Hand Free Navigation System In Laparoscopy. Surgical Experience

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Abstract

Objective: We describe the second navigation system developed in Mexico, a novel device to hold the laparoscopic camera during surgery. Unlike others systems, it is worn by the surgeon on his thorax and its position is controlled directly by the surgeon's body movements or by a joystick.
Material and Methods: The laparoscope holder consists of two parts: an electromechanical holder arm and harness to hold it and mounted on the surgeon's thorax. Electromechanical holder arm. In the last extreme of the portalaparoscope is installed manually, the laparoscope with a clasp and in the other extreme it has a spherical joint that provides a circular motion to the laparoscope. We designed and built in 2001 the first model to hold and place the laparoscope, it was built in acrylic, aluminum in the bioelectronics laboratory, and is composed of two parts. The system was designed and built in the bioelectronic laboratory in the Cinvestav and the surgical procedures at the Escuela Superior de Medicina of the IPN (Instituto Politécnico Nacional), on June 21, 2001. In February 2003 we carried out the first surgical experience on humans.
Results: It was possible to navigate in six directions: inside, outside, to the right, to the left, up and down inside the abdominal cavities in experimental animals. Advantages, The motions were developed succesfully and more easily by the surgeon's body aided by himself or by the physical joystick to place and position the laparoscope. We performed 4 cholecystectomies, 2 with traditional laparoscopic surgery and 2 were assisted by an electromechanical arm.The time was shorter with the technique assisted by the new device. There were discrete movements of the images displayed on the screen caused by involuntary movementes of the surgeon due to itching, coughing, sneezing, breathing, talking, being distracted chatting,

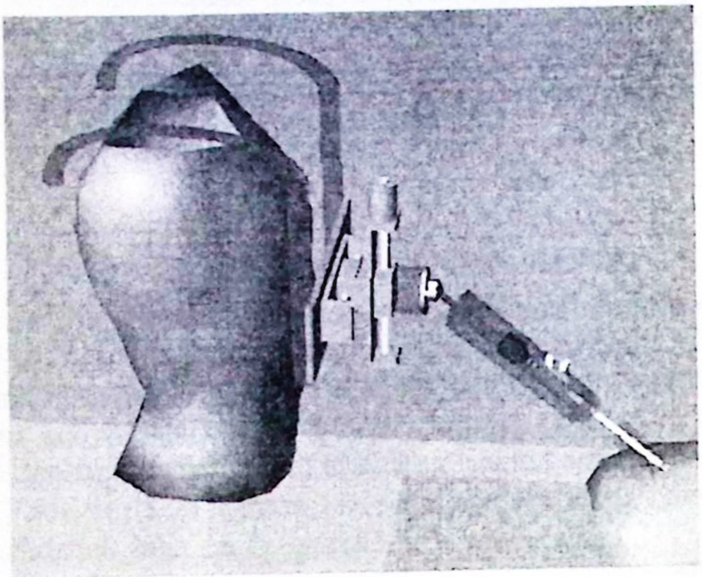
Discussion: We consider that the system can be better, to avoid contamination we can sterilize submerging the portalaparoscope in special solutions and the rest of the equipment we can cover with sterile plastic. The system provides better hand -eye coordination and positioning during surgery and to improve accuracy. We could integrate voice recognition to control the mechanical arm and exist all possibilities to be robotsized, it would be lighter.

1. Introduction.

There are several robotic arms that have been created since the beginning of 1990, with different models, characteristics applications and versions. Many of them are in experimental or in laboratory areas and others are in commercial developing process. The surgeon has looked for devices and systems in order to control absolutely the laparoscope and avoid the limits of verbal communication with the human assistance during the navigation. There are robotic arms to be applied in the next areas: Neurosurgery (Minerva) (1), Neurobot, Orthopedic (Orthodoc) (2), Robodoc, Caspar (3), laparoscopy (4), (Aesop) (5,6), Lars, laparobot, Zeus, da Vinci (7), and radiotherapy. These systems can be passive, semiactive and active devices, and can be controlled by different interfaces: voice recognition, phyisical joysticks, head motions, robotic vision, pedal, data gloves, control feedback (8), optical zoom (9) to have better motions that are built with 4,5,6,7, or 8 joints. The functions are different depending of the surgical area. For example: in orthopedic surgery (to plan the surgery, to perfom the medular duct, to place the prothesis) in laparoscopy (to place and position the laparoscope, to take biopses, to process surgical images). The robotic arms can be controlled in the same place (Operating room) or from a distant operating room (telesurgery). The surgeons can manipulate the robot with the next objectives: to plan, to assist (10), to guide and to perform the surgery. The surgeons can manipulate robots with different applications like: surgical education, and aid to surgeons. There are different areas that integrate the medical robotics (11): computer, mechatrionics (12) engineering, surgery, robotic. None of these systems are mounted to the surgeon's body. The great limitations of these new technologies are found in the majority of the hospitals in the world. These limitations are the cost and the volume of the equipment necessary in the operating room, moreover the specialized people have to adjust the robotics systems maintaining the good functioning of the equipment. Our particular search in the navigation area has permitted us go in the area of the development of robots to perform the navigation, exploring the voice recognition, keyboard and joystick to the manipulation, trying to find our solutions. On June 12, 1996, we performed the first surgical robotics experience in Mexico (13), in 2000 we constructed the first robotic arm to hold the laparoscope (14,15).

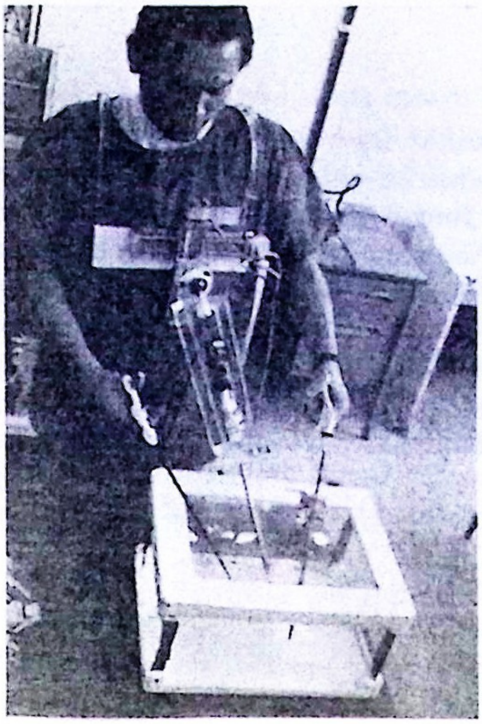
2. Material and methods

The harness has a passive and spherical joint (Rotula), and this joint joins a laparoscope holder using an aluminum plate.The system is installed manually in the last extreme on the laparoscope holder with a clasp and in the another the joint is attached in two linear rails and these in an acrylic and aluminum square platform (placed on the surgeon's thorax) (Picture 1,2). And this plate can move or slide with rails, up, down, over the harness. The system is complemented with servomotors, making it active. With these characteristics or options, the system adjusts



Picture 1.- Virtual model of the Hand free navigation system. Lateral view.

according to the surgeon's physique. Moreover to place the laparoscope in the surgical field and avoid efforts. In both versions, the harness permits the manipulation with hand-free navigation (HFN) to perform the surgery, without limiting the surgeon's field. The espherical joint provides a circular motion to the laparoscope and all system acquire more degrees of freedom. The laparoscope moves inside the cavity taking as the point of support the sliding of the abdominal wall independently of the deep inside the cavity. Moreover it permits the required angular slide in any plane. In the X axis more or less 50 degrees since a frontal point insertion and for the Y axis more or less 30 degrees and the same complementary movements in the cavity space. The results of the angular slide increase according to the change of the surgical body in any direction, increasing the visual space to the procedure. The spherical joint has a minimal mechanical friction to avoid unnecessary efforts, permitting the surgeon to attach or unattached easily the laparoscope to the harness during surgical procedures. The harness has an electromechanical device on its frontal surface with a linear slide that has two degrees of freedom. This control permits the surgeon to make a minimum effort to replace the laparoscope inside the cavity and it becomes an ergonomic system. We used two motors of direct electrical current of gear-transmission and the adaptation was performed by PWM (pulse width modulation) and provide motions to the laparoscope in two planes, in vertical and horizontal sense. This permits a successive approximation with the electromechanical system of 0.1 mm . The speed in each axis was 2.5 cm a second with a longitude slide of 19 cm, and in the motors' activation in the experimental test we employed the keyboard. The weight of the system is 2.78 kilo (6.12 lbs) without the laparoscope (160 grs.) and the micro camera (380 grs.). In total weight is 3.320 kilo (7.304 lbs).The system was tested by the surgeon initially in the physical laparoscopic simulator. It performed movements with chicken pieces to evaluate the motions of the system. Once the manipulation and acquired experience with the system with hand-free navigation had been verified. We followed with surgery on dogs. The surgeon wore the system mounted on the harness on the thorax with the help of an engineer.



Picture 2. Hand Free Navigation System, mounted on the surgeon's thorax. Bioelectronic's laboratory at the (Centro de Investigación y de Estudios Avanzados) CINVESTAV. Mexico City.

The surgeon performed the HFN initially with the body motions. Later the slide laparoscope is complemented with the electromechanical system. In both X and Y axes a keyboard was used. Finally the system is disarticulated by the surgeon with the help of the engineer. The surgeon could navigate in the X axis 200 degrees and with the Y axis give or take 40 degrees. The depth of the insertion was not limited by the surgeon and he had no pain. The spherical joint and the abdominal wall as a point of support permits an ideal linear slide in the cavity. The harness system permits the surgeon to connect or disconnect with the sensorial surgical universe around him such as tissues and organs. The laparoscope connection or disconnection with the harness demonstrated that it is vital to perform quickly the next tasks. The fast-port insertion, initial laparoscope insertion and laparoscopic cleaning, permit the performing of the surgical procedures with continuity. This system avoids changes in the surgeon's position or on his body. The complementary electromechanical position permits a good relationship between the surgeon and the organs, and this complement permits fast access and security as the surgeon performs the approximation with his body motions. We designed and built the system in the bioelectronics laboratory in the Cinvestav (Centro de Investigación y Estudios Avanzados) of the Instituto Politécnico Nacional. We performed three laparoscopic surgical procedures assisted with the hand free navigation system. With the engineering attendance the surgeon placed on his thorax a device then the engineer placed the arm to the device and finally the laparoscope to the arm but previously the laparoscope was inserted to the abdominal cavity. With the system total installation the surgeon performed the navigation manipulating the laparoscope in the beginning with the corporal motions then with the physical joystick. The surgeon dissected the gall bladder and the cystic vessels were dissected and clamped. Finally the system was disarticulated with the engineer in attendance and with the first assistant.

3. Results

A new navigation system was built in laparoscopic surgery to the surgeon's thorax. The system caused fatigue to the surgeon when he could not obtain a good position to control the scope requiring a spinal flexibility for long periods. The best advantage of the system is the speed to manipulate the laparoscope by the surgeon over the time employed with human assistance to hold the laparoscope. We removed the gall bladder also to clamp the cystic duct and blood vessels.The manual control was employed less and the device's motions were slow. The system offered a better speed of manipulation because the surgical time was reduced when we employed it. With the human assistance the surgical time was 45 minutes and with the device 27. The capacity of motions and thus a better accuracy and security to patients.

4. Discussion.

We present a new concept of endoscopic manipulation or navigation as well as a generic idea for its multiple uses in different surgical areas where fiber optics such as arthroscopy, neurosurgery, laparoscopy, urology, gynecology (16,17) etc. are used. The electromechanical arm once it is articulated to the surgeon's thorax offers more degrees of freedom to the human's arms that due to their nature have a redundancy sufficient to survive, not so the robotic arms that for economical reasons are built with a limited redundancy. From there, the described system offers possibilities to interact with the surgical work field, also a better hand-eye coordination, and the man-machine relationship is closer. However it presents disadvantages that would better with time like: fatigue positions or when there are involuntary movements such as itching, coughing, sneezing, breathing, talking, being distracted chatting, and the surgeon's body movements which were stabilized or decreased thanks to the stability given by the spherical articulation of the rotula maintaining this way an effective hand-eye coordination. It is possible to build a lighter system, to add voice recognition to control the mechanical arm or attach to the surgical instruments, including to robotize the system. We suggest employing this system in shorter surgical procedures or when the circumstances require accuracy with the tool manipulation. The designed system is an alternative navigation with free hands in laparoscopic surgery and it permits a faster relationship with the tissues and organs than robots do. This is the second navigation system developed totally in Mexico. This system was presented in 6th International Workshop CAS 2001, Computer Assisted Surgery and Rapid Prototyping in Medicine, Nuremberg, Germany (18).

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