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Nuclear medicine instrumentation – Routine tests –

Part 3: Positron emission tomographs

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International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR MEDICINE INSTRUMENTATION – ROUTINE TESTS –

Part 3: Positron emission tomographs

FOREWORD

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IEC 61948-3, which is a technical report, 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 technical report is based on the following documents:

Enquiry draft	Report on voting
62C/376/DTR	62C/383/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this technical report the following print types are used:

- requirements, compliance with which can be tested, and definitions: in roman type;
- explanation, advice, introductions, general statements, exceptions and reference: in smaller roman type;
- *test specifications: in italic type*;
- TERMS DEFINED IN CLAUSE 3 OF THIS TECHNICAL REPORT OR LISTED IN THE INDEX OF DEFINED TERMS: SMALL CAPITALS.

IEC 61948 consists of the following parts, under the general title *Nuclear medicine instrumentation – Routine tests:*

Part 1: Radiation counting systems

Part 2: Scintillation cameras and single photon emission computed tomography imaging

Part 3: Positron emission tomographs

The committee has decided that the contents of this 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- withdrawn;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.

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

INTRODUCTION

This technical report is based on the German Standard DIN 6855-4 "Qualitätsprüfung nuklearmedizinischer Messsysteme – Teil 4: Konstanzprüfung von Positronen-Emissions-Tomographen (PET)".

NUCLEAR MEDICINE INSTRUMENTATION – ROUTINE TESTS –

Part 3: Positron emission tomographs

1 Scope and object

This technical report is valid for POSITRON EMISSION TOMOGRAPHS utilizing stationary or moving detectors in a circular arrangement. It is not valid for SPECT-systems operated in coincidence mode. In the framework of QUALITY CONTROL, this technical report describes test methods suitable for the purpose of routine testing. Methods used for acceptance testing are described in IEC 61675-1:1998.

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 61675-1:1998, *Radionuclide imaging devices – Characteristics and test conditions – Part 1: Positron emission tomographs*

IEC 61948-2:2001, *Nuclear medicine instrumentation – Routine tests – Part 2: Scintillation cameras and single photon emission computed tomography imaging*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE A certain number of terms used in this document have been drawn from IEC 60788, IEC 61675-1 and IEC 61948-1 (see Index of defined terms).

3.1
quality control
part of the quality assurance in nuclear medicine including tests of instruments with appropriate test methods

NOTE Includes both acceptance test and routine test.

[IEC 61948-1:2001, definition 3.1]

3.2
acceptance test
test carried out at the request and with the participation of the user or his representative to ascertain by determination of proper performance parameters that the instrument meets the specifications claimed by the vendor

[IEC TR 61948-1:2001, definition 3.2.1]

NOTE An ACCEPTANCE TEST should be carried out at the time of installation and when appropriate after major service. During or immediately after ACCEPTANCE TEST, REFERENCE DATA are collected to be used as a standard for comparison with future ROUTINE TESTS.

3.3
routine test
test of a piece of equipment or its components, which is repeated at specified intervals, to establish and document changes from the initial status described by REFERENCE DATA

NOTE A ROUTINE TEST could be carried out by the user with simple test methods and equipment.

[IEC TR 61948-1:2001, definition 3.2.2]

3.4
reference data
a set of data measured immediately after acceptance testing, using test methods designed for routine testing

[IEC TR 61948-1:2001, definition 3.2.3]

3.5
positron emission tomograph
tomographic device which detects the ANNIHILATION RADIATION of positron emitting RADIONUCLIDES by COINCIDENCE DETECTION

[IEC 61675-1:1998, definition 2.1.3.1]

3.6
annihilation radiation
ionizing radiation that is produced when a particle and its antiparticle interact and cease to exist

[IEC 61675-1:1998, definition 2.1.3.2]

3.7
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 SPATIAL RESOLUTION in all three dimensions

NOTE The PROJECTION BEAM mostly has the shape of a long thin cylinder or cone. In positron emission tomography, it is the sensitive volume between two detector elements operated in coincidence.

[IEC 61675-1:1998, definition 2.1.2.2]

3.8
line of response
LOR
the axis of the PROJECTION BEAM

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

[IEC 61675-1:1998, definition 2.1.3.5]

3.9
relative sensitivity per line of response
ratio of the COUNT RATE of TRUE COINCIDENCES, measured for a specific PROJECTION BEAM and assigned to the corresponding LINE OF RESPONSE, to the mean COUNT RATE of TRUE COINCIDENCES of all lines of response

3.10
count rate
number of counts per unit of time

[IEC 61675-1:1998, definition 2.7.2]

3.11
total field of view
dimensions (three-dimensional) of the TOMOGRAPHIC VOLUME

[IEC 61675-1:1998, definition 2.1.2.8.3]

3.12
tomographic volume
juxtaposition of all volume elements which contribute to the measured PROJECTIONS for all PROJECTION ANGLES

[IEC 61675-1:1998, definition 2.1.2.8]

3.13
total coincidences
sum of all coincidences detected

[IEC 61675-1:1998, definition 2.1.3.6]

3.14
true coincidence
result of COINCIDENCE DETECTION of two gamma events originating from the same positron annihilation

[IEC 61675-1:1998, definition 2.1.3.6.1]

3.15
random coincidence
result of COINCIDENCE DETECTION in which both participating photons emerge from different positron annihilations

[IEC 61675-1:1998, definition 2.1.3.6.4]

3.16
system axis
axis of symmetry, characterized by geometrical and physical properties of the arrangement of the system

NOTE For a circular POSITRON EMISSION TOMOGRAPH, the SYSTEM AXIS is the axis through the centre of the detector ring. For tomographs with rotating detectors it is the axis of rotation.

[IEC 61675-1:1998, definition 2.1.2.7]

3.17
transverse resolution
SPATIAL RESOLUTION in a reconstructed plane perpendicular to the SYSTEM AXIS

[IEC 61675-1:1998, definition 2.4.1]

3.18
count loss
difference between measured COUNT RATE and true COUNT RATE, which is caused by the finite RESOLVING TIME of the instrument

[IEC 61675-1:1998, definition 2.7.1]

3.19
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

[IEC 61675-1:1998, definition 2.1.2.4]

3.20
line source
straight radioactive source approximating a δ-function in two dimensions and being constant (uniform) in the third dimension

[IEC 61675-1:1998, definition 2.10]

3.21
calibration factor
the relation between measured COUNT RATE per unit volume and the real ACTIVITY concentration in the object

NOTE Although the CALIBRATION FACTOR is related to the acquisition configuration affecting the sensitivity of the system (e.g. 2D, 3D) it is independent of the actual acquisition parameters (e.g. acquisition time, ACTIVITY injected, etc.) and reconstruction parameters. Especially it should be independent of the object under study.

3.22
normalization
the process of setting up the system and creating corrections to maintain the performance of the system

4 Test methods

4.1 CALIBRATION FACTOR and cross-calibration

For each mode of operation used, e.g. 2D/3D, the CALIBRATION FACTOR is determined by irradiating the TOTAL FIELD OF VIEW with a uniform flux of a positron emitting RADIONUCLIDE using a cylindrical phantom, which is filled either with a homogeneous aqueous solution or with a homogenous solid matrix containing the ACTIVITY with a known ACTIVITY concentration. The phantom has to be centred both transaxially and axially within the TOTAL FIELD OF VIEW.

The total amount of ACTIVITY used shall be such that the COUNT LOSSES are less than 5 %, and that the RANDOM COINCIDENCE rate is less than 5 % of the total coincidence rate.

The measured SINOGRAMS are reconstructed applying all corrections (NORMALIZATION, COUNT LOSS, decay, attenuation, scatter, and RANDOM COINCIDENCES). From the reconstructed homogeneous volume the CALIBRATION FACTOR relating COUNT RATE per unit volume element to the ACTIVITY concentration in the phantom shall be determined and shall be checked for being constant.

The accuracy of this test is critically dependent upon the accurate knowledge of the ACTIVITY concentration of the phantom. This can be assured by using a phantom filled with a long-lived positron emitter (e.g. Ge-68) with a certified ACTIVITY concentration, or by using a dose calibrator or well counter of known accuracy to assay the phantom's ACTIVITY concentration.

When using quantitative PET-applications, the traceability of the ACTIVITY concentration as measured in the dose calibrator, well counter (if necessary) and tomograph has to be assured (cross-calibration).

4.2 RELATIVE SENSITIVITY PER LINE OF RESPONSE and goodness of NORMALIZATION

The sensitivity of all lines of response is tested by irradiating the TOTAL FIELD OF VIEW with a uniform flux of a positron emitting RADIONUCLIDE using rotating line or plane sources, ring sources or uniform cylindrical phantoms centred on the SYSTEM AXIS.

From the acquired SINOGRAMS the RELATIVE SENSITIVITY PER LINE OF RESPONSE, related to the average of all sensitivities per LINE OF RESPONSE, shall be calculated. These data shall be condensed by appropriate methods on a per detector element base to reduce the amount of data (e.g. by adding all LOR's originating from one detector element). These data shall be checked for constancy.

In addition, all SINOGRAMS acquired shall be numerically compared to the corresponding reference SINOGRAMS acquired immediately after the actual NORMALIZATION measurement in use to check the goodness of NORMALIZATION.

4.3 TRANSVERSE RESOLUTION

For POSITRON EMISSION TOMOGRAPHS, where reconstructed resolution might change electronically due to detector design and alignment, TRANSVERSE RESOLUTION in the radial and tangential direction shall be measured for a LINE SOURCE suspended in air and arranged parallel to the SYSTEM AXIS at a radial displacement of r = 10 cm. These data shall be compared to the reference resolution data measured at acceptance testing according to IEC 61675-1:1998.

4.4 PIXEL size

For POSITRON EMISSION TOMOGRAPHS, where PIXEL size might change electronically due to detector design, PIXEL size has to be checked in an analogous manner to IEC TR 61948-2: 2001. Tomographic acquisitions shall be carried out for two LINE SOURCES, which are arranged parallel to each other at 10 cm distance and which are positioned parallel to each of the X, Y, and Z-axes of the tomograph. From the reconstructed images the PIXEL size for each coordinate direction shall be calculated and compared to the REFERENCE DATA.

4.5 Mechanical parts

All mechanical parts, such as interplane septa, transmission sources, patient bed and so on, shall be checked with respect to mechanical stability and safety of operation.

4.6 Viewing and documentation system

The system(s) used for image display (hardware and/or software) as well as the system used for hardcopies should be included in the quality chain. As procedures are strongly dependent on the actual configuration, specific recommendations are beyond the scope of this technical report.

5 Frequency of ROUTINE TESTS

ROUTINE TESTS shall be carried out at the time intervals given in Table 1.