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Systematic approach of bone tumors

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Systematic approach of Bone tumors :

Teaching Points

- A systematic approach improves accuracy in diagnosing bone tumors and guides clinical management.
- Age and location along with imaging features such as margins, matrix, periosteal reaction, and soft-tissue extension are key to narrowing the differential diagnosis.
- A structured checklist ensures consistent evaluation and reporting by Bone-RADS scoring system (Figure.8).
- Includes original illustrations to clarify and highlight the key radiologic features of common bone tumors.
- Sample case demonstrates lesion evaluation checklist.

Background

Bone tumors represent a heterogeneous group of lesions, ranging from incidental benign findings to aggressive malignancies. Accurate diagnosis requires a structured approach to improve precision, support communication, and guide management. Evaluation begins with patient age (Figure.1) and lesion location, both within the bone (epiphyseal, metaphyseal, diaphyseal; central, eccentric, cortical or juxtacortical) (Figure.2) and skeletal (axial vs. appendicular) (Figure.3). Lesion analysis includes density (Figure.4), matrix mineralization, number of lesions, and aggressiveness indicators.

<u>Signs of aggressiveness include:</u>

Margins (Figure.5) : Permeative or moth-eaten patterns per Lodwick classification [2] suggest malignancy.

Periosteal reaction (Figure.6) : lamellated, perpendicular, Codman triangle, or sunburst types imply rapid growth.

Endosteal scalloping and cortical destruction (Figure.8) indicate slow vs. aggressive expansion.

Pathologic fracture and soft-tissue mass suggest high-grade lesions.

A known primary malignancy raises concern for metastases.

Age

	<30		>30
B	Simple bone cyst Aneurysmal bone cyst Nonossifying fibroma Osteofibrous dysplasia Chondroblastoma Osteoblastoma Eosinophilic granuloma	B	Enchondroma Giant cell tumor Paget disease
M	Ewing sarcoma Neuroblastoma metastases Osteosarcoma	M	Metastatic disease Multiple myeloma Lymphoma Chordoma Chondroblastoma Fibrosarcoma Malignant fibrous histiocytoma

Figure 1

Location : 1) Transverse And longitudinal

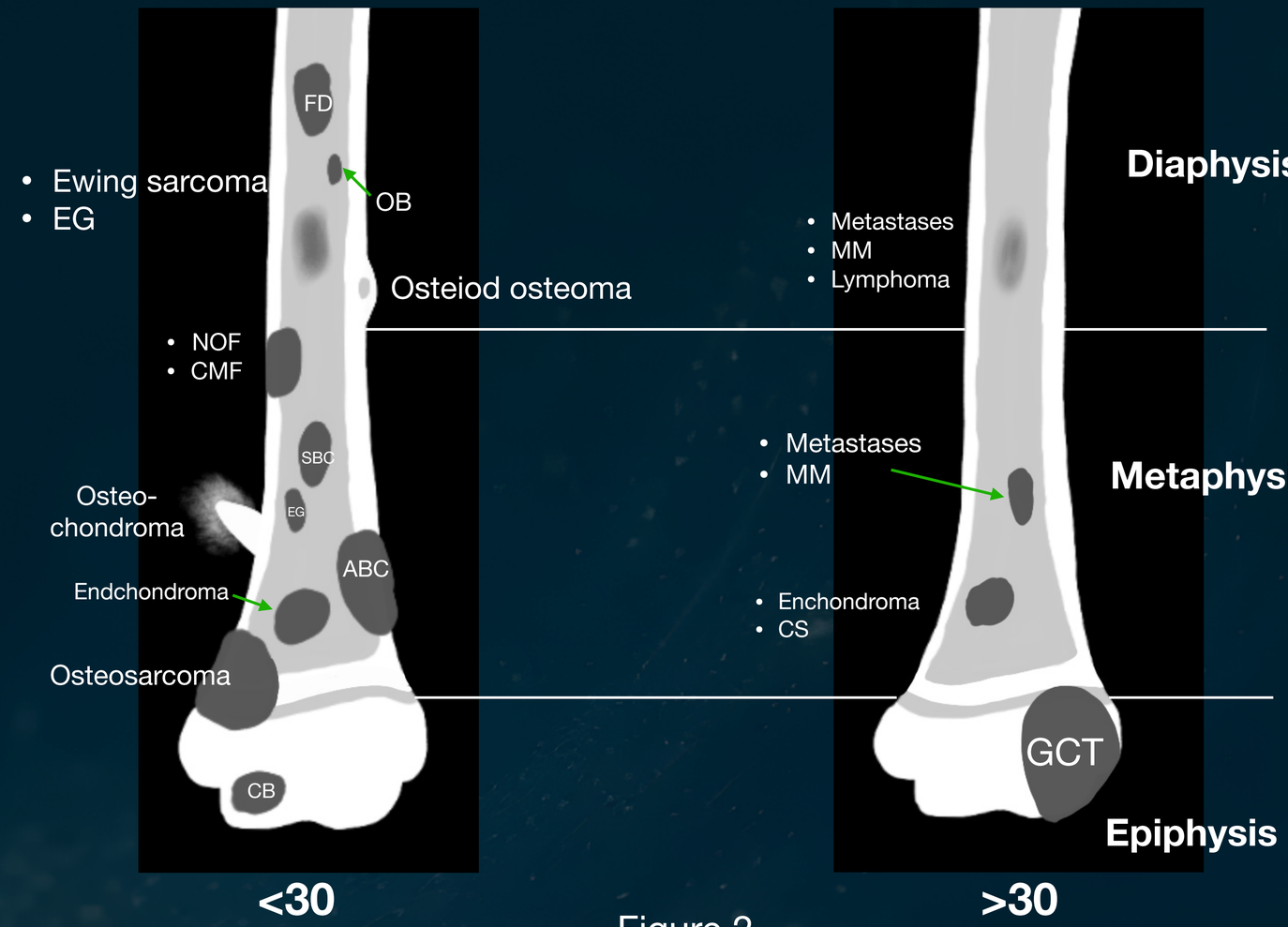
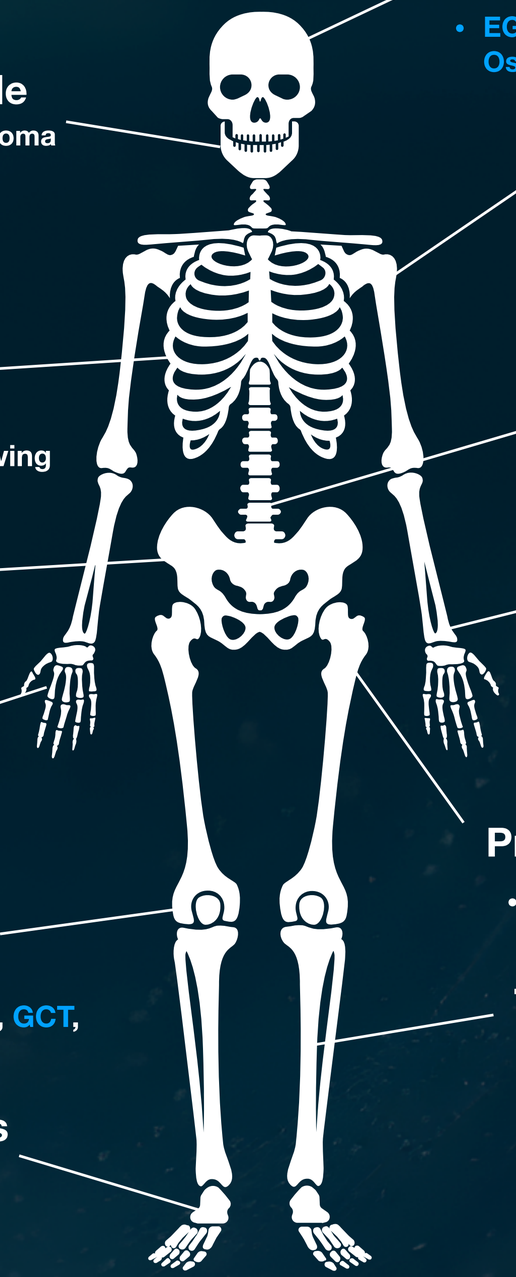


Figure 2

Location : 2) Bone/Skeleton

- Bone tumor have characteristic location in the skeleton



Skull
- EG, Metastases, MM, Osteoma

Mandible
- Adamantinoma

Humerus
- Adamantinoma, virtually all bone tumors

Ribs
- Metastases, Enchondroma, CS, Ewing sarcoma

Spine
- Metastases, MM, Osteoblastoma, Chordoma, Hemangioma, ABC, OO

Pelvis
- Osteosarcoma, CS, SBC, Lymphoma, GCT, Ewing sarcoma, Chordoma

Distal radius
- GCT, EG

Hands
- Enchondroma

Proximal femur
- SBC, ABC, Ewing sarcoma, FD, EG, OO

Around the knee
- Osteosarcoma, Ewing sarcoma, Chondroblatoma, NOF, ABC, SBC, GCT, Osteochondroma

Tibia
- NOF, FD, OO, Adamantinoma

Calcaneus
- SBC, Osteoblastoma, Chondroblastoma

- Those tumor on blue have higher frequencies in the respective location

- **EG** = Eosinophilic granuloma, **ABC** = aneurysmal bone cyst, **CS** = chondrosarcoma, **FD** = fibrous dysplasia, **GCT** = giant cell tumor, **MM** = multiple myeloma, **NOF** = nonossifying fibroma, **SBC** = simple bone cyst, **OO** = osteoid osteoma.

Figure 3

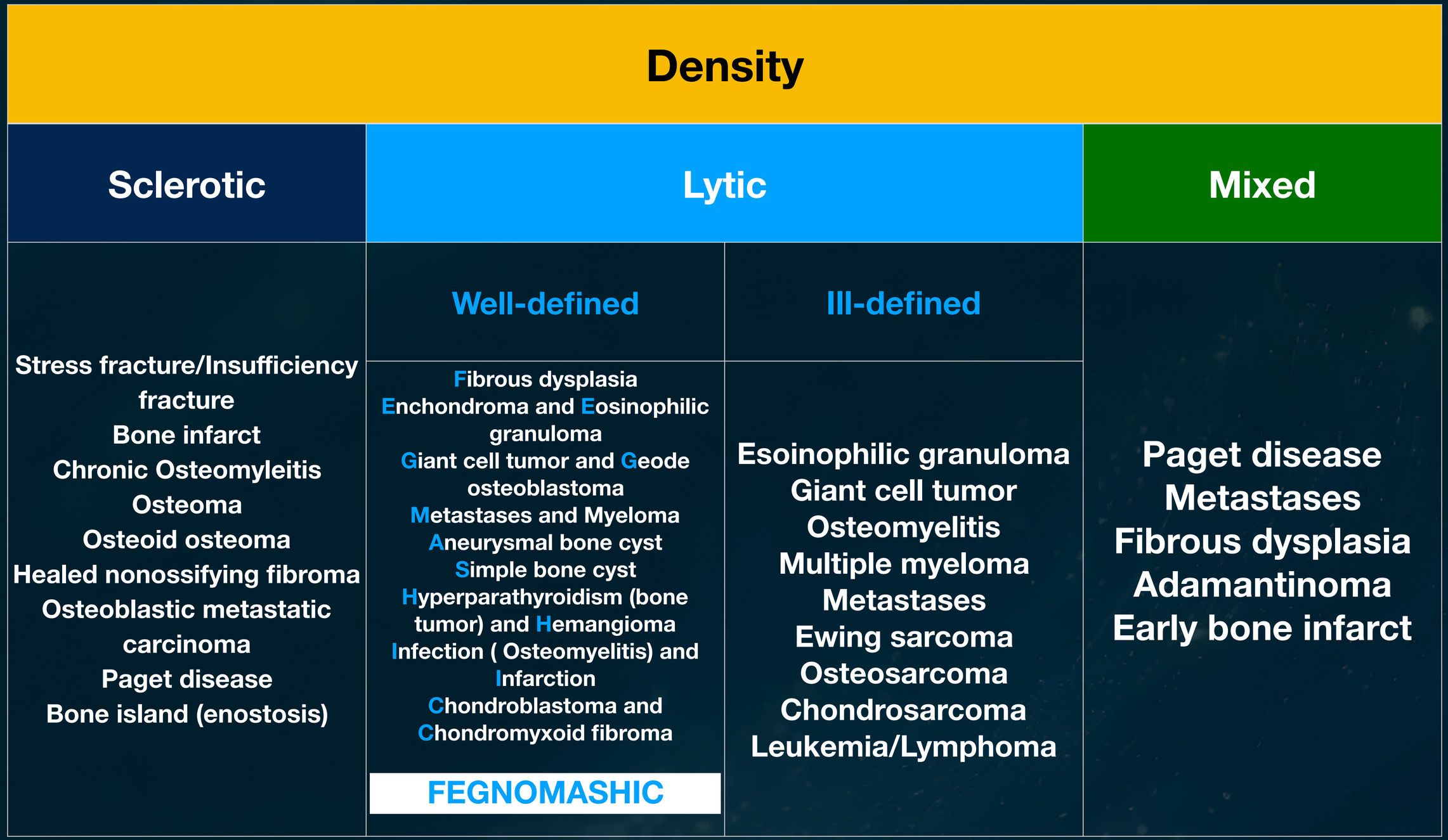
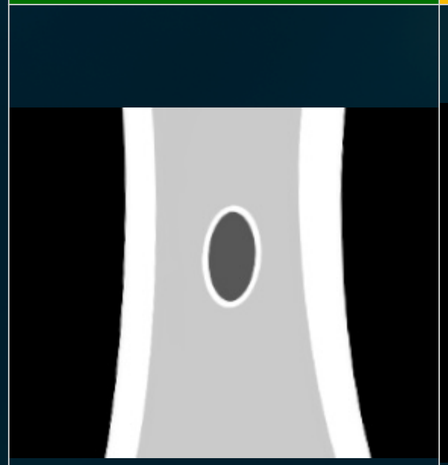
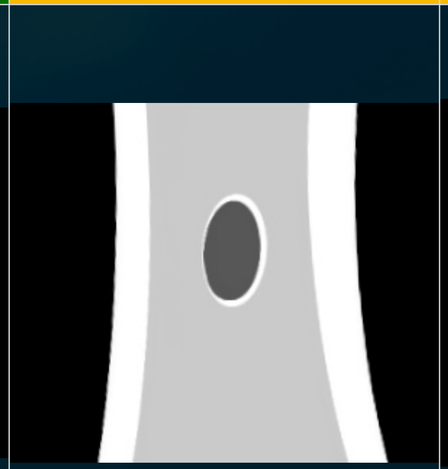
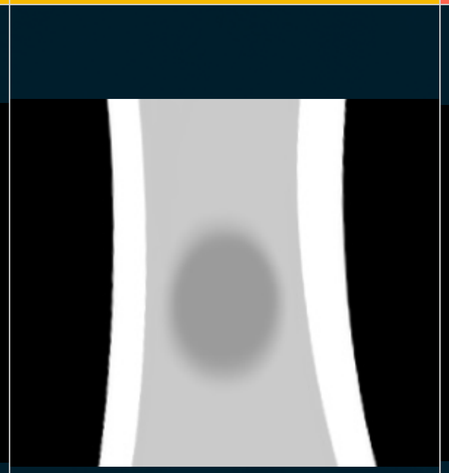
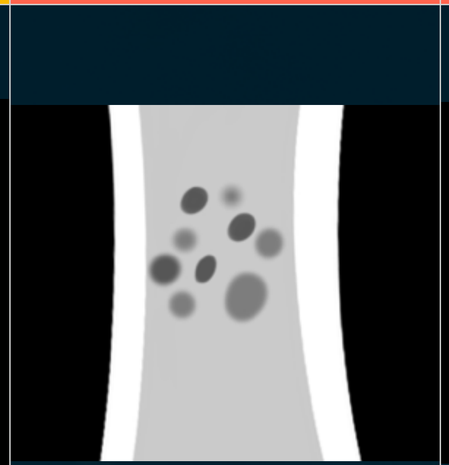
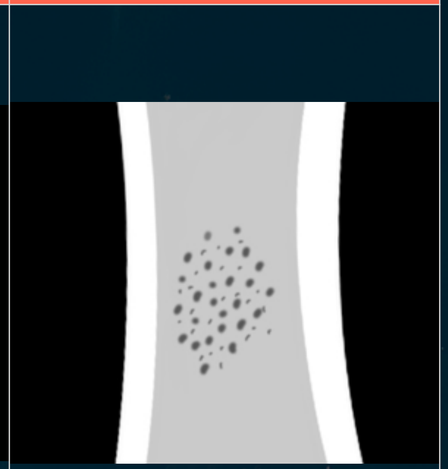

Density
Sclerotic
Lytic
Mixed
Well-defined
Ill-defined
Stress fracture/Insufficiency fracture
Bone infarct
Chronic Osteomyleitis
Osteoma
Osteoid osteoma
Healed nonossifying fibroma
Osteoblastic metastatic carcinoma
Paget disease
Bone island (enostosis)
Fibrous dysplasia
Enchondroma and Eosinophilic granuloma
Giant cell tumor and Geode osteoblastoma
Metastases and Myeloma
Aneurysmal bone cyst
Simple bone cyst
Hyperparathyroidism (bone tumor) and Hemangioma
Infection (Osteomyelitis) and Infarction
Chondroblastoma and Chondromyxoid fibroma
FEGNOMASHIC
Esoinophilic granuloma
Giant cell tumor
Osteomyelitis
Multiple myeloma
Metastases
Ewing sarcoma
Osteosarcoma
Chondrosarcoma
Leukemia/Lymphoma
Paget disease
Metastases
Fibrous dysplasia
Adamantinoma
Early bone infarct

Figure 4

Lodwick Classification	Type I (geographic)			Type II (Moth-eaten)	Type III (Permeative)
	Type IA	Type IB	Type IC		
					

Modified L-M system	Grade IA	Grade IB	Grade II	Grade IIIA	Grade IIIB	Grade IIIC
	Geographic, well defined lesion with a sclerotic rim	Geographic, well defined without sclerotic rim	Geographic, ill-defined with a wide zone of transition	Changing margin or progressive endosteal scalloping at surveillance	Non-geographic moth-eaten or permeative	Radiographically occult

Figure 5

Periosteal reaction

Nonagressive periosteal reaction
Thin
Solid
Thick irregular
Separated

Agressive periosteal reaction	Found In
Lamellated (onion skin)	Sarcomas, Osteomyelitis, Chondroblastoma
Perpendicular (hair-on-end)	Typically Ewing sarcoma, can present in Osteosarcomas
Divergent (sunburst)	Osteosarcomas
Codman triangle	Commonly osteosarcomas, occasionally infection and mets

Figure 6

Cortical involvement

Endosteal scalloping	Expansile remodling/cortical insufflation (Ballooning)	Cortical destruction
Erosion of the inner surface of the cortex	The bone has time to produce new periosteum as the inner surface is being eroded, resulting in expansion	Seen in high grade malignant and aggressive lesions

Figure 7

Structured Report and Management (ACR Bone-RADS™ v2023)

Margins	IA = 1 IB = 3 II = 5 IIIA-C = 7
Periosteal reaction	None = 0 Non-agressive = 2 Agressive = 4
Endosteal erosion	Mild = 0 Moderate = 1 Deep = 2
Pathological fracture	If yes = 2
Soft tissue mass	If yes = 4
Know primary cancer	If yes = 2

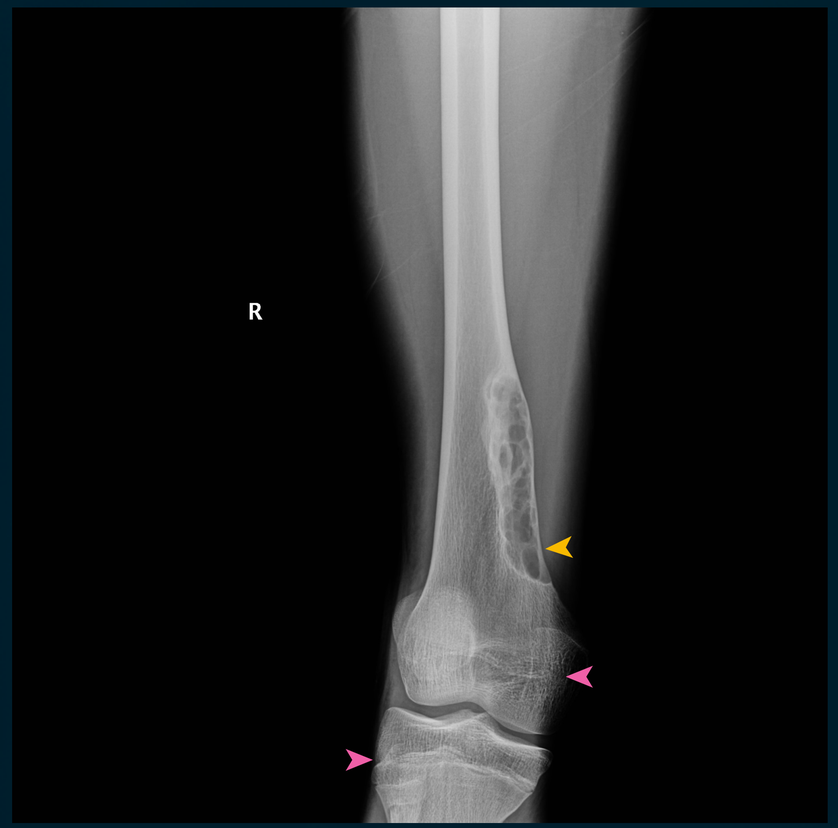
ACR Bone-RADS™ Score	Management
0 Incompletely Characterized Point Total = N/A	• Further workup is necessary • Additional radiographic views or cross-sectional imaging for further evaluation
1 Very Low Risk Point Total = 1–2	• If asymptomatic, consider workup to be complete vs annual surveillance to ensure expected stability • If symptomatic or change in clinical presentation, consider advanced imaging and orthopedic oncology referral for treatment of benign tumor
2 Low Risk Point Total = 3–4	• Short interval (3-6 month) surveillance to ensure stability • Consider advanced imaging to assess tumor composition and possibly biopsy to confirm benignity if needed • Consider orthopedic oncology referral for surveillance or treatment of benign tumor
3 Intermediate Risk Point Total = 5–6	• Orthopedic oncology referral for probable biopsy and treatment planning • Recommend advanced imaging such as CT, MRI, or bone scan for further characterization
4 High Risk Point Total ≥ 7	• Orthopedic oncology referral for recommended biopsy and treatment planning • Advanced imaging for tumor staging including additional sites of disease

ACR Bone-RADS™ score, assessment categories and management. American College of Radiology Committee on Bone-RADS™. Bone-RADS™ v2023 Assessment Categories and Scoring System. Available at: https://www.acr.org/-/media/ACR/Files/RADS/Bone-RADS/Bone-RADS-v2023-Assessment-Categories-Table-_Final.pdf. (Reprinted with permission from the ACR.)

Figure 8

Sample case

- AP radiograph of a 14 year old boy with right knee pain.



Checklist		Points
Patient age	<30	-
Location (skeleton)	Distal femur	-
Location (transverse)	Eccentric	-
Location (longitudinal)	Diaphyseal-metaphyseal	-
Density	Lytic	-
Mineralization	None	-
Margins	Lodwick IA, Modified Lodwick-Madewell IA	+ 1
Number	Single	-
Periosteal reaction	None	+ 0
Cortical involvement	Moderate endosteal scalloping (➤) Expansile remodeling	+ 1
Pathologic fracture	None	+ 0
Soft-tissue mass	No	+ 0
Other	Open growth plates (➤)	-
	Total	2

ACR Bone-RADS™ Score	Management
1 Very Low Risk	• If asymptomatic, consider workup vs annual surveillance • If symptomatic or change in clinical presentation, consider advanced imaging and orthopedic oncology referral

Differential diagnosis

- Giant cell tumor
- Aneurismal bone cyst
- Nonossifying fibroma
- Chondromyxoid fibroma
- Fibrous dysplasia

Final diagnosis

Nonossifying fibroma (NOF)

- References:

  - González-Huete A, Salgado-Parente A, Suevos-Ballesteros C, et al. Radiographic evaluation of bone tumors. RadioGraphics. 2023;43(11):e230048.

  - Benndorf M, Bamberg F, Jungmann PM. The Lodwick classification for grading growth rate of lytic bone tumors: a decision tree approach. Skeletal Radiol. 2022;51(4):737–745.

  - American College of Radiology. Bone-RADS v2023: Assessment Categories and Scoring System. Reston, VA: ACR; 2023. Available from: https://www.acr.org/-/media/ACR/Files/RADS/Bone- RADS/Bone-RADS-v2023-Assessment-Categories.pdf