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World J Gastroenterol 2006 April 28; 12(16):2606-2609
World Journal of Gastroenterology ISSN 1007-9327

RAPID COMMUNICATION

Clinical characteristics of remote Zeus robot-assisted laparoscopic cholecystectomy: A report of 40 cases

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Supported by the Jieping Wu Medical Foundation, No. 2003-49-A
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Received: 2005-09-13 Accepted: 2005-11-18

Abstract

AIM: To summarize the performing essentials and analyze the characteristics of remote Zeus robot-assisted laparoscopic cholecystectomy.

METHODS: Robot-assisted laparoscopic cholecystectomy was performed in 40 patients between May 2004 and July 2005. The operating procedures and a variety of clinical parameters were recorded and analyzed.

RESULTS: Forty laparoscopic cholecystectomy procedures were successfully completed with Zeus robotic system. And there were no post-operative complications. Total operating time, system setup time and performing time were 100.3 ± 18.5 min, 27.7 ± 8.8 min and 65.6 ± 18.3 min, respectively. The blood loss and post-operative hospital stay were 30.6 ± 10.2 mL and 2.8 ± 0.8 d, respectively. Camera clearing times and time used for operative field adjustment were 1.1 ± 1.0 min and 2.0 ± 0.8 min, respectively. The operative error was 7.5%.

CONCLUSION: Robot-assisted laparoscopic cholecystectomy following the principles of laparoscopic operation has specific performing essentials. It preserves the benefits of minimally invasive surgery and offers enhanced ability of controlling operation field, precise and stable operative manipulations.

Key words: Zeus; Robotic surgical system; Laparoscopic cholecystectomy

Zhou HX, Guo YH, Yu XF, Bao SY, Liu JL, Zhang Y, Ren YG, Zheng Q. Clinical characteristics of remote Zeus robot-assisted laparoscopic cholecystectomy: A report of 40 cases. *World J Gastroenterol* 2006; 12(16): 2606-2609

http://www.wjgnet.com/1007-9327/12/2606.asp

INTRODUCTION

During the past two decades, the benefits of laparoscopic surgery for the patients are less trauma and pain, a shorter post-operative hospitalization, a better cosmetic result and a faster return to normal activity[1]. However, although there are clear benefits to the patients, surgeons face distinct disadvantages. Working through fixed entry points limits maneuverability of the instruments inside the body cavity to five degrees of freedom (DOF). Looking at a two-dimensional screen, surgeons are handicapped by the loss of the visual perception of depth, and the need for a human assistant to hold and move the camera makes surgeons loss the independent ability of controlling operation field [2]. Reduced dexterity and impaired visual control are considered the major burdens of laparoscopic surgery and the attempts in developing robotic telemanipulation systems aim at overcoming these problems. Nowadays both Zeus and da Vinci robotic telemanipulation systems are available to patients. After the success of the first laparoscopic cholecystectomy with Zeus robotic surgical system of our hospital on 26 April 2004, we performed the same operation in the other 40 patients between May 2004 and July 2005, and acquired some experience.

MATERIALS AND METHODS

Patients

Between May 2004 and July 2005, forty patients (24 females and 16 males), with average age 36 years (range 14-50 years) underwent the robot-assisted laparoscopic cholecystectomy in our hospital. Six cases were cholecystopolyp and the others were cholecystolithiasis combined with chronic cholecystitis. Informed consents were obtained from all patients before operation.

Operation

Zeus robotic surgical system (Computer Motion Com-

pany, IEC 60601, Class III, Type CF) consists of Aesop (automatic endoscopic system optimal position), Hermes (acoustic center), Zeus surgical system (three separate robotic arms, operator console, optic console), and Socrates (remote co-operating system).

All the patients in supine position were under the total intravenous combined inhalation anesthesia. The left and right robotic arms were placed at each side of the patient's head. Aesop arm was placed beside the left hip. All robotic arms were attached to the sidebars of the operating table. The movable lower limits of the three arms were set at an optimal distance that a palm was able to insert between the robotic arm and the patient's abdominal wall, and then the instrument adapter was installed onto its robotic arms. Pneumoperitoneum was established after the puncturation with Verres needle at the umbilicus and the cavity pressure was maintained at 12 mmHg. The first 10-mm trocar was introduced at the umbilicus and the 10-mm 30º laparoscope was inserted to explore the abdominal cavity. Under laparoscopic vision, another 10-mm trocar and a 5-mm trocar were respectively introduced at 5-cm below the xiphoid process and 5-cm below the right costal margin in anterior axillary line. A dissection clamp and a grasper were inserted through the trocars. The laparoscope, a grasper and a dissection clamp were engaged with the instrument adapters of Aesop arm, left robotic arm and right robotic arm. Then the three robotic arms were adjusted in a double 90º position, i.e., the angle between the forearm and the upper arm of a robotic arm was 90º, and the angle between the laparoscopic instruments in the adapters and the forearm was also 90º. The condition of double 90º offered the largest range of motion. The surgeon wearing a microphone sat before the operator consol which was placed about 5 m far from the operating table, and steered two egg-shaped manipulators to control the left or right robotic arm. In the mean time, Aesop was acoustically controlled to move up and down, left and right, forward and backward, so as to offer the optimal operative field. An assistant standing by the operating table prepared to adjust the tiny regulator of Aesop or another two robotic arms. An instrument nurse also stood by the table to replace the instruments at any moment. The surgeon steered the grasper of the left robotic arm to retract the neck of gallbladder to expose the Calot's triangle and manipulated the dissection clamp of the right robotic arm to dissect the cystic duct and cystic artery. The cystic artery and duct were sheared after double ligation with clips separately, and then gallbladder was cut down from the liver with the diathermy hook. The gallbladder was pulled out by the assistant from the port below xiphoid process[3].

All the operation procedures were recorded on videotape for later analysis. Time parameters included total operative time, system setup time and performing time. The total operative time was defined as the time from disinfection of the operative field to skin closure. The system setup time was defined as the time from disinfection to the start of grasping the neck of gallbladder. The performing time was defined as the time from the start of grasping the neck of gallbladder to the moment the gallbladder was completely freed from the liver. Minimally invasive parameters included the blood loss, post-operative complications and post-operative hospital stay. Parameters of operative field included camera clearing time and time used for operative field adjustment. Camera clearing time was defined as the time that the laparoscope was taken out to clear the contaminant on the camera during operation. Time used for operative field adjustment mean the time which was taken for the surgeon to stop perform to adjust the operative field or clear the camera. The rate of operative error mean the percent that the cases in which operative errors, such as hepatic laceration or gallbladder perforation happened, occupied among the 40 cases. Conversion cases mean the number of procedures converted to other procedures, such as open procedure or conventional laparoscopic procedure.

RESULTS

Forty laparoscopic cholecystectomy procedures were successfully completed with Zeus robotic system and there were no conversion cases. Total operating time, system setup time and performing time were 100.3 ± 18.5 min, 27.7 ± 8.8 min and 65.6 ± 18.3 min, respectively. The blood loss and postoperative hospital stay were 30.6 ± 10.2 mL and 2.8 ± 0.8 d, respectively. Camera clearing time and time used for operative field adjustment were 1.1 ± 1.0 and 2.0 ± 0.8 min, respectively. The operative error was 7.5%. All the patients began to intake diet at 6-9 h after operation. Their wound healed well without oozing blood and infection, and there were no post-operative complications in any of the patients.

DISCUSSION

At the beginning of 1999, two US companies, Computer Motion and Intuitive Surgical, received European CE accreditation for the clinical application of Zeus and da Vinci robotic surgical systems that were independently invented. In 2000, the two companies received FDA accreditation too, which indicated that robotic surgical systems began to be formally available to patients in the world[4]. In 2001 September 7, a medical team led by French doctor Marescaux accomplished the famous Zeus robot-assisted cholecystectomy, cross over Atlantic Ocean, named as "Lindbergh operation", which created a precedent of remote operation[5]. Up to now, the safety and feasibility of robotic surgical systems applied in general surgery, thoracic/vascular surgery and gynaecology/urology have been demonstrated. Until 2000, more than 6000 robot-assisted procedures were performed, thirty-seven percent among them were in general surgery, mainly cholecystectomy[6]. In the late two years, the technique of robot-assisted operation became more and more mature and wide, and the number of procedures increased quickly. After the success in the first Zeus robot-assisted laparoscopic cholecystectomy in Chinese mainland by our hospital, the other 40 cases were accomplished between May 2004 and July 2005. Based on these, the robot-assisted operative characteristics and performing essentials were analyzed.

Robotic surgical system is a new achievement which is resulted from the medical application of highly developed automatic technique, computer image technique and con-

trol technique. The advanced system possesses the enormous superiority over conventional laparoscopic surgery and forms its characteristics. During Zeus robot-assisted procedures, there was no need for a human assistant to hold the camera, who often provides error and unstable operative field or contaminates camera by touching tissue. The surgeon directly control the camera engaged with Aesop arm by voice, which restores his capability to master operative field as open operation. Moreover, the arm cannot shake and has the ability to memory the previous position. Therefore, the adjustment of operative field is quick and convenient and the operative field is direct-viewing and stable[7]. In our study, camera clearing time and time used for operative field adjustment were merely 1.1 ± 1.0 and 2.0 ± 0.8 min, respectively. There was no vibration of laparoscopic instruments in all the 40 procedures, which benefits from the mechanism and working principle of Zeus robot. First, with the surgeon sitting at a remote and ergonomically designed workstation, Zeus robotic system eliminates the need to twist and turn in awkward positions, which is in favour of the long and precise operation[8]. Second, it is the 12- to 15-fold magnification of image by the camera of Zeus system that conduces to accurate operation[9]. Third, it provides adjustable motion scaling and tremor reduction. Motion scaling reduces the surgeon' s motion at the console to finer movements within the patient. When the system is set to 5:1, a 5-cm sweep by surgeon's hand is a 1-cm sweep within the abdomen. This promotes the accuracy of operation. Tremor reduction can completely eliminate any tremor from the surgeon's hand, which increases the stability of operation, thereby decreasing operative errors[10]. The operative error was lower than that of early conventional laparoscopic surgery. The endowrist at the tip of instrument provides the surgeon with six degrees of freedom inside the patient's body. The additional degrees of freedom increase the dexterity and create the sense of actually having the surgeon's hand within the abdominal cavity during laparoscopic surgery. This vastly simplifies tasks such as suturing, tying and complex dissection, all of which are extremely challenging for most surgeons with standard laparoscopic equipment[11]. Nio *et al*.[12] selected 20 medical students without any surgical experience to perform at random a set of laparoscopic tasks either manually or robot-assisted (Zeus). This task consisted of dropping beads into receptacles, running a 25-cm rope, capping a hypodermic needle, suturing, and performing a laparoscopic cholecystectomy on a cadaver liver of a pig. The dropping beads exercise and the laparoscopic cholecystectomy required more time when performed with robotic assistance, as compared with manual performance. Grasping the beads, the rope, and either the needle or the cap were tasks that required fewer actions to complete when performed with robotic assistance. As compared with the robot-assisted rope-passing exercise, more failures were made in the manually performed procedure, mainly caused by unintentional dropping of the rope. Therefore, robot-assisted laparoscopic surgery by participants without any surgical experience might require more time, but actions can be performed more precisely as compared with manual laparoscopic surgery. Zeus robot-assisted laparoscopic cholecystectomy preserves the benefits of minimally invasive surgery. Robotic surgical system overcomes the technical limit of conventional laparoscopic surgery and expends the field of minimally invasive surgery into cardiac surgery. Kappert *et al*.[13] performed 29 off-pump totally endoscopic coronary bypass (TECAB) on a beating heart with the Da Vinci system and an endoscopic stabilizer (Intuitive Surgical Company). Patients were operated upon via four 1-cm chest incisions using the da Vinci robot for the internal thoracic artery (ITA) harvesting and for performance of anastomoses on the beating heart. In this series, they had a 100% survival rate. Conversion rate to a median sternotomy was 3.4%; time of harvesting was 26 min; time of anastomosis was 29 min; and operating time was 130 min. Post-operative time in ICU was 17 h; and post-operative hospital stay was 7 d. In robotic surgery, extra time is needed to setup and position the robotic arms and instruments before starting of the actual dissection[14]. However, the setup time decreased from 40-50 min to 20-30 min with increasing experience. If the robotic systems are placed at independent operating room and arms are fixed on the operating table the total operative time will reduce.

Zeus robot-assisted cholecystectomy is performed by the surgeon who controls the robotic arms via manipulators to accomplish the operation. It is not a job fulfilled 'automatically' by the robot according to a certain input program. The surgeon should follow the operative principle of conventional laparoscopic cholecystectomy, be familiar with the working rational of robotic systems, and continue to summarize the performing essentials as the accumulation of experience: (1) Installation of the robotic arms. Installation should depend on the body height and body type of the individual patient. Generally, the left and right robotic arms were placed at each side of the patient's head. Aesop arm was placed beside the left hip. The movable lower limits of the three arms were set to insert a palm between the robotic arm and the patient' s abdominal wall. The three robotic arms are adjusted in a double 90º position; (2) Place of trocar ports. The left trocar port should be placed in anterior axillary line 5 cm below the right costal margin, lower than that of conventional laparoscopic cholecystectomy, so as to favor the left robotic arm to retract gallbladder from various angles; (3) Tactile feedback is compensated by visual feedback. During robot-assisted procedures the surgeon cannot touch both the tissue and the instruments and lose the tactile feedback, which makes performing and judging more difficult. But, high-resolution and vivid three-dimensional operative field provided by robotic surgical system make it possible for the surgeon to observe the tiny morphological change of tissue. Thus the surgeon should utilize the high-quality visual feedback to compensate the lost tactile feedback, such as observing the deformation of tissue under pressure to judge strength[15]; (4) Conversion of the performing habits. During robot-assisted procedures, basic surgical manipulations, such as incision, separation, hemostasis, suture and so on, are converted to squeeze, relax, or rotate the egg-shaped manipulators. Due to these entirely changes of operative maneuvers, the surgeon is forced to form new habits through special training and practice.

Though the experience through the 40 Zeus robot-as-

sisted laparoscopic cholecystectomies was preliminary, we understood the advanced technical advantages of robotic surgical system, such as independent fine visualization, restored dexterity, *etc*. With the experience accumulated and performing craft enhanced, these advantages will convert to superior therapeutic efficacy, and the system will become a new therapeutic technical platform for the surgeons.

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