Imaging of Bone and Soft Tissue Tumors

Approach from a radiologist's point of view

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uniklinik balgrist
EXPERTISE IN MOTION

Patient Management

Patient Management

Patient Management

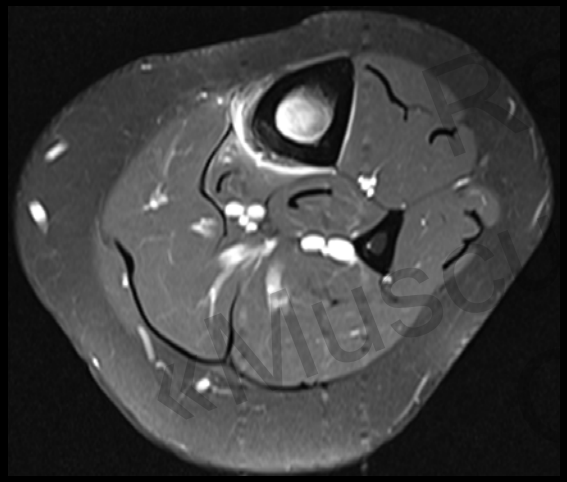
Jigsaw pieces provided by Radiologists

- Consultant for state of the art imaging protocols and completeness of imaging studies to ensure optimal diagnostic yield
- Dignity of a lesion → Differential diagnosis
- Resection planning, biopsy planning
- Image guided biopsy

Radiologic-Orthopedic Interface

What‘s that?

When can you biopsy that?



T1-weighted fat-saturated post KM

Radiologic-Orthopedic Interface

Correct Question would be:

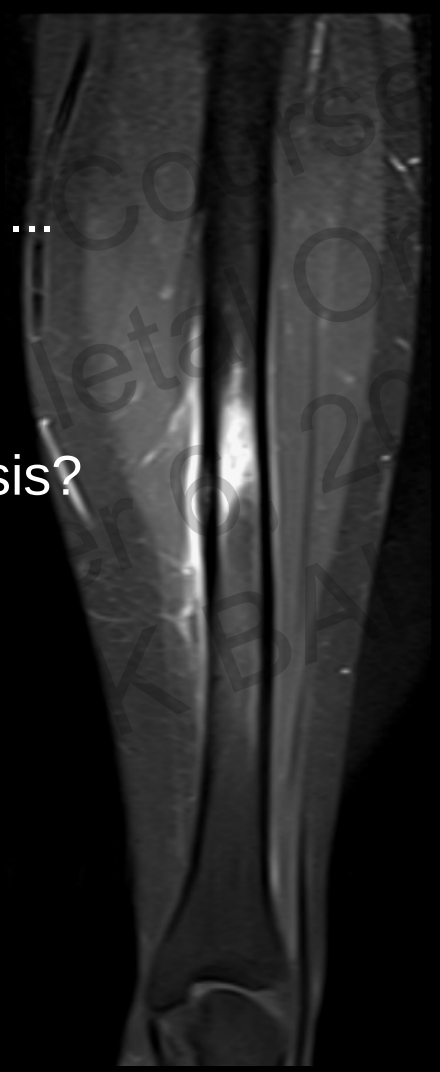
I have a patient with a history of ...

-Is the imaging sufficient?

-What‘s the (differential) diagnosis?

-Is a biopsy needed?

-Is a biopsy feasible?



Radiologic-Orthopedic Interface

Diagnosis:

Stress Fracture with typical history of excessive sports training.

Teaching points:

- Stress fractures can mimick bone tumors and should never be biopsied.
- History is key!
- Imaging is always influenced by the patients history/differential diagnosis.

Radiologic-Orthopedic Interface

Imaging overkill

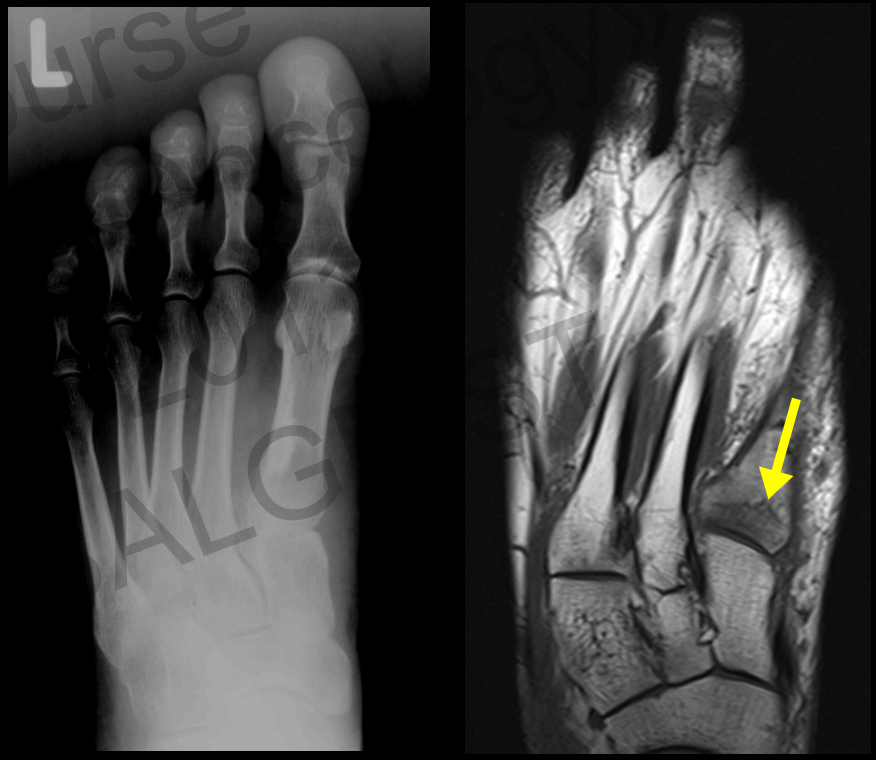
Radiologists know certain pathologies almost exclusively from plain radiographs!

- More images (MRI) do not imply more diagnostic security
- More images can divert from the important findings on plain films
- Well known benign lesion diagnosed on plain films can look malignant on MR images.

Radiologic-Orthopedic Interface

Imaging overkill

T1-weighted fat-saturated post KM



T1-weighted

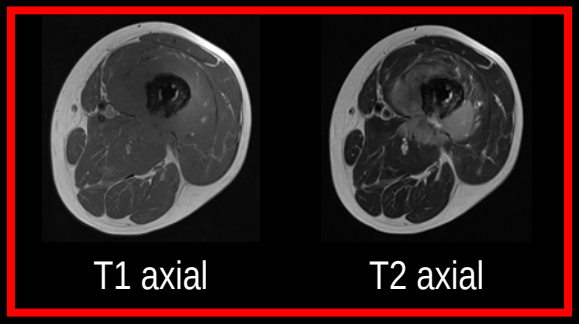
State of the art imaging

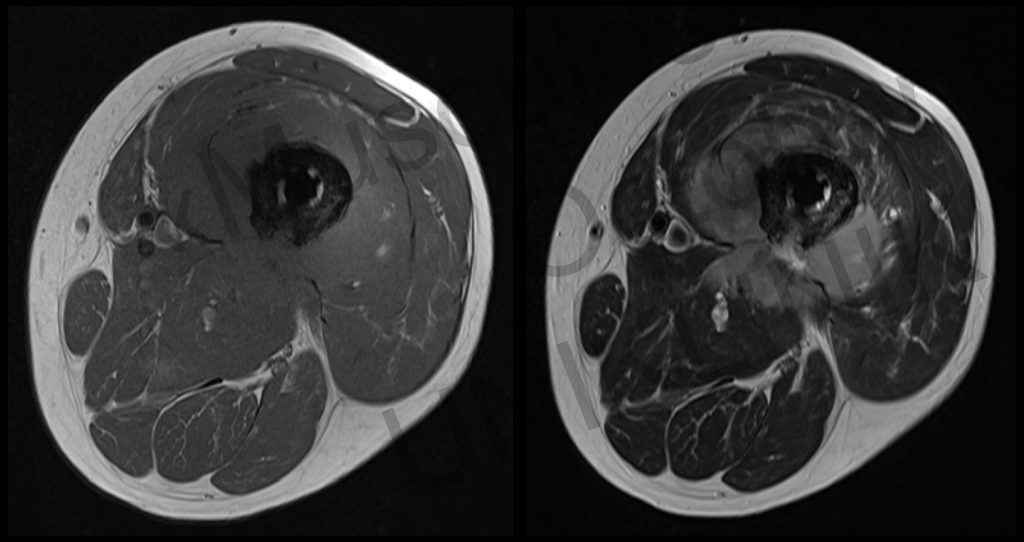
1. Plain films – Mandatory in 2 planes!
2. MRI – Soft tissue
3. CT scan – Osteolysis, matrix mineralization
4. PET-CT – Whole body, staging, tumor viability
5. PET-MRI – Research, indications to be defined

State of the art MR imaging

- Robust, old, well-known sequences
- Optimal planes depending on anatomy:
  - axial
  - second best
- Tagging with capsule on the skin if there is a small nodule or the like

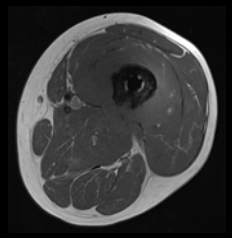
State of the art MR imaging

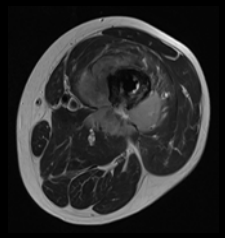


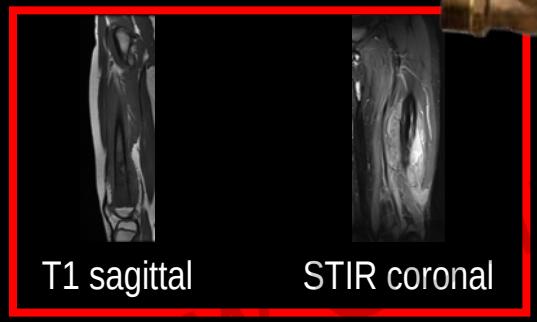


- Anatomy
- Compartment
- Muscles
- Vessel & Nerves
- Fat Tissue

State of the art MR imaging

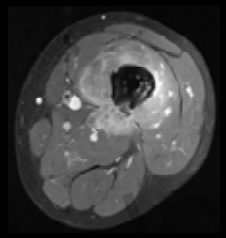

T1 axial


T2 axial

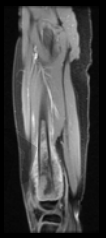

T1 sagittal

STIR coronal

KM


Post KM fat-sat

T1 axial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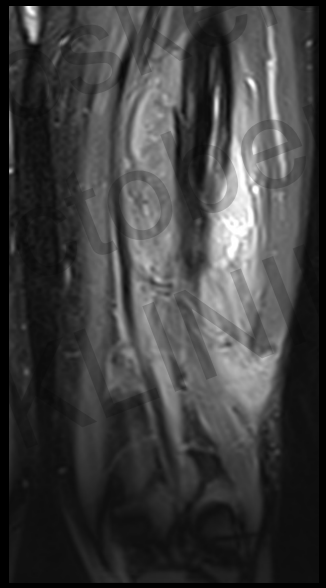
T1 sagittal


T1


STIR

- Additional information about aforementioned anatomical questions
- Fluid collections
- Skip lesions

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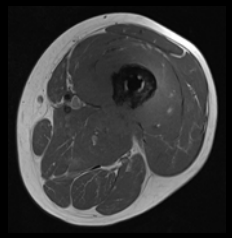
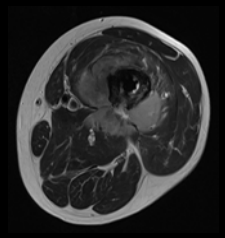
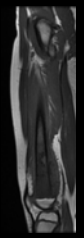
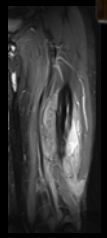
State of the art MR imaging

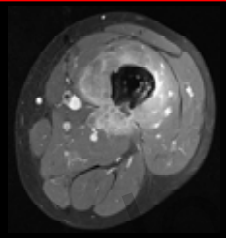

T1 axial

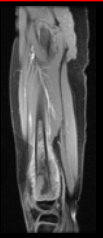

T2 axial

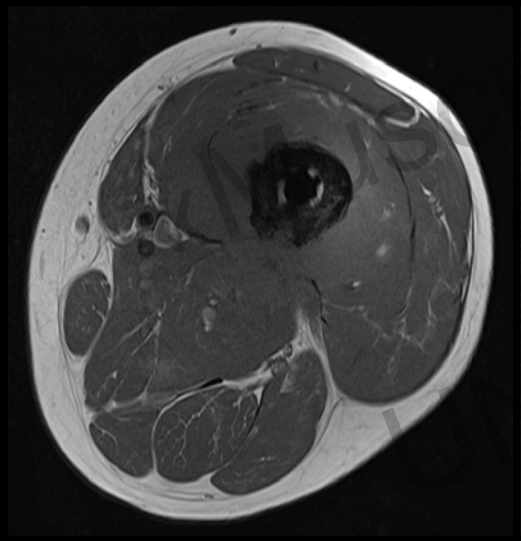

T1 sagittal

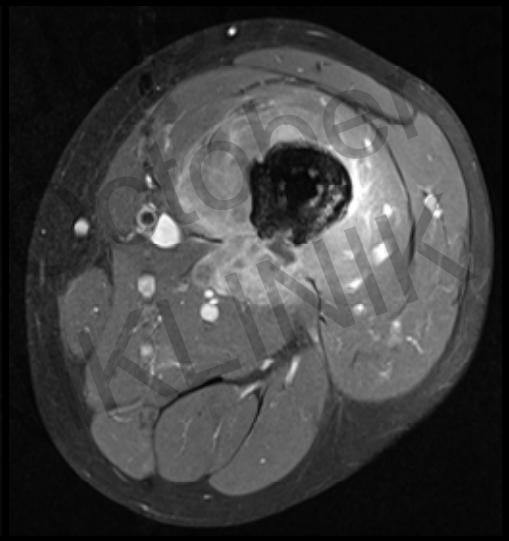

STIR coronal

KM


Post KM fat-sat
T1 axial

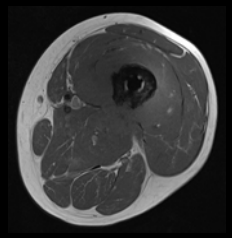

Post KM fat-sat
T1 sagittal

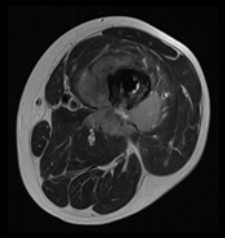

T1


T1 fs post KM

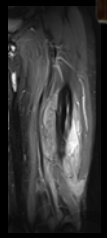
- Tumor tissue
- Tumor size
- Necrosis
- Infiltration in adjacent structures

State of the art MR imaging

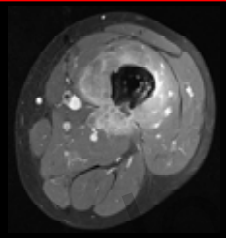

T1 axial

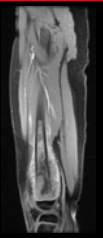

T2 axial


T1 sagittal


STIR coronal

KM


Post KM fat-sat
T1 axial


Post KM fat-sat
T1 sagittal

- Tumor tissue
- Tumor size
- Necrosis
- Infiltration in adjacent structures

Posttreatment (follow-up) MR imaging

Main focus on Follow-up MRI

- because of high rate of recurrence (about 50%)
- more examinations are performed as follow-up examinations than for treatment planning
- early recognition of recurrent disease is crucial for treatment

Ref.: Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. Radiographics. 2009;29(1):119–134.

Posttreatment (follow-up) MR imaging

Compare with pre-treatment images

As a general rule, the signal intensitiy and enhancement characteristics of a recurrent tumor typically mimics those of the original tumor.

At least primarily calcifying tumors should be imaged using radiographs also

Ref.: Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. Radiographics. 2009;29(1):119–134.

Posttreatment (follow-up) MR imaging

Importance of patient history

- Radiation therapy or reconstructive surgery

  ➔ Alteration of imaging appearance of surgical bed in a time-dependent manner

- Many different types of changes….

Ref.: Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. Radiographics. 2009;29(1):119–134.

Posttreatment MR imaging

MR Imaging Findings after Treatment of Soft-Tissue Tumors

Treatment Modality and Effect	Findings	Time of Onset after Treatment	Prevalence
Radiation therapy			
Marrow composition	Increased fat content in marrow	Complete marrow replacement at 6–8 weeks	Common
	Radiation osteitis	Variable (reported averages are 9 and 42 months)	Approximately one-third to one-half of patients
Soft-tissue change	Edemalike signal intensity of subcutaneous fat	Variable; maximum, 12–18 months	Common; returns to normal in 50% of patients in 2–3 years
	Increased signal intensity of muscle	Variable; maximum, 12–18 months	Common; returns to normal in 50% of patients in 2–3 years
Pseudotumor	Masslike area of abnormal enhancement	Average, 40 months (range, 11–61 months)	Limited data; approximately 5%–10%
Radiation-induced sarcoma	Focal mass within the irradiated field	Typically, 8–12 years (range, 2–40 years)	Rare
Chemotherapy			
Tumor hemorrhage	Increased internal signal intensity on T1-weighted images; may cause increase in tumor size	Usually 1 month	Common
Tumor necrosis	Progressive decrease in intralesional enhancement	Usually 1 month	Common
Surgery			
Hemorrhage	Age dependent	Immediately	Common
Seroma	Fluidlike signal intensity	Variable; weeks to months	Common
Reconstruction			
Normal myocutaneous flap	Muscle atrophy	Immediately	100%
	Fatty overgrowth	Immediately	100%
	Abnormal signal intensity of muscle	Immediately	In one-third of patients, abnormal fluid-sensitive signal intensity returns to normal within 2 years
	Abnormal contrast enhancement	Immediately	Abnormal contrast enhancement seen in two-thirds of patients returns to baseline in one-third of patients within 18 months
All modalities			
Tumor recurrence	Focal mass with signal intensity mimicking that of the original tumor	Generally early	Varies with grade of tumor, but overall around 50%

Ref.: Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. Radiographics. 2009;29(1):119–134.

Posttreatment MR imaging

Radiation therapy

- Subcutaneous edema: Peaking at 12-18 month, in 50% normal over the ensuing 2-3 years
- Bone marrow change: 1-6 weeks after initiation of therapy, regeneration of bone marrow is rare
- Radiation osteitis: 8-49 months post initiation
- Muscle edema, Fibrosis, Seroma

Chemotherapy

- Initially chemotherapy may cause an increase in tumor size because of intralesional edema, hemorrhage, and necrosis

Ref.: Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. Radiographics. 2009;29(1):119–134.

Posttreatment imaging

Recurrent tumor

Presence of discrete nodule or mass with signal characteristics that typically mirror those of the original tumor

Post-surgery

Metallic implants

Hematoma

Seroma

Soft tissue edema

Myocutaneous flaps

Post-radiation

Osteitis

- bone marrow edema

- fatty change

Tumor necrosis

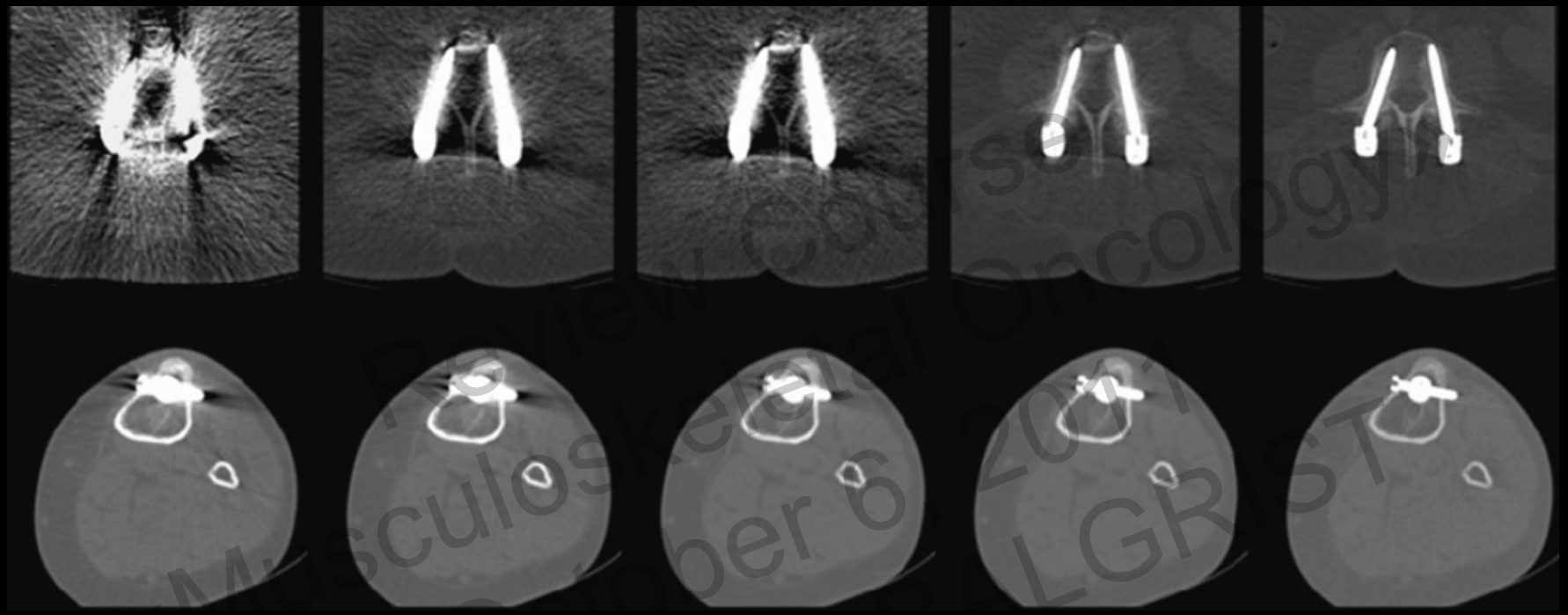
Strategies

- Full clinical history / surgery report

- Baseline MRI postsurgery for comparison purposes

- Advanced imaging techniques

Posttreatment: Advances CT



64 keV | 69 keV | 88 keV | 105 keV | optimal keV

Dual-energy CT: Monoenergetic extrapolation

Ref.: Bamberg F, et al. Metal artifact reduction by dual energy computed tomography using monoenergetic extrapolation. Eur Radiol. 2011 Jul.;21(7):1424–1429.

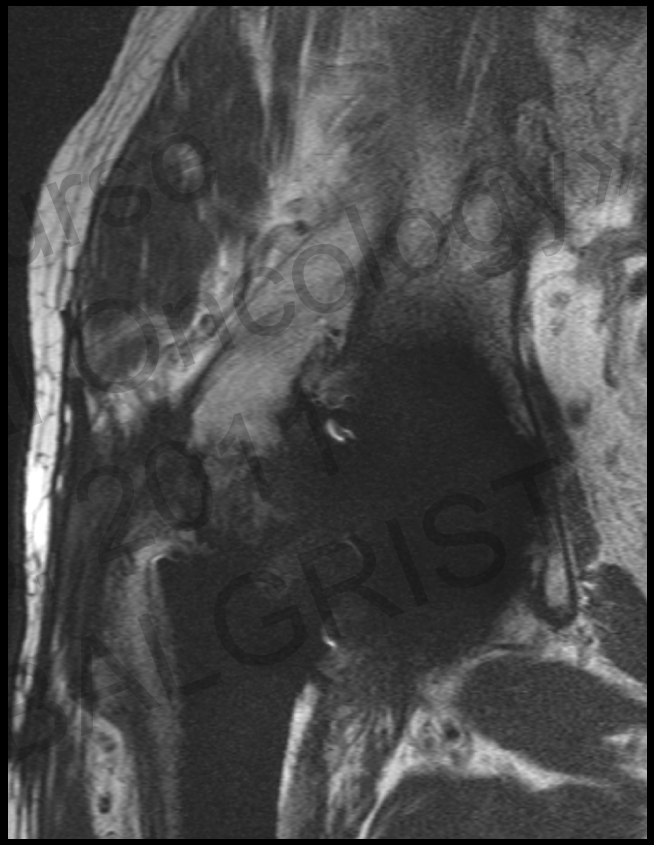
Posttreatment: Advances CT

Dual-energy CT: Monoenergetic extrapolation

Ref.: Bamberg F, et al. Metal artifact reduction by dual energy computed tomography using monoenergetic extrapolation. Eur Radiol. 2011 Jul.;21(7):1424–1429.

Posttreatment: Optimal MRI

80 Hz/Pixel



390 Hz/Pixel

Increasing Bandwidth

Posttreatment imaging: Optimal MRI

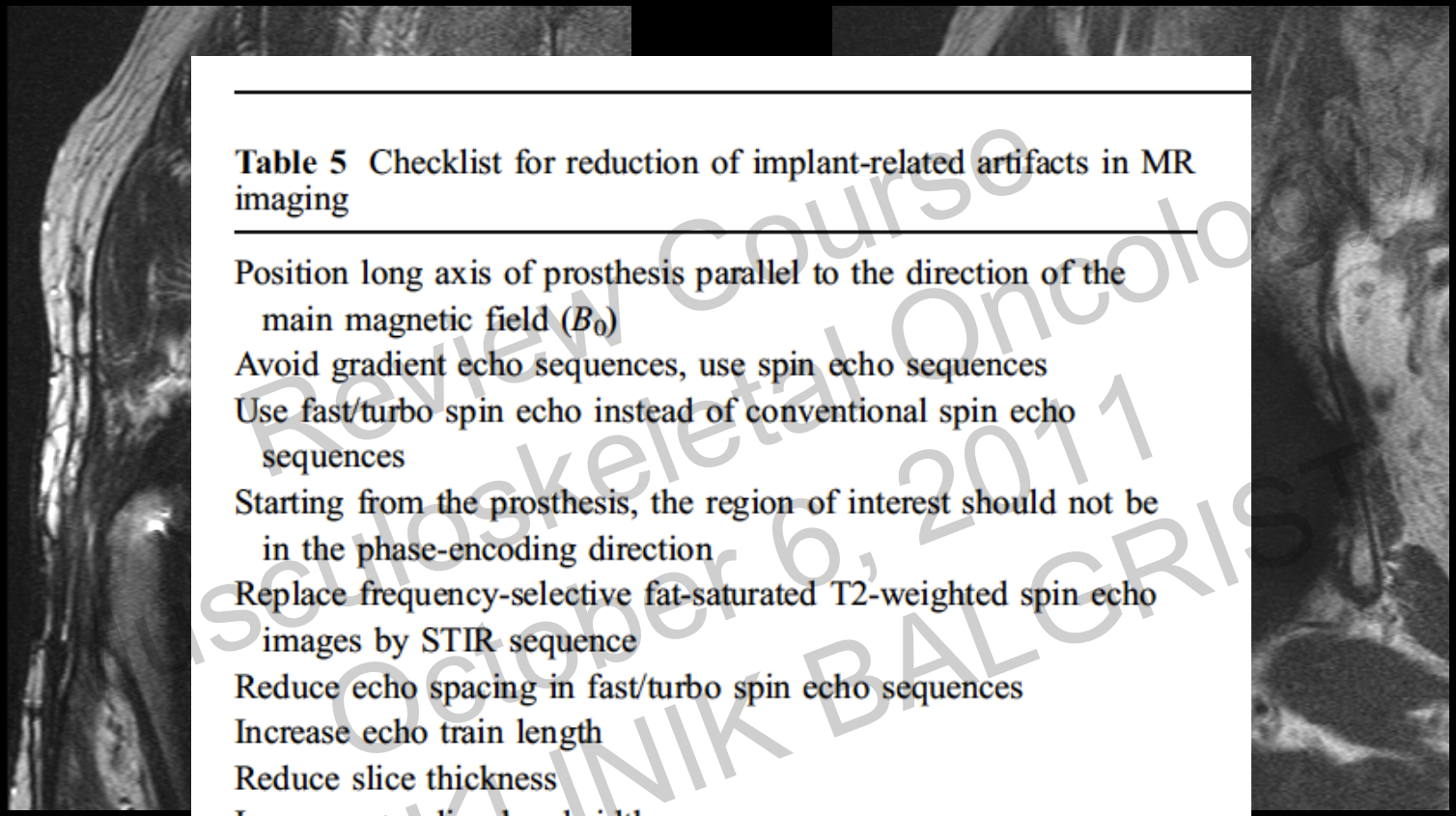


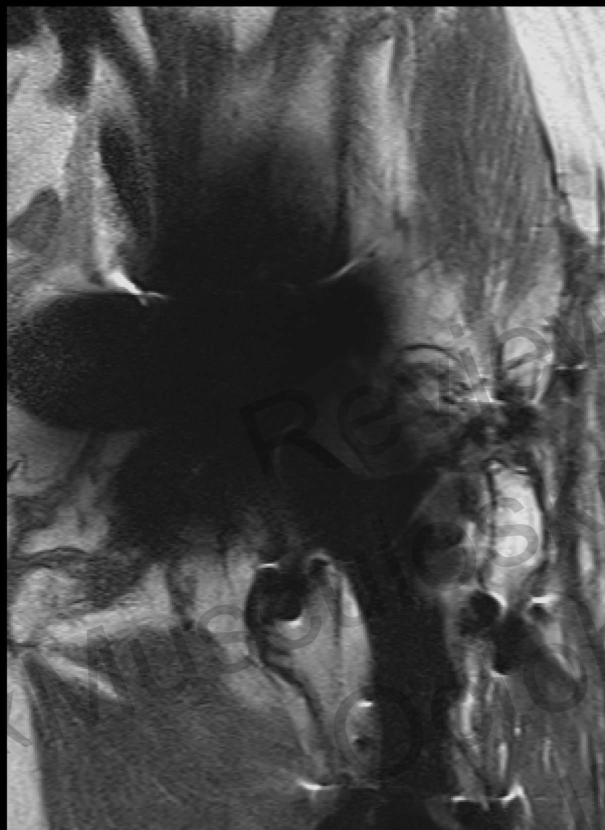
Table 5 Checklist for reduction of implant-related artifacts in MR imaging

Position long axis of prosthesis parallel to the direction of the main magnetic field (B_0)
Avoid gradient echo sequences, use spin echo sequences
Use fast/turbo spin echo instead of conventional spin echo sequences
Starting from the prosthesis, the region of interest should not be in the phase-encoding direction
Replace frequency-selective fat-saturated T2-weighted spin echo images by STIR sequence
Reduce echo spacing in fast/turbo spin echo sequences
Increase echo train length
Reduce slice thickness
Increase sampling bandwidth
Increase matrix size (e.g., 512×512)

Increasing Bandwidth

Ref.: Buck FM, et al. Shoulder arthroplasty. Eur Radiol. 2008 Dec.;18(12):2937–2948.

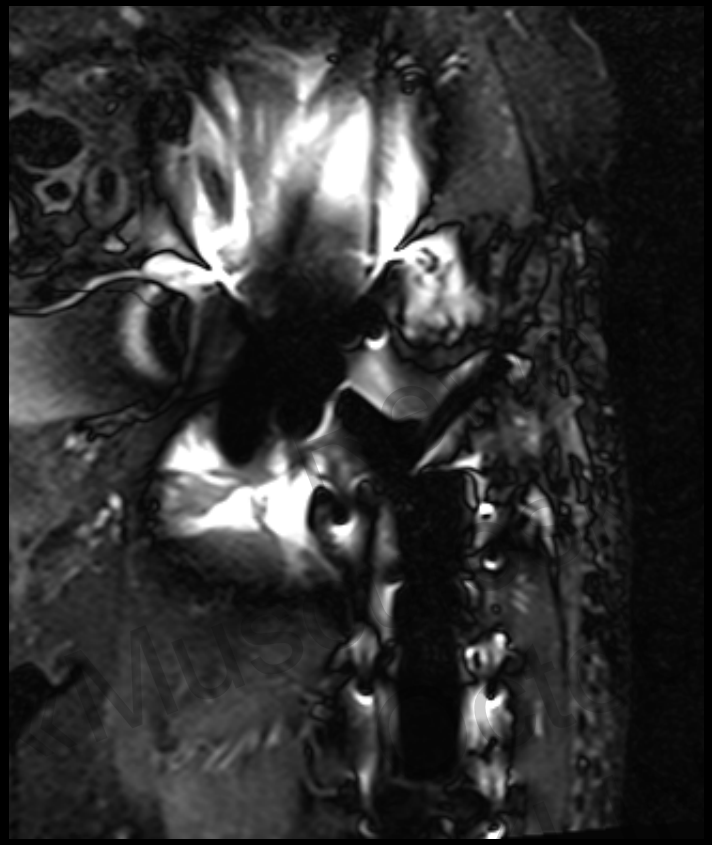
Posttreatment: Advances MRI



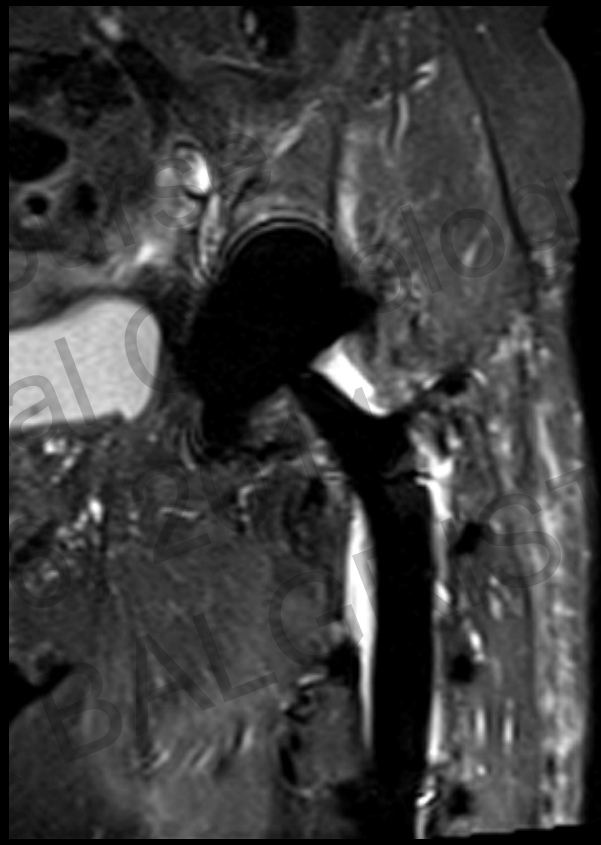
standard sequence
(turbo spin echo, high bandwidth)

WARP SPACE

Posttreatment: Advances MRI

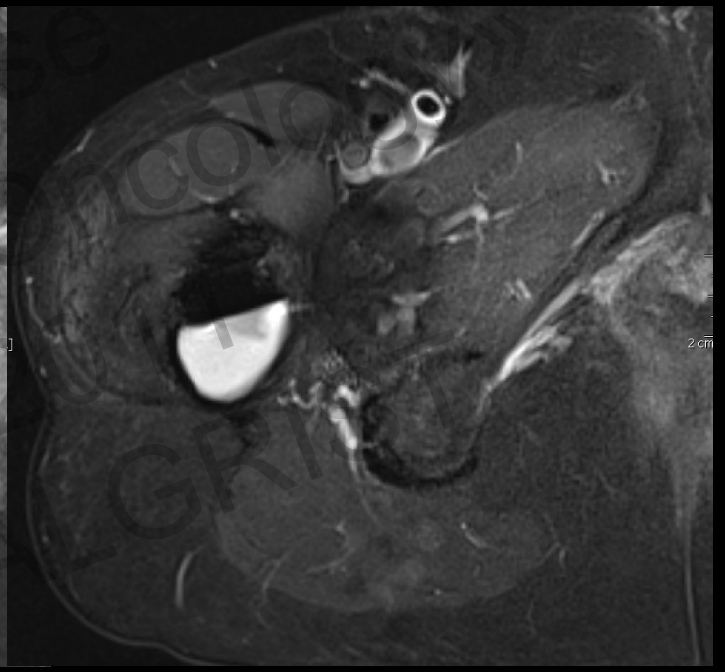


standard STIR
(high bandwidth)



WARP TSE

Posttreatment: Advances MRI

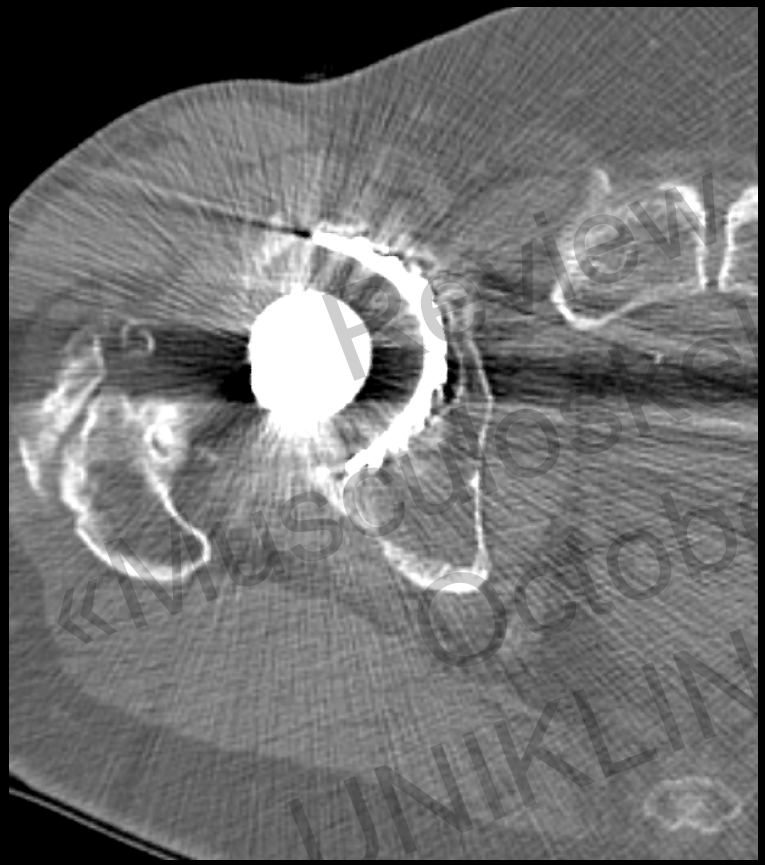


standard STIR
(high bandwidth)

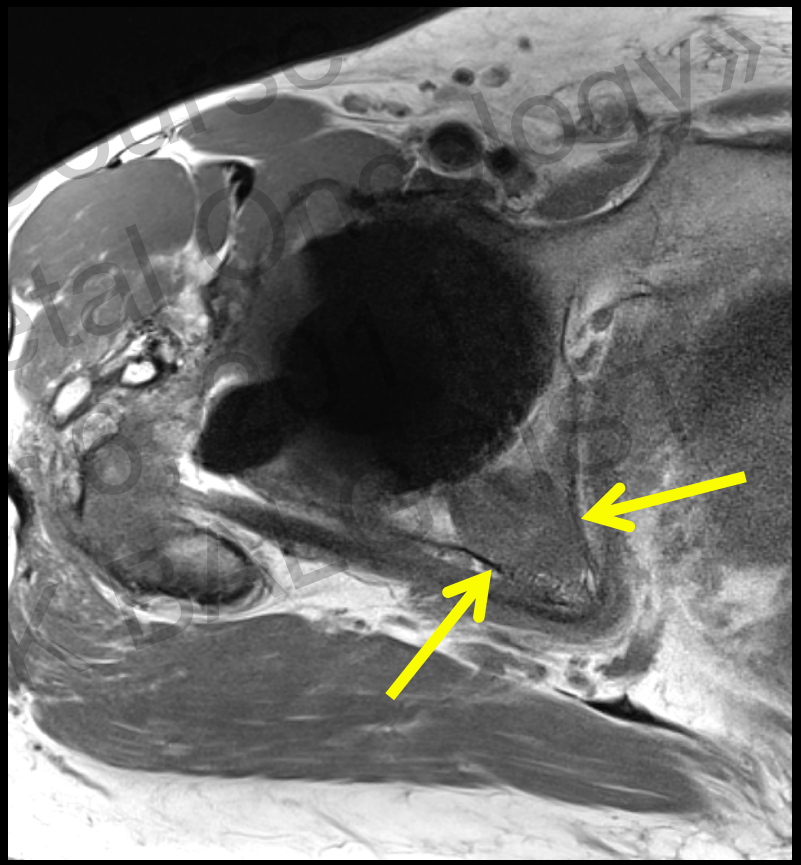
new STIR IR

Periprosthetic Osteolysis?

Periprosthetic Osteolysis?



CT



MRI

Periprosthetic Osteolysis?

CT

MRI

Dignity of a Lesion

- primarily evaluated on plain films

  NOT on MR images!

- Two most important aspects of evaluating a bone tumor are:
  - Tumor location
  - Patient age

  NOT radiologic appearance!

This information alone is enough to narrow the differential diagnosis without even looking at any images!

Ref.: Miller TT. Bone tumors and tumorlike conditions: analysis with conventional radiography. Radiology. 2008 Mar. 1;246(3):662-674

Dignity of a Lesion

- Criteria
  - Tumor localization (in the body)
  - Patient Age

- Specific radiographic features:
  - Tumor location (inside the bone)
  - Margins
  - Zone of transition
  - Periosteal reaction
  - Presence of a soft-tissue component

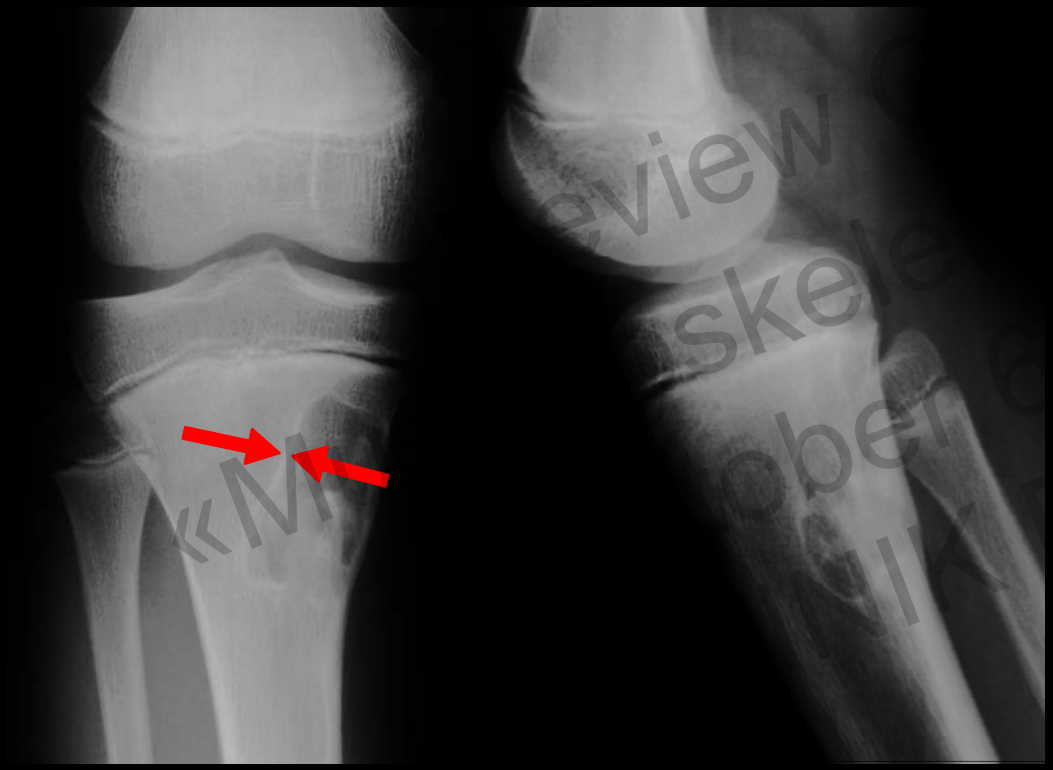
Tumor Localization

Most bone tumors often occur in a characteristic location in the skeleton

- axial versus appendicular skeleton
- long versus flat bones
- predilection for sites of rapid bone growth usually the metaphyseal region, e.g. osteosarcoma
- follow the distribution of red bone marrow, e.g. Ewing sarcoma

Zone of Transition

Non-ossifying Fibroma

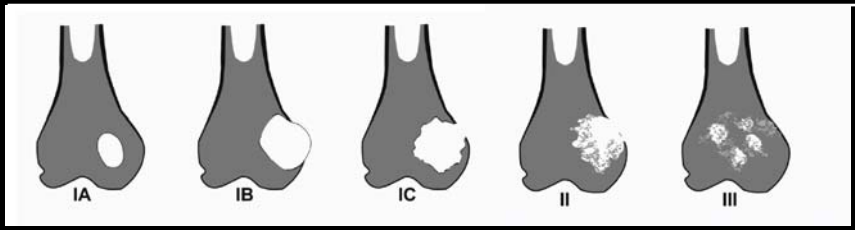


well-defined lesion

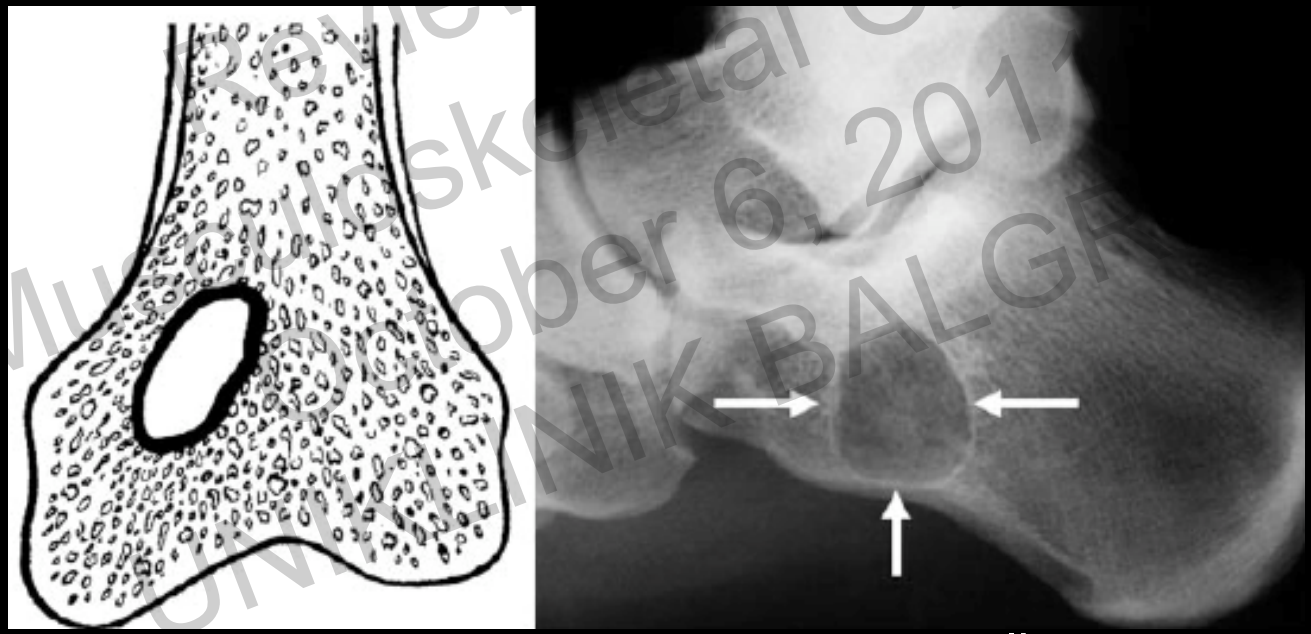
Ewing's Sarcoma

ill-defined lesion

Margins: Lodwick's Classification



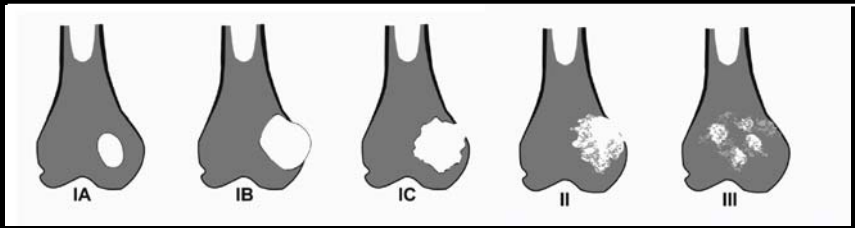
Type 1a – Geographic Lesion: Well-defined lucency with sclerotic rim.



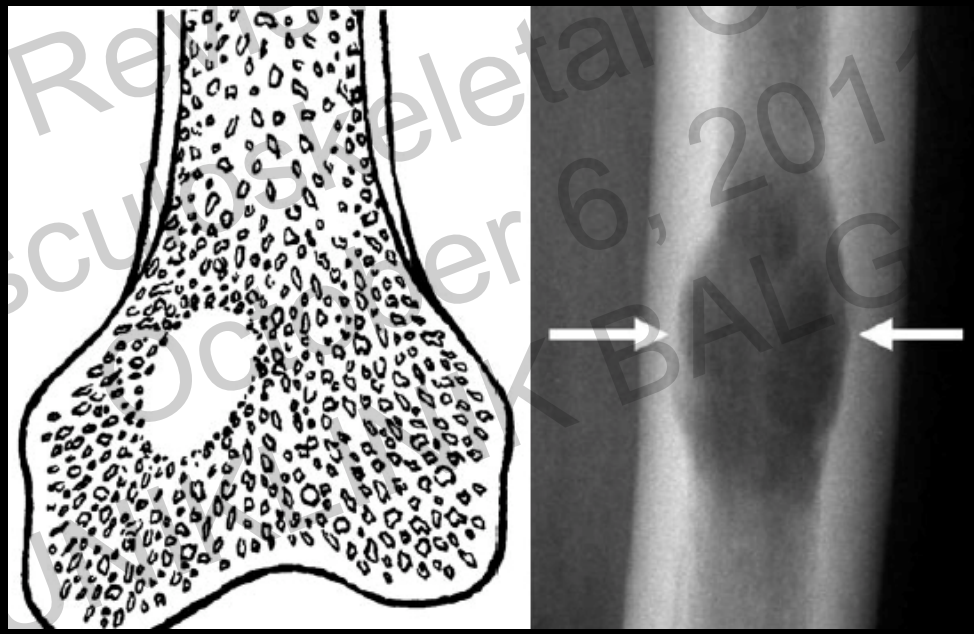
Intraosseous lipoma

Ref.: Lodwick GS et al. Determining growth rates of focal bone lesions. Radiology 1980;134:577-583.
Miller TT et al. Bone tumors and tumorlike conditions... Radiology 2008 Mar. 1;246(3):662-674.

Lodwick's Classification



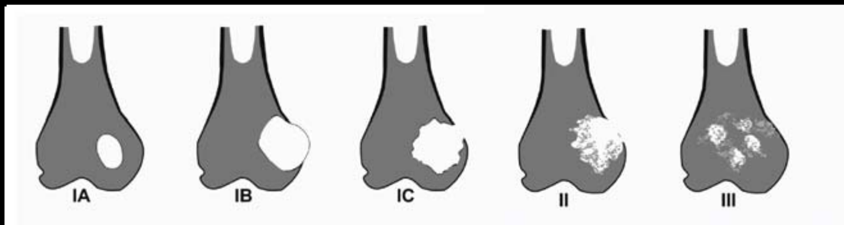
Type 1b – Geographic Lesion: Well-defined lucency without sclerotic rim and endosteal scalloping.



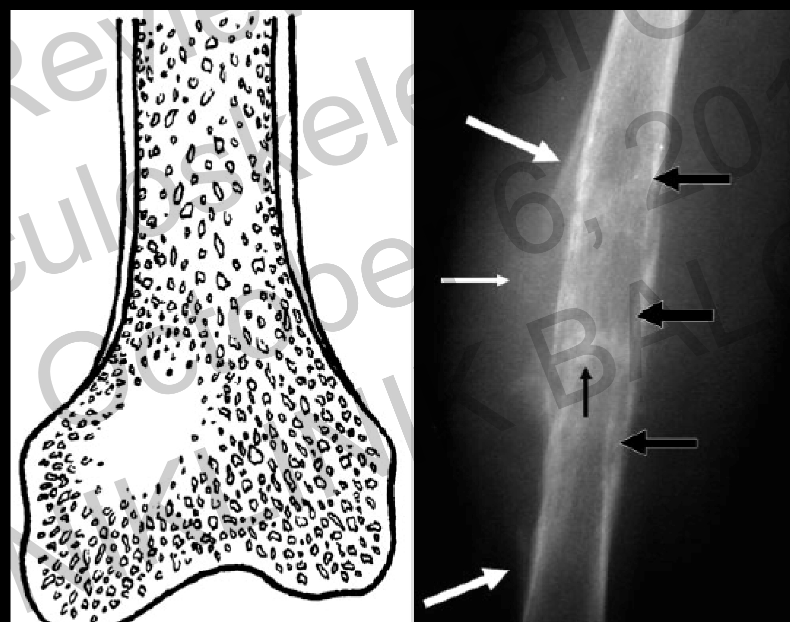
Myeloma

Ref.: Lodwick GS et al. Determining growth rates of focal bone lesions. Radiology 1980;134:577-583.
Miller TT et al. Bone tumors and tumorlike conditions... Radiology 2008 Mar. 1;246(3):662-674.

Lodwick's Classification



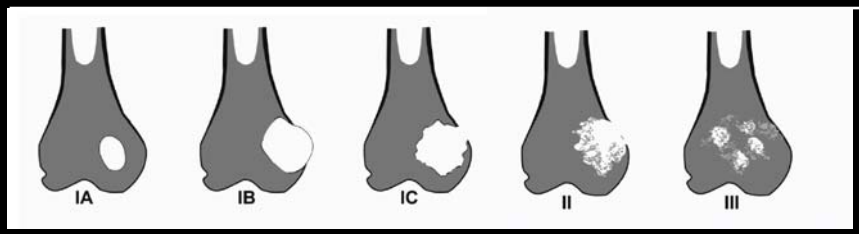
Type 1c – Geographic Lesion: Ill-defined lytic lesion with cortical disrupton. Codman triangle. New bone formation.



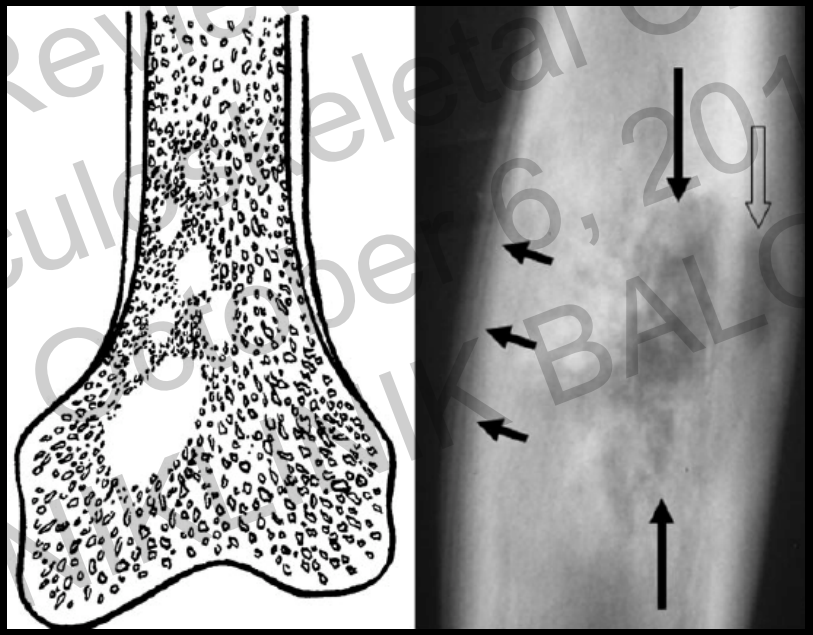
Osteosarcoma

Ref.: Lodwick GS et al. Determining growth rates of focal bone lesions. Radiology 1980;134:577-583.
Miller TT et al. Bone tumors and tumorlike conditions... Radiology 2008 Mar. 1;246(3):662-674.

Lodwick's Classification



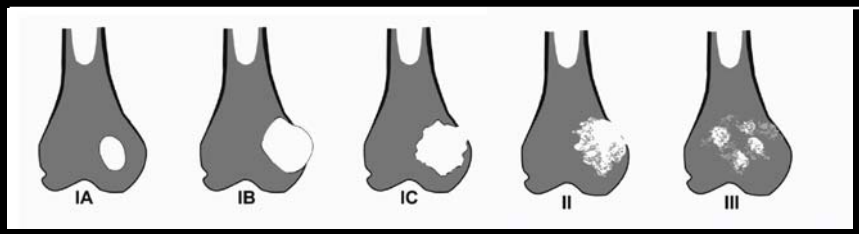
Type 2 – Moth-eaten Lesion: Ill-defined patchy lytic lesion with multi-lamellated periosteal reaction.



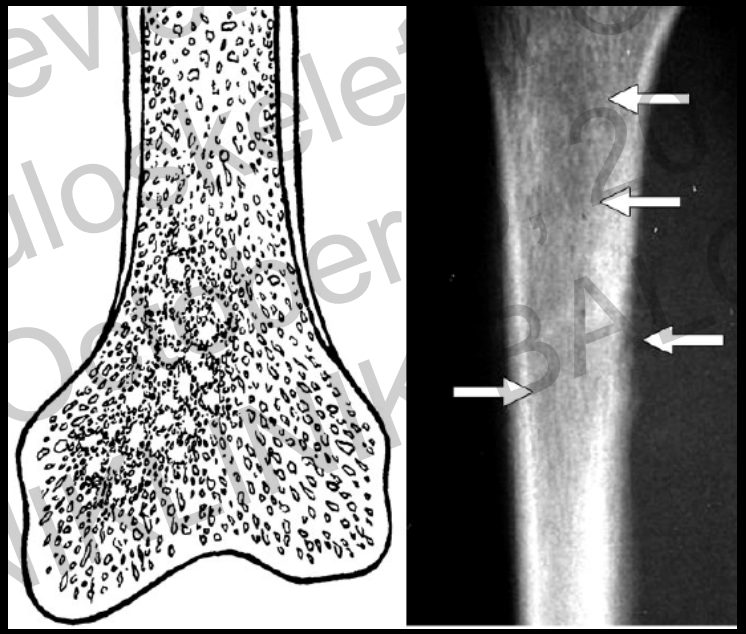
Osteosarcoma

Ref.: Lodwick GS et al. Determining growth rates of focal bone lesions. Radiology 1980;134:577-583.
Miller TT et al. Bone tumors and tumorlike conditions... Radiology 2008 Mar. 1;246(3):662-674.

Lodwick's Classification



Type 3 – Permeated Lytic Lesion: Fine permeated pattern with ill-defined small patchy lucencies.



Ewing's Sarcoma

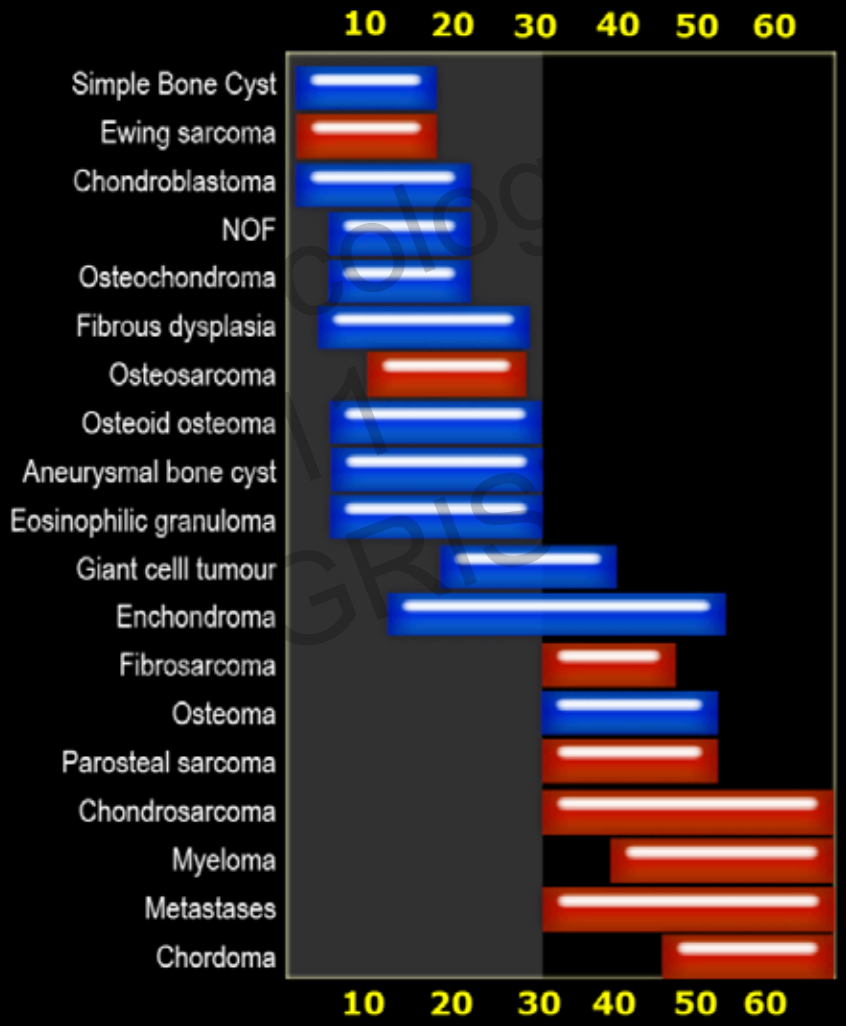
Ref.: Lodwick GS et al. Determining growth rates of focal bone lesions. Radiology 1980;134:577-583.
Miller TT et al. Bone tumors and tumorlike conditions... Radiology 2008 Mar. 1;246(3):662-674.

Patient Age

The most important piece of clinical information when assessing a bone tumor is the patient's age.

For example:

- Simple simple bone cysts and chondroblastomas occur in skeletally immature people
- Giant cell tumors in skeletally mature people
- Conventional osteosarcoma have two age peaks: In teenagers (de novo), in pagetic or previously irradiated bone, in adults older than 50 years



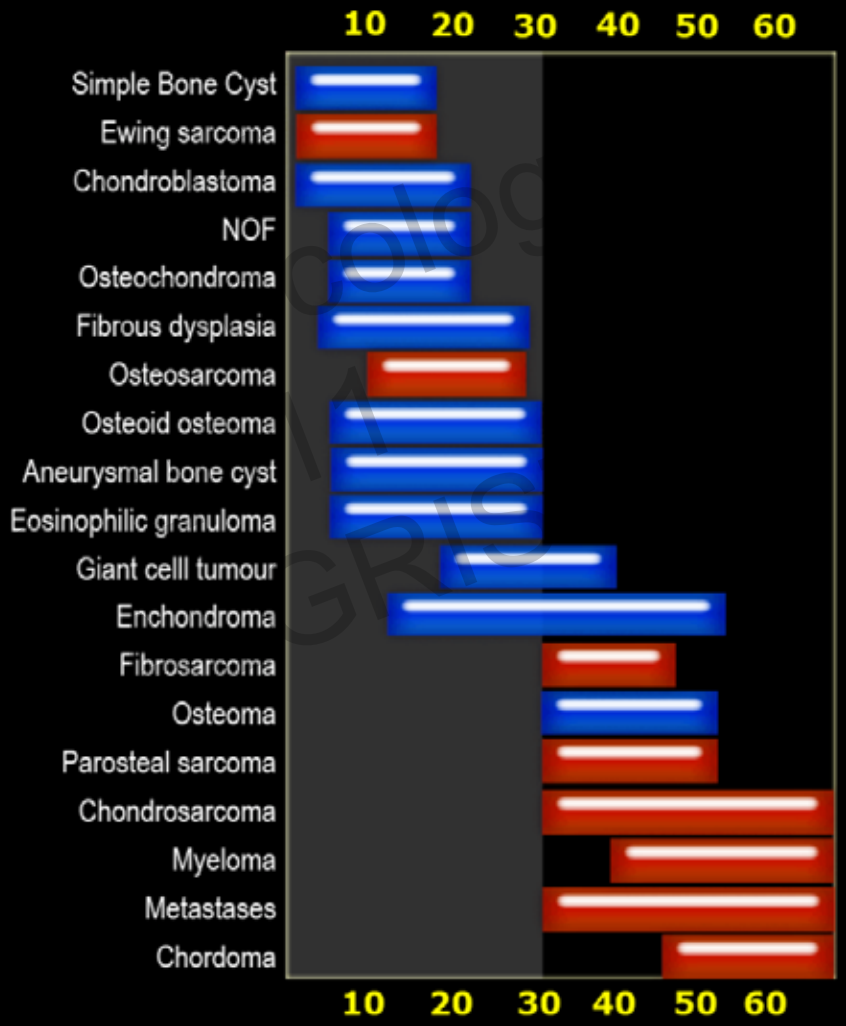
Ref.: Miller TT. Bone tumors and tumorlike conditions: analysis with conventional radiography. Radiology. 2008 Mar. 1;246(3):662-674

Patient Age

The most important piece of clinical information when assessing a bone tumor is the patient's age.

For example:

- Malignant bone lesion in an adult <u>over 40 years</u> old is much more likely to be:
  - metastatic carcinoma
  - myeloma
  - metastatic non-Hodgkin lymphoma rather than a primary bone sarcoma.

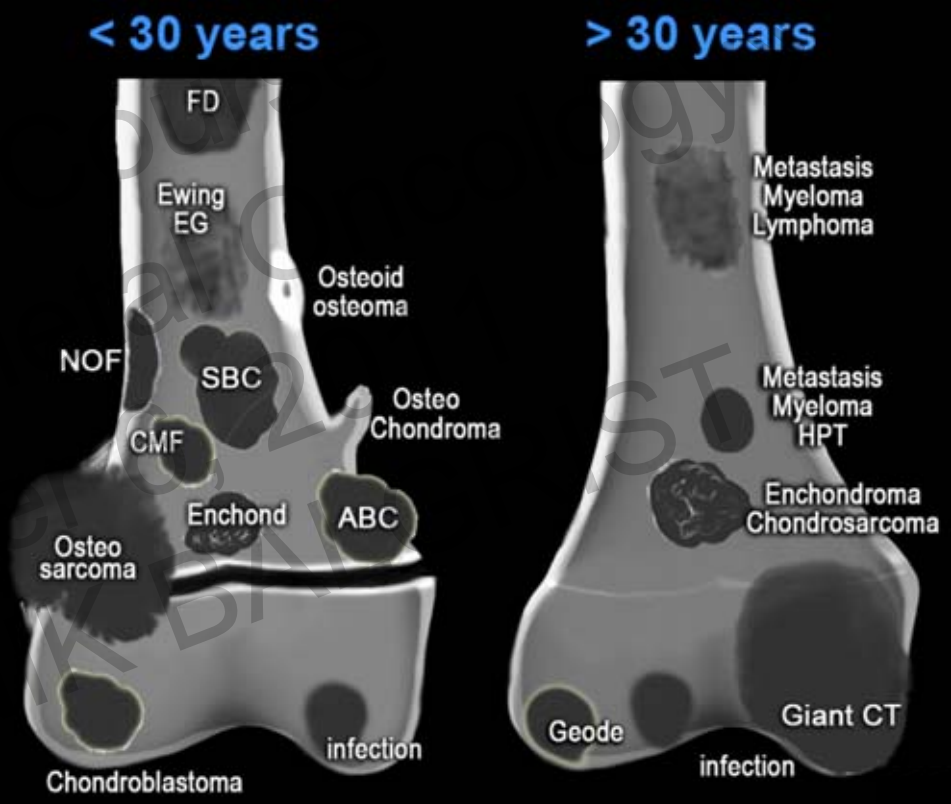


Ref.: Miller TT. Bone tumors and tumorlike conditions: analysis with conventional radiography. Radiology. 2008 Mar. 1;246(3):662-674

Radiographic features: Location

A lesion in a long bone may be characterized by its:

- longitudinal location
  - epipyseal
  - metaphyseal
  - diaphyseal
- transverse location
  - medullary
  - cortical
  - juxtacortical

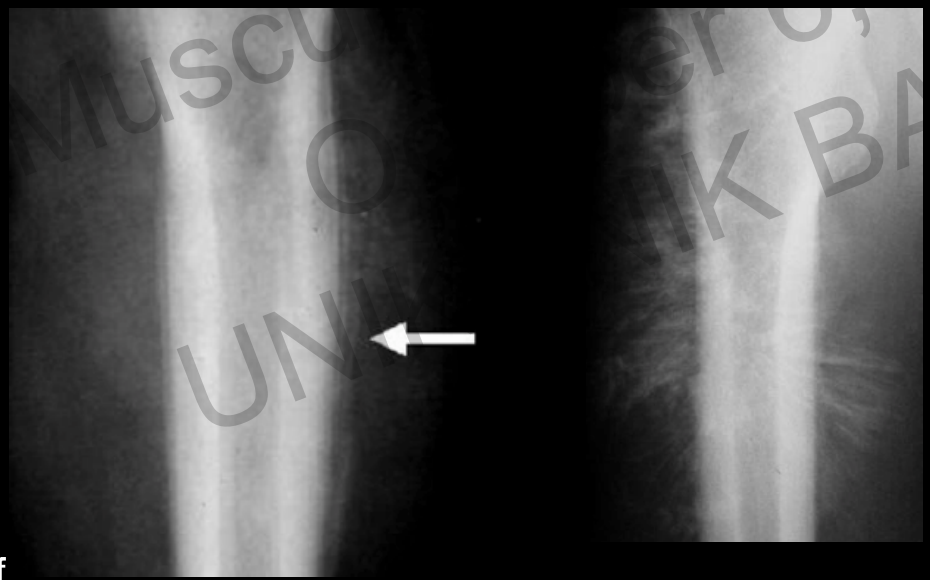


Periosteal reaction

Hypertrophic osteoarthropathy in a patient with lung cancer

Ref.: www.radiologyassistant.nl

Periosteal reaction



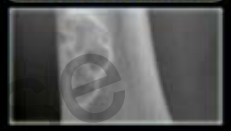
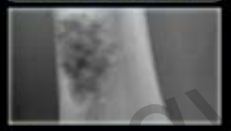
Osteosarcoma

Radiographic features: Margin

The margin of a lesion and type of periosteal reaction are indicators of lesion aggressiveness, but not necessarily of whether it is benign or malignant.

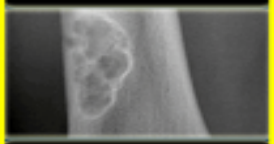
A well-defined lesion with a sclerotic rim and thick unilamellar periosteal reaction is the most innocuous appearance

A permeated pattern with spiculated periosteal reaction is the most aggressive.

Age	Well-defined	ill-defined	Sclerotic
			
0 - 10	EG SBC	EG - Ewing Osteosarcoma Leukemia	Osteosarcoma
10 - 20	NOF, Osteoblast Fibr dysplasia EG SBC ABC Chondroblast CMF	Ewing EG Osteosarcoma	Osteosarcoma Fibr dysplasia EG Osteoid osteo Osteoblastoma
20 - 40	Giant CT Enchondroma Chondrosarcoma (low grade) HPT - Brown tumor Osteblastoma	Giant CT	Enchondroma Osteoma Bone island Parosteal Osteosar Healed lesions: - NOF, EG - SBC, ABC - Chondroblast
40+	Metastases Myeloma Geode	Metastases Myeloma Chondrosarcoma (high grade)	Metastases Bone island
All ages	Infection	Infection	Infection

Ref.: www.radiologyassistant.nl

Radiographic features: Margin

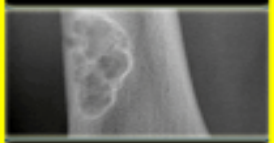
Age	Well-defined
	
0 - 10	EG SBC
10 - 20	NOF, Osteoblast Fibr dysplasia EG SBC ABC Chondroblast CMF
20 - 40	Giant CT Enchondroma Chondrosarcoma (low grade) HPT - Brown tumor Osteblastoma
40+	Metastases Myeloma Geode
All ages	Infection

Fibrous Dysplasia	Any age, no periosteal reaction
Eosinophilic granuloma Enchondroma	Age under 30 Calcified matrix (except in phalanges)
Giant Cell Tumor	Epiphysis closed, epiphyseal location abuts articular suface, nonsclerot margin
NOF	Age under 30, juxtacortical
Osteoblastoma	Like ABC, located in spine
Metastasis Myeloma	Age over 40
ABC	Age under 30, expansile
SBC	Age under 30, centrally
Hyperparathyroidism	Other signs of hyperparathyroidism
Infection	Always included in differential
Chondroblastoma CMF	No calcified matrix Mention when considering M

Well-defined Osteolytic

Eccentric	Centrally	Must be < 30
GCT	SBC	EG - ABC - NOF SBC Chondroblastoma
Epiphyseal		**Age > 40**
Chondroblastoma GCT Geode, infection		metastasis myeloma geode, infection
Exclude if periostitis	**Ca++**	**Multiple**
Fibrous Dysplasia NOF, SBC Enchondroma	Enchondroma Low grade chondros Osteomyelitis Eosinophilic granul Mets (breast)	FD, EG mets, myeloma enchondroma Hyperparathyroidism Infection

Radiographic features: Margin

Age	Well-defined
	
0 - 10	EG SBC
10 - 20	NOF, Osteoblast Fibr dysplasia EG SBC ABC Chondroblast CMF
20 - 40	Giant CT Enchondroma Chondrosarcoma (low grade) HPT - Brown tumor Osteblastoma
40+	Metastases Myeloma Geode
All ages	Infection

Non-ossifying Fibroma

Brown tumor - HPT

Radiographic features: Margin

Age	Well-defined	ill-defined
		
0 - 10	EG SBC	EG - Ewing Osteosarcoma Leukemia
10 - 20	NOF, Osteoblast Fibr dysplasia EG SBC ABC Chondroblast CMF	Ewing EG Osteosarcoma
20 - 40	Giant CT Enchondroma Chondrosarcoma (low grade) HPT - Brown tumor Osteblastoma	Giant CT
40+	Metastases Myeloma Geode	Metastases Myeloma Chondrosarcoma (high grade)
All ages	Infection	Infection

Ewing's Sarcoma

Metastases

Radiographic features: Margin

Age	Sclerotic
	
0 - 10	Osteosarcoma
10 - 20	Osteosarcoma Fibr dysplasia EG Osteoid osteo Osteoblastoma
20 - 40	Enchondroma Osteoma Bone island Parosteal Sarcoma Healed lesions: - NOF, EG - SBC, ABC - Chondroblast
40+	Metastases Bone island Chondrosarcoma
All ages	Infection

LSMFT – liposclerosing myxofibrous tumor

Osteoid Osteoma

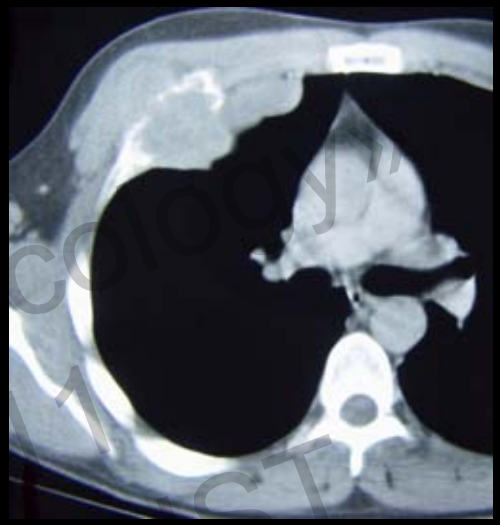
Ref.: www.radiologyassistant.nl

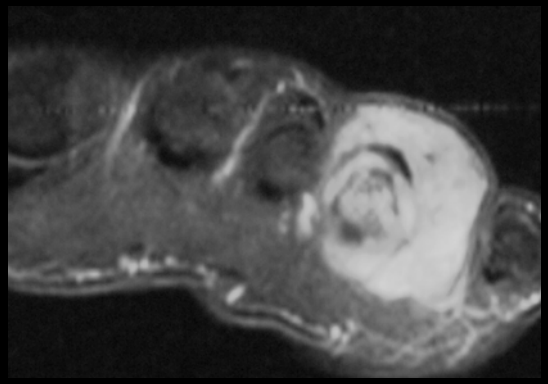
Soft-Tissue Component

The presence of a soft-tissue component:

- suggests a malignant process

- typical tumors that often have a soft-tissue component:
  - osteosarcoma
  - Ewing's sarcoma
  - lymphoma





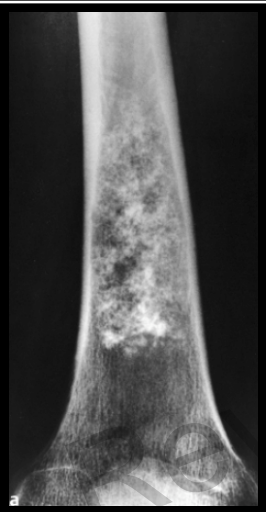
So What?!?

Do we need these criteria ...

We need biospy anyway ...

Leave me alone lesions

non-ossifying fibroma

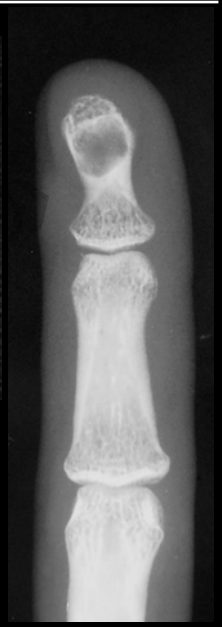


enchondroma

melorheostosis

osteochondroma

junvenile bone cyst



inclusion cyst of finger

metaphyseal cortical irregularity

osteoidosteoma

bone infarct

myositis ossificans

Ref.: Hamers S. "Leave me alone lesions" des Knochens. Radiologie up2date 2002 Jul. 2;1-30.

So What?!?

Yes, we need these criteria to:

- obviate biopsy of lesions that should not be biopsied

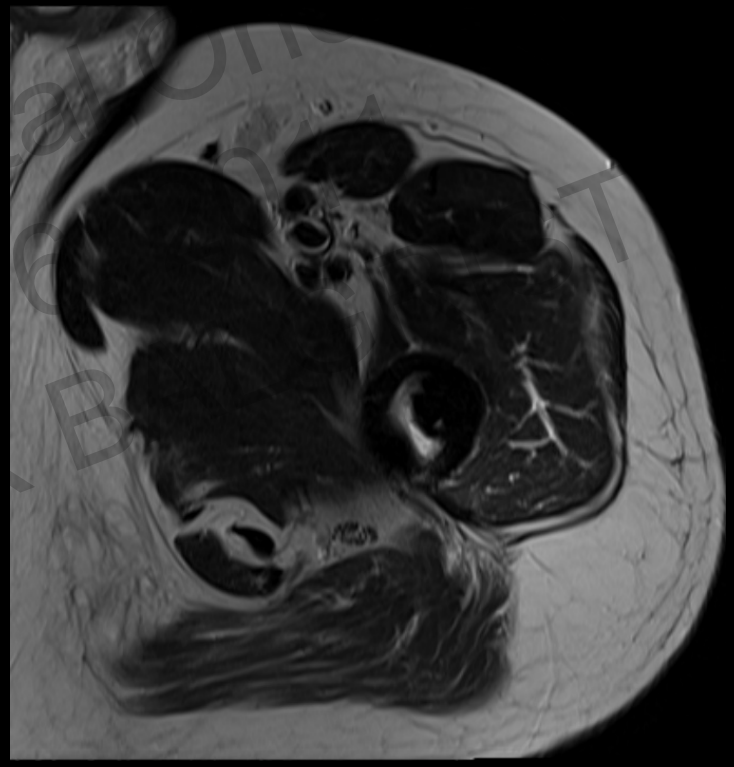
And also….

- know where biopsy should be performed (vital tumor tissue)
- plan the biopsy direction
- plan surgery

Surgery Planning

- T1-weighted & T2-weighted sequences
- axial plane

medial



lateral

T1

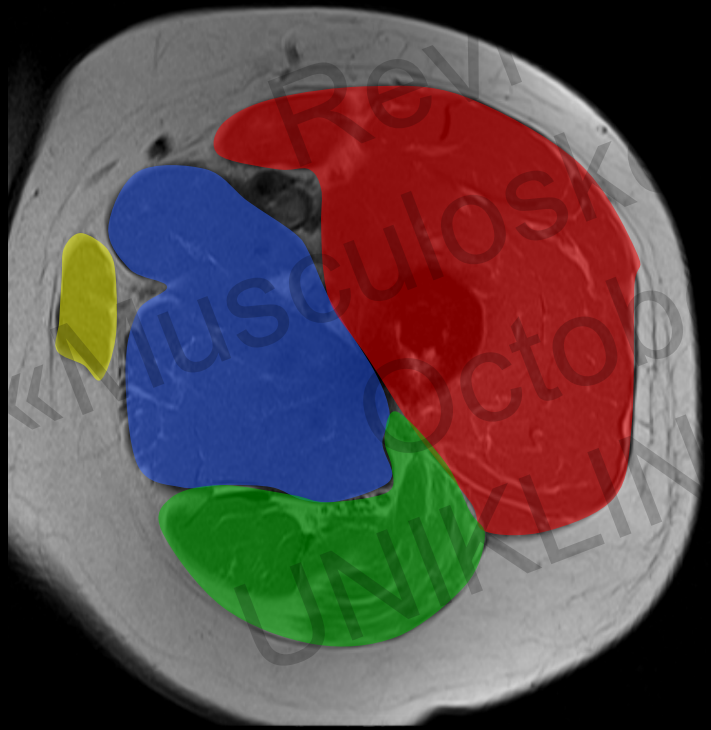
T2

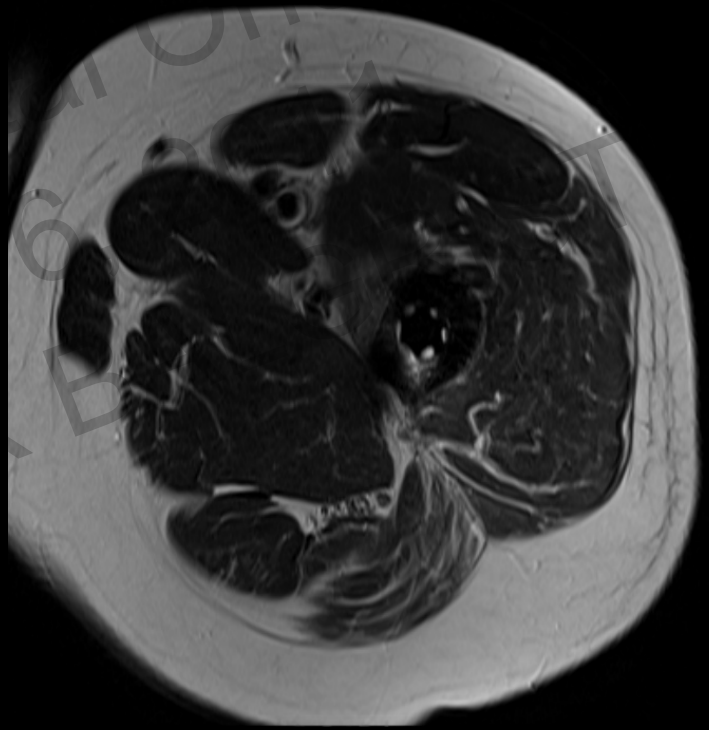
Leiomyosarcoma

Surgery Planning

- Identify compartments
- Vessels
- Nerves

medial





lateral

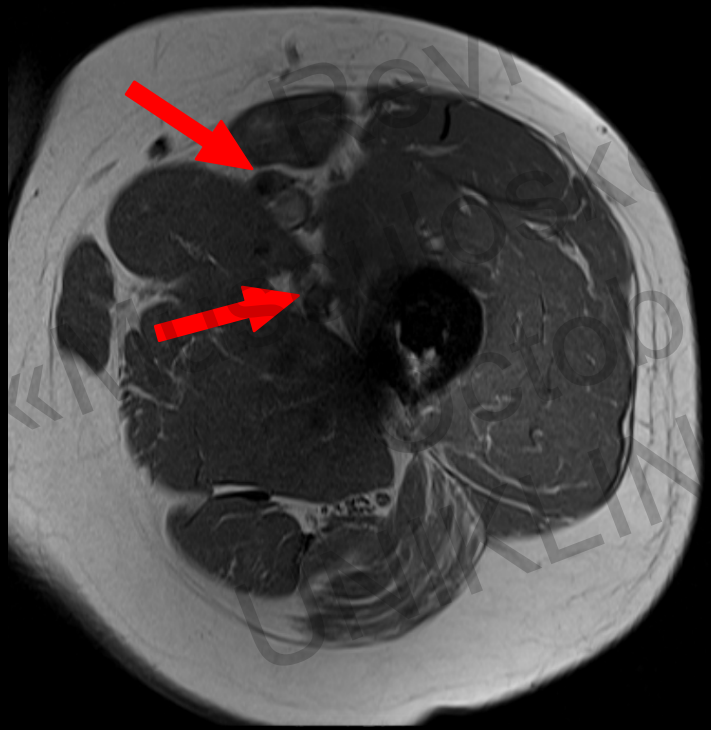
T1

T2

Leiomyosarcoma

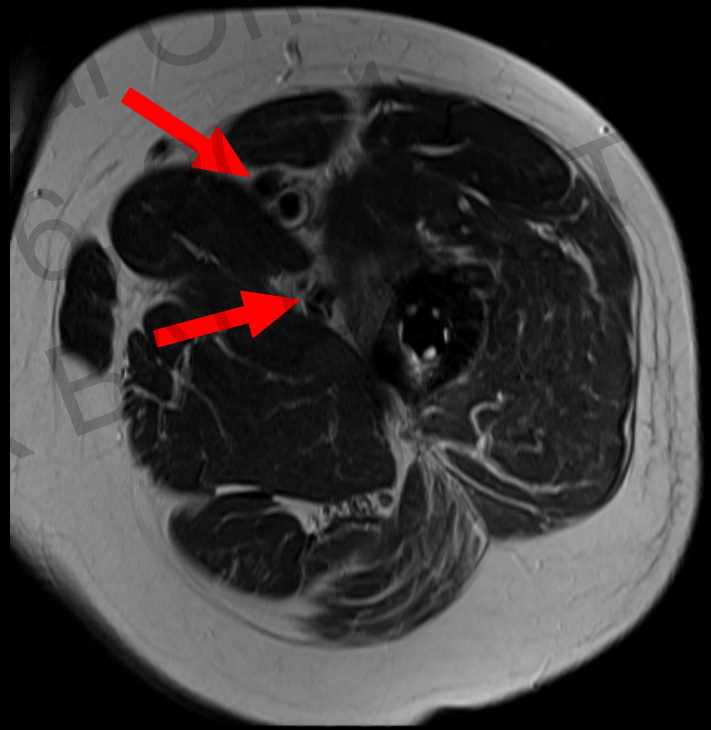
Surgery Planning

- Identify compartments
- Vessels
- Nerves



medial

T1



lateral

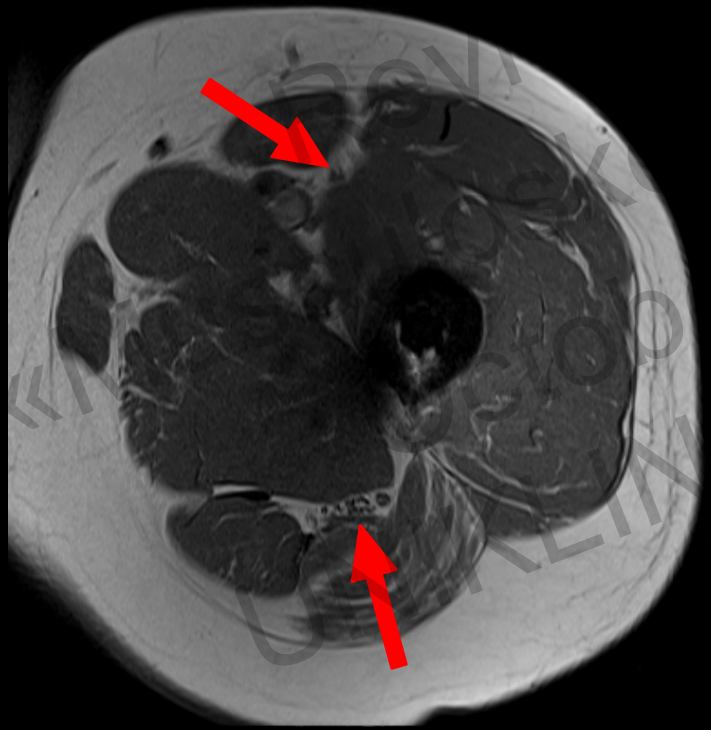
T2

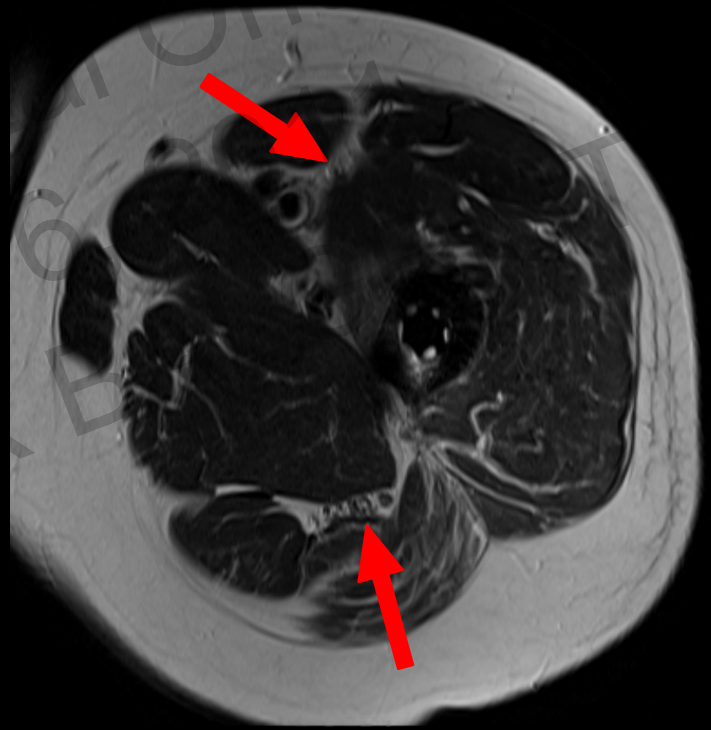
Leiomyosarcoma

Surgery Planning

- Identify compartments
- Vessels
- Nerves

medial





lateral

T1

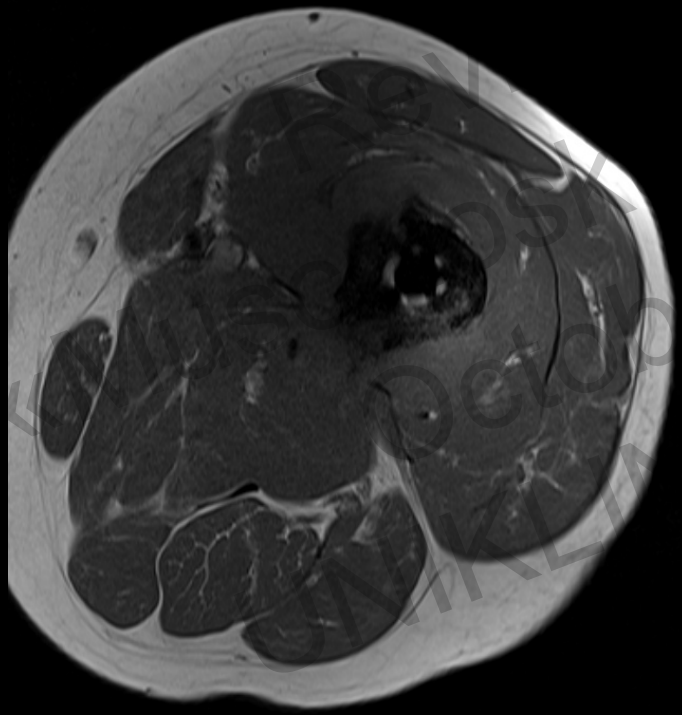
T2

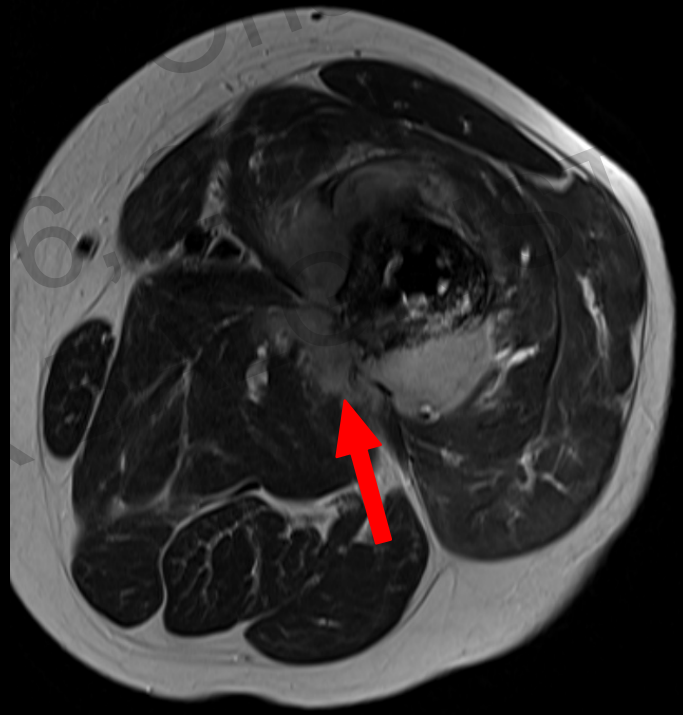
Leiomyosarcoma

Surgery Planning

- Scrolling through the images
- Define compartments, vessels and nerves involved

medial





lateral

T1

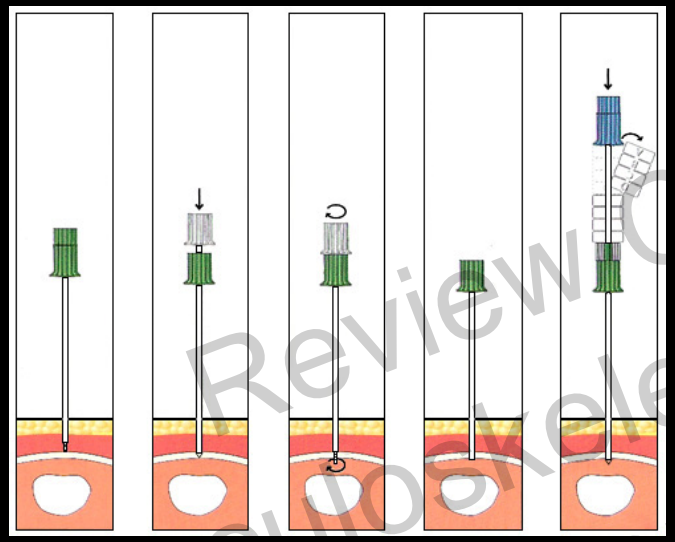
T2

Leiomyosarcoma

Image-guided Biopsy

BONE

Bonopty



Trapsystem

SOFT TISSUE

Spirotome

Coaxial Achieve "Snapper"

Thank you for your attention!