An Investigation of an Accuracy of Iterative Reconstructions in Quantitative SPECT

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There is a well recognized clinical demand for imaging procedures that would provide quantitative information about the processes inside living organisms. In nuclear medicine (SPECT, in particular) tracer molecules labeled with a radioactive isotope are injected into the patient body, and radioactive emissions from this isotope are recorded at several locations around the patient. The diagnosis is based on the analysis of an image which is reconstructed from these data (projections). To provide clinicians with quantitative information, the complex inverse problem needs to be solved with a maximum possible accuracy. From the mathematical perspective, this corresponds to the restoration of a true 3D volumetric distribution of the tracer from the set of 2D detected data.

The mathematical description of this problem leads to an under-determined system of algebraic equations with an extremely large matrix (system matrix). The coefficients of both matrix and right-hand side reflect the complex ways in which the emitted photons are interacting with the body and are recorded by the detector.

The goal of this study is to estimate the mathematical accuracy of the iterative ordered subsets expectation maximization (OSEM) method in different realistic oncological situations. Numerical model imitating thyroid phantom was created to reproduce some of the clinical cases from the Internal Radiotherapy Dosimetry study. Monte-Carlo simulations and analytical projectors were used to create noisy and noiseless sets of projections, respectively. The quantitative capability of the method was evaluated by performing a comparative analysis of true and reconstructed distributions. The influence of physical conditions of the study (the activity distribution inside the true image; the number of projections; incorporation of photon attenuation, scatter, and distance-dependent resolution loss into the system matrix) and algorithmic parameters (number of sub-sets and iterations, initial guess) on the solution accuracy and the convergence behavior was studied.