A Touch-Controlled Laparoscope Manipulator: Preliminary Trial to Evaluate the Performance on Female Porcine Pelvic Surgery and an Initial Experience in A Human Robot-Assisted Laparoscopic Segmental Salpingectomy

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Abstract: Background: A laparoscope manipulator enables the surgeon to perform an advanced surgery by offering the ability to stabilize and control the visual field. However, there are several problems to be solved such as difficulties to control and a long set-up time causing prolonged operating time. The novel laparoscope manipulating robot (KhonKaen-LMR) was introduced to overcome these problems. **Methods:** To evaluate the feasibility and safety of KhonKaen-LMR in real robot-assisted pelvic surgeries, the study was divided into 2 experiments. The first experiment was performed in live porcine robot-assisted pelvic surgeries and the second was in a robot-assisted human laparoscopic segmental salpingectomy. **Results:** The first experiment was performed in ten operations in three-month-old female pigs. The horizontal motion of the scope was from -25 degrees to +30 degrees (55 degree span) and the vertical motion of the scope was from 24 degrees to 51 degrees (27 degree span). The median optimal depth of the laparoscope position was 9.5 cm (range 6–12.5 cm). The median duration of machine set-up was 3 min (range, 2–11 min). The incised wounds showed no accessory tears and were completely healed in 7 days post-operation. The second experiment was scheduled in a 38 year-old woman for robot-assisted segmental salpingectomy. The duration of setting up was 7 min. The total operating time was 22 min. The surgeon and assistants were very impressed on the convenience of the control system. The laparoscope could move directly to the target point without image rotation which was similar to being moved by an assistant. No adverse effects that were related to the range or speed were noticed. A complete recovery was encountered in 7-day follow up. **Conclusion:** This new laparoscope manipulator was safe and feasible to operate in humans. It seemed to be quick to set-up and easy to control.

Key words: Laparoscopic surgery, robotically assisted surgery, camera assistant, minimally invasive surgery.

1. Introduction

Robot-assisted laparoscopic surgery, which is at the forefront of technology, has encompassed various technological fields. Specialty knowledge and new capabilities enable surgeons to practice new or more

difficult types of operations such as non-traumatic brain surgery, precision tumor resection or intrauterine fetal surgeries. Despite advanced laparoscopic procedures for gynecologic surgery that have been developed for nearly 20 years, laparoscopic procedures have not been widely adopted in clinical practice [1–3]. The evolution of laparoscopy from a monocular view to the video screen has enabled all in the operating room to see the procedure in real time. This has meant

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the surgeon must rely on an assistant to hold the scope which has many drawbacks [4]. Many surgeons have embraced the da Vinci robotic surgical system over conventional laparoscopy because of its technologic advantages such as the autonomy of camera control [1].

Laparoscope manipulating robot (LMR), one such technology, enables the surgeon to perform advanced minimally invasive procedures by offering the ability to stabilize and control the visual field [5–9]. In addition, it allows solo surgery in easy operations such as segmental salpingectomy either for female sterilization or unruptured tubal pregnancy by reducing some of the difficulty resulting from the assistant's scope movement.

Although the advantages of robot-assisted laparoscopy are well documented, there are several problems to be solved such as difficulties to control, a long set-up time resulting in a prolonged operating time and significantly high initial and maintenance cost. In addition, a large apparatus can interfere with surgical space. This novel laparoscope manipulating robot (KhonKaen-LMR), which received a very encouraging the gold medal award from the International Federation of Inventors' Associations, was introduced to overcome these problems.

This study was designed to evaluate the performance of KhonKaen-LMR by performing in real pelvic operations.

2. Patients and Methods

To measure the feasibility and safety of the KhonKaen-LMR, the study was divided into 2 experiments. The first experiment was in a live porcine robot-assisted pelvic surgery model. The experiment was to evaluate the robotic set-up time, optimal position for uterine horn operation, and the safety of the operations. The second was to assess the implementation of the LMR in a robot-assisted human laparoscopic segmental salpingectomy for female sterilization. The evaluation included the set-up time, total operating time, the impression of the surgeon and

assistant on the performance and the safety of the robot-assisted surgery. The operations were performed by an experienced laparoscopic gynecologist. The study was approved by the Animal Care and Use Committee of Khon Kaen University and the Khon Kaen University Ethics Committee (Reference No:AE 02/53).

2.1 Instrument and Control

The KhonKaen-LMR is composed of two separate parts: (1) a high dexterity positioning mechanical component and (2) a high performance control system. The positioning part is composed of four rigid components. The first component (A) is a stand on the floor close to operative table. A-B, B-C and C-D are connected with mechanical joints. The camera holding component (D) was moved spherically in three mutually perpendicular directions (3-DOFs, x,y,z) over the umbilical port (pivot point). A laser source was attached to the first component (A) as a guide in the set-up processes (Fig. 1).

A high performance control system is composed of two types of intuitive interfaces. First the control system is a touch user controlled interface. In the surgery room, the interface control system must be operated by using the surgeon's index finger to touch on the screen sensor, displaying the surgical view from the scope, at the selected view-point. Then the corresponding motors of the robotic arm will move the laparoscope until that view-point is moved to the center of the touch screen monitor. The second control is a remote controlled joystick which can be operated by an assistant during the time that the operator cannot drop an instrument to free his hand.

2.2 First Experiment

In the first experiment, ten consecutive robot-assisted pelvic surgeries were scheduled on three-month old female pigs. The robot was positioned on the right side of the operating table, opposite to the surgeon. After induction of pneumo-peritoneum,

Fig. 1 (Left) The robot is composed of four rigid components (A,B,C,D) which is moved in three spherically perpendicular directions (x,y,z). Left upper figure is a touch user controlled interface. (Right) The range of motions which is commensurate with typical motions is from -30 degrees to +30 degrees in the left to right direction (X). The optimal up/down direction(Y) is 28 degrees and the optimal in/out motion (Z) is 9.5 cm. A laser pointer which is attached to the component A is used as a guide in positioning set-up.

setting up the robot and insertion of all surgical ports, each uterine horn was explored and dissected with the help of the robot in manipulation of the scope video camera. The time to set-up the machine was recorded. The three-dimensional moving parameters were then taken at the point where the surgeon had located and clearly identified the uterine horns. Finally, after the laparoscope camera port was removed, the incised wounds were explored to identify any unexpected trauma caused by unexpected motion of the robotic arm. Seven days after the operation, a followed up for the post-operative health and the surgical wound healing was conducted.

2.3 Second Experiment

The second experiment was performed ten months later in a human patient after receiving permission from the University Ethics Committee (Reference No: HE 531191). The control software was rewritten to make it easier to use. The range of motion was limited according to the results of the first experiment for the safety of human operation.

The details of the new system were carefully explained to the patients and their informed consent

was obtained. The operation with assistance by the LMR was performed as follows: First, a skin incision about 12 mm long was made on the upper side of the patient's umbilicus. The laparoscope was inserted through a port applied to the incision. Second, the robotic arm which was covered with a sterilized plastic bag was then set. By using the laser beam guide, the robotic arm was moved until the beam was pointed at the umbilical port. Third, the laparoscope was then fixed to the robotic arm and tested to move in all directions by using the touch user controlled interface. The segmental salpingectomy was then performed by use of a 5 mm port in the left umbilical aspect for the surgeon's right hand and a 5 mm port in the left lower quadrant for the left hand. While grasper forceps were used to control the fallopian tube by the surgeon's right hand, a 5 mm pulse-modulating electrocoagulator and cutting device (*Gyrus PK*) which was controlled by the surgeon's left hand, was then used to coagulate and cut a tubal segment of 2–3 cm long and removed. The operator controlled the desired operative view by pointing the left hand index finger on the selected view-point showing on the screen sensor. Then, the other side was performed by the same processes. The

tubal sections were submitted in 10% buffered formalin for pathological evaluation. The operating time was measured in three categories; the time from skin incision to closure for the total operating time, the time for setting up the robot and added that in order to reach the optimal angle for the pelvic operation in 3-month pigs, which was very close to human pelvic field, the LMR needed to move from -30 degrees to +30 degrees (a 60 degree span) in the left to right direction (X), from +20 degrees to +60 degrees (a 40 degree span) in the up/down direction (Y) and 15 cm range for the in/out motion (Z). The results will lead the inventors to build a small and ergonomic camera holding robot. In addition, the limitations of robotic movement will ensure safety during operations.

Future experiments and development will be targeted toward a smaller apparatus and is expected to generate capability for more complex surgical procedures. The robotic arm will move in a spherical slide motion in limited range which can provide more work space on the operating table. The small-size robot can be mounted on the standard railing of the operating table with no need to reposition it when the operative table was tilted or moved up-down. In addition, it will also be modified to allow easy fixation or removal of the laparoscope to the robot-holding part for scope cleaning [15, 24].

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