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ESTIMATION OF EXPOSURE DOSE OF HUMAN HEAD DURING CT SCANNING PROCEDURE USING MONTE CARLO SIMULATION

Abstract: *In this study we present method for determination of exposure dose on human head during computer tomography (CT) scanning procedure. Method is based on scan data obtained by CT. The gray level of image is converted to attenuation coefficient distribution in the head model. The exposure dose is calculated using this model data by Monte Carlo method simulation. This method is based on quantification of interaction between X-ray photon and head tissue. Obtained simulation results can be helpful to improve design, safety and quality of CT system for head imaging.*
Key words: *Monte Carlo, Computer Tomography, Exposure Dose*

1. INTRODUCTION

Recent studies in radiology suggest that computed tomography (CT) scans comprise only (3-11) % of all radiological exams, yet contribute to (35-45) % of the total radiation dose to the patient population [1,2].
Further research into the complex relationship between radiation exposure, image quality, and diagnostic accuracy should be encouraged, in order to establish the minimum radiation dose necessary to provide adequate diagnostic information [3].
According to this information protection of patients during scanning procedure is main requirement during imaging procedure and design of CT devices. The one way to minimize radiation dose is to better understand mechanisms of dose absorption and factor like construction of X-ray device, type of filter being used and characteristic of patient tissue. Dose reduction can be achieved using appropriate filterers [4,5] suitable reconstruction algorithms [6,7] or special mode of X-ray source operation [7].
In this study we try to calculate dose of CT scanner by Monte Carlo Simulation using multi slice image data.
The final goal is to develop tool for exposure dose calculation with the aim of enhancing quality of CT devices.

2. COMPUTER TOMOGRAPHY

2.1 Basic relation

Computer tomography (CT) is a non-destructive method for characterizing 3D objects by using X-ray radiation. This method is based on the differences in attenuation coefficient of X-ray beams for various materials and tissues. The final result is a grey level CT image where corresponding grey level is proportional to attenuation coefficient.
CT medical imaging includes exposure of the object of radiation at one side and detecting attenuated radiation at the other side of the object and this procedure is repeated from more than one direction. The next step is image reconstruction from the projection by using a number of techniques. All of these techniques are based on solving systems of integral equations which are formed as a result of total attenuation of the radiation beam from the source to the detector. Monochromatic X-ray reduction for homogenous materials is given by the relation

$$I = I_0 e^{-\mu \cdot d}, \qquad (1)$$

where I_0 is intensity of initial radiation, I is final intensity radiation after path length d in tissue with linear attenuation coefficient μ. If there are multiple materials, the equation becomes:

$$I = I_0 e^{-\sum_i \mu_i \cdot d_i}. \qquad (2)$$

Linear attenuation coefficient is very sensitive to energy variation of initial X-photon; that is to say the equations 1 and 2 are valid only for monochromatic beam.
If a polychromatic X-ray source is used, taking into account the fact that the attenuation coefficient is a strong function of X-ray energy, the complete solution would require solving the equation over the range of the X-ray energy (E) spectrum utilized:

$$I = \int I_0(E) e^{-\mu(E)\cdot d} dE . \qquad (3)$$

This equation largely complicates the reconstruction process and obtaining final results. For this reason the equation (1) is more applicable with a note that μ represents effective attenuation coefficient with spectral characteristics included.

2.2 CT number

CT numbers are also known as the Hounsfield units which are proportional to mean linear attenuation coefficient and they are formed at the end of reconstruction process.
The corresponding CT number is given by

$$CT = K \frac{\mu_t - \mu_w}{\mu_w} . \qquad (4)$$

Where μ_t, μ_w are linear attenuation coefficients of X – ray in tissue and water respectively and K is scale factor. The K is chosen to satisfy -1000 value of CT