ACCEPTANCE TESTING ON A MULTIPLE-DETECTOR SPECT SYSTEM

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ABSTRACT

Single Photon Emission Computed Tomography (SPECT) system is a nuclear medicine imaging device using a rotating scintillation camera and a computer system to acquire, reconstruct and process a patient tomographic images in transverse-axial, coronal and sagittal planes. The system can have one detector or more. The advantage of multiple detectors is the higher sensitivity, shorter time study and the ability to perform more patient studies per day.

Acceptance testing of the SPECT system by the physicist is an important step towards the acquiring of images of the highest possibility quality over the operating life of the instrument. The test should be performed after the system is installed, carefully tuned, clinical operative, and before patient studies are initiated. The major purpose of the acceptance test is to assure the user that the system is performing according with the specifications as quoted by the manufacturer. The National Electrical Manufacturers Association (NEMA) has prepared a protocol detailing test conditions to be used by manufacturers. The document provides specific protocol to measure the performance parameters and traceability from manufacturer to user. Two test methods, performance standards and class standards are measured in the acceptance testing which include the intrinsic and system resolution, spatial linearity, energy resolution, flood field uniformity sensitivity and count rate performance. Furthermore, whole body imaging, multiple window spatial registration (MWSR) must be included that in the acceptance test of single and multiple detectors. SPECT phantom study, will offer the information on the SPECT performance in terms of tomographic uniformity, contrast, resolution and lesion detectability. Images should be compared from each detector and all detectors. Best image quality should be obtained from all detectors.

In this paper, the result of the acceptance test of the triple detector SPECT, TRIAD XLT 20 will be presented. All the results are within acceptable limit under NEMA Standards and manufacturer guidelines. The acceptance testing of a system is a critical step towards the achievement of high quality performance of any damage, deficiencies or flaws before the warranty has expired. No instrument should be put into routine use unless it has been shown through acceptance testing to be performing optimally. An instrument that does not perform correctly at installation has a high likelihood of never doing so.

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INTRODUCTION

Single Photon Emission Computed Tomography (SPECT) system is a nuclear medicine imaging device using a rotating scintillation camera and a computer system to acquire, reconstruct and process a patient tomographic images in transverse-axial, coronal and sagittal planes. The system can have one detector or more. Triple detector SPECT system is shown in Figure 1. The advantage of multiple detectors is the higher sensitivity, shorter time study and the ability to perform more patient studied per day.

Acceptance testing of the SPECT system by the physicist is an important step towards the acquiring of images of the highest possible quality over the operating life of the instrument. The test should be performed after the system is installed, carefully tuned, clinical operative, and before patients studied are initiated. The major purpose of the acceptance test is to assure the user that the system is performing in accordance with the specifications as quoted by the manufacturer. This is extremely difficult to do in a rigorous manner. For the most part, the system performance has been measured by the manufacturer under test conditions which are impossible for the user to duplicate. The manufacturer uses specialized equipment and test procedures which are not openly documented and which vary from manufacturer to manufacturer. After the camera has been shipped, performance measurements as initially done in the factory are impossible to repeat as the specialized equipment is not available to field service representatives. Further, many manufacturer's specifications are class standards, indicating that they are not measured on each and every system, and therefore may never have been measured on a given system.

In an effort to encourage more complete and uniform performance specifications, the National Electrical Manufacturers Association[1] (NEMA) has prepared a protocol detailing test conditions to be used by manufacturers. These standards detail the equipment and techniques to be used in measuring a set of performance parameters. The document provides the user with specific protocols to allow them to measure the same set of performance parameters and thus provide traceability from manufacturer to user. Two types of standard, class standard as defined earlier and performance standards, which represents test measurement specifications that apply to and must be met by every system covered by the specification, are measured in the acceptance testing.

Tomographic techniques are very sensitive to inadequate calibration procedures. In order to ensure artifact free images, the first performance task conducted should be the center of rotation calibration and correction and the uniformity correction. There should be coincidence of both collimator and detector axes of rotation. Separate centers of rotation should be acquired for each detector. In addition, each detector must have its own unique reference flood. The collimators should be uniquely identified so that the reference floods for uniformity correction will be applied to the correct collimator. The acceptance test of a multiple detector system is more critical than a single detector system as it is essential that response of all detectors be matched to each other. All calibration factors and centroid locations should be within 0.5% of each other. Quantitative comparisons should be performed for each detector separately and then after the responses of all detectors have been added together to ensure that the added image has not been degraded. The system sensitivity variation between each detector must not be greater than 5%. SPECT performance study using JASZCZAK phantom filled with Tc-99m solution should be acquired and reconstructed for each detector and for all detectors. Transverse – axial slices from each reconstructed image should be compared which the image contrast should stay the same but the signal-to-noise ratio should improve. Carefully examine the section of solution which represents tomographic uniformity and noise, no ring artifact should be observed in this region. Sphere and rod sections represent tomographic resolution and contrast. The smallest cold sphere of diameter 9.5 mm and at least the 7.9 mm cold rod diameter should be visualized. The collimator hole angulation measurements[2] should be added in the SPECT acceptance testing.

LOG BOOK

A permanent record book should be initiated at the time of acceptance testing of a new system. The user should record all available performance data obtained from the manufacturer, the results of the test including the labeled images and all information necessary for the reference test at some later date. Subsequent quality control, component failure and maintenance records should be kept in the same log book.

MATERIAL AND METHOD

Radioactive sources

Point source Tc-99m, Co-57, Ga-67

Line source Tc-99m, Co-57

Flood or sheet source Tc-99m, Co-57, Ga-67

Phantom and accessories

Jaszczak phantom

SPECT System Spatial Phantom

Solid acrylic scatter phantom

Resolution (Bar) phantom

Orthogonal Hole Test Pattern (OHTP)

Useful Field Of View (UFOV) Mask

Copper Absorber 13 plates 2 mm thick

Bubble level and level protractor

Equipment

A triple detector SPECT TRIAD XLT-20, rectangular detectors with useful field of view (UFOV) 18x23", center field of view (CFOV) 15x20" and 3/8" NaI(Tl) crystal thickness, has been tested under NEMA protocol and manufacturer's guildeline for the planar and tomographic specifications.

RESULT

A. Physical inspection for damage and production flaws PASS

B. Planar study

Result on planar study is shown in Table 1 for Class Standards and Table 2 for Performance Standards.

Table 1 Result on planar study for Class Standards

	Class Standards	Result			Worst
		Head 1	Head 2	Head 3	Case
C1	Intrinsic count rate performance in air.				
	20% observed count rate loss,cps	104,000	101,000	102,000	<60,000
C2	System count rate performance in scatter				
	Collimator LEUR_PAR				
	20% observed count rate loss	34,300			<30,000
	Dead Time (microsecond)	5.2			N/A
C3	System spatial resolution with scatter				
	FWHM (mm)	6.34	6.94	7.44	7.60
	FWTM (mm)	13.74	13.92	14.39	14.65
	Collimator ME_PAR				
	FWHM (mm)	9.83	9.53	9.67	11.90
	FWTM (mm)	20.15	18.61	19.87	23.93
C4	System spatial resolution without scatter				
	Collimator LEUR_PAR				
	FWHM (mm)	6.65	6.68	7.07	7.20
	FWTM (mm)	12.69	12.46	12.55	12.95
	Collimator ME_PAR				
	FWHM (mm)	9.46	9.26	10.07	11.20
	FWTM (mm)	16.90	17.09	16.66	20.10

Table 2 Result on planar study for Performance Standards

	Performance Standards	Result			Worst Case
		Head 1	Head 2	Head 3	
P1	Intrinsic Flood Field Uniformity				
	Integral UFOV	1.6%	2.0%	1.5%	2.5%
	CFOV	1.6%	1.8%	1.5%	2.0%
	Differential UFOV	1.3%	1.7%	1.3%	2.0%
	CFOV	1.3%	1.4%	1.0%	1.5%
P2	Intrinsic Energy Resolution (Tc-99m)				
	FWHM(%)	9.5%	9.8%	9.8%	9.9%
P3	Intrinsic energy Resolution				
	FWHM(mm) UFOV	4.0	3.9	4.0	4.0
	CFOV	3.7	3.7	3.7	3.8
	FWTM(mm) UFOV	7.5	7.4	7.5	7.8
P4	Intrinsic Spatial Linearity				
	Absolute(mm) UFOV x	0.41	0.33	0.38	0.60
	y	0.42	0.31	0.31	0.60
	CFOV x	0.24	0.33	0.31	0.40
	y	0.27	0.30	0.31	0.40
	Differential (mm) UFOV x	0.12	0.14	0.14	0.20
	CFOV y	0.20	0.11	0.14	0.25
	CFOV x	0.12	0.14	0.14	0.20
	y	0.19	0.11	0.14	0.20
P5	Intrinsic Maximum Count Pate. keps	131	124	125	110
P6	Maximum Window Spatial	0.49	0.32	0.29	1.0
	Registration (mm)				
P7	System Sensitivity (cpm μCi^{-1})				
	Collimator LEUR_FAN	200	199	199	N/A
	System Variation		0.87%		5.0%
	Collimator LEUR_PAR	141	138	141	N/A
	System Variation		2.66%		N/A
	Collimator ME_PAR	161	159	160	N/A
	System Variation		1.23%		N/A
P8	Angular Variation of Flood Field Sensitivity				
	Maximum Sensitivity Variation		0.10%		2.5%

D. Tomographic study.

Result on tomographic study is shown in Table 3

Table 3 Result on Tomographic study

T1	Center Of Rotation (COR) Correction and Calibration				
	Angle Dependent Maximum Deviation after x-y alignments, mm				
	x	0.09	0.11	0.10	0.5
	y	0.10	0.10	0.10	0.5
T2	System Spatial Resolution with Scatter (mm)				
	Tangential	6.7			7.3
	Radial	9.3			9.8
	Central	10.4			10.4
T3	SPECT Performance Study Jaszczak phantom Transverse-Axial slices				
	Visualized minimum sphere diameter (mm)		9.5		N/A
	Visualized minimum rod diameter (mm)		7.9		N/A

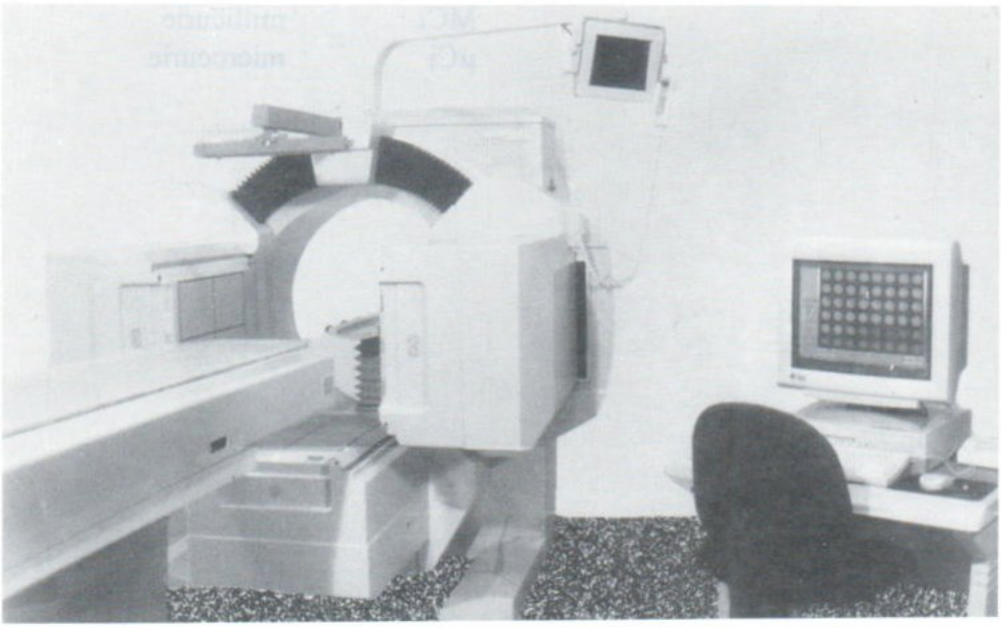

Fig. 1. Triple Detector SPECT System

DISCUSSION AND CONCLUSION

The Acceptance testing of a system is a critical step towards the achievement of high quality performance. It should be carried out immediately after the installation, so that the supplier can be informed of any damage, deficiency or flaws before the warranty has expired. The results from this study show that all of the values are within the acceptance level of the manufacturer's worst case. The instrument should not put into routine use unless it has been shown through acceptance testing to be performing optimally. An instrument that does not perform correctly at installation has a high likelihood of never doing so.

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2. American Association of Physicists in Medicine. AAPM Report No.22. Rotating scintillation camera SPECT acceptance testing and quality control. New York 1987.

ABBREVIATION

CFOV	Central Field Of View
UFOV	Useful Field of View
Cpm	counts per minute
Cps	counts per second
FWHM	Full Width at Half Maximum
FWTM	Full Width at Tenth Maximum
LEUR_PAR	Low Energy Ultra high Resolution Parallel hole collimator
LEUR_FAN	Low Energy Ultra high Resolution Fan beam collimator
ME_PAR	Medium Energy Parallel Hole Collimator
MCi	millicurie
µCi	microcurie