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The Procedure for SPECT and BEAM Images Adjustment Visualisation of EEG Electrodes in SPECT Images

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Preliminary results of research to devise a method allowing spatial alignment of BEAM maps obtained from EEG examinations with SPECT data are presented. The main concept of the method presented lies in simultaneous recording of multi-channel EEGs during SPECT examination, and also in visualizing location of EEG electrodes on SPECT images that provide spatial three dimensional coordinates assignment. The proposed methodology of simultaneous SPECT and EEG examinations could be a significant complement to results of epileptic focus localisation obtained with the ISAS method used for the last few years. The ISAS method allows localisation of focuses with 80% confidence, but it requires carrying out MRI examinations for alignment of compared anatomical structures on two SPECT images. Complementing these results with a BEAM map analysis would improve significantly the effectiveness of the examinations. This work presents results of experiments carried out on the Jaszczak phantom.

Key words: EEG visualization, EEG mapping, SPECT images, image registration.

Introduction

SPECT examinations (Single Photon Emission Computed Tomography) provide planar brain images showing concentration of radiopharmaceuticals (Figure 1).

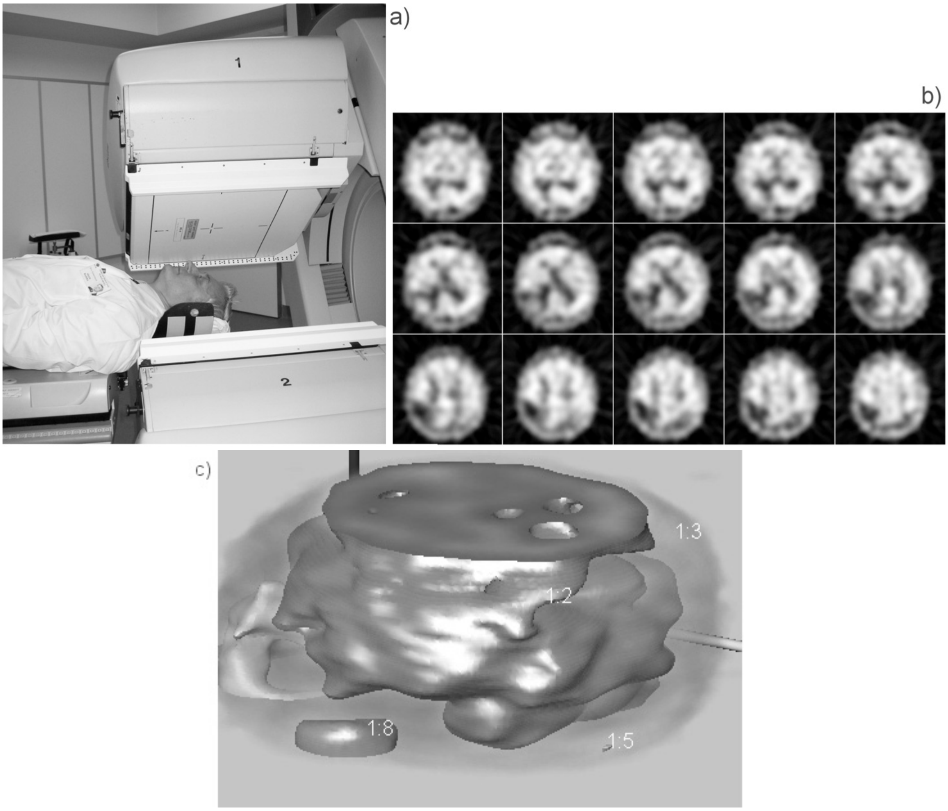


Figure 1. SPECT examination (a), part of a SPECT image sequence of the brain (b) and an example of a 3D reconstruction of the structures depicted in sequence (c) (using a 3D Constructor Image ProPlus package, courtesy of M. Młodkowski, MSc from WIKOM).

In EEG (electroencephalography) studies maps of the brain bioelectrical activity on the scalp are created (BEAM – Brain Electrical Activity Map) (Figure 2).

However, both methods lack scalp geometry, which is necessary for the comparison of the images acquired using these methods. The analysis of simultaneously recorded SPECT and BEAM images with known electrode coordinates could significantly improve the results of epileptic focus localisation obtained by the SPM method (Statistical

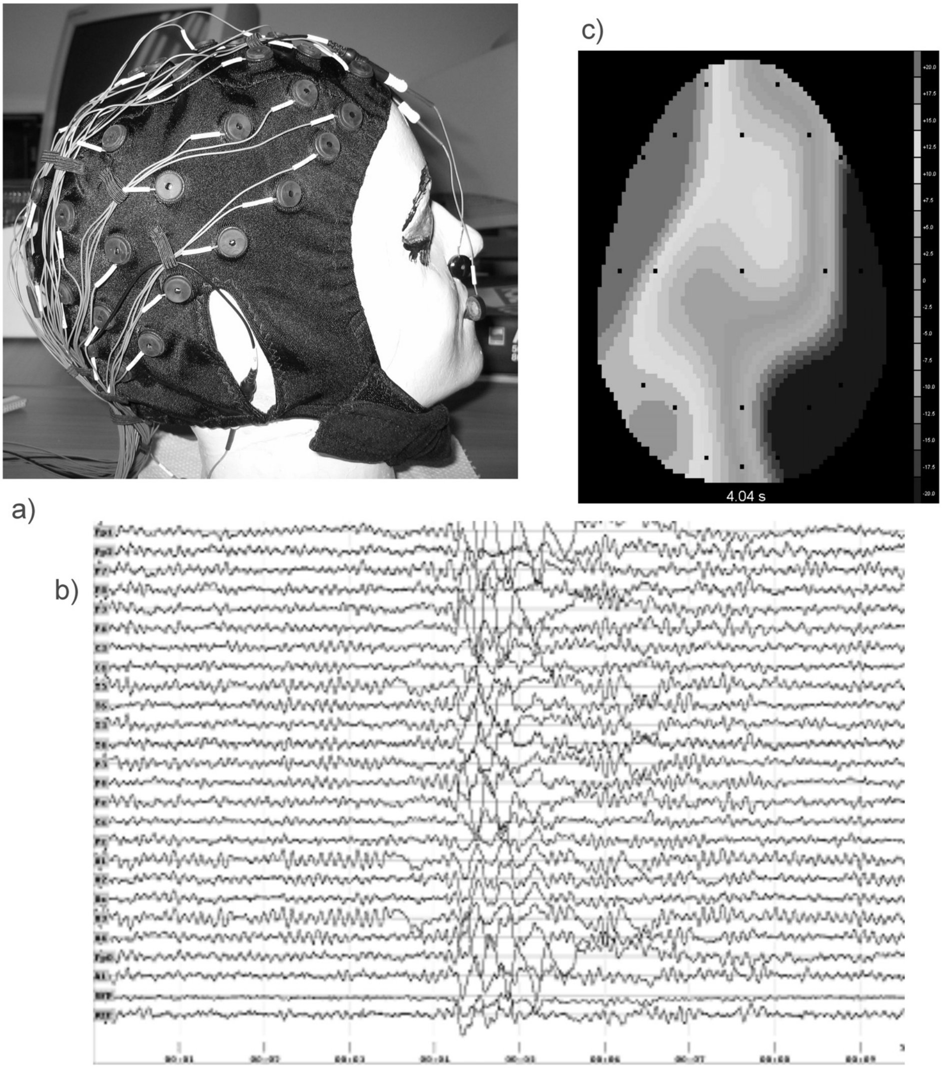


Figure 2. EEG examination: electrode placement (a), multichannel EEG recording (b), example of a BEAM image with electrode locations marked on the image according to a 10-20 system (c).

Parametric Mapping) [6], proposed by Nelly et al. [9] (or similar earlier methods like SISCOM). In the ISAS method, localization is made by analysing the differences between SPECT images recorded for the application of radiopharmaceuticals before the end of seizure activity (ictal) (1) or after the end of seizure activity (postictal), and (2) images for the application of radiopharmaceuticals in the intra-seizure period. In case (1), focus localisation according to McNelly et al. [9] is performed with the accuracy of around 80% by analysing the areas of increased brightness in SPECT images. In case (2), focus localisation can be performed with accuracy of the brain side only using the so-called an ischaemia asymmetry index (by the analysis of differences in the brightness of SPECT images of the left and right brain sides). This method, however, requires MRI (Magnetic Resonance Image) examination to align anatomical structures in both SPECT images compared [1, 9].

The determination of electrode coordinates on the scalp surface during SPECT examination would improve focus localisation and it would simplify the examination. The proposed methodology of simultaneous SPECT and EEG examinations could thus be of great importance in the examinations which aim at preoperative localisation of an epileptic focus.

Brain bioelectrical activity mapping (BEAM) is widely used in electroencephalography as a method of layout visualisation of different parameters characterising brain bioelectric activity. In our previous study [2] some methods and criteria for quantitative as well as for comparative analysis of BEAM images have been proposed. Simultaneous comparative analysis is not only a single BEAM image, but also a sequence of images with the results obtained from other techniques. With simultaneous analysis of results obtained using the SPECT method and brain bioelectrical activity mapping it is necessary to devise a method of spatial alignment of BEAM maps with structures visible in SPECT images [8]. This would allow for the assessment of excitation propagation, which is important, for example, in epileptic focus localization. Below is presented a preliminary description of the research aimed at devising a technique of spatial alignment of images of both types [3, 4, 5].

Materials and methods

The proposed method consist in simultaneous recording of multi-channel EEGs during a SPECT examination and visualisation of EEG electrodes on SPECT images, which make it possible to determine coordinates in a three dimensional space.

An EEG signal will be recorded with a multi-channel battery operated device (holter) and analysed in a NeuroScan 4.3 system.

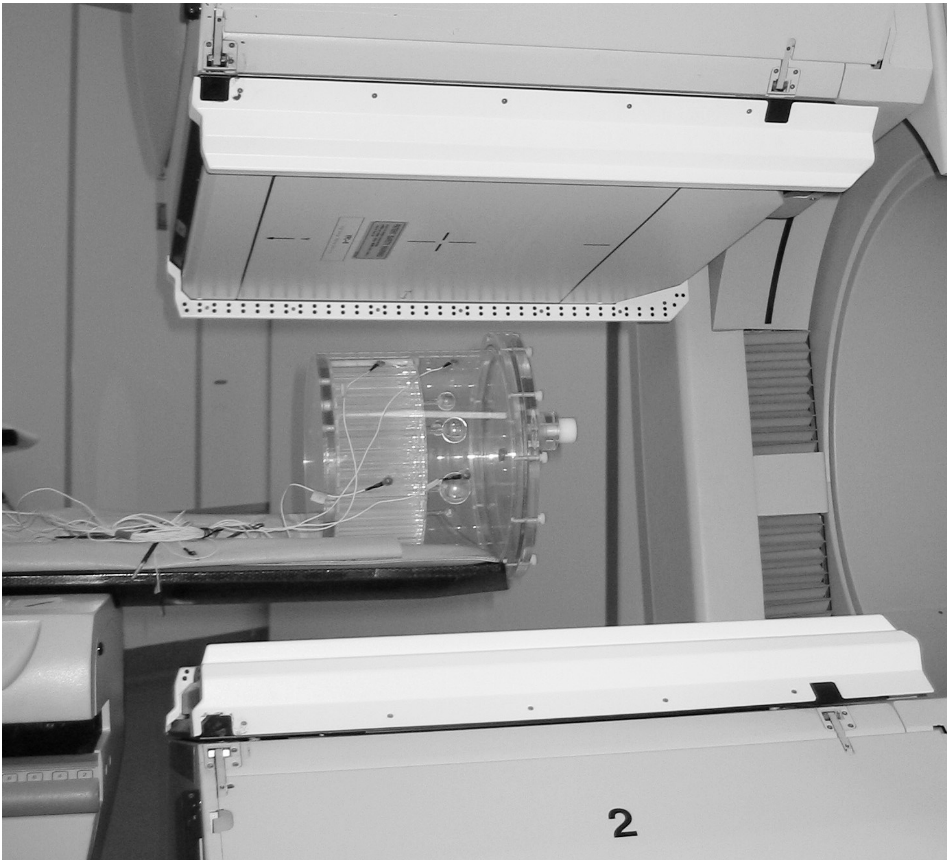


Figure 3. SPECT examination of the Jaszczak phantom with electrodes located on the surface.

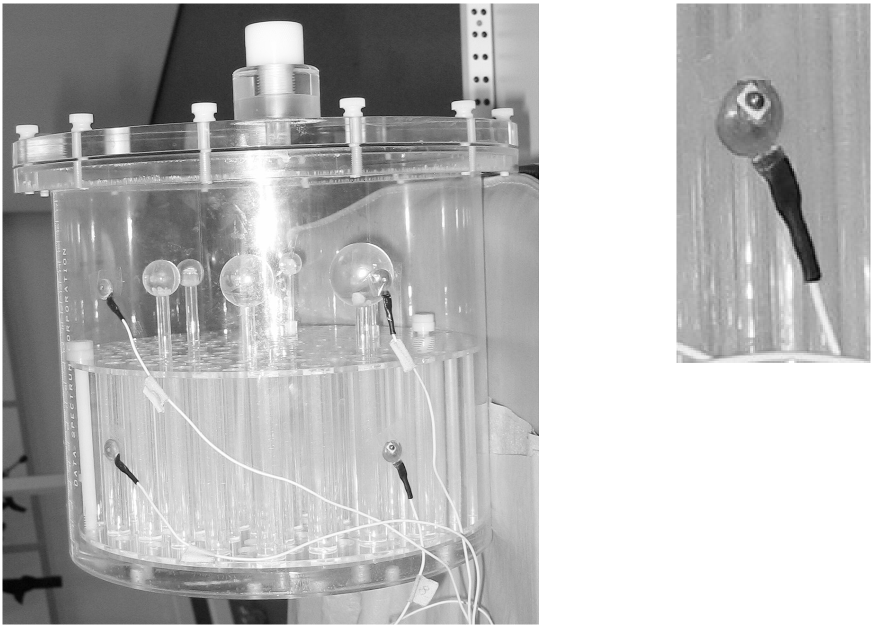
SPECT examination will be performed with a rotatory scintigraphic 2-head VARICAM ELSCINT camera and analysed in an APEX v.5.5 system at XPERT station.

Preliminary experiments with the Jaszczak phantom (Figure 3) were aimed at devising a method of visualising EEG electrode placement in SPECT examination, which makes it possible to determine their coordinates in a three dimensional space.

Four SPECT examinations (experiments) of the Jaszczak phantom were performed:

1. without electrodes,
2. with several electrodes,
3. with eight electrodes, marked by Pb spheres (Figure 4a).
4. with three electrodes filled with an isotope solution (Figure 4b).

a)



b)

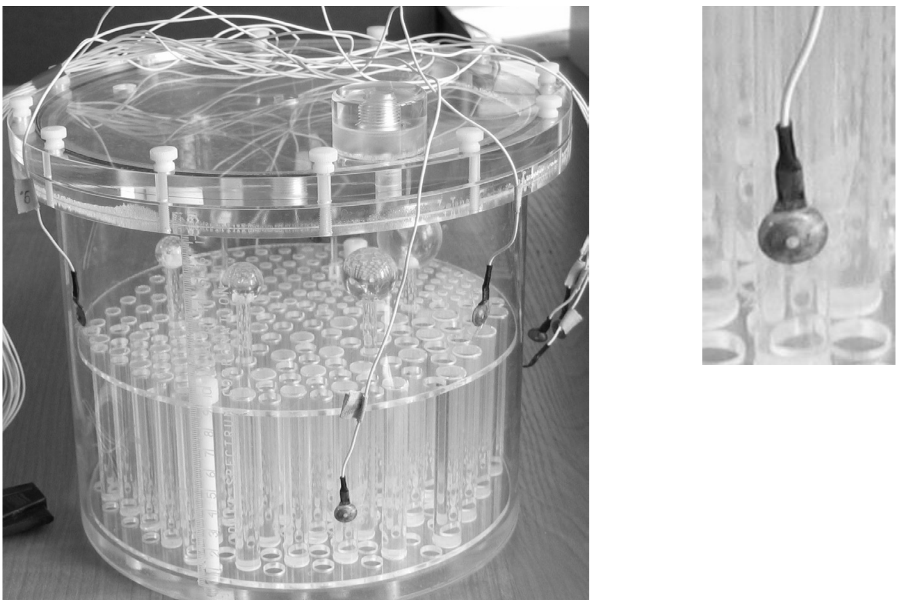


Figure 4. Electrode positions on the Jaszczak phantom: a) eight electrodes marked by Pb spheres, b) three electrodes filled with isotope solution.

a)

b)

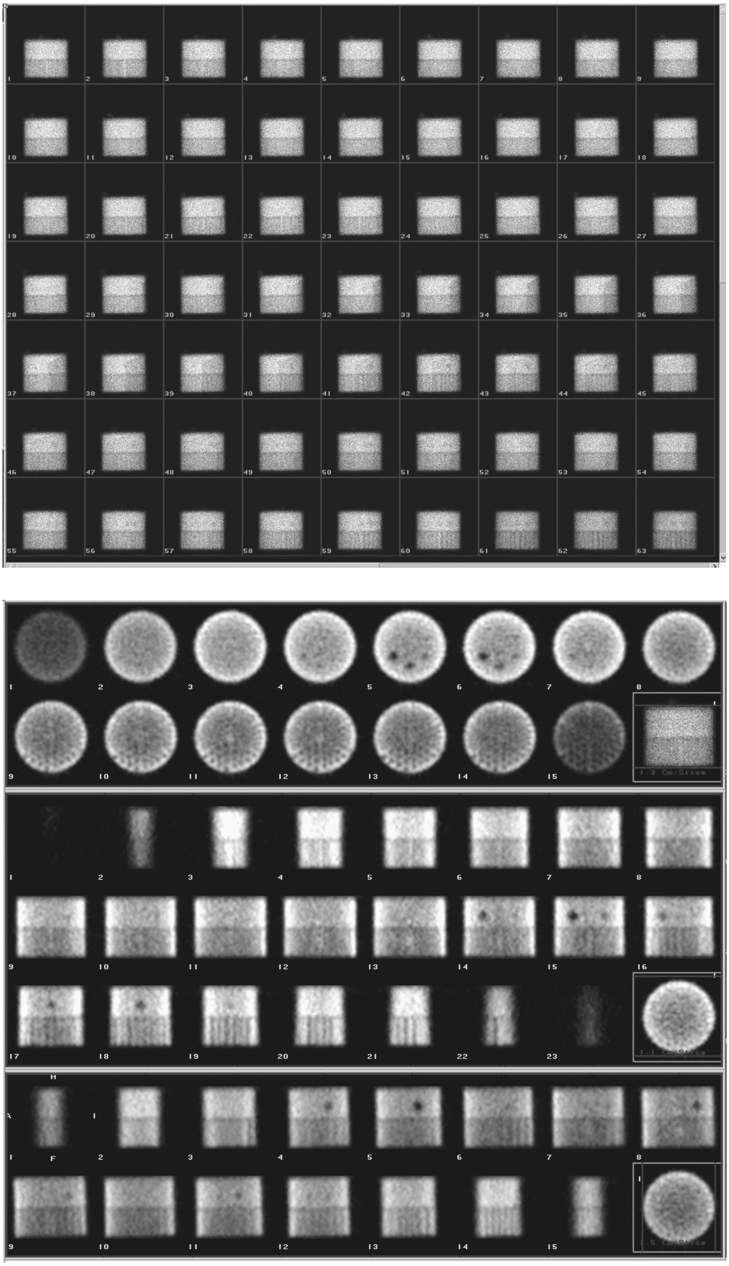


Figure 5. Results of SPECT phantom examination without electrodes: a) original images, b) images after reconstruction – sequence of sections perpendicular to the axis and two sequences of sections parallel to phantom's axis.

In all SPECT examinations, the Jaszczak phantom was filled with water solution of Tc^{99m} isotope. In the third experiment, eight electrodes were marked with Pb markers – spheres and hemispheres of 2.5 mm and 1mm in diameter, glued onto the internal and external electrode surfaces. In the fourth examination, the electrodes were filled with the same solution, their activity being 100 times higher than that of the solution in the phantom.

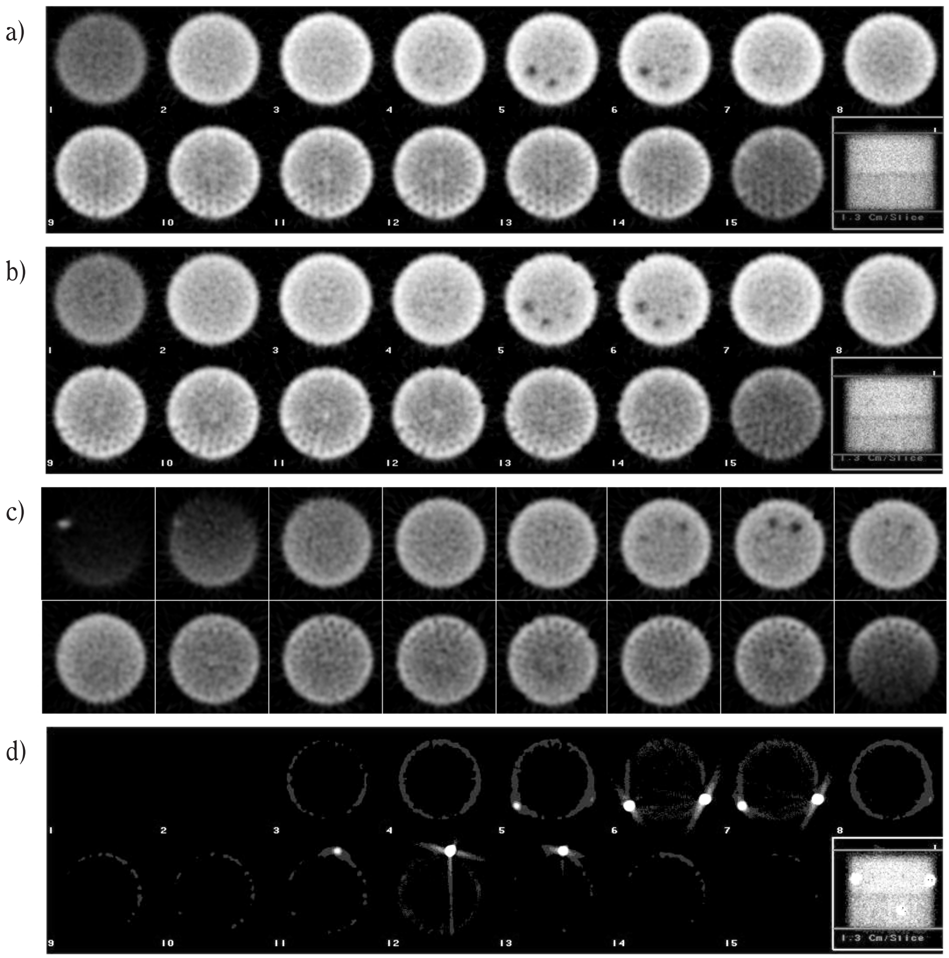


Figure 6. Results of SPECT examination (selected images from a sequence of section images perpendicular to the axis): a) for the phantom without electrodes – magnification of a fragment for Figure 5b, b) with several electrodes, c) with eight electrodes marked by Pb spheres, d) with three electrodes filled with isotope solution.

Results

Results of SPECT examination for the phantom without electrodes (Figure 5) and the comparison of SPECT images after reconstruction for the phantom without electrodes (Figure 6a), with electrodes (Figure 6b), with electrodes marked by Pb spheres (Figure 6c) and with electrodes filled with an isotope solution (Figure 6d) are shown.

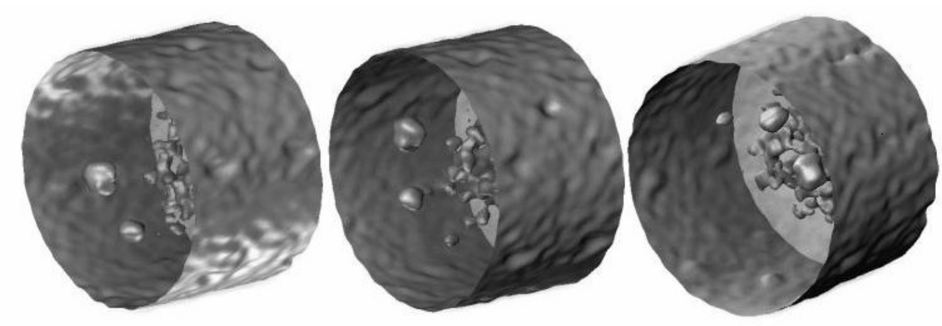


Figure 7. 3D visualisation of phantom surface with several electrodes (from images presented in Figure 6b) for three projections (using 3D Constructor Image ProPlus package courtesy of M. Młodkowski, MSc. from WIKOM).

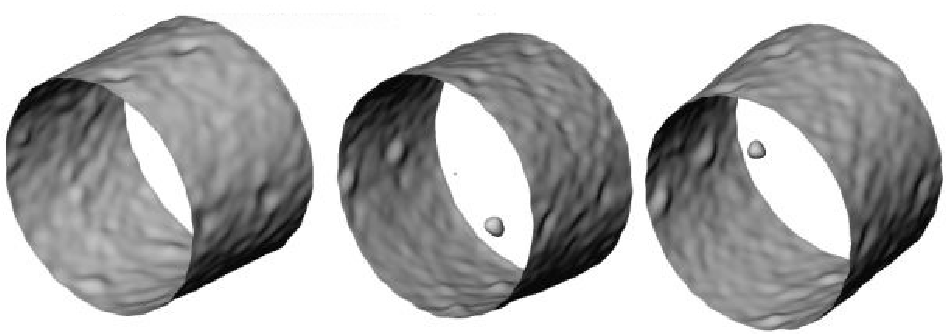


Figure 8. 3D visualisation of phantom surface with eight electrodes marked by Pb spheres (from the images presented in Figure 6c) for three projections (using 3D Constructor Image ProPlus package courtesy of M. Młodkowski, MSc from WIKOM).

Figure 7 and Figure 8 present 3D visualisations of the phantom surface with electrodes alone and with electrodes marked by Pb spheres.

Comments

Visible "hollows" at the edges of phantom sections with electrodes in Figure 6b and at the surface visible in Figure 7 and at the edges of phantom sections with electrodes marked by Pb spheres (Figure 6c and Figure 8) do not permit unambiguous localisation of electrodes and cannot provide a basis for the determination of coordinates. The electrodes marked by Pb spheres were not significantly more visible in SPECT images.

In the experiment with electrodes filled with isotope solution (Figure 6d) the electrodes were visible, however, it is necessary to optimize the isotope solution activity to achieve the appropriate brightness dynamics of SPECT images. Using other markers can also be considered [7].

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