Objectives…….

1. Recognize how the study of human imaging can make the clinician’s evaluation and management of the patient more comprehensive.

2. Discuss and describe the clinical impact of imaging technologies used in musculoskeletal conditions.

3. Describe, compare and contrast the major roles of conventional radiography, magnetic resonance imaging, computed tomography, ultrasound, and bone scintigraphy in clinical decision making.
Objectives……

4. Acquire an ability to transform visually three-dimensional anatomy into two-dimensional radiographic anatomy to enable identification of normal and abnormal anatomical structures on radiographs.

5. Describe and discuss the evidence-informed clinical practice guidelines to promote appropriate imaging or treatment decisions.
Goals……..

• *NOT* to teach you A through Z, but.....
  – Review some information
  – Add some new knowledge
  – Stimulate further thinking.................
General Outline

• Integration of Imaging into PT Practice
• Special Imaging Techniques
• General Principles and Evaluation of Tissue
• Diagnostic Imaging Clinical Prediction Rules (CPRs)
• Case-Based Learning
• Summary
Integration of Imaging into Physical Therapy Practice
Changing Perspectives on Diagnostic Imaging in PT Education
The Traditional Model

• PT gradually **evolved** into profession with specialized areas of practice, including **primary care**, requiring considerable expertise in MSK **evaluation**
  – In response, professional **education** of PTs in US has undergone many **changes** in recent decades

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
The Traditional Model

• Until recently, most PT education programs contained little if any curricular content related to diagnostic imaging
  – Perhaps based on assumption that b/c PTs do not make medical diagnoses, study of diagnostic imaging added little to expertise as rehabilitation specialists
  – Prevailing perception that diagnostic imaging not useful in daily PT practice
  – Absence of diagnostic imaging instruction from PT curricula appeared to reflect traditional model of medicine.....as well as PTs restricted scope of practice

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
An Evolving Model

• Response of PT profession to modern patient needs has resulted in an expanded professional identity and higher professional standards
  – Developments catalysts for legislative changes relating to state practice acts
  – Laws permitting clients direct access to PT enacted in many US states
• More than ever PTs may be first health-care professionals patients encounter

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
An Evolving Model

• Potential for PT to be primary care provider has changed profession’s perception of importance of diagnostic imaging in curriculum
  – As result, diagnostic imaging now integral component of PT education
A New Perception Emerges

• Evidence supports PTs should do following:
  1. Recognize when diagnostic imaging is needed to complete a comprehensive examination
  2. Integrate information from radiologist’s written report into PT treatment plan
  3. Understand diagnostic image visually to obtain information that may not be stated on radiologist’s report but may be useful to PT
  4. Recognize when diagnostic imaging needed and when it is not needed to promote an optimal patient outcome
  5. Communicate effectively regarding diagnostic imaging with referring physician, radiologist, and others involved in care of patient

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
A New Perception Emerges

• Orthopaedic Section – Special Interest Group Imaging
  – 2016 White Paper
Undefined Issues

• As profession of PT continues to evolve, following issues will require closer scrutiny and eventually demand clarification:
  – Can non-military PTs legally (according to each state’s practice act) *refer* patients directly to a radiologist to obtain diagnostic imaging and receive a written report?
    • Fairly new question to profession and has yet to be fully explored
    • [New Wisconsin Law Allows PTs to Order X-Rays](#)
  – Can radiologists legally *receive* referrals from and generate written reports for non-physicians, such as PTs, according to their state practice acts?

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Undefined Issues

– Will insurance companies *reimburse* radiologists for technical and professional fees generated through direct referral from a PT to a radiologist?

– What is PTs legal scope of practice regarding use of diagnostic imaging *information*, including both visual information and information from written radiologist’s report?

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
General Principles and Evaluation of Tissue
Outline

– Introduction
– Categories of Imaging
– Standard X-ray Films
– Major Densities
Introduction

• Diagnostic imaging an important tool for differential diagnosis of many MSK conditions
• DPT’s working in direct access roles assuming greater diagnostic responsibility
• Role of MSK imaging in PT practice becoming increasingly important (Deyle, 2005)
Introduction

• Availability of diagnostic studies to DPTs may vary depending upon practice setting
  – US Army DPTs (direct access) hold privileges for ordering imaging studies and laboratory tests considered essential to their diagnostic role (Deyle, 2005)
  – DPTs who do not have ability to order imaging studies should still be familiar with *indications* and *role* of diagnostic radiology
    • In these situations, DPTs should establish proper professional interactions with individuals who can facilitate ordering necessary imaging studies (Deyle, 2005)
CATEGORIES OF IMAGING

A. Reflective Imaging

• Ultrasound (US) and Magnetic Resonance Imaging (MRI)
  – US and MRI examples of reflective imaging
  – Energy inserted into system, captured, and converted into image when it is returned
    • US from mechanical compression of molecules
    • MRI combination of electromagnetic and radio energy combined to produce signals from body that can be collected and analyzed to produce image

(McKinnis, 2013; Swain & Bush, 2008)
CATEGORIES OF IMAGING

B. Ionizing Radiation Imaging

• Standard x-rays (standard or plain films), digital x-rays, and computed tomography (CT) require *ionizing radiation* exposure with its associated risks

(McKinnis, 2013; Swain & Bush, 2008)
CATEGORIES OF IMAGING

• CT form of ionizing radiation that penetrates matter and creates collectable image through computer
  – Capable of producing image or “slice” as narrow as 3 mm thick
• Angled to analyze axially, coronally, sagittally, and tangentially
• Software converts x-rays that penetrate body to Hounsfield units
  – Represent over 2000 levels of specificity between black and white
  – Water zero point with air at negative 1000 and metal at positive 1000
• Generally…..CT imaging of choice for evaluating bony pathology, whereas MRI imaging of choice for soft tissue pathology

(McKinnis, 2013; Swain & Bush, 2008)
CATEGORIES OF IMAGING

C. Emission Imaging

• Bone scan example of emission imaging
  – Blood drawn and tagged with radiopharmaceutical agent, reintroduced to body, and allowed to circulate throughout entire body
  – As radiopharmaceutical agent decays, it emits γ-rays
  – Over short period of time, areas of body with increased metabolic activity—increased circulation—emit greater concentrations of γ-rays
  – After sufficient time, usually 2 or 3 hours, body scanned with scintillation camera to collect γ emissions and produce image that demonstrates areas of increased metabolic activity

(McKinnis, 2013; Swain & Bush, 2008)
Bone Scan

• Bone scan *binary*.....yes or no answer
• Demonstrates increased *metabolic* activity but *not* what is *causing* increased metabolic activity
• Scans are non-specific and not diagnostic
  – As with all other forms of imaging, when combined with history, examination, labs, etc., bone scanning techniques may help confirm diagnosis, but it is not diagnostic by itself

(McKinnis, 2013; Swain & Bush, 2008)
Bone Scan

• Used for identifying:
  – Occult injuries to skeletal system
  – Demonstrating degenerative changes
  – Documenting extent of certain metastatic lesions

• Time sensitive and positive (before standard/conventional x-rays are positive) for certain fractures such as:
  – Early overuse and/or stress syndromes or
  – Scaphoid fractures

(McKinnis, 2013; Swain & Bush, 2008)
Bone Scan

• With compromised vascular supply, bone scan can be diagnostic before other forms of imaging, as in early avascular necrosis of hip
• Bone scans more expensive than standard films….but significantly less expensive than CT or MRI

(McKinnis, 2013; Swain & Bush, 2008)
STANDARD X-RAY FILMS

• X-ray evaluation (known as *plain* or *routine* film), m/c used form of imaging

• Visual and interpretive discipline that follows series of *analytical* steps (standard or routine series) to arrive at clinically relevant information about existence or nonexistence of pathology

• Visualization of anatomy from observation requires *diligence* and *practice* to learn and improve
  – Based upon thorough working knowledge of *anatomy* and *spatial* relationships

(McKinnis, 2013; Swain & Bush, 2008)
STANDARD X-RAY FILMS

• Plain films occasionally allow clinician to see with his or her mind pathology that may not be visible, but creates boney displacement or reactions such as lesions in surrounding skeletal structures

• When appropriate, conventional radiographs represent cost-effective and highly specific imaging modality useful for demonstrating a wide range of skeletal pathology

(McKinnis, 2013; Swain & Bush, 2008)
STANDARD X-RAY FILMS

• Radiographs are useful to distinguish air, bone, calcification, fat, soft tissue, and fluids
• Depending upon intent of image, beam of ionizing radiation directed at standardized \textit{angle} to area to be imaged
• Each substance or tissue \textit{absorbs} varying amounts of radiation producing images of relative \textit{radiodensity} and \textit{radiolucency}

(McKinnis, 2013; Swain & Bush, 2008)
X-ray Production

• Four Major Densities:
  1. Air
     – Most **radiolucent** and absorbs least numbers of particles from beam resulting in **darkest** portion and/or most exposed area of negative/film/plate
     – Air and/or gas normally found within trachea, lungs, and colon

(McKinnis, 2013; Swain & Bush, 2008)
X-ray Production

• Four Major Densities:
  2. Fat
     – Fat absorbs more of beam than air or gas but less than other densities
     – Air and fat considered radiolucent (black on x-ray, greater film exposure b/c more x-ray energy transmitted through these media in body to film or cassette)
     – Varies between anatomical locations, individuals, and genders
     – Found from subcutaneous tissue to pericardium and omentum surrounding intestines

(McKinnis, 2013; Swain & Bush, 2008)
X-ray Production

• Four Major Densities:
  3. Fluid
  – Fluid *more* absorbent than air or gas and fat, and normally represents varying densities of soft tissue organs and muscle
  – Fluid *intermediate* radiolucency

(McKinnis, 2013; Swain & Bush, 2008)
X-ray Production

• Four Major Densities:
  4. Bone
    – Bone *most* dense, naturally occurring substance in body
    – Calcium prime example of metal-like density found in body
    – Calcifications and/or mineralization occur in non-bony locations of body for various reasons
      • Examples: myositis ossificans in muscle, pituitary mineralization in base of brain, aortic calcific depositions, and renal calculi
    – Within bone itself various densities
      • Cortical bone *much* denser than cancellous bone

(McKinnis, 2013; Swain & Bush, 2008)
X-ray Production

• Four Major Densities:
  4. Bone cont’d
    – Perceived differences in images may depend upon angle of exposure to beam
      • AP view of scapula vs. lateral view of same bone or oblique view or AP view of mid-shaft of femur compared with axial view
    – Bone considered *radio-opaque*

(McKinnis, 2013; Swain & Bush, 2008)
Summary of Four Densities

• Air absorbs least radiation, thus appears most radiolucent or has the darkest appearance on radiographs
• Fat, fluids, soft tissue, muscle, bone, and metal progressively absorb more ionizing radiation, thereby producing relatively more white or radiopaque appearance on radiograph

(McKinnis, 2013; Swain & Bush, 2008)
AP Lumbar Spine with Densities Marked

(McKinnis, 2013; Swain & Bush, 2008)
Metals are completely radio-opaque.....least radiolucent

(McKinnis, 2013; Swain & Bush, 2008)
General Uses
Radiographs

• Typically, radiographs used to demonstrate bone origin pathology, relationship of bone structures, or relationship of foreign objects to skeletal structures
  – Degree of detail provided for muscle, ligament, or tendon injuries not diagnostically adequate

(McKinnis, 2013; Swain & Bush, 2008)
Bone Pathology

• Radiographs demonstrate fine *cortical* and *trabecular* detail of bone
  – Characterize certain types of bone reactions associated with benign/malignant *neoplasms* and *infections*
  – *Fractures* ranging from simple to complex, avulsion fractures, and later-stage stress fractures may be identified with radiographs

(McKinnis, 2013; Swain & Bush, 2008)
Indications and Limitations

• Plain radiographs *not* considered *sensitive* to *early* changes associated with tumors, infections, and some fractures

• However, plain films may be more *specific* than bone scans and even MRI in differentiating potential etiologies of lesions b/c of their proven ability to characterize specific calcification patterns and periosteal reaction

• Due to lack of sensitivity of plain radiographs for many subtle pathologies, more sensitive procedures should be considered when pretest likelihood strongly suggests pathology….despite *normal* plain films

(McKinnis, 2013; Swain & Bush, 2008)
Indications and Limitations

• Plain film radiographs not sensitive to *subtle* pathology
  – Significant changes to structure of bone must occur before radiographs reveals it

• Thus, chance of *false negative* for subtle, early-stage pathology, such as stress injuries, metabolic bone disease, infectious processes, non-displaced fractures, and neoplasms, *high* with plain radiographs

(McKinnis, 2013; Swain & Bush, 2008)
General Outline

• Integration of Imaging into PT Practice
• **Special Imaging Techniques**
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Special Imaging Techniques
Computed Tomography (CT)

- CT another radiologic modality utilizing ionizing radiation, radiation detectors, and computer for data processing
- CT system includes X-ray tube within circular scanning gantry, patient table, X-ray generator, and computerized data-processing unit

(McKinnis, 2013; Swain & Bush, 2008)
Computed Tomography (CT)
Computed Tomography (CT)

• Patient positioned on table and then moved inside scanning gantry
• X-ray tube rotated 360° around patient, while computer collects data and formulates axial image through area of interest
  – Thin axial image called a *slice*
• Multiple X-ray beams projected at different angles and levels produce series of computer-generated *cross-sectional* images or slices of body

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Computed Tomography (CT)

- Computer determines relative impedance of body tissues to X-rays and subsequently assigns relative density values to each point in body
  - Images constructed of relative *shades of gray*
  - Bone and soft tissue differences most striking
- Limited ability to differentiate between types of soft tissue (tendons and ligaments), but CT provides excellent *cortical* and *trabecular* definition of bone
- CT suitable to examine spine and extremities and may be combined with *arthrography* for joint injuries

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Limitations and Indications

• CT generally considered *less* complex and expensive alternative to MRI
  – Disadvantages of CT include *higher* radiation doses and *higher* cost when compared to conventional radiography

• Recent advances in MRI capability challenging traditional diagnostic advantages of CT for bone pathology….although CT still preferred for details of *cortical* bone
  – Combination of CT and MRI may be used for evaluating combinations of bone and soft tissue injuries

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Limitations and Indications

• MRI considered more useful for disc herniations, but reconstruction of thin (1 mm) axial images from spinal segment into images in sagittal, coronal, or oblique planes may allow CT to provide additional details of spinal osteophytes and spinal fractures
  – Fractures range from stress fractures of pars interarticularis to complex burst fractures of vertebral bodies

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Magnetic Resonance Imaging (MRI)

• MRI becoming imaging of choice for wide spectrum of musculoskeletal pathology d/t ability to image both bone and soft tissue structures with excellent resolution in 3 dimensions (Deyle, 2005)

• MRI uses magnetic fields from large and powerful magnets to produce computer-generated axial, sagittal, and cross-sectional images

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI Physics

• MRI uses magnetic properties of body’s tissues rather than ionizing radiation

• Patients in MRI scanner exposed to strong magnetic field and radiofrequency (RF) pulses that produce measurable changes in body’s atoms

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI Physics

• MRIs depend on intrinsic spin of atoms (typically hydrogen) with odd number of neutrons or protons, which produces magnetic moment

• Atomic nuclei of tissues placed within field align to direction of magnetic field
  – Atoms subjected to additional influence of RF pulses from magnetic coils and atomic response registered
MRI

1. The magnetic field is used to align hydrogen protons in the body.

2. Radio frequency waves are absorbed by the protons and then emitted as a signal.

3. A radio frequency coil picks up the signal and transmits it to the computer.

4. The computer processes the data and an image is generated.
MRI Physics

• RF pulses cause nuclei to absorb energy and produce resonance characteristic for type of tissue
  – Upon removal of RF pulse, energy absorbed released as electrical signal from which digital images derived

• Signal intensity refers to strength of radio wave that tissue emits following removal of RF pulse

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI Physics

• Strength of radio wave produces either bright high-signal-intensity or dark-low-signal-intensity images

• Signal intensity in specific tissue depends upon both upon T1 and T2 relaxation times, and relative concentration of hydrogen ions

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Image Quality

• Patient movement important factor that can dramatically decrease image quality
  – Voluntary and involuntary patient movements, respiratory movements of ribcage, or peristaltic movements of bowel can reduce quality of images

• Slices too thin or acquired too close to each other can produce interference and also decrease image quality

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
T1 and T2 Images

• *Longitudinal* or T1 relaxation refers to return of protons to equilibrium following application and removal of RF pulse

• *Transverse* or T2 relaxation time describes associated loss of coherence or phase between individual protons immediately following application of RF pulse

• Tissue contrast enhanced by varying RF pulse sequences to increase differences in T1 and T2 relaxation
  – MRIs referred to as T1 or T2 weighted

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
T1 Images

• Subacute hemorrhage and fat have characteristic bright signal intensity
  – Due to typical high fat content, bone appears bright in T1-weighted MRI
• Abscesses or cysts that contain high levels of proteinaceous material appear medium to bright appearance, while other soft tissues appear characteristic low signal intensity
• T1-weighted images well-suited to reveal details of anatomy as they clearly delineate architecture of variety of soft tissue structures

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
T1 Weighted Image
T2 Images

• By comparison, fluids demonstrated as high signal-intensity images in T2-weighted MRIs
  – “2” in H2O helps remember that fluids and fluid-containing structures, such as bursae, inflamed tendons, tumors, and abscesses have bright appearance in T2-weighted images

• T2-weighted images, overall, reveal less detail in soft tissue structures........therefore less suited for study of fine anatomic features

• Proton-density weighted images combine properties of T1- and T2-weighted images and produce good anatomic detail with little tissue contrast

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
T2 Weighted Image
Contrast Differences for T1 & T2 Weighted Images

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI
Contraindications

• Any implants or objects of *ferromagnetic* metal absolute contraindications for procedure:
  – Examples include cerebral aneurysm clips, pacemakers, shrapnel, unstable orthopaedic hardware, and undetected metal slivers machinist may have lodged in eye
  – MRIs may be obtained in presence of firmly implanted orthopaedic hardware with possibility of some local signal interference

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI
Contraindications

• Relative contraindication of MRI includes intolerance of procedure by *claustrophobic* patients and inability of patients to be *motionless* during procedure
  – Relative *high* cost of procedure is limiting factor

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI

Indications

• MRI produces high-quality images of *large* joint components:
  – Such as fibrocartilage, ligaments, capsules, and synovium,
  – Also *small* joints and fine soft tissue structures

• Standard MRI of joints includes images in 3 orthogonal planes, one of which suppresses characteristic bright signal of fat for improved contrast

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
MRI
Indications

• Adding intra-articular contrast to an MRI study increases the sensitivity to diagnose rotator cuff tears, labral lesions, or articular cartilage injuries

• Compared to the gold standard of arthroscopy for the evaluation of anterior cruciate ligament injuries, MRI has a diagnostic accuracy of more than 90%

• MRI useful to diagnose muscle and tendon tears

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Scintigraphy

• Scintigraphy or bone scans reveal uptake of radiopharmaceutical substance (radio-labeled phosphate) into areas of reactive bone
  – Hours prior to bone scan substance injected into patient
• Skeletal system subsequently scanned by detector to reveal areas of ↑ radionuclide uptake

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone
Metabolism

• Normal bone has *some* metabolic activity, thus incorporating some of radiopharmaceutical substance

• Most *metabolically* active areas, such as bone attempting to heal after fracture or responding to a neoplasm or infection, have recognizably ↑ *uptake* at those areas
  – Areas of bone with most uptake appear as *dark* or “*hot*” areas on scan

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Indications

• Bone scans primarily used to scan for presence and distribution of lesions
  – For example, patients diagnosed with cancer may subsequently undergo bone scan to help screen for metastasis to skeletal structures
• Bone scans sensitive but not specific, as many pathologies produce similar appearances on bone scan

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Indications

• Bone scans considered sensitive for changes in bone associated with:
  – Fractures (including stress fractures)
  – Infections
  – Tumors

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
DPT Applications

• Bone scans commonly utilized by PTs in US Army to detect stress fractures among training soldiers
  – Radiographs may eventually reveal stress fractures, but their lack of sensitivity limits their diagnostic use

• Complete and displaced femoral neck fractures and subsequent avascular necrosis of femoral head can result from unrecognized or improperly treated FNSF

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Scan vs. X-ray
Ultrasound (US)

- US imaging *fast* and *inexpensive* tool capable of producing excellent images of musculoskeletal system *without* use of ionizing radiation
  - Highly *sensitive* to identification of fine *soft tissue* changes

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
US Physics

• Images created by use of sound waves produced by sound head and directed into area of interest
  – Sound waves sent into tissues under sound head through water-soluble coupling medium and sound waves imaged as they return
• Differences in signal return provide ability to distinguish among structures and integrity of given structure

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
US Physics

- US thought to produce better images of more superficial structures making it more useful in thin patients
- Substances that reflect sound (i.e., bone and metal) cannot be adequately imaged for diagnostic purposes

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Practical Applications

• Although primarily used for research purposes, some PTs currently use US in clinic to image:
  – Real-time muscle contractions
  – Tendon gliding
  – Muscle size

• Valuable rehabilitation information on broad spectrum of soft tissue injuries and conditions could be provided to PT through US images

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Clinical
Applications

• US excellent modality for imaging *rotator cuff*, but often unable to image some aspects of glenoid labrum

• US useful in evaluation of traumatic *hemarthrosis* of knee, while certain structures, such as menisci, articular cartilage, and cruciate ligaments, can be *difficult* to image and distinguish
Clinical Applications

- *Early* changes associated with *rheumatoid arthritis* (i.e., synovitis, capsular swelling of MCP/talocrural joints, and bone erosion) better demonstrated with US than clinical examination or conventional radiography
- US helpful role in diagnosis of acute *muscle* and *tendon* injuries

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
DPT
Applications

• **Operator** skill and experience may be factor in diagnostic utility of US images
  – Might account for disparity of reported sensitivity for MSK pathology

• Power **Doppler** US produces detailed images of intramuscular and intratendinous structures and can demonstrate **hyperemia** in rotator cuff and biceps tendon.....as well as other soft tissue shoulder pathology

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
General Outline

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Outline

– Standard Views
– Orientation of Films
– Bone Dynamics

– Systematic Analysis of X-rays
– “ABCS”
Standard Views

• Standard views (or routine views), represent proven optimal positional exposures to make reasonable initial examination of specific anatomical region or joint

• Number of exposures required varies from a minimum of two exposures taken at 90° to one another, to cervical and lumbar spine series that require five exposures each

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
“One view is no view”

• Rule that reinforces requirement for minimum of two views taken at 90° to one another to provide a perspective on position of potential pathology

• Example:
  – Displaced oblique, distal tibial fracture may seem nondisplaced on anterior/posterior view, but with additional depth provided by lateral projection and mortise view, fracture becomes obvious, with or without displacement

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Radiographs of a hollow plastic pipe from two different perspectives....two entirely different images

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Three views of ankle fracture evident on mortise view
ORIENTATION OF FILMS FOR INTERPRETATION

A. Check patient's name on film to ensure you have correct films
B. Check dates so that films can be viewed chronologically
C. Orient films correctly on view box by date and sequence that you want to evaluate
   – Be consistent in manner you read them

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
ORIENTATION OF FILMS FOR INTERPRETATION

D. Check for Right ("R") and Left ("L") markers

E. Develop a system! This is critical!
   – Be consistent with your system
   – In standard views of x-ray films in anterior/posterior and posterior/anterior projections, film always positioned so projection of patient in anatomic position as if patient facing you

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
BONE DYNAMICS

• Bone reacts to its environment like any other tissue but in slow motion
  – Understanding this concept critical to evaluating images of bone

• Bone is dynamic living tissue that reacts to its environment
  – Described by “Wolff’s Law”…..stressed bone reacts over time by strengthening areas of increased stress and demineralizing or eliminating areas of lowered stress (stress shielding)

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
SYSTEMATIC ANALYSIS OF X-RAY FILMS OF MUSCULOSKELETAL IMAGES

• Most critical factor in successfully evaluating plain x-ray films........**disciplined, systematic analysis**!!!
  – Ensures critical structures carefully viewed and analyzed in an orderly fashion that minimizes tendency to focus on preconceived “pathology”
  – Medical practice model mandates radiologist evaluate all films taken and generate report unbiased by complete history and physical examination

• Effective system for evaluation of musculoskeletal system is “**ABCS**” system..... **alignment, bone** density and dimension, **cartilage**, and **soft tissue**

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Alignment

• “A” used to study size, number, shape, and alignment of bones
• Alignment in radiology refers to one bone's relationship to bones it is immediately connected to
  – Most bony articulations maintained by connective tissue (CT)
• Assessment of alignment relates to stability and integrity of bones and CTs that maintain these critical relationships
  – Instability may result from trauma/fractures, connective tissue damage, or laxity caused by stretching, congenital anomalies, and acquired or inherent diseases
  – Pathology visualized includes fractures, dislocations, and cortical alterations

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone

• “B” used as reminder to study bone density
  – Including general and focal bone density, and trabecular alterations indicative of metabolic bone disease, infections, tumors, and arthritic changes
• Health of skeletal system interconnected to overall health of organism through many interdependent physiologic feedback loops and chemical checks and balances
• Bone is evaluated in two major areas:
  – Bone density
  – Bone dimension

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Density

• Density specific to region of skeletal system and to that portion of bone being imaged, along with age of patient and existence of co-morbidities
  – In vertebral column (with a few notable exceptions), segments above and below good indicators of appropriate density of segment of interest
  – Exception first and second cervical segments whose densities and dimensions are atypical

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Density

– In extremities, cortical bone should appear dense on periphery and less dense along medullary canal

• Articular portion of long bones from metaphysis to articular surface composed of cancellous bone and should have consistent trabecular patterns throughout
  – Any inconsistency or abrupt change, areas of ↑ or ↓ density, or significant variation in normal trabecular pattern should arouse suspicion, and warrant further investigation

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Density

• When reviewing overall shape and integrity of bone, periosteum noted and evaluated for any swelling or “lifting” away from bone
  – In healthy bone, periosteum tightly adherent to surface of cortical bone
  – If it is elevated from bone, it indicates pathologic change in its normal relationship to cortex

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Dimensions

• Dimensions in systematic evaluation of plain x-rays specific to anatomic region and bone being evaluated
  – For example, spinal segments immediately above and below area of interest excellent indicators of appropriate dimensions of segment being studied, whereas extremities evaluated for dimensions typical or “within normal limits”

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Bone Dimensions

• Comparison views that evaluate one side with respect to other can be helpful if other extremity not involved

• Specific endocrine, physiologic, and nutritional pathologies result in abnormal shapes and sizes of bone
  – For example:
    • Hypersecretion of growth hormone from pituitary during growth period produces tall person, and this same hypersecretion after epiphyseal plates closed results in condition known as acromegaly

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Cartilage

• “C” reminder for studying cartilage space, including width and symmetry of joint space and contour and density of subchondral bone
  – Degenerative and rheumatoid arthritis among more common pathologies producing joint space alterations
• Intervertebral discs in spine and articular surfaces of synovial joints composed of cartilage
  – Cartilage “spacer” between bony articular surfaces
• In spine and extremities, bones demonstrate ↓ distance b/w articular surfaces, especially in weight-bearing joints as cartilage worn away or after removal
• In extremities, “cartilage” portion of systematic evaluation includes hyaline/articular cartilage and meniscal or labral fibrocartilage

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
AP Knees

• Left knee ↑ varus and medial femoral condyle “bone on bone” with medial tibial plateau

• Lack of joint space, flattening of medial femoral condyle and ↑ density of bones in contact
  – ↑ density characteristic of “bone on bone” degeneration

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
AP Lumbar Spine

- Scoliosis, severe degenerative changes, demineralization, and osteophytosis
- ↓ joint space at multiple levels

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Soft Tissue

• “S” reminder to study soft issue for gross swelling, capsular distension, periosteal elevation, and signs specific to certain areas of body, such as appearance or increased visibility of fat pads of elbow

• Soft tissue affects structure of musculoskeletal system (MSK)

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Soft Tissue

• Systematic approach to evaluating spine and joints of MSK requires critical review of soft tissue visible in area being studied
  – Visible portion of lung viewed for changes in consistency or displacement while reviewing shoulder and neck films
  – Displacement of trachea on AP view of cervical spine may indicate pressure from space occupying lesion (SOL), pneumothorax or hemothorax

• Margins of joint space and soft tissue surrounding joint assessed for swelling and soft tissue displacement

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Lateral view of cervical spine with alignment points identified........

- **Alignment**: Anterior longitudinal ligament (ALL) line smooth. Posterior longitudinal line smooth. Spinous process laminar interface line smooth.

- **Bone**: Density consistent among vertebral bodies and spinous processes. Dimensions equal between vertebral bodies.

- **Cartilage**: Disk spaces between vertebral bodies equal.

- **Soft tissue**: Note soft tissue anterior to ALL.

- **A** = ALL; **B** = PLL; **C** = Spinous processes laminar interface line; **D** = Vertebral bodies; **E** = Spinous processes; **F** = Height of the vertebral bodies.

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
General Outline

• Integration of Imaging into PT Practice
• Special Imaging Techniques
• General Principles and Evaluation of Tissue

• Diagnostic Imaging Clinical Prediction Rules (CPRs)
• Case-Based Learning
• Summary
Appropriate Use of Radiographs

• Overuse of radiologic imaging studies significant *economic* problem in US for many years

• Although radiographic studies inexpensive compared with some advanced imaging studies, economic impact of lower-cost but higher-volume procedures can be substantial (Deyle, 2005)
Appropriate Use of Radiographs

• Clinical prediction or decision rules that indicate need for radiographic studies for specific types of injuries developed to help reduce unnecessary imaging studies

• Clinical decision rules (CDRs) or clinical prediction rules (CPRs) quantify individual contribution of components of examination for determining diagnosis, prognosis, or treatment in a given patient
  – Formally test, simplify, and increase accuracy of diagnostic and prognostic assessments
Clinical Prediction Rules (CPR)

- What are CPR?
- Why use CPRs?
- How to use CPRs?
- Statistical Definitions
- Lower Extremity CPR
- Upper Extremity CPR
- Cervical Spine CPR
- Summary
What are Clinical Prediction Rules?

- CPRs are *algorithmic* decision tools designed to aid *clinicians* in:
  - Diagnosis
  - Prognosis
  - Intervention

- Use clinical findings to find statistically meaningful *predictors*:
  - History
  - Physical Examination
  - Diagnostic

(Glynn & Weisbach, 2010)
Why Use CPRs?

- Evidence-based health care defined as conscientious, explicit, and judicious use of *best available* evidence
- CPRs provide best available “real-world” evidence to improve:
  - Patient/clinical outcomes
  - Quality of care
  - Clinical decisions, especially less experienced doctors or uncommon clinical conditions
  - Patient satisfaction
  - Referrals

(Glynn & Weisbach, 2010)
How to Use CPRs?

• CPRs intended to augment clinical decision-making in areas where further research required
  – Should not use CPRs in isolation

• Use CPRs along with:
  – Current existing evidence
  – Patient preferences
  – Clinical experience

(Glynn & Weisbach, 2010)
## Interpretation of Likelihood Ratio (LR) Values

<table>
<thead>
<tr>
<th>Positive LR</th>
<th>Negative LR</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10</td>
<td>&lt; 0.1</td>
<td>Large, often conclusive shifts in probability</td>
</tr>
<tr>
<td>5-10</td>
<td>0.1-0.2</td>
<td>Moderate shifts in probability</td>
</tr>
<tr>
<td>2-5</td>
<td>0.2-0.5</td>
<td>Small, sometimes important shifts in probability</td>
</tr>
<tr>
<td>1-2</td>
<td>0.5-1.0</td>
<td>Probability to small, rarely important degree</td>
</tr>
</tbody>
</table>

(Glynn & Weisbach, 2010)
# Sensitivity vs. Specificity

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Proportion of patients with a disease who test <strong>positive</strong></td>
<td>Proportion of patients without the disease who test <strong>negative</strong></td>
</tr>
<tr>
<td><strong>100% (1.0) Means</strong></td>
<td>The test correctly identify every person who <strong>has</strong> the target disorder</td>
<td>The test correctly identify every person who <strong>does not have</strong> the target disorder</td>
</tr>
<tr>
<td><strong>Statistical Outcome</strong></td>
<td>True Positive</td>
<td>True Negative</td>
</tr>
<tr>
<td><strong>Ideal Test Result</strong></td>
<td>Negative Test Result</td>
<td>Positive Test Result</td>
</tr>
<tr>
<td><strong>Test Interpretation</strong></td>
<td>They are definitely <strong>not positive</strong> → They <strong>DON’T</strong> have it</td>
<td>They are definitely <strong>not negative</strong> → They <strong>DO</strong> have it</td>
</tr>
<tr>
<td><strong>The Rule</strong></td>
<td>Rule Out (SnOut)</td>
<td>Rule In (SpIn)</td>
</tr>
</tbody>
</table>
Lucchesi et al. (1995) reported 95% sensitivity and 16% specificity for ankle fractures; 93% sensitivity and 12% specificity for midfoot fractures
CONCLUSION: When applied during the first hour after injury the OARs significantly overestimate the need for radiographs (false positives). However, a negative finding rules out the need to obtain radiographs. It appears the AT's decision making based on the totality of the examination findings is the best filter in determining referral for radiographs.

Abstract
The original and modified Ottawa Ankle Rules (OARs) were developed as clinical decision rules for use in emergency departments. However, the OARs have not been evaluated as an acute clinical evaluation tool.

OBJECTIVE: To evaluate the measures of diagnostic accuracy of the OARs in the acute setting.

METHODS: The OARs were applied to all appropriate ankle injuries at 2 colleges (athletics and club sports) and 21 high schools. The outcomes of OARs, diagnosis, and decision for referral were collected by the athletic trainers (ATs) at each of the locations. Contingency tables were created for evaluations completed within 1 h for which radiographs were obtained. From these data the sensitivity, specificity, positive and negative likelihood ratios, and positive and negative predictive values were calculated.

RESULTS: The OARs met the criteria for radiographs in 100 of the 124 cases, of which 38 were actually referred for imaging. Based on radiographic findings in an acute setting, the OARs (n = 38) had a high sensitivity (.88) and are good predictors to rule out the presence of a fracture. Low specificity (0.00) results led to a high number of false positives and low positive predictive values (.18).

CONCLUSION: When applied during the first hour after injury the OARs significantly overestimate the need for radiographs. However, a negative finding rules out the need to obtain radiographs. It appears the AT's decision making based on the totality of the examination findings is the best filter in determining referral for radiographs.
• Stiell et al. (1996) reported 100% sensitivity for knee fractures.....if no predictor variables present, knee fracture unlikely and imaging may not be needed
Pittsburgh Knee Rules for Radiography

- Seaberg et al. (1994) reported 100% sensitivity and 79% specificity for knee fractures

(Seaberg et al., 1994)
OKR vs. PDR

CONCLUSION: The PDR was found to be more specific than the OKR, with equal sensitivity. Interobserver agreement was moderate for the OKR and substantial for the PDR.

Abstract

PURPOSE: The aim of this present study was to compare the diagnostic accuracy and reproducibility of 2 clinical decision rules (the Ottawa Knee Rules [OKR] and Pittsburgh Decision Rules [PDR]) developed for selective use of x-rays in the evaluation of isolated knee trauma. Application of a decision rule leads to a more efficient evaluation of knee injuries and a reduction in health care costs. The diagnostic accuracy and reproducibility are compared in this study.

METHODS: A cross-sectional interobserver study was conducted in the emergency department of an urban teaching hospital from October 2008 to July 2009. Two observer groups collected data on standardized case-report forms: emergency medicine residents and surgical residents. Standard knee radiographs were performed in each patient. Participants were patients 18 years and older with isolated knee injuries. Pooled sensitivity and specificity were compared using \( \chi^2 \) statistics, and interobserver agreement was calculated by using \( \kappa \) statistics.

RESULTS: Ninety injuries were assessed. Seven injuries concerned fractures (7.8%). For the OKR, the pooled sensitivity and specificity were 0.86 (95% confidence interval [CI], 0.57-0.96) and 0.27 (95% CI, 0.21-0.35), respectively. The PDR had a pooled sensitivity and specificity of 0.86 (95% CI, 0.57-0.96) and 0.51 (95% CI, 0.44-0.59). The PDR was significantly (\( P = .002 \)) more specific. The \( \kappa \) values for the OKR and PDR were 0.51 (95% CI, 0.32-0.71) and 0.71 (95% CI, 0.57-0.86), respectively.

CONCLUSION: The PDR was found to be more specific than the OKR, with equal sensitivity. Interobserver agreement was moderate for the OKR and substantial for the PDR.
Predictors of Scaphoid Fracture

- Logistic regression model identified 4 variables as independent predictors of fracture:
  - Male gender \( (p = 0.002) \)
  - Sports injury \( (p = 0.004) \)
  - Anatomical snuff box pain on ulnar deviation of wrist within 72 hours of injury \( (p < 0.001) \)
  - Scaphoid tubercle tenderness at 2 weeks \( (p < 0.001) \)
- Presence of all 4 variables represents 91% fracture risk
- No patients had scaphoid fracture if there **no** snuff box pain with ulnar deviation within 72 hrs

(Duckworth et al., 2012)
Potential Management Algorithm Based on CPR

Scaphoid fracture confirmed on radiographs

- YES: Immobilise and refer to next fracture clinic
- NO: Does the patient have ASB pain on ulnar deviation of the wrist?
  - YES: Is the patient male, sustained their injury during sports or have pain on thumb-index finger pinch?
  - NO: Risk of fracture 0% Discharge with advice
  - YES: ≥ 1 factor positive = Risk of fracture 26% Immobilise and refer to next fracture clinic
    All three positive = Risk of fracture 74% Consider referral for further imaging

- NO: Risk of fracture 0% Consider discharge

Two-week review
Consider gender, sports and scaphoid tubercle tenderness
  0 factors positive = Risk of fracture 9%
  All three positive = Risk of fracture 91%

(Duckworth et al., 2012)
Diagnostic Imaging for Trauma of Cervical Spine

• Controversy regarding most efficient imaging protocol for patients with acute trauma to c-spine
  – In past, accepted that radiographs obtained first
  – However, CT significantly more sensitive to detecting subtle injuries and better at visualizing craniocervical and CT junctions
  – Additionally, MRI recommended for any patient with neurological deficit for its ability to demonstrate position of bony fragments as well as injury to spinal cord, disk, and soft tissues

• Thus, radiographic examination not necessary in patients with suspected significant injury, if these advanced modalities are available
  – Significant injury includes fracture, dislocation, or instability

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Evidence-Based Guidelines

• Two evidence-based guidelines established to help clinician decide if patient has potential for significant c-spine injury and if radiographic examination necessary or not:
  – Canadian C-Spine Rule (CCR)
  – National Emergency X-Radiography Utilization Study (NEXUS)

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Canadian C-Spine Rule

• CCR applies to patients who are *alert* and medically *stable*
• Tool designed to decide whether conventional radiography of c-spine necessary for patients who have sustained *traumatic injury* involving head or neck
  – Guide specifically meant to identify patients at risk for “clinically important cervical spine injury, defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging”

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
CCR

• Decision whether to order conventional radiographs based on answers to 3 questions:

1. Are there any high-risk factors that mandate radiography?
   – Examples include age ≥ 65 years, dangerous MOI, or paresthesias in extremities
   – If answer is yes, then radiographs should be obtained

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
2. Are there any low-risk factors that allow safe assessment of ROM?
   – Examples include simple rear-end motor vehicle accident, normal sitting position, patient being ambulatory at any time, delayed onset of neck pain, or absence of midline cervical spine tenderness
   – If answer is no, then radiographs should be obtained
   – If answer is yes, then clinician can move to question 3

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
3. Is patient able to *rotate* neck *actively* at least 45° to right and left?

   – If patient is unable, then radiographs should be obtained
   – If patient is able, then no radiographs necessary

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
The Canadian C-Spine Rule

Please check off all choices within applicable boxes:

1. Any One High-Risk Factor Which Mandates Immobilization?
   - No
   - Yes
     - Age ≥ 65 years
     - Dangerous mechanism *
     - Numbness or tingling in extremities

   Yes

2. Any One Low-Risk Factor Which Allows Safe Assessment of Range of Motion?
   - No
   - Yes
     - Simple rearend MVC **
     - Ambulatory at any time at scene
     - No neck pain at scene when asked
     - No pain during midline c-spine palpation

   No

3. Patient Voluntarily Able to Actively Rotate Neck 45° Left and Right When Requested, Regardless of Pain?
   - No
   - Yes

   No C-Spine Immobilization ***

   Able

C-Spine Immobilization

Dangerous Mechanism
- Fall from elevation ≥3 feet/5 stairs
- Axial load to head, e.g., diving
- MVC high speed (≥100 km/hr), rollover, ejection
- Motorized recreational vehicle e.g., ATV
- Bicycle collision with object e.g., post, car

Simple Rearend MVC Excludes:
- Pushed into oncoming traffic
- Hit by bus/large truck
- Rollover
- Hit by high speed vehicle (≥100 km/hr)
Based on prospective study by Stiell et al. (2001), CCR had sensitivity of 100% and specificity of 43%.

Authors estimated that using decision rule radiography ordering rate would have been 58% for patients in their study compared to actual rate of almost 70%.

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Sensitivity and Specificity

• Sensitivity defined as test’s ability to obtain positive test when target condition really present........a true positive

• Specificity defined as test’s ability to obtain negative test when condition really absent........a true negative
  – In other words, how discriminating is imaging technique in identifying suspected pathology?
• National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria developed to help identify patients following trauma who do not need diagnostic imaging for c-spine based on their clinical presentation

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
NEXUS

- Guideline states radiography indicated following trauma unless patient meets all five criteria:
  1. No posterior midline cervical tenderness
  2. No evidence of intoxication
  3. Normal level of alertness and consciousness
  4. No focal neurological deficit
  5. No painful distracting injuries (e.g., an injury in an area other than c-spine that may distract patient from neck pain)

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Figure 11. National Emergency X-Radiography Utilization Study (NEXUS) Criteria

Meets all low-risk criteria?
1. No posterior midline cervical-spine tenderness
2. No evidence of intoxication
3. A normal level of alertness
4. No focal neurologic deficit
5. No painful distracting injuries

If YES:
No Radiography

If NO:
Radiography
NEXUS

• Validity study by NEXUS researchers reported sensitivity of 99.6% and specificity of 12.9% when applying criteria to population of 34,069 patients (Hoffman et al., 2000)
Evidence-Based Guidelines

• To summarize, patients who have sustained *acute trauma* should have radiography if:
  – Dangerous MOI (diving accident, fall from height, motor vehicle accident)
  – > 65 years of age
  – Paresthesias in extremities
  – Midline tenderness over spine
  – Unable to rotate neck 45° to left and right

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
ACR
Recommendations

• If patient meets clinical criteria of CCR or NEXUS guidelines, current [ACR Appropriateness Guidelines for Suspected Spinal Trauma](#) recommend:
  – CT with sagittal and coronal reformatting or both CT and MRI as complementary studies to assess instability or myelopathy

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Cross-Table

Lateral

• Lateral view first radiograph evaluated if history of trauma and *not* being evaluated in trauma center where advanced imaging is readily available
  – Lateral view allows assessment of normal cervical alignment with series of parallel vertebral lines
  – Discontinuity or obvious step-offs in bony alignment may indicate presence of fracture/dislocation
• In severe trauma cases *cross-table lateral view*, performed on supine, immobilized patient, functions as preliminary diagnostic screen
  – Majority of c-spine injuries can be grossly identified on lateral view

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Lateral Flexion and Extension Stress Views

• Lateral flexion/extension stress views performed to expose excessive segmental motion during functional movement
  – Conventional radiographs represent static pictures that capture joints only at one point in time.........instability may be present, but joint position at that moment may not show it
  – Stress films give joints more opportunity to reveal instability by imposing mechanical stress
  – Normal conventional radiograph on patient who exhibits clinical signs or symptoms of joint instability (such as spinal cord compression signs) warrants further imaging studies

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Lateral Flexion and Extension Stress Views
Radiologic Signs of Cervical Spine Trauma

• Evaluation of radiographs for significant signs of cervical trauma includes examination of:
  – Soft tissues
  – Vertebral alignment
  – Joint characteristics

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Radiologic Signs of Cervical Spine Trauma

• Abnormal *soft tissue* signs include:
  1. Widened retropharyngeal or retrotracheal spaces
     • Helpful way to remember these prevertebral soft tissue distances in adults is “6 at 2 and 22 at 6”
  2. Displacement of trachea or larynx
  3. Displacement of prevertebral fat pad

• Any of these signs suggest presence of *edema* or *hemorrhage* indicating associated pathology

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Lateral View

**Figure 7-25** Radiographic spatial relationships in lateral view of the cervical spine.

**Figure 7-28** Lateral cervical spine radiograph.
Radiologic Signs of Cervical Spine Trauma

- Abnormal *vertebral alignment* signs include:
  1. Loss of *parallelism* as outlined for lateral view, indicating fracture, dislocation, or severe degenerative changes
  2. Loss of *lordosis*, indicating muscle spasm in response to underlying injury
  3. Acute *kyphotic* angulation with widened *interspinous* space, indicating rupture of posterior ligaments
  4. *Rotation* of vertebral body, indicating unilateral facet dislocation, hyperextension fracture, muscle spasm, or disk or capsular injury

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
APOM

Figure 7-15 Radiographic spatial relationships at C1–C2.

Figure 7-18 AP open-mouth cervical spine radiograph.
Radiologic Signs of Cervical Spine Trauma

• Abnormal **joint signs** include:
  1. Widened **ADI** indicating degeneration, stretching, or rupture of transverse ligament
  2. Widened **interspinous** process space (known as “fanning”), indicating rupture of interspinous and other posterior ligaments
  3. Widened **IVD** space, indicating posterior ligament rupture
  4. Narrowed **IVD** space, indicating rupture of disk and extrusion of nuclear material
  5. Loss of facet joint **articulation** indicating dislocation

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Potential Injury to Spinal Cord and Spinal Nerves

• Injuries to c-spine first broadly classified as stable or unstable injuries
  – Reference to immediate or subsequent potential risk to spinal cord and spinal nerve roots

• **Stable** injuries protected from significant bone or joint displacement by intact posterior spinal ligaments
  – Examples include compression fractures, traumatic disk herniations, and unilateral facet dislocations

• **Unstable** injuries show significant displacement initially or have potential to become displaced with movement
  – Examples include fracture–dislocations and bilateral facet dislocations

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Three Column Model

1. Anterior
   – ALL
   – Anterior half of vertebral body, disc, and supporting soft tissues

2. Middle
   – PLL
   – Posterior half of vertebral body, disc, and supporting soft tissues

3. Posterior
   – Posterior elements
   – Facet joints
   – Associated soft tissues

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Three Column Model

• Disruption of only **one** column is generally considered **stable**
• Disruption of 2 or 3 columns implies **instability**
  – Flexion/extension films may highlight instability **not** evident on **neutral** lateral

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Evaluation of Alignment

- Instability may be subtle.
- Disruption of any one of the anatomical lines may indicate injury.
Potential Injury to Spinal Cord and Spinal Nerves

• C1–C2 and C6–C7 most frequently injured levels
  – Adults characteristically injure their lower c-spine and children more frequently injure their upper c-spine

• C-spine fractures have 40% incidence of associated neurological injury
  – Approximately ⅔ of all spinal cord injuries occur in c-spine

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Fractures

- Mechanism of injury (MOI) broadly classified as either being *direct* force (such as blow to head) or *indirect* force (such as rapid acceleration/deceleration in motor vehicle accident)
  - Mechanisms of injury further defined by motion or position of neck during injury
Characteristics of Cervical Spine Fractures

• Two fracture configurations seen in c-spine:
  – Avulsion fractures and compression/impaction fractures
• Avulsions occur as bone fragment pulled off by violent muscle contraction or by passive resistance of ligament applied against an oppositely directed force

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Characteristics of Cervical Spine Fractures

• Compression or impaction fractures result when adjacent vertebrae forced together
  – For example, axial compression force produces comminuted or “burst” fracture of impacted vertebral body
  – Flexion force compresses impacted vertebral body into an anterior wedge shape
  – Extension force fractures and compresses articular pillars

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Flexion and Extension Injuries
Fractures of C3–C7

• Some of more commonly seen fractures include:
  – *Wedge* fracture: occurs when an interposed vertebra is compressed anteriorly by two adjacent vertebrae owing to *hyperflexion* forces
    • ⅔ of these fractures in c-spine occur at C5, C6, or C7
    • May be *stable* fracture b/c ligamentous structures at least partially intact

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Lateral hyperflexion and hyperextension views 38 YOF involved in MVC. (A) Avulsion fracture of SP of C6 (large arrow). Compression fracture present at anterior superior corner of vertebral body of C6 (small arrow). (B) Hyperextension film shows widening of C6–C7 interspace (wavy arrow). Wide interspaces signs of ligamentous disruption at that segment.
Fractures of C3–C7

– *Burst* fracture: occurs when IVD axially compressed and NP driven through an adjacent vertebral endplate, causing literal bursting apart of vertebral body and resulting in comminution
  
  • Fracture may be stable *or* unstable, depending on fracture configuration

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Fracture–dislocation of 5\textsuperscript{th} cervical vertebra in 15 YOM who after MVC. (A) Plain film shows posterior displacement of C5 (\textit{wide} arrows). \textbf{Small} arrows point to prevertebral shadow displaced anteriorly b/c of edema. (B) CT axial view of C5 shows burst fracture of vertebral body and fractures of both laminae (arrows). (C) MRI reveals edema of spinal cord from level of C3 through C7 (arrows). (D) Plain film of internal fixation restoring vertebral alignment and stabilizing spinal segments.
Fractures of C3–C7

– **Teardrop** fracture: occurs when triangular fragment of bone becomes separated from anteroinferior corner of vertebral body b/c of either **avulsion** force sustained during hyperextension or **compressive** force sustained during hyperflexion

  • **Flexion** teardrop fracture most **severe** of lower cervical fractures
  • Force necessary to cause this fracture often associated with additional injury, such as IVD tearing, ligament rupture, and facet dislocation, rendering this a potentially **unstable** injury
  • Posterior displacement of vertebral body can cause anterior **cord compression** resulting in quadriplegia

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
• (A) Anteroinferior fracture of C2 body (white arrow), known as teardrop fracture. (B) Same patient, CT sagittal reformation, with black arrow pointing to triangular fragment on body of C2.
Fractures of C3–C7

– **Articular pillar** fracture: fractured by a compressive hyperextension force combined with a degree of lateral flexion
  • Occurs most frequently at C6 and usually a *stable* injury

– **Clay shoveler’s** fracture: avulsion fracture of SP produced by hyperflexion forces or forceful muscular contraction of trapezius/rhomboids often associated with repetitive heavy labor of upper extremities (as seen in shoveling)
  • Occurring most frequently at C6, C7, and T1, this fracture is *stable*

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Fractures of C3–C7

– Transverse process fracture: uncommon fracture, but usually occurs at largest TVP in c-spine (C7)
  • Usually results from lateral flexion forces causing an avulsion at tip of contralateral TVP

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Imaging

• Radiologic imaging consists of AP, APOM, and lateral views
  – If instability suspected and patient without neurological complaint, willing, cooperative, and fully conscious, flexion and extension stress views are obtained
  – CT with reconstructions may be obtained to characterize fracture patterns and assess degree of spinal canal compromise
  – MRI may be used to delineate spinal cord, disk, and canal abnormalities further
  – Follow-up imaging studies used to monitor progress of healing as well as segmental stability

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Treatment

• Initially, in emergency setting, stable fractures immobilized with cervical orthosis and unstable fractures immobilized with tong traction to decompress canal indirectly

• After imaging studies completed and extent of injuries defined, treatments vary depending on stability:
  – Conservative treatment for stable fractures involves some kind of rigid orthosis (such as a Philadelphia collar or halo traction)
  – Operative treatments can achieve stabilization via interspinous wiring, bilateral plating, anterior plating, and bone grafts
Cervical Spine Sprains

• Cervical sprains are injuries to ligaments of spine
  – Terms hyperflexion and hyperextension sprains more accurately define MOI, direction of force, and ligaments susceptible to disruption
  – AKA “whiplash”

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Hyperflexion Sprains

- Hyperflexion sprains disrupt *posterior* ligament complex
  - Posterior ligament complex includes all posterior ligaments and facet joint capsules
  - With extreme force, injury to posterior annulus fibrosus and posterior aspect of IVD, transient facet dislocations, avulsion fractures of SPs, and impaction fractures of anterior vertebral bodies may occur
  - Magnitude of force, direction, and degree of flexion determine injury severity and number of structures compromised
Flexion and Extension Injuries
Hyperflexion Sprains

• Imaging

– Tears of posterior ligaments allow *superior* vertebra of segment to rotate or translate *anteriorly* on its subjacent vertebra

– Vertebral segment no longer aligns in normal lordotic curve and shows *hyperkyphotic* angulation on lateral radiograph

  • Thus, injured segment appears to be *flexed*, whereas remainder of spine in relatively neutral alignment

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
• Hyperkyphotic angulation in 40 YOF with complaints of chronic neck pain.
• Only history of injury an incident 5 years earlier whereby patient ran into wall while playing racquetball.
• Note loss of cervical lordosis and hyperkyphotic angulation of C4–C5 and C5–C6 segments.
• Possible ligamentous injury occurred at one or more segments in past and adaptive shortening of soft tissues occurred.
• Lateral hyperflexion and hyperextension films would provide valuable information regarding segmental mobility available.
Hyperflexion Sprains

• Imaging
  – At times posterior complex may be torn, but lateral radiograph does *not* reveal any signs of joint instability
    • If there is history of trauma and joint instability or hypermobility, or if either clinically suspected or needs ruled out, lateral flexion and extension *stress* films should be obtained

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Hyperextension Sprains

• Hyperextension sprains result when neck forced past end ranges of extension
  – Hyperextension injuries may happen as isolated injury, or as rebound action of head/following hyperflexion
  – Severe sprains disrupt anterior ligaments and soft tissues, resulting in transient posterior subluxation of vertebral segment

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
Flexion and Extension Injuries
Hyperextension Sprains

• Imaging
  – Lateral view may demonstrate vertebral misalignment secondary to ligamentous or IVD disruption
  – Lateral F/E stress views obtained to evaluate joint stability
  – Routine radiographs screen for associated fractures

(McKinnis, 2013; Swain & Bush, 2008; Deyle et al., 2005)
• 22 YOF sustained a hyperflexion–hyperextension sprain while driving in demolition derby contest.

• (A) Plain film shows loss of cervical lordosis and hyperkyphotic angulation at C5–C6.

• (B) Flexion film shows slight anterior displacement of C5 on C6 (arrow) and widening of C5–C6 interspinous space.

• (C) Extension film shows reluctance or inability of patient to hyperextend neck and persistent hyperkyphotic angulation of C5–C6 segment. Findings suggest ligamentous disruption at C5–C6 segment.
General Outline

• Integration of Imaging into PT Practice
• Special Imaging Techniques
• General Principles and Evaluation of Tissue
• Diagnostic Imaging Clinical Prediction Rules (CPRs)
  • Case-Based Learning
• Summary
Review of Cases....... 

• See examples for discussion......
• Recognize how imaging can make the clinician’s evaluation and management of the patient more comprehensive

• Recognize clinical impact of imaging technologies used in MSK conditions

• Contrast the major roles of conventional radiography, magnetic resonance imaging, computed tomography, ultrasound, and bone scintigraphy
Summary

- Understanding of normal and abnormal anatomical structures on radiographs
- Integration of evidence-informed clinical practice guidelines to promote appropriate imaging or treatment decisions
Thanks For Your Time!!!

• Thanks to KPTA and you clinicians/doctors!!

Questions???

Comments or Feedback.....

bryan.bond@stmary.edu
References


References


