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MODERN METHODS OF MORPHOMETRIC ASSESSMENT OF STRUCTURAL COMPONENTS OF THE INTESTINAL WALL

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Abstract. *The present study reviews modern methods of morphometric assessment of the structural components of the intestinal wall. The role of quantitative analysis in studying the microarchitecture of the intestine and in increasing the objectivity of morphological investigations is demonstrated. The principal morphometric parameters used in the analysis of the intestinal wall are described, including villus height, crypt depth, thickness of the mucosal and muscular layers, as well as the intestinal lumen area. Particular attention is given to the application of digital microscopy, automated image analysis, and modern morphometric software. It is noted that the implementation of digital technologies, 3D reconstruction methods, and elements of artificial intelligence significantly expands the possibilities of morphological analysis and contributes to improving the accuracy and reproducibility of the obtained data. The перспективность (prospects) of using morphometric methods in both fundamental and applied morphological research is emphasized.*

Keywords: *morphometry, intestinal wall, intestinal villi, intestinal crypts, digital microscopy, morphological analysis, quantitative morphology.*

In modern morphology, quantitative methods of analysis are gaining increasing importance, as they allow an objective evaluation of the structural organization of tissues and organs. One of these methods is morphometry, which represents a set of quantitative approaches for studying the morphological parameters of cells, tissues, and their structural components.

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The application of morphometric methods makes it possible to obtain precise and reproducible data on the microscopic architecture of biological structures, thereby significantly expanding the possibilities of morphological research [5,7].

Quantitative morphological analysis is of particular importance in the study of the intestinal wall, which is characterized by a complex multilayered organization and a high degree of functional specialization. Morphometric assessment of parameters such as villus height, crypt depth, mucosal thickness, and the ratio of the different layers of the intestinal wall enables a more detailed analysis of the structural and functional characteristics of this organ and allows the identification of morphological changes under various physiological and pathological conditions [9].

It should be noted that traditional descriptive histology, which is primarily based on qualitative characterization of morphological structures, has certain limitations associated with the subjectivity of interpretation and insufficient accuracy in evaluating structural changes. In this regard, the introduction of quantitative morphometric methods contributes to increasing the objectivity of morphological studies and provides the possibility of statistical processing of the obtained results [2].

In recent years, digital technologies for morphological analysis have developed significantly, including digital microscopy, automated image processing, and morphometric software systems. The use of such technologies allows a substantial increase in measurement accuracy, accelerates the processing of morphological data, and ensures standardization of research results. Thus, the application of modern digital morphometric methods opens new prospects for a deeper study of the structural organization of the intestinal wall and expands the possibilities of modern morphology [10].

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The aim of the study was to analyze modern methods of morphometric assessment of the structural components of the intestinal wall and to determine their significance in morphological research.

The material of the study consisted of histological preparations of the intestine. To identify the features of the microscopic structure of tissues, general histological and special staining methods were used, including hematoxylin and eosin staining, PAS reaction, and Masson's trichrome staining.

Microscopic examination was carried out using light microscopy. To increase the accuracy of quantitative analysis, digital microscopy methods were applied with subsequent computer processing of the obtained images.

Morphometric analysis was performed using specialized image processing software, including ImageJ and Morphology software, which allow quantitative assessment of morphological structures.

During the study, the main morphometric parameters of the intestinal wall were determined, including villus height, crypt depth, thickness of the mucosal layer, thickness of the muscular layer, and the intestinal lumen area.

The obtained quantitative data were subjected to statistical processing using generally accepted methods of variation statistics.

One of the most important directions of quantitative morphological analysis is the morphometric assessment of the main structural components of the intestinal wall. Of particular importance is the morphometry of intestinal villi and crypts, including the determination of villus height, crypt depth, and their ratio, which allows an assessment of the functional state of the intestinal mucosa.

An important element of morphometric analysis is also the quantitative evaluation of epithelial cells, including the determination of their density, size, and distribution within the epithelial layer. Such parameters allow an objective

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characterization of the condition of the intestinal epithelial lining and the identification of possible structural changes [3,4].

In addition, morphometric studies include measurement of the thickness of the main layers of the intestinal wall, including the mucosal, submucosal, and muscular layers. Analysis of these parameters makes it possible to evaluate the structural organization of the intestinal wall and to identify morphological changes under various physiological and pathological conditions.

Another important parameter is the assessment of the surface area of the mucosal membrane, which is directly related to the functional activity of the intestine, particularly the processes of absorption and secretion. Comprehensive morphometric analysis of these parameters makes it possible to obtain an objective quantitative characterization of the structural organization of the intestinal wall [1,6].

In recent years, modern technological approaches have been actively introduced into morphological research, significantly expanding the possibilities of quantitative tissue analysis. One of the most promising directions is digital morphometry, based on the use of digital microscopy and specialized software tools for precise measurement of morphological parameters [8].

Automatic analysis of microscopic images also plays an important role, allowing objective quantitative evaluation of structural components of tissues, reducing the influence of subjective factors, and increasing the reproducibility of research results. Modern software systems are capable of automatically detecting the boundaries of structural elements, measuring their dimensions, and performing statistical processing of the obtained data.

Another promising direction in the development of morphometric research is three-dimensional (3D) tissue reconstruction, which enables spatial

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analysis of the microscopic architecture of organs and tissues and allows a more detailed study of their structural organization.

Furthermore, methods of artificial intelligence and digital pathology are increasingly being used in modern morphology. The application of machine learning algorithms and neural network technologies makes it possible to automate the analysis of histological images, improve the accuracy of morphometric measurements, and significantly accelerate the processing of large volumes of morphological data.

The conducted analysis demonstrated that modern morphometric methods significantly expand the possibilities of quantitative evaluation of the structural components of the intestinal wall. The use of digital microscopy and specialized image processing software makes it possible to obtain accurate and reproducible data on tissue morphometric parameters.

The application of morphometric methods provides a higher level of objectivity in morphological research compared with traditional descriptive approaches. Quantitative analysis of parameters such as villus height, crypt depth, and the thickness of different layers of the intestinal wall contributes to a more precise characterization of the structural organization of the intestine.

In addition, the introduction of modern morphometric technologies is of great importance for both experimental morphology and clinical diagnostics. Quantitative assessment of morphological changes makes it possible to detect early structural alterations and objectively evaluate the influence of various factors on the morphofunctional state of the intestinal wall.

Conclusions. Modern morphometric methods allow an objective and quantitative assessment of the structural organization of the intestinal wall. The use of digital technologies significantly expands the possibilities of morphological research and increases the accuracy of the analysis of



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microscopic structures. Morphometric analysis represents a promising direction for the development of both fundamental and clinical morphology.

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