Medical Imaging Fundamentals

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Main Themes

• Describe the major modalities in radiology (medical imaging)
  • Essential Physics and Engineering
  • Strengths and Limitations
• Understand different imaging roles
  • Structural versus Functional
  • Static versus Real-Time
• Overview of developments in medical imaging
Structure versus Function (1)

Structural imaging is like a roadmap.

Structure versus Function (2)

Functional imaging tells us about processes and activity.
Structure versus Function (3)

Combining Structure and Function has many advantages.

X-Ray Imaging (1)

Images based on:
1. X-Ray energy
2. Tissue Composition
3. Tissue density
X-Ray Imaging (2)

2D Projection Imaging

X-Ray Fluoroscopy
X-Ray Angiography

Angiography with injected contrast

Computed Tomography (CT)

3D Tomography from multiple projections
### X-Ray Imaging Summary

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>🎉 2D images are simple and relatively cheap</td>
<td>🎉 2D images have overlapping structures</td>
</tr>
<tr>
<td>🎉 Imaging is very fast</td>
<td>🎉 Ionizing radiation</td>
</tr>
<tr>
<td>🎉 High spatial resolution</td>
<td>🎉 Poor soft tissue contrast</td>
</tr>
<tr>
<td>🎉 Good patient access</td>
<td>🎉 Limited functional info</td>
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<tr>
<td>🎉 Real time guidance possible</td>
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### Magnetic Resonance Imaging

**Images based on:**

1. Proton density  
2. Tissue Composition  
3. Pulse Sequence
Body MRI

Axial scan of abdomen

Skeletal MRI

Scan of Head and Neck Region

cpmcnet.columbia.edu/dept/radiology/eastside/mri.html
Cine MRI

Functional MRI

Identification and mapping of brain activity is critical for neurosurgery applications.

http://www.fmri.org/bigimages/3.gif
## MRI Summary

<table>
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<tr>
<th>Strengths</th>
<th>Limitations</th>
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<tr>
<td>😊 Excellent soft tissue visualization</td>
<td>😊 High magnetic fields create a challenging work environment</td>
</tr>
<tr>
<td>😊 Good spatial resolution</td>
<td>😊 Possible spatial distortions</td>
</tr>
<tr>
<td>😊 Fine control over tissue detail and contrast</td>
<td>😊 Very limited access to patient</td>
</tr>
<tr>
<td>😊 No ionizing radiation</td>
<td></td>
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<tr>
<td>😊 Functional imaging of blood oxygenation, spectroscopy, etc.</td>
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## Ultrasound

**Images based on:**

1. Reflected waves
2. Tissue Composition
3. Movement and Flow
Ultrasound Probe

http://www.scielo.br/img/revistas/abc/v82n5/20280f1.gif

3D Ultrasound

www.gederskeepsake.com
Breast Imaging

Ultrasound

Fetal mouse hearts
Doppler Ultrasound

Flow Direction and Velocity are color-coded.

Ultrasound Summary

Strengths

- Inherently Real-Time
- Physically compact and easy to maneuver
- Excellent measure of flow and motion
- No ionizing radiation

Limitations

- Limited field of view
- Low spatial resolution
- Noisy or “speckly” images
Nuclear Medicine

Images based on:
1. Injected radioactive tracer
2. Tissue biochemistry

PET and SPECT

PET = Positron Emission Tomography

SPECT/SPET = Single Photon Emission (Computed) Tomography
CT/SPECT System

Combined CT and SPECT
(GE Hawkeye)

CT/PET System

Combined CT and PET (Siemens Biograph)
Tracer (FDG) concentrates in areas with increased glucose metabolism.

Non specific uptake also seen in the kidneys, bladder, liver.

Whole body FDG-PET can scan for disease over a wide area.
Patterns in FDG uptake also can reveal areas of increased or decreased neural activity.

http://www.research.ucla.edu/chal/assets/images/PETscans.gif

SPECT (Single Photon Emission Computed Tomography)

Tracer targeted to prostate specific membrane antigen (PSMA) can localize metastatic or invasive prostate cancer.
Combined CT and PET

Nuclear Medicine

Intraoperative probes give real-time detection of tracers.

NeoProbe

Gamma Medica
## Nuclear Medicine Summary

<table>
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<th>Strengths</th>
<th>Limitations</th>
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<tr>
<td>☑ Unique biochemical information</td>
<td>☑ Poor spatial resolution</td>
</tr>
<tr>
<td>☑ Wide variety of tracers</td>
<td>☑ Noisy images</td>
</tr>
<tr>
<td>☑ Passive detectors can be used in many situations</td>
<td>☑ Uptake is not always specific</td>
</tr>
<tr>
<td></td>
<td>☑ Ionizing radiation</td>
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