Robot-Assisted Surgery for Gastric Cancer: Experience at Our Institute

Jun Isogaki Shusuke Haruta Mariko Man-i Koichi Suda Yuichiro Kawamura
Fumihiko Yoshimura Toshiki Kawabata Kazuki Inaba Ken Ishikawa
Yoshinori Ishida Keizo Taniguchi Seiji Sato Seiichiro Kanaya Ichiro Uyama

Department of Surgery, Fujita Health University School of Medicine, Toyoake, Japan

Key Words

Robotic surgery · Da Vinci surgical system · Gastrectomy

Abstract

Objective: The robot-assisted surgical system was developed for minimally invasive surgery and is thought to have the potential to overcome the shortcomings of laparoscopic surgery. We introduced this system for the treatment of gastric cancer in 2008. Here we report our initial experiences of robot-assisted surgery using the da Vinci system. **Methods:** A retrospective review of robot-assisted gastrectomy for gastric cancer patients was performed in our institute. The clinicopathological features and surgical outcomes were analyzed. Whereas the procedures of the gastrectomy were similar to those of the usual laparoscopic surgery, several aspects such as the port placement and the role of the assistant were modified from those for conventional laparoscopic surgery. **Results:** From January 2008 to December 2010, 61 patients with gastric cancer underwent robot-assisted surgery. Gastrectomy was distal in 46 patients, total in 14, proximal in 1 and no operation was converted to the open procedure. D2 lymph node dissection was performed on 28 patients in the distal gastrectomy group and on 11 in the total gastrectomy group. Complications occurred in 2 cases (4%): these

consisted of ruptured sutures and hemorrhage from the anastomotic site. **Conclusions:** This study demonstrated that robot-assisted gastrectomy using the da Vinci system can be applied safely and effectively for patients with gastric cancer.

Copyright © 2011 S. Karger AG, Basel

Introduction

The technique of laparoscopic surgery has developed rapidly, and indications for this procedure are spreading. In the field of gastric surgery, laparoscopic surgery for gastric cancer was first reported in 1991 [1] and has since become increasingly frequent. In early gastric cancer, the laparoscopic gastrectomy has become a common alternative to open gastrectomy.

The advantages of laparoscopic gastrectomy are well reported, including a favorable clinical course after operation, a rapid return of gastrointestinal function, an early oral intake, a reduction of postoperative pain and a short hospital stay [2, 3]. However, laparoscopic surgery is not commonly used for advanced gastric cancer, and in this situation, open gastrectomy with D2 lymph node dissection (LND) is often performed. Laparoscopic gas-

Fig. 1. The surgeon sits at the surgeon console and operates the master controls below the display.

trectomy with D2 LND is a complicated procedure that is mainly performed in high-volume hospitals specializing in laparoscopic gastrointestinal surgery. Some of the factors that prevent the generalization of such complex laparoscopic surgery are the shallow 2-dimensional laparoscopic vision on the monitor and the intricate manipulations of the forceps required through the fixed ports. In recent years, however, robotic surgery has been recognized as having the potential to overcome the drawbacks of laparoscopic surgery. We introduced robotic surgery for gastrectomy in 2008 and report our experiences here.

The da Vinci Surgical System

The da Vinci surgical system was developed as a robot-assisted surgical system for minimally invasive surgery. It was initially implemented in the fields of cardiovascular and urological surgery [4–6], but its application is spreading to various fields including general surgery [7–13].

The da Vinci surgical system consists of three components: the surgeon console (fig. 1), patient-side cart (fig. 2) and vision system (fig. 3).

The surgeon sits at the surgeon console, the optical system of which provides a high-definition, 3-dimensional intracorporeal image of the patient. The surgeon operates the master controls and foot pedals below the display. Manipulation of the master controls is directly

Fig. 2. The patient-side cart is positioned beside the patient during the operation. The robotic arms are equipped with a camera and three EndoWrist instruments.

reflected in the movement of the surgical instruments of the patient-side cart. The patient-side cart is positioned beside the patient during the operation and is equipped with one camera arm and three or four robotic arms. EndoWrist instruments are attached to the robotic arms. These instruments have up to 7 degrees of freedom and reflect the hand movements of the surgeon exactly (fig. 4). Various types of EndoWrist instruments designed for specific functions such as grasping, dissecting, needle-holding, electric cautery and vascular clipping are available and are easily interchangeable by the assistant. The robotic arms and EndoWrist instruments are controlled by the computer, which includes the functions of tremor reduction and motion scaling. The vision system is equipped with a light source and high-resolution imaging devices, which provide the surgeon with precise 3-dimensional images of the surgical field without the need for special glasses.

Fig. 3. The vision system is equipped with high-resolution imaging devices. This provides precise 3-dimensional images without the need for special glasses.

Fig. 4. The dissecting forceps (EndoWrist instruments). All EndoWrist instruments have up to 7 degrees of freedom and move precisely according to the surgeon's instructions.

Fig. 5. The port placement in distal gastrectomy. The camera port is inserted at the umbilicus (1). Two ports (8-mm diameter) are placed in the bilateral hypochochondriac regions (2, 4). The 2nd and 3rd robotic arms are inserted into these ports. A further two ports (12-mm diameter) are placed at both sides of the lateral abdomen (3, 5). The left lateral abdominal port (5) is used for the 1st robotic arm.

Operative Procedures

We started to use the da Vinci Surgical System for gastric cancer treatment at Fujita Health University from January 2008. At present, robotic surgery is used in our institute to treat various conditions including cancer of the stomach, esophagus, colon and lung, and prostatic diseases. Here we describe our procedures for distal gastrectomy with D1+ β LND.

After induction of general anesthesia, the patient is placed in the reverse Trendelenburg position. The first port is inserted through a small laparotomy at the umbilicus (fig. 5). After pneumoperitoneum is established with 10 mm Hg intra-abdominal pressure, the laparoscope is introduced through the port and intraperitoneal exploration is carried out. Two ports (8-mm diameter) are placed at the bilateral hypochochondriac regions. These ports are placed slightly outside of what is usual in laparoscopic surgery to prevent interference between the robotic arms. The 2nd and 3rd robotic arms are inserted into these ports. A further two ports (12-mm diameter) are placed at both sides of the lateral abdomen. An additional 8-mm port is inserted into the left lateral abdominal 12-mm port (port-in-port) and is used for the 1st robotic arm. The patient-side cart is moved next to the patient after the port insertion and the robotic arms are connected to the ports. The assistant stands by the

Fig. 6. The operative field is mainly maintained by the 3rd robotic arm by grasping the tissue to the ventral side. The gastropancreatic fold (black arrows) is pulled up by the 3rd robotic arm (white arrow). Adequate tension of the tissue can be obtained by this maneuver.

Fig. 7. The root of the right gastroepiploic vein (white arrow) is exposed using the 1st and 2nd robotic arms. The 3rd arm pulls up the adipose tissue including the station no. 6 (infrapyloric) lymph nodes.

patient and inserts laparoscopic instruments such as the grasping forceps, laparoscopic coagulation shears, vessel sealing system, and electric cautery device through the right lateral abdominal port according to the surgeon's requests.

The surgeon manipulates the 1st and 3rd robotic arms with the right hand and the 2nd arm with the left hand. In conventional laparoscopic surgery, the operative field is maintained mainly by the bilateral forceps of the assistant. Whereas in robot-assisted surgery, the operative field is maintained mainly by the 3rd robotic arm by grasping the tissue to the ventral side (fig. 6). The surgeon manipulates the dissecting forceps in the 1st arm and the grasping forceps in the 2nd arm. The dissecting forceps can cauterize tissue as they are equipped with a bipolar electric cautery device.

In robot-assisted surgery, the role of the assistant is significant. The assistant performs the following manipulations beside the patient-side cart: the assistant sometimes opens up the operative field using grasping forceps with gauze, occasionally performs the surgical procedures (instead of the operator) using the vessel sealing system and a vessel clip, and observes the extracorporeal movement of robot arms responding appropriately when interference occurs. Because these manipulations are complicated, in our institute two assistants are placed on each side of the patient.

Distal Gastrectomy with D1+ β LND

The general procedures for distal gastrectomy are similar to those usually used for laparoscopic surgery. The D1+ β LND includes the dissection of perigastric (station no. 1, 3, 4sb, 4d, 5 and 6) and the following lymph nodes: station no. 7 (along the left gastric artery), no. 8a (along the common hepatic artery), and no. 11p (along the proximal splenic artery) [14, 15].

The gastrocolic ligament is spread out by the 3rd robotic arm and the assistant's grasping forceps, and divided using the dissecting forceps of the 1st arm and the assistant's laparoscopic coagulation shears. The left gastroepiploic vessels are divided at their roots using vessel clips and laparoscopic coagulation shears. The gastrocolic ligament is divided toward the pylorus. Station no. 6 (infrapyloric) lymph nodes are dissected and the right gastroepiploic vessels are divided at their roots (fig. 7). The 1st arm is then removed from the left lateral abdominal port and the duodenum is divided slightly distal to the pyloric ring using a linear stapler inserted via the left lateral abdominal port by the assistant. After transection of the duodenum, the 1st arm is returned to its original port. Station no. 5 (suprapyloric) lymph node is dissected and the right gastric vessels are divided at their roots. The lesser omentum is divided up to the right side of the cardia using the dissecting forceps of the 1st arm. Station no.

Fig. 8. The adipose tissue including the station no. 8a lymph nodes (white arrow) is pulled up by the 2nd robotic arm and is exfoliated from the common hepatic artery (black arrow) by the 1st robotic arm.

8a and 9 lymph nodes are then dissected (fig. 8). The left gastric vein and artery are divided and LND is completed at station no. 7. The gastropancreatic fold is dissected up to the gastric cardia. Station no. 1 and 3 (along the right cardia and the lesser curvature) lymph nodes are dissected. The stomach is transected using the linear stapler inserted via the left lateral abdominal port. The specimen is put into a bag and retrieved through the enlarged umbilical incision.

The gastroduodenostomy is performed intracorporeally using the linear stapler, based on the procedure reported by Kanaya et al. [16]. In brief, small holes are made at the stump of the stomach and that of the duodenum. A linear stapler is inserted into each hole via the left lateral abdominal port and fired by the assistant. The common entry hole is closed using the linear stapler and a drain is inserted at the dorsal side of the anastomosis.

Results

We started to use the da Vinci surgical system for gastric cancer treatment from January 2008. Up to December 2010, 61 patients with gastric cancer underwent robotic operation. These patients comprised 34 men and 27 women, with a mean age of 64 years (range 33–89). Postoperative data are shown in table 1. Gastrectomy was distal in 46 patients, total in 14, proximal in 1 and no opera-

Table 1. Patient operative data (mean $\pm$ SD)

	Total gastrectomy (n = 14)	Distal gastrectomy (n = 46)
Operative time, min	520 $\pm$ 177	388 $\pm$ 85
Blood loss, g	150 $\pm$ 234	61.8 $\pm$ 46.5
Dissected lymph nodes, n	43 $\pm$ 14	42 $\pm$ 18
Complication, n		
Ruptured suture	1	1
Hemorrhage from anastomotic site		1
Mortality, n	1	

tion was converted to the open procedure. D2 LND was performed on 28 patients in the distal gastrectomy group and 11 in the total gastrectomy group. We noted no complications thought to be directly related to the robotic surgical system. However, 1 patient who underwent total gastrectomy died from pulmonary embolism.

In the distal gastrectomy group, mean blood loss was 61.8 g (range 4–204) and mean operative time was 388 min (range 200–656). The mean postoperative hospital stay was 13.3 days (range 8–43). Complications occurred in 2 cases (4%): these consisted of ruptured sutures and hemorrhage from the anastomotic site.

Discussion

Laparoscopic surgery was first applied for gastric cancer in 1991 by Kitano et al. [1]. The development of the surgical technique and instruments has since allowed the procedure to be performed in many institutes. However, the limited view of the operative field and difficulties with the movement of the instruments have impeded the adaptation of laparoscopic surgery to complex operational procedures such as gastrectomy with D2 LND. The da Vinci surgical system was introduced in 1999 as a robot-assisted surgical procedure. This system enables the precise handling of instruments and provides high-resolution 3-dimensional images, and thus has the potential to overcome the shortcomings of laparoscopic surgery. The use of robotic surgery in complex procedures such as cardiac and prostatic surgery is well reported [4, 5, 17]; however, the literature contains few reports of robotic surgery for gastric cancer [10, 11, 18]. In 2002, Hashizume et al. [18] reported the first 2 cases of distal gastrectomy using the da Vinci surgical system. In 2009, Kim et al. [19] reported 100 cases of robotic gastrectomy, describing an

average total operative time of 233 min and a complication rate of 13%, as well as noting the feasibility of robotic surgery for gastric cancer. These outcomes are not inferior to those of conventional laparoscopic surgery or open surgery. The present series of our procedures performed since 2008 includes various types of surgery for gastric cancer. The complication rate was similar to that reported by Kim et al. [19] and to that of conventional laparoscopic surgery; our mean operative time, however, was rather longer. The reason for this is not clear, but it may relate to the fact that we are still becoming accustomed to the technical requirements of robotic surgery and in the future, as we get used to the robotic system, the operative time may be reduced.

We performed not only D1+ β LND but also D2 LND in the current series. Whereas the D2 LND is an essen-

tial procedure for the treatment of gastric cancer [14, 15], laparoscopic gastrectomy with this type of LND is technically difficult and is performed only in limited institutes. As we reported previously, D2 LND has been performed laparoscopically in our institute [20–23]. From our experiences, the da Vinci surgical system has the potential to make complex procedures, such as gastrectomy with D2 LND, easier than with the laparoscopic technique.

The da Vinci surgical system has the potential to become more common in gastric cancer surgery due to the precise visual equipment and good operability. Although a further accumulation of cases and long follow-ups after surgery are required, gastrectomy with the da Vinci surgical system may become a useful alternative to open and laparoscopic surgery.

References

- 1 Kitano S, Iso Y, Moriyama M, Sugimachi K: Laparoscopy-assisted Billroth I gastrectomy. *Surg Laparosc Endosc* 1994;4:146–148.
- 2 Adachi Y, Shiraishi N, Shiromizu A, Bandoh T, Aramaki M, Kitano S: Laparoscopy-assisted Billroth I gastrectomy compared with conventional open gastrectomy. *Arch Surg* 2000;135:806–810.
- 3 Kitano S, Shiraishi N, Fujii K, Yasuda K, Inomata M, Adachi Y: A randomized controlled trial comparing open versus laparoscopy-assisted distal gastrectomy for the treatment of early gastric cancer: an interim report. *Surgery* 2002;131:S306–S311.
- 4 Tatroles AJ, Pappas PS, Gordon PJ, Slaughter MS: Minimally invasive mitral valve repair using the da Vinci robotic system. *Ann Thorac Surg* 2004;77:1978–1982, discussion 1982–1984.
- 5 Nifong LW, Chu VF, Bailey BM, Maziarz DM, Sorrell VL, Holbert D, Chitwood WR Jr: Robotic mitral valve repair: experience with the da Vinci system. *Ann Thorac Surg* 2003;75:438–442, discussion 443.
- 6 Abbou CC, Hoznek A, Salomon L, Lobontiu A, Saint F, Cicco A, Antiphon P, Chopin D: Remote laparoscopic radical prostatectomy carried out with a robot: report of a case (in French). *Prog Urol* 2000;10:520–523.
- 7 Breitenstein S, Nocito A, Puhan M, Held U, Weber M, Clavien PA: Robotic-assisted versus laparoscopic cholecystectomy: outcome and cost analyses of a case-matched control study. *Ann Surg* 2008;247:987–993.
- 8 Hyung WJ: Robotic surgery in gastrointestinal surgery (in Korean). *Korean J Gastroenterol* 2007;50:256–259.
- 9 Hagen ME, Inan I, Pugin F, Morel P: The da Vinci surgical system in digestive surgery (in French). *Rev Med Suisse* 2007;3:1622–1626.
- 10 Song J, Oh SJ, Kang WH, Hyung WJ, Choi SH, Noh SH: Robot-assisted gastrectomy with lymph node dissection for gastric cancer: lessons learned from an initial 100 consecutive procedures. *Ann Surg* 2009;249:927–932.
- 11 Song J, Kang WH, Oh SJ, Hyung WJ, Choi SH, Noh SH: Role of robotic gastrectomy using da Vinci system compared with laparoscopic gastrectomy: initial experience of 20 consecutive cases. *Surg Endosc* 2009;23:1204–1211.
- 12 Jacob BP, Gagner M: Robotics and general surgery. *Surg Clin North Am* 2003;83:1405–1419.
- 13 Giulianotti PC, Coratti A, Angelini M, Sbrana F, Cecconi S, Balestracci T, Caravaglios G: Robotics in general surgery: personal experience in a large community hospital. *Arch Surg* 2003;138:777–784.
- 14 Japanese Gastric Cancer Association: Japanese Classification of Gastric Carcinoma – 2nd English edition. *Gastric Cancer* 1998;1:10–24.
- 15 Shimada Y: JGCA (the Japan Gastric Cancer Association). Gastric cancer treatment guidelines. *Jpn J Clin Oncol* 2004;34:58.
- 16 Kanaya S, Gomi T, Momoi H, Tamaki N, Isobe H, Katayama T, Wada Y, Ohtoshi M: Delta-shaped anastomosis in totally laparoscopic Billroth I gastrectomy: new technique of intraabdominal gastroduodenostomy. *J Am Coll Surg* 2002;195:284–287.
- 17 Patel VR, Thaly R, Shah K: Robotic radical prostatectomy: outcomes of 500 cases. *BJU Int* 2007;99:1109–1112.
- 18 Hashizume M, Shimada M, Tomikawa M, Ikeda Y, Takahashi I, Abe R, Koga F, Gotoh N, Konishi K, Maehara S, Sugimachi K: Early experiences of endoscopic procedures in general surgery assisted by a computer-enhanced surgical system. *Surg Endosc* 2002;16:1187–1191.
- 19 Kim HH, Hyung WJ, Cho GS, Kim MC, Han SU, Kim W, Ryu SW, Lee HJ, Song KY: Morbidity and mortality of laparoscopic gastrectomy versus open gastrectomy for gastric cancer: an interim report – a phase III multicenter, prospective, randomized trial (KLASS trial). *Ann Surg* 2010;251:417–420.
- 20 Yoshimura F, Inaba K, Kawamura Y, Ishida Y, Taniguchi K, Isogaki J, Satoh S, Kanaya S, Sakurai Y, Uyama I: Clinical outcome and clinicopathological characteristics of recurrence after laparoscopic gastrectomy for advanced gastric cancer. *Digestion* 2011;83:184–190.
- 21 Shinohara T, Kanaya S, Taniguchi K, Fujita T, Yanaga K, Uyama I: Laparoscopic total gastrectomy with D2 lymph node dissection for gastric cancer. *Arch Surg* 2009;144:1138–1142.
- 22 Uyama I, Sugioka A, Matsui H, Fujita J, Komori Y, Hasumi A: Laparoscopic D2 lymph node dissection for advanced gastric cancer located in the middle or lower third portion of the stomach. *Gastric Cancer* 2000;3:50–55.
- 23 Uyama I, Sugioka A, Fujita J, Komori Y, Matsui H, Hasumi A: Laparoscopic total gastrectomy with distal pancreatectomy and D2 lymphadenectomy for advanced gastric cancer. *Gastric Cancer* 1999;2:230–234.