MEASUREMENT OF INCORPORATED HIGH ACTIVITIES WITH NUCLEAR MEDICINE EQUIPMENT

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INTRODUCTION

The purpose of this work is the comparison between two instruments frequently used in nuclear medicine: the Whole Body Counter and the SPECT-camera.

Since decades the WBC is a well-established method for quantitative measurement of activity. Apart from some methods of localisation the WBC serves exclusively for the proof of incorporated low activities.

The SPECT-camera is a relatively new imaging system with increasing popularity in nuclear medicine diagnostics. Because of its excellent tomographic abilities it is used almost always in a qualitative way. In the last years one tried to involve the SPECT-camera more and more also in quantitative tasks.

This work tests the capabilities of two of such instruments concerning the quantitative determination of such high activities like they are used for SPECT-acquisitions.

MATERIALS AND METHODS

In order to execute the quantitative measurement of activity under conditions near to such when measuring patients, a torso-kidney-phantom was developed according to MIRD (1) specifications. The phantom made of Plexiglas represents a 20cm high section of the human torso. Two kidney-cavities located at half height of the phantom can be filled with activity (see Figure 1).

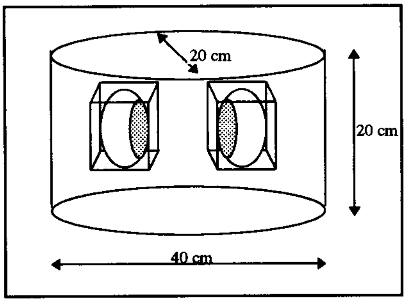

Figure1. Torso-phantom

The WBC (Canberra ACCUSCAN II) is build in *shadow shield*-geometry with 10cm strong steel slabs. Two detector-systems are available for the detection of radiation: A NaJ-scintillation-detector with a crystal size of 5x3x20 inches. It is mostly used for the quantitative evaluation because of its higher efficiency. And a co-axial Germanium-detector with 30% relative efficiency mainly used for the element-identification because of its higher energy-resolution.

The evaluation of the WBC-spectra was done using ABACOS-plus software installed on a DEC MicroVAX 3400.

At activities of 400 MBq of Tc^{99m} the detector-system of the WBC delivers deadtimes of 97%. With the help of a simple collimator built of 1cm strong lead-slabs, which leave a 5mm gap in front of the detector, the deadtime is reduced to 25%.

The source can be measured in *scan-* or in *fixed*-geometry. While deadtime-losses can not be corrected when the source is scanning under the detector, they can be partly corrected in *fixed*-geometry by adding the lost time to the predetermined acquisition time.

For the SPECT-measurements an ELSCINT Apex Helix HR doublehead-camera with an Apex SP-1 processing-station and CLIP-software was used. The acquisitions of the Tc^{99m}-filled kidney-torso-phantom were performed with those acquisition-parameters, which are standard in clinical kidney-studies: Isotope Tc^{99m}, 3° step-and-shoot acquisition, acquisition time 20min, matrix 128x128.

The following correction- and segmentation-algorithms were performed on the acquisition-data before and after the reconstruction: decay-correction, attenuation-correction according to the *first-order Chang* method (2), Compton-scatter-correction according to the *multi energy window* method (3) and finally for the determination of the active volume a segmentation according to a 30% *fixed threshold* method (4,5) or the method of the second deviation (6).

RESULTS

When measuring Tc^{99m}-sources from 1 to 500 MBq with the WBC in scan-geometry, the NaJ-detector shows an activity-dependent efficiency caused by short-term deadtime-effects (see Figure 2). This leads to negligible quantitative errors at activities under 50 MBq, but to errors up to 30% at higher activities. By using an efficiency-curve calculated by means of *least-squares-fit* instead of one single efficiency-value the accuracy for the entire area of activity can be increased to only 2.5% deviation.

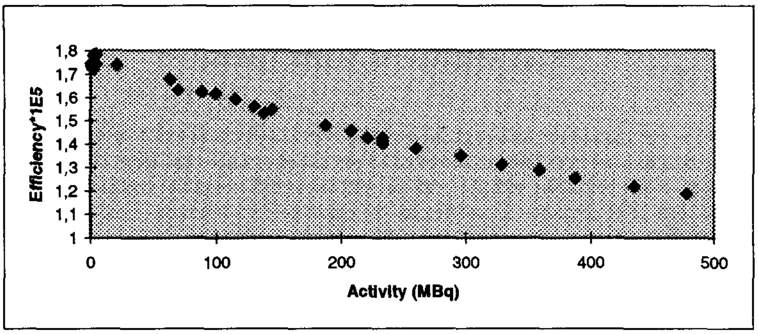

Figure 2. Efficiency of the NaJ-detector in scan-goemetry

Measurements with the Germanium-detector in scan-geometry deliver qualitatively analogous results, but with a more flat curve because of the detector's lower efficiency and the better time resolution (see Fig. 3).

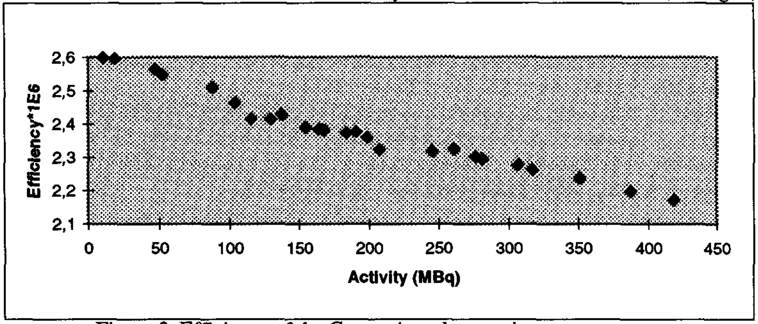

Figure 3. Efficiency of the Germanium-detector in scan-geometry

In a geometry with the source placed motionless under the detector, pile-up effects lead to a similar efficiency course despite electronic deadtime-correction. The above mentioned correction reduces in this geometry too the quantitatve deviations from 15% to 2.5% for NaJ- and Ge-detector.

The evaluation of the SPECT-acquisitions showed different accuracy for quantitative measurement of activity depending on the methods of correction used. The Compton-correction method implemented on this system was useless in this case, since the algorithm itself causes 20% quantitative error.

At the determination of the active volume no essential difference between the two segmentation methods was recognisable. With attenuation-corrected acquisition-data only a negligibly higher accuracy was to reach, than with uncorrected data. Under the ideal conditions of measurement present when working with a motionless phantom placed always identically a quantitative accuracy of 9% is possible with a SPECT-system. No activity dependence could be seen (see Figure 4).

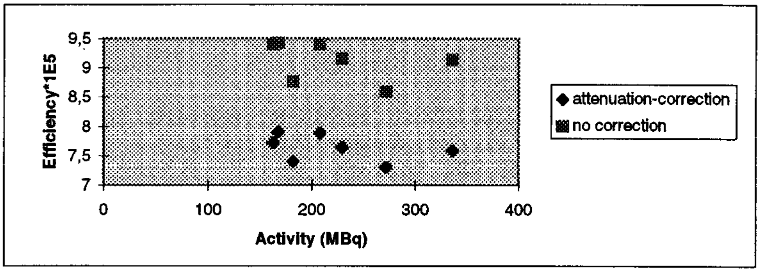

Figure 4. Efficiency of the SPECT-camera

DISCUSSION

Although the WBC is not thought for such high activities, it could easily be adapted by a simple slit-collimator. The still remaining deadtime effects could be corrected by the use of activity-dependent efficiency-values.
At activities between 1 and 500 MBq with the NaJ- as well as with Germanium-detector using this procedure an accuracy of less than 2.5% deviation is possible for the quantitative determination of activity. Even at slight changes in the position or size of the measured object this accuracy can be kept.

The most essential role in quantitative measurement of activity with a SPECT-system has the selection of the mechanisms of correction. Only certain combinations of correction- and segmentation-algorithms have a positive impact on the accuracy.
Only under the ideal conditions of acquisition when working with a phantom errors of 9% for the quantitative determination of activity and 25% for the determination of volume are possible with a SPECT-system. Deviations from this ideal conditions like the above mentioned cause uncertainties of more than 50%.

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