The Robin Heart story

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Streszczenie

Artykuł przedstawia postępy polskiego robota chirurgicznego Robin Heart. Rozpoczety w 2000 r. projekt wszedł w fazę przygotowań pierwszych produktów, które wejdą na sale operacyjne. Po pierwszych eksperymentach na zwierzętach robotów Robin Heart modeli 1,2,Vision oraz mc2 wiadomo, że robot toru wizyjnego spełnił wszystkie oczekiwania odbiorców. Trwa przygotowanie nowego modelu Robin Heart PortVisionAble, lekkiego, walizkowego robota toru wizy jnego o szerokim obszarze zastosowań w małoinwazyjnej chirurgii tkanek miękkich. Doskonalimy robota narzędziowego Robin Heart oraz mechatroniczne narzędzia serii Robin Heart Uni System. Prowadzimy działania dla uruchomienia w Polsce produkcji robotów medycznych.

Introduction

The initiated by the author project results are the family of Robin Heart robot and universal mechatronic tools series **Robin Heart** Uni System for use during minimally invasive surgery on the heart and other soft tissues. The number of endoscopic procedures, less invasive than traditional surgery, performed through natural orifices in the patient's body, or through special openings called ports, is on the rise. The purpose of robots is to improve efficiency, repeatability (standardization) and reducing the invasiveness of surgical procedures (extension of the group of patients for whom successful surgical intervention is possible). Robot is intended to keep the surgeon in the most comfortable, dexterous and ergonomic position.

The **robot** is one of the few words of Slavic origin, which entered the global language of modern science and technology. Medical robotics, as the technical discipline, deals with the synthesis of certain functions of the physician or nurse by means of using some mechanisms, sensors, actuators and computers. Medical robotics includes the manipulators and robots dedicated to support the surgery, therapy, prosthetics and rehabilitation.

Currently several types of medical robotic systems are applied in the surgery, including: **robots replacing the assistant during the operation** – like AESOP, EndoAssist or Polish prototype Robin Heart Vision; **surgical robots** – like Zeus, da Vinci or Polish prototype Robin Heart (*).

Robin Heart

We started the first research grant in 2000. Several models of the robot have been developed, differing in control and mounting systems. Spherical model was created (2001), Robin Heart 0 (2002), a prototype of Robin Heart 1 and model of Robin Heart 2 (2003), Robin Heart Vision (2008) and Robin Heart mc2 (2010) and more than 200 publications and presentations at scientific conferences have been prepared till now.

The Robin Heart 0 and Robin Heart 1 have

an independent base and are controlled via an industrial computer and specialist software. The Robin Heart 2 is fixed to the operating table and has two arms, on which one can fix various surgical instruments. The control system uses its own software as well as signal and specialist microprocessors. Thanks to its modular structure, it can be adjusted for surgery of different types. The Robin Heart Vision, will become the surgeon's partner in the operating room next year. It will replace a human assistant who usually holds the endoscope to enable the observation of the operative field of laparoscopic instruments. The Robin Heart Vision is easy to use and install, and will be conveniently carried in a suitcase in future. The Polish heart surgery robot is an original design.

The process of projecting a robot starts by determining the tool-tissue reaction (mechanical characteristic, the forces for specific operations, dynamic analysis of the work of a tool) and the person-tool/man-machine contact (kinematic analysis of the surgeon's motion). The surgeon's motion and tool trajectory in natural environment are analysed with the use of optical biometry techniques. The forces applied during the impact of tools on tissue during typical surgical activities are measured. The construction assumptions as well as the functionality and ergonomics of the innovative tools can best be verified by means of video-recording. As a result, a user-friendly surgical work station and an efficient surgical tool are constructed.

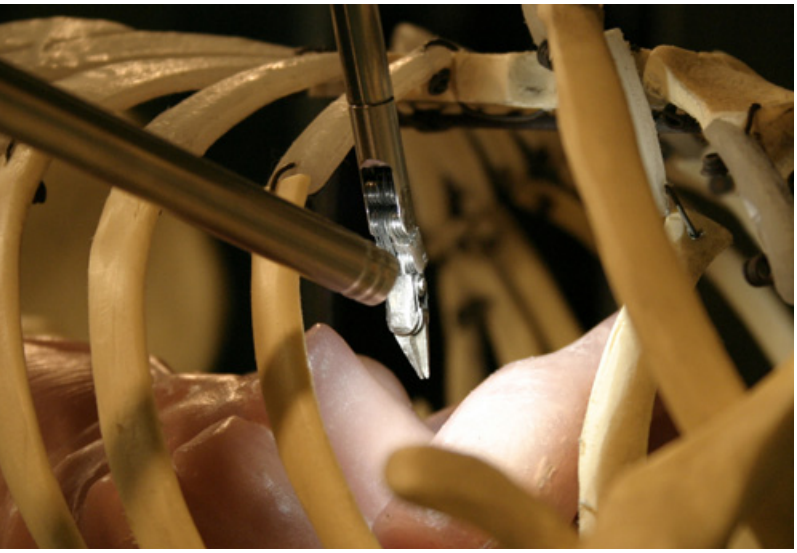


Figure: Research. Virtual and real condition for testing the Robin Heart robot. Using a Virtual Reality technology an interactive model of surgery room equipped with a Robin Heart system was created using EON Professional software. This computer modelling method allows for an advance procedure training and will be used as a low cost training station for surgeons in the future. Model allows for a better understanding process of less invasive surgery treatment and a robot behaviour. The link between this type of modelling and a Computer Aided Design (CAD) techniques is using an accurate CAD robot models in a VR software together with a precise reflection of workspace geometry. This approach gives a surgeon easy and intuitive way to understand a technical information and use it to optimize and plan medical process. Presented model of Operating Room in Virtual Reality environment has been performed in FCSD and successfully used from 2006.

The robot, or actually a "tele-manipulator", is the first ever tool capable of assisting a surgeon by providing the capability to directly use surgery simulation and planning methods.

The Robin Heart Shell console is equipped with a consulting program that makes it possible to obtain all patients diagnostic information during the operation, as well as elements of operation planning on the screen. The 3D virtual operating theatre introduced in our laboratory allows surgeons to train some elements of an operation, check the best placement of the ports in order to avoid arms collisions.

The introduction of feedback from field operations; the implementation of force-feedback loop, and spatial visualization will improve working conditions in the new surgeon console Robin Heart Shell 3. The robot should provide all the information needed not only to the surgeon to correct tool orientation (vision), but also to take appropriate course of action in this area (selection and tool task).

The future plans connecting with development of polish robot Robin Heart include carrying out of a robotically assisted implantation and servise artificial organs like Heart Ventrical Assist Device Polvad (Artificial Organs Robotically Assisted Surgery project – AORobAS) [1].

Tests

The Robin Heart manipulator has very good and relatively large working space, in which surgeon can select small subspace with very good isotropic kinematics' properties for manipulating of objects with good position accuracy. System was verified both functionally and technically. Standard technical evaluation allowed to estimate the value of positioning resolution equal 0.1 mm. The mile stone of the project were an animal experiment, carried out in January 2009 (Robin Heart model 1, 2, Vision) and May 2010 (Robin Heart mc2) . The operations were performed on pigs at the Centre of Experimental Medicine (CEM), the Silesian Medical University in Katowice. The goal of these experiments was to show the constructors the area of indispensable changes which will be introduced to worked out devices before study of technology of serial production and

clinical initiating. Robin Heart system experiment carried out on pigs allowed to verify many aspects of very complex project and was the source of hints for future development. A pre-operation planning stage included surgeon trainings on virtual anatomy and physical models with the usage of real pig tissues. A common control system for all three robotic arms was created PXI bus hardware, working in real time operating system, controlled by software written in LabView environment.

In the course of the animal experiment the surgical task achieved in the abdominal space was cholecystectomy, and in the chest and heart: the repair of heart valves (with extracorporeal circulation) using the Robin Heart models 1, 2, & Vision. In the last phase of the experiment, the efficiency of the Robin Heart Uni System mechatronic tools was checked – they be mounted on the robot's arm (and controlled from the console) or held in the surgeon's hand (manual control) . Elements of operations in the abdomen and heart cavities were successfully performed. The robotically supported TECAB was not performed due to collision of robots during mammary harvesting procedure. It was decided to build a new robot. After 9 months, in 2010 the first experiment was conducted, by means of a specially designed robot Robin Heart mc2. Purpose of the experiments has been achieved: new construction functionality has been accepted by the surgical team.

Robin Heart mc2 creates a completely new job opportunities for surgeon – both in the local area and globally. It can be compiled as an arm of the platform (a small robot with two endoscopic tools and endoscope for observation) or as telemanipulator working for three people – the mean surgeon and his assistant, and an assistant holding the endoscope (controlled from console by one operator). It is really new solution for robotically assisted surgery.

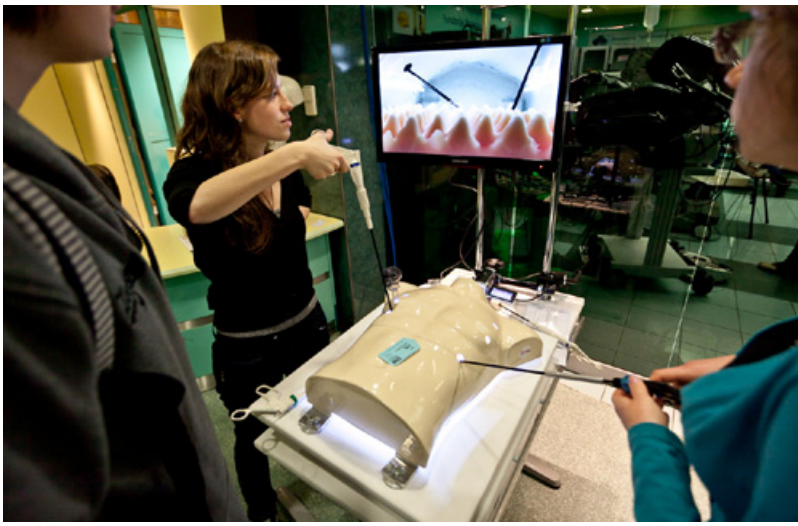
As conclusions from the experiment users (surgeons) have expressed good opinion on the ergonomics and possibilities of controlling the robotic arms by means of the Robin Heart Shell console. The opportunities of operating by means of the Robin Heart Uni System, universal mechatronic tool for both; robot and hand, are very promising (as it may be mounted on the robot's arm or controlled manually).

The model of teleoperation has been performed in December 2010 between Zabrze (FCSD) and Katowice (CEM) successfully (signal delay under 1 ms, video delay about 280 ms).

The technical and ergonomic laboratory tests carried out allowed us to verify and improve our robots. Based on the tests found that one of the robot meets all user requirements and the next stages of implementation can start. Robin Heart Vision telemanipulator designed to position the endoscope during surgery is characterized by spherical arm kinematics by 4 degrees of freedom and the displacement range of 187°, 117°, 340° and 165 mm. Accuracy of positioning the tip of the robot arm in not worse than 0,1 mm. Surgical robots Robin Heart families need further work to improve strength and performance tools [1].

Conclusion

The **Robin Heart** system includes the planning system, training system (Fig 6), experts' program, as well as tele-manipulators and automatic surgical tools. In the Polish Robin Heart surgical robot many of the original solutions were introduced: telescopic sliding motion to move the tool (2002), mechatronic tool "for the hand (2006) and the robot", and Robin Heart mc2 (2010) is the first surgical robot that can work for three persons (two surgeons and assistant responsible for endoscope orientation). Currently, a new model; Robin Heart PortVisionAble, lightweight robot for control endoscopic vision system for wide applications in the area of minimally invasive soft tissue surgery is prepared. We improve surgical robot Robin Heart and mechatronic tools series Robin Heart Uni System. We act for the start of production medical robots in Poland. The Robin Heart family of Polish robots has a chance of becoming a commonly used high-tech technical and tele-medical system facilitating the performance of some parts of operations in minimally invasive, precise manner, safe for the patient and the surgeon.



Original test and training station at Surgical Workshop.

References

[1] Zbigniew Nawrat. Robot chirurgiczny Robin Heart – projekty, prototypy, badania, perspektywy. Śląski Uniwersytet Medyczny w Katowicach. Katowice 2011.

(*) Article was based on publication [1]