The Quality Control of Gamma Camera in Nuclear Medicine

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=국문초록=

核醫學分野에서의 Gamma Camera의 品質管理에 關한 硏究

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우리나라에 방사성동위원소가 진단 및 치료에 이용된지 20여년이 되었으며 특히 80년대에 들어와서는 Scintillation Camera의 급격한 증가가 이뤄지게 되었다. 그러나 많은 기기의 증가로 품질관리가 필요하게 되었다. 핵의학장비의 품질관리 목적은 장비기능의 정상여부를 조기에 발견하여 항상 균등한 질의 영상을 재현시켜 진단을 보다 정확하게 하는데 있다. 따라서 Scintillation Camera를 사용할 때 사용자는 기계의 기능과 성능을 항상 정확하게 파악하여 적절한 대책을 세워 보다 정확한 영상을 얻을 수 있도록 해야 한다. 저자들은 이러한 점을 고려하여 Scintillation Camera의 품질관리에 대한 원칙과 기술적인 문제점을 문헌고찰과 함께 보고하는 바이다.

The developments of nuclear medicine devices being used, especially the advanced gamma-camera, are discussed as the basis for quality control. Quality control of gamma-camera is necessary to insure maximum diagnostic information at the minimum possible risk of the patients. Also, the principles of quality control and procedures of gamma-camera are reviewed on the basis that characterize gamma-camera performance.

Introduction

The application of nuclear medicine to clinics become generalized and got the important position in field of diagnosis. In, April 1960, the era of nuclear medicine in Korea began with the radioisotope clinic in the Seoul National University Hospital with the first radioisotope equipment which used the radioactive materials for the purpose of diagnosis and treatment of the disease. The reactor TRIGA MARK II in the Atomic Energy Research Institute was installed in March 1962 and produced radioisotopes like ^{198}Au, ^{32}P, ^{51}Cr, ^{131}I, etc., in 1968. The production of the radioisotope has been continuously increased from 2,819 mCi in 1968 to 224,694 mCi in 1981 with an average increment of about 55% per year for 13 years. About 40 hospitals provided nuclear medicine diagnosis services. Since the first scanner with color attachment was installed at the Cancer Research Hospital in 1964,

more than 50 imaging devices of various types have been now widely available.

By 1984, The medical cyclotron (50Mev) will be installed in Cancer Research Hospital and produce various short-lived radionuclides which will be used for diagnosis and radiotherapy. The quality control in nuclear medicine equipments should be performed on regular basis as recommended by preventive maintenance schedule.

The objective of quality control program for nuclear medicine instrumentation is to evaluate the operational characteristics and to obtain the assurance that the devices are indeed performing within an acceptable range described as an evaluation all devices including scintillation camera, scanner, gamma counter, external probe and dose calibrator etc., should be included in the quality control.

In 1980, gamma camera that enabled whole-body imaging come into general use and the interest of the use ^{99m}Tc started to grow.

Although the field of nuclear medicine instrumentation has grown rapidly, the relative importance of the enviromental condition such as temperature, humidity and background radiation in laboratories has been neglected. Some of the parameters of quality control in gamma camera will be described following.

Environment condition

Normal operation of nuclear medicine equipments requires an ambient environment of 10°C to 32.2°C with a non-condensing relative humidity between 35% and 6%. The annual average temperature and humidity are approximately 12°C and 69%, respectively.

But summer is the hottest and the dampest season of the year. The daily average humidity is increased nearly 80% with temperature variation between 26°C and 30°C (See figure I).

The air condition and dehumidifier had been operated to keep normal condition during the summer. And in the winter average temperature always keeps below zero. The temperature and humidity in laboratories are the most important problem in these seasons.

Temperature variance of nuclear medicine equipment during operation must not exceed 3 to 4°C per hour to avoid damage to the crystal.

Temperature transition within normal condition was controlled by steam heater and electric heater.

Spatial resolution

Spatial resolution refer to the ability of an imaging device to reproduce two separate parallel line sources of radioactivity as separate entities. Anger type gamma camera come with a set of parallel-hole collimators. Their spatial resolution is best for sources close to the face of collimator. Low energy gamma rays are negligible septal penetration and edge penetration in gamma camera. The performance of any collimator is determined by the geometry of its holes but the spatial resolution of an Anger camera is not determind only by the geometric resolution, Rg of its collimator. The camera has an intrinsic spatial resolution, Ri. Hence system resolution will be as follows::

$$Rs = \sqrt{Ri^2 + Rg^2}$$

This relationships is valid only the line source measurements in air. In clinical practice, we deal only with volume sources embedded in a scattering medium.

Finally, the resultant overall resolution will be as follows:

$$R = \sqrt{Ri^2 + Ss^2 + Rg^2}$$

Procedure of intrinsic and system spatial resolution

In general. There are two methods to measure resolution. Direct method using a computer are:

1. A line source may be prepared using a length of thin polyethylene tubing field with 2 mCi of ^{99m}Tc solution.

2. Place a line source on the face of the detector without collimator for intrinsic spatial resolution or with collimator for system spatial resolution.

3. Counting rate may be obtained both the X and Y directions using a computer system and

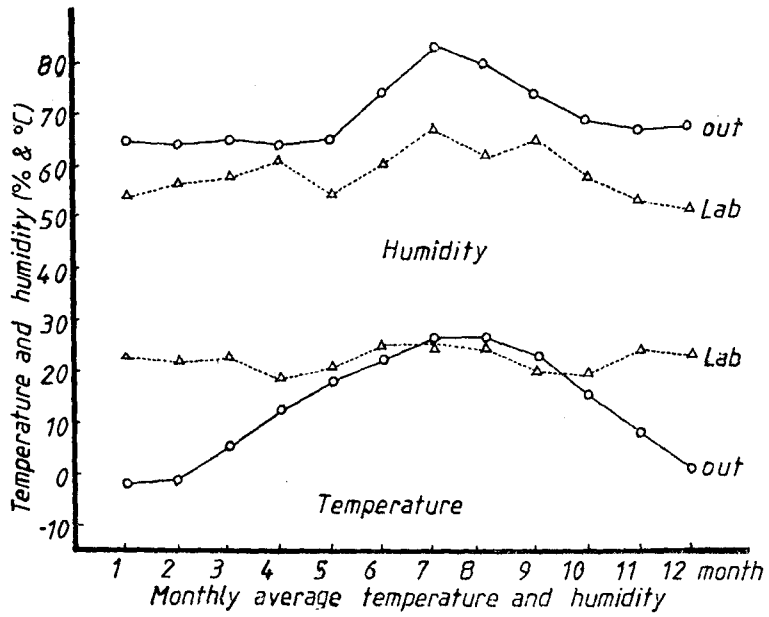


Fig. 1.

expressed as full width at half maximum (FWHM) in millimeters.

The other method, two adjacent parallel line sources spaced just one FWHM apart are imaged as a barely distinguishable double line.

Therefore, the actual separation of the source is equal to one FWHM. This method is based on visual inspection. Recently, bar phantom and orthogonal hole have been proposed for qualitative measurements of resolution.

Uniformity

Uniformity refer to the abilty of an imaging instrument to reproduce with fidelity an image of a uniformly distributed radioactive source.

Non-uniformity appear to depend on spatial distortion, variations in the energy window and imbalanced photomultiplier.

Non-uniformity showed:

1. increased false positive readings
2. increased a simulated cold lession
3. decreased ability to distinguish normal.

Artifacts manifesting diameter cold spot on intrinsic flood scintiphotos suggest that the detector may need re-alignment (See figure 2).

In addition, intrinsic flood field uniformity shall be expressed as integral and differential uniformity.

Procedure of intrinsic flood field uniformity

The source should be placd below the detector because of the damage of detector's crystal from falling source.

1. Remove collimator and mount the resolution pattern support plate.
2. Place a point source (200 to 300 uCi) of ^{99m}Tc at 1.5 meter from the face of the detector.
3. Peak the instrument for ^{99m}Tc, 20% window setting.
4. Accumulate a 2,000 K counts for a field flood image and record the data.
5. Assess image for uniformity.

Integral non-uniformity

Maxium and minimum deviation

$$U+=\frac{Max-m}{m}\times 100\% \quad U-=\frac{Min-m}{m}\times 100\%$$

Differential non-uniformity

Maximum difference between two adjacent pixels as % of greater.

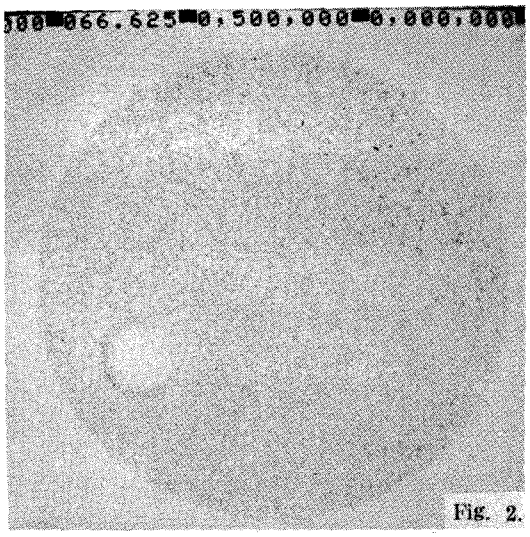
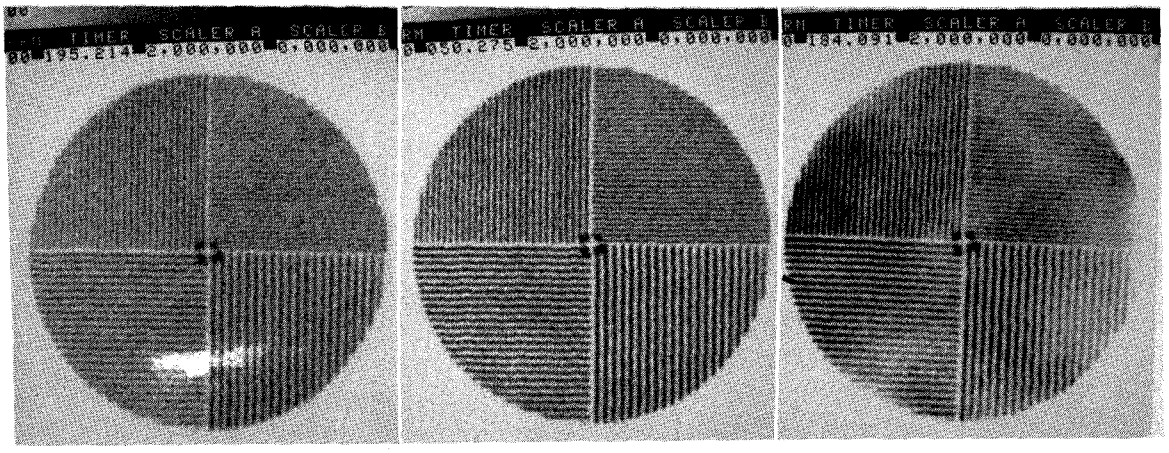


Fig. 2.

Percent window 20%.



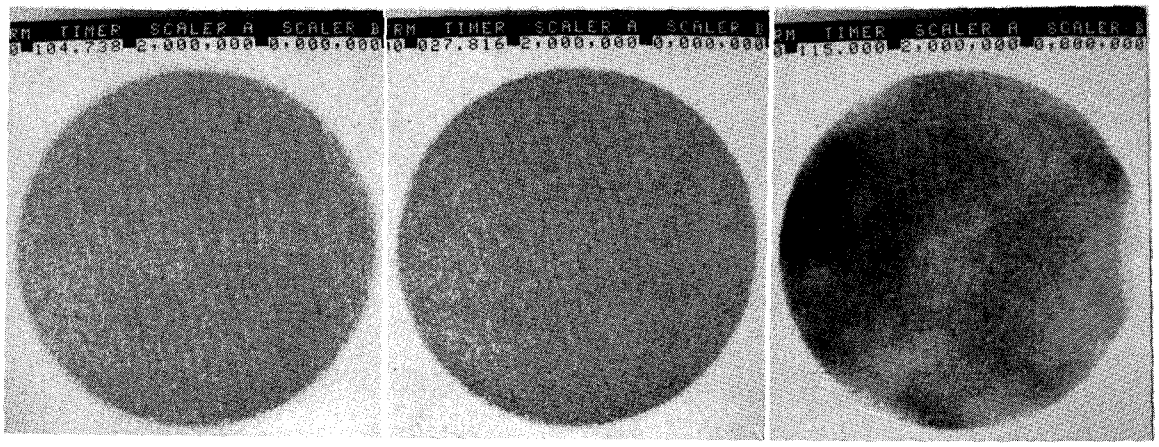
25% of Peak width Below Photopeak.

Symmetry window

Fig. 3.

25% of Peak width Above Photopeak.

Percent window 20%



25% of Peak width Below Photopeak

Symmetry window.

Fig. 4.

25% of Peak width Above Photopeak.

$$U_D = \frac{\text{High-low}}{\text{High}} \times 100\%$$

Spatial distortion or Spatial linearity

Spatial distortion refer to the ability of an imaging instrument to reproduce array of linear source of radioactivity that conserves all the spatial and geometric relationships of array.

Line sources, lead-bar phantoms or orthogonal hole test patterns (OHP) are usually used to determine deviation of the the image from the straight line.

Procedure of spatial distortion

1. With collimator on, and mount the resolution pattern support plate or invert detector and place a bar phantom.
2. Place a point source (2 to 3 mCi) of ^{99m}Tc at 1.5 meter from the face of the detector or place a field flood phantom on top of bar phantom.
3. Set a 20% window and peak the instrument for ^{99m}Tc.
4. Take a 2,000 K counts image
5. Assess image for spatial distortion.

Intrinsic efficiency check or sensitivity

Intrinsic efficiency checks should be taken to verify the counting efficiency of system. These checks determine the maximum count rate that system will accept. A significant change in this maximum rate from previous checks indicates a possible malfunction in the system.

Procedure of intrinsic efficiency

1. Remove collimator
2. Place 200 to 300 uCi of ^{99m}Tc at 1.5 meter from the face of detector.
3. Peak the instrument for ^{99m}Tc.
4. Accumulate the 2,000 K counts and record time
5. Calculate efficiency:

$$\frac{2,000,000}{\text{sec} \times \text{mCi}} = \frac{\text{counts/sec}}{\text{mCi of } ^{99m}\text{TC}}$$

Intrinsic energy resolution

Intrinsic energy resolution characterizes its ability to accurately identify the photopeak events. This parameter determines its ability to distinguish between primary gamma events and scattered events.

This test is intrinsic and done without a collimator.

Flow chart for scintillation camera operation

1. Preparation
   A. Attach proper collimator
   B. Position flood source on collimator face
   C. Set window range, preset count

↓

2. Photopeak adjustment
   A. Center photopeak in analyzer window
   B. Record date and photopeak setting

↓

3. Flood field image
   A. Accumulate 2,000 K-count image
   B. Record date, CRT intensity and elapsed time of count

↓

4. Spatial distortion-resolving power check
   A. Position bar phantom on collimator face and flood source on top of bar phantom
   B. Accumulate 2,000K-count image
   C. Record date, elapsed time of count and CRT intensity

↓

Keep date in quality control log book

↓

Proceed with clinical studies

Procedure of intrinsic energy resolution

1. Remove collimator
2. Place 200 to 300 uCi of ^{99m}Tc at more than I meter from the face of detector.
3. Accumulate the 1,000 K counts.
4. From curve, determine FWHM
5. Calculate % resolution:

$$\%\text{resolution} = \frac{\text{FWHM}}{140} \times 100$$

Photopeak calibration

Proper pulse height analyzer window adjust is very important for high quality imaging. A window with the lower level set to exclued scatter and upper level set symmetrically on the photopeak is most desirable (See figure 3, 4).

The best time for checking photopeak is while preparing for taking flood field imaging at least

once a day and whenever a different isotope is used.

Quality control of gamma camera for routine testing

Routine operation

1. Monitor displays should be off if not used.
2. A collimator should be attached at all times.
3. Detector should be faced down when not in use.
4. Avoid rapid changes in environmental temperature.
5. Avoid radioactive contamination of the collimators, detector and housing.

Commercial availability of quality control apparatus

1. PLES: Parallel line equal spacing bar phantom
2. OHTP: orthogonal hole test pattern
3. BRH test pattern: Orthogonal hole graded spacing test pattern
4. 90° bar quadrant phantom
5. Hine-Duley phantom

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