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New Generation Cardiac SPECT Systems

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Abstract. The cardiac SPECT is a good study because of the large clinical demand and the need for improved image quality. SPECT imaging usually suffers from poor spatial resolution and high statistical noise due to patient radiation safety concerns. Scientists proposed some high count sensitivity cardiac SPECT systems that do not use conventional collimation and the introduction of diagnostic quality hybrid SPECT/CT systems. While there has been steady progress with reconstruction algorithms, exciting new processing algorithms have become commercially available that promise to provide substantial reductions in SPECT acquisition time without sacrificing diagnostic quality. New advances in nuclear cardiology instrumentation will allow SPECT imaging with low radiation doses.

Introduction

Single photon emission computed tomography (SPECT) is a rapidly developing field and new developments have been produced in both hardware technology and image reconstruction algorithms. The cardiac SPECT has been the important clinical device of cardiology for decades. It uses radioactive tracers that are injected into the blood to produce pictures of the heart. The cardiac SPECT is a very proven technology that is effective in diagnosing heart disease in many patients [1]. There are shortfalls with this technology that has been improved upon over the years. The relative weaknesses and strengths that exist among imaging techniques are important to be understood. One can notice that the spatial resolution of MRI and CT is significantly higher than that of SPECT. However, the detection sensitivity of SPECT is significantly higher than those given by functional modalities and moreover can detect tracer concentration. Both approaches use the tracer principal to detect physiological abnormality or disturbed biochemical process.

Conventional Cardiac SPECT Scan

Scintillation cameras used in cardiac nuclear medicine are highly sophisticated devices, particularly those equipped for SPECT. Adding more detectors to a scintillation camera system can increase sensitivity obviously. It seems obvious that doubling the number of detectors can double the number of photons that are acquired in the same amount of time, but conventional camera design is limited to imaging heart using only small portion of available useful area of Nal (TI) crystal detectors when applying standard parallel hole collimators.

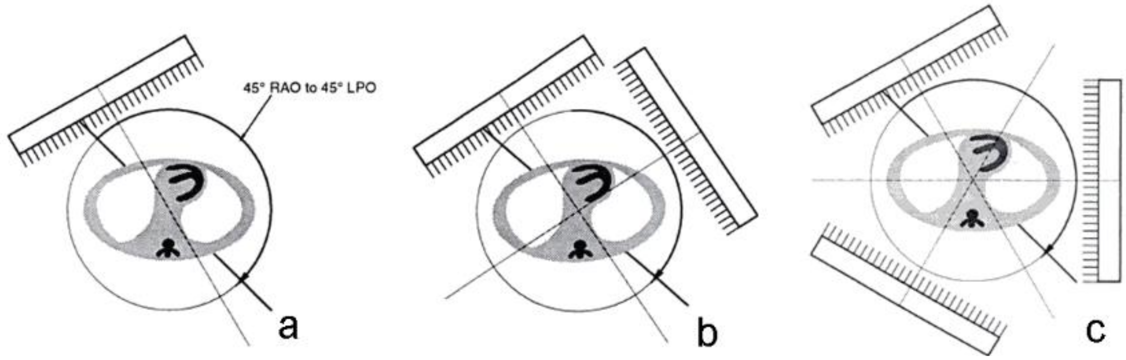

Fig.1. Multi-detector SPECT camera configuration. **a**:standard single detector camera; the counts can be collected in the 180^0 between 45^0 RAO(right anterior oblique) and 45^0 LPO (left posterior oblique); **b**: two detectors double the sensitivity for 360^0 orbits; **c**: three detectors will increase sensitivity by 50% for 180^0,but triple the sensitivity for 360^0 orbits.

Hardware Advances in Cardiac SPECT

Current cardiac SPECT systems offered by GE Healthcare, Philips and Siemens are all based on conventional dual-head systems that revolve about the patient to collect projection information. The new designs vary in number and type of scanning or stationary detectors to increase the geometric efficiency and resolution when applying slits/slats collimators. Several new systems have been developed recently that are departures from the conventional SPECT system design. The key characteristic of the new dedicated cardiac imaging systems now available is significantly increased photon sensitivity. Most of the customization has been to minimize the size of the system so that it can easily fit into an office-size room. One highly advertised feature of new cardiac systems is the ability to do noncircular orbit. The orbit seeks to minimize the distance from the camera to the body throughout the tomographic acquisition, maximizing resolution.

D-SPECT

Spectrum Dynamics SPECT (D-SPECT) is a novel SPECT for cardiac. Based on novel detector technology and an unique acquisition geometry, D-SPECT provides better energy resolution due to the use of Cadmium Zinc Telluride (CZT) and higher sensitivity due to the use of wide-angle collimators combined with region-centric data acquisition compared to conventional SPECT [2].

The system has an obviously different design consisting of 10 individual collimated pixelated CZT detectors, each with a dimension of approximately 4cm×16cm. Each detector rotates around its central axis with programmable angular orientation, as shown in Fig. 2a. The patient reclines on a chair with the right-angle gantry positioned over the chest. By first obtaining a fast scout scan to identify the location of the heart, the CZT detectors independently rock back and forth to acquire the heart projection data. Each detector confines its sampling to the region of the heart. The combination of the slits and the slats provide pinhole sampling. Fig. 2b shows a D-SPECT cardiac scanner obtained U. S. Food and Drug Administration approval. The initial performance characteristics of the D-SPECT camera, including markedly improved sensitivity with spatial resolution recovery and higher patient throughput, offer great promise for clinical dynamic SPECT protocols. This system has been reported to have higher count sensitivity than conventional SPECT systems with a two times improvement in spatial resolution [3].

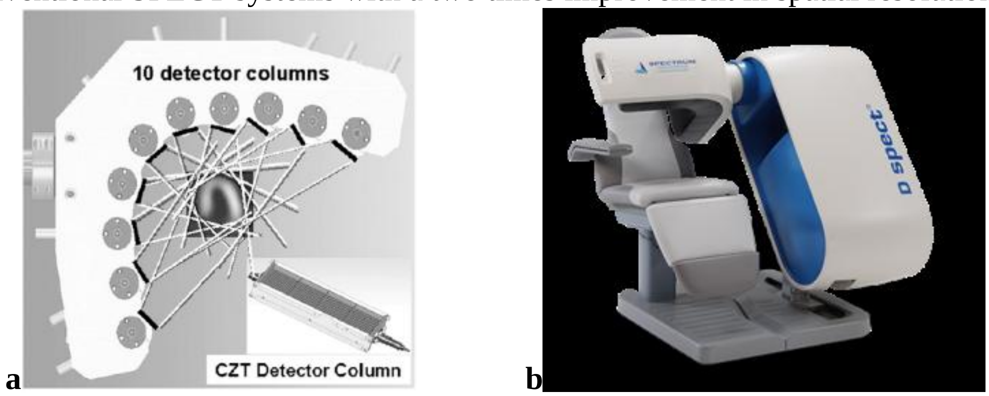

Fig.2. New cardiac SPECT systems.(a) Cardi Arc uses slit–slat approach to acquire projection information. D-SPECT detector head consists of 10 pixelated CZT detector columns. (b) D-SPECT cardiac scanner.

E-SPECT

Based on an emission imaging device shaped as an arc in the form of a part of an ellipse with multiple collimated detector columns, Sheng first proposed a new cardiac SPECT system in an elliptical orbit(E-SPECT) at the Rush University Medical Center (Chicago, USA)in 2004 to improve the geometric efficiency and the spatial resolution. E-SPECT shown in Fig.3 has a semi elliptical arc of pixilated CZT detectors with a series of lead thin plates (slats) to provide axial collimation for the detectors [4, 5]. A curved lead thin plate with a set of elongated pinholes (slits) is located in the front of the slats. The collimators consists of multiple slit-hole collimators (12~14) whose segments are only directed toward the patient's heart. Motion of the slit plate provides all of the required angular sampling in 6~10 steps. The detector system completely surrounds and is close to the patient as near as possible, so it can provide more detectors and has higher geometric efficiency for the central region.

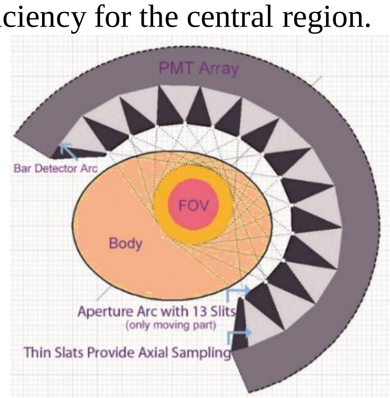

Fig. 3. E-SPECT detector

Fig.4. E-SPECT cardiac scanner

In this system, the heart is well centered in the small field of view (FOV). An integrated transmission imaging device, which is a low dose and low cost x-ray CT, is designed to determine the location of the heart and derive attenuation maps for correction. The detector system used for SPECT also detects transmitted photons from a point source which rotates along the arc notch of designed SPECT The system with slit–slat collimation for cardiac imaging can obviously increase the geometric efficiency for the central region. Imaging resolution can be achieved by adjusting slit width and the slat spacing. The total system geometric efficiency for the central region of E-SPECT is over two times that of one of the dual-head SPECT systems. The signal to noise ratio of this system in the central region is double that of other SPECT systems with a two times improvement in spatial resolution. It has in common the potential for ten times increase in count sensitivity. Better quality images used in E-SPECT are a motivation for hybrid SPECT/CT.

Software Advances

The new SPECT scanner devices are coupled with improved image reconstruction techniques. Most systems now offer compensation for image resolution loss (especially needed for the high-sensitivity collimation). Since the new cardiac SPECT data are all reconstructed with OSEM, the final resolution is dependent on position and on the activity distribution within the FOV. Iterative image reconstruction is a time consuming process especially in the case if we use it with attenuation correction and compensation for the distance dependent spatial resolution of the detector. The optimizing OS-EM algorithm is superior to other reconstruction algorithms and has been successfully applied to the SPECT system [5, 6].

Dose Reduction

New scanners and software technologies have been put into clinical practice primarily to reduce the radiation dose. With conducting such prospective low-dose studies, the quality of the images could potentially suffer significantly even if the injected dose is too low. It is possible for D-SPECT or E-SPECT camera to further reduce the radiation dose.

Conclusion

While SPECT has many applications in neurology and oncology, the majority of SPECT systems are performed in the field of cardiology. SPECT is now a cornerstone with any patient with heart diseases. The new generation of SPECT systems should be able to offer increased accuracy. The performance of new cardiac SPECT is discussed with relation to both in terms of optimal hardware design (e.g., detector system and slit-slat collimator) and software development (e.g., iterative reconstruction algorithms, compensation). In SPECT, many approaches were investigated to increase sensitivity through optimal design of collimators. As new generation cardiac SPECT, D-SPECT and E-SPECT can significantly improves the geometric efficiency for the central region, relative to other SPECT systems. Further development of this system depends largely upon the collimator design and detector modules (such as semiconductor detector), and fast iterative reconstruction algorithms.

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