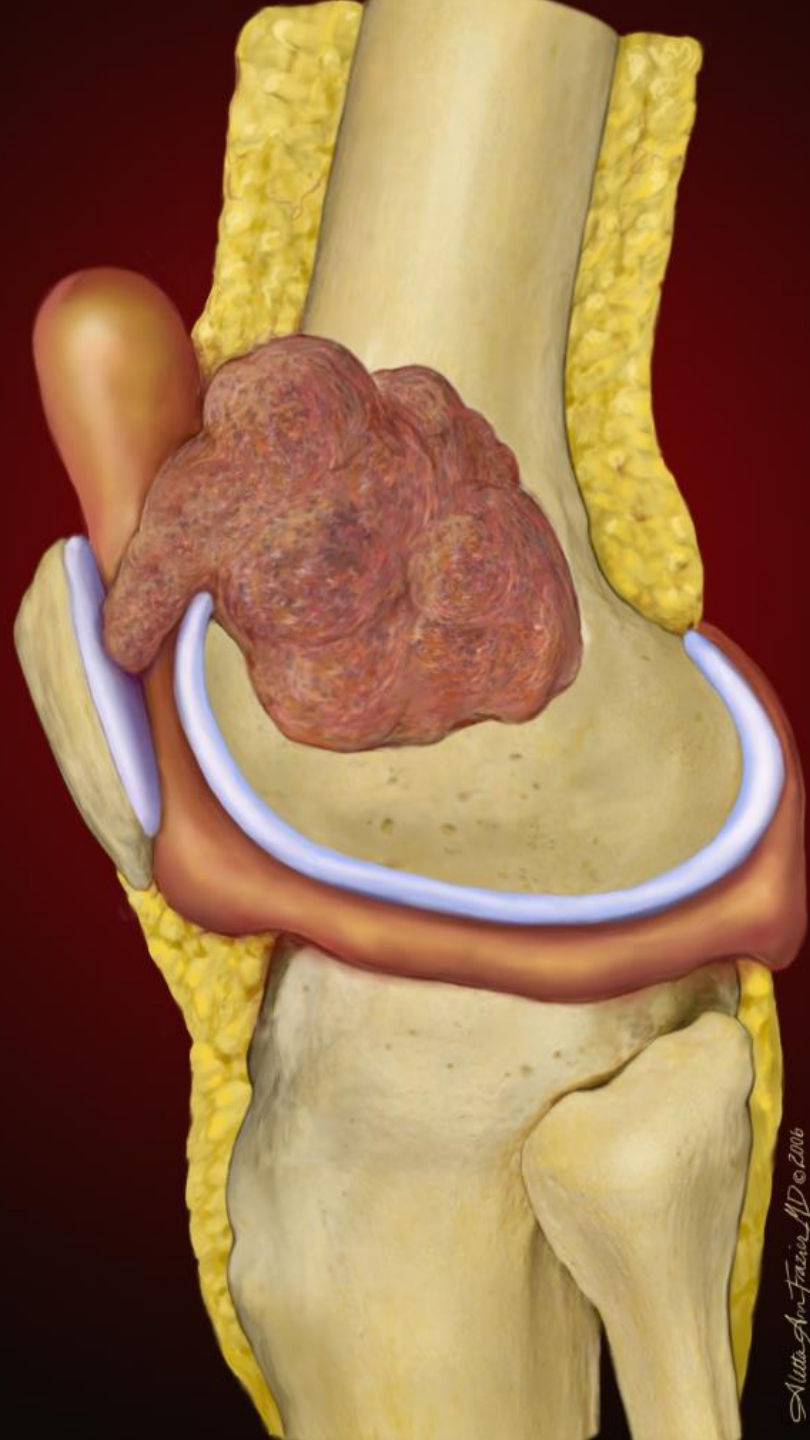
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T1



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T2

S46

I194



T2

S46

I194

T2

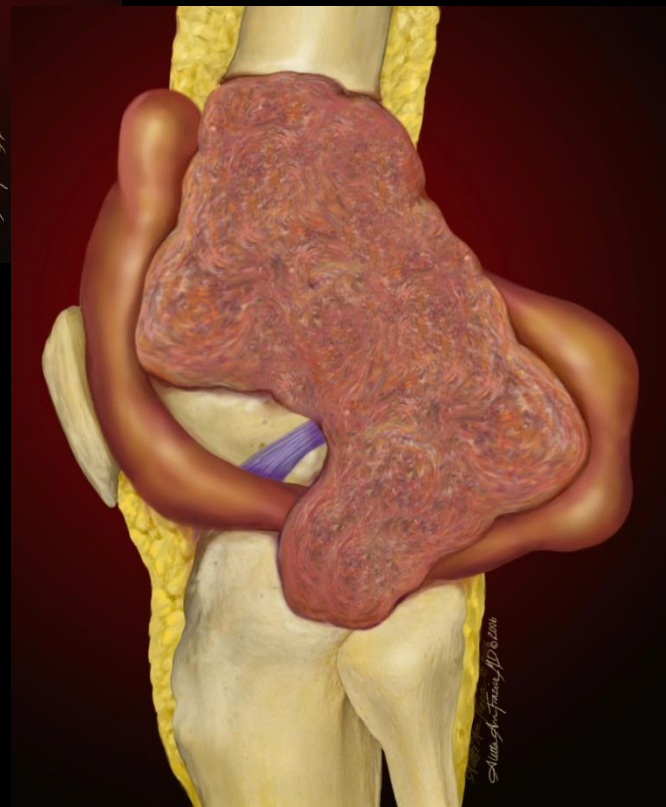
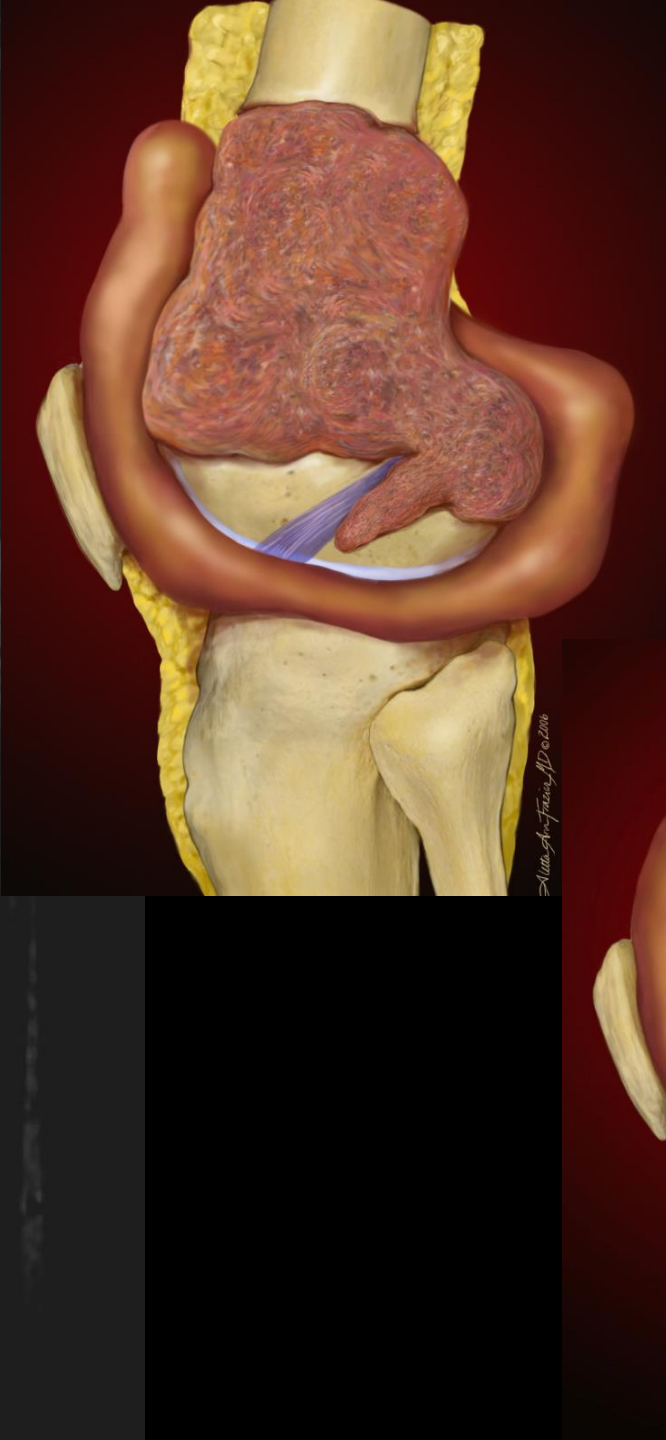
S46

I194

T2

S46

I194



T2

S46



I194



T2

S46

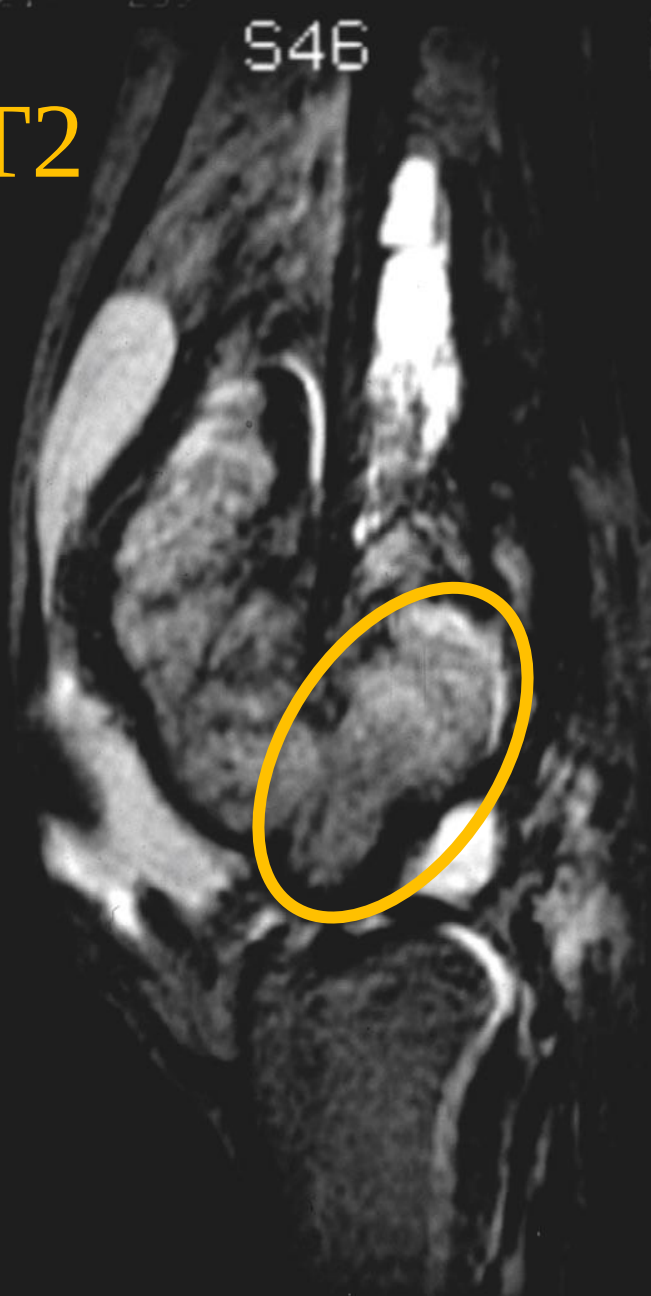
I194



T2

S46

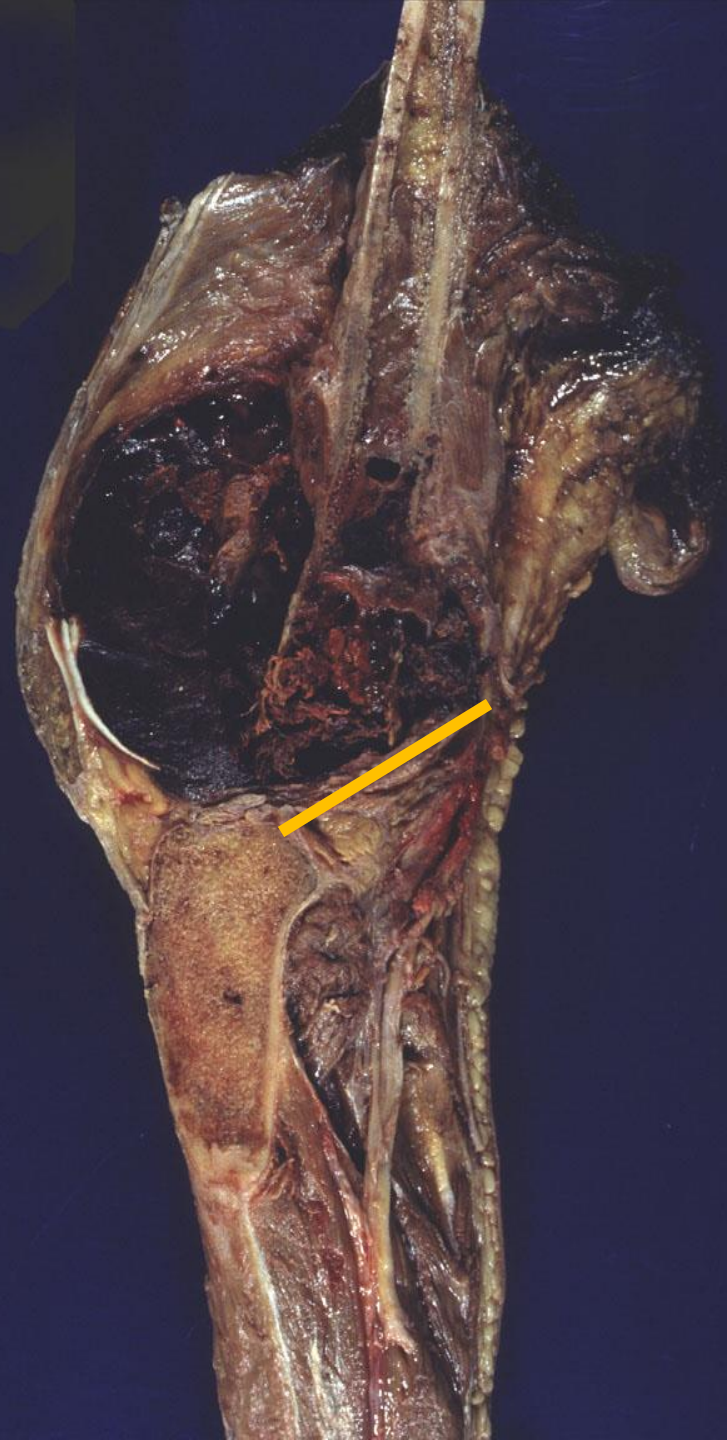
I194



T2



I194



T2



I194

OSSEOUS TUMOR CONCLUSIONS

- Osseous tumor evaluation for differential diagnosis remains the primary domain of RADIOGRAPHS!
- Radiologists do very well in this evaluation because lesion appearance **REFLECTS BIOLOGIC ACTIVITY**
 - Aggressive lesions requiring further workup
 - Nonaggressive lesions (often “don’t touch” lesion)
- Probably only area of radiology where what we say can change pathologic diagnosis

OSSEOUS TUMOR CONCLUSIONS

- MRI/CT are vital to stage and diagnose lesions
 - Extent (intramedullary/soft tissue)
 - Neurovascular/Joint involvement
 - Adds to limiting differential diagnosis
 - Direct biopsy
 - Give orthopod anatomic landmark
- Staging determines orthopedic oncologic treatment



The Wine Bone
Specialists Prefer

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IMAGING OF BONE TUMORS

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