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# DETERMINATION OF CT PARAMETERS OF TRABECULAR BONE BASED ON THE RESULT OF CT RECONSTRUCTION SIMULATION OF A PHANTOM IMAGE OF BONE MICROSTRUCTURE

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**Relevance.** Determining the parameters of bone tissue based on the results of a CT scan is a necessary tool for detecting bone mass loss due to different pathologies as well as evaluation the consequences of radiation treatment of bone metastases.

**Objective.** Evaluation the parameters of human trabecular bone phantom CT-reconstructed images. Investigation of the influence of Radon and Inverse Radon transform on estimation the parameters of trabecular structures on reconstructed phantom image.

**Results**. One of the most important parameters of the trabecular bone is bone volume fraction (bone volume/total volume BV/TV ratio) [1]. The basic method of investigation of the trabecular bone micro-structure is histomorphometry ex vivo [2].

The microscopy image of thin histological slice of bone biopsy specimens [2] was used for creation of the binary phantom trabecular bone image that consists of trabecular lines (white, 255) and background (black, 0) (Fig.1a), ratio BV/TV=0,241 as for normal trabecular bone.

Next MATLAB Simulation of CT-scanning (Radon transform with angle step ⟨=$1^0$) was applied for CT scan data acquisition. CT scan acquisition is based on the use of projections data. Projection is mathematically described by linear integrals in the projection direction and is called the Radon integral transform. The 2D Radon transformation of a function is its projection onto an axis along the line *L*, which is at a distance *s* from the origin of coordinates and is its linear integral:

$$\Re(s,\theta)=\int_{-\infty}^{\infty} f\left(s\cos\theta-y'\sin\theta,\, s\sin\theta+y'\cos\theta\right)dy' ,\qquad (1)$$

where $x'$ and $y'$ are the current coordinates when the gentry is rotated CCW on angle ⟨.

The task of image reconstruction in CT is to restore the function *f(x,y)* that would determine what proportion of the total attenuation of X-rays falls on each element of the image. The result of the back projection shows that the obtained values can create certain errors in the future CT image. Function $f(x,y)$ is defined by the 1D inverse Fourier transform of the function $\Re_{\Phi}(\omega,\theta)$ as

$$f(x,y)=\int_{0}^{\pi} d\theta \int_{-\infty}^{\infty} |\omega| \Re_{\Phi}(\omega,\theta)\exp\left[i2\pi\omega(x\cos\theta+y\sin\theta)\right]d\omega .\qquad (2)$$

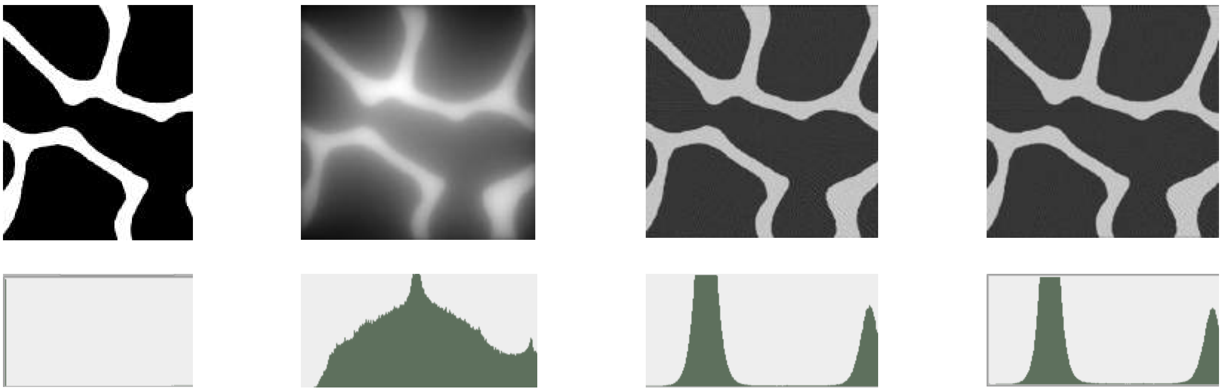
The results of back projection for the phantom image are shown in Fig. 1b, the histogram of the reconstructed image shows the appearance of a wide range of grayscales without clear evidence of bone/background segmenting due to very noisy data. Ratio BV/TV = 0,139 did not correspond to the initial value for the phantom image (value as for rarified bone structure).

To obtain a clearer reconstructed CT image, strengthening the boundaries of the structures on it, the projection data are previously subjected to mathematical filtering (filtered back projection, FBP). The Rama-Lak filter emphasizes higher frequencies, so it often emphasizes noise in images as well. Because of this, various modifications of this filter are used to reduce noise by suppressing the amplification of high frequencies. Standard Shepp-Logan filter applied to very noisy data [3] (Fig. 2).

The results of filtered back projection of the phantom image with use of the Rama-Lak filter (Fig. 1c) and Shepp-Logan filter (Fig. 1d) shows clear segmentation of the bone trabecular lines. The histograms consist of two separated zones for the background and bone.

Despite the discrepancy with the initial histogram and the presence of a different distribution of grayscale values on the image, the ratio BV/TV corresponds to the initial one for the phantom image before reconstruction.

phantom image (a) | back projection (b) | FBP& Ram-Lak (c) | FBP& Shepp-Logan (d)



0 255 | 0÷177 178÷255 | 170÷224 21÷85 | 161÷229 20÷90

BV/TV = 0,241 | BV/TV = 0,139 | BV/TV = 0,241 | BV/TV = 0,24

**Figure 1 – Results of bone phantom image reconstraction and histogram analysis**

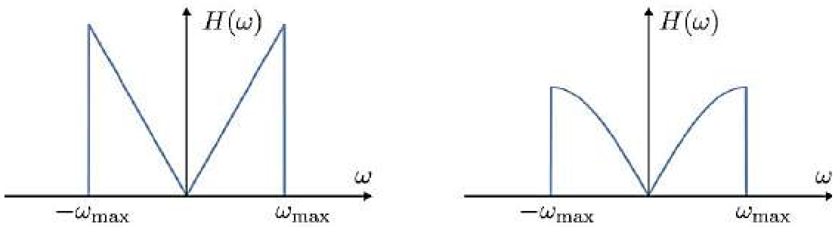



**Figure 2 - The responses in frequency domain for the Ram-Lak and Shepp-Logan filters**

**Conclusion.** The parameters of human trabecular bone based on analysis of phantom CT-reconstructed images are evaluated. MATLAB Simulation of Radon transform of the bone phantom image and Inverse Radon Transform with Ram-Lak or Shepp-Logan filtering allows accurate BV/CV estimation for the reconstructed phantom image of trabecular bone as predicted for initial image.

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