Adaptive Imaging: Nuclear Medicine

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- None

Other

- I am the PI of R01HL111883 to develop C-SPECT. This research scanner will be discussed.

Learning Objectives

- Appreciate the patient-specific adaptations for nuclear medicine, particularly in cardiac imaging.
- Appreciate the possibilities for adaptive imaging within a scan, particularly for cardiac imaging.

Definition of adaptive SPECT imaging: using information within the scan sequence to alter the collimation or positioning for more-optimal performance.

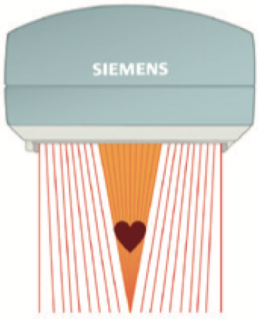
State of the Art in Cardiac Imaging

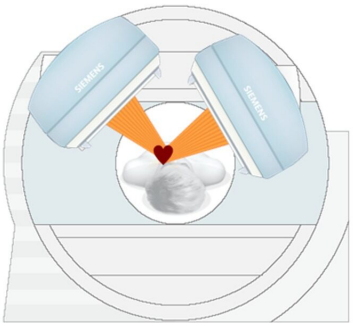
- Traditional Dual-Head
- Siemens IQ SPECT
- GE NM530C
- D-SPECT (Spectrum Dynamics)
- Digirad Cardius 3XPO
- Cardiarc/C-SPECT

Traditional Dual-Head

- Patient is (typically) supine
- Two parallel-beam collimators with 90 degree offset
- Rotate through 90 degrees for a total of 180 degrees of data
- Challenging for dynamic scanning because of the slow mechanical rotation.

Siemens IQ SPECT





Images from Siemens website.

- Spatially variant focal length cone-beam collimator.
- As it rotates, it translates side-to-side to center the heart on the detector.
- Utilizes a larger portion of the detector for the heart compared to traditional dual-head.* This gives higher sensitivity.

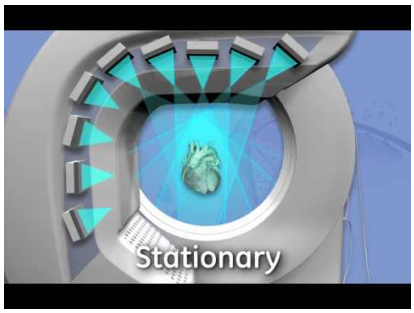
IQ SPECT positions the heart in the center of the collimator field of view and positions the detectors at a 28 cm radius for the cardio-centric orbit. IQ SPECT uses the flexibility of the Symbia™ gantry to position each detector at an optimal distance to maximize sensitivity gain and minimize feelings of claustrophobia.**

https://www.siemens-healthineers.com/en-us/molecular-imaging/iq-spect-technology/acquisition (accessed 7/11/2019).

*We will see this trend continue and become more extreme for dedicated cardiac scanners.

**All collimator types have worse resolution as you move further away.

GE Discovery NM530C: Stationary Pinhole Imaging



- Strengths:
  - Stationary Imaging
  - CZT for better energy resolution
- Weaknesses
  - 3D Sampling Critera (pinhole, but 3 rows of apertures help)
  - Positioning/Heart sampling

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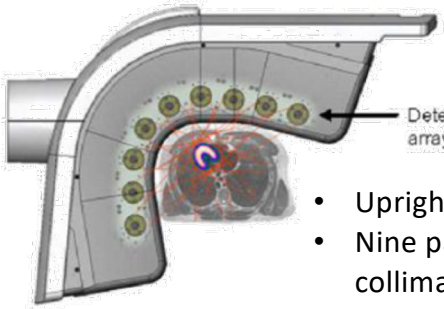
D-SPECT



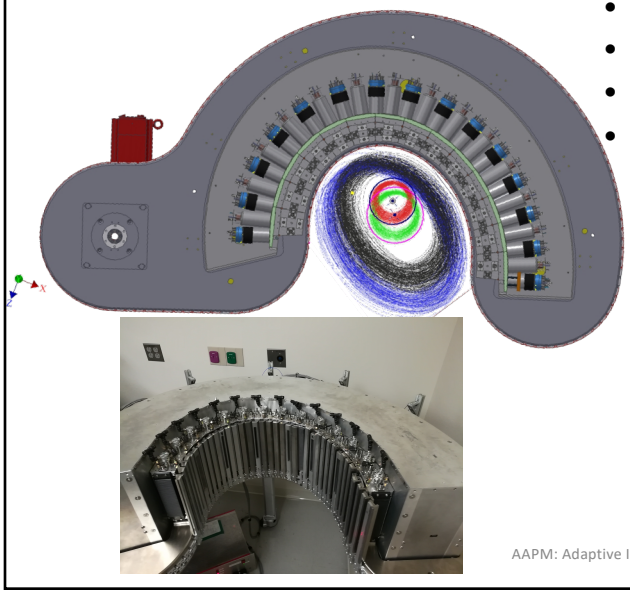
- Upright and supine imaging.
- Nine parallel-beam collimators (4 cm trans. FOV).
- Each swivels independently to locate and sample the heart
- No attenuation correction

- Strengths:
  - CZT for better energy resolution
  - More flexibility in heart positioning
  - Potentially faster frame rates.
- Weaknesses
  - Small FOV per detector

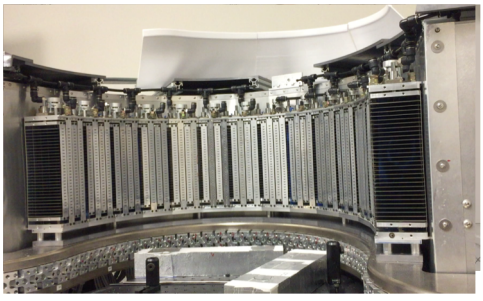
Digirad Cardius-3 XPO

- 3 small FOV solid-state cameras
- Rotates the patient for angular sampling
- Transmission source gives attenuation correction.
- Compact and open design
- The small detectors focus on the heart and give high efficiency while truncating

Cardiarc/C-SPECT



- Stationary imaging using slit-slat collimators
- Pixelated NaI detectors with large total area
- Integrated transmission source
- Adaptive: different resolution-sensitivity-FOV tradeoff points



Patient-Specific Adaptions

- Very little is currently done for patient-specific adaptations
  - Sometimes adjust dose by BMI.
  - Sometimes contour patients: better resolution but slower.
  - IQ SPECT adjusts patient positioning relative to detector to improve sensitivity.
  - D-SPECT directs its collimators towards the heart, increasing the overall efficiency for the heart.
- What else could be done
  - Choose a different resolution-sensitivity-FOV tradeoff based on patient size.

Collimator Properties with Increasing Distance

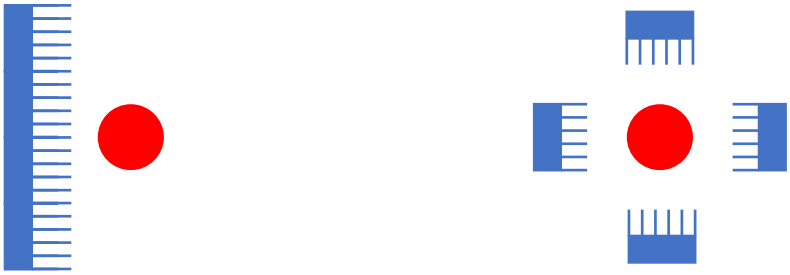
Collimator Type	Parallel-Beam	Fan-Beam	Cone-Beam	Pinhole	Slit-Slat
Sensitivity	Independent	Increasing*	Increasing*	Decreasing	Decreasing
Resolution	Increasing**	Increasing**	Increasing**	Increasing**	Increasing**
Transverse FOV	Independent	Decreasing	Decreasing	Increasing	Increasing
Axial FOV	Independent	Independent	Decreasing	Increasing	Independent

*If in the shrinking FOV
**Getting worse

Collimator Tradeoffs

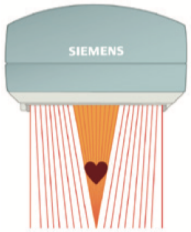
Key point: Collimator design for a specific task involves the tradeoff of spatial resolution, sensitivity, and FOV.

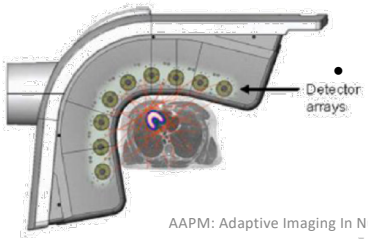
- Given a certain detector area, how can it best be used for imaging:
  - Smaller-diameter and longer holes give better resolution
  - Larger-diameter and shorter holes give higher sensitivity
  - What most dedicated systems are doing is trading FOV for improved sensitivity



How systems use FOV for cardiac imaging

Key point: Modern systems do not typically have substantially improved spatial resolution; they have improved efficiency by trading FOV.

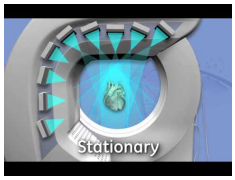


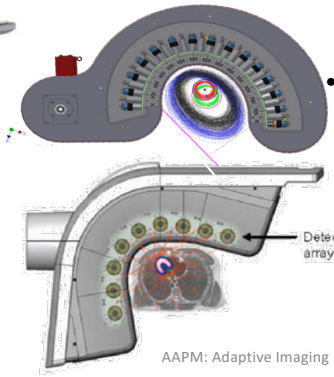


- Traditional dual head (or general purpose): the heart projects onto only a small portion of the detector.
- IQ SPECT uses magnification to use more of the detector for the heart
- GE NM530C sets the magnification to fill the detectors with the heart.
- D-SPECT's detectors are smaller than the heart and swivel to expand their FOV.
- Digirad, like Cardiarc, C-SPECT, and GE, fills the detector with the heart and truncates the rest.

Complete Sampling with Modern Scanners

Key point: Modern systems potentially allow better dynamic imaging because they limit the amount of motion needed to acquire complete data.



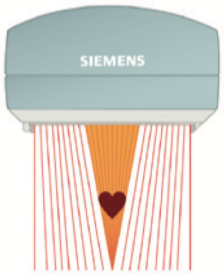


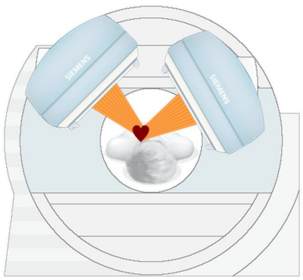
- Traditional dual head scanners require 90 degrees of rotation to obtain completely sampled data.
- GE NM 530C and Cardiarc/C-SPECT acquire completely sampled data without motion, allowing for fast dynamics*.
- D-SPECT uses a fast-sweeping motion to complete the FOV since the FOV is smaller than its detectors. This also allows much faster dynamics than traditional dual-head.

*R.G. Wells et al., "Optimization of SPECT Measurement of Myocardial Blood Flow with Corrections for Attenuation, Motion, and Blood Binding Compared with PET." J. Nuc. Med. 58(12), pp. 2013-2019, 2017.

Adaptive Imaging in Modern Scanners (Cont.)

- Siemens IQ SPECT adjusts the detector/collimator positioning to optimize efficiency.
- D-SPECT individually focuses its detectors at the heart, swiveling to complete the FOV.





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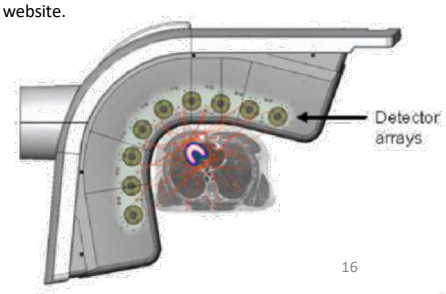
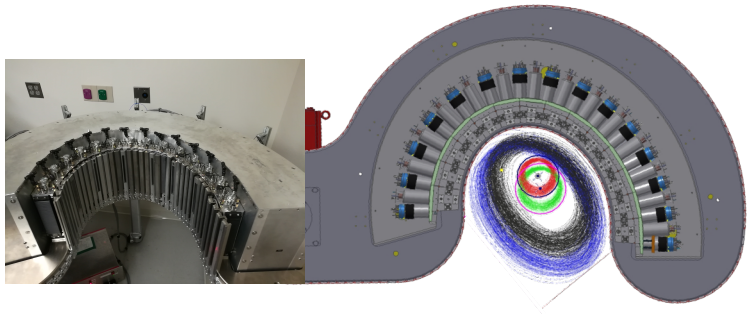
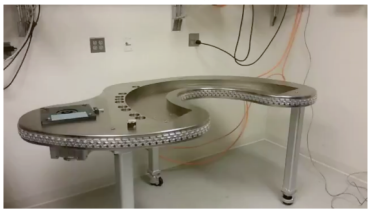


Adaptive Imaging in Modern Scanners (Cont.)

- C-SPECT is designed to be adaptive.
- The concept is to identify the location of the heart using either a scout (high sensitivity, large FOV) scan or a transmission scan.
- Categorize the patient as fitting best into the “large-patient” or “small-patient” sweet spot.
- Change the collimation to large or small patient.
- Automatically re-position the patient.
- Scan





Summary

- Currently, not many adaptations per patient are made for clinical cardiac SPECT
  - Sometimes adjust dose by BMI
  - Sometimes contour patients: better resolution but slower
  - IQ SPECT adjusts patient positioning relative to detector to improve sensitivity
  - D-SPECT focuses its detectors at the heart
- Compared to traditional dual-head scanners, modern cardiac scanners typically trade FOV for higher sensitivity, using cardiofocal imaging.
- Modern scanners typically have better angular coverage allowing for limited or no scanner motion, enabling fast dynamics.
- Dynamic cardiac imaging may have a future due to the stationary nature and high sensitivity of modern, dedicated systems.
- Adaptive imaging – where the scanner adjusts to the patient’s image during the scan sequence – potentially allows for more optimal patient-specific imaging.

Bibliography

- J. Wu and C. Liu, “Recent advances in cardiac SPECT instrumentation and imaging methods.” Phys. Med. Biol. 64(6) 06TR01, 2019.
- Physics in Nuclear Medicine, 4th Edition, S.R. Cherry, J.A. Sorenson, and M.E. Phelps, Elsevier Saunders, 2012.
- R.G. Wells et al., “Optimization of SPECT Measurement of Myocardial Blood Flow with Corrections for Attenuation, Motion, and Blood Binding Compared with PET.” J. Nuc. Med. 58(12), pp. 2013-2019, 2017.