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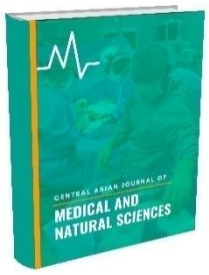

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Surgical Robotic Systems: a History of Formation

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Annotation: Robot-assisted surgery occupies an important place in modern medicine. The article is devoted to the history of the formation and use of surgical robotic systems. Information is given on both the first primitive robots and modern high-tech devices such as da Vinci. The possibilities of modern robotic systems in various fields of surgery and their technical features are presented.

Keywords: robot, robot-assisted surgery, surgical robots, healthcare.

Introduction. Today it is impossible to imagine life without the participation of robots - they are represented in all spheres of human labor - from the production of cars to the most time-consuming surgical interventions. The healthcare system presents a whole galaxy of robotic solutions for use without direct contact with patients. These include laboratory and transport systems. Robotic laboratory complexes are capable of ensuring the uninterrupted functioning of a multidisciplinary institution with a minimum expenditure of human resources, which is undoubtedly an economically beneficial aspect.

For the first time the word "robot" was used in 1923 by the Czech writer Karel Capek in his popular science play "RUR" (Rossum's Universal Robots). The word "robot" comes from the Czech word robots, which means hard physical labor. The play takes place in a future where robots were created and sold to do hard work.

Isaac Asimov in his novel "Round Dance" proposed the word "robotics" for use and formulated the so-called laws of robotics, which have become immutable for many writers [1,3,4].

Currently, all over the world, including Uzbekistan, there is a tendency towards minimal invasiveness when performing surgical interventions. Initially, this led to the transition from traditional open surgery to laparoscopic. The widespread and widespread introduction of laparoscopic technology has led to a significant reduction in the time of hospital stay, a decrease in the number of postoperative complications, and faster rehabilitation. The pinnacle of modern technological developments in the field of minimally invasive surgery has become a robot-assisted surgery.

The history of the development of surgical robotic systems begins with neurosurgery. In 1985, the Programmable Universal Manipulation Arm (PUMA) 560 robotic system was used to perform a CT-guided pinpoint biopsy of the brain (Fig. 1). Currently, this technology is not used.

The first robot to perform the urological procedure, transurethral resection of the prostate (TURP), was Probot created in 1988. To perform TURP using this robot in the preoperative period, a 3D model of the prostate was constructed, the resection boundaries were marked by the surgeon, and the trajectory of the resectoscope was calculated by the robotic system (Fig. 2).

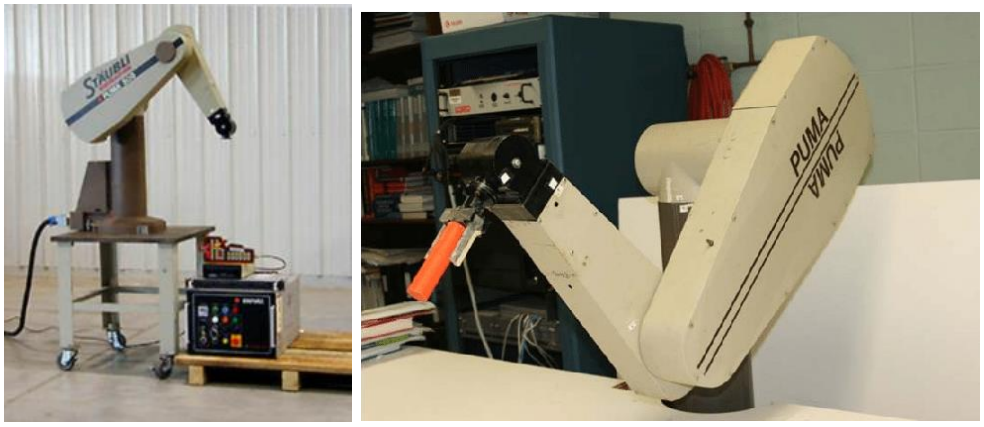

Fig. 1. The first surgical robot PUMA 560 during the experiment [2].

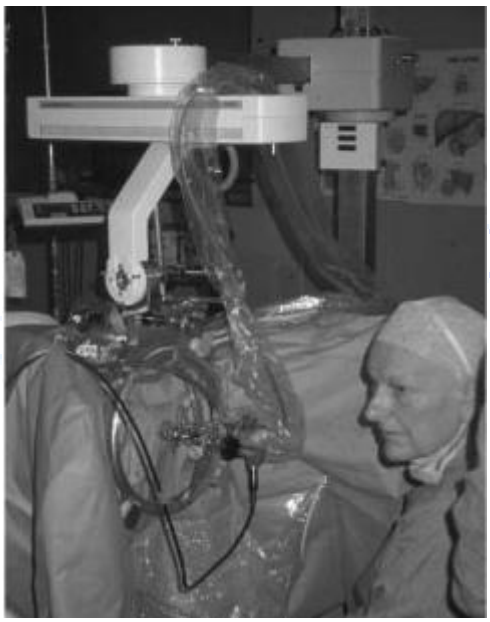

Fig. 2. Surgical robot Probot during the TURP procedure [5].

Subsequently, robots have evolved in terms of increased power and maneuverability, and also performed more complex surgical tasks.

In 1994, Computer Motion manufactured the first surgical robot to be certified by the US FDA (Food and Drug Administration) - Automated Endoscopic System for Optimal Positioning (AESOP). This system was originally developed by NASA (Nation Aeronautics and Space Administration) for the space program. It was a mechanical arm designed to automatically reposition the endoscope when performing surgery. Two years later, the AESOP system received a voice recognition function, which made it possible to execute the surgeon's voice commands (Fig. 3).

Fig. 3. The first surgical robot AESOP.

Urology specialists from Johns Hopkins University Hospital have performed a variety of operations using the AESOP system, such as nephrectomy, retroperitoneal lymphadenectomy, pyeloplasty, orchopexy and nephropexy. This robotic system has ensured the transition of laparoscopic operations to the category of robotic-assisted ones. She was able to completely replace the assistant during surgical interventions.

However, the concept of telemanipulation with a video camera alone was insufficient, so the next step in the evolution of robotic-assisted surgery was the development of remote telerobotic surgery. The concept of this project was that the surgeon is at the console, and the computer translates his movements to the manipulators located in the patient's body. The telerobot must be directly at the operating table and be able to manipulate not only the camera, but also several “hands” with instruments. Developments in robotic telemedicine were simultaneously initiated by three government agencies in the United States, leading to the creation of a military prototype capable of providing assistance to the wounded directly on the battlefield. In this case, the surgeon was deep in the rear and carried out manipulations remotely using television broadcast [1].

Computer Motion has received funding to develop a robot capable of mimicking hand movements. As a result, in 1990 the Zeus system was introduced with two subsystems - the surgeon and the patient. The surgeon's subsystem consists of a console with a video monitor and two handles that control the operation of manipulators. Manipulators hold tools. The surgeon's console can be located anywhere in the operating room. The patient's subsystem consists of three robotic arms attached to the operating table (Fig. 4) [5].

Fig. 4. Surgical robot Zeus [6].

The Zeus robotic surgical system was the first to anastomose the fallopian tube in 1998 at the Cleveland, Ohio Clinic. On September 3, 2001, Zeus performed the world's first transatlantic telesurgery. Laparoscopic cholecystectomy was performed in Strasbourg while surgeon Dr. Jacques Marescot was in New York. In 2003, Computer Motion, Inc. merged with Intuitive Surgical Inc. and stopped developing Zeus [7].

Intuitive Surgical Inc. managed to buy out a prototype of a robotic system created by military organizations for civilian use. The result was the da Vinci robotic surgical system based on telemedicine telemedicine principles. The da Vinci system is currently the only such system and the undisputed leader in the field of robotic surgery. It was originally developed for robotic-assisted coronary artery surgery and was first used for this purpose at the Heart Center in Leipzig. Up to now, the following system modifications have been replaced: da Vinci 2000, da Vinci S, da Vinci Si and da Vinci Xi.

The da Vinci system consists of three components (Fig. 5):

1) surgeon console;

2) patient console;

3) vision cart - optical system.

The surgeon's console is the control panel for the entire system and the operator's workstation. Surgeon has total control of the wristed instrument on each of four arms and the patient trolley camera using two joysticks and foot pedals and can customize settings at the console.

Fig. 5. Components of the da Vinci robotic system.

The movements of the surgeon's hands are completely copied by the joysticks and transmitted to the manipulators, leveling tremors and providing the possibility of precision dissection. Foot pedals provide activation of the coagulation process (mono- and bipolar coagulation is possible), switching between manipulators and the camera, as well as focusing the optical system (Fig. 6). With the help of the console, the surgeon has the ability to remotely control the system, so the console can be located outside the operating room [6].

Fig. 6. The location of the surgeon behind the console and the console of the patient.

The immersive effect is provided by an optical system consisting of two parallel cameras that transmit an isolated image for each eye. In this case, the transmitted image is three-dimensional, which allows the surgeon to determine the volumetric position of the patient's organs and tissues in space. Each camera is equipped with its own light source and has its own control panel. The connection between the surgeon and the operating room is provided by a microphone and speakers located both on the surgeon's console and on the patient's cart in the operating room.

The patient trolley carries working manipulators and is in direct contact with the patient during the entire procedure. Three manipulators with instruments attached to them, as well as one manipulator with a camera, are connected to the surgeon's console using a computer interface.

During the preparation of the patient's cart for the operation, all manipulators are put on special sterile covers and remain in them throughout the entire procedure. One of the differences of the latest generation Xi system is the ability to install the camera in any of the four manipulators. To perform robotic surgery, Endo Wrist instruments are used, which are modeled on the human wrist and have 6° freedom of movement, exceeding the range of motion of the human hand (Fig. 7). The Endo Wrist instrument set includes a variety of clamps, needle holders, scissors; mono polar and bipolar electrosurgical instruments; scalpels and other specialized instruments (more than 40 types in total). Endo Wrist instruments are available in 5 mm or 8 mm diameters. An important feature is the clear limitation of the use of the toolkit. Each tool can be applied only 10 times, while when changing tools, the interface recognizes the type of the new tool and the number of times it has been used [1].

Fig. 7. Endo Wrist technology ("end-wrist").

It is currently the most widely used robotic surgical system, with over 3400 units sold worldwide and many scientific publications.

Robotic surgery has shown a high degree of compliance with regard to surgical interventions in urology. In 2001, a robot-assisted prostatectomy for prostate cancer began in Europe and today it is the most performed robotic operation in the world. In reconstructive urology, robotic-assisted plastic surgery of the pyeloureteral segment is successfully performed. Also in 2001, the first robot-assisted nephrectomy was performed, and in 2003, a robot-assisted radical cystectomy. Robot-assisted operations are performed primarily on da Vinci robots.

More recently, the world's first endoscopic robot Avicenna Roboflex has appeared, which was developed by ELMED ™ for retrograde intrarenal surgery (RIRS) and flexible laser ureterorenoscopy (FURLAS) procedures [8,9]. Avicenna Roboflex is a system that allows you to fragment and break up stones in different parts of the urinary tract through the natural urinary tract without incisions or punctures (Fig. 8). The advantage of the system is the ability to perform these procedures in an ergonomic sitting position, without a lead apron and outside the radiation zone. All functions (back and forth, rotation, tilt) of the flexible endoscope can be controlled using the system touch screen and the arm controls on the console.

Fig. 8. Endoscopic robotic system Avicenna Roboflex.

Conclusion. More than three decades have passed since the first robotic surgery was performed, and today robotic-assisted surgery has firmly entered the arsenal of surgical methods for treating many diseases. The use of robots in surgery provides significant advantages over open and even laparoscopic surgery, but these advantages are limited by the high cost of robot-assisted surgery. The future use of robotic systems will be driven by randomized clinical trials demonstrating their benefits, as well as the development of new robotic platforms and technologies.

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