Oncology 520

Imaging Cancer

John Mercer
Oncologic Imaging
jmercer@ualberta.ca

Why do we want to image cancer?

Cancer provides novel signatures at the cell and tissue level that permit imaging.

Abnormal tissue growth (space filling lesion) and normal tissue displacement, density, vascularity, chemical composition.

Abnormal organ function, tissue environment (pH, oxygenation).

Energy utilization, cell proliferation, nutrient consumption.

Production / release of unique chemical and biochemical signatures.

Gene expression and downstream intracellular products (mRNA, proteins).

Gene expression and cell surface proteins (receptors, transporters).

Often multiple signatures are present.

STRUCTURAL **FUNCTIONAL** **MOLECULAR**

Molecular imaging is a “hot” topic recently.

Unlike structural or functional behavior of tumors their “molecular” behavior can be unique to each individual.

Molecular imaging interrogates cells at the level of gene expression.

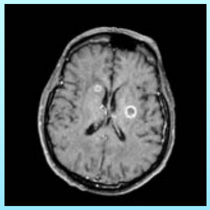
Molecular imaging has the potential to stratify patients for potential therapies and thus come closer to a goal of personalized medicine.

example

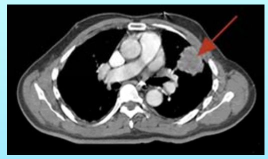
- p21 protein (from *p21*gene upregulation) is a cyclin dependent kinase, active in promoting resistance to radiation therapy.
- Tumors expressing high levels of p21 protein following radiation therapy are more resistant to treatment.
- Knowledge of p21 status could allow treatment modification to compensate.
- Thus p21 is an attractive target for molecular imaging.

Society of Nuclear Medicine: “Molecular imaging is the visualization, characterization and measurement of biological processes at the molecular and cellular levels in humans and other living systems.”

Some examples of structural images



1. MRI – brain tumor. Image contrast created due to different physical and chemical structure of tumor relative to normal brain.

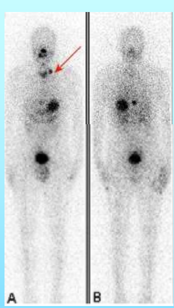


2. X-ray CT – Lung tumor. Image contrast due to differing tissue density of tumor and normal lung.

3. Radionuclide image – Bone metastases. Altered bone structure at site of metastases absorbs more radiopharmaceutical creating contrast to normal bone.

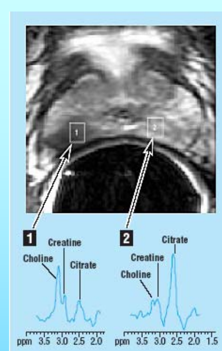
1. http://emedicine.medscape.com/article/358274-overview
2. http://www.compassoncology.com/diagnostics.php
3. Nat Clin Pract Endocrinol Metab. (2007) Nature Publishing Group

Some examples of functional images



1. I -131 gamma camera image of papillary thyroid carcinoma during treatment. Contrast due to functional accumulation of iodine in tumor.

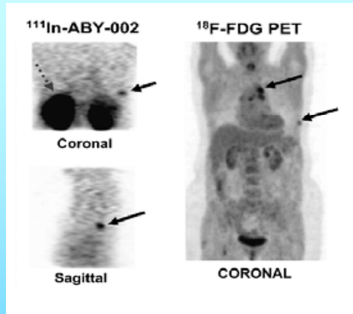
2. F-18 FDG PET scan on *BRAF* mutant melanoma. Contrast due to increased uptake of glucose in tumor.

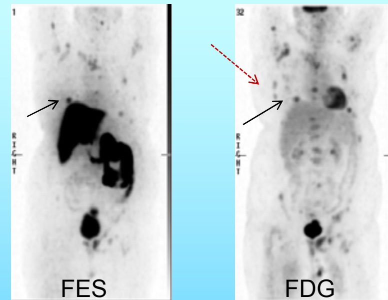


3. Magnetic resonance spectroscopy. Tissue levels of choline and citrate altered in prostate cancer (1 = tumor).

1. http://www.bordet.be/en/services/medical/nuclear/therapy/thyroid/thyroid2.htm
2. http://www.nature.com/nature/journal/v467/n7315/fig_tab/nature09454_F4.html
3. http://www.prostate-cancer.org/pcricms/node/169

Some examples of molecular images





1. In-111 peptide image. Peptide targets HER2 positive receptors in breast cancer metastases. Presence or absence of receptor provides contrast.

2. Molecular imaging of estrogen receptor positive breast metastases with F-18 fluoroestradiol (FES) and metastases with FDG. Concordant (solid black arrow) and non-concordant (red arrow).

1. J Nuc Med, 51;892 (2010)

Overview:

Modalities used in cancer imaging:

1. X-ray and x-ray CT

2. Magnetic Resonance Imaging

3. Nuclear Medicine
   - single photon - gamma imaging - SPECT
   - positron emission tomography – PET
   - molecular imaging

4. Developing technologies

(5. Ultrasound)

General Principals:

Cancer can be imaged if there is a difference between the cancer and surrounding normal tissue.

Each modality exploits a structural or functional difference to provide a "contrast" between normal and diseased tissue.

Imaging requires either transmission of a signal through the body or emission of a signal from the body (or both).

Images will provide some combination of structural, functional and molecular information.

All imaging modalities have strengths and limitations.

X-ray and X-ray/CT:

The "plain x-ray" uses low energy x-rays which are transmitted from source to detector through the tissue to be examined.

Structures are imaged due to the difference in absorption of x-rays. This difference is determined by density and by elemental composition of the absorbing material. There is a high atomic mass number dependency for low energy x-ray absorption by the photoelectric effect.

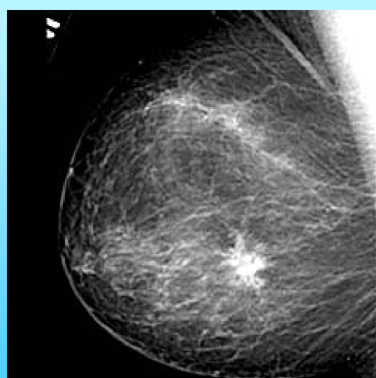
X-ray and X-ray/CT:

Medical x-rays are selected to allow tissue penetration and to maximize contrast properties.

Use		Accelerating potential	Target	Source type	Average photon energy
X-ray crystallography		40 kV 60 kV	Copper Molybdenum	Tube	8 keV - 17 keV
Dianostic X-rays	Mammography	26 - 30 kV	Rhodium Molybdenum	Tube	20 keV
	Dental	60 kV	Tungsten	Tube	30 keV
	General	50 - 140 kV	Tungsten	Tube	40 keV
	CT	80 - 140 kV	Tungsten	Tube	60 keV
Baggage screening	Carry-on/Checked bags	80 - 160kV	Tungsten	Tube	80keV
	Container screening	450kV - 20MV	Tungsten	Tube/Linear accelerator	150keV - 9MeV
Structural analysis		150 - 450 kV	Tungsten	Tube	100keV
X-ray therapy		10 - 25 MV	Tungsten/High Z material	Linear accelerator	3 - 10 MeV

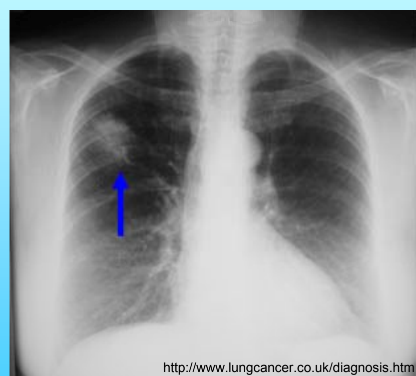
X-ray and X-ray CT:

Modern x-ray technology provides high resolution and high contrast images.



X-ray mammogram showing a growth in the breast

http://www.med.unc.edu/radiology/breastimaging/services/mammography



Planar x-ray with suspected lung cancer

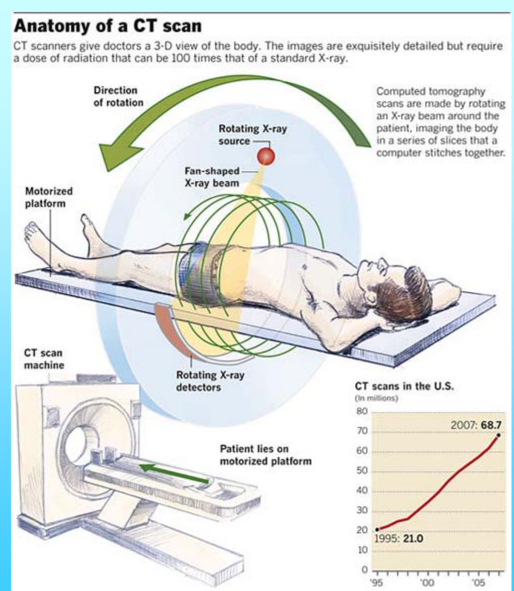
X-ray CT (CAT Scan).

Computerized axial tomography (CAT) scan (commonly CT scan).

Allows slice imaging or 3-D reconstruction of x-ray absorption data.

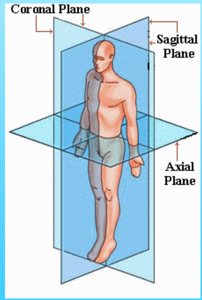
X-ray CT (CAT Scan).

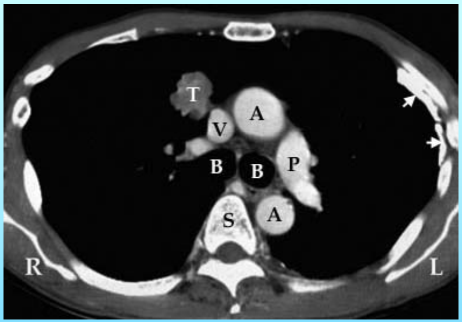
The principle behind CT is that the internal structure of an object can be reconstructed from multiple projections of the object. An x-ray tube circling the patient produces an x-ray beam that passes through the patient and is absorbed by a ring of detectors surrounding the patient. The intensity of the x-ray beam that reaches the detectors is dependent on the absorption characteristics of the tissues it passes through. Each tissue will be exposed from multiple directions. Using Fourier analysis, the information obtained from the different amounts of x-ray absorption can reconstruct the density and position of the different structures contained within each slice.



X-ray CT (CAT Scan).

This CT shows a tumor mass (T) in the right lung. The irregular shape suggests that it is a cancer. Examination of a biopsy section would be necessary for diagnosis.





A = Aorta
P = Pulmonary artery
V = Superior vena cava
B = Bronchus
S = Vertebral body of spinal column
T = Tumor
Scapula = irregular, thin, radio-opaque structures just above "R" and "L"
Arrows indicate two calcified scars related to old, healed tuberculosis. These scars lie next to ribs.

X-ray CT (CAT Scan).

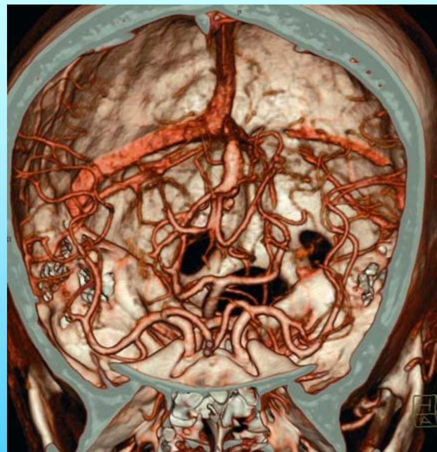
Images can be enhanced by the use of contrast agents.

Intravenous, oral or rectal administration with high density solutions or suspensions.

Iodine agents used for injection (Z# = 53).

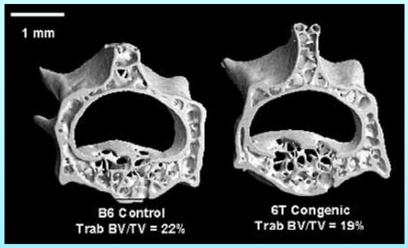
Often used for CT angiography.

Images enhanced with software reconstruction tools.



http://www.medical.siemens.com/siemens/en_US/rg_marcom_FBAs/images/presskits/RSNA2006/SOMATOMSensation_HeadAngioVRT.jpg

X-ray CT (CAT Scan).



Strengths:
High resolution images
Non invasive
Plain x-ray has low radiation dose.
Relatively inexpensive and available.
Whole body imaging possible.
High resolution microCT animal imaging instrumentation is available

Weaknesses:
Can not differentiate isodense lesions from surrounding tissue.
CT radiation doses high.
Can not differentiate between surgical site disruption of tissue and residual or recurrent tumor.
Measures tissue structure but not activity or function.

Magnetic Resonance Imaging (MRI)

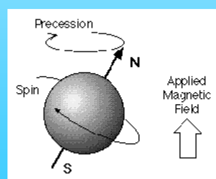
The detailed discussion of the physics of MRI is beyond the scope of this lecture. An excellent E-book is available at http://www.cis.rit.edu/htbooks/mri/

Some basic principals:

MRI can observe energy emissions from nuclei that have spin. Nuclei that have been imaged in vivo include ^{1}H, ^{31}P, ^{23}Na, ^{13}C, ^{19}F.

^{1}H is by far the most important being in high isotopic abundance and high tissue concentration.

Nuclei with spin are induced to emit energy by aligning them in a strong stable magnetic field and then exciting them to a high energy state with pulses of radiofrequency radiation.

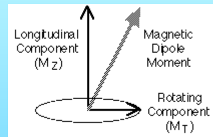


Magnetic Resonance Imaging (MRI)

Some basic principals (continued):

Excited spinning nuclei return to their ground state and emit radiofrequency radiation.

Two distinct emissions occur; one fast emission due to the loss of transverse magnetic vector from the spinning nuclei (T2 signal) and one slower emission due to the loss of longitudinal magnetic vector (T1 signal).



Different tissues will have different time constants for the T1 and T2 emissions based on physical and chemical properties. The difference in T1 and T2 values for different tissues provides contrast necessary for imaging.

Emissions and their point of origin (tissue voxel) are determined using a RF coil placed in close proximity to the imaged tissue.

Magnetic Resonance Imaging (MRI)

Instrumentation:

Requires stable high magnetic fields produced with superconducting magnets. The physics of magnetic field generation may limit fields for human scanners (at present there are clinical machines up to 11 Tesla).

Whole body coils or specialized coils (head, knee) are used.

Image reconstruction generates “slice” information in 3 dimensions at high resolution.

Magnetic Resonance Imaging (MRI)

Low grade liposarcoma.
Coronal image.

http://sarcoma.org/pathology_review/round%20cell%20and%20soft%20tissue%20tumors/source/well_dif_liposarc_mri.html

Magnetic Resonance Imaging (MRI)

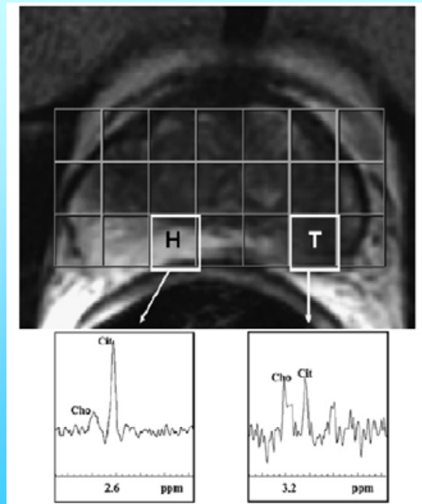
Basic MRI is a structural imaging technique relying on tissue differences related to physical and chemical environment.

Enhancements:
Functional MRI (fMRI) is a modern enhancement of the technology whereby changes in the blood flow characteristics (rate, volume, oxygenation) are determined by rapid sequential imaging. Deoxyhemoglobin acts as an internal contrast agent for T2 signals.

The ability of MRI to be tuned to the specific output signals of nuclei such as ^{31}P, ^{23}Na and ^{19}F has allowed the use of techniques to determine tissue function based on endogenous biomolecules or the distribution of tracer drugs incorporating these nuclei.

Magnetic Resonance Spectroscopy (MRS) allows cellular biomolecules to be observed as a unique fingerprint associated with a tissue volume. This is a new and rapidly developing molecular imaging technique.

Magnetic Resonance Spectroscopy (MRI)



Gleason grade 5 + 4 prostate cancer in a 59-year-old man. MR spectroscopy shows normal spectra in the healthy (H) right peripheral zone and suspicious spectra with elevated choline and reduced citrate in the left peripheral zone tumor (T).

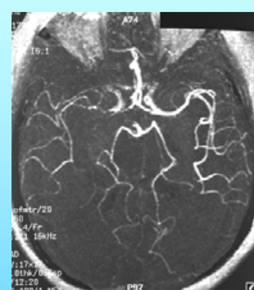
Radiol Clin N Am 45 (2007) 207–222

Magnetic Resonance Imaging (MRI)

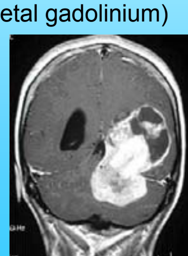
Enhancements:

MRI angiography is possible using fast image acquisition. Tissue voxel (blood) moves between excitation and T1 or T2 signal emission.

Tumor images and angiograms can be enhanced by using a contrast agent (typically a complex of the metal gadolinium)



Brain angiogram



Meningioma enhanced by gadolinium DTPA administration

Magnetic Resonance Imaging (MRI)

Strengths:
High resolution images.
Non invasive.
No ionizing radiation dose.
Whole body imaging possible.
Can be used in some circumstances for functional imaging.
Animal imaging instruments at high field (9.4T) are available.
Can be incorporated into multimodality platforms (PET/MR)

Weaknesses:
Expensive instruments and waiting times.
Imaging can be stressful for some patients.
Can not differentiate between surgical site disruption of tissue and residual or recurrent tumor.
Measures tissue structure in standard clinical application but not activity or function.

Nuclear Medicine – SPECT and PET imaging

Uses internally deposited gamma-emitting radioactive drugs.

“Conventional” Nuclear medicine uses single photon emitters such as ^{99m}Tc, ^{111}In and ^{123}I, incorporated into radiopharmaceuticals with particular biological distribution characteristics. Both planar imaging and three dimensional imaging with single photon emission computerized tomography (SPECT or SPET) are possible.

Positron emission tomography (PET) uses positron emitters such as ^{11}C, ^{15}O, ^{18}F and ^{124}I incorporated into radiopharmaceuticals and the features of positron annihilation to produce an image.

Both SPECT and PET use expensive camera systems to record the imaging data.

Contrast requires more or less activity in the tumor relative to surrounding normal tissue.

Nuclear Medicine – SPECT

The sequence of events in SPECT imaging:

A radioactive tracer is prepared. There are a variety of commercial "kits" which can be rapidly labeled with radionuclides such as ^{99m}Tc. Each tracer will have a particular biological distribution that will target it to a particular anatomical site.

The radiopharmaceutical is administered (usually iv) and some time is allowed for the distribution and localization of the radioactivity.

The radionuclide decays with the production of a penetrating gamma ray which exits the body.

The patient is imaged using multiple views with a gamma camera.

Following imaging the radionuclide disappears from the body by biological elimination or physical decay.

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Nuclear Medicine – SPECT

The sequence of events in SPECT imaging:

Collected information from the multiple images is used to reconstruct a 3-dimensional picture of the location of the radioactivity in the body.

Information is interpreted in slices (tomographs) to define the anatomical lesions.

Conventional 2 headed SPECT gamma camera.

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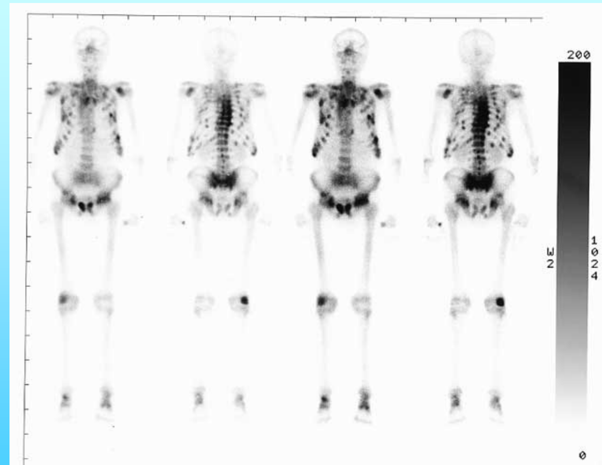
Nuclear Medicine – SPECT

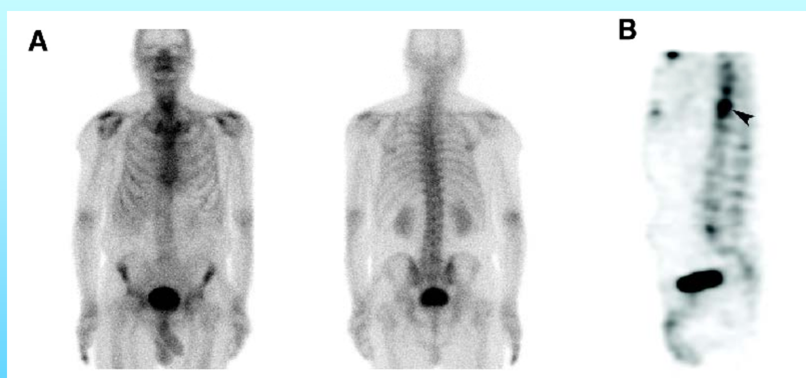
Planar images following the administration of the bone scanning agent ^{99m}Tc-MDP.

Intense uptake of tracer in metastatic lesions in a patient with advanced malignant melanoma.

MDP images may be seen before structural changes are visible by CT or MRI.



Nuclear Medicine – SPECT



J Nucl Med: 47, 287 (2006)

Bone scan with Tc-99m MDP. Bone metastasis from primary prostate tumor in vertebra is not apparent from planar images (A) but is readily visible from the SPECT sagittal "slice" (B).

Nuclear Medicine – SPECT

Strengths:
Can detect lesions before they are visible by x-ray or MRI.
Whole body imaging possible with capability to detect metastatic disease.
Mature technology available in most major centers.
Tracers well developed and available.
Non-invasive.
Animal imaging systems available.

Weaknesses:
Relatively poor resolution compared to MRI and CT.
Ionizing radiation injected.
Medical personnel will receive radiation doses.
Relatively expensive camera systems.
No universal agent for all tumors.
It is not generally a quantitative technique.

Nuclear Medicine – PET

The sequence of events in PET imaging:

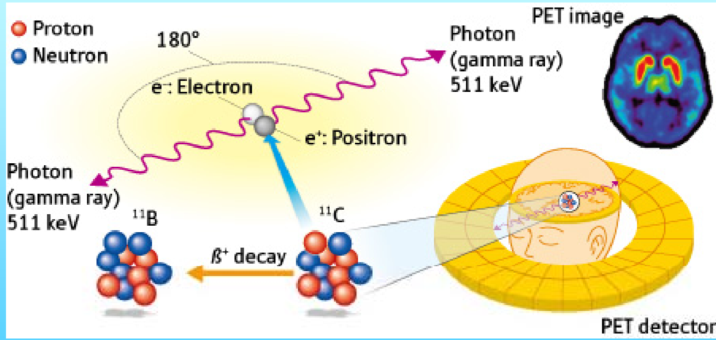
As with SPECT imaging, a radiopharmaceutical is prepared and injected and a decay event occurs and is detected once the drug localizes at a target site.

Unlike conventional imaging radionuclides PET radionuclides do not produce a gamma ray directly. A positron particle (β^+) is produced which interacts with an electron to produce two back-to-back gamma rays following a process called annihilation.

The simultaneously emitted photons are detected by a specialized camera system (PET camera).

Nuclear Medicine – PET

Positron production and annihilation.



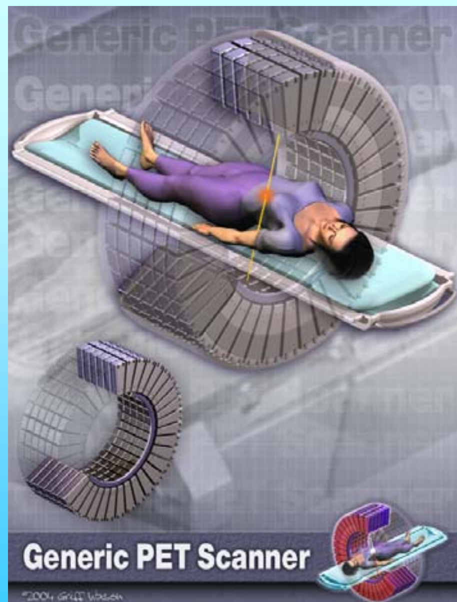
http://www.rikenresearch.riken.jp/eng/frontline/5656

Nuclear Medicine – PET

Camera design.

Simultaneous or "coincidence" detection of the 0.511MeV gamma rays provide positional information of the deposited radionuclide.

Image reconstruction provides 3 dimensional information on the location of activity in the body.



Nuclear Medicine – PET

The major radionuclides of interest in clinical and research PET

Radionuclide	Half life	Emissions	β^+ energy (E_{max}) (MeV)	Range of E_{max} β^+ (mm in water)
Carbon-11	20.4 min	β^+ only	0.97	4
Nitrogen-13	9.9 min	β^+ only	1.20	5
Oxygen-15	122 sec	β^+ only	1.74	8
Fluorine-18	110 min	β^+ only	0.64	2.5
Copper-62	9.74 min	β^+ only	2.9	13
Copper-64	12.7 hr	β^+, β^-, gamma	0.66	2.6
Bromine-76	16 hr	β^+, gamma	3.4	17
Iodine-124	4.15 day	β^+, gamma	2.1	10

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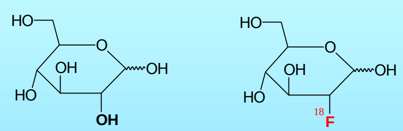
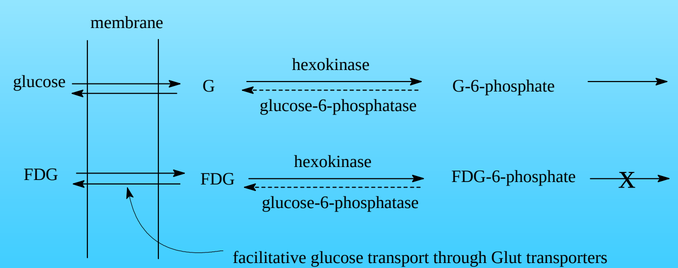
Nuclear Medicine – PET

The PET wonder drug – ^{18}F-fluorodeoxyglucose (^{18}F-FDG).



glucose   2-fluoro-2-deoxyglucose (FDG)



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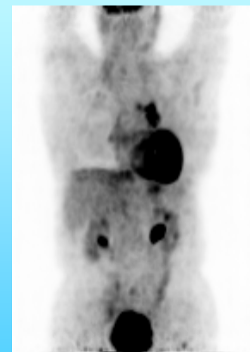
Nuclear Medicine – PET

The PET wonder drug – ^{18}F-fluorodeoxyglucose (^{18}F-FDG).

FDG indicates energy utilization or metabolic activity of tissue based on glucose uptake.

Most tumors will take up FDG avidly based on metabolism, enzyme modifications and GLUT transporter up regulation.



Lung tumor and normal distribution of FDG in a patient imaged at the CCI.

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Nuclear Medicine – PET

^{18}F-fluorodeoxyglucose (^{18}F-FDG).

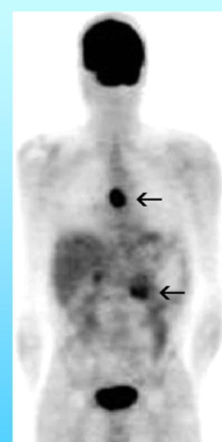
FDG dominates the PET clinical oncology imaging field but has limitations.

Brain imaging is complicated by high normal uptake of glucose.

Prostate and other slow growing tumors may not be FDG avid.

FDG measures metabolism but not proliferation of tumor cells.

Uptake in inflammatory tissues may compromise post treatment imaging.



18F-FDG PET scan (coronal view) of a patient with synchronous carcinoma of mid esophagus (top arrow) and Grawitz's tumor of left kidney (bottom arrow).

Journal of Nuclear Medicine Vol. 46 No. 8 1321-1325

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Nuclear Medicine – PET – examples of other tracers

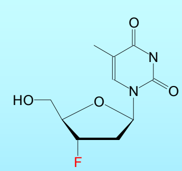
Agent	Biochemical process or measurement	In vivo application
L-[methyl-^{11}C]-methionine	Enhanced membrane transport related to protein synthesis rate (PSR).	Brain, head and neck, lung breast, lymphoma
L-[1-^{11}C]-tyrosine	Protein synthesis rate.	Brain and other applications where PSR is in question.
O-(2-[^{18}F]-fluoroethyl-L-tyrosine	Artificial amino acid tracer. Accumulation due to transport.	General indicator of tumor metabolism relative to protein synthesis.
Methyl-^{11}C-choline	Precursor for biosynthesis of phospholipids.	Prostate and brain.
^{18}F-fluoromisonidazole	Preferential hypoxic tissue trapping.	Imaging tumor hypoxia.
^{62}Cu/^{64}Cu-ATSM	Preferential hypoxic tissue trapping.	Imaging tumor hypoxia.
3'-deoxy-3'-[^{18}F]-fluorothymidine (^{18}F-FLT)	Measurement of thymidine kinase activity / cellular proliferation.	Brain tumors. General tumor imaging and evaluation.
16α-[^{18}F]-fluoroestradiol-17β (^{18}F-FES)	Estrogen receptor levels.	Breast tumor. Determination of receptor status in primary and metastatic disease.

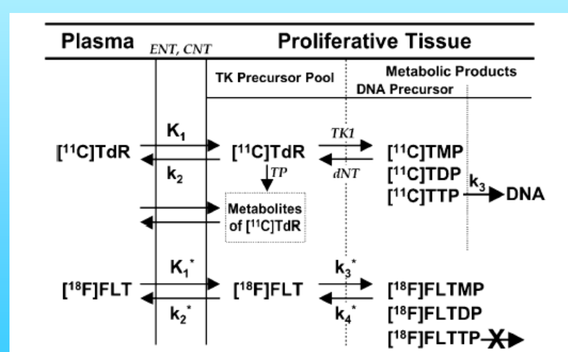
Nuclear Medicine – PET – ^{18}F-fluorothymidine (FLT)

FLT acts as a surrogate marker of DNA synthesis but is not incorporated into DNA.

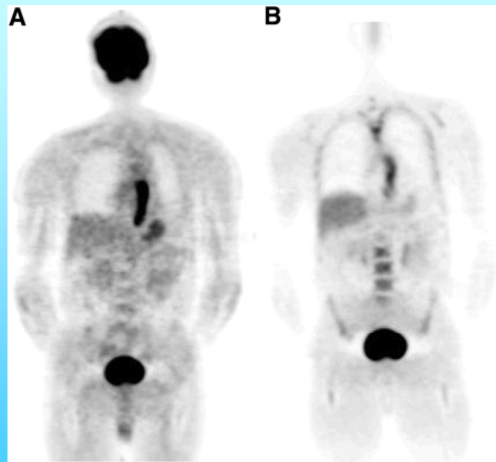
FLT is a substrate for cytosolic thymidine kinase 1 which in turn is reflective of cells proliferative activity.

FLT seems to provide an earlier indication of cellular response to therapy than FDG.





Nuclear Medicine – PET – ^{18}F-fluorothymidine (FLT)



18F-FDG PET (A) and 18F-FLT PET (B) of patient 2 with long esophageal tumor.

Journal of Nuclear Medicine Vol. 46 No. 3 400-404

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Nuclear Medicine – PET

Strengths:
Almost all tumors are imaged with a few PET radiopharmaceuticals.
Medium to high resolution imaging.
Quantitative imaging is possible.
Relatively non-invasive.
Functional and molecular imaging can be performed.
Animal imaging is well developed at high resolution.

Weaknesses:
Requires local isotope production (cyclotron).
Very expensive infrastructure.
Not readily available except at major centers – wait times.
Injected radionuclides provide radiation doses to patients and staff.

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Fused images – PET and CT

Image fusion provides enhanced diagnosis of tumors and precise localization of lesions.

Imaging is best developed with combined PET and CT scanners.

Patient undergoes PET and CT simultaneously by movement through the camera.

Provides combined structural and functional information

Imaging Cancer – Dr. John Mercer

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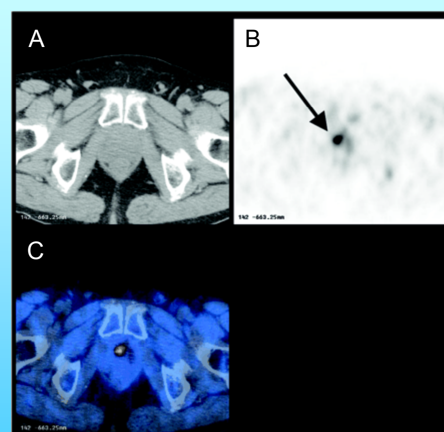
Fused images – PET and CT

Prostate cancer imaged with ^{11}C-choline (a marker of phospholipid synthesis) and fused with a CT scan.

Both structure/anatomy and functional information are obtained.

Can aid biopsy, surgery or radiation therapy.

A. Axial CT image through pelvis.
B. PET image with ^{11}C- choline at same level.
C. Fused PET-CT image.



Journal of Nuclear Medicine Vol. 46 No. 10 1642-1649

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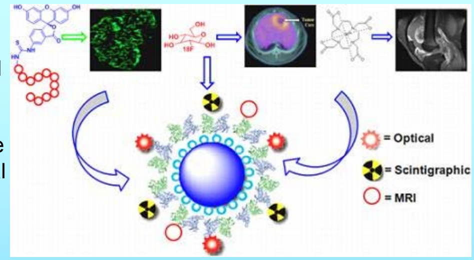
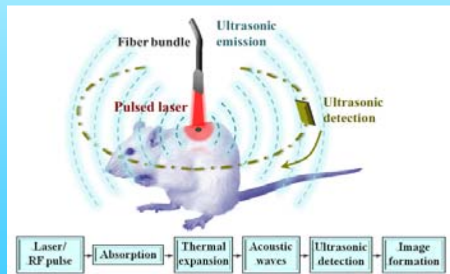
Developing Technologies

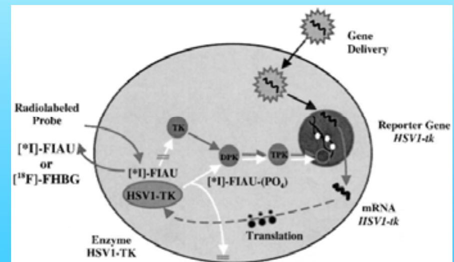
- PET/MR scanners (last 3-4 years).
- Multimodality imaging probes based on nanotechnology.
- Optical imaging combined with semiinvasive imaging. Fluorescence guided surgery, endoscopy, intravital microscopy.
- Photoacoustic imaging.
- Imaging gene therapy.



Cancers **2010**, *2*(2), 1251-1287; doi:10.3390/cancers2021251



http://www.biophotoacoustics.com/Research.php



http://www.nature.com/jcbfm/journal/v22/n10/fig_tab/9591309f1.html

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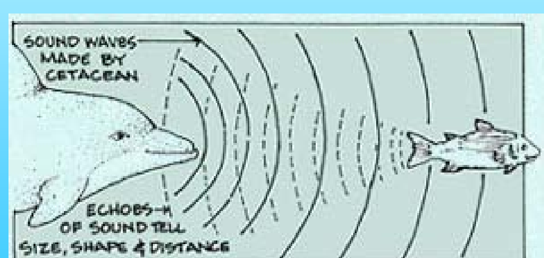
Ultrasound (US)

What is Ultrasound?

Ultrasound is a medical imaging technique that uses high frequency sound waves and their echoes. The technique is equivalent to the echolocation used by animals such as bats, whales and dolphins. The use of ultrasound for marine navigation (SONAR) is used by submarines.



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Ultrasound (US)

The Sequence of events in ultrasound imaging:

An ultrasound machine directs high-frequency (eg; 5 megahertz) sound pulses into the body using a device called a transducer.

The sound waves are partially reflected at boundaries between different tissues.

The reflected sound waves get returned to the probe where they are detected and processed by the ultrasound machine.

Sound waves not reflected travel on until another tissue boundary is encountered.

Ultrasound (US)

The Sequence of events in ultrasound imaging: (continued)

The position and other features of the boundary producing the reflected pulse can be reconstructed by the ultrasound machine. Using the speed of sound in tissue (1,540 m/s) and the time of the each echo's return.

The ultrasound machine displays the distance and intensity information as a two dimensional image.

In a typical ultrasound, millions of pulses and echoes are sent and received each second. The probe can be moved along the surface of the body and angled to obtain various views.

Tissues are “contrasted” by the presence of a boundary layer which reflects the US pulse.

Ultrasound (US)

Frequency - Adult imaging uses lower frequencies (2.0mHz to 3.0mHz) than pediatric imaging (5.0mHz to 7.5mHz and 10mHz).
The higher the frequency the less penetration; the lower the frequency the greater the penetration *but* with loss of definition for small structures.
Attenuation is tissue dependent.

Tissue Attenuation at 1 MHz

Tissue	Attenuation Coefficient (dB/cm)
air	10
blood	0.18
bone	3-10
lung	40
muscle	1.65-1.75
other soft tissues	1.35-1.68
water	0.002

Ultrasound (US)

Photo courtesy Dynamic Imaging Limited
Ultrasound machine with various transducer probes

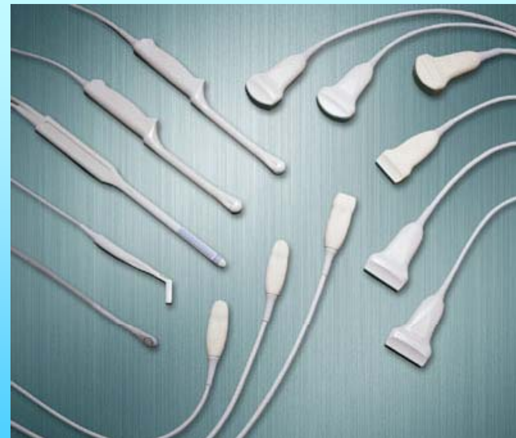
A basic ultrasound machine has the following parts:

transducer probe - probe that sends and receives the sound waves
central processing unit (CPU) - computer that does all of the calculations and contains the electrical power supplies for itself and the transducer probe
transducer pulse controls - changes the amplitude, frequency and duration of the pulses emitted from the transducer probe

display - displays the image from the ultrasound data processed by the CPU
keyboard/cursor - inputs data and takes measurements from the display
disk storage device (hard, floppy, CD) - stores the acquired images
printer - prints the image from the displayed data

Ultrasound (US)

Transducers come in many styles including probes that can be moved across the surface of the body and probes designed to be inserted through various openings of the body (vagina, rectum, esophagus) so that they can get closer to the organ being examined (uterus, prostate gland, stomach); getting closer to the organ can allow for more detailed views.



www.sonomed.com/ Sonde.html

Ultrasound (US)

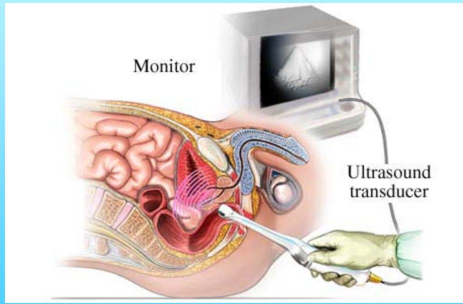
Sagittal image of the right upper quadrant shows a huge hepatocellular tumor within the right lobe of the liver.

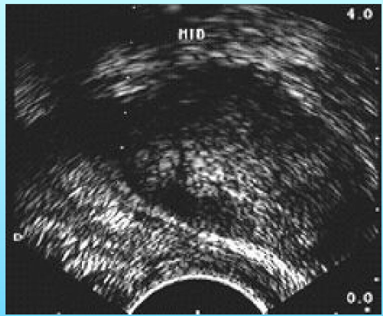
Ultrasound (US)

This 65 year old male presented with a 3 week history of decreased vision . A 14 x 13 mm base and 6.5 mm high choroidal melanoma was noted superotemporal to the optic nerve and fovea. A small collar-button was noted next to the tumor's apex (arrow).

Ultrasound (US)

Commonly used in the assessment of the prostate gland in a process called transrectal ultrasound (TRUS)





Transrectal ultrasound (TRUS), sagittal section: Typical hypoechoic cancer of the peripheral zone - Note slight bulging of the contour of the prostate gland in the area of the lesion.

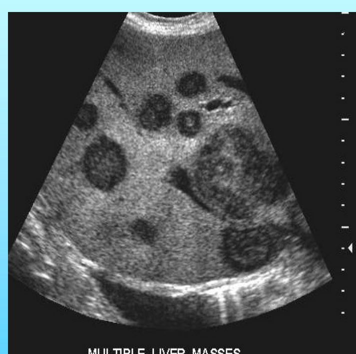
Ultrasound (US)

Enhancements to ultrasound include;

Doppler ultrasound. Ultrasound can detect and compute the speed of moving tissue (blood flow).

3-D ultrasound imaging can enhance observations of tumors or other lesions as well as it's use in obstetrics.

Ultrasound (US)



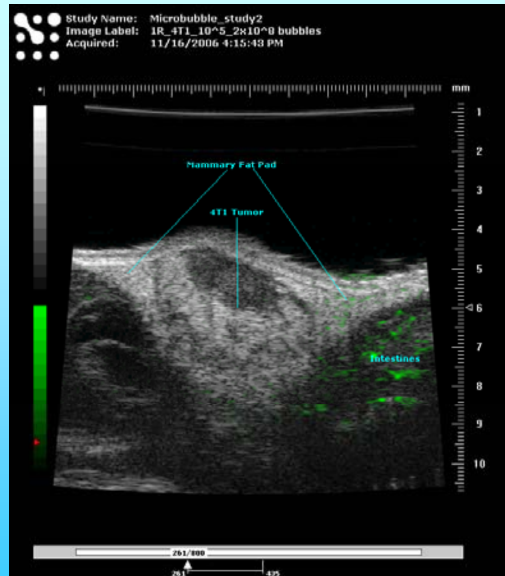
http://smiswi.sasktelwebhosting.com/ultrasound.htm

Ultrasound (US)

High resolution animal imaging instrumentation;

Microbubbles enhance contrast for visualizing blood flow.

http://www.visualsonics.com/



Ultrasound (US)

<u>Strengths:</u>

Non invasive.
No ionizing radiation dose.
Inexpensive, portable equipment used.
Higher resolution animal imaging instruments are available.

<u>Weaknesses:</u>

Generally low resolution imaging in humans.
Can not differentiate between surgical site disruption of tissue and residual or recurrent tumor.
Tissues located by US will require biopsy to confirm tumor.
Measures tissue structure in standard application but not activity or function.