Feasibility of robot-assisted laparoscopic surgery:

an evaluation of 35 robot-assisted laparoscopic cholecystectomies
Abstract

Introduction: Laparoscopic surgery offers patients distinct benefits but is not without its disadvantages to surgeons in terms of manoeuvrability and visualisation. Robotic telemanipulation systems were introduced with the objective of providing a solution to the problems in this field of surgery.

Methods: The feasibility of robot-assisted surgery was assessed by performing 35 laparoscopic cholecystectomies with the da Vinci robotic system. Time necessary for system set-up and operation was recorded, as were complications, technical problems, postoperative hospital stay, morbidity, and mortality.

Results: Thirty-four of 35 cholecystectomy procedures were completed laparoscopically with the da Vinci system. Technical problems occurred in three cases, resulting in one intraoperative complication (a mini-laparotomy caused by the loss of an instrument part). Median hospitalisation was 2 days. There were no postoperative deaths or morbidity within 30 days after surgery. System set-up time decreased as the experience of the operating team increased. Operating times were comparable with those reported for standard laparoscopic cholecystectomy.

Conclusion: Robot-assisted surgery was repeatedly proven as a safe and feasible approach to laparoscopic cholecystectomy.

Introduction

During the past two decades, laparoscopic surgery has become the treatment of choice for routinely performed surgical interventions in the abdomen, such as cholecystectomy and surgery for gastro-oesophageal reflux disease. The benefits of laparoscopic procedures for the patient, compared with those of open surgery, are clear and well described 1-6.

Although there are clear benefits to the patient, the surgeon faces distinct disadvantages. First, working through fixed abdominal entry points significantly diminishes manoeuvrability. Second, surgeons are handicapped by the loss of visual perception of depth that is intrinsic to working with a two-dimensional visualisation system.

Attempts have been made to solve these disadvantages by developing new surgeon-friendly instrumentation to support laparoscopic surgery. Recently, robotic telemanipulation systems have been introduced with the objective of providing dexterity and a view comparable with those of open surgery 7.

To evaluate the feasibility of robotic surgery, we performed robot-assisted laparoscopic cholecystectomy in 35 patients. As a routinely performed procedure, this operation offered us the opportunity to assess the feasibility of operating with a robotic telemanipulation system under well-controlled circumstances.

Patients and Methods

Between June 2000 and September 2001, robot-assisted laparoscopic cholecystectomy was performed in 35 patients (25 females and 10 males). Selection criteria were identical to those for elective laparoscopic cholecystectomy in our institute. Indications for surgery were biliary colic (29 patients), recent biliary pancreatitis (2 patients), and chronic right upper quadrant pain (4 patients). Ultrasonography confirmed the presence of gallstones in all 35 patients. Median age was 46 years (range, 22–72), median weight was 84 kg (range, 55–143), and median body mass index was 28 (range, 18–45).

The surgical procedure was performed with the assistance of the da Vinci system (Intuitive Surgical, Mountain View, CA, U.S.A.), which consists of a three-armed, table-side robotic cart, carrying the camera system and instruments, and a master console, where the surgeon is seated. Both the articulated robotic instruments and the three-dimensional camera system can be controlled from the console with two manipulators.

Three experienced laparoscopic surgeons (I. B., R. S. and I. B. R.) were trained by a system engineer to perform the laparoscopic cholecystectomies with the da Vinci system. The da Vinci system was positioned over the patient’s right shoulder (Figure 1). In every case, one of these surgeons controlled the master console while one of the other surgeons assisted at the operating table. After pneumoperitoneum was established, the camera trocar was introduced at the level of the umbilicus. The right
robot arm trocar was positioned in the left hypochondrium and the left arm in the right upper inguinal region. An additional trocar for an instrument to retract the gallbladder was placed in the epigastric region. The tableside surgeon assisted in retracting the gallbladder, clipping and changing the instruments. The console surgeon performed the actual cholecystectomy.

Complications and technical problems were noted and evaluated; postoperative hospitalisation, morbidity, and mortality were recorded; and the time necessary for system set-up and total operating room time were recorded.
Results

Acute cholecystitis, diagnosed by the finding of oedema around the gallbladder and attached omentum, was apparent at the time of surgery in 6 of 35 patients (17%). In 6 of 35 cases (17%), findings were chronic cholecystitis with attached omentum, fibrosis in Calot’s triangle, and dense adhesions between the gallbladder and the liver bed. In the remaining 23/35 cases (66%), uncomplicated gallstone disease was found.

In 34 of 35 cases (97%), the cholecystectomy was completed laparoscopically with the da Vinci system. There was one conversion to an open procedure, caused by the surgeons’ inability to expose the gallbladder sufficiently because of severe cholecystitis.

Mechanical problems occurred in three cases. In these cases the replaceable hook of the electrocautery instrument detached during the procedure. The hook could be removed laparoscopically in two of three cases, but this problem resulted in a 4-cm mini-laparotomy in one case. This was the single robot-related surgical complication.

Median total hospitalisation time was 2 days (range 1–10). Nine of 35 patients (26%) were dismissed on postoperative day 1, 23 of 35 (66%) on postoperative day 2, and 1 (3%) on postoperative day 3. The patient in whom a mini-laparotomy was performed stayed in the hospital for 4 days. The patient requiring conversion was hospitalised for 10 days because of simultaneous herniated nucleus pulposus repair. There were no postoperative deaths or morbidity within 30 days after surgery.

The median time needed to install and drape the robotic system was 15 minutes (range, 12–35). This set-up time decreased as the experience of the operating team increased, resulting in a reproducible time of 15 minutes in the last 25 cases (Figure 2). Median effective surgery time (skin to skin) was 82 minutes (range, 40–180) (Figure 2).

With increasing experience, the time needed for system set-up and draping decreased. Operating time remained constant during the 35 cases performed and was comparable to operating time in standard laparoscopic cholecystectomy.
Discussion

The surgeon’s limited dexterity is the principal disadvantage in laparoscopic surgery. Working through fixed entry points limits manoeuvrability of the instruments inside the body cavity to five degrees of freedom (Fig. 3). Moreover, the fixed entry point introduces a momentum in the surgeon’s movements, causing reversed instrument action and variability in the angular displacement performed outside the patient’s body and the resulting effect inside.

Additional problems in laparoscopic surgery are the loss of the eye–instruments–target axis and the loss of visual perception of depth. With such limitations, laparoscopic surgery has become a skill requiring extensive training, and the technique is known to have a steep learning curve 8.

Computer-assisted instrumentation was developed to overcome the problems of laparoscopic surgery. A start was made with computer-assisted camera guidance systems, such as the robot-assisted AESOP (Computer Motion, Goleta, CA, U.S.A.), TISKA (Karl Storz GmbH and Co., Tuttlingen, Germany), FIPS (Karl Storz GmbH and Co.), and Endoassist (Armstrong Healthcare Ltd., Wycombe, UK) 9-13. A breakthrough was the development of the concept of robotic telemanipulation systems.

With this concept the surgeon works from a remote master console, controlling a tablesde robotic servant. A computer is placed between the surgeon’s hands and the end-effectors (the instruments); thus, computer power is used to eliminate the disadvantages of laparoscopic surgery. The da Vinci system eradicates opposite instrument movement and variability in angular displacement, thus allowing the surgeon to perform laparoscopic manipulations while mimicking the natural movements of

Figure 3

Rotation of the end-effector of the instrument is made possible in two planes around the instrument’s tip, adding two degrees of freedom to the surgeon’s range of motions (dotted, the five degrees of freedom of classic laparoscopic surgery).
open surgery. The intuitive control of surgical manipulation is enhanced by restoration of the eye–hand–target axis, due to the integration of the visual system and manipulators in the master console. The surgeon’s manoeuvrability is vastly enhanced by two joints at the tip of the robotic instruments, offering two additional degrees of freedom, for a total of seven (Fig. 3). Tremors and trocar resistance thus are eradicated. Visual perception of depth is restored by a double optic system, providing separate images for both eyes, resulting in a true three-dimensional image.

Although laparoscopic cholecystectomy is a relatively simple procedure in which surgeons would not benefit most from these advantages, it offered us the opportunity to assess the feasibility of working with this novel technology in a well-known and safe environment. This study repeatedly demonstrated the technical feasibility of robot-assisted laparoscopic cholecystectomy. The number of procedures converted to an open procedure (1/35; 3%) is comparable to conversion rates reported for standard laparoscopic cholecystectomy 14-16. The mini-laparotomy, resulting from loss of the replaceable hook of the electrocautery instrument, was the single technical complication resulting from use of the system. The reliability of the electrocautery instrument was optimised during this study by the introduction of a modified replaceable hook. Most patients in this study (32/35; 91%) were discharged from the hospital by postoperative day 2. These numbers correspond with those reported for standard laparoscopic cholecystectomy at our institute and in the literature 17,18.

Although set-up is still an issue of concern in relatively short endoscopic procedures, it decreased to 15 minutes in the last 25 cases because of the operating team’s increasing experience. Effective surgery time did not contribute to this time decrease, because it was comparable with surgery time in standard laparoscopic cholecystectomy at our facility as well as in the literature 18,19. The time loss should decrease further with improvements in the ergonomics of the system and the design of dedicated operating theatres, where the robotic systems may be easily integrated. In the near future surgeons will have the choice between the current tableside cart and a robotic servant attached to the ceiling or wall in the operating theatre.

Because the systems currently being used are the first generation of robotic telemanipulators, a number of shortcomings still need to be addressed. The most important is the lack of force feedback. Currently this has to be compensated for by visual feedback. In the reports on laparoscopic cholecystectomies, the lack of force feedback was not described as disturbing, although handling fragile tissue required some experience. For procedures demanding higher technical skills, such as knot tying, this issue becomes more apparent. There is a distinct learning curve for surgeons striving to understand forces applied by the system 20.

Costs of the robotic hardware and the disposable accessories are a considerable factor. A reduction of these costs and of the system size and weight would improve the ability to implement systems in daily practice. The devices must become easier to install to ensure the ideal placement for a procedure and to prevent conflicts with other equipment, such as operating lights and anaesthesia tools. Improved system
ergonomics can also contribute to shorter installation times, alleviating pressure on tight operating schedules. In addition, a decrease in instrument and camera size must be achieved to minimise patient trauma. A broader range of instruments is required, with more surgeons in various disciplines working with the system.

Now that the feasibility of robot-assisted surgery in a routinely performed procedure has been evaluated, the use of these systems in more complex procedures will need to be assessed. Already, the use of these systems has shifted to procedures demanding higher manipulative capacities. Recently, there have been case reports on robot-assisted Nissen fundoplication, nephrectomy, adrenalectomy and Heller myotomy. Even procedures that require microscopic suturing, such as coronary and tubal bypasses, have been reported. In our clinic, the system is currently used for Nissen fundoplication, both abdominal and thoracic oesophageal myotomy, para-oesophageal hernia repair, and adrenalectomy. In our experimental laboratory the feasibility of intestinal anastomosis, bilidigestive bypass surgery, paediatric gastric fundoplication, and aortic reconstructive procedures is being assessed. After demonstration of the feasibility of robotic assistance in a broad spectrum of gastrointestinal surgical interventions, the demand will rise for prospective randomised trials to assess the true value of robot-assisted surgery.

In conclusion, laparoscopic surgery has entered a new era with the introduction of robotic telemanipulation systems. The results of the current study clearly support the feasibility of the use of this system in performing a standard laparoscopic surgical procedure. The value of robot-assisted surgery in other, more complex procedures will have to be assessed in the upcoming years.
References


