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CONSTRUCTION OF A STATISTICAL THREE-DIMENSIONAL MODEL OF THE HUMAN DIAPHRAGM ON THE BASIS OF TOMOGRPAHY FINDINGS

Abstract. *The work is devoted to the construction of a statistical three-dimensional model of the human diaphragm based on computed tomography data. As a result of the study, a statistical computer model of the human diaphragm was obtained, which in the future will allow us to classify the anatomical structure of the patient's diaphragm and identify possible deviations, as well as the peculiarities of their occurrence.*
Keywords: *brain, computed tomography, statistical modelling, reconstruction*

Introduction. When a surgeon performs surgery his awareness and knowledge of the internal anatomical structure of a patient and personal structure in particular play a crucial role. The diaphragm occupies a special position among such structures. Its function is very important while performing surgery on certain kinds of hernias. Although, there are a number of evidences concerning general anatomical structure of the diaphragm [1-2] and its analysis with the use of intrascopic methods [4], the data concerning the peculiarities of its structure depending on the type of the body, gender, age and other factors are not much available. Modern studies in the field of medical anatomy require application of mathematical methods as to formalization of description of the anatomical structures [4-5]. Their use should level certain subjectivity of investigations and the quality of the description of an examined structure [6].

Therefore, construction of statistical models describing three-dimensional structure of the diaphragm and its peculiarities is uninvestigated multi-disciplinary area having great theoretical and practical value.

Objective: to construct statistical three-dimensional model of the human diaphragm on the basis of volumetric tomographic examinations of patients. To achieve the goal the key points of the diaphragm should be measured enabling to describe it and visualize by means of three-dimensional graphics.

Materials and methods. The study was carried out at the Department of Operative Surgery and Topographic Anatomy, Kharkiv National Medical University. The reference data were specimens of computed tomography presented in DICOM format obtained by means of the computer scanner Toshiba Aquilion 16. Tomographic examination was performed at the supply voltage on the tube equal 120 kW, and current – 300 mA. Pixel range was 0,8 mm ×0,8 mm, and the distance between sections – 0,8 mm.

The sample of tomographic examination in three planes is presented on Fig. 1.

A three-dimensional model of the diaphragm was suggested to introduce by means of the use of 55 apices of the diaphragmatic surface located on the parallel sagittal sections and one additional apex – a basic one. In this way the diaphragmatic surface is formed by 84 triangles consisting of an appropriate connection of the apices (Fig. 2).

Having conducted appropriate constructions applying original software designed by the authors three-dimensional models of the diaphragm were obtained (Fig. 3).

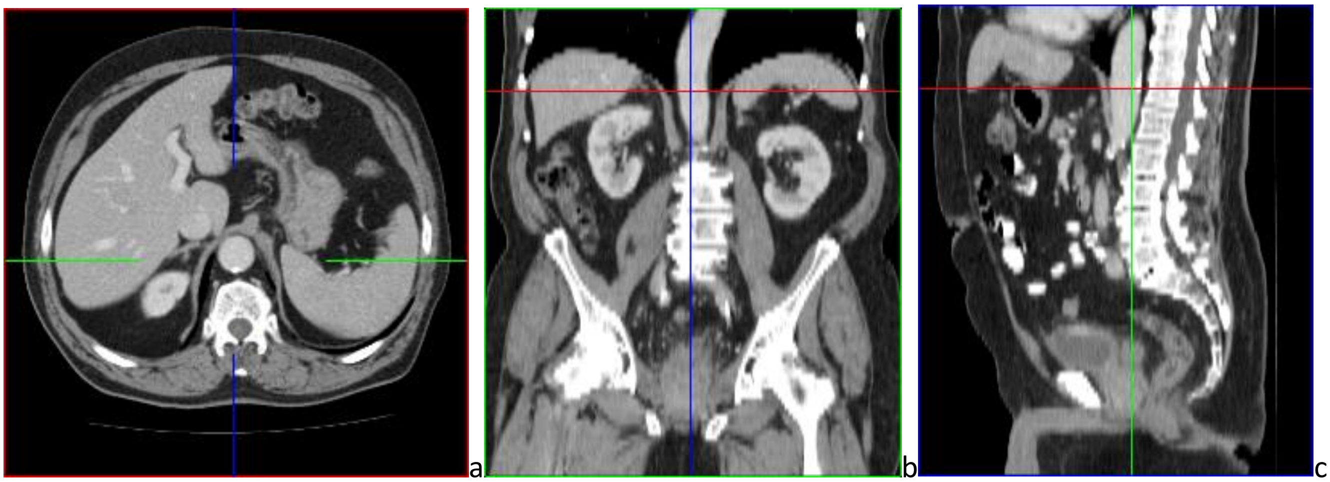

Fig. 1. The sample of examined tomographic investigation : a – axial section; b – coronary section; c – sagittal section

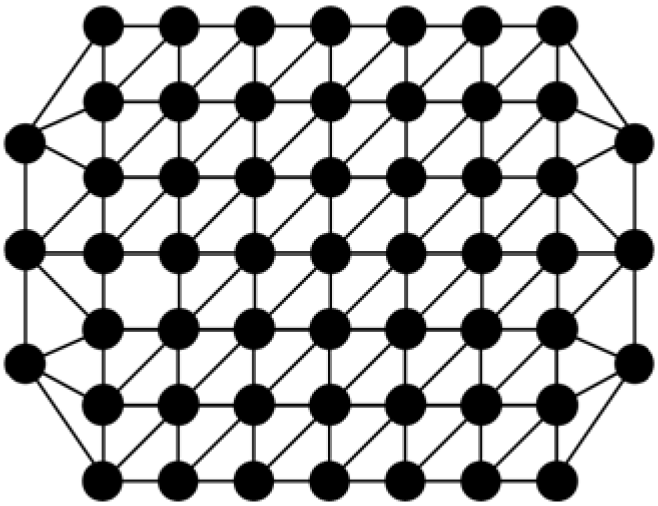

Fig. 2. Schematic structure of apical connections of a three-dimensional diaphragmatic model

Indicating the three-dimensional model for the first patient as M_1, the whole set of examinations will be marked as M:

$$M = \{M_1, ..., M_n\} = \left\{ \begin{pmatrix} x_1 \\ y_1 \\ z_1 \\ ... \\ y_{56} \\ z_{56} \end{pmatrix}_1, ..., \begin{pmatrix} x_1 \\ y_1 \\ z_1 \\ ... \\ y_{56} \\ z_{56} \end{pmatrix}_n \right\}$$

where x_1, y_1, z_1, ..., y_{56}, z_{56} – coordinates of apices of an appropriate investigation model;

n – number of patients.

Therefore, having the whole set of investigations available we have got the vector of mean values (μ) and covariant matrix (Σ):

$$\mu = \frac{1}{n}\sum_{i=1}^{n} M_i$$

$$\Sigma = \frac{1}{n-1}\sum_{i=1}^{n}(M_i - \mu)(M_i - \mu)^T$$

These two constituents together with normal distribution (N) form a statistical three-dimensional model of the human diaphragm described in the following way:

$$\begin{pmatrix} x_1 \\ y_1 \\ z_1 \\ ... \\ y_{56} \\ z_{56} \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_{x_1} \\ \mu_{y_1} \\ \mu_{z_1} \\ ... \\ \mu_{y_{56}} \\ \mu_{z_{56}} \end{pmatrix}, \begin{pmatrix} \sigma_{x_1}^2 & \sigma_{x_1}\sigma_{y_1} & \sigma_{x_1}\sigma_{z_1} & ... & \sigma_{x_1}\sigma_{y_{56}} & \sigma_{x_1}\sigma_{z_{56}} \\ \sigma_{y_1}\sigma_{x_1} & \sigma_{y_1}^2 & \sigma_{y_1}\sigma_{z_1} & ... & \sigma_{y_1}\sigma_{y_{56}} & \sigma_{y_1}\sigma_{z_{56}} \\ \sigma_{z_1}\sigma_{x_1} & \sigma_{z_1}\sigma_{y_1} & \sigma_{z_1}^2 & ... & \sigma_{z_1}\sigma_{y_{56}} & \sigma_{y_{56}}\sigma_{z_{56}} \\ ... & ... & ... & ... & ... & ... \\ \sigma_{y_{56}}\sigma_{x_1} & \sigma_{y_{56}}\sigma_{y_1} & \sigma_{y_{56}}\sigma_{z_1} & ... & \sigma_{y_{56}}^2 & \sigma_{y_{56}}\sigma_{z_{56}} \\ \sigma_{z_{56}}\sigma_{x_1} & \sigma_{z_{56}}\sigma_{y_1} & \sigma_{z_{56}}\sigma_{z_1} & ... & \sigma_{z_{56}}\sigma_{y_{56}} & \sigma_{z_{56}}^2 \end{pmatrix} \right)$$

where σ – the element of covariant matrix Σ.

Fig. 3. The sample of a three-dimensional model of the diaphragm: a – visualization with sagittal section; b – visualization without sagittal section

Results and discussion. Therefore, a statistical model of the human diaphragm was constructed on the basis of 30 intrascopic examinations of patients. Numerous values of the statistical model are obtained including the vector of mean values (μ) 168×1 in size and covariant matrix (Σ) 168×168 in size. The values obtained correspond to the normal law of distribution which is indicative of further possibility to apply the model.

Conclusions. 1. Three-dimensional models of patients on the basis of tomographic data with the use of an original software are constructed.

2. The statistical model of the human diaphragm is obtained on the basis of three-dimensional models. This model will promote to determine and visualize a typical model of the human diaphragm.

3. The statistical model of the human diaphragm is obtained enabling to conduct mathematical modeling of different deviations from the normal values using Gauss distribution and at the same time to construct a three-dimensional structure of the obtained diaphragm. It enables to simulate pathologies of different nature both for training of students and further scientific investigations.

Prospects of further studies. A promising direction of further studies is construction of statistical models considering different pathological deviations which will enable to apply the data obtained for preliminary analysis of patient's condition, and moreover, to determine anatomical signs and peculiarities promoting occurrence of these deviations from the norm. One more prospective direction is the research directed to the analysis of the diaphragm according to the gender, age, constitution of the body, and, for example, for sportsmen to solve the tasks of sport medicine.

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