

# MUSCULOSKELETAL RADIOLOGY

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## INTRODUCTION

The following curriculum guide comprises a list of subjects which are important to a thorough understanding of disorders that affect the musculoskeletal system. It does not include every musculoskeletal condition, yet it is comprehensive enough to fulfill three basic requirements: 1. to provide practicing radiologists with the fundamentals needed to be valuable consultants to orthopedic surgeons, rheumatologists, and other referring physicians, 2. to provide radiology residency program directors with a guide to subjects that should be covered in a four year teaching curriculum, and 3. to serve as a "study guide" for diagnostic radiology residents. To that end, much of the material has been divided into "basic" and "advanced" categories. Basic material includes fundamental information that radiology residents should be able to learn, while advanced material includes information that musculoskeletal radiologists might expect to master. It is acknowledged that this division is somewhat arbitrary. It is the authors' hope that each user of this guide will gain an appreciation for the information that is needed for the successful practice of musculoskeletal radiology.

- I. Aspects of Basic Science Related to Bone
  - A. Histogenesis of developing bone
    1. Intramembranous ossification
    2. Endochondral ossification
    3. Remodeling
  - B. Bone anatomy
    1. Cellular constituents
      - a. Osteoblasts
      - b. Osteoclasts
    2. Non cellular constituents
      - a. Organic matrix
      - b. Inorganic matrix

- C. Bone physiology
    - 1. Mineralization of bone
    - 2. Calcium homeostasis
    - 3. Bone resorption
    - 4. Bone formation
    - 5. Humoral regulation
      - a. Parathyroid hormone
      - b. Calcitonin
      - c. Vitamin D
      - d. Other humoral factors
  - D. Regional anatomy to include bony, marrow, cartilaginous, ligamentous, musculotendinous, neural, vascular, lymphatic, and fatty constituents.
- II. Techniques Relevant to Musculoskeletal Radiology
- A. Radiography
    - 1. Routine views
    - 2. Specialized views
  - B. Computed tomography
  - C. Magnetic resonance imaging
  - D. Fluoroscopy
  - E. Conventional tomography
  - F. Ultrasonography
  - G. Densitometry
  - H. Leg length or axis determination
  - I. Bone age determination
  - J. Interventional procedures
    - 1. General considerations
      - a. Evaluation of patients for interventional procedures requires a knowledge of appropriate indications and contraindications, objectives, alternatives, and possible complications. Coordination with the referring physician is essential to ensure appropriate patient selection and, for biopsy, appropriate approach.
    - 2. Arthrography, major joints
      - a. Shoulder
      - b. Hip (including prosthesis evaluation)
      - c. Wrist (radiocarpal joint)
    - 3. Arthrography, less common sites
      - a. Wrist (midcarpal joint, distal radioulnar joint)
      - b. Spinal facet
      - c. Sacroiliac
      - d. Knee
      - e. Elbow
      - f. Ankle
    - 4. Percutaneous biopsy

- a. Presumed metastases
- b. Presumed primary tumors

### III. Normal Features and Variants

- A. Sequence of ossification at joints (e.g., elbow)
- B. Physiologic radiolucencies
- C. Bone island (enostosis)
- D. Vascular channels
  - 1. Nutrient canal in phalanx or long bone cortex
  - 2. Vertebral body
  - 3. Scapula
  - 4. Iliac bone
- E. Normal sulci
  - 1. Preauricular sulcus (paraglenoid fossa)
  - 2. Rhomboid fossa
- F. Supracondylar process
- G. Dorsal defect of patella
- H. Epiphyseal ossification from multiple centers (e.g., bipartite patella)
- I. Irregular epiphyseal ossification (e.g., Meyer dysplasia)
- J. Periosteal reaction of infancy
- K. Physiologic bowing
- L. Transverse (growth) line
- M. Vacuum joint

### IV. Congenital and Developmental Abnormalities of the Spine

- A. Os odontoideum
- B. Klippel-Feil
- C. Sprengel deformity
- D. VATER association
- E. Vertebral anomaly (e.g., butterfly vertebra, hemivertebra)
- F. Spinal dysraphism, meningomyelocele
- G. Diastematomyelia
- H. Caudal regression syndrome including sacral agenesis
- I. Schmorl node
- J. Scheuermann disease
- K. Limbus vertebra
- L. Scoliosis

### V. Congenital Anomalies and Dysplasias (Basic)

- A. Developmental dysplasia of the hip
- B. Proximal femoral focal deficiency
- C. Blount disease
- D. Discoid meniscus
- E. Foot deformity
  - 1. Tarsal coalition
  - 2. Talipes equinovarus (clubfoot)

- 3. Pes planus
  - 4. Pes cavus
  - 5. Metatarsus adductus varus
  - 6. Vertical talus
  - 7. Rocker-bottom foot
  - F. Congenital pseudarthrosis
  - G. Madelung deformity
  - H. Pectus excavatum
  - I. Pectus carinatum
  - J. Asphyxiating thoracic dysplasia (Jeune)
  - K. Thanatophoric dwarfism
  - L. Achondroplasia
  - M. Chondrodysplasia punctata (stippled epiphyses)
  - N. Chondroectodermal dysplasia (Ellis-van Creveld)
  - O. Cleidocranial dysplasia (dysostosis)
  - P. Spondyloepiphyseal dysplasia
  - Q. Multiple epiphyseal dysplasia
  - R. Dysplasia epiphysealis hemimelica
  - S. Osteogenesis imperfecta
  - T. Osteopetrosis
  - U. Pyknodysostosis
  - V. Osteopoikilosis
  - W. Melorheostosis
  - X. Osteopathia striata
  - Y. Diaphyseal dysplasia
    - 1. Engelmann
    - 2. Van Buchem
  - Z. Metaphyseal dysplasia (Pyle)
  - AA. Pachydermoperiostosis
  - BB. Nail-patella syndrome
  - CC. Holt-Oram
  - DD. Macrodystrophia lipomatosa
  - EE. Fibrodysplasia (myositis) ossificans progressive
  - FF. Mucopolysaccharidosis (general findings)
  - GG. Neurofibromatosis
  - HH. Tuberous sclerosis
  - II. Trisomy 21 (Down syndrome)
  - JJ. Marfan syndrome
  - KK. Ehlers-Danlos syndrome
  - LL. Turner syndrome
- VI. Congenital Anomalies and Dysplasias (Advanced)
- A. Achondrogenesis
  - B. Hypochondroplasia
  - C. Pseudoachondroplastic dysplasia
  - D. Diastrophic dwarfism

- E. Metatrophic dwarfism
  - F. Mesomelic dwarfism
  - G. Spondylometaphyseal dysplasia
  - H. Metaphyseal chondrodysplasia (dysostosis)
  - I. Dyschondrosteosis
  - J. Idiopathic osteolysis (Hajdu-Cheney)
  - K. Tarsal-carpal osteolysis
  - L. Arthrogryposis multiplex congenita (amyotonia congenita)
  - M. Amniotic band syndrome
  - N. Mucopolysaccharidosis (MPS) types
    - 1. Hunter syndrome (MPS II)
    - 2. Hurler syndrome (MPS I-H)
    - 3. Maroteaux-Lamy syndrome (MPS VI)
    - 4. Morquio syndrome (MPS IV)
    - 5. Sanfilippo syndrome (MPS III)
- VII. Infection
- A. Basic concepts
    - 1. Routes of spread
      - a. Hematogenous
      - b. Spread from a contiguous source
      - c. Direct implantation
    - 2. Sites of localization
      - a. Infants
      - b. Children
      - c. Adults
      - d. Intravenous drug users
  - B. Osteomyelitis
    - 1. Terminology
      - a. Sequestrum
      - b. Involucrum
      - c. Cloaca
      - d. Brodie abscess
      - e. Sclerosing osteomyelitis of Garre
    - 2. Organisms
      - a. Bacterial
      - b. Tuberculous
      - c. Fungal
      - d. Syphilis
      - e. Rubella
      - f. Leprosy
      - g. Lyme disease
      - h. Bacillary angiomatosis
      - i. Parasitic infection
      - j. Hydatid disease
      - k. Cysticercosis

3. Miscellaneous
  - a. Sarcoidosis
  - b. Osteitis pubis
  - c. Pyomyositis
  - d. Gas gangrene
  - e. Ainhum
  - f. Necrotizing fasciitis
  - g. Chronic multifocal osteomyelitis

## VIII. Tumors and Tumor-Like Lesions (Basic)

### A. Natural history

### B. Staging criteria

### C. Bone lesions

1. Cartilaginous
  - a. Enchondroma
    - i. Ollier disease
    - ii. Maffucci syndrome
  - b. Chondromyxoid fibroma
  - c. Chondroblastoma
  - d. Osteochondroma
    - i. Hereditary multiple exostoses
  - e. Juxtacortical (periosteal) chondroma
  - f. Chondrosarcoma
    - i. Primary
    - ii. Secondary
    - iii. Clear cell
    - iiii. Dedifferentiated
2. Osseous
  - a. Osteoma
  - b. Osteoid osteoma
  - c. Osteoblastoma
  - d. Osteosarcoma
    - i. Parosteal
    - ii. Periosteal
    - iii. Telangiectatic
3. Fibrous and fibrohistiocytic
  - a. Fibroxanthoma (nonossifying fibroma)
  - b. Fibrous dysplasia
    - i. McCune - Albright syndrome
  - c. Fibrosarcoma
  - d. Malignant fibrous histiocytoma
4. Vascular
  - a. Hemangioma
  - b. Angiosarcoma
5. Miscellaneous
  - a. Simple (unicameral) bone cyst

- b. Langerhans cell histiocytosis (histiocytosis X)
  - c. Giant cell tumor
  - d. Aneurysmal bone cyst
  - e. Adamantinoma
  - f. Ewing sarcoma
  - g. Chordoma
  - h. Multiple myeloma/plasmacytoma
  - i. Leukemia
  - j. Lymphoma
    - i. Hodgkin
    - ii. Non-Hodgkin
  - k. Metastasis
- D. Soft tissue lesions
1. Adipose tissue
    - a. Lipoma
      - i. Intramuscular
      - ii. Intermuscular
    - b. Liposarcoma
  2. Vascular and lymphatic
    - a. Hemangioma
    - b. Lymphangioma
    - c. Angiosarcoma/lymphangiosarcoma
  3. Fibrous and fibrohistiocytic
    - a. Fibromatoses
      - i. Palmar (Dupuytren contracture)
      - ii. Plantar
      - iii. Intraabdominal (Gardner syndrome)
      - iiii. Extraabdominal (aggressive)
    - b. Fibrosarcoma
    - c. Malignant fibrous histiocytoma
  4. Muscle
    - a. Leiomyosarcoma
    - b. Rhabdomyosarcoma
  5. Peripheral nerve
    - a. Neurofibroma
    - b. Schwannoma
    - c. Malignant peripheral nerve sheath tumor
    - d. Morton neuroma
  6. Synovial
    - a. Localized giant cell tumor of tendon sheath (nodular tenosynovitis)
    - b. Ganglion
    - c. Synovial sarcoma
  7. Bone and cartilage forming
    - a. Myositis ossificans

- b. Extraskkeletal osteosarcoma
- c. Extraskkeletal chondrosarcoma

IX. Tumors and Tumor-Like Lesions (Advanced)

A. Bone lesions

- 1. Cartilaginous
  - a. Mesenchymal chondrosarcoma
- 2. Osseous
  - a. High grade surface osteosarcoma
- 3. Fibrous and fibrohistiocytic
  - a. Benign fibrous histiocytoma
  - b. Osteofibrous dysplasia (ossifying fibroma of long bone)
  - c. Desmoplastic fibroma
- 4. Vascular
  - a. Hemangiomatosis (angiomatosis)
  - b. Gorham disease
  - c. Glomus tumor
  - d. Hemangiopericytoma
  - e. Lymphangioma
  - f. Hemophilic pseudotumor
- 5. Miscellaneous
  - a. Lipoma
  - b. Adamantinoma
  - c. Primitive neuroectodermal tumor
  - d. Intraosseous ganglion
  - e. Epidermoid inclusion cyst

B. Soft tissue lesions

- 1. Adipose tissue
  - a. Fibrolipomatous hamartoma of nerve
  - b. Lipomatosis
  - c. Parosteal lipoma
  - d. Liposarcoma (types)
    - i. Well differentiated (atypical lipoma)
    - ii. Myxoid
    - iii. Round cell
    - iiii. Pleomorphic
    - iiiii. Dedifferentiated
- 2. Vascular and lymphatic
  - a. Glomus tumor
  - b. Hemangiopericytoma
  - c. Hemangioendothelioma
  - d. Kaposi sarcoma
  - e. Lymphangiomatosis
- 3. Fibrous and fibrohistiocytic
  - a. Elastofibroma

- b. Infantile fibromatosis
- c. Juvenile aponeurotic fibroma (calcifying juvenile fibroma)
- d. Fibrous hamartoma of infancy
- e. Myofibromatosis
- f. Fibromatosis coli
- g. Dermatofibrosarcoma protuberans
- 4. Muscle
  - a. Leiomyoma
  - b. Rhabdomyoma
- 5. Peripheral nerve
  - a. Plexiform neurofibroma
  - b. Granular cell tumor
  - c. Clear cell sarcoma
  - d. Extraskeletal Ewing sarcoma
    - i. Primitive neuroectodermal tumor
    - ii. Askin tumor
- 6. Bone and cartilage forming
  - a. Fibro-osseous pseudotumor of the digit
- 7. Miscellaneous
  - a. Myxoma
  - b. Alveolar soft part sarcoma
  - c. Epithelioid sarcoma
  - d. Malignant mesenchymoma
  - e. Lymphoma
  - f. Metastasis

## X. Trauma

### A. General principles

- 1. Biomechanics of fractures
  - a. Relationship of force and deformation
  - b. Mechanisms of direct and indirect loading
  - c. Relevant anatomy and terminology
- 2. Biomechanics of soft tissue injuries
- 3. Open fractures
  - a. Mechanism
  - b. Classification
  - c. Implications for treatment
- 4. Gunshot wounds
- 5. Stress injuries
  - a. Mechanisms
  - b. Pathophysiology
  - c. Epidemiology
  - d. Imaging diagnosis
  - e. Implications for treatment
- 6. Thermal trauma

- a. Burns
  - b. Cold injury
- 7. Traumatic myonecrosis
- B. Trauma in adults
  - 1. Hand
    - a. Volar plate fracture
    - b. Gamekeeper thumb
    - c. Bennett fracture
    - d. Carpometacarpal dislocation
  - 2. Wrist
    - a. Scaphoid fracture
    - b. Perilunate injuries
    - c. Chronic carpal instability
      - i. Dorsal intercalated segment instability
      - ii. Volar intercalated segment instability
      - iii. Scapholunate advanced collapse
    - d. Distal radioulnar joint injury
    - e. Carpal tunnel syndrome
  - 3. Forearm and elbow
    - a. Galeazzi fracture/dislocation
    - b. Monteggia fracture/dislocation
  - 4. Shoulder
    - a. Rotator cuff tear
    - b. Labral injury
    - c. Adhesive capsulitis
  - 5. Clavicle and acromioclavicular joint
    - a. Post-traumatic osteolysis
  - 6. Thoracic cage
  - 7. Spine
    - a. Spondylolysis
    - b. Spondylolisthesis
  - 8. Pelvis and hip
    - a. Acetabular fracture
    - b. Hip dislocation
    - c. Femoral neck fracture
  - 9. Knee
    - a. Meniscal injury
    - b. Ligament injury
    - c. Extensor mechanism injury
    - d. Articular cartilage injury
    - e. Segond fracture
    - f. Tibial plateau fracture
  - 10. Ankle
    - a. Mechanisms of injury
    - b. Ligament injury
  - 11. Foot

- a. Calcaneal fracture
  - b. Lisfranc fracture/dislocation
- C. Trauma in children
  - 1. Biomechanics of immature skeleton
  - 2. Growth plate injuries
  - 3. Hand, wrist, and forearm
    - a. Torus fracture
    - b. Greenstick fracture
    - c. Plastic bowing
  - 4. Elbow
    - a. Radial head dislocation
    - b. Supracondylar fracture
    - c. Entrapped epicondyle
  - 5. Shoulder
  - 6. Spine
  - 7. Hip
    - a. Slipped capital femoral epiphysis
  - 8. Knee
    - a. Osteochondritis dissecans
    - b. Cortical desmoid
  - 9. Tibia, ankle, and foot
    - a. Toddler fracture
    - b. Triplane fracture
  - 10. Battered child
    - a. Reporting statutes
    - b. Metaphyseal corner fracture
- D. Fracture healing
  - 1. Pathophysiology
  - 2. Biomechanics
  - 3. Time course
  - 4. Treatment
    - a. Casting
    - b. Hardware
  - 5. Complications
    - a. Malunion
    - b. Nonunion
    - c. Premature physeal closure
- E. Post-surgical imaging
  - 1. Indications
  - 2. Principles of treatment
  - 3. Complications
  - 4. Joint replacement
  - 5. Bone grafting
  - 6. Spinal stabilization
  - 7. Limb salvage procedures

- XI. Metabolic, Systemic, and Hematologic Disorders (Basic)
  - A. Osteoporosis
    - 1. Disuse
    - 2. Related to aging (postmenopausal, senile)
    - 3. Idiopathic juvenile
    - 4. Transient
    - 5. Reflex sympathetic dystrophy
  - B. Osteomalacia
    - 1. Dietary
    - 2. Gastrointestinal malabsorption
      - a. Liver disease
      - b. Anticonvulsant therapy
    - 3. Tumor induced
    - 4. Renal osteodystrophy
    - 5. Vitamin D dependent rickets
    - 6. Milk-alkali syndrome
  - C. Parathyroid disorder
    - 1. Primary hyperparathyroidism
      - a. Subperiosteal resorption
      - b. Brown tumor
    - 2. Secondary hyperparathyroidism
  - D. Pituitary disorder
    - 1. Gigantism
    - 2. Acromegaly
  - E. Intoxication, poisoning
    - 1. Heavy metal (lead)
    - 2. Fluorine
    - 3. Hypervitaminosis A
    - 4. Hypervitaminosis D
  - F. Complication of drug use
    - 1. Prostaglandin (periostitis)
  - G. Osteonecrosis
    - 1. Causes
    - 2. Bone infarction
    - 3. Legg-Calve-Perthes disease
    - 4. Freiberg infraction
    - 5. Kienbock disease
    - 6. Kohler disease
    - 7. Spontaneous osteonecrosis of the knee
  - H. Hematologic disorder
    - 1. Sickle cell disease or variant
    - 2. Thalassemia or variant
    - 3. Iron deficiency anemia
    - 4. Hemophilia

5. Idiopathic myelofibrosis
  6. Extramedullary hematopoiesis
  7. Fatty marrow reconversion
- I. Miscellaneous
1. Hemochromatosis
  2. Alkaptonuria
  3. Amyloidosis
  4. Paget disease
  5. Calcification/ossification secondary to venous stasis
  6. Calcification/ossification secondary to paraplegia
  7. Hypertrophic osteoarthropathy
    - a. Primary (pachydermoperiostosis)
    - b. Secondary (pulmonary, etc.)
  8. Infantile cortical hyperostosis (Caffey disease)

- XII. Metabolic, Systemic, and Hematologic Disorders (Advanced)
  - A. Parathyroid disorder
    - 1. Hypoparathyroidism
    - 2. Pseudohypoparathyroidism
    - 3. Pseudopseudohypoparathyroidism
  - B. Thyroid disorder
    - 1. Cretinism, hypothyroidism
    - 2. Hyperthyroidism
    - 3. Thyroid acropachy
  - C. Hematologic disorder
    - 1. Erythroblastosis
    - 2. Fanconi syndrome
    - 3. Spherocytosis
    - 4. Thrombocytopenia/absent radius syndrome
    - 5. Polycythemia vera
    - 6. Aplastic anemia
    - 7. Drug-induced myelosuppression
    - 8. Radiation induced marrow changes
  - D. Miscellaneous
    - 1. Scurvy
    - 2. Hypophosphatasia
    - 3. Cushing syndrome
    - 4. Mastocytosis
    - 5. Wilson disease
    - 6. Cerebral palsy
    - 7. Muscular dystrophy
  
- XIII. Joint Disorders
  - A. Normal anatomy
    - 1. Types of joints
      - a. Fibrous
      - b. Cartilaginous
      - c. Synovial
    - 2. Intervertebral discs
    - 3. Enteses
  - B. General features that should be evaluated for each specific disorder
    - 1. Distribution of involvement
    - 2. Soft tissue changes
    - 3. Joint space width
    - 4. Bone density
    - 5. Osteophytes
    - 6. Subchondral lesions
    - 7. Osseous erosions
    - 8. Proliferative new bone
    - 9. Joint deformity

- 10. Calcification
- C. Specific diseases
  - 1. Osteoarthritis
    - a. Primary
    - b. Secondary
    - c. Erosive (inflammatory)
  - 2. Inflammatory joint diseases
    - a. Rheumatoid arthritis
    - b. Psoriatic arthritis
    - c. Reiter syndrome
    - d. Ankylosing spondylitis
    - e. Enteropathic spondyloarthropathy
    - f. Juvenile chronic arthritis
  - 3. Septic arthritis
    - a. Bacterial
    - b. Tuberculous
  - 4. Connective tissue disease
    - a. Systemic lupus erythematosus
    - b. Scleroderma
    - c. Dermatomyositis and polymyositis
  - 5. Crystal-associated arthropathies
    - a. Gout
    - b. Calcium pyrophosphate dihydrate crystal deposition disease
    - c. Calcium hydroxyapatite deposition disease
  - 6. Neuropathic osteoarthropathy
    - a. Diabetes mellitus
    - b. Syringomyelia
  - 7. Miscellaneous
    - a. Jaccoud arthropathy
    - b. Arthropathy associated with acquired immune deficiency syndrome
    - c. Hemophilic arthropathy
    - d. Pigmented villonodular synovitis
    - e. Synovial chondromatosis
    - f. Lipoma arborescens
    - g. Osteitis condensans ilii
    - h. Degenerative disc disease
    - i. Diffuse idiopathic skeletal hyperostosis
    - j. Tumoral calcinosis