Introduction to Radiology

Course Overview

• Four Live Lectures
• Four Required On-line modules
• Lab session
• Four quizzes
• Two examinations
Course Overview

• Expectations
  – Active participation and preparation
  – Utilization of provided on-line materials
  – Exciting Fun Course

Introduction Lecture

• Historical overview
• X-rays
• Appropriateness Criteria
• Application of the various technologies to be discussed in the course
Ionizing Radiation Historical Overview

• Wilhelm Conrad Röentgen
  – 1845 – 1923
  – November 8, 1895 – discovery of the x-ray
    • Discovered effect of passing this ray through materials
    • First radiograph of his wife’s hand
  – 1901 – Nobel Prize Physics

• Antoine Henri Becquerel
  – 1852-1908
  – Radioactive nature of Uranium
  – 1903 – Nobel Prize Physics

Ionizing Radiation Historical Overview

• Marie and Pierre Curie
  – 1867-1934, 1859 – 1906
  – Marie coined term “radioactivity”
  – Discovery of Polonium and Radium
  – 1903 - 1910 – Nobel Prize Physics - Chemistry
  – Died July 4, 1934 – Pernicious Anemia

• William D. Coolidge
  – Patent holder for the original x-ray tube 1913

• Robert S. Ledley
  – Patent holder for original CT scanner 1975
US Historical Overview

- George D. Ludwig
  - Late 1940’s research for the Navy
  - Classified work using US to evaluate tissues
  - Report June 1949 first published work on US applications
- Douglass Howry, Joseph Holmes
  - Pioneering work in B-Mode ultrasound
- Joseph Holmes, William Wright and Ralph Meyerdirk
  - First articulated arm scanner 1963
- James Griffith, Walter Henry NIH
  - Mechanical oscillating real-time apparatus 1973
- Martin H. Wilcox
  - Linear array real time scanner 1973

NM Historical Overview

- Benedict Cassen, Lawrence Curtis, Clifton Reed
  - Automated scintillation detector 1951
- Hal Anger
  - Scintillation Camera 1958
- Picker Corporation
  - 3 inch rectilinear scanner 1959
- John Kuranz – Nuclear Chicago
  - First commercial Anger (Gamma Camera)
MRI Historical Overview

- Felix Bloch, Edward Purcell
  - NMR Spectroscopy
- Paul Laterbur, Peter Mansfield
  - 2003 Nobel Prize Physiology / Medicine
- Raymond Damadian
  - First patent in field of MRI 1970

Imaging Modalities

- Ionizing Radiation:
  - Diagnostic Radiology (X-rays)
  - Interventional Radiology
  - Computed Tomography (CT)
  - Nuclear Medicine
  - Positron Emission Tomography (PET)
- No Ionizing Radiation:
  - Diagnostic Ultrasound (Ultrasonography)
  - Magnetic Resonance Imaging (MRI)
X-Rays

- High energy electromagnetic radiation
- Behaves both like a particle (photon) and a wave
- Production of X-Rays
  - Free electrons produced at filament of x-ray tube (cathode)
  - High Speed movement of electrons
  - Rapid deceleration of electrons at anode
  - Emission of a x-ray photon

X-ray Tube Schematic

[Diagram of x-ray tube with labeled parts: Envelope, Anode – Tungsten Target, Electron Beam, Cathode, Window, Collimator, X-rays]
Production of Image

- X-ray pass through tissue to expose detector
- Passage depends on
  - Tissue characteristics
    - Density
    - Atomic Number
    - Number of electrons per gram
    - Thickness

Production of Image

- Differential absorption of X-ray as the beam passes through the patient
- Unabsorbed X-rays expose the detector (i.e. film, CR Plate, solid state detector), creating the image (photographic effect)
- Differential absorption of X-ray by the tissues is the cardinal feature of image formation
- Special terms used on x-ray reports
  - Radiopaque, Radiolucent, High attenuation, Low attenuation, Water density
Standard X-Ray Machine

Fluoroscopic Imaging Unit
Natural Densities

- Natural densities in the body
  - Bone
  - Soft tissue and body fluid
  - Fat
  - Lung and air containing organs

- Appearance on the radiographic image
  - White shades of Gray
  - Black

Image Density X-ray

- Radiopaque – High attenuation
  - Appears white on film – black on fluoroscopy
  - X-ray photons don’t reach the detector

- Radiolucent – Low attenuation
  - Appears black on film – white on fluoroscopy
  - X-ray photons unimpeded traveling to detector

- Water density
  - Appears grey on film
  - All soft tissues
### Natural Contrast

- Differential contrast between bone and soft tissues
- Differential contrast between soft tissues and air
- Little difference between various tissue types i.e. fat, muscle, solid organs, blood….

---

### Natural Contrast

- Pathologic processes may cause differences in natural densities that can be visualized on the X-ray;
  - high density tumor in air filled lung- white
  - Low density cyst in radio-opaque bone- black
- Pathologic processes of almost the same density as adjoining structures are not visible on X-ray.
- May need to use additional artificial contrast to visualize a density difference
Contrast Agents

• Contrast material (radio-opaque or radio-lucent) administered to see structures or pathologic processes that would not be seen otherwise
• Some useful contrast agents
  – Barium sulfate in the GI tract
  – Iodine compounds in the vessels
  – Carbon dioxide in the vessels or GI tract
  – Naturally occurring air in the GI tract

Fluoroscopic Room

- Video Camera
- Radiosensitive Screen
Appropriateness Criteria

- Guidelines to assure proper imaging choices
- Based on attributes developed by the Agency for Healthcare Research and Quality (AHRQ)

Appropriateness Criteria

- Validity – lead to better outcomes based on scientific evidence
- Reliable and reproducible – other experts should develop same recommendations based on the same scientific evidence
- Clinical applicability – guideline indicates target population
Appropriateness Criteria

– Clinical flexibility – specify expectations
– Clarity – unambiguous, clear definitions
– Multidisciplinary – all affected groups should be represented
– Scheduled review – fixed time to review and revise
– Documentation – evidence used and approach taken is documented

ACR Appropriateness Review Criteria Overview

Appropriateness Criteria

• ACR Appropriateness Criteria search engine:
  • http://www.acr.org/SecondaryMainMenuCategories/quality_safety/app_criteria.aspx
• Allows searching by 10 diagnostic imaging expert panels
• Useful resource when evaluating what clinical exam may be useful
Appropriateness Criteria

• Electronic Decision Support for Medical Imaging
• Future opportunities to improve health care

X-Ray

• Ionizing radiation
  – Exposure concerns
• Somewhat limited discrimination between structures of similar density
  – Tumor vs. normal organs
• Inexpensive
• Readily available
• First line imaging tool
X-Ray

- Primary applications:
  - Chest Imaging
    - Infiltrates
    - Masses
    - Cardiac silhouette
  - Abdominal imaging
    - Gas/bowel distribution
    - Free air
    - Calcifications
    - Organomegaly/masses

X-Ray

- Primary Applications
  - Bone and Joint imaging
    - Trauma
    - Neoplasm
  - Soft Tissues
    - Mass
    - Foreign bodies
  - Breast imaging
X-Ray

• Secondary applications:
  – Contrast enhanced examination
    • Urinary tract
      – IVU
      – Cystography, urethrography
      – Angiography
    • Pulmonary/Cardiac
      – Pulmonary
      – Coronary
      – Great vessels
  • General
    – Neoplasm
    – Vascular abnormalities

X-Ray

• Secondary applications:
  – Dual energy
    • Lung lesions
    • Soft tissue calcifications
  – Bone density evaluation
  – Tomography – tomosynthesis
Interventional Radiology

- Minimally invasive technology
  - Biopsy
  - Cavity drainage
    - Infections
    - Neoplasm
  - Revascularization
    - TPA
    - Angioplasty
    - Stenting

Interventional Radiology

- Lumen restoration / drainage
  - Biliary tree
  - Ureters
  - Others
- Vertebroplasty/ kyphoplasty
**Computed Tomography**

- Ionizing radiation
  - Requires concern and careful utilization
- Excellent discrimination between subtle tissue density differences
- Moderately expensive
- Readily available
- Growing spectrum of applications across a broad spectrum of diseases and body parts

**Computed Tomography**

- Primary applications:
  - First line evaluation in suspected cerebral vascular events – hemorrhagic vs. ischemic
  - First line evaluation in soft-tissue and skeletal trauma
  - First line evaluation in suspected pulmonary embolism
  - First line evaluation in suspected urinary calculi
Computed Tomography

• Primary applications:
  – Head & Neck
    • CVA evaluation
    • Carotid and intra-cerebral vascular evaluation
    • Head-neck trauma – evaluation for subdural and epidural hematoma – evaluation for cervical fracture
    • Neoplasm staging
  – Thorax
    • Lung- mediastinum nodule/ mass evaluation,
    • Cardiac, coronary, pulmonary and great vessel vascular evaluation
    • Airway evaluation
    • Neoplasm staging

Computed Tomography

• Primary applications:
  – Abdomen/ Pelvis
    • Solid organ evaluation
    • Urinary tract evaluation for calcification
    • CT angiography
    • CT colonography
    • CT urography
    • Lumbar spine evaluation (pacemakers, stimulators)
    • Neoplasm Staging
Computed Tomography

- Primary applications:
  - Bones & Joints
    - 3-D joint reconstructed images
    - Evaluation of fracture union
    - Evaluation of neoplasm / extent
- Secondary applications:
  - Evaluation of patients with a contraindication to MRI imaging
  - Bone mineral density analysis

Nuclear Medicine / PET

- Ionizing radiation
- Radio-isotopes attached to molecules targeting specific organs or metabolic processes
- Spatial resolution limited
- Able to evaluate temporal resolution of uptake/ events
Nuclear Medicine / PET

• Primary applications:
  – First line evaluation of biliary function evaluation
  – First line evaluation of cardiac perfusion
  – First line evaluation of solid pulmonary nodules
  – First line evaluation for many neoplasms, staging – treatment response

Nuclear Medicine / PET

• Primary applications:
  – Head & Neck
    • Brain death evaluation – cerebral blood flow
    • CSF flow evaluation
    • Bone abnormality evaluation
  – Thorax
    • V-Q Scanning – Ventilation Perfusion scanning for Pulmonary Embolism detection – secondary exam
    • Pulmonary nodule evaluation (PET)
    • Cancer staging (PET)
Nuclear Medicine / PET

- Primary applications:
  - Abdomen & Pelvis
    - Liver – spleen scanning
    - Hepatobiliary scanning
    - Renal scanning
    - Bladder & Reflux evaluation
    - GI bleed evaluation
    - Cancer staging (PET)
  - Soft tissues – Bone & Joints
    - Bone scanning
    - Tumor scanning (Gallium, PET)
    - Infection scanning (labeled white cells, Gallium)

Magnetic Resonance Imaging

- No ionizing radiation
- Utilize magnetic fields and radio waves
- Contraindication: implanted devices, ferro-magnetic metals
- Relative contraindication: claustrophobia
- Differentiation of distribution of Hydrogen ions as impacted by adjoining molecules
- Ability to do spectral analysis (remember organic chemistry)
Magnetic Resonance Imaging

- Primary applications:
  - First line evaluation of suspected neurologic abnormality
  - First line evaluation of soft tissue mass/neoplasm
  - First line evaluation of joint disarrangements
  - First line evaluation of bone neoplasm

Magnetic Resonance Imaging

- Primary applications:
  - Head
    - Neoplasm
    - Infection
    - CVA
    - Developmental anomalies
    - Trauma
    - MR angiography
  - Neck
    - Effect of arthritis and degenerative changes
    - Neoplasm
    - Trauma
    - MR Angiography
Magnetic Resonance Imaging

- Primary applications:
  - Thorax
    - Spine – cord, roots, bodies
    - Heart – function, perfusion
    - MR angiography
  - Abdomen
    - Liver – mass, iron content, biliary tree
    - MR Cholangiography
    - Kidneys
    - MR Urography
    - MR Colonography
    - Retroperitoneum

Magnetic Resonance Imaging

- Primary applications:
  - Pelvis
    - Prostate
      - Neoplasm
      - Hypertrophy
      - CAD
    - Uterus & Ovaries
      - Masses
      - Leiomyoma
    - Spine
      - Cord
      - Roots
      - Foramina
      - Stenosis
      - Arthritis
Magnetic Resonance Imaging

• Primary applications:
  – Bones & Joints
    • Tendons and ligaments injury
    • Articular cartilage evaluation
    • Muscle abnormality
    • Trauma – fracture, contusion
    • Mass/ Neoplasm – appearance and extent
  – Soft tissues
    • Mass/ Neoplasm
    • MR angiography

Ultrasound

• No ionizing radiation
• Principles of fairly uniform speed of sound transmission in human tissues
• Ability to differentiate fairly subtle tissue differences based on echo reflection and interactions
• Application of Doppler principles for fluid motion
Ultrasound

• Primary applications:
  – First line evaluation of pregnancy and developing fetus
  – First line evaluation for differentiation of cystic from solid masses/structures
  – First line evaluation of liver and biliary tree
  – First line evaluation of kidneys and bladder
  – First line evaluation of thyroid gland

Ultrasound

• Primary applications:
  – Head & Neck
    • Thyroid
    • Adenopathy
    • Orbits & globe
    • Salivary glands
    • Fetal brain
    • Soft tissue masses
  – Thorax
    • Cardiac
    • Pleural effusions
    • Breast lesions
    • Soft tissue masses
Ultrasound

• Primary applications:
  – Abdomen
    • Liver
    • Pancreas
    • Spleen
    • Kidneys
    • Aorta
    • Splanchnic and renal vessels

• Primary applications:
  – Pelvis
    • Pregnant uterus and fetus
    • Uterus
    • Fallopian tubes
    • Ovaries
    • Bladder
    • Prostate
    • Testes and scrotum
Ultrasound

• Primary applications:
  – Soft tissues, bones & joints
    • Tendons, Ligaments and supporting structures
    • Fluid collections and masses
    • Vascular malformations
    • Artery and vein evaluation
    • Foreign bodies