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What are the reasons for a longer operation time in robotic gastrectomy than in laparoscopic gastrectomy for stomach cancer?

Heli Liu[1,2] · Takahiro Kinoshita[1] · Akiko Tonouchi[1] · Akio Kaito[1] · Masanori Tokunaga[1]

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Abstract

Background Many studies have shown that robotic gastrectomy requires a longer operation time than laparoscopic gastrectomy. However, no study has analyzed the exact reason for this difference in detail. We therefore investigated the reasons why more time is needed in robotic gastrectomy.

Methods Ten consecutive cases of robotic distal gastrectomy (RDG) performed in our institution were selected to measure the operation time in detail. Ten cases of laparoscopic distal gastrectomy (LDG) performed during the same period were chosen for comparison. The operation videos and electronic medical records of these 20 patients were retrospectively reviewed. The overall operation time, operation time in each step, and time required for instrument changes were measured. The number of intraoperative instrument changes and camera cleanings were also counted.

Results The overall operation time (including effective time and junk time) was 56.8 min longer for RDG than LDG (273.7 vs. 216.9 min, respectively; $p=0.000$). The effective time was only 15.3 min longer for RDG than LDG (145.9 vs. 130.6 min, respectively; $p=0.094$). The time needed for the six technical steps was also not significantly different between the two groups. However, the junk time (instrument setup and docking or positioning of surgical arms) was 41.5 min longer for RDG than LDG (127.8 vs. 86.2 min, respectively; $p=0.001$). The number of instrument changes was not different between RDG and LDG ($p=0.277$), but the time required for each was longer for RDG than LDG ($p=0.000$). The number of camera cleanings was lower for RDG than LDG (10.7 vs. 15.5 times, respectively; $p=0.005$).

Conclusions To reduce the operation time in RDG, a smarter and simpler system for setup should be developed to reduce the junk time. Additionally, a system for swifter instrument changes and more sophisticated energy devices are warranted to reduce the effective time.

Keywords Robotic distal gastrectomy · Laparoscopic distal gastrectomy · Operation time · Operative steps

Gastric cancer is the fourth most common malignant tumor and third leading cause of cancer-related death worldwide, and the estimated number of new cases reaches 1 million each year. Gastric cancer is particularly prevalent in East Asian countries, such as China, Japan, and Korea [1]. Surgery is still the mainstay treatment for the cure of gastric cancer, and laparoscopic surgery is increasing in popularity, as in other fields. According to the 2014 Japanese gastric cancer treatment guidelines (English ver. 4), laparoscopic surgery can be considered as an option in general clinical practice to treat clinical Stage I cancer, which is an indication for distal gastrectomy [2]. Several reports providing supportive evidence of its applicability to more advances stages have been published, but the long-term outcomes of randomized studies are pending [3–6]. Meanwhile, the technical difficulties of the procedure and long learning curve to obtain proficiency are hindering wider performance of this procedure in clinical practice.

Robotic technology is one of the latest developments in minimally invasive surgery and has shown potential to solve the shortcomings of conventional laparoscopic surgery [7, 8]. Robotic surgery was first put into practice in 2000, after being approved by the US Food and Drug Administration. The first report of robot-assisted gastrectomy was published

✉ Takahiro Kinoshita
takkinos@east.ncc.go.jp

1 Gastric Surgery Division, National Cancer Center Hospital East, 6-5-1 Kashiwanoha, Kashiwa, Chiba 277-8577, Japan

2 Department of Gastrointestinal Surgery, Xiangya Hospital, Central South University, Changsha 410008, Hunan, People's Republic of China

in 2003 by Giulianotti et al. [7]. Recent reports and meta-analyses have shown that the short-term outcomes and oncologic outcomes of robotic gastrectomy are either better or not inferior to those of laparoscopic gastrectomy [9–12]. Advantages of robotic gastrectomy include better ergonomics, less fatigue, tremor filtering, and more meticulous dissection by devices with multiple degrees of freedom. Suda et al. [9] reported that local rather than systemic complication rates were attenuated by using a surgical robot, and the authors speculated that the outstanding dexterity and precise maneuverability of the robotic instruments might have contributed to the reduction in local complications such as pancreatic fistula or intra-abdominal abscess formation. In contrast, the longer operation time and higher costs are concerns when using this technique. Cost is anticipated to decrease in the future with continued technological progression or higher numbers of candidate patients. A detailed analysis of the current surgery is necessary to identify the exact reasons for the longer operation time and thus establish ways to reduce it. The aim of the present study was therefore to identify the reasons why robotic gastrectomy requires more time through a comparison with conventional laparoscopic gastrectomy in a Japanese high-volume center with quality assurance.

Materials and methods

Patients

In this single-institution retrospective cohort study, we analyzed the clinical data and operative videos of patients with clinical Stage I/II gastric cancer who underwent radical distal gastrectomy either with a robotic or laparoscopic approach at the National Cancer Center Hospital East Japan. Robotic distal gastrectomy (RDG) for gastric cancer was initiated in June 2014 using the da Vinci Si Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA). To diminish the effect of the learning curve, we selected consecutive 10 patients (RDG group) as the study cohort after attaining experience with 30 cases (April 2016–November 2016). As the control cohort, 10 patients were chosen from those who underwent conventional laparoscopic distal gastrectomy (LDG) during the same period. At the time of the study, around 600 LDG procedures had already been performed in our institution. We reviewed the electronic medical records and operation videos of these 20 patients. This study was approved by the domestic institutional review board in our center.

Preoperative evaluation and surgical procedure

All patients underwent preoperative chest and abdominal computed tomography and upper gastrointestinal endoscopy to confirm the diagnosis of gastric carcinoma. All patients had a tumor located in the lower or middle third of the stomach according to the Japanese classification of gastric cancer [13]. Following the 2014 Japanese gastric cancer treatment guidelines (ver. 4), the standard D1+ or D2 radical operation was performed by RDG or LDG [2]. The technical steps for systematic lymphadenectomy or reconstruction were completely identical between RDG and LDG, which were performed according to our standardized procedures [14]. The lymph node stations were numbered in accordance with the 2014 Japanese gastric cancer treatment guidelines (ver. 4) [2]. Five ports were placed in both RDG and LDG. In terms of energy devices, monopolar electrocautery, ultrasonic shears, or Maryland-type bipolar forceps were used in RDG depending on the situation. In LDG, ultrasonic shears (Harmonic ACE®+; Ethicon Endosurgery, Cincinnati, OH, USA) or an ultrasonic-bipolar integrated device (Thunderbeat: Olympus, Tokyo, Japan) was used. Reconstruction was employed by either an intracorporeal Billroth-I delta-shaped anastomosis or iso-peristaltic Roux-en-Y anastomosis using linear staplers. As for the stapling devices, either a Powered Echelon (Ethicon Endosurgery) or iDrive Ultra (Medtronic, Minneapolis, MN, USA) was used in both RDG and LDG, and the stapler was introduced from an assistant laparoscopic port in RDG.

For detailed analyses of the operation time, the surgical process was divided into six technical steps (Figs. 1, 2). In each step, strict definitions of the measuring times were used.

(a) *port placement* from insertion of the second port (following camera port) to completion of insertion of the fifth port.
(b) *4sb lymph node dissection* from the first cutting of the middle part of the greater omentum to completion of the clearance along the proximal greater curvature line.
(c) *4d and 6 lymph node dissection* from the cutting of the right part of the greater omentum to division of the duodenum using a linear stapler.
(d) *suprapancreatic lymph node dissection, including 5, 7, 8a, and 9 (11p and 12a in D2)* from the first cutting of the peritoneum at the suprapancreatic region to completion of the clearance of adipose tissues around the celiac artery and its main branches.
(e) *1 and 3 lymph node dissection* from the first dissection of the posterior leaf of the lesser curvature to completion of clearance of the adipose tissue along the proximal part of the lesser curvature.
(f) *reconstruction stage* from creation of a small hole at the edge of the remnant stomach to completion of closure of the entry hole.

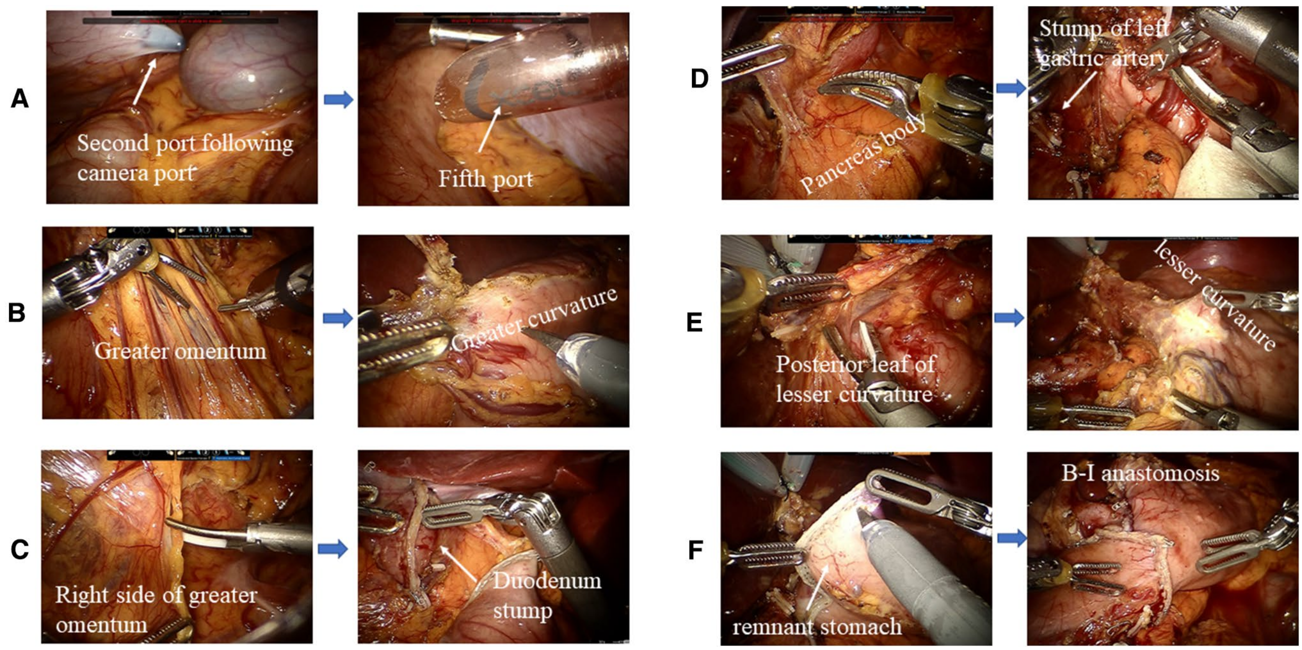

Fig. 1 Technical steps in robotic distal gastrectomy. **A** Port placement; **B** 4sb lymph node dissection; **C** 4d and 6 lymph node dissection; **D** suprapancreatic lymph node dissection, including 5, 7, 8a, 9, 11p, and 12a; **E** 1 and 3 lymph node dissection; and **F** reconstruction stage

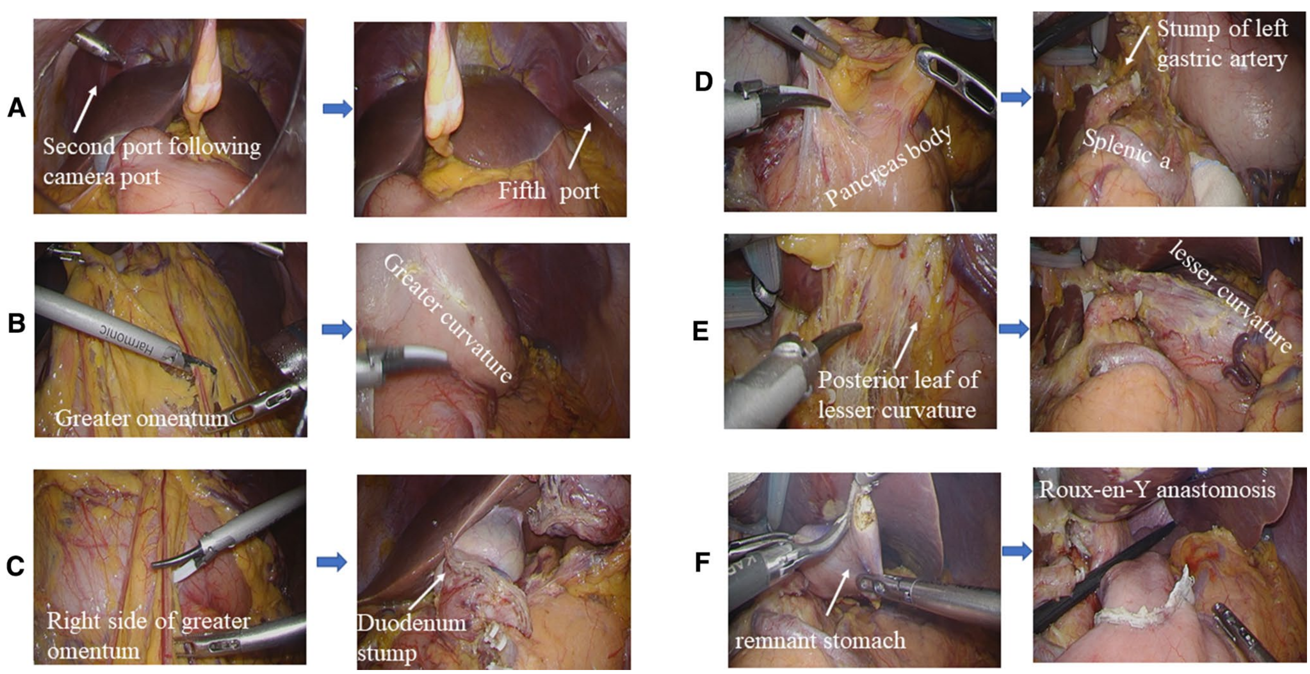

Fig. 2 Technical steps in laparoscopic distal gastrectomy. **A** Port placement; **B** 4sb lymph node dissection; **C** 4d and 6 lymph node dissection; **D** suprapancreatic lymph node dissection, including 5, 7, 8a, 9, 11p, and 12a; **E** 1 and 3 lymph node dissection; and **F** reconstruction stage

RDG was performed by a chief surgeon (T.K.), and LDG was performed by staff surgeons with adequate experience or by resident surgeons supervised by the chief surgeon (T.K.). The chief surgeon and all staff surgeons had obtained skill qualification from the Japan Society of Endoscopic Surgery.

Data from operative videos

By reviewing the operative videos, the overall operation time and time spent in each technical step were strictly measured by experienced surgeons (H.L. and T.K.) following the aforementioned definition in all 20 patients. The overall operative time was defined as the time from starting the skin incision to complete closure of all wounds. The overall time comprised two parts: the effective time (time required for the six technical steps) and junk time (setup, docking, and adjustment of surgical instruments other than those used in the six technical steps). The number of instrument changes and camera cleanings were also counted in all 20 patients. The number of bleeding events was counted; a bleeding event was defined as that requiring suturing, clipping, or compression using gauze. Finally, time needed for instrument changes was also measured in one representative case from the RDG and LDG groups.

Clinical parameters

We reviewed the following clinical and pathological factors from the medical records: sex, age, body mass index, comorbidities, tumor location, tumor size, lymph nodes harvested, pathological stage, depth of invasion, lymph node metastasis, extent of lymphadenectomy, reconstruction style, postoperative complication rate, postoperative hospitalization, and postoperative follow-up condition. The postoperative complications were graded according to the Clavien–Dindo classification [15].

Statistical analysis

All statistical analyses were performed using IBM SPSS statistics version 18 (SPSS Inc., Chicago, IL, USA). The Chi-square test and Student's t test were used for statistical analyses. A p value of <0.05 was considered statistically significant. Descriptive statistics are presented as mean ± standard deviation or percentage.

Results

Patient characteristics and short-term outcomes

The patients' demographic information is summarized in Table 1. There were no significant differences between the two groups of patients in the general background information, including sex, age, body mass index, comorbidities, tumor location, lymph nodes harvested, pathological stage, depth of invasion, extent of lymphadenectomy, reconstruction style, postoperative complication rate, minor bleeding events, and postoperative hospitalization. Although there was tendency toward a larger tumor size and higher frequency of lymph node metastasis in the LDG than RDG group ($p=0.376$ and $p=0.211$, respectively), the two groups were well balanced. The number of harvested lymph nodes

Table 1 Patients' baseline characteristics and short-term outcomes

	RDG ($n=10$)	LDG ($n=10$)	p value
Male/female	5/5	5/5	1.000
Age (years)	59.1 ± 11.6	61.6 ± 9.3	0.601
Body mass index (kg/m^2)	21.9 ± 1.9	21.7 ± 2.2	0.827
Comorbidities	3 (30%)	4 (40%)	0.639
Tumor location (L/M/U)[a]	4/6/0	3/7/0	0.639
Tumor size (mm)	40.7 ± 19.9	55.9 ± 49.0	0.376
Lymph nodes harvested	38.9 ± 7.4	35.8 ± 17.4	0.610
pStage (0/1/2/3/4)[b]	0/9/1/0/0	0/8/1/1/0	0.589
T (1/2/3/4)	9/0/1/0	6/2/1/1	0.443
N (0/1/2/3)	10/0/0/0	7/2/0/1	0.211
Extent of lymphadenectomy (D1/D1+/D2)	0/4/6	0/4/6	1.000
Reconstruction style (B-I/R-Y)	4/6	4/6	1.000
Complications, grade 2	1 (10%)	0 (0%)	1.000
Minor bleeding events	2 (20%)	2 (20%)	1.000
Postoperative hospitalization (days)	8.4 ± 1.8	8.3 ± 1.1	0.880

Data are presented as *n, n* (%), or mean ± standard deviation

[a]Japanese classification of gastric carcinoma (4th English edition)

[b]AJCC Staging Classification (7th edition); *RDG* robotic distal gastrectomy, *LDG* laparoscopic distal gastrectomy; *B-I* Billroth-I, *R-Y* Roux-en-Y

was similar between the RDG and LDG groups (38.9 ± 7.4 and 35.8 ± 17.4, respectively; $p = 0.610$). Postoperative hospitalization and minor bleeding events were also not significantly different between the two groups ($p = 0.880$ and $p = 1.000$, respectively). One patient in the RDG group developed a minor wound infection.

Time difference

The overall operation time was significantly longer for RDG than LDG (273.7 ± 21.5 vs. 216.9 ± 21.6 min, respectively; $p = 0.000$), and further analysis showed that the effective time was only 15.3 min longer for RDG than LDG (145.9 ± 17.5 vs. 130.6 ± 21.0 min, respectively; $p = 0.094$) (Fig. 3A). The operation time for each technical step (port placement; 4sb lymph node dissection; 4d and 6 lymph node dissection; suprapancreatic lymph node dissection, including 5, 7, 8a, 9, 11p, and 12a; 1 and 3 lymph node dissection; and reconstruction stage) was also not significantly different between the two groups ($p > 0.05$) (Fig. 3B). However, the junk time was 41.5 min longer in the RDG than LDG group, with statistical significance (127.8 ± 25.4 vs. 86.2 ± 23.7 min, respectively; $p = 0.001$) (Fig. 3A).

We also examined the frequency of instrument changes and camera cleanings and found that the number of instrument changes was slightly lower in the RDG than LDG group (49.2 ± 7.9 vs. 54.8 ± 13.7 times, respectively), although the difference was not statistically significant ($p = 0.277$). The number of camera cleanings was significantly lower in the RDG than LDG group (10.7 ± 2.7 vs. 15.5 ± 3.9 times, respectively; $p = 0.005$) (Fig. 3C). The time needed for each instrument change was significantly longer in the RDG than LDG group (19.8 ± 5.4 vs. 9.0 ± 3.5 min, respectively; $p = 0.000$) (Fig. 3D).

Discussion

To the best of our knowledge, this is the first study to compare the operation time of robotic gastrectomy with that of conventional laparoscopic gastrectomy in detail. The results of this study clearly indicate that the time for dissection or reconstruction was almost identical between the two groups but that the main cause of the prolonged time in robotic surgery is the junk time, which involves activities such as setting, docking, or adjusting the surgical instruments. When evaluating the operation time, the surgical quality or learning curve may easily influence the outcomes. The main strength of this study may be the quality assurance of the surgery. All surgical procedures were performed in a high-volume center in Japan with a high level of experience with gastric cancer surgery and where the basic procedure for

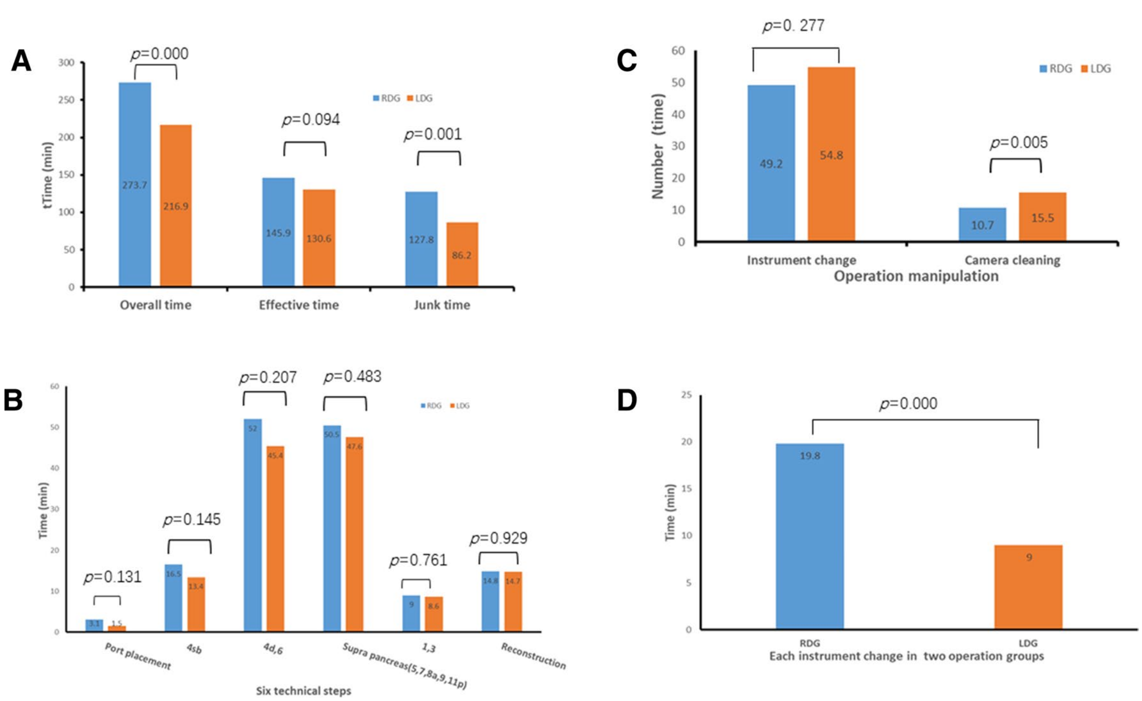

Fig. 3 Detailed analysis of the operation time and frequency of instrument changes in the two operation groups. **A** Overall operation time, effective time, and junk time in the two operation groups. **B** Time needed in the six technical steps of the two operation groups. **C** Number of instrument changes and camera cleanings in the two operation groups. **D** Time needed for each instrument change in the two operation groups. *RDG* robotic distal gastrectomy, *LDG* laparoscopic distal gastrectomy

distal gastrectomy has been well standardized. Additionally, surgical data were collected after a sufficient learning curve in both laparoscopic and robotic surgery; i.e., after 600 cases and 30 cases, respectively.

Surgical success was achieved in both operation groups according to the definition established by Yang et al. [16] (no conversion to open surgery, no in-hospital major postoperative complications, no readmission, no margin involvement, and an adequate number of retrieved lymph nodes). The overall operation time for RDG in our study was 273.7 min, which is similar to that in reports from Korea and shorter than that in reports from Japan [8, 9]. Finally, the overall operation time for RDG in our study was around 1 h longer than that for LDG.

The distal subtotal radical gastrectomy procedure has been strictly standardized in our institution, as mentioned above. This allowed us to accurately examine the time needed in each technical component. We observed that the effective time (time for dissection or reconstruction) was not substantially different (around 15 min) between RDG and LDG ($p > 0.05$). In particular, the time required for reconstruction was almost identical. This is understandable because the same stapler was used in the two groups, and the suturing performance during robotic surgery is excellent. Nevertheless, there may be a 15-min time period for dissection during robotic surgery that can be reduced. In the current robotic system, available energy devices are limited. Ultrasonic shears are available, but they lack joints at their shaft, which absolutely diminishes the advantage of the surgical robot. The development of more sophisticated energy devices with a thinner articulating shaft and sufficient coagulation–cut ability are warranted.

The junk time was significantly longer in RDG than LDG (around 40 min) ($p = 0.001$), which seems to be a pivotal cause of the prolonged operation time in RDG. The junk time mainly includes setup, docking, and adjustment of the surgical instruments. Additionally, because of the clumsy robotic arms, the time required for instrument changes was also apparently longer in RDG. To save time, the surgeon endeavors to reduce the frequency of instrument changes and camera cleanings. This might be the main reason why the numbers of instrument changes and camera cleanings were slight lower in RDG than LDG. Therefore, we believe that the industrial development of smarter techniques will decrease this time dramatically.

Only after overcoming the drawback of a longer operation time and higher cost will robotic surgery demonstrate long-term vitality. Some authors have pointed out that patient selection will play an important role in shortening operations and decreasing cost [17]. However, we believe doctors and companies must work together to create new tools and more feasible workflow is more important. For example, the repeating Hemolok clip in robot arms and smarter energy devices should be developed, and setup and docking should be more simplified.

In conclusion, robotic surgery has initiated a new era of minimally invasive surgery. Our findings might provide a reference for modifying or refining instruments of robotic surgery, which will objectively benefit patients.

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Compliance with ethical standards

Disclosures Drs. Heli Liu, Takahiro Kinoshita, Akiko Tonouchi, Akio Kaito, and Masanori Tokunaga have no conflicts of interest or financial ties to disclose.

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