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HOLODOCTOR PLANNING SOFTWARE REAL-TIME SURGICAL INTERVENTION

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ABSTRACT

Objective: Today we have quite a lot of methods of examination, which include computer and MRI, ultrasound with three-dimensional image reconstruction, etc. However, there are cases when it is difficult to isolate a tumor from an organ and calculate its volume characteristics, for example, tumor in the abdomen. So, it is important to carry out analytical research of modern computer software ability and to find the optimal one. Methods: The following programs were used to compare the results of studies (CT and MRI reconstruction): Vitrea2 and DoctorCT-Slicer. Of more than 300 patients, mostly with kidney disease, who underwent examination and processing of the results using these programs in the CCC, a random sample of 120 people, formed three comparison groups. 60 clinical cases were treated using the program Vitrea2 and the results of the 60 clinical cases were processed through our AT the HoloDoctor. Results: The analytical research of general parameters of 3 software: HoloDoctor, DoctorCT-Slicer, Vitrea2 was conducted. 2 real clinical cases were reviewed by using augmented reality glasses – HoloLens. Conclusion: The loading of 3D models of the organ or organ systems with the presence of a simulation module to DoctorCT-Slicer will allow preoperative simulation actions including the use of holographic reality glasses. The program DoctorCT-Slicer also provides the integration of 3D reconstructions of bodies in the simulation complex HoloDoctor with the use of holographic reality points to simulate surgery.

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Introduction

Currently, the number of patients who need high-tech surgical interventions in the provision of medical care in the fields of urology, oncology, and cardiovascular surgery is growing. Patients with a complex pathology need diagnostics based on the use of digital technologies. Today we have quite a lot of methods of examination which include computer and magnetic resonance imaging (MRI), ultrasound with three-dimensional image reconstruction, etc. However, there are cases when it is difficult to isolate a tumor from an organ and calculate its volume characteristics, for example, tumor in the abdomen.

Majority of computer software for view, description, and reconstruction of DICOM images adapted for foreign users. The interfaces of such programs are cumbersome and difficult to configure. Besides, the use of a long time (about 3-4 hours per patient) is spent on manual processing and reconstruction of medical images of DICOM-files [1,2].

The creation of 3D models of organs in such programs as Vitrea, Amira is quite successful but requires a few long time and additional resources. In addition, existing computer software is not able to create 3D models of the internal structure of organs, if the images were obtained without the use of contrast agents [3].

Moreover, there is practically no medical program based on the use of holographic images superimposed on real objects (technology of mixed reality HoloLens) for both diagnostic clinicians and doctors.

For surgeons performing cavity operations, the accuracy of positioning and depth of penetration of tools are important. Often, urologist surgeons for removing the tumor in the brain substance of the kidney, act almost blindly. Experts use the

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tumor ultrasound machines and intraoperative MRI scanner to refine the localization, but this navigation method is inconvenient, cumbersome, and harmful for the health of the surgeon.
The developed earlier program complex DoctorCT did not completely solve the needs of the radiologists and surgeons, so it was decided to adapt and modify the program using the program designer, 3D Slicer.
The aim of our work was to test the developed software complex HoloDoctor with an additional module, DoctorCT-Slicer [3], which allows the reconstruction of images obtained with the help of a computer and MRI and planning for complex abdominal operations with the use of mixed reality.

Material and Methods

Software HoloDoctor development was conducted by the staff Stavropol State Medical University (StSMU) and North Caucasus Federal University (NCFU), a study of the possibilities of this program in the Radiology Department and in the surgical hospital short-stay Stavropol regional Clinical Consultative and Diagnostic Center (SCCCD).
The materials were the images of patients' organs (DICOM-files) obtained by MRI on PHILIPS "Ingenia 1.5 T" and multispiral computed tomography on Toshiba's "Aguilion 64" during 2015-2018. During the testing of the program, HoloLens mixed reality glasses were used.
Vitrea2 and DoctorCT-Slicer programs were used to compare the results of the studies (CT and MRI reconstruction). Of the more than 300 patients, mostly with kidney disease, who underwent examination and processing of the results using these programs in the CCC, a random sample of 120 people, formed three comparison groups. 60 clinical cases were treated using the program Vitrea2 and 60 clinical cases were processed through our AT the HoloDoctor. The majority of patients were examined for diseases of parenchymal organs. The examination also revealed 1 patient was with 2 tumors and metastases in one kidney; 10 patients with tumor processes (up to 6 mm in size) in the kidneys; 15 patients revealed metastases of tumors in the kidneys from distant organs; 1 patient was examined with cardiac myxoma; and 10 clinical cases had renal hydronephrosis.

Results and Discussion

We conducted research related to the integration of reconstructions of three-dimensional images in the HoloDoctor software package for simulation of surgical intervention in augmented reality glasses HoloLens.
Table 1 shows the analytical comparison of functional parameters of HoloDoctor, DoctorCT-Slicer, and Vitrea2 computer software.

Table 1: Comparison of developed software functional parameters

Computer software	HoloDoctor	DoctorCT-Slicer	Vitrea2
Functional	1.Automated assessment of the form and volume of the detected tumors. 2. Downloading the obtained 3D models of organ or organ systems to the simulation module. 3. Visualization and segmentation of Dicom images in semi-automatic mode 4. Quantitative, morphological, and functional analysis of images and 3D models. 5. View and describe Dicom in mixed reality HoloLens glasses. 6. The open source code of the software package. 7.Reconstruction of the organ without the use of contrast agent. 8.The function of semi-automatic removal of artifacts during Dicom reconstruction. 9. The ability to highlight the anatomical structures of the organs by tinting objects. 10. Possibility to send 3D models for 3D printing. 11. The preservation of layered painted model of the body.	1. Image processing is carried out only in manual mode 2. Downloading the obtained 3D models of organ or organ systems to the simulation module. 3. Reconstruction of the organ using a small amount of contrast agent. 4. Export images to a graphic file or a new series of DICOM images 5. Calibration of the image dimensions; display of projection images in other series. 6. Possibility to send 3D models for 3D printing. 7. Construction of 3D models based on several series of images of the same fabric shot in different modes.	1. Improved 2D, 3D and 4D imaging and analysis of medical images. 2. Image processing is carried out in manual mode 3. Quantitative and functional analysis of images and 3D models. 4. Export images to a graphic file or a new series of DICOM images 5. Reconstruction of the organ using a small amount of contrast agent. 6. Carrying out multiplanar reconstruction.

Two programs were used for the comparison of the results of studies (CT and MRI reconstruction): DoctorCT - Slicer, and Vitrea. The results are illustrated by the following clinical cases.

Clinical case No. 1. Optional description of volumetric education of the right kidney (tumor) algorithm "Pachipara and Enrico»:

Two programs DoctorCT-Slicer and its foreign analog, Vitrea2 were used for 3D reconstruction of the heart obtained by CT (using bolus contrast and injector) and MRI. 2 tomographs (different technologies) were used specifically for the comparison of the results of the study, as well as to build a three-dimensional multilayer model of the heart. The data of a patient (a 57-year-old woman) who complained of chest pain, short breath, and high blood pressure were processed.

Preoperative examination data:

CT of the heart: There was a parietal formation on the right wall of the left atrium, fixed on the leg, and modular structure with calcifications. The contours were clear. The formation extended to the mouth of the right upper pulmonary vein, with the size of 27.8 × 17.3 × 13.9 mm.

DIAGNOSIS: Neoplasm in the left atrium, left atrial myxoma.

The program Doctor CT-Slicer allowed to make more various and convenient manipulations with visualization of anatomical features of the heart, to carefully study the area of surgical intervention and highlight the tumor color in the left atrium (tumor) while maintaining a 3D model of the reconstructed heart for the simulation of surgical intervention in real time, based on the specific morphological features of the patient in the simulation software HoloDoctor. In addition, the technology of mixed reality-HoloLens holography glasses- were used for visualization and description of the clinical case, as well as for further surgical intervention planning in the form of viewing and cutting through the layers of the 3D model of the heart. This allowed the radiologist to quickly describe the clinical case and perform a correct diagnosis in 20 minutes, and the surgeon to plan the operation.

Clinical case No. 2. Two programs DoctorCT-Slicer and Vitrea were used for 3D reconstruction of studies obtained by CT (using bolus contrast and injector). The data of a patient (a 67-year-old woman) who complained of the CCC of aching pain in the hypochondrium on both sides were processed.

Preoperative examination data:

CT of the kidneys: Signs of heterogeneous volume formation in the left kidney, were observed with the size of 57.8 × 37.3 × 43.9 mm (see figure 1). The excretory renal function was not impaired.

Preliminary Diagnosis of the tumor in the upper pole of the left kidney:

The program DoctorCT-Slicer gave some great opportunities to conduct manipulation with the visualization of the anatomical features of the kidney, carefully examine the area of the surgical intervention, and "paint" the tumor of the left kidney (the tumor) while preserving the reconstructed 3D model of the kidney with a cyst for simulation of the surgical intervention in real time, based on the patient's specific morphological characteristics in CyberSklif, and the virtual endoscopy of the organs and blood vessels (in our case, the ureter, calyx, and pelvis of the kidney, descending part of aorta).

Two programs DoctorCT-Slicer and Vitrea were used for 3D reconstruction of studies obtained by CT (using bolus contrast and injector). The data about the patient (a 67-year-old woman) who complained of the CCC of aching pain in the hypochondrium on both sides were processed.

Preoperative examination data:

CT of kidneys: Signs of heterogeneous volume formation in the left kidney was observed with the size of 57.8 × 37.3 × 43.9 mm (see figure 1).

The excretory renal function was not impaired.

DIAGNOSIS: Tumor in the upper pole of the left kidney was proved.

Conclusion: The program DoctorCT-Slicer gives more opportunities to conduct manipulation with the visualization of the anatomical features of the kidney, carefully examine the area of the surgical intervention, and "paint" the tumor of the left kidney (the tumor) while preserving the reconstructed 3D model of the kidney with a cyst for the simulation of the surgical intervention in real time, based on specific morphological characteristics of the patient in the complex HoloDoctor. The program Vitrea cannot save the reconstructed 3D model of the organs (in this case, a kidney) for 3D printing and visualization in a specific color (brown kidney, red arteries, and yellow or red tumors), there is no way to save multi-layered painted model of the body. However, it is possible to conduct a virtual endoscopy of organs and blood vessels (in our case, the ureter, cups, and pelvis of the kidney, the descending part of the aorta).

An important functional advantage of the new program was the possibility to transfer the images to HoloLens – the augmented reality glasses.

Conclusion

Software DoctorCT-Slicer allows an automated evaluation of the shape and volume of the detected tumors, makes it possible to identify the anatomical structure by touch-up objects and gives high-definition images of their reconstruction due to the higher quality image artifacts.

Loading the 3D models of the organ or organ systems into DoctorCT-Slicer in the presence of a simulation module will allow preoperative simulation actions including the use of holographic reality glasses.

The program DoctorCT-Slicer also provides the integration of 3D reconstructions of bodies in the simulation complex, HoloDoctor, by using the points of holographic reality for simulating the surgery.

Recommendations

Software DoctorCT-Slicer can be used for the development of additional software systems for planning surgical interventions to optimize the quality of images, construct clearer structures in 3D models, and create a database of DICOM images, using neural networks for automatic recognition of medical images and a preliminary diagnosis under the supervision of a specialist.

Author's Contribution

G. J. Hite provided clinical research by doing a practical investigation. A. E. Mishvelova, G.A. Bledzhyants, and C. V Nuzhnaya tested the software and carried out the analytical research. E. A. Melchenko and A.A. Vlasov assisted in providing clinical research. O.I. Anfinogenova managed the scientific work, M. Yu. Kukharchuk prepared the manuscript, Osadchiy S.S. optimized the software, synchronized the software, and augmented reality glasses.

Conflict of Interest

The authors declare no conflicts of interest.

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