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Application of 3D Technologies in Surgery on the Example of Liver Echinococcosis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Preoperative assessment of an echinococcal liver cyst with surrounding tissue structures is extremely important for planning the course of surgical intervention. The paper presents the first experience of treating a patient with a parasitic cyst using three-dimensional reconstruction of the liver affected by echinococcus at the preoperative stage. The use of this approach made it possible to avoid the development of intraoperative complications and get a good treatment result.

Keywords: Echinococcosis; liver; 3D technology; HoloDoctor; surgery; DICOM.

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1. INTRODUCTION

The laparoscopic approach in the treatment of echinococcal liver cysts is one of the rapidly developing directions in the surgical treatment of this parasitic pathology [1]. At the same time, the preoperative assessment of the cyst condition and the planning of a surgical treatment strategy are based on radiation imaging methods (ultrasound, magnetic resonance imaging (MRI) and computed tomography (CT)) [2-4]. Unfortunately, most of these diagnostic techniques have the ability to represent the image in two projections [5-7].

A promising direction of medical visualization is virtual three-dimensional (3D) reconstruction using specialized software, which allows not only to better represent the spatial relationships between the cyst and the surrounding anatomical structures, but also to study surgical anatomy in an interactive form before surgery [8-11]. Three-dimensional reconstruction allows you to quickly and visually provide images in 3D, using the standard for creating, storing, transmitting and visualizing digital medical images (DICOM) from data obtained during MRI or CT [12-16].

Currently, there is a fairly large number of studies that emphasize the usefulness and need for the development of 3D technologies in medicine, both from an educational point of view, and for planning and surgical training [17-24]. Unfortunately, there are very few studies evaluating the anatomical features of bile and vascular changes under the influence of a parasitic cyst and the possibility of reducing intraoperative complications (wounds of liver structures, the development of bile fistulas, etc.) by creating a 3D reconstruction in the laparoscopic hepatology of echinococcosis.

The purpose of this study was to evaluate the effectiveness of using 3D liver reconstruction technology in laparoscopic treatment in a patient with an echinococcal liver cyst.

2. MATERIALS AND METHODS

Under our supervision in the clinic of pediatric surgery there was a patient V., 8 years old (medical history No. 1324) with a clinical diagnosis: Echinococcal cyst of the VII-VIII segments of the liver. Stage-CE1.

The patient complained of pain in the right hypochondrium. From the anamnesis – there was a close contact with a dog living in the yard, which was fed sheep offal (liver, lungs and kidneys). The condition is closer to satisfactory. The skin is pink, clean. There are no peripheral edema. Frequency of respiratory movements – 19 per minute. No pathology from the respiratory system was detected during auscultation. Heart rate-89 beats / min, blood pressure-116/69 mmHg. Heart tones - sonorous, rhythmic. On the part of the liver, its departure from under the edge of the costal arch by +2 cm was noted, the edge was acute, elastic, moderately painful along the mid-clavicular line. Symptoms of irritation of the peritoneum and *defans musculorum* are negative. The child underwent a comprehensive examination, including ultrasound of the abdominal organs: a parasitic cyst of the right lobe of the liver. Liver CT scan: echinococcal cyst of the right lobe of the liver in segments VII-VIII, measuring 69.6 mm in diameter, volume 350 cm^3, cyst type CE1 (Fig. 1). According to the conducted laboratory research: there is an increase in eosinophils in the general blood test (6%). Biochemical blood analysis did not show any pathological changes. Enzyme immunoassay with determination of IgG class antibodies to Echinococcus in blood serum-1/50 (titer less than 1/100 result – negative).

The child underwent a preoperative chemotherapy cycle with the antiparasitic drug Nemazol at a dose of 15 mg/kg for 14 days.

The patient underwent a 3D reconstruction of the liver. The data for 3D reconstruction were obtained in DICOM format from the CT scan and processed in the following programs: DoctorCT version 1.0 (Stavropol, Russia) with the DICOM module version 3.0, Cyberscliff 1.0 (Stavropol, Russia-certificate of state registration No. 2017619901); the program for viewing Builder3D bundled with Windows 10 (Microsoft, USA). CT images were obtained by a multi-dimensional high-resolution scanning method with a slice thickness of 0.5 mm. Next, two-dimensional images were processed using medical image processing algorithms. Initially, a noise reduction algorithm (anisotropic diffusion filter) was used, and then an algorithm for segmenting the anatomical structures of interest and creating a three-dimensional image of each structure. These images were exported to a sterolitographic (stl) file. After that, the final processing of the virtual reconstruction was performed.

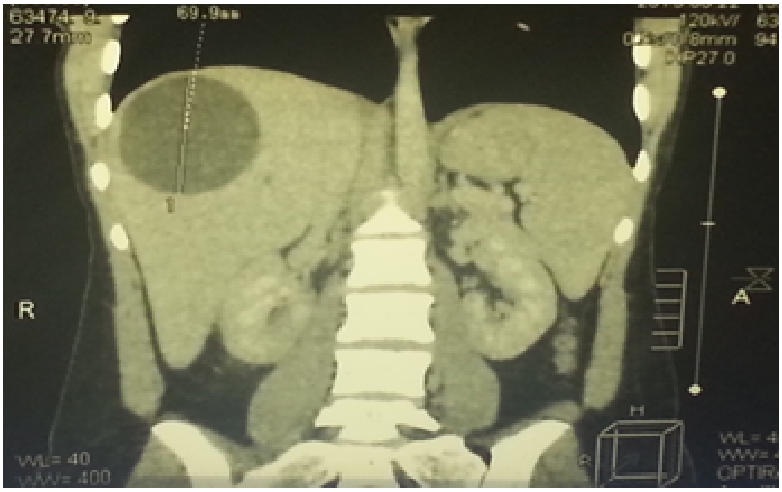
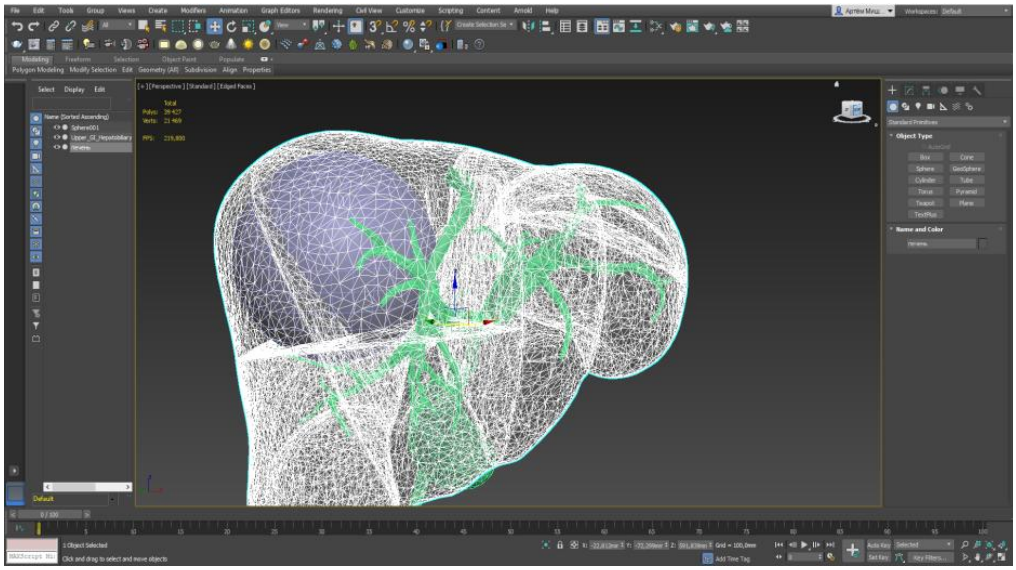


Fig. 1. Computed tomography of the liver of a patient with an echinococcal cyst of the VII-VIII segment of the liver, measuring 69.6 mm in diameter, with a volume of 350 cm^3

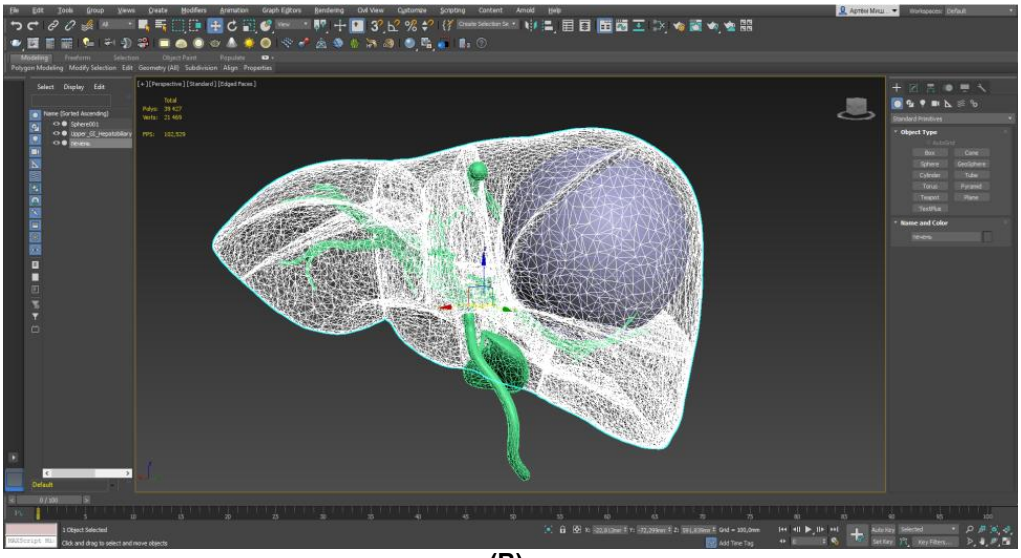
3. RESULTS AND DISCUSSION

In the preoperative period, we applied the technology of creating a 3D reconstruction for the topical determination of a parasitic cyst in the liver and its relationship with large vessels and bile ducts (taking into account the possibility of opening bile fistulas in the postoperative period). During the creation of the 3D model, the real topical location of the cyst was revealed, both in the organ and in relation to the abdominal wall and cavity. At the same time, the presence of intimate contact between the cyst and the segmental bile duct was established, as well as the attraction of the thinnest liver tissue with the cyst to the right lateral and posterior surface of the abdominal cavity (Fig. 2).

Based on the data obtained, we have compiled the tactics of surgical treatment, taking into account the data obtained and the expected difficulties in carrying out the surgical manual. Taking into account the 3D reconstruction of the liver with a cyst, the setting of laparoscopic ports was changed [7]. The first 5mm port was installed in the pericupial area (for the video camera). The second port (5 mm) was located in the right mesogastrium along the antero-axillary line. The third port (Endopath Xcel, Johnson & Johnson (USA) 12 mm) is installed in the epigastrium along the middle line. The rotation of the child with the operating table on the left side with the raised head end was performed. After the liver revision, the data on the 3D reconstruction of the liver with the localization of an echinococcal cyst were fully confirmed. In the place of the greatest fibrous changes in the liver, they were covered with tape napkins soaked in glycerin. Next, a cyst puncture was performed with the evacuation of a clear liquid in the volume of 390 ml. Glycyrine was injected into the cyst with an exposure of 5 minutes and its subsequent evacuation. Using the G11 electrosurgical ultrasound generator and Enseal Artificial bipolar coagulation (Johnson&Johnson, USA), the cyst was opened and the fibroly altered liver tissue with its “refined” parenchyma was removed. An endomesh was inserted through a 12 mm trocar, followed by immersion in it and evacuation of the chitin shell and resected cyst walls. During the revision of the residual cavity, as was established during the creation of the 3D reconstruction, a biliary fistula was found, which opened in depth and was covered with a fibrin film. It and the residual cavity were treated with a plasma flow using an Arco 3000 electrosurgical device (Söring GmbH, Germany). To control the effectiveness of the performed manipulation, the PVC drainage was placed in the residual cavity. In the postoperative period, the presence of a small flow rate of the bile discharge was visualized by the control drainage. Conservative therapy (diet therapy, antisecretory therapy) was carried out. On day 7, the drainage was removed from the abdominal cavity. A control ultrasound on the 10th postoperative day showed the presence of a slit-like cavity up to 1.0 cm in size. The child was discharged with recovery under the supervision of a pediatrician and a pediatric surgeon at the place of residence.



(A)



(B)

Fig. 2. 3D reconstruction of the liver. The cystic formation of the liver is visualized in the VII-VIII segment of the liver, with adjacent segmental and subsegmental bile ducts. A – top view; B-bottom view

The technology of virtual reconstruction of organs and pathological structures containing them is an extremely popular trend in modern invasive medicine. Based on the joint work of the surgical team and the IT team, we have gained successful experience in using a new high-precision instrument for modern surgery. Since the 3D reconstruction developed from CT images in the form of DICOM files was useful not only when the operation was planned, but also proved to be a useful tool during surgery.

In the planning of surgical intervention, a better understanding of spatial relations can be obtained by studying the pathological structure in an organ or tissues in an interactive mode in 3D format, since this approach helps to more accurately assess the conditions under which the operation can be performed, as well as to predict and prevent possible complications. To date, there are numerous publications on various sections of oncology, in which virtual reconstruction before surgery is already a routine

event (removal of a tumor, placement of endovascular and endobronchial prostheses, etc.). In addition to virtual 3D reconstructions, there are more and more opportunities to create 3D models of organs and tissues. A new field is opening up for surgery of the future, in which it is possible to create a 3D model of the organ and its surrounding structures so realistic that it is possible to work out an operative reception for a personal patient, taking into account all the anatomical nuances that can be implemented in a printed model. This reduces the operation time and significantly improves its safety for the patient. An additional value of 3D modeling is the possibility of visual representation of the course of surgical intervention for the patient and his family, thereby improving the relationship between the doctor and the patient.

4. CONCLUSION

Thus, the result obtained in this work indicates that the use of virtual 3D reconstruction in surgical hepatology is a useful tool for improving the result of laparoscopic echinococcectomy and in the future will take an appropriate place in the planning of preoperative preparation.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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