Research Article

Features of the use of Methods of Planning and Conducting Surgical Interventions in Orthopedics with the Assested Technology of Additional Reality

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Abstract

The purpose of this work was to investigate the possibilities of using augmented reality and computer processing in the holo doctor program in traumatology (osteology), as well as to test in practice the methodology developed by us for planning and conducting surgical interventions on the skeleton with the assested technology of additional reality. The technique developed by us allows us to perform preoperative planning using original software and additional reality glasses (additional reality complex). During the operation, the additional reality complex performs assistance, providing access to the data of additional methods of examination of the patient and making an "overlay" on the operating field in glasses of additional reality of normal anatomy or previously performed MRI or CT data. A new method of simulation and use of augmented reality glasses with the holo doctor program for implantological treatment demonstrated a good visualization of both the anatomical features of the implant placement zone, the possibility for the surgeon to carefully study the intervention zone before the operation, to perform surgical intervention in the conditions of the patient's real anatomy, including with the use of augmented reality navigation. In 2019-2021, more than 40 operations were performed on the knee joints, ligaments and spine.

Keywords: Surgical intervention; Additional reality glasses; Robotic assisted surgery; 3D images

Introduction

Patients with complex pathology are prescribed examinations based on digital technologies for the purpose of diagnosis. [1-4] To date, these methods of examination include computer and magnetic resonance imaging. [5,6] Modern software for processing images obtained during CT and MRI is supplied together with these devices. [7] The functions of these programs are sometimes not enough for carrying out more complex work with the obtained data, including for differentiating tumors in various diseases. [8-11] The creation of 3D models of organs on these programs is carried out quite successfully, however, it requires somewhat large time costs and additional resources. [12-16] In addition, the software used is not able to create 3D models of the internal structure of organs if the images were obtained without the use of contrast agents. [6,17-21] In addition, there is a very limited number of programs for viewing, describing and reconstructing DICOM images obtained from CT, MRI, for diagnosis and treatment planning using neural networks (for example, Amira for life sciences (Germany), UNIM (Russia)). In addition, there are practically no medical programs based on the use of holographic images superimposed on real objects (hololens mixed reality technology) for both diagnostic doctors and surgeons.

Recently, many high tech methods of diagnosis and treatment of various diseases has appeared (X-ray, MRI, ultrasound, PACS server, patient monitoring devices and MIS). [22-30] At the same time, if these equipment are not included in the unified information environment of the medical center, their work becomes less effective and it is not possible to apply programs for planning, simulation and intraoperative navigation.

The solution of these problems is associated with the creation of a new type of simulator for planning and navigating surgical interventions. The purpose of this work was to investigate the possibilities of using augmented reality and computer processing in the holo doctor program in traumatology (osteology), as well as to test in practice the methodology developed by us for planning and conducting surgical interventions on the skeleton with the assested technology of additional reality.

How to Cite this Article: Mishvelov AE, et al. Features of the use of Methods of Planning and Conducting Surgical Interventions in Orthopedics with the Assested Technology of Additional Reality. Ann Med Health Sci Res. 2021;11:1594-1598.

Materials and Methods

The technique developed by us allows us to perform preoperative planning using original software and additional reality glasses (additional reality complex). During the operation, the additional reality complex performs assistance, providing access to the data of additional methods of examination of the patient and making an "overlay" on the operating field in glasses of additional reality of normal anatomy or previously performed MRI or CT data.

The method includes the stages of planning a surgical operation, surgical navigation in real time using augmented reality, and at the stage of planning a surgical operation, a computer or magnetic resonance tomography is performed on the patient and 3-4 separate three-dimensional models are formed on the basis of DICOM files (directly the bone, its blood vessels, ligaments, pins, etc.) on a computer in the program. The resulting multilayer model is placed in a simulator program, with the addition of models of the body surface and large vessels. The method developed by us allows planning the course of surgery on the human skeleton and on the organs of the lumbar region. The surgeon works with 3D models of bones in the form of holography with the ability to view the anatomical structure of the bone in the form of a 3D model obtained after CT.

3D images in the system are created by MRI scanning and computed tomography of internal organs, while the program itself selects a certain color for each of the organs (after DICOM reconstruction). The resulting image is transmitted to the hololens augmented reality glasses.

Preoperative planning begins with a CT scan of the patient, after which the exact structure of the organ appears for submission to the CT planning system. There is a combination of the CT image taken earlier (for 1 hour) and the CT obtained in real time of the patient. This module will allow radiologists to reduce the time for processing and describing medical images.

With the help of the system, Microsoft imposes a layer of mixed reality on the patient during surgery. The surgeon can use it to track the position of an organ, organ systems, and surgical instruments in real time.

The program simulates manipulations on the created 3D image of a real patient using surgical instruments in the corresponding specialty. This system is fully adapted for the use of augmented reality glasses (hololens mixed reality glasses) for practicing, combining and simulating various manipulations in surgery, which will allow projecting virtual organs on the patient's body.

With the help of gestures, a medical specialist can point to the desired organ, and in addition, remove it from the illustration. Then the image is connected to mixed reality glasses, and the doctor can see a virtual 3D map of the internal organs of a person directly on his body. The system interacts with a surgical dummy (special markers are pasted for the operation of a simulator program using mixed reality-holography), using pre-taken medical CT and MRI data.

When developing the real-time surgical intervention simulator module, the need for cross-platform product was taken into account, in particular, the need to support the display in augmented reality glasses (hololens glasses), the use of infrared cameras, stereo sensors (TOF cameras) and pointers with sensors.

To simulate the navigation of surgical intervention in real time (we have prepared a system with additional modules (a module for hololens glasses and a navigation module), which allows you to make an incision and stitch the tissues of a selected area on the human body or organ, select simulation modes for planning an operation using an alarm (warning the system about the close distance of blood vessels if the surgeon is approaching a dangerous zone), intraoperative navigation mode of surgical intervention, selection of surgical instruments-laser, scalpel, trocar, wound expander, etc. A special function of virtual angioscopy has also been developed, which allows you to virtually view the internal selected structures of the organ along a given trajectory. In the presented clinical case, we used this function in viewing the lumen of the ureter and the renal pelvis, exiting blood vessels before surgery (planning the course of surgical intervention).

On the surface of the human body, using markers, previously marked key points are outlined, according to which the position of virtual models of organs and real objects is combined into a single coordinate system. Virtual models can be displayed on the screen in the operating room, as well as superimposed on the image (of the human body and organs) from the cameras of hololens augmented reality glasses. The pointer or marker (separately) is used as a virtual camera (the pointer is a virtual camera) to observe on the screen in real time models of anatomical structures that the pointer is directed at. The surgeon places the pointer/marker at the points of the intended use of surgical instruments (for example, trocars) and correlates the position of the pointer model with the position of the organ models, thereby the surgeon plans access to internal structures taking into account the individual anatomy of the patient.

Also, a software module (for a simulation surgical system) with the function of importing 3D models of organs or organ systems in object format for navigating surgical intervention has been finalized, which allows you to load a multi-layered, highly polygonal, obtained 3D model, for example, a 3D model of bone and surrounding tissues with vessels or a kidney with vessels, a neoplasm. Thus, the following functionality is obtained: Loading a 3D model, overlaying a map of blood vessels, scrolling a 3D model, zooming in and out of an organ model, instrument setup mode, simulation mode and navigation of surgical intervention both in augmented reality and on a windows personal computer.

Results and Discussion

In 2020, a surgical operation with the use of augmented reality glasses was performed for the first time in the Stavropol regional clinical hospital. Modern technologies have helped to speed up the implementation of autoplasty (a method of surgery).

The anatomical atlas and the system of interaction with hololens augmented reality glasses were tested during several real operations on the knee joint performed in the trauma and orthopedic department of the stavropol regional hospital.

We chose the first patient according to the degree of complexity of the operation, namely, the patient was injured during a football match.

The developed methodology was tested on the basis of the Stavropol regional clinical hospital (Semashko str., Stavropol, Russia). The methodology was tested in traumatology (osteology) using augmented reality in 2020-2021 [Figure 1].

Clinical case 1

Diagnosis: The patient had damaged ligaments in the knee joint (cruciate ligaments of the knee joint), and there was also a small crack in the tibia [Figure 2].

The course of the operation: Hololens augmented reality glasses were used to navigate the surgical intervention, which allowed reducing the operation time by 28 minutes, instead of 2 hours, they were carried out in 1 hour and 32 minutes. This technology allows you to overlay visual objects created on a computer (in this case, a 3D model of the tibia, knee joint, pins, blood vessels) and additions to the existing objective reality. And also, the software allows you to display everything that the surgeon needs in preoperative planning. Right during the operation, the surgeon received the results of all studies, images, MRI, CT data, which supplemented his knowledge.

The new holo doctor software orto expands the boundaries for training, it shows the doctor's work through his own eyes,

Figure 1: Performing surgical interventions on the knee joint with the assisted technology of additional reality on the basis of the Stavropol regional clinical hospital.

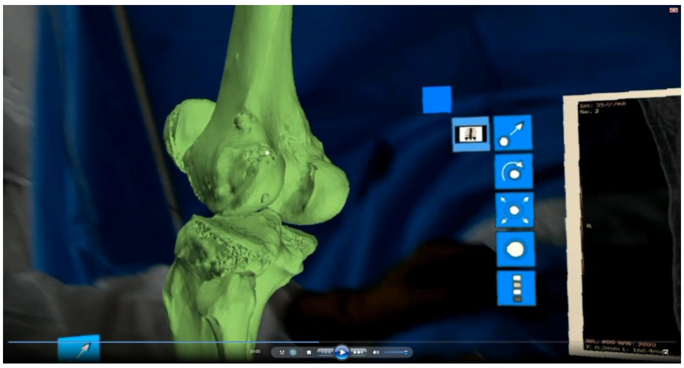

Figure 2: Demonstration of 3D reconstruction of the fibula in augmented reality glasses.

allows you to get a hint from a more experienced colleague in real time right in the operating room. And before that, they used hololens augmented reality glasses to describe medical images, work out, and combine 3D models.

Results: In the additional reality glasses, a 3D model of the knee joint with a small fracture of the tibia, a CT patient and a medical history in convenient sectors are displayed. Under aseptic conditions, an arthroscopic chamber was inserted into the knee joint cavity under the tourniquet by a lower-lateral approach, an arthroscopic instrument through a lower-medial access. 25 ml of blood with an admixture of viscous synovial fluid was released.

The joint is abundantly washed. During the examination of the joint cavity, it was found that the ligaments in the knee joint (cruciate ligaments of the knee joint) were damaged, and there was also a small crack in the tibia. The plateau was raised under arthroscopic control. An L-shaped incision was made along the outer margin 2 cm below the articular gap, made by a MOS plate with angular stability.

Stitches for punctures and wounds. Aseptic dressing, the elevated position of the limb is given, the area of the right knee joint is cold. Plaster immobilization, elastic bandaging of the lower extremities. The duration of the operation in augmented reality glasses was 40 minutes. The duration of the event was reduced from 60 minutes to 40 minutes.

Clinical case 2

Diagnosis: Closed intra-articular fracture of the external condyle of the left tibia, with displacement of fragments [Figure 3].

The course of the operation: Osteosynthesis of the external condyle of the left tibia under arthroscopic control with the use of additional reality glasses.

Result: With the use of additional reality glasses, a 3D model of the fracture is exposed. The CT patient is placed in convenient sectors. Under aseptic conditions, an arthroscopic chamber was inserted into the knee joint cavity under the tourniquet by a lower-lateral approach, an arthroscopic instrument through a lower-medial access. 40 ml of blood with an admixture of viscous synovial fluid was released.

The joint is abundantly washed. During the examination of the

Figure 3: Viewing and navigation in augmented reality glasses of Holo Lens 3D reconstruction, and DICOM images of a closed intra-articular fracture of the external condyle of the left tibia, with the displacement of fragments.

joint cavity, it was established: An impression fracture of the lateral condyle of the femur. A trepanation window (1.5 cm ×1. 5 cm in size) in the cortical layer is made on the inner surface of the lower leg 4 cm below the articular surface. The plateau was raised under X-ray and arthroscopic control. The congruence of the articular surface has been restored, fixation with 2 spokes. An L-shaped incision was made along the outer margin 2 cm below the articular gap, made by a MOS plate with angular stability. The spokes are removed; the left condyle is stable under arthroscopic control. The bone defect is covered with an osteoplastic matrix; an extracellular collagen matrix is laid on the defects of the cartilage tissue.

Stitches for punctures and wounds. Aseptic dressing the elevated position of the limb is given, the area of the left knee joint is cold. Plaster immobilization. Elastic bandaging of the lower extremities

Conclusion

When studying the possibilities of using augmented reality technologies in ontology, all the tasks set have been solved. Clinical cases were processed and integrated with hololens augmented reality glasses for describing medical images, working out, combining 3D models.

A new method of simulation and use of augmented reality glasses with the holo doctor program for implantological treatment demonstrated a good visualization of both the anatomical features of the implant placement zone, the possibility for the surgeon to carefully study the intervention zone before the operation, to perform surgical intervention in the conditions of the patient's real anatomy, including with the use of augmented reality navigation. In 2019-2021, more than 40 operations were performed on the knee joints, ligaments and spine.

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