Tumors of Soft Tissue
Anatomy, Work-Up, and MR Features

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Outline

I. Soft Tissue Anatomy
   • Compartmental

I. Imaging Work-Up
   • Post-Treatment Imaging

II. Soft Tissue Tumors—MR Features
   • WHO Classification
Soft Tissue Anatomy
Soft Tissue

- Derived from mesenchyme:
  1. Skeletal muscle
  2. Fat
  3. Fibrous tissue
  4. Vascular structures
  5. Associated peripheral nervous system
1. Local staging
   • Depends on which anatomic spaces (compartments) are involved
   • Intracompartamental lower stage

2. Biopsy
   • Risk of seeding malignant cells along needle track
   • Determines subsequent surgical approach; track usually resected
Compartmental Anatomy

• **Natural Barriers define compartments:**
  - Joint capsule
  - Cortex/periosteum
  - Tendon origins/insertions
  - Major fascial septae

• **Extracompartamental spread by:**
  - Direct tumor invasion
  - Fracture
  - Hemorrhage
  - Poorly planned biopsy

Compartmental Anatomy

General

- Skin/Subcutaneous fat
- Bone
- Paraosseous
  - Space between bone and overlying tissues
- Intraarticular
- Muscle
- Neurovascular
  - Not a compartment, but can provide route of extracompartmental spread
Compartmental Anatomy
Upper Extremity

- Upper Arm
  - Anterior
  - Posterior
- Forearm
  - Dorsal
  - Volar
- Purely Extracompartmental
  - Periclavicular
  - Axilla
  - Antecubital fossa
  - Wrist
  - Dorsum of hand
Compartmental Anatomy
Lower Extremity

- Thigh
  - Anterior
  - Posterior
  - Medial
- Lower Leg
  - Anterior
  - Deep posterior
  - Superficial posterior
  - Lateral
- Foot
  - Medial, central, lateral plantar
- Purely Extracompartmental
  - Inguinal
  - Popliteal fossa
  - Ankle
  - Dorsum of foot
Work-Up
Soft Tissue Tumors
Preliminary Evaluation

• Clinical History

✓ Previous lesion/underlying malignancy?
✓ Prior surgery/radiation?
✓ Painful vs painless
✓ Trauma
✓ Anticoagulation
✓ Stability over time/Variation in size
Soft Tissue Tumors

Initial Evaluation

- > 1 lesion limits DDx

- Multiple soft tissue tumors:
  - Lipomas
  - Fibromatoses
  - Neurofibromas
  - Angiomatous lesions
  - Myxomas
  - Mets (rare)

Kransdorf MJ, Murphey MD. AJR 2000; 175: 575-587
Soft Tissue Tumors

Imaging

- Radiographs (Always)
  - Specific calcifications (exostosis, phleboliths, synovial chondromatosis, myositis ossificans)
  - Non-specific calcifications (dystrophic in slow growing mass suggests synovial sarcoma)
  - Osseous Involvement
Soft Tissue Tumors

Imaging

- Sonography
  - Fast
  - Inexpensive
  - Ideal for solid vs. cystic when anatomically accessible

- CT
  - Further evaluate pattern of mineralization
  - Relationship to nearby complex osseous structures (Pelvis, shoulder, paraspinal)

- MRI
  - Modality of choice
  - Superior soft tissue contrast
Soft Tissue Tumors

Imaging

• MR cannot reliably distinguish benign from malignant soft tissue masses

• Non Specific:
  • Contrast enhancement (solid v. cystic, hematomas, necrosis for biopsy or trtmt response)

• Suggestive of malignancy:
  • Larger (5% benign tumors > 5 cm)
  • Heterogenous signal (infarction, necrosis)
  • Well-defined borders
  • Deep (1% benign tumors are deep) > superficial

Kransdorf MJ, Murphey MD. AJR 2000; 175: 575-587
Post-Treatment Imaging
Soft Tissue Tumors
Post-Treatment Imaging

• 50% patients with soft tissue sarcomas have local recurrence

• Increase Risk for Local Recurrence:
  • Tumor diagnosis
  • High Grade
  • Deep location
  • Unable to obtain wide margins
  • Radical resection vs marginal excision
  • Positive Surgical margins

• Radiation or chemotherapy (time course)
• Reconstructive surgery (time course)
Soft Tissue Tumors
Post-Treatment Imaging

- MR
  - Discrete nodule (Post surgical changes more variable)
  - Recurrent tumor looks like the primary tumor (review pre-op)
  - Markers noting scar margins
  - Contrast (necrosis/response, hematoma)

Soft Tissue Tumors

Radiation

- Marrow changes
  - As early as 8 days
  - Increasing fatty signal (1-6 wks)
  - Complete fatty replacement in 6-8 wks
  - Can see focal non specific signal (radiation osteitis), mean 9 months

Soft Tissue Tumors
Radiation

- **Soft Tissue Changes**
  (Peak 12-18 mo; half return to nl in 2-3 yrs)

  - Trabecular/lattice-like subcutaneous signal
  - Diffuse muscle enhancement, preservation of shape and architecture
  - Signal persists in intermuscular septae longer
  - Pseudotumor
  - Sarcoma

Kransdorf MJ, Murphey MD. RCNA 2006; 44:463-472
Soft Tissue Tumors
Post-Treatment Changes

Chemotherapy
- May increase tumor size at first due to hemorrhage
- Necrosis predicts response

Postoperative Fluid and Hemorrhage:
- Similar appearance seen with non-oncologic procedures
- Most seromas resolve in 3-18 months
Soft Tissue Tumors
Post-Treatment Changes

• **Reconstructive Surgery**
  
  • Myocutaneous flaps used in > 2/3

• **Rotational Flaps**
  
  • Rotated into position preserving native neurovascular pedicle

• **Free Flaps**
  
  • Completely detached with vascular pedicle reanastomosed
Soft Tissue Tumors
Reconstructive Surgery

- Atrophy with time (less with those providing function)
- Increased T2 signal initially
- Signal returns to baseline within 2 yrs (1/3 cases)
- Enhancement in 3/4; returns to baseline in 18 months in 1/3

Soft Tissue Tumors
Post-Treatment Changes


4 months

31 months

Soft Tissue Tumors
Soft Tissue Tumors

- Benign 100X more common than malignant
- Soft tissue sarcomas 2-3X more common than primary malignant bone tumors
- Tumors classified histologically based on adult tissue they resemble
- Many demonstrate specific MR features, but majority are nonspecific
Soft Tissue Tumors
WHO Classification

- Neurogenic
- Vascular
- Fibroblastic
- Adipocytic
- Fibrohystiocytic
- Smooth Muscle
- Perivascular
- Skeletal Muscle
- Chondro-osseous
- Tumors of uncertain differentiation
Neurogenic Tumors
Peripheral Nerve Sheath Tumors

Benign

- Schwannomas/Neurofibromas
  - Fascicular Sign
  - Split Fat Sign

- Neurofibroma
  - Target pattern (T2)
  - Infiltrative: resection sacrifices nerve

- Schwannoma
  - Eccentric
  - Displaces nerve: resection spares nerve
Peripheral Nerve Sheath Tumors
Malignant

- Pain, rapid growth
- No target, split fat, or fascicular sign
- Intralesional hemorrhage and necrosis (peripheral enhancement)
- Inhomogenous (T1, T2, Post)
- Nodular
- Along course of large nerve
Peripheral Nerve Sheath Tumors

Malignant

Malignant Peripheral Nerve Sheath Tumor?
Malignant Peripheral Nerve Sheath Tumors

- MR and CT not reliable in characterizing benign vs. malignant
- Surgical resection of entire lesion often not feasible
- Biopsy may yield false negative due to sampling error
MPNST and FDG-PET

- FDG PET sensitive (95%) in detecting MPNST in patients with NF1

- Can also detect mets or second primaries (GIST which is associated with NF1)

Bredella MA, et al. AJR 2007; 189:928–935
MPNST and PET

- PET specificity lower (72%)

- Can use 11-C Methionine PET to increase specificity (91%)

Bredella MA, et al. AJR 2007; 189:928–935
Vascular Tumors
# Vascular Anomalies

## Tumors of Childhood

- Hemangioma
  
  *Childhood neoplasm with a proliferative and involutive phase (not applicable to any adult lesion)*

## Vascular Malformations

- Capillary
- Venous
- Lymphatic
- Ateriovenous
- Mixed

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Vascular Malformations

- Prevalence 1.5%
- Pelvis, extremities, intracranial most common
- Not neoplastic (do not proliferate or involute)
Vascular Malformations

**Low Flow**
- Venous
- Capillary
- Lymphatic

**High Flow**
- Arteriovenous malformation
- Arteriovenous fistula

Low Flow Malformations

- Venous most common of the extremities
- Present at birth, grow proportionately with patient, do not regress
- Forearm flexors and quadriceps muscle most common (venous)
High Flow Malformations

- AVM
  - Feeding arteries and draining veins connected by multiple dysplastic vessels

- AVF
  - Direct connection between arteries and veins, bypassing capillary bed
Vascular Malformations
MR Assessment

1. Distinguish from Hemangioma
   - Age + no mass effect (caution atypical low flow lesions which can appear mass-like and share features of hemangiomas, angiosarcomas, myxoid, fibrosarcoma)

2. Low vs. High Flow
   - Flow voids
   - Feeding arteries, draining veins, dysplastic vessels

3. Focal, multifocal, or diffuse

4. Adjacent tissue involvement
   - Skin, subcutaneous, muscle, tendon, bone
   - Can contain fat, hemosiderin, Ca++, thrombus

5. Connection to normal vessels
   - Arterial vs. Deep Venous (DVT risk)
Fibrous Tumors
I. Benign Fibrous Proliferations
   • Nodular Fasciitis
   • Proliferative Fasciitis
   • Proliferative Myositis
   • Fibroma of the Tendon Sheath
   • Keloid/Hypertrophic Scar
   • Elastofibroma

II. Fibromatoses
   • Superficial (Palmar, Plantar, Penile)
   • Deep (Intraabdominal, extraabdominal)

III. Fibrosarcomas

I. Fibrous Proliferations of Infancy/Childhood
Benign Fibroblastic Proliferations
Nodular Fasciitis

- Most common benign mesenchymal lesion histopathologically misdiagnosed as sarcoma
- 20-40 years
- < 4 cm, rapidly growing
- Upper extremity (volar forearm)

Benign Fibroblastic Proliferations

Nodular Fasciitis

- Typically subcutaneous, and attached to superficial fascia
- Low to intermediate signal on T1 and Intermediate to high signal on T2
- Enhance
- Fascial tail sign

Courtesy Tudor Hughes, M.D.
Benign Fibroblastic Proliferations

Elastofibroma

- > 55 years
- Between posterior chest wall and inferomedial scapula border (also about greater trochanter and olecranon)
- Bilateral (25%)
- Signal similar to skeletal muscle intermixed with streaky fat signal
- Heterogenous enhancement

Courtesy Tudor Hughes, M.D.
Fibromatoses
Superficial

- **Palmar Fibromatosis** (Dupuytren Disease)
  - Volar aponeurosis of hand
  - > 30 years
  - Variable T2 depends on collagen maturity and may suggest propensity to recur

- **Plantar Fibromatosis** (Ledderhose Disease)
  - Bilateral 20-50%
  - M > F (2X)
  - Associated palmar fibromatosis (10-65%)

Fibromatoses
Deep (Desmoid Tumors)

I. Intraabdominal
   • FAP (Gardner Syndrome)

II. Abdominal
   • Pregnant women, or OCP
   • Rectus abdominis and Internal Oblique

III. Extraabdominal
   • > 5 cm
   • Typically solitary
   • Can be aggressive, local recurrence high (87% in < 20 yo)
Deep Fibromatoses

MR Features

• Non-enhancing, T2 hypointense bands corresponding to collagen bundles (86%)

• Infiltrative border or fascial tail (80%)

• Evaluation of response to treatment:
  • Decreased cellularity and increased collagen show low T2 signal (positive response)
Lipomatous Tumors
## Lipomatous Tumors

### Benign
- Lipoma
- Lipomatosis
- Lipomatosis of nerve
- Lipoblastoma
- Angiolipoma
- Spindle cell/Pleomorphic lipoma
- Myolipoma
- Chondroid lipoma
- Hibernoma

### Malignant
- Liposarcoma
  - Well-differentiated
  - Dedifferentiated
  - Myxoid
  - Pleomorphic
  - Mixed-type
Lipoma

- Most common soft tissue tumor (50%)

- Benign neoplasm vs. local hyperplasia of fat cells

- Superficial
  - Upper back, neck, proximal extremities, abdomen
  - < 5 cm

- Deep
  - Intra vs. Intermuscular (arbitrary) (if both = infiltrating)

Lipoma

- Multiple (5-15%)
- Thin, non enhancing septa (< 2 mm)
- No capsule with intramuscular and some subcutaneous lipomas
- Intramuscular lipomas have irregular margins, striated
- No malignant transformation
Lipoma
Lipomatosis of Nerve (Fibrolipomatous Hamartoma)

- < 30 years old
- Median nerve (85%)
- Macrodactyly (27-67%)
  (Macrodystrophia lipomatosa)
- *Lipomatosis of the nerve with or without macrodactyly*
Lipoblastoma

- < 3 years old
- Superficial, extremities
- Progress to mature lipomas
- Imaging appearance can be similary to myxoid liposarcoma (rare < 10 yrs old)

Bancroft LW, et al. Skeletal Radiology 2006; 36: 719-733
Soft Tissue Sarcomas
Soft Tissue Sarcomas

• 75% arise in extremities
• Usually develop de novo (not from dedifferentiation of benign tumor)
• Hematogenous metastasis (lungs)

• > 50 subtypes (75% are the following):
  • Undifferentiated Pleomorphic Sarcoma (MFH)
  • Liposarcoma
  • Leiomyosarcoma
  • Synovial Sarcoma
  • Malignant Peripheral Nerve Sheath Tumor
Undifferentiated Pleomorphic Sarcoma (MFH)

- Histologic diagnosis of exclusion
- Non specific MR features
- Peripheral enhancement common (necrosis, hemorrhage, or myxoid content)
Undifferentiated Pleomorphic Sarcoma (MFH)
Liposarcoma

• Second most common type of soft tissue sarcoma

• Five histologic subtypes:
  - Well-differentiated
  - Dedifferentiated
  - Myxoid
  - Pleomorphic
  - Mixed-type
Well-Differentiated Liposarcoma

- Most common subtype (50%)
- Deep soft tissues of extremities (65-75%), retroperitoneum (20-33%)
- No metastatic potential
- *Atypical lipomatous lesion* reserve for subcutaneous lesions

Well-Differentiated Liposarcoma

• > 75% of the lesion composed of fat
• Thick, enhancing septa (> 2mm)
• Liposarcoma > lipoma:
  - Male
  - > 66 years old
  - < 75% fatty
  - Calcifications
  - Size > 10 cm
  - Septa > 2 mm
  - Nonlipomatous nodular or globular foci

Myxoid Liposarcoma

- Second most common subtype
- Younger pt ($4^{th}-5^{th}$ decade)
- *Intermuscular, lower extremity*

- Pathognomonic MR:
  - Fatty septa or nodules in a myxoid mass
  - May simulate a cyst (unusual location) or myxoma (*intramuscular*)
Leiomyosarcoma

- Smooth muscle
- Intermuscular and subcutaneous, rarely in association with a vessel (vein)
- Irregular rim enhancement
- Ca++ uncommon
Courtesy Tudor Hughes, M.D.
Synovial Sarcoma

- 2\textsuperscript{nd}-4\textsuperscript{th} decade
- Deep soft tissues of extremities and adjacent to joints or tendon sheaths (popliteal fossa)
- Triple T2 signal (relative to fat)
- Heterogeneous signal and variable contrast enhancement
- Ca++ (33%)
- Fluid-fluid levels
- Bone erosion (20%)
Synovial Sarcoma
Summary

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II. Imaging Work-Up
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II. Soft Tissue Tumors—MR Features
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Thank You!


References