Kochyna K.V., Kurbasava D.M.
Belarusian State Medical University

DETERMININATION OF OPTIMAL ACCESS DURING EXTRANASAL SURGICAL INTERVENTION ON MAXILLARY SINUSES USING 3D MODELS

The use of three-dimensional (3D) modeling and 3D printing is increasing in all areas of human life, including in the medical field. This is particularly true for surgical specialties. 3D visualization methods help to plan surgical procedures, as well as during the training phase. Over the past 10 years, there has been a significant increase in the number of publications on this topic, indicating its growing popularity [1, 29-31]. This is supported by the intensive development of 3D technology, which confirms the great potential of its use in medicine, and particularly in otorhinolaryngology.

Almost any area of the human body that a doctor may be interested in can be recreated using 3D printing technology in the form of a three-dimensional model. A necessary element for 3D printing is a digital three-dimensional model of the anatomical area of interest. This model will later serve as the basis for creating a physical 3D object. Computed tomography (CT) and magnetic resonance imaging (MRI) scans of the patient, which provide information about the individual anatomical features of the body in three mutually perpendicular planes, are used as the initial data for subsequent modeling and 3D printing. The characteristics of the 3D model that results from the process depends directly on the quality of the initial data. The smaller the gap between the slices of anatomical areas in the CT scan, the better the final "picture" will be. Therefore, it is recommended to use either a CT or MRI with a "slice thickness" of less than 1 millimeter in order to capture fine details [2, 26–35].

The effectiveness of surgical treatment of chronic sinusitis is a top priority for otorhinolaryngologists at the present time, as the prevalence of this condition is quite high and shows no signs of decreasing. Preoperative planning with the use of a 3D model allows to determine the optimal location of a bone defect for trepanation during external access. This is necessary for a successful surgical intervention. Thus, personalized surgical access, considering the anatomical features of the facial skeleton, individual size and shape of the sinuses, increases the safety and effectiveness of the surgical procedure [4, 1323–1341].

The aim of the study was to determine the optimal localization of a trepanation defect when using external access during surgical interventions on the maxillary sinuses.

Materials and methods. Currently, there is a wide range of software available for creating 3D models based on CT or MRI data.

Their difference is in the external interface, the range of functions they perform, and the technical features they offer. Some of these software packages are available to any Internet user. One of the programs that allows us to create 3D models of anatomical areas based on CT scans is 3D Slicer. This software has several features, including support for the DICOM format for transmitting image data. The graphical interface is also user-friendly and easy to use[5, 53 – 58]. The 3D Slicer is based on a license model that does not restrict the use of its source code for modelingpurposes. This is intended to expand the user community and simplify the transition to a commercial product.Since its inception in the late 1990s, the 3D Space program has undergone several improvements, with significant changes to the software, functionality, and graphical interface occurring every 4-5 years.Due to the lack of approval from the US Food and Drug Administration (FDA), the 3D Slicer software is positioned by developers as a program for use in clinical research. 3D Slicer differs from other commercial software in that it includes experimental tools that are not available in otherwork programs used in clinics [5, 53-58].

The 3D Slicer software has powerful visualization capabilities that support a variety of research techniques, such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET). This software can be used to create two-, three-, and four-dimensional images from data collected by using these techniques. Support for 3D formats is most popular due to the significant number of purposes for their use and is accompanied by a wide range of tools designed for this type of data. Support for newer and less frequently used two- and four-dimensional data formats is undoubtedly the basis for the further development of the program and the expansion of its application range. 2D images allow us to visualize cross-sections of 3D or 4D formats, as well as perform basic image manipulation such as zooming, panning, and multi-plane reformatting. They also support cross- and synchronous scrolling for parallel viewing on multiple devices [5, 53 – 58].

During the research, a 3D model of the facial skeleton of a specific patient was created with the maxillary sinus reconstructed inside. The creation was carried out using the fifth generation 3D Slicer software (version 5.0).

The shape of the maxillary sinuses varies greatly, and it is difficult to describe their configuration using simplegeometric shapes.The definition of a polyhedron comes closest to describing the relief of the maxillary sinus. A polyhedron is a three-dimensional geometric figure whose surface is composed of a finite number of flat polygons. Each of the polygons is considered to be a face of a polyhedron. The sides and vertices of these polygons are, respectively, the edges and vertices of the polyhedron. A polyhedron is convex if it lies entirely on one side with respect to each of the planes that contain its faces. It is not possible to unambiguously represent the sinus cavity as a convex polyhedron. In order to solve the mathematical problem of finding the point on the anterior surface of the maxillary wall from which a direct tool can achieve maximum amount of space inside the sinus, we propose the following sequence of steps:

- the search is conducted for an area that may be a potential "bottleneck" during the formation of the trepanation hole. To determine it along the Y-axis, a number of sections are created and the section with the smallest area is selected. The area highlighted in blue in Figure 1 has a complex configuration due to the irregularities of the sinus surface caused by anatomical protrusions. This feature can lead to difficulty in accessing the extreme points of the sinus cavity.On the contrary, the green zone is relatively wide and has a smooth relief. So the sections in this zone are not the smallest in area. Based on this, the areas highlighted in blue and green are excluded from the calculations. The calculation is carried out for the sections in the area indicated in Figure 1 in orange. In the future, as the number of observations increases, the calculation area is expected to expand;

- a geometric center is searched for the found section with a minimum plane which provides an equidistant position from the boundary of the cavity. The center of mass is shown in red in Figure 1.;

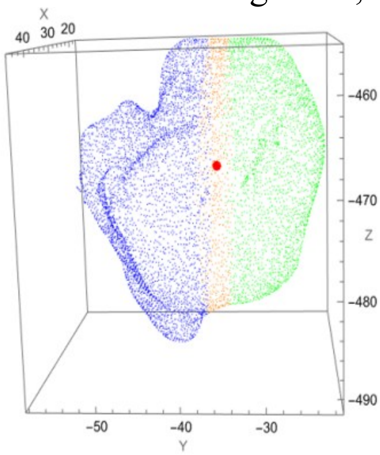

Figure 1. The sinus cavity with the found minimum cross-section along the Y axis.

- to determine the localization of the trepanation hole on the anterior surface of the maxilla it is necessary to find the point on the bone where the distance to the geometric center of the found smallest section is considered the shortest. The mutual position of the sinus cavity and the bone area where the trepanation hole is supposed to be applied is shown in Figure **2.** To determine this, a perpendicular is drawn from the center of mass to the anterior surface of the maxilla.

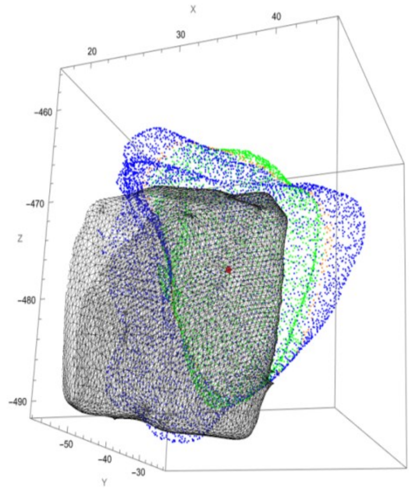

Figure 2. The relative position of the sinus cavity in relation to the maxilla.

The relative position of the maxillary sinus, a fragment of the facial skeleton, and the point for opening the sinus, constructed using the algorithm, is shown in Figure 3.

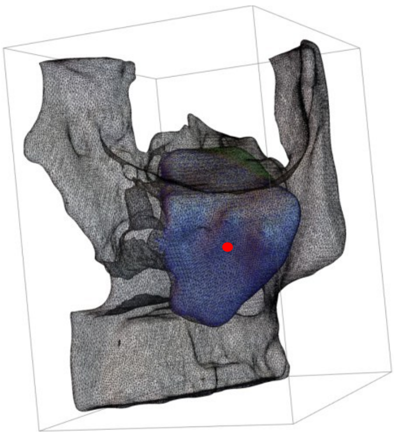

Figure 3. The relative position of the sinus cavity and the area of the facial skeleton.

Results. During the spatial analysis of the patient's CT data using the spatial and numerical computing package Mathematica Wolfram 12.3 it was possible to determine the optimal localization for opening the sinus through its anterior wall. A mathematical algorithm has been proposed that includes a certain set of calculations to determine a point on the anterior surface of the maxilla. This point can be used to access the sinus and reach the maximum number of points inside it. The initial stage involves a geometric analysis of the sinus configuration, taking into account individual anatomical features and the degree of its pneumatization. The next step is to find a narrow place - the section with the smallest area, which will restrict the angle of movement of the instruments inside the sinus. At the final stage of the calculations, considering the relative position of the cavity inside the maxilla, a projection of the desired point is obtained. The projection of the desired point, considering the relative position of the cavity inside the maxilla is determined at the final stage of calculations. The proposed algorithm is based on the results of calculations of spatial coordinates obtained through 3D modeling using CT data. The result obtained can be considered preliminary and requires further research in this area.

Conclusion. Preoperative planning with determination of the optimal localization of the trepanation incision is one of the possible directions of application of 3D modeling in otorhinolaryngology. The use of spatial and numerical calculation methods based on the data of a particular patient allows us to take into account the anatomical features of their facial skeleton the individual size and shape of the sinus.

An integrated approach to solving the problem of determining the optimal access for surgical treatment of patients with pathology of the paranasal sinuses will increase the effectiveness of treatment and minimize the negative consequences during extranasal surgical intervention on paranasal sinuses. This approach will help to ensure optimal results and improve the quality of life for patients.

References

1. Egorov, I. A. Application of 3D printing technology in medicine / I. A. Egorov, O. V. Semenchuk // CHRONOS : multidisciplinary sciences. – 2022. – T. 6. – № 3 (65). – Pp. 29-31.
2. Bagaturija, G. O. Prospects for the use of 3D-printing when planning surgery. Georgij O. Bagaturija / / Medicine: theory and practice. – 2016. - T. 1. – № 1. - P. 26–35.
3. E. V. Kochyna, P. A. Zatoloka MODERN APPROACHES TO PLASTICS OF BONE DEFECTS OF THE PARANASAL SINUSES// Medical journal.– 2022. – № 2. – C.12–16.
4. Fedorov, Andrey. 3D Slicer as an Image Computing Platform for the Quantitative Imaging Network / Andrey Fedorov, Reinhard Beichel, Jayashree Kalpathy-Cramer // Magn Reson Imaging. – 2012. – Nov., № 30 (9). – P. 1323–1341.
5. Kochyna, E.V. Modern possibilities and directions of using 3D modeling in otorhinolaryngology / E. V. Kochyna, P. A. Zatoloka // Military medicine - 2023. – No. 1. – pp. 53-58.

Материалы XXXIV международной научно-практической конференции

Наука в современном информационном обществе

8-9 апреля 2024 г.

Bengaluru, India