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Application of Augmented Reality Technology in Abdominal Surgery in Patients with Liver Diseases

Sabina Anvarovna Medzhidova[1], Nariman Aminullaevich Koshenov[2], Lianna Ruslanovna Nahusheva[3], Aminat Arturovna Gafurova[1], Alexandra Yuryevna Kara[4], Patimat Kamilevna Abakarova[1], Liliya Vyacheslavovna Khomutova[5], Ali Abdulkhalimovich Dolaev[5], Artem Evgenievich Mishvelov[5,6]

[1] *Dagestan State Medical University, Makhachkala, Republic of Dagestan, RUSSIA.*
[2] *Saratov State Medical University, Saratov, RUSSIA.*
[3] *Kabardino-Balkarian State University, Nalchik, Republic of Kabardino-Balkaria, RUSSIA.*
[4] *Rostov State Medical University, Rostov-on-Don, RUSSIA.*
[5] *Stavropol State Medical University, Stavropol, RUSSIA.*
[6] *Socmedica, Skolkovo, Moscow, RUSSIA.*
**Corresponding Author (Tel: +79183500889, Email: EMishvelov @yandex.ru).*

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Abstract

Currently, there is an increase in liver diseases requiring surgical intervention. The analysis of medical literature revealed the most important issues in surgical hepatology: diagnosis, planning of surgical intervention and prevention of complications. Augmented reality technology is widely used in modern medicine to solve the tasks set. Russian scientists have created a software package "HoloDoctor", which allows solving the tasks. At the same time, the time of operations using the HoloDoctor software package is reduced by 20-30% compared to traditional methods. The developed complex provides the diagnosis of the disease and treatment planning, and also allows performing surgical operations in real-time, minimizing the risk of medical error and preventing the development of complications.

Disciplinary: Medicine, therapy

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1 Introduction

Currently, there is an increase in the number of patients with surgical liver pathology requiring surgical intervention [1].

According to the medical literature, hepatocellular cancer ranks 7th in the structure of cancer incidence in the world. Metastatic liver damage is diagnosed in 20-70% of oncological patients, liver hemangiomas account for about 2% of benign liver formations. Cases of diagnosis of parasitic cysts (echinococcosis of the liver, opisthorchiasis liver abscesses) are not uncommon. Cases of combined damage to the liver and other abdominal organs have increased [2].

Surgical interventions have a high risk of intraoperative and postoperative complications, posing a threat to the patient's life. Therefore, the surgeon requires knowledge of the anatomical features of a particular patient and high accuracy during the operation [3].

One of the most difficult types of abdominal surgery is liver surgery, which is performed by a hepatologist surgeon [4]. The following benign and malignant diseases of the liver and bile ducts require surgical treatment: liver abscess, liver cyst, echinococcosis, liver hemangiomas, liver adenomas, liver cancer, bile duct cancer, liver metastases [5].

At the present stage in surgical hepatology, one of the most difficult and debatable problems of liver diseases is the diagnosis and surgical interventions. Modern technologies are widely used to reduce the risk of medical errors at the stage of diagnosis, optimize surgical intervention and prevent the development of complications [6-12].

2 Literary review

A global trend in the development of the healthcare system is the use of virtual, augmented and mixed reality technologies in medicine. Augmented reality is the integration of digital information in the form of images, computer graphics, text, video, audio and other objects of the real (physical) world in real-time. Virtual reality creates a computer simulation of objects and situations of a real or physically non-existent world, while the user, being in virtual reality, can perform actions with virtual reality objects, move in it in real-time, receive information through the organs of vision, hearing, smell and touch [13]. The combination of augmented and virtual reality is called mixed reality, in which the objects of the virtual world are organically integrated into the physically existing world, forming a single whole and forming a new reality [14,15].

The use of augmented reality technology in surgical hepatology has found application with the help of specialized software "HoloDoctor". The operation of this technology is based on the creation of a virtual three-dimensional (3D) reconstruction of the organ and adjacent tissues, providing an opportunity to visualize the spatial relationship between the pathological focus and the surrounding anatomical structures, thus, studying surgical anatomy in an interactive form before surgery in a particular patient [16]. Three-dimensional reconstruction allows you to quickly and visually present images in 3D using the standard for creating, storing, transmitting and visualizing digital medical images (DICOm) from data obtained during MRI or CT [17,18]. The developed software package "HoloDoctor" is used by doctors, according to the built technological cycle. The technological cycle is based on the following algorithm:

• Creation of a conveyor system for digital processing of Dicom images (in the radiology department), which allows for reconstructions of organs with CT, MRI, then the obtained 3D models of organ systems or a separate organ after digital processing are uploaded to a PACS server or to a surgical intervention simulator for further use.

• Uploading to the graphics station from the PACS server on the ARM or from the station itself (with HoloDoctor.Viewer) into the HoloDoctor.Surgery 3D simulator program of an organ or organ system (a multi-layered (segmented) model with vessels and a pathological focus).

• Processing by the operator (surgeon) of the 3D model.

• Saving the finished script as a 3D model or video recording to the PACS server.

• Downloading ready-made scenarios of surgical intervention simulation in the operating room from the PACS server to monitors [19].

The developed module for simulation of surgical intervention planning has a number of advantages, thanks to the following functions:

1. Loading 3D models of organs and organ systems (multilayer) in obj format.

2. Placement of key points of interest in surgical intervention and selection of surgical instruments for simulation of surgical intervention.

3. Incision and stitching of liver tissues and surrounding tissues in real-time simulation; intraoperative navigation of surgical intervention in real-time; overlay of a map of blood vessels in the liver (portal vein, hepatic artery, hepatic ducts, gallbladder duct).

4. Alarm in dangerous situations during simulation of surgical intervention [20].

The principle of operation of the surgical intervention Module using "HoloLens" glasses it is based on medical imaging [21]. To plan the course of a surgical operation, it is necessary to work out the operation scenario. The patient is undergoing a standard CT or MRI procedure [22]. Next, the radiologist builds a 3D model of the internal organs and tissues of the surgical field zone from the Dicom images obtained. The developed software module for viewing Dicom images allows you to identify pathological neoplasms in order to assess the severity and dynamics of pathological processes (diseases). Next, the surgeon plans an operation scenario based on the resulting 3D model.

Before the operation, the doctor puts on augmented reality glasses, the visualization system projects a 3D model onto the skin. The surgeon begins the operation. Throughout the operation, the navigation system monitors the position of the instruments, and the access trajectory in accordance with the intended scenario [23,24].

Module functionality:

1) Alarm system about the danger of approaching the most important blood vessels.

2) Surgical navigation based on optical infrared tracking.

3) Measuring the distance from the tip of the pointer to anatomical structures.

4) Specialized loader convector 3D models in the simulator, i.e. loading multi-layered 3D models of the human body, organ, and organ systems (kidneys, heart, human body with CT, MRI).

5) Export the results of building 3D models of organs for 3D printing.

6) The ability to make an incision in any place of the organ, or body.

7) Action function: "Making an incision" and animation of the opening of tissues in a pre-selected place on the model by the user's hand.

8) Intraoperative navigation of surgical intervention without ultrasound devices.

9) The possibility of angioscopy (virtual viewing of the cavity of organs, and vessels).

10) The possibility of virtual colonoscopy (viewing blood vessels from the inside).

11) Navigation of the course of surgical intervention (“HoloLens").

12) Cutting and stitching with a laser scalpel.

13) Laser stitching of wound tissues.

14) The possibility of specifying reference points.

15) Illumination of fabrics.

16) Full access to the field of surgery: scaling of the model of an organ or organ systems, image detailing, which allows you to study every centimeter of the body and each of its inner layers-files obtained on CT and MRI.

17) Selection of modes (additional modules) for dentistry, traumatology on a computer and in augmented reality glasses.

The developed complex provides diagnostics and planning of surgical intervention taking into account the topographic and anatomical relationships of the pathological focus with the liver, large vessels and bile ducts in a particular patient and reduces the risk of medical error [25].

The analysis of domestic and foreign literature shows that, despite the long period of development of surgical hepatology, the problems of diagnosis, treatment and prevention of complications remain relevant [26-28]. Currently, modern augmented reality technologies are being introduced into surgical practice to solve the tasks set. Therefore, the purpose of this study is to study the features of the use of augmented reality technology in abdominal surgery for liver diseases.

3 Method

This study examines the clinical case of patient M., born in 1985, who applied to a medical institution with complaints of aching pains in the epigastric region and right hypochondrium, hyperthermia up to 40°C with chills, sweating, feeling weak, significant weight loss. This condition is noted within two weeks.

It is known from anamnesis that for several years he has been consuming river fish, including raw which corresponds to consumer behavior and industry implications for recent years [29].

Physical examination: the condition is severe, the patient is adynamic, and the skin and mucous membranes are icteric. In the lungs, there is a weakening of breathing on the right. Heart tones are rhythmic, muted, blood pressure is 90/60 mmHg, the pulse is 100 beats per minute, and weak filling. The abdomen is soft, painful in the epigastric region and the right hypochondrium. The liver protrudes from under the edge of the costal arch by 5 cm, its edge is smooth, dense, and painful. The size of the liver according to Kurlov is 25 x 18 x 15 cm.

Laboratory tests: general blood test - hemoglobin 98 g/l, erythrocytes 3.6 · 1012 /l, leukocytes 8.0 · 109 / l, ESR 33 mm/h; biochemical blood test - hypoproteinemia and increased transaminases; stool analysis - eggs of Opisthorchis felineus; blood culture revealed hemolytic staphylococcus.

Instrumental studies: liver scintigraphy - the liver is enlarged in size, and the accumulation of radiopharmaceutical is sharply reduced in the upper pole of the right lobe; a similar picture in the posterior and lateral projections. Rheohepatography - blood filling processes are disrupted in all departments, volumetric blood flow is significantly reduced in the right half of the liver. Computed tomography (CT) using a multi-dimensional high-resolution scan with a 0.5 mm slice thickness diagnosed a liver abscess and a cyst of the right lobe of the liver.

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 computer programs: DoctorCT version 1.0 (Stavropol, RF) with DICOm module version 3.0; Cyberscliff 1.0 (Stavropol, RF - certificate of state registration No. 2017619901); program for viewing Builder3D bundled with Windows 10 (microsoft, USa). Next, two-dimensional images were processed using medical image processing algorithms [30]. Initially, a noise reduction algorithm (anisotropic diffusion filter) was used, and then an algorithm for segmenting 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.

Augmented reality technology was used in the work - virtual 3D reconstruction of the liver, surrounding tissues and pathological structures using the HoloDoctor software and hardware complex, which includes the following modules: anatomical atlas module, data analysis module and surgical intervention simulation module, through the use of augmented reality glasses.

4 Result and Discussion

Due to the severity of the patient's condition, a puncture and drainage of the liver abscess were performed under local anesthesia. During the puncture, up to 800 ml of thick pus was evacuated and active aspiration from the abscess cavity was established. Active antibacterial and detoxification therapy was carried out, the cavity was sanitized through drainage.

Against the background of the treatment, the patient's condition stabilized and after 2 weeks from the moment of hospitalization, surgery was performed.

Augmented reality technology was used in the preoperative period. To determine the localization of liver abscess and parasitic cyst, their relationship with large vessels and bile ducts, a 3D reconstruction of the area of surgical interest was created. At the same time, it was found that the right half of the liver was “soldered” to the diaphragm. In the right lobe of the liver, there is a spherical seal with a diameter of up to 15 cm. The gallbladder is stretched, and poorly emptied. The right vessels and duct are isolated and doped in the liver gate. The right hepatic vein is stitched through the liver tissue.

Based on the information received, the tactics of surgical intervention were compiled taking into account the topographic data and the expected intra- and postoperative complications. Taking into account the 3D reconstruction of the liver, doping of the elements of the neck of the gallbladder was performed, right hemihepatectomy, omentohepatopexy was performed. Halstead-Pikovsky drainage was installed in the bile ducts, through which purulent bile with a large number of opisthorchis was released. Drainage of the right subdiaphragmal space was carried out.

A large abscess and several small ulcers were detected in the preparation of the right half of the liver. Histological examination: opisthorchiasis purulent cholangitis with liver abscesses.

It should be noted that the data of 3D reconstruction of the liver and adjacent tissues with a pathological focus during surgery completely coincided.

In the postoperative period, the patient suffered right-sided pleurisy, stopped by punctures. The ducts were washed through the drainage with antiseptics, iodinol and antibiotics. After that, recovery came with a favorable prognosis.

The conducted research has shown that currently, the use of augmented reality technology in abdominal surgery for liver diseases is an urgent direction. In this work, using a specific example, the development of domestic scientists - the HoloDoctor software and hardware complex in the mode of the Simulation Module for surgical intervention planning was successfully used as innovative technology.

5 Conclusion

Augmented reality technologies are increasingly being used in modern healthcare. The main objective of augmented reality technology is to transfer 3D objects in real-time to a real environment, creating the opportunity to plan surgical interventions in abdominal surgery. In the planning of surgical intervention, an understanding of spatial relationships can be obtained by studying the pathological structure in an organ or tissues in real-time in 3D format. 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.

The practical activity of a hepatologist surgeon is closely related to the risk of medical error at the stage of diagnosis and treatment planning, intraoperative and postoperative complications. Therefore, domestic scientists have developed a software package “HoloDoctor”, which allows performing surgical operations in real-time and includes the following modules: anatomical atlas module, data analysis module and surgical intervention simulation module, through the use of augmented reality glasses “HoloLens".

Thanks to innovative technology, the time of operations using the HoloDoctor software package is reduced by 20-30% compared to traditional methods. The developed complex provides diagnostics and planning of surgical intervention taking into account the topographic and anatomical relationships of the pathological focus with the liver, large vessels and bile ducts in a particular patient and reducing the risk of medical error.

Thus, in modern medical practice, the use of augmented reality technology in abdominal surgery for liver diseases is a popular and relevant direction.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgement

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Sabina Anvarovna Medzhidova is a student of Dagestan State Medical University, Makhachkala, Republic of Dagestan, Russia

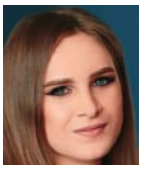
Nariman Aminullaevich Koshenov is a Student of Saratov State Medical University named after Razumovsky, Saratov, Russia

Lianna Ruslanovna Nahusheva is a student of Kabardino-Balkarian State University, Nalchik, Republic of Kabardino-Balkaria, Russia

Aminat Arturovna Gafurova, student of Dagestan State Medical University, Makhachkala, Republic of Dagestan, Russia

Alexandra Yuryevna Kara is a Student of Rostov State Medical University, Rostov-on-Don, Russia

Patimat Kamilevna Abakarova is a student of Dagestan State Medical University, Makhachkala, Republic of Dagestan, Russia



Liliya Vyacheslavovna Khomutova is a student of Stavropol State Medical University, Stavropol, Russia

Ali Abdulkhalimovich Dolaev is a student of Stavropol State Medical University, Stavropol, Russia

Artem Evgenievich Mishvelov is a Junior Researcher at the 3D Technology Laboratory of Stavropol State Medical University, Stavropol, Russia. Head of Project Activities in the North Caucasus Federal District, Socmedica, Skolkovo, Moscow, Russia.