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Radionuclide imaging devices – Characteristics and test conditions –

Part 2: Single photon emission computed tomographs

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

Part 2: Single photon emission computed tomographs

FOREWORD

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International Standard IEC 61675-2 has been prepared by subcommittee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry, of IEC technical committee 62: Electrical equipment in medical practice.

This consolidated version of IEC 61675-2 consists of the first edition (1998) [documents 62C/206/FDIS and 62C/215/RVD] and its amendment 1 (2004) [documents 62C/378/FDIS and 62C/379/RVD].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

In this standard, the following print types are used:

– TERMS DEFINED IN CLAUSE 2 OF THIS STANDARD OR LISTED IN ANNEX A: SMALL CAPITALS.

The requirements are followed by specifications for the relevant tests.

Annex A is for information only.

A bilingual version of this standard may be issued at a later date.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

Part 2: Single photon emission computed tomographs

1 General

1.1 Scope and object

This part of IEC 61675 specifies terminology and test methods for describing the characteristics of Anger type rotational GAMMA CAMERA SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHS (SPECT), equipped with parallel hole collimators. As these systems are based on Anger type GAMMA CAMERAS this part of IEC 61675 shall be used in conjunction with IEC 60789. These systems consist of a gantry system, single or multiple DETECTOR HEADS and a computer system together with acquisition, recording, and display devices.

This part of IEC 61675-2 also specifies test conditions for declaring the characteristics of single photon computer tomographs operated in coincidence mode as well as in single photon mode.

The test methods specified for coincidence mode are based on the test methods for dedicated PET tomographs as described in IEC 61675-1 to reflect as well as possible the clinical use of coincidence detection. Tests have been modified to reflect the limited sensitivity and COUNT RATE CHARACTERISTICS of the single photon computer tomographs operated in coincidence detection mode only when needed.

The test methods specified in this part of IEC 61675 have been selected to reflect as much as possible the clinical use of Anger type rotational GAMMA CAMERA SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHS (SPECT). It is intended that the test methods be carried out by manufacturers thereby enabling them to describe the characteristics of SPECT systems on a common basis.

No test has been specified to characterize the uniformity of reconstructed images because all methods known so far will mostly reflect the noise of the image.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60788:1984, *Medical radiology – Terminology*

IEC 60789:1992, *Characteristics and test conditions of radionuclide imaging devices – Anger type gamma cameras*

IEC 61675-1, — *Radionuclide imaging devices – Characteristics and test conditions – Part 1: Positron emission tomographs*

2 Terminology and definitions

For the purposes of this part of IEC 61675 the definitions given in IEC 60788, IEC 60789 and IEC 61675-1 (some of which are repeated in this clause), and the following definitions apply.

Defined terms are printed in small capital letters.

2.1
SYSTEM AXIS
Axis of symmetry characterized by geometrical and physical properties of the arrangement of the system

NOTE The SYSTEM AXIS of a GAMMA CAMERA with rotating detectors is the axis of rotation.

2.1.1
COORDINATE SYSTEMS

2.1.2
FIXED COORDINATE SYSTEM
Cartesian system with axes X, Y, and Z, Z being the SYSTEM AXIS. The origin of the FIXED COORDINATE SYSTEM is defined by the centre of the TOMOGRAPHIC VOLUME (see Figure 1). The SYSTEM AXIS is orthogonal to all TRANSVERSE SLICES.

2.1.3
COORDINATE SYSTEM OF PROJECTION
Cartesian system of the IMAGE MATRIX of each two-dimensional projection with axes X_p and Y_p (defined by the axes of the IMAGE MATRIX). The Y_p axis and the projection of the system axis onto the detector front face have to be in parallel. The origin of the COORDINATE SYSTEM OF PROJECTION is the centre of the IMAGE MATRIX (see Figure 1).

2.1.4
CENTRE OF ROTATION (COR)
Origin of that COORDINATE SYSTEM, which describes the PROJECTIONS of a TRANSVERSE SLICE with respect to their orientation in space

NOTE The CENTRE OF ROTATION of a TRANSVERSE SLICE is given by the intersection of the SYSTEM AXIS with the mid-plane of the corresponding OBJECT SLICE.

2.1.5
OFFSET
Deviation of the position of the PROJECTION of the COR (X'_p) from $X_p = 0$. (See Figure 1)

2.2
TOMOGRAPHY (see annex A)

2.2.1
TRANSVERSE TOMOGRAPHY
In TRANSVERSE TOMOGRAPHY the three-dimensional object is sliced by physical methods, e.g. collimation, into a stack of OBJECT SLICES, which are considered as being two-dimensional and independent from each other. The transverse image planes are perpendicular to the SYSTEM AXIS.

2.2.2
EMISSION COMPUTED TOMOGRAPHY (ECT)
Imaging method for the representation of the spatial distribution of incorporated RADIONUCLIDES in selected two-dimensional SLICES through the object

2.2.2.1
PROJECTION
Transformation of a three-dimensional object into its two-dimensional image or of a two-dimensional object into its one-dimensional image, by integrating the physical property which determines the image along the direction of the PROJECTION BEAM

NOTE This process is mathematically described by line integrals in the direction of projection and called the Radon-transform.

2.2.2.2
PROJECTION BEAM
Determines the smallest possible volume in which the physical property which determines the image is integrated during the measurement process. Its shape is limited by the SPATIAL RESOLUTION in all three dimensions.

NOTE In SPECT the PROJECTION BEAM usually has the shape of a long thin diverging cone.

2.2.2.3
PROJECTION ANGLE
Angle at which the PROJECTION is measured or acquired

NOTE For illustration see Figure 1.

2.2.2.4
SINOGRAM
Two-dimensional display of all one-dimensional PROJECTIONS of an object slice, as a function of the PROJECTION ANGLE

The PROJECTION ANGLE is displayed on the ordinate. The linear PROJECTION coordinate is displayed on the abscissa.

2.2.2.5
OBJECT SLICE
A slice in the object. The physical property of this slice that determines the measured information is displayed in the tomographic image.

2.2.2.6
IMAGE PLANE
A plane assigned to a plane in the OBJECT SLICE

NOTE Usually the IMAGE PLANE is the mid-plane of the corresponding OBJECT SLICE.

2.2.2.7
TOMOGRAPHIC VOLUME
Ensemble of all volume elements which contribute to the measured PROJECTIONS for all PROJECTION ANGLES

NOTE For a rotating GAMMA CAMERA with a circular field of view the TOMOGRAPHIC VOLUME is a sphere provided that the radius of rotation is larger than the radius of the field of view. For a rectangular field of view, the TOMOGRAPHIC VOLUME is a cylinder.

2.2.2.7.1
TRANSVERSE FIELD OF VIEW
Dimensions of a slice through the TOMOGRAPHIC VOLUME, perpendicular to the SYSTEM AXIS. For a circular TRANSVERSE FIELD OF VIEW it is described by its diameter.

NOTE For non-cylindrical TOMOGRAPHIC VOLUMES the TRANSVERSE FIELD OF VIEW may depend on the axial position of the slice.

2.2.2.7.2
AXIAL FIELD OF VIEW
Dimensions of a slice through the TOMOGRAPHIC VOLUME parallel to and including the SYSTEM AXIS. In practice it is specified only by its axial dimension given by the distance between the centres of the outermost defined IMAGE PLANES plus the average of the measured AXIAL SLICE WIDTH measured as EQUIVALENT WIDTH (EW).

2.2.2.7.3
TOTAL FIELD OF VIEW
Dimensions (three-dimensional) of the TOMOGRAPHIC VOLUME

2.3
IMAGE MATRIX
Arrangement of MATRIX ELEMENTS in a preferentially cartesian coordinate system

2.3.1
MATRIX ELEMENT
Smallest unit of an IMAGE MATRIX, which is assigned in location and size to a certain volume element of the object (VOXEL)

2.3.1.1
PIXEL
MATRIX ELEMENT in a two-dimensional IMAGE MATRIX

2.3.1.2
TRIXEL
MATRIX ELEMENT in a three-dimensional IMAGE MATRIX

2.3.2
VOXEL
Volume element in the object which is assigned to a MATRIX ELEMENT in the IMAGE MATRIX (two-dimensional or three-dimensional). The dimensions of the VOXEL are determined by the dimensions of the corresponding MATRIX ELEMENT via the appropriate scale factors and by the system's SPATIAL RESOLUTION in all three dimensions.

2.4
POINT SPREAD FUNCTION (PSF)
Scintigraphic image of a POINT SOURCE

2.4.1
PHYSICAL POINT SPREAD FUNCTION
For tomographs, a two-dimensional POINT SPREAD FUNCTION in planes perpendicular to the PROJECTION BEAM at specified distances from the detector

NOTE The PHYSICAL POINT SPREAD FUNCTION characterizes the purely physical imaging performance of the tomographic device independent from, e.g. sampling, image reconstruction and image processing, but dependent on the COLLIMATOR. A PROJECTION BEAM is characterized by the entirety of all PHYSICAL POINT SPREAD FUNCTIONS as a function of distance along its axis.

2.4.2
AXIAL POINT SPREAD FUNCTION
Profile passing through the peak of the PHYSICAL POINT SPREAD FUNCTION in a plane parallel to the SYSTEM AXIS

2.4.3
TRANSVERSE POINT SPREAD FUNCTION
Reconstructed two-dimensional POINT SPREAD FUNCTION in a tomographic IMAGE PLANE

NOTE In TOMOGRAPHY, the TRANSVERSE POINT SPREAD FUNCTION can also be obtained from a line source located parallel to the SYSTEM AXIS.

2.5
SPATIAL RESOLUTION
Ability to concentrate the count density distribution in the image of a POINT SOURCE to a point

2.5.1
TRANSVERSE RESOLUTION
SPATIAL RESOLUTION in a reconstructed plane perpendicular to the SYSTEM AXIS

2.5.1.1
RADIAL RESOLUTION
TRANSVERSE RESOLUTION along a line passing through the position of the source and the SYSTEM AXIS

2.5.1.2
TANGENTIAL RESOLUTION
TRANSVERSE RESOLUTION in the direction orthogonal to the direction of RADIAL RESOLUTION

2.5.2
AXIAL RESOLUTION
For tomographs with sufficiently fine axial sampling fulfilling the sampling theorem, SPATIAL RESOLUTION along a line parallel to the SYSTEM AXIS

2.5.3
EQUIVALENT WIDTH (EW)
Width of that rectangle having the same area and the same height as the response function, e.g. the POINT SPREAD FUNCTION

2.6 Tomographic sensitivity

2.6.1
SLICE SENSITIVITY
Ratio of COUNT RATE as measured on the SINOGRAM to the ACTIVITY concentration in the phantom

NOTE In SPECT the measured counts are not numerically corrected for scatter by subtracting the SCATTER FRACTION.

2.6.2
VOLUME SENSITIVITY
Sum of the individual SLICE SENSITIVITIES

2.6.3
NORMALIZED VOLUME SENSITIVITY
VOLUME SENSITIVITY divided by the AXIAL FIELD OF VIEW of the tomograph or the phantom length, whichever is the smaller

2.7
SCATTER FRACTION (SF)
Ratio between the number of scattered photons and the sum of scattered plus unscattered photons for a given experimental set-up

2.8
SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)
EMISSION COMPUTED TOMOGRAPHY utilizing single photon detection of gamma-ray emitting RADIONUCLIDES

2.8.1
DETECTOR POSITIONING TIME
Fraction of the total time spent on an acquisition which is not used in collecting data

2.8.2
DETECTOR HEAD TILT
Deviation of the COLLIMATOR axis from orthogonality with the SYSTEM AXIS

2.8.3
RADIUS OF ROTATION
Distance between the SYSTEM AXIS and the COLLIMATOR front face

2.9
RADIOACTIVE SOURCE
See rm-20-02 of IEC 60788

2.9.1
POINT SOURCE
RADIOACTIVE SOURCE approximating a δ-function in all three dimensions

2.9.2
LINE SOURCE
Straight RADIOACTIVE SOURCE approximating a δ-function in two dimensions and being constant (uniform) in the third dimension

2.10
POSITRON EMISSION TOMOGRAPHY
PET
emission computed tomography utilizing the annihilation radiation of positron emitting radionuclides by coincidence detection

[IEC 61675-1, definition 2.1.3]

2.10.1
POSITRON EMISSION TOMOGRAPH
tomographic device, which detects the annihilation radiation of positron emitting radionuclides by coincidence detection

[IEC 61675-1, definition 2.1.3.1]

2.10.2
ANNIHILATION RADIATION
IONIZING RADIATION that is produced when a particle and its antiparticle interact and cease to exist

[IEC 61675-1, definition 2.1.3.2]

2.10.3
LINE OF RESPONSE
LOR
axis of the PROJECTION BEAM

NOTE In PET, it is the line connecting the centres of two opposing detector elements operated in coincidence

[IEC 61675-1, definition 2.1.3.5]

2.10.4
TOTAL COINCIDENCES
sum of all coincidences detected

[IEC 61675-1, definition 2.1.3.6]

2.10.4.1
TRUE COINCIDENCE
result of COINCIDENCE DETECTION of two gamma events originating from the same positron annihilation

[IEC 61675-1, definition 2.1.3.6.1]

2.10.4.2
SCATTERED TRUE COINCIDENCE
TRUE COINCIDENCE where at least one participating PHOTON was scattered before the COINCIDENCE DETECTION

[IEC 61675-1, definition 2.1.3.6.2]

2.10.4.3
UNSCATTERED TRUE COINCIDENCES
difference between true coincidences and scattered true coincidences

[IEC 61675-1, definition 2.1.3.6.3]

2.10.4.4
RANDOM COINCIDENCE
result of COINCIDENCE DETECTION in which both participating PHOTONS emerge from different positron annihilations

[IEC 61675-1, definition 2.1.3.6.4]

2.10.5
SINGLES RATE
COUNT RATE measured without COINCIDENCE DETECTION, but with energy discrimination

[IEC 61675-1, definition 2.1.3.7]

2.10.6
TWO-DIMENSIONAL RECONSTRUCTION
in TWO-DIMENSIONAL RECONSTRUCTION, the data are rebinned prior to reconstruction into sinograms, which are the PROJECTION data of transverse slices, which are considered being independent of each other and being perpendicular to the SYSTEM AXIS. So, each event will be assigned, in the axial direction, to that transverse slice passing the midpoint of the corresponding LINE OF RESPONSE. Any deviation from perpendicular to the SYSTEM AXIS is neglected. The data are then reconstructed by two-dimensional methods, i.e. each slice is reconstructed from its associated sinogram, independent of the rest of the data set

NOTE This is the STANDARD method of reconstruction for POSITRON EMISSION TOMOGRAPHS using small axial acceptance angles, i.e. utilizing septa. For POSITRON EMISSION TOMOGRAPHS using large axial acceptance angles, i.e. without septa, this method is also called “single slice rebinning”.

[IEC 61675-1, definition 2.1.4.1]

2.10.7
THREE-DIMENSIONAL RECONSTRUCTION
in THREE-DIMENSIONAL RECONSTRUCTION, the LINES OF RESPONSE are not restricted to being perpendicular to the SYSTEM AXIS. So, a LINE OF RESPONSE may pass several transverse slices. Consequently, transverse slices cannot be reconstructed independent of each other. Each slice has to be reconstructed utilizing the full three-dimensional data set

[IEC 61675-1, definition 2.1.4.2]

2.11
RECOVERY COEFFICIENT
measured (image) ACTIVITY concentration of an active volume divided by the true ACTIVITY concentration of that volume, neglecting ACTIVITY CALIBRATION FACTORS

NOTE For the actual measurement, the true ACTIVITY concentration is replaced by the measured ACTIVITY concentration in a large volume.

[IEC 61675-1, definition 2.5]

2.12
NORMALIZED SLICE SENSITIVITY
slice sensitivity divided by the axial slice width (EW) for that slice

[IEC 61675-1, definition 2.6.1.1]

2.12.1
COUNT RATE CHARACTERISTIC
function giving the relationship between observed COUNT RATE and TRUE COUNT RATE

[IEC 60788, definition rm-34-21]

2.12.2
COUNT LOSS
difference between measured COUNT RATE and TRUE COUNT RATE, which is caused by the finite RESOLVING TIME of the instrument

[IEC 61675-1, definition 2.7.1]

2.12.3
ADDRESS PILE UP
<GAMMA CAMERA> false address calculation of an artificial event which passes the ENERGY WINDOW, but is formed from two or more events by the PILE UP EFFECT

[IEC 61675-1, definition 2.7.4, modified]

2.12.4
RADIOACTIVE SOURCE
quantity of radioactive material having both an ACTIVITY and a specific ACTIVITY above specific levels

[IEC 60788, definition rm-20-02]

3 Test methods

All measurements shall be performed with the PULSE AMPLITUDE ANALYZER WINDOW as specified in Table 1 of IEC 60789. Additional measurements with other settings as specified by the manufacturer can be performed. Before the measurements are performed, the tomographic system shall be adjusted by the procedure normally used by the manufacturer for an installed unit and shall not be adjusted specially for the measurement of specific parameters. If any test cannot be carried out exactly as specified in the standard, the reason for the deviation and the exact conditions under which the test was performed shall be stated clearly.