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Performance Measurements of Gamma Cameras

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FOREWORD

Reason for Changes

NEMA NU 1-2012 (hereinafter referred to as 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:

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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 or 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 remain absent in this revision (consistent with the 2007 version). The relative importance of individual tests to the characterization of Gamma camera systems is left to the manufacturers 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. The 2001 and 2007 versions acknowledged the emergence of discrete pixel detectors, such as pixelated NaI(Tl) and CsI(Tl) detectors, and direct conversion detectors, such as CdTe and CdZnTe (CZT) detectors. Notes regarding the applicability of each test procedure to discrete pixel detectors that were placed near the beginning of each test in the 2007 version are retained in this version.

The NEMA NU 1 task force recognizes, however, that novel SPECT systems are now being deployed that might be characterized by different design constraints or performance capabilities. As a result, many of the tests within the NEMA NU 1 standard define setup or imaging conditions that may not be relevant to describing the delivered quality or performance of new or novel SPECT systems now on the market.

Standard Gamma cameras were developed to deliver large-area planar images with high spatial fidelity to a parallel projection view. The prescribed image evaluation steps for uniformity were chosen to describe this type of 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.

Similarly, the prescribed image evaluation steps for reconstructed resolution, which dictate 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.

Standard Gamma cameras were designed using 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 alternate detection methods.

The NEMA NU1 task force also recognizes that there would be an advantage to reform the standard metrics in order to adequately evaluate the performance of new, non-standard SPECT systems. As of this revision, however, there is no consensus on how to best adapt the NEMA NU 1 standard in order to best characterize novel SPECT system performance.

Changes to definitions and test procedures

Intrinsic Count Rate Performance in Air (Section 2.6) was amended to include the details for an alternate method (Copper Plates Method). This method was included by reference in the 2007 version. The traceability of this method to the Decaying Source Method must be demonstrated by the manufacturer if the Copper Plates Method is to be used.

Intrinsic Count Rate Performance and System Count Rate Performance were amended to accommodate detectors with very high count rate performance (i.e., low dead-time losses, typical of pixelated detectors). Instead of reporting observed count rate at maximum and 20% loss, alternatively, the maximum count rate tested and percentage count loss at that rate can be reported.

Intrinsic Energy Resolution (Section 2.3) was amended to allow an isotope other than Co-57 to determine the keV per channel calibration factor.

Intrinsic Flood Field Uniformity (Section 2.4) was amended for clarity and to include measurements of defective pixels and defective pixel clusters for discrete pixel detectors. The term “defective pixel” was added to the list of defined terms.

Edits for correctness or clarity, of either the test phantom or the source strength, were made to the 2007 version: Sections 2.5 (Multiple Window Spatial Registration), 3.3 (System Planar Sensitivity and Collimator Penetration and Scatter), 4.1 (System Alignment) and 4.2 (SPECT Reconstructed Spatial Resolution without Scatter). In particular, the diameter of the test phantom for System Planar Sensitivity and Collimator Penetration and Scatter is now allowed to be specified by the manufacturer not only for small FOV cameras but also for cameras with focusing collimators.

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 Standards Publication NU 1-2012, 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 Standards 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

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 Gamma cameras

The following types of medical radionuclide imaging instruments are not included in this standard:

a) Coincidence imaging Gamma cameras or systems (these are covered by NEMA NU 2-2012, “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.