NEMA NU 1-2023

Performance Measurements of Gamma Cameras

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Reason for Changes

NEMA NU 1 was developed by the Molecular Imaging Section of the Medical Imaging & Technology Alliance (MITA) of the National Electrical Manufacturers Association (NEMA). Regulations regarding the maintenance of standards by NEMA require that standards be reviewed and, if necessary, updated every five years. Section approval of a standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time of approval, the NEMA NU 1 task force was composed of the following members:

NEMA NU 1 Task Force

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In the preparation of NEMA NU 1, input of users and other interested parties has been sought and evaluated. Inquiries, comments, and proposed recommended revisions should be submitted to the relevant MITA product section at the following address:

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Changes to the Standard

The categorization of tests by section as either “Primary” or “Secondary” tests of system performance remains absent in this revision (consistent with the previous versions). The relative importance of individual tests in the characterization of gamma camera systems is left to the manufacturer and user community to determine. The use of “appropriate clinical mode” is also retained, which might affect energy windows and variable count rate operation with respect to the 2001 standard.

As originally scripted, the NEMA NU 1 standard was intended to apply to standard gamma cameras that utilize large-area-crystal detectors with multi-channel collimators. Standard gamma cameras were developed to deliver planar images from a parallel or non-parallel projection.

The NEMA NU 1 task force version recognizes the emergence of clinically deployed novel SPECT systems using discrete pixel detectors, such as pixelated NaI(Tl) and CsI(Tl) detectors, and direct conversion detectors, such as CdTe and CdZnTe (CZT) detectors, as well as image formation using other

than multi-channel collimators. Many of the tests within the previous NEMA NU 1 standard define setup or imaging conditions that may not be relevant to describing the delivered quality or performance of non-standard SPECT systems.

Notes regarding the applicability of each test procedure to discrete pixel detectors that were placed near the beginning of each test in the previous versions are retained in this version.

Standard gamma cameras were designed using photomultiplier tubes (PMT) optics. The prescribed image setup and processing steps for uniformity were chosen to preserve spatial variations with a scale length of a PMT and may not be appropriate for SPECT systems that employ non-standard detection methods. In the 2018 version, we introduced suggestions in order to better adapt the previous procedure to non-standard detection methods. In the 2023 version, we clarified language around the execution of the tests and improved the efficiency. We recognize that the expansion of tests can be time-consuming and we attempted to streamline as much as possible, while maintaining the fundamental nature of the tests.

The prescribed image evaluation steps for uniformity were chosen to describe the standard gamma camera design and may not be appropriate for novel SPECT systems that employ advanced reconstruction techniques and algorithms and for which a large-area uniform projection image is not expected.

The prescribed image evaluation steps for reconstructed resolution, which utilize filtered back-projection, were chosen as appropriate to the standard gamma camera design. This technique may not be appropriate for novel SPECT systems that employ advanced reconstruction algorithms and where filtered back-projection is not the preferred or appropriate reconstruction technique.

Standard gamma cameras deliver a relatively low count rate per unit detector area that limits the total counts and statistical significance in realistic acquisition scenarios. The prescribed image setup and processing steps in NEMA NU 1 were often chosen to minimize the impact of low image count density while preserving relevant performance metrics.

Changes to Definitions and Test Procedures

- Section 4.2.4.2: New figure illustrating point sources in 3D used for Full Width at Half Maximum (FWHM) calculation.
- Section 6.2.2: Added clarification for radionuclide preparation recipe.
- Section 6.2.3: Clarity of language around the preparation of the phantom, along with recommended methods.
- Section 6.3.5: Additional details on phantom. The figures were updated to accurately reflect the phantom cross-section. Figure 6-3 removed.
- Section 7.2.1: Clarification of language surrounding the Test Conditions.

CAUTION—Persons using this measurement standard must be in compliance with all applicable federal and state regulations (Ref: NRC Regulatory Guide 10.8, *Guide for the Preparation of Applications for Medical Programs*) for the use, handling, and possession of radioactive material.

The purpose of NEMA NU 1 is to provide uniform criteria for the measurement and reporting of gamma camera performance parameters by which a manufacturer may specify his device and, when doing so, reference "NEMA NU 1-2023 *Performance Measurements of Gamma Cameras*."

NEMA NU 1 does not establish minimum performance levels.

Specific measurement equipment, as set forth herein, is required in order to accomplish the purpose of this standard: the uniform and accurate specification of performance characteristics. Without this equipment, the measurements performed would be limited, inaccurate, non-quantitative, or too time-consuming.

Section 1
Scope

This NEMA technical publication establishes definitions, quantitative measurements of performance characteristics, and reporting techniques for the specification of the following gamma camera parameters:

a. Intrinsic Spatial Resolution
b. Intrinsic Spatial Linearity
c. Intrinsic Energy Resolution
d. Intrinsic Flood Field Uniformity
e. Multiple Window Spatial Registration
f. Intrinsic Count Rate Performance in Air
g. Intrinsic Spatial Resolution at 75 kcps
h. Intrinsic Flood Field Uniformity at 75 kcps
i. System Spatial Resolution Without Scatter
j. System Spatial Resolution with Scatter
k. System Planar Sensitivity and Collimator Penetration and Scatter
l. Detector Shielding
m. System Count Rate Performance with Scatter
n. System Alignment
o. SPECT Reconstructed Spatial Resolution Without Scatter
p. SPECT Reconstructed Spatial Resolution with Scatter
q. System Volume Sensitivity
r. Detector-Detector Sensitivity Variation
s. Whole-Body System Spatial Resolution Without Scatter
t. Tomographic Contrast and Absolute Quantification Accuracy
u. SPECT/CT Co-Registration Accuracy

The following types of medical radionuclide imaging instruments are included in this standard:

a. Single detector, single crystal planar gamma cameras
b. Single detector, single crystal tomographic gamma cameras
c. Multiple detector planar and tomographic gamma cameras
d. Whole-body gamma camera devices
e. Discrete pixel detector planar and tomographic gamma cameras

The following types of medical radionuclide imaging instruments are <u>not</u> included in this standard:

a. Coincidence imaging gamma cameras or systems (these are covered by NEMA NU 2-2018 *Performance Measurements of Positron Emission Tomographs*).
b. All medical radionuclide imaging devices not included above.

1.1 Definitions

absolute linearity: The maximum distortion or displacement of the X and Y image location with respect to the actual source location over the gamma camera field of view (FOV).

appropriate clinical mode: All tests shall be performed in a clinically consistent mode of operation with appropriate energy, linearity and uniformity corrections, pixel size, and photopeak window being employed. The count rate mode employed during tests shall be the same mode as used clinically under the same count rate conditions.

center of rotation (COR): The pixel in a SPECT projection image at which the mechanical rotation center (axis of rotation AOR) is imaged.