

Dual (Multi) Energy CT

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Why bother?

- Traditional CT is really just a map of pixel densities
 - Inherent tissue density (based on attenuation of x-ray beam by the tissue)
 - Density of iodine (administered contrast agents)
- Lots of assumptions (some well-supported) employed in order to establish diagnoses

How were these problems addressed early on by CT?

- Use of pre and post contrast imaging
 - The contribution of iodine can be better determined
 - Still some limitations (example?)
 - Still not much information about tissue other than density
 - Things that are the same density cannot be delineated
- Standard CT radiation settings
 - Technical limitations limit choices (typically 110-140 kVp)
 - If techniques are not standardized, published literature may not be generalizable (example?)

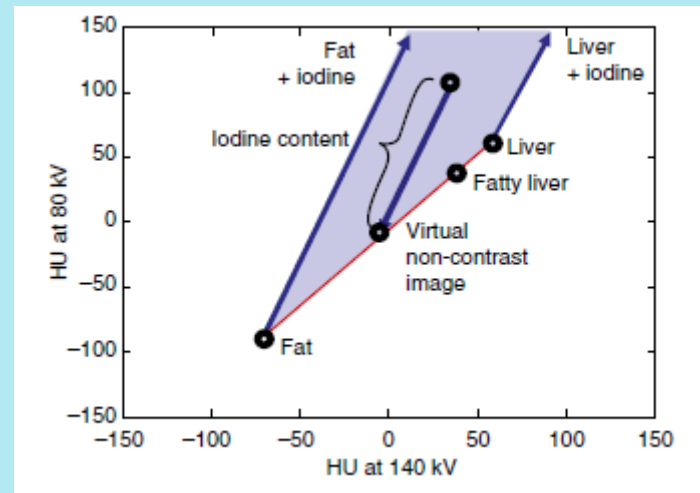
Problems with traditional CT

- Most CT has transitioned to single phase post-contrast imaging (faster, cheaper, less radiation)
 - Problem: Iodine and inherent tissue density cannot be readily differentiated
- Clinicians are used to the powerful capabilities of MRI and other advanced techniques and expect more of CT
 - Problem: too often “indeterminate”
 - Improved differentiation can reduce need to order additional studies

How can Dual Energy CT help?

- Physics: Different materials may have similar density on traditional CT (at a single energy), but have different densities at low and high energy.
- Physics: **how much** a material changes between low and high energy beams is specific to each material.
 - If you know this, you know what the material is.

Assessment of the slope of density change at low (80) and high (140) energy (kV)

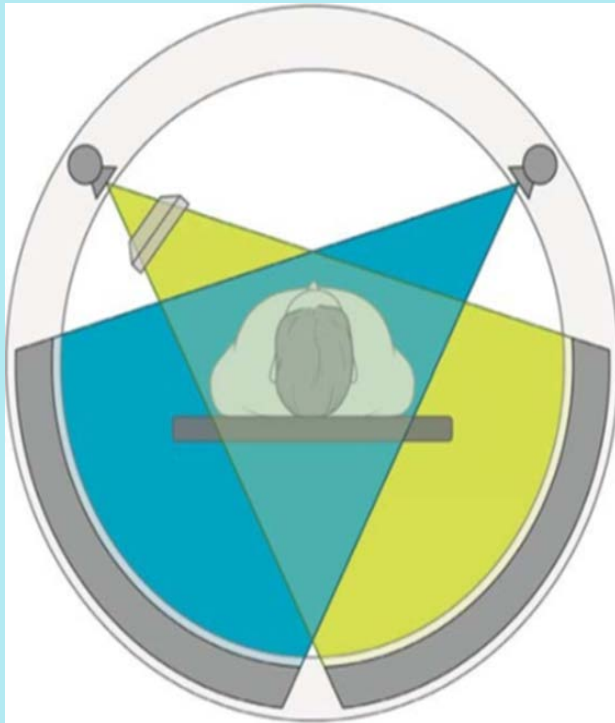


How can we scan with 2 different energy levels?

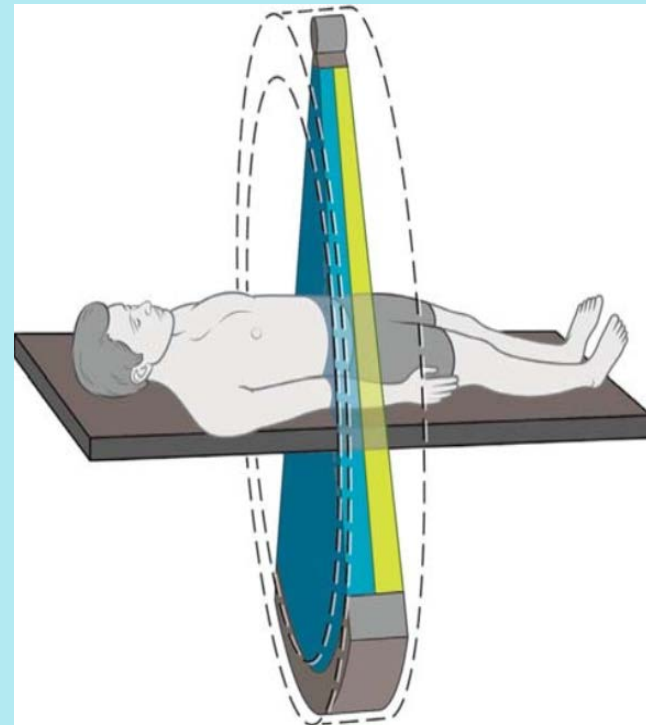
- Requires hardware that is part of the CT scanner
 - can't be done on regular CT scanners
- Each manufacturer has different techniques (different scanner designs) to achieve this
 - The differences need to be understood as it affects how the images can be made and presented for interpretation

DECT: Different Approaches

Dual-Source DECT (Siemens)

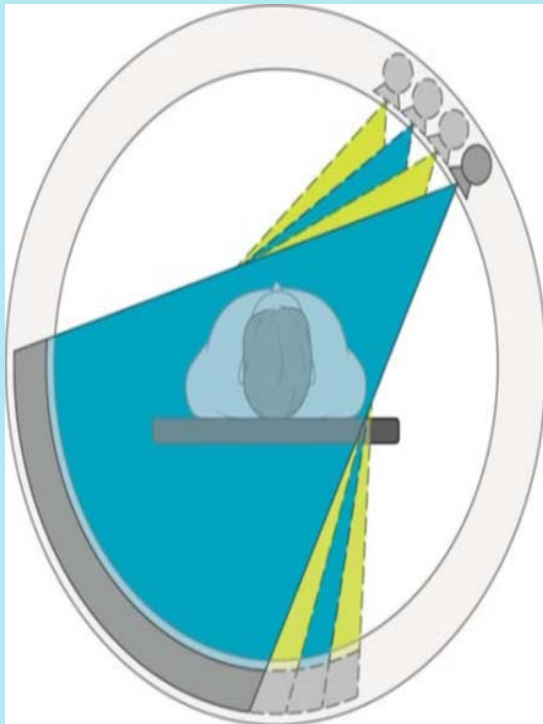


Single Source Twin Beam (Siemens)

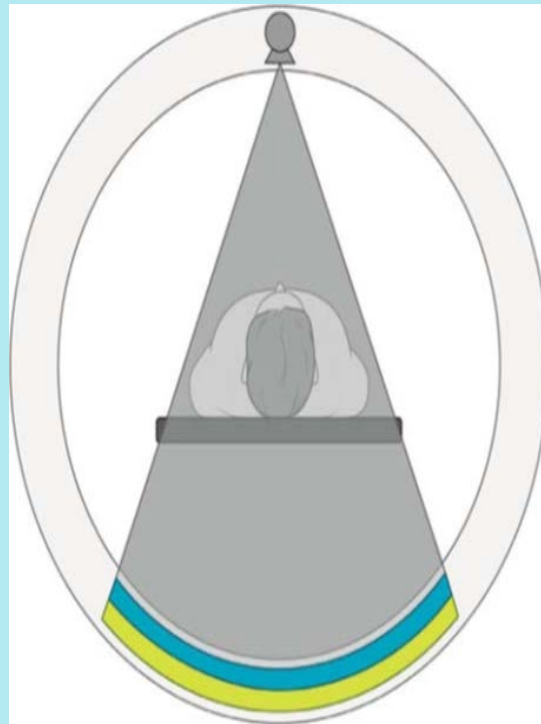


DECT: Different Approaches

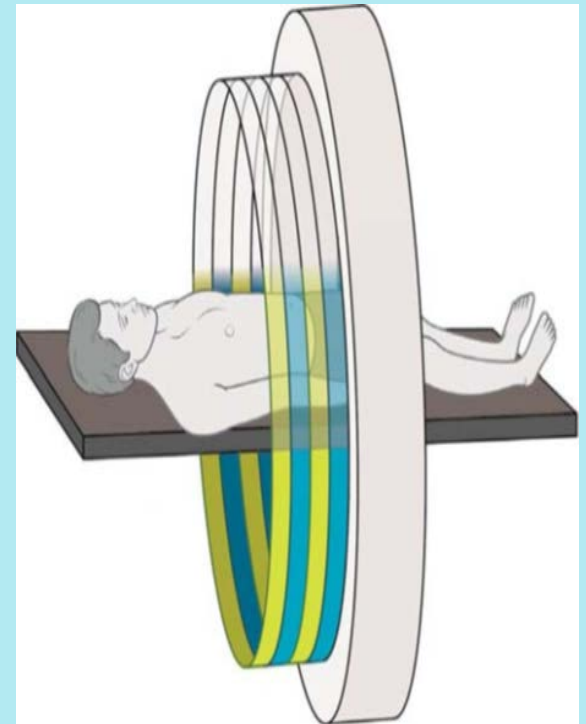
Single-Source
Rapid Switching
DECT
(GE)



Dual Layer
Detector DECT
(Philips)



Single-Source
Sequential DECT
(Toshiba)



Post-processing

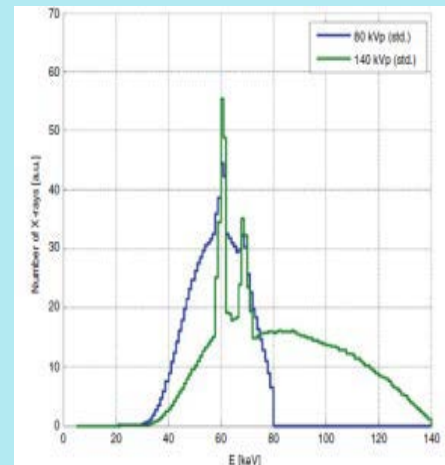
- To achieve added value, post-processing of data is required
- Depending on the type of DECT scanner what is presented may be somewhat different
 - Some may be considered strengths or weaknesses
- The ultimate goal and the way images are interpreted should not be affected by the scanner type

What is Material Separation

- All functions using Multienergy CT depend on good material separation
 - Obtained by processing data from 2 distinct x-ray beams (low energy and high energy)
- A wider separation between the energies of the two different beams or “kV settings” should improve material separation

Multi-energy X-ray Beams

- X-ray beams are NOT purely single energy (Bremsstrahlung)
 - Reported in “peak” kV (the mean is much lower)
 - There are x-rays of nearly all energies in each beam
 - Non-Gaussian curve of energies



Spectral separation

- The less the overlap in x-ray energies of the 2 beams (spectral separation), the better the ability to perform material decomposition
 - ALSO, greater spectral separation allows less radiation to the patient (photons with overlapping energies have no value but add to effective dose)

Different MECT Methods: how do they Achieve Material Separation

- Dual Source
- Single Source
 - 2 methods
- Detector based

Rapid kV Switching Scanners

- DECT must be performed prospectively
 - Scanner can be used in single or DECT mode (> radiation)
- No traditional single energy CT image can be made for interpretation
 - A reconstruction (78 keV) can be made to approximate a 120 kVp scan.
- Settings can be rapidly manipulated by the radiologist to optimize assessment of disease

Dual Energy Reconstructions

- Most basic is the identification of IODINE by the DECT software, which can then be removed or looked at alone
 - Virtual Non-contrast
 - An image that has the iodine take out, leaving behind the density of the other materials only
 - Functions similarly to a real pre-contrast image (HU)
 - Iodine Map
 - Inverse of the VNC, but iodine can also be quantified
 - Easy to immediately recognize what “enhances”

Dual Energy Reconstructions (cont.)

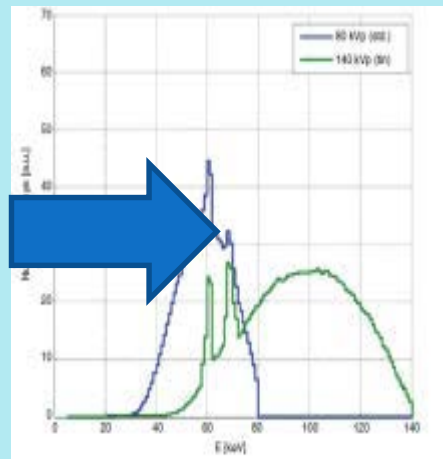
- Virtual Monoenergetic Images
 - Images that look as if the scan was performed at a single energy instead of traditional poly-energetic beam
 - Images can be made for any energy level between 40-190
 - Low energy great for iodine imaging as the closer the energy level is to the k-edge of iodine (33-39 keV), the brighter the iodine looks
 - Higher energy has less beam hardening from dense structures like bone and metal

Dual Source DECT

- DECT must be performed prospectively
 - Scanner can be used in single or DECT mode (= radiation)
- An approximation of a traditional single energy CT image can be made for interpretation
 - A blended image reconstruction of the 2 images can be made to approximate a 120 kVp scan.
- Settings can be manipulated by the radiologist but more efficient to send routine reconstructions automatically

Dual Source Multienergy CT

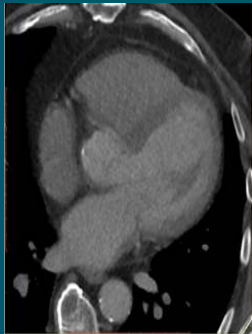
- 2 entirely different x-ray tubes (90 degree offset) scan the patient concurrently (not the same FOV)
 - 2nd generation 140 kV highest
 - 3rd generation 150 kV (improved spectral separation)



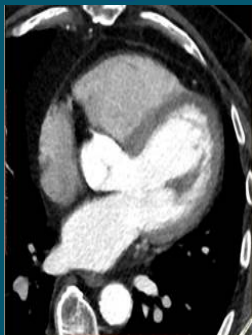
Dual Source MECT

- With 2 different sources, can have different filters on each source
- Spectral separation can be markedly improved with use of a Tin filter (Sn) on higher energy tube to “narrow” the beam
 - Will discuss filters later

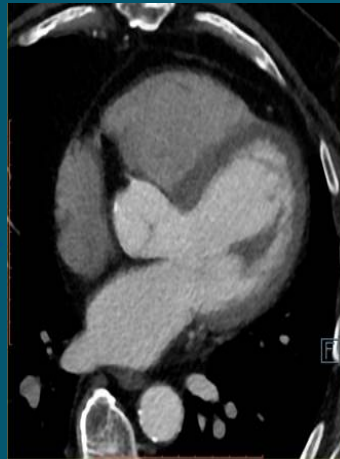
Dual Source DECT - Post Processing



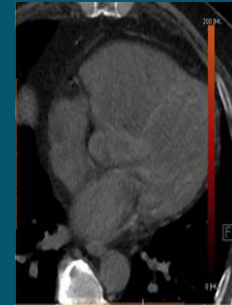
Sn 150 kVp



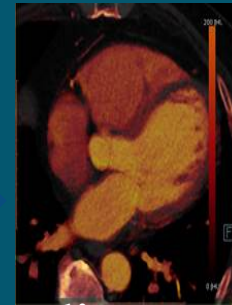
90 kVp



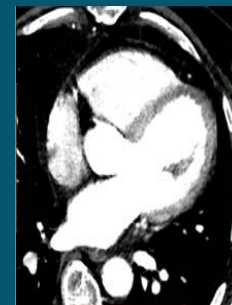
Mixed 120 kVp
60% of 90kVp
40% of 150kVp



Virtual Unenhanced



Iodine Map



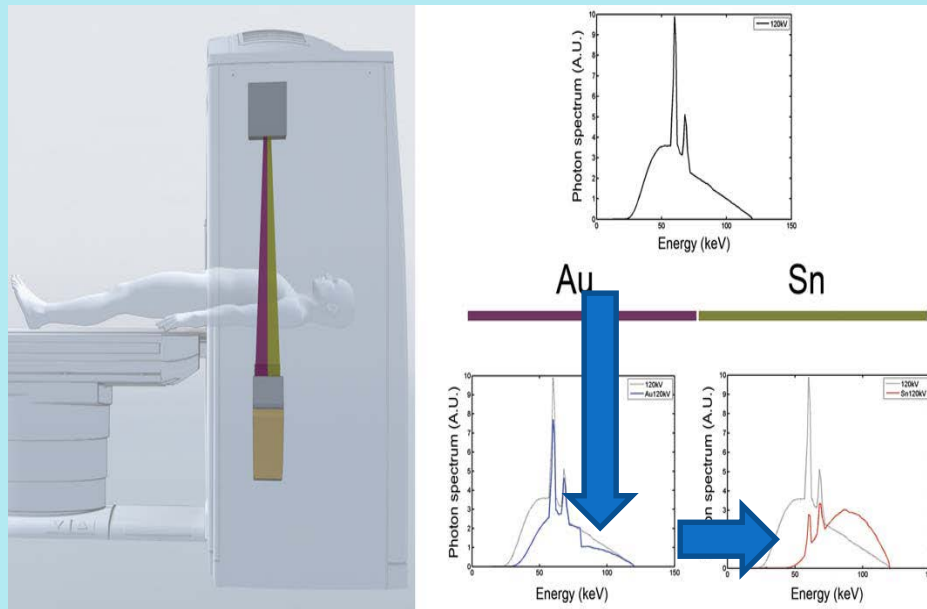
Virtual Monoenergetic

Monoenergetic Imaging



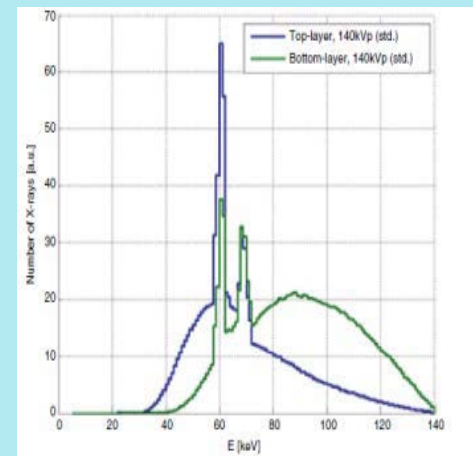
Twin Beam DECT

- A single radiation source is split by a filter that has 2 different elements
 - Gold (Au)
 - Tin (Sn)



Dual Layer Detector DECT

- The difference is that a single energy beam is separated into 2 datasets at the detector level instead of emitter
- DECT can be performed retrospectively
- A true traditional single energy CT image can be made for interpretation
- Similar functionality to other DECT





END