INTERNATIONAL STANDARD

IEC 61675-2

1998

AMENDMENT 1
2004-12

Amendment 1

Radionuclide imaging devices – Characteristics and test conditions –

Part 2: Single photon emission computed tomographs

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FOREWORD

This amendment has been prepared by subcommittee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry, of IEC technical committee 62: Electrical equipment in medical practice.

The text of this amendment is based on the following documents:

FDIS	Report on voting
62C/378/FDIS	62C/379/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication 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- withdrawn,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.

Introduction to this amendment

Since this International Standard was first published in 1998, further developments of single photon computer tomographs allow some of the tomographs to be operated in coincidence detection mode as well. To comply with this trend, this amendment describes test conditions in concordance with the test methods established for dedicated PET systems.

Page 2

CONTENTS

Add the title of new subclause 3.7 as follows:

Add the titles of new Figures 8 to 13 as follows:

Page 4

1.1 Scope and object

Add, after the first paragraph, the following new text:

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.

2 Terminology and definitions

Replace the first sentence by the following:

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.

Add, at the end of this clause, on page 9, the following new definitions:

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]

Page 9

3 Test methods

Add, on page 15, the following subclauses:

3.7 Test methods for single photon computer tomographs operated in coincidence detection mode

For all measurements, the tomograph shall be set up according to its normal mode of operation, i.e. it shall not be adjusted specially for the measurement of specific parameters. If the tomograph is specified to operate in different modes influencing the performance parameters, for example with different energy windows, different axial acceptance angles, with and without septa, with TWO-DIMENSIONAL RECONSTRUCTION and THREE-DIMENSIONAL RECONSTRUCTION, the test results shall be reported in addition. The tomographic configuration (e.g. energy thresholds, axial acceptance angle, reconstruction algorithm, radius of rotation, configuration of heads) shall be chosen according to the manufacturer's recommendation and clearly stated.

If any test cannot be carried out exactly as specified in this standard, the reason for the deviation and the exact conditions under which the test was performed shall be stated clearly.

The test phantoms shall be centred within the tomograph's AXIAL FIELD OF VIEW, if not specified otherwise.

Single photon computer tomographs operated in coincidence mode must also conform to all planar and SPECT tests (e.g. 3.1 to 3.6).

NOTE For tomographs with an AXIAL FIELD OF VIEW greater than 16,5 cm, this centring will only produce performance estimates for the central part. However, if the phantoms were displaced axially in order to cover the entire AXIAL FIELD OF VIEW, false results could be obtained for the central planes, if the axial acceptance angle of the detectors was not fully covered with ACTIVITY.

3.7.1 SPATIAL RESOLUTION

3.7.1.1 General

SPATIAL RESOLUTION measurements are used to estimate the ability of a tomograph to reproduce the spatial distribution of a tracer in an object in a reconstructed image. The measurement is performed by imaging POINT (or LINE) SOURCES in air and reconstructing images using a sharp reconstruction filter. Although this does not represent the condition of imaging a patient, where tissue scatter is present and limited statistics require the use of a smooth reconstruction filter, the measured SPATIAL RESOLUTION provides a best-case comparison between tomographs, indicating the highest achievable performance.

3.7.1.2 Purpose

The purpose of this measurement is to characterize the ability of the tomograph to recover small objects by characterizing the width of the reconstructed TRANSVERSE POINT SPREAD FUNCTIONS of radioactive POINT SOURCES or of extended LINE SOURCES placed perpendicular to the direction of measurement. The width of the spread function is measured by the FULL WIDTH AT HALF MAXIMUM (FWHM) and the EQUIVALENT WIDTH (EW).

To define how well objects can be reproduced in the axial direction, the AXIAL SLICE WIDTH (commonly referred to as the slice thickness) is used. It is measured with a POINT SOURCE, which is stepped through the tomograph's TRANSVERSE FIELD OF VIEW axially in small increments and is characterized by the EW and the FWHM of the AXIAL POINT SPREAD FUNCTION for each individual slice.

The AXIAL RESOLUTION is defined for tomographs with sufficiently fine axial sampling (volume detectors) and could be measured with a stationary POINT SOURCE. For these systems the AXIAL RESOLUTION (EW and FWHM) is equivalent to the AXIAL SLICE WIDTH. These systems (fulfilling the sampling theorem in the axial direction) are characterized by the fact that the AXIAL POINT SPREAD FUNCTION of a stationary POINT SOURCE would not vary if the position of the source were varied in the axial direction for half the axial sampling distance.

3.7.1.3 Method

3.7.1.3.1 General

For all systems, the SPATIAL RESOLUTION shall be measured in the transverse IMAGE PLANE in two directions (i.e. radially and tangentially). In addition, for those systems having sufficiently fine axial sampling, an AXIAL RESOLUTION also shall be measured.

The TRANSVERSE FIELD OF VIEW and the IMAGE MATRIX size determine the PIXEL size in the transverse IMAGE PLANE. In order to measure accurately the width of the spread function, its FWHM should span at least ten PIXELS. A typical imaging study of a brain, however, requires a 260 mm TRANSVERSE FIELD OF VIEW, which together with a 128 x 128 IMAGE MATRIX and 6 mm SPATIAL RESOLUTION, results in a FWHM of only three PIXELS. The width of the response may be incorrect if there are fewer than ten PIXELS in the FWHM. Therefore, if possible, the PIXEL size should be made close to one-tenth of the expected FWHM during reconstruction and should be indicated as ancillary data for the TRANSVERSE RESOLUTION measurement. For volume imaging systems, the TRIXEL size, in both the transverse and axial dimensions, should be made close to one-tenth the expected FWHM, and should be indicated as ancillary data for the SPATIAL RESOLUTION measurement. For all systems, the AXIAL SLICE WIDTH is measured by moving the source in fine steps to sample the response function adequately. For the AXIAL SLICE WIDTH measurement, the step size should be close to one-tenth the expected EW. It is assumed that a computer-controlled bed will be used for accurate positioning of the RADIOACTIVE SOURCE.

3.7.1.3.2 RADIONUCLIDE

The RADIONUCLIDE for the measurement shall be ^{18}F, with an ACTIVITY such that the percent COUNT LOSS is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

3.7.1.3.3 RADIOACTIVE SOURCE distribution

3.7.1.3.3.1 General

POINT SOURCES or LINE SOURCES, respectively, shall be used as described in 3.7.1.3.3.2 to 3.7.1.3.3.4.

3.7.1.3.3.2 TRANSVERSE RESOLUTION

Tomographs shall use LINE SOURCES, suspended in air to minimize scatter, for measurements of TRANSVERSE RESOLUTION. The sources shall be kept parallel to the long axis of the tomograph and shall be positioned radially at 100 mm intervals along Cartesian axes in a plane perpendicular to the long axis of the tomograph i.e. r = 10 mm, 100 mm, 200 mm ... up to the edge of the TRANSVERSE FIELD OF VIEW. The last position shall be not more than 20 mm from the edge and shall be stated. Each of these positions yields two measurements of TRANSVERSE RESOLUTION, which shall be distinguished by being in the radial or tangential direction.

NOTE The SPATIAL RESOLUTION at r = 0 mm may yield artificial values due to sampling, so this measurement is done at the position r = 10 mm.

3.7.1.3.3.3 AXIAL SLICE WIDTH

The AXIAL POINT SPREAD FUNCTION for POINT SOURCES suspended in air shall be measured for all systems. The POINT SOURCES shall be moved in fine increments along the axial direction over the length of the tomograph, at radial positions of *r* = 0 mm, 100 mm, ... in 100 mm steps up to the edge of the TRANSVERSE FIELD OF VIEW. The last position shall be not more than 20 mm from the edge and shall be stated. The source is stepped in the axial direction by one-tenth of the expected EW of the axial response function. For each radial position, the measured values shall be corrected for decay. This measurement does not apply to THREE-DIMENSIONAL RECONSTRUCTION.

3.7.1.3.3.4 AXIAL RESOLUTION

For systems having axial sampling at least three times smaller than the FWHM of the AXIAL POINT SPREAD FUNCTION the measurement of AXIAL RESOLUTION can be made with stationary POINT SOURCES. POINT SOURCES suspended in air are positioned at radial intervals of 100 mm, starting at the centre and extending to a distance which depends on the TRANSVERSE FIELD OF VIEW, as described in the measurement of AXIAL SLICE WIDTH (3.7.1.3.3.3). Each POINT SOURCE shall be imaged at axial intervals of ±80 mm, starting at the centre of the tomograph and extending to within 20 mm from the edge of the AXIAL FIELD OF VIEW.

3.7.1.3.4 Data collection

Data shall be collected for all sources in all of the positions specified above, either singly or in groups of multiple sources, to minimize the data acquisition time. At least 50 000 counts shall be acquired in each response function, as defined below.

3.7.1.3.5 Data processing

Reconstruction using a ramp filter with the cut-off at the Nyquist frequency of the PROJECTION data shall be employed for all SPATIAL RESOLUTION data.

3.7.1.4 Analysis

The RADIAL RESOLUTION and the TANGENTIAL RESOLUTION shall be determined by forming one-dimensional response functions, which result from taking profiles through the TRANSVERSE POINT SPREAD FUNCTION in radial and tangential directions, passing through the peak of the distribution.

The AXIAL RESOLUTION of the POINT SOURCE measurements is determined by forming one-dimensional response functions (AXIAL POINT SPREAD FUNCTIONS), which result from taking profiles through the volume image in the axial direction, passing through the peak of the distribution in the slice nearest the source.

The AXIAL SLICE WIDTH is determined by forming one-dimensional response functions (AXIAL POINT SPREAD FUNCTIONS), which result from summing the counts per slice collected for each slice at each axial location of each radial source location.

Each FWHM shall be determined by linear interpolation between adjacent PIXELS at half the maximum PIXEL value, which is the peak of the response function (see Figure 6). Values shall be converted to millimetre units by multiplication with the appropriate PIXEL size.

Each EQUIVALENT WIDTH (EW) shall be measured from the corresponding response function.

EW is calculated from the formula

$$EW = \sum_i \frac{C_i \times PW}{C_m}$$

where

ΣC_i is the sum of the counts in the profile between the limits defined by 1/20 cm on either side of the peak;

C_m is the maximum PIXEL value;

PW is the PIXEL width (or axial increment in the case of the AXIAL SLICE WIDTH) in millimetres (see Figure 7).

3.7.1.5 Report

RADIAL and TANGENTIAL RESOLUTIONS (FWHM and EW) for each radius, averaged over all slices, shall be calculated and reported as TRANSVERSE RESOLUTION values. AXIAL SLICE WIDTHS (EW and FWHM) for each radius, averaged over all slices for each type (e.g. odd, even) shall be reported. Transverse PIXEL dimensions and axial step size shall also be reported.

For systems where AXIAL RESOLUTION is to be measured, AXIAL RESOLUTION (FWHM and EW), averaged over all slices, shall be reported. For these systems, the axial PIXEL dimension in millimetres shall also be reported.

For systems utilizing THREE-DIMENSIONAL RECONSTRUCTION, RESOLUTION data as listed above shall not be averaged. Graphs of TRANSVERSE RESOLUTION and AXIAL RESOLUTION shall be reported, showing the RESOLUTION values (RADIAL RESOLUTION, TANGENTIAL RESOLUTION, and AXIAL RESOLUTION) for each radius as a function of slice number.

3.7.2 RECOVERY COEFFICIENT

3.7.2.1 General

The finite RESOLUTION of a tomograph leads to a spreading of image counts beyond the geometrical boundaries of the object. This effect becomes more important as the object size decreases. The RECOVERY COEFFICIENT provides an assessment of the ability of the tomograph to quantify the ACTIVITY concentration as a function of the object size.

3.7.2.2 Purpose

The objective of the following procedures is to quantify the apparent decrease in tracer concentration in a region of interest (ROI) of an image of spherical sources of different diameters.

3.7.2.3 Method

A number of hollow spheres, filled with an ACTIVITY concentration of ^{18}F from a stock solution, are placed in the water-filled head phantom (see Figures 2 and 8), which is in turn placed in the centre of the TRANSVERSE FIELD OF VIEW. The phantom shall be held in position without introducing additional attenuating material. At least two samples from this solution are counted in a well counter. The spheres are arranged to be coplanar.

For systems utilizing THREE-DIMENSIONAL RECONSTRUCTION, the measurements shall be done at the axial centre of the tomograph and halfway between the axial centre and the edge of the AXIAL FIELD OF VIEW.

After data acquisition, the spheres are removed and the cylinder filled with a uniform solution of ^{18}F from which at least two samples are taken for well counting.

3.7.2.4 Data collection

The data collection shall be carried out at low COUNT RATES such that the COUNT LOSS is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

Care should be taken to acquire sufficient counts so that statistical variations do not significantly affect the result. So, for the slice containing the spheres, at least 500 000 counts shall be acquired. COUNT RATES and scanning times shall be stated.

3.7.2.5 Data processing and analysis

Reconstruction shall be performed using a ramp filter with a cut-off at the Nyquist frequency and with all corrections applied. The method of ATTENUATION correction shall be by an analytical calculation. The ATTENUATION coefficient used shall be reported. The scatter correction method used shall be clearly described.

Circular ROIs of diameter as close as possible to the FWHM as measured in 3.7.1.3.3.3 are defined centrally on the image of each sphere. The precise ROI diameter should be stated.

A large ROI (diameter: 150 mm) is centred on the image of the uniform cylinder. Calculation of the RECOVERY COEFFICIENT (RC_{si}) for each sphere is obtained from the equation:

$$RC_{si} = \left(\frac{\dfrac{C_{si}}{SM_s}}{\dfrac{C_u}{SM_u}} \right)$$

where

C_{si} are the ROI counts/pixel/s for sphere *i*;

SM_s *are* the sample counts/s/cm³ (stock solution spheres);

C_u are the ROI counts/pixel/s (head phantom);

SM_u are the sample counts/s/cm³ (head phantom);

C_u/SM_u represents a calibration factor for a large reference object.

Care shall be taken to correct for any dead-time and sample volume effects in the well counter. RC_{si} is then plotted against sphere diameter to give recovery curves.

3.7.2.6 Report

Graphs of RECOVERY COEFFICIENTS for each axial position described in 3.7.2.3 shall be reported.

The scatter correction method used shall be clearly described, as well as the ATTENUATION coefficient used.

3.7.3 Tomographic sensitivity

3.7.3.1 General

Tomographic sensitivity is a parameter that characterizes the rate at which coincidence events are detected in the presence of a RADIOACTIVE SOURCE in the limit of low ACTIVITY where COUNT LOSSES and RANDOM COINCIDENCES are negligible. The measured rate of TRUE COINCIDENCE EVENTS for a given distribution of the RADIOACTIVE SOURCE depends upon many factors, including the detector material, size, and packing fraction, axial acceptance window and septa geometry, ATTENUATION, scatter, dead-time, and energy thresholds, radius of rotation and detector head geometry.