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Quality issues with PET and PET-CT in 2005

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The quality of a PET study depends on instrument performance, the acquisition schedule and the data processing part including reconstruction, visualization and, in the case of PET-CT, registration of the two modalities. Further major components are the selection and preparation of the radiopharmaceutical and the diagnostic efficacy which are, however, not addressed in this paper.

Since both imaging modalities make use of ionizing radiation, the basic legislation dealing with quality is the EU Directive 97/43/EURATOM of 1997 which had to be implemented by the member states by May 2000.

Quality control of the performance of imaging equipment and procedures to achieve optimum performance are specifically requested in the directive. Basically, the directive outlines a quality system for imaging equipment, which national legislation should implement and, where desirable and useful, expand by adding details. The three pillars on which quality control of instrumentation is based are acceptance testing, regular performance testing and external quality control, i.e. inter-laboratory comparison studies.

PET is a relatively new imaging modality of clinical nuclear medicine. Instrumentation with reasonably stable technical features and performance parameters developed only a few years back. Standards for assessing the performance of a PET system are available (NEMA NU2-2001 and IEC 61675-1). They are useful both for the comparison and selection of PET systems and for acceptance testing The performance parameters tested are spatial resolution, sensitivity, scatter and randoms fraction, count rate losses, noise-equivalent count rates, correction accuracy and image quality.

Unfortunately, the NEMA and IEC standards are not strictly compatible. This may lead to difficulties caused by national legislation which tends to favour European and international standards, whereas equipment specifications are available mostly in terms of NEMA performance parameters only.

Minimum performance standards, if they do exist, are suitable to guide in the selection and replacement of equipment. Due to the economic implications they are extremely difficult to define. It is not surprising, therefore, that no official standards or recommendations are available. For dedicated PET scanners recommendations have been published for Australia by an ANZSNM medical physics SIG. Reimbursement policy may also serve as an indicator of minimum performance standards such as the decision of the HCFA to reimburse certain types of gamma camera PET studies for systems with a sufficiently high sensitivity only.

Regular performance testing for PET systems is less well defined. For dedicated PET systems manufacturer specific recommendations are available. These are a mixture of performance tests and equipment specific calibration procedures. Common features are that they all check frequently, usually daily, detector sensitivity and the validity of the normalization data. Less frequently, usually at half-yearly intervals, calibration of the sensitivity is required. Gamma camera PET systems are still used in significant numbers. Acceptance and regular performance tests for the conventional part of such a system is well established for both planar and SPECT performance and are presented elsewhere. The acceptance procedures of the NEMA standard for PET performance have been applied successfully for the additional system components required for PET imaging and results have been published by several authors. Regular performance testing is more complex requiring special procedures due to the additional mechanical rotation and to the poor count rate capabilities compared to dedicated PET scanners. A useful guide covering both acceptance and regular performance testing of gamma camera PET systems has been published recently in the IPEM Report No. 86.

Regular performance testing of both dedicated PET and gamma camera PET systems is relatively new so that little experience is yet available about the significance of the various procedures, especially with respect to slowly deteriorating parameters and associated action levels.

External quality control, i.e. inter-laboratory comparison studies, have been occasionally carried out for PET systems. The comparison of performance in terms of image quality is best evaluated by using a total performance phantom. The NEMA procedure to assess image quality using the IEC body phantom has shown to be useful also for inter-laboratory comparisons. The procedure is designed such that it permits a comparison of image quality including not only physical performance parameters such as spatial resolution or noise characteristics but also the effect of reconstruction algorithms. Furthermore, based on the "lesion" contrast values calculated from the phantom images, it permits to "calibrate" SUV measurements with respect to reconstruction parameters.

Acceptance and constancy testing for CT systems is regulated by two standards. The standard IEC 61223-3-5 from 2004 covers acceptance testing, the standard EN 61223-2-6 deals with constancy tests. These are referred to in national legislation. In addition to parameters characterizing the quality of a CT image, it includes dose measurements using the CTDIw. CT testing is based on manufacturer-supplied phantoms and evaluation programmes which are both standard accessories of a CT system. The test procedures can be carried out much faster than for the PET part of dual modality systems.

New quality issues arising from PET-CT systems are the accuracy of registration between the PET and the CT images. Special phantoms producing caracteristic landmarks both in the CT and in the PET mode are used to check the alignment of static images. A more difficult problem is caused by patient motion which can produce inherent image distortions between the two modalities such as is most evident in the case of lung images. Elastic registration algorithms or special acquisition techniques are expected to eliminate this type of registration artefacts.