BioE 220/Rad 220
Introduction to Imaging and Image-based Human Anatomy

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Why this course?

Medical imaging is important in medicine
  • better diagnostic studies
  • trend away from surgery to
    image-guided minimally invasive therapies

Many of us work with medical images
  • imaging technology
  • medical devices
  • biomechanics
  • medical profession

Great way to learn anatomy

Other reasons…
Course goals

• 50% Introduce the basics physics of medical imaging.

• 50% Introduce normal human anatomy, with an emphasis on how it appears on images, and with an emphasis on what kinds of imaging are used in different regions of the body.
Course goals

• At the end of this course, you will:
  – Be able to identify x-ray, CT, MRI, and ultrasound images
  – Understand the basics of how these images are produced
  – Know the body areas in which each type of imaging is used and why
  – Know basic human anatomy and how it appears on images
  – To answer, “What am I looking at?”
Instructors

50% Imaging Physics
  Kim Butts Pauly, Ph.D.

50% Anatomy
  Shreyas Vasanawala, M.D., Ph.D
  Greg Zaharchuk, M.D., Ph.D.
TAs

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Weekly Review Sessions and Office Hours
Course logistics

- Lectures M,W 2:30-4:20 pm in Glazer learning center (Lucas Center, P083)
- Labs (Demos) outside of the lecture time. Material will reinforce material taught in class. Not a lot of new material.
Lecture Notes

• Lectures posted on the web in Adobe Acrobat (.pdf) format at:
  • http://bioe220.stanford.edu
    Or
    http://rad220.stanford.edu
  • Password protected page for handouts
  • All homeworks, announcements etc. will be via website
Bioengineering 220
vs.
Radiology 220

• no difference
• check your grading basis
  (some people have selected medical school grades)
Textbooks: Bushberg and Weir

Bushberg
-right level, physics material is right out of this book
- more information than we will cover, great resource
- 2nd Edition vs 3rd Edition (doesn’t matter)

Weir
-single frames vs stack of images in a movie (qt or avi)
- more detail than we require

- anatomy lists on the website specify exactly what you are responsible for knowing
Course Work

• Reading Material
• Problem Sets
  – Physics Problems
  – Identification of anatomy - open book
• Labs (Demos)
  – fun, review of what we learn in class
• Exams:
  – physics understanding
  – identification of anatomy on images (memory - closed book)
• Grading
  – Problem sets: (30% of grade)
  – Midterm Exam (30% of grade)
  – Final Exam (40% of grade)
Thorax Anatomy

1. 1st rib
2. 2nd rib
3. 3rd rib
4. 4th rib
5. 5th rib
6. 6th rib
7. 7th rib
8. 8th rib
9. 9th rib
10. 10th rib
11. 11th rib
12. 12th rib
13. Breast- fatty tissue
14. Breast- fibro glandular tissue
15. Carina
16. Costa-diaphragmatic sulcus
17. Costal cartilage
18. Costa-vertebral sulcus
19. Diaphragm
20. Esophagus
21. Intercostal muscles
22. Intermediate bronchus
23. Lingula
24. Lingular bronchus
25. Lower lobe
26. Pulmonary vein – lower lobe
27. Pulmonary vein – upper lobe
28. Sternum (body)
29. Trachea
30. Upper lobe
31. Upper lobe bronchus
32. Xyphoid process
What level of difficulty is the class?

Prerequisite - college level physics. Concepts get a bit harder when we talk about MRI.

Key concept you should understand:

If you move a bar magnet around a coil loop, you will induce a current in the coil.
Let’s get started…
What you will learn to do when you look at images…

1. Identify the modality

...
X-Ray

- Uses ionizing radiation
- Projection imaging
- Excellent depiction of bone
- Poor depiction of soft tissue
Computed Tomography (CT)

- Uses ionizing radiation
- Cross sectional imaging
- Better depiction of bone and soft tissues
- Contrast (intravenous and oral) improves images
Ultrasound (US)

- No ionizing radiation
- Cross sectional imaging
- Needs “acoustic window” of fluid to image
- Real time, and color flow imaging available
Magnetic Resonance Imaging (MRI)

- No ionizing radiation
- Cross sectional imaging
- Excellent soft tissue contrast
- Sensitive to motion
- Unique methods of generating contrast
What you will learn to do when you look at images...

1. Identify the modality...

   ...

2. Identify the image location...

   ...
Projection Modalities vs. Cross Sectional Modalities

Radiography

CT

Ultrasound

MRI
Image Conventions

Human anatomy has its own special language
  Imaging conventions
  Important in avoiding mistakes (wrong kidney removed, etc.)

Defined in the next few slides…
  Imaging Planes
  Relationship Terms
  Presentation of Images (Anatomic Position)
Axial Plane (CT, MRI)
Transverse Plane (Ultrasound)
Coronal Plane (MRI, CT)
Sagittal Plane (MRI, CT)
Longitudinal Plane (Ultrasound)
In Radiography,

A/P View

Lateral View
Medial - towards the midline

Lateral - away from the midline
**Superior** -
towards the top of the head

**Inferior** -
towards the tip of the toes
Anterior - towards the front

Posterior - towards the back
Proximal - Towards origin of the limb

Distal - Towards end of the limb
Image Presentation

- Left and right refer to the patient’s left and right sides
- Coronal images are displayed like you are looking at the patient
Image Presentation

- Axial images are displayed as if you are looking up from the patient’s feet and the patient is on his back.
Image Presentation

- Sagittal images are displayed as if the patient is looking to the left.
What you will learn to do when you look at images...

1. Identify the modality...

2. Identify the image location...

3. Describe the images
Voxels - what you are imaging

Eight-by-eight array of voxels in the patient - Z is slice thickness
Pixel - Picture Element
2D representation of a Voxel

Eight-by-eight pixel image that represents voxels in the patient
Image Quality

• Many factors affect image quality
  – Image resolution
  – Signal-to-noise
  – Image contrast
  – Proper positioning
  – Artifacts
Image Resolution

- Resolution is the ability to distinguish two points in an image.
- The ultimate resolution can be determined by the detector (x-ray) or the choice of the operator (MRI).

From Non-invasive coronary angiography, Sriharan et al.
Example

- Different resolutions
- Same number of pixels

- Will define resolution for each modality as we go.
Signal-to-Noise Ratio (SNR)

\[
\text{SNR} = \frac{S}{\sigma_n}
\]

(a good measure)

\(S\) = Signal from tissue of interest

\(\sigma_n\) = Standard deviation of the noise

Rose criteria - minimum acceptable SNR is about 5
Signal-to-Noise Ratio (SNR)

- Image SNR is a measure of the noise in the image relative to the signal from tissues of interest.

**Signal from tissue (S)**

**Signal from noise (n)**
SNR Comparison
Image Contrast -- CT

- A measure of the signal difference between 2 tissues

Signal from liver (L)

Signal from kidney (K)

Liver to Kidney contrast = L - K
Image Contrast MRI

- Signal from white matter (W)
- Signal from cerebral spinal fluid (F)

Fluid to White Matter Contrast = \( \frac{W-F}{(W+F)/2} \)
Contrast-to-Noise Ratio (CNR)

\[ \text{CNR} = \frac{S_A - S_B}{\sigma_n} \]

\[ \text{SNR}_A - \text{SNR}_B = \frac{S_A}{\sigma_n} - \frac{S_B}{\sigma_n} = \frac{S_A - S_B}{\sigma_n} \]

\( S = \) Signal from tissue of interest (A or B)

\( \sigma_n = \) Standard deviation of the noise
Image Contrast Example 2

Signal from white matter = 54

Signal from cerebral spinal fluid = 200

$\sigma_n = 5$

Fluid to White Matter CNR = \[
\frac{200-54}{5} = 29.2
\]
Image Contrast - try to get what is needed

- Like SNR, contrast needed is subjective
- We often will inject or ingest contrast agents to improve image contrast
The required image contrast affects the choice of imaging modality…

Radiograph

MRI

Bony Details

Soft Tissue Contrast
Multiple Projections
Patient Positioning
What you will learn to do when you look at images…

1. Identify the modality…

2. Identify the image location…

3. Describe the images...

4. Learn the basic physics for each modality and how that affects the appearance of the anatomy...

5. Identify the anatomy…
Skeleton Overview
Skull Radiography

Skull Mandible
Skull CT

Skull
Mandible
Cervical Spine - Radiographs

C1-C7 Vertebra

Atlas (C1)
Axis (C2)
Cervical Spine - CT

C1-C7 Vertebra
Cervical Spine - CT

C1-C7 Vertebra
Thorax

Clavicles
Scapula
T1-T12
Vertebra
Ribs 1-12
Thoracic Spine - radiographs

T1-T12 (or 13) Vertebra
Clavicles
Ribs
Thoracic Spine - CT

T1-T12 (or 13) Vertebra

Clavicles
Ribs
The Shoulder - Radiography
The Shoulder - CT

Clavicle
Scapula
- Glenoid
- Acromion
- Coracoid
Humerus
The Elbow - Radiography

Humerus
Radius
Ulna
Capitellum

capitellum, i.e. capitulum

Radius
Ulna
The Elbow - Radiography

Humerus
Radius
Ulna

Radius
Ulna
The Elbow - CT

Humerus
Radius
Ulna
Radiography - Forearm

Radius
Ulna
Carpal Bones
Hand and Wrist - Radiography

Fingers (1-5)
-1 Thumb
-2 Index
-3 Middle
-4 Ring
-5 Little

-Joints:
-Radiocarpal
-Carpal-
-Metacarpal
-Metacarpal-
-phalangeal
-Interphalangeal
-(proximal and distal)

distal phalanx
middle phalanx
proximal phalanx
Distal phalanx
proximal phalanx
metacarpals
8 carpals

ulna radius
Carpal Bones
Carpal bones
Hand and Wrist - CT

Fingers (1-5)
- 1 Thumb
- 2 Index
- 3 Middle
- 4 Ring
- 5 Little

-Joints:
- Radiocarpal
- Carpal-Metacarpal
- Metacarpal-phalangeal
- Interphalangeal
  -(proximal and distal)
Lumbar Spine - Radiography

L1-L5 Vertebra

Sacrum
Bony pelvis

Sacrum
Ilium
Pubis
Ischium
Femur

Symphysis
Pubis
Bony pelvis

Sacrum
Ilium
Pubis
Ischium
Femur

Symphysis
Pubis
Femur - radiography

AP Femur

greater trochanter

lesser trochanter

Lateral Femur
Knee

Femur
Patella
Tibia
Fibula
Knee

Femur
Patella
Tibia
Fibula
Lower Leg

Tibia
Fibula
Ankle Mortise
Talus
Ankle - Radiography

Tibia
Fibula
Talus
Tarsal bones (7)

Talar dome

Talus

Calcaneus
Radiographs: Foot

Tarsals (7)
- Metatarsals (1-5)
- Prox. Phalanges (1-5)
- Mid. Phalanges (2-5)
- Dist. Phalanges (1-5)

Medial Sesamoid
Lateral Sesamoid

1 phalanx
2 phalanges
Radiographs: Foot

- Tarsals (7)
- Metatarsals (1-5)
- Prox. Phalanges (1-5)
- Mid. Phalanges (2-5)
- Dist. Phalanges (1-5)
- Medial Sesamoid
- Lateral Sesamoid
Foot and Ankle CT

- Tibia
- Fibula
- Talus
- Calcaneus
- Navicular
- Cuboid
- Cuneiform (3)
- Metatarsals (1-5)
- Prox. Phalanges (1-5)
- Mid. Phalanges (2-5)
- Dist. Phalanges (1-5)
- Medial Sesamoid
- Lateral Sesamoid
Nuclear Medicine
Scintigraphy
Bone Scan
Normal Variation

Bipartite patella

Normal
Normal Variation

Single renal arteries

Two right renal arteries
Next lecture

- Radiography
- Chest and Mammography