Robotic gastrectomy for elderly gastric cancer patients: comparisons with robotic gastrectomy in younger patients and laparoscopic gastrectomy in the elderly

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Abstract

Background Robotic surgery for gastric cancer has been adopted to overcome technical difficulties in performing laparoscopic gastrectomy. This study aimed to investigate the feasibility and safety of robotic gastrectomy in elderly gastric cancer patients.

Methods Patients who underwent laparoscopic or robotic gastrectomy from 2003 to 2010 in a single high-volume center were included in this study. We retrospectively compared preoperative characteristics, perioperative factors, and oncological parameters among an elderly (≥ 70 years old) robotic gastrectomy group ($n = 49$), a younger (< 70 years old) robotic gastrectomy group ($n = 321$), and an elderly laparoscopic gastrectomy group ($n = 132$).

Results The elderly robotic group presented with more comorbidities than the younger robotic group. Except for

number of retrieved lymph nodes (36.5 vs. 41.5; $P = 0.007$), short-term operative outcomes including complications and pathological parameters were comparable between the two robotic groups. The elderly robotic group showed comparable disease-specific survival to the younger robotic group although overall survival was worse. Compared to their laparoscopic counterparts, the elderly robotic group showed longer mean operation time (227 vs. 174 min). Nevertheless, the incidence and severity of postoperative complications was not different between the two elderly groups. Overall and disease-specific survival were also comparable between the elderly groups. In multivariate analysis, age and surgical approach were not risk factors for overall and major complications.

Conclusions The outcomes of robotic gastrectomy in the elderly did not differ from those in younger robotic gastrectomy patients and were comparable to those in elderly patients who underwent laparoscopic gastrectomy. Thus, robotic gastrectomy could be a safe and feasible approach in elderly patients.

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Keywords Gastrectomy · Robot · Laparoscopy · Elderly · Minimally invasive surgery

Introduction

Gastric cancer is the fourth leading cause of cancer mortality and is responsible for 8.8 % of all cancer deaths worldwide [1]. Despite gradual decreases in its overall incidence, gastric cancer has been increasingly discovered in the elderly because of their extended life expectancy [2]. A larger number of these elderly patients are candidates for gastric resection [3]; however, a higher rate of

comorbidities places elderly patients at greater risk of postoperative morbidity and mortality [4, 5].

Laparoscopic gastrectomy offers better short-term postoperative outcomes than open surgery because of its minimal invasiveness [6–10]. Laparoscopic gastrectomy is reported to be beneficial even for the elderly, showing fewer associated pulmonary and cardiac complications, compared to open surgery [3, 11]. Nevertheless, older age and comorbidity are reported to be related to a higher incidence of systemic complications after laparoscopic gastrectomy [12].

Although laparoscopic gastrectomy has gained greater acceptance among surgeons, a limited range of movement of the laparoscopic instruments makes performing a precise lymphadenectomy difficult. As an alternative minimally invasive approach, robotic gastrectomy was introduced to overcome the limitations of laparoscopic gastrectomy, and is being increasingly performed [13–18]. However, reports on the safety and feasibility of robotic gastrectomy for elderly patients are lacking. In fact, the same concerns for potential hazards to elderly patients that were raised when laparoscopic gastrectomy was first introduced have also been raised for robotic gastrectomy, including prolonged operative time and pneumoperitoneum. To evaluate the safety and feasibility of robotic gastrectomy in elderly patients, we compared the surgical outcomes thereof with those for robotic gastrectomy in younger patients and with those for laparoscopic gastrectomy in elderly patients.

Patients and methods

Patients

From a prospective database maintained by the Department of Surgery, Yonsei University College of Medicine, we identified a total of 1465 laparoscopic ($n = 1023$) and robotic ($n = 442$) radical subtotal or total gastrectomies that were performed for patients with primary gastric adenocarcinoma between May 2003 and December 2010. Excluding patients who underwent combined operations and had a past history of gastric operations, the study included 940 patients in the laparoscopic group and 370 patients in the robotic group. Patients were then categorized according to age (elderly group, 70 years or older; younger group, younger than 70 years old). Among the patients who underwent robotic gastrectomy, 49 patients were assigned to the elderly group and 321 patients were placed in the younger robotic gastrectomy group. Of the 759 patients who underwent laparoscopic gastrectomy, 132 patients were assigned to the elderly laparoscopic gastrectomy group.

We compared preoperative patient characteristics, perioperative outcomes, and oncological parameters in the elderly robotic gastrectomy group with those in the young robotic gastrectomy group and the elderly laparoscopic gastrectomy group. Tumors were staged according to the seventh edition of the International Union Against Cancer Classification (UICC) and the American Joint Committee on Cancer (AJCC) [19]. Complications were graded according to the Clavien–Dindo classification [20].

The indications for robotic and laparoscopic gastrectomies were the same: clinically diagnosed gastric cancer without invasion to the serosal layer and without lymph node involvement in the extraperigastric area. Preoperative diagnosis was made by upper endoscopy, and clinical staging was performed with endoscopic ultrasound and abdominopelvic computed tomography. A detailed explanation of the operative systems and instruments, incision sizes, cost of surgery, and the expected postoperative course for both the robotic and laparoscopic approaches was given to each patient. Whether to undergo laparoscopic gastrectomy or robotic gastrectomy was decided by the individual patient after discussing both approaches, because the extra expenses incurred for robotic surgery are billed to the patient in Korea. All patients provided written informed consent for their operations. This retrospective study to compare surgical outcomes with other age groups and surgical techniques was approved by the Institutional Review Board (IRB) of Severance Hospital, Yonsei University College of Medicine (4-2011-0692). Because of the retrospective nature of the study, signed patient informed consent was waived per the IRB approval.

Surgical technique

The surgical techniques for the robotic and laparoscopic gastrectomies with lymph node dissection have been described in detail previously [21–24]. The da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was used to perform all robotic gastrectomies. The extent of lymph node dissection, either D1, D1+, or D2, was determined according to the Japanese Classification of Gastric Carcinoma [25].

Statistical analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) software, version 19.0 (IBM, Armonk, NY, USA). Factors including age, gender, body mass index (BMI), comorbidity, American Society of Anesthesiologists (ASA) score, conversion to another method, resection extent, reconstruction, lymph node dissection extent, operative time, estimated blood loss (EBL), maximum

level of postoperative high sensitivity C-reactive protein (hs-CRP; tested on postoperative days 0, 1, 3, and 5), postoperative complications, mortality, restoration of bowel function, and hospital stay, as well as tumor histology, size, location, margin, and TNM classification, were included for analysis. The robotic surgery in the current study was done as a clinical routine, not on an experimental basis. Thus, all parameters belong to our center's routine follow-up protocol and were derived from a prospectively designed database for the retrospective analyses. Patients were followed from the date of operation until December 31, 2012 or their death. Categorical and continuous variables were analyzed, respectively, by the chi-square test or Fisher's exact test and Student's *t* test or Mann–Whitney *U* test, as appropriate. Overall survival was recorded as from the time of surgery until death from any cause. Disease-specific survival was measured as the time

from surgery to gastric cancer-related death. Overall and disease-specific survival curves were depicted by the Kaplan–Meier method and compared by log-rank test. Multivariate analyses were conducted to assess risk factors for complications via logistic regression analysis. All *P* values < 0.05 (two-sided) were considered statistically significant.

Results

Clinicopathological characteristics

Differences between the elderly robotic gastrectomy group and the two other groups are shown in Table 1. The proportion of male patients in the elderly robotic gastrectomy group (75.5 %) was higher than that in the younger robotic

Table 1 Clinicopathological characteristics

Variables	Robotic gastrectomy in elderly patients (<i>n</i> = 49)	Robotic gastrectomy in younger patients (<i>n</i> = 321)	<i>P</i> ₁	Laparoscopic gastrectomy in elderly patients (<i>n</i> = 132)	<i>P</i> ₂
Age (years)*	74.8 ± 4.8	51.1 ± 10.2	<0.001 ^a	73.1 ± 3.7	0.029 ^a
Sex			0.040 ^b		0.116 ^b
Male	37 (75.5)	190 (59.2)		83 (62.9)	
Female	12 (24.5)	131 (40.8)		49 (37.1)	
Comorbidity			<0.001 ^b		0.096 ^b
No	9 (18.4)	184 (57.3)		41 (31.1)	
Yes	40 (81.6)	137 (42.7)		91 (68.9)	
Hypertension	31 (63.3)	61 (19.0)		69 (51.5)	
Diabetes mellitus	12 (24.5)	30 (9.3)		17 (12.9)	
Pulmonary	2 (4.1)	6 (1.9)		10 (7.6)	
Cardiac	7 (14.3)	15 (4.7)		13 (9.8)	
Renal	8 (16.3)	11 (3.4)		12 (9.1)	
Hepatic	3 (6.1)	17 (5.3)		5 (3.8)	
CVA	5 (10.2)	5 (1.6)		7 (5.3)	
Tuberculosis	6 (12.2)	21 (6.5)		12 (9.1)	
Others	8 (16.3)	36 (11.2)		16 (12.1)	
ASA score			<0.001 ^c		0.572 ^c
1	10 (20.4)	206 (64.2)		40 (30.3)	
2	31 (63.3)	96 (29.9)		72 (54.5)	
3	8 (16.3)	19 (5.9)		19 (14.4)	
4	0 (0)	0 (0)		1 (0.8)	
BMI (kg/m ²)*	24.2 ± 3.1	23.5 ± 3.0	0.118 ^a	24.1 ± 3.3	0.864 ^a

Values in parentheses are percentages

CVA cerebrovascular accident, ASA American Society of Anesthesiologists, BMI body mass index

*P*₁, robotic gastrectomy in elderly patients versus robotic gastrectomy in younger patients

*P*₂, robotic gastrectomy in elderly patients versus laparoscopic gastrectomy in elderly patients

* Values are mean ± SD

^a Student's *t* test

^b Chi-square test

^c Fisher's exact test

gastrectomy group (59.2 %; $P = 0.04$). As well, more elderly robotic gastrectomy patients presented with at least one comorbid condition (81.6 %) than those in the younger robotic gastrectomy group (42.7 %; $P < 0.001$). In regard to individual comorbid conditions, the elderly robotic gastrectomy group showed a higher prevalence of hypertension, diabetes mellitus, cardiac disease, renal disease, and cerebrovascular disease than the younger robotic gastrectomy group. Furthermore, the elderly robotic gastrectomy patients showed a higher ASA score than the younger robotic gastrectomy patients ($P < 0.001$). No significant differences in patient characteristics were noted between the elderly robotic gastrectomy and laparoscopic gastrectomy groups, except for age: the elderly robotic gastrectomy patients were older (mean, 74.8 years) than the elderly laparoscopic gastrectomy patients (mean, 73.1 years; $P = 0.029$).

Operative outcomes

The elderly robotic gastrectomy and younger robotic gastrectomy groups exhibited no significant differences in operative outcomes (Table 2). “There was no open or laparoscopic conversion in the robotic groups, while one laparoscopic gastrectomy in an elderly patient was converted to an open gastrectomy.” Mean operative time for the elderly robotic gastrectomy group (227.3 min) was approximately 50 min longer than that for the elderly laparoscopic gastrectomy group (174.3 min; $P < 0.001$). However, the mean EBL of the elderly robotic gastrectomy group (84.8 ml) was less than that of the elderly laparoscopic gastrectomy group (156.7 ml), although the difference was not statistically significant ($P = 0.056$). As a measure of the invasiveness of the surgical procedures, maximum postoperative hs-CRP values were similar between the elderly robotic gastrectomy group (110.5 mg/l) and the elderly laparoscopic gastrectomy group (103.9 mg/l; $P = 0.543$). Baseline hs-CRP ($P = 0.277$) and the difference between baseline and maximum postoperative hs-CRP ($P = 0.502$) were also similar between the two elderly groups.

Pathological findings

As shown in Table 3, there were no differences in tumor size and location, T classification, N classification, TNM stage, length of margin, and number of metastatic lymph nodes between the elderly and younger robotic groups. However, the proportion of patients with differentiated adenocarcinoma in the elderly robotic gastrectomy group was significantly higher than that in the younger robotic gastrectomy group (67.3 % vs. 36.1 %; $P < 0.001$). Additionally, the number of retrieved lymph nodes in the elderly robotic group ($n = 36.5$) was significantly smaller

than that in the younger robotic group ($n = 41.5$; $P = 0.007$). The number of retrieved lymph nodes in the elderly robotic group was larger compared to that of laparoscopic elderly groups, but the difference was statistically marginal ($P = 0.053$). When the number of retrieved lymph nodes was compared, based on the extent of lymph node dissection (D1+ or D2) in subtotal and total gastrectomy, no statistical differences were found between the groups, although the numbers of retrieved lymph nodes were still larger in robotic elderly groups than those in laparoscopic elderly groups, respectively. No significant differences in pathological findings, except for N classification ($P = 0.028$), were noted between the elderly robotic and the elderly laparoscopic groups.

Short-term outcomes

Complication rate in the elderly robotic gastrectomy group (14.3 %) did not differ from that in the younger robotic gastrectomy group (11.8 %; $P = 0.639$). The severity of complications in the elderly robotic group, measured according to the Clavien–Dindo classification, was also comparable to that in the younger robotic group ($P = 0.633$). Postoperative restoration of bowel function, first passage of flatus, resumption of soft diet, and hospital stay were also not significantly different between the elderly and younger robotic groups (Table 4).

As well, no statistical differences between the robotic and laparoscopic elderly groups were noted in terms of rate and severity of complications ($P = 0.659$, $P = 0.311$, respectively) or postoperative recovery. Only one instance of postoperative mortality occurred in the elderly laparoscopic group, as a consequence of intraabdominal bleeding.

Multivariate analysis of risk factors for postoperative complications

Multivariate logistic regression analysis showed male gender [hazard ratio (HR) 2.35, confidence interval (CI) 1.04–5.33] and an ASA score of 3 or 4 (HR 2.96, CI 1.15–7.63) to be significant risk factors for overall complications after robotic gastrectomy, but age was not (Table 5). Among elderly patients, male gender (HR 5.53, CI 1.64–18.65) and higher BMI (HR 1.18, CI 1.02–1.36) were risk factors for overall complications; type of approach (laparoscopic vs. robotic) was not.

With regard to major complications (grade 3 or higher according to Clavien–Dindo classification), age therefore was not shown to be a risk factor in the robotic group. As all major complications occurred in male patients, we were unable to calculate the HR and CI thereof. Among elderly patients, no variable, including type of procedure, was shown to be a risk factor for major complications.

Table 2 Operative findings

Variables	Robotic gastrectomy in elderly patients (<i>n</i> = 49)	Robotic gastrectomy in younger patients (<i>n</i> = 321)	<i>P</i> ₁	Laparoscopic gastrectomy in elderly patients (<i>n</i> = 132)	<i>P</i> ₂
Conversion			N/A		1.000 ^a
Yes	0	0		1 (0.8)	
No	53	321		131 (99.2)	
Resection			0.389 ^b		0.500 ^b
Distal	39 (79.6)	236 (73.5)		112 (84.8)	
Total	10 (20.4)	85 (26.5)		20 (15.2)	
LN dissection			1.000 ^a		0.502 ^a
D1	0 (0)	6 (1.9)		5 (3.8)	
D1+	28 (57.1)	179 (55.8)		70 (53.0)	
D2	21 (42.9)	136 (42.4)		57 (43.2)	
Operative time (min)*	227.3 ± 47.2	219.6 ± 47.5	0.290 ^c	174.3 ± 55.4	<0.001 ^c
EBL (ml)*	84.8 ± 105.1	71.4 ± 121.0	0.492 ^c	156.7 ± 320.0	0.056 ^c
hs-CRP (mg/l) [†]					
Baseline*	1.4 ± 1.6	2.2 ± 6.9	0.521 ^c	2.0 ± 3.3	0.277 ^c
Maximum*	110.5 ± 49.1	101.6 ± 53.6	0.361 ^c	103.9 ± 52.9	0.543 ^c
Difference* [‡]	109.1 ± 48.8	99.4 ± 53.6	0.320 ^c	101.8 ± 52.6	0.502 ^c

Values in parentheses are percentages

N/A not available, LN lymph node, EBL estimated blood loss, hs-CRP high-sensitivity C-reactive protein

*P*₁, robotic gastrectomy in elderly patients versus robotic gastrectomy in younger patients

*P*₂, robotic gastrectomy in elderly patients versus laparoscopic gastrectomy in elderly patients

* Values are mean ± SD

[†] hs-CRP was evaluated among patients without postoperative complications

[‡] Difference between baseline and maximum postoperative hs-CRP values

^a Fisher's exact test

^b Chi-square test

^c Student's *t* test

Survival analysis

Long-term follow up of survivors over a median of 57.8 months revealed significant differences in overall survival ($P = 0.002$) between the elderly and younger robotic gastrectomy groups, but not in disease-specific survival ($P = 0.222$) (Fig. 1). Three patients in the elderly robotic gastrectomy group (6.1 %), 18 patients in the younger robotic gastrectomy group (5.6 %), and 7 patients in the elderly laparoscopic gastrectomy group (5.3 %) experienced tumor recurrence during the study period. However, overall survival ($P = 0.800$) and disease-specific survival ($P = 0.569$) between the elderly robotic and laparoscopic groups were similar.

Discussion

In the present study, we found that the outcomes of robotic gastrectomy in elderly patients are comparable to those of robotic gastrectomy in younger patients, even

despite the fact that a greater number of elderly patients presented with co-morbidities. Moreover, robotic gastrectomy in the elderly showed similar postoperative outcomes to laparoscopic gastrectomy in the elderly: the rate and severity of postoperative complications based on Clavien–Dindo classification were similar between the two elderly groups despite a significant difference in mean operative time. As well, overall and disease-specific survival for patients in the elderly robotic gastrectomy group were similar to those in the elderly laparoscopic gastrectomy group.

Chronological age does not seem to affect short-term outcomes, including operation time, pathological outcomes, and recovery after robotic gastrectomy. Similar to previous studies that compared laparoscopic gastrectomies between elderly and younger patients [3, 26, 27], the robotic elderly group in this study had a higher number of comorbidities than the younger robotic group; nevertheless, postoperative outcomes were similar. Previous studies also report no difference in survival between elderly and younger gastric cancer patients [4, 28]. In this study, male

Table 3 Pathological parameters

Variables	Robotic gastrectomy in elderly patients (<i>n</i> = 49)	Robotic gastrectomy in younger patients (<i>n</i> = 321)	<i>P</i> ₁	Laparoscopic gastrectomy in elderly patients (<i>n</i> = 132)	<i>P</i> ₂
Tumor location			0.456 ^a		0.120 ^a
U	9 (18.4)	50 (15.6)		10 (7.6)	
M	11 (22.4)	101 (31.5)		32 (24.2)	
L	29 (59.2)	170 (53.0)		90 (68.2)	
Differentiation			<0.001 ^a		0.391 ^a
Differentiated	33 (67.3)	116 (36.1)		78 (59.1)	
Undifferentiated	16 (32.7)	205 (63.9)		54 (40.9)	
T classification			0.499 ^b		0.139 ^b
1	35 (71.4)	250 (77.9)		100 (75.8)	
2	4 (8.2)	26 (8.1)		20 (15.2)	
3	7 (14.3)	26 (8.1)		9 (6.8)	
4a	3 (6.1)	19 (5.9)		3 (2.3)	
N classification			0.352 ^b		0.028 ^b
0	37 (75.5)	263 (81.9)		109 (82.6)	
1	8 (16.3)	32 (10.0)		11 (8.3)	
2	1 (2.0)	14 (4.4)		11 (8.3)	
3	3 (6.1)	12 (3.7)		1 (0.8)	
TNM stage			0.330 ^b		0.166 ^b
Stage I	36 (73.5)	263 (81.9)		111 (84.1)	
Stage II	8 (16.3)	35 (10.9)		16 (12.1)	
Stage III	5 (10.2)	23 (7.2)		5 (3.8)	
Tumor size (cm)*	2.7 ± 1.4	2.5 ± 1.4	0.230 ^c	2.7 ± 1.5	0.885 ^c
Proximal margin (cm)*	4.2 ± 2.4	3.7 ± 2.5	0.271 ^c	4.1 ± 2.6	0.833 ^c
Distal margin (cm)*	7.5 ± 4.0	7.7 ± 4.5	0.730 ^c	6.3 ± 3.7	0.065 ^c
Metastatic LN*	0.8 ± 2.0	0.8 ± 2.7	0.959 ^c	0.6 ± 1.9	0.567 ^c
Retrieved LN*					
All	36.5 ± 11.0	41.5 ± 15.7	0.007 ^c	32.6 ± 12.2	0.053 ^c
STG (D1+)	33.4 ± 10.3	37.1 ± 14.4	0.264 ^c	31.5 ± 11.4	0.515 ^c
STG (D2)	39.4 ± 9.9	42.3 ± 12.9	0.368 ^c	36.4 ± 11.8	0.329 ^c
TG (D1+)	39.0 ± 16.0	48.5 ± 16.6	0.162 ^c	30.0 ± 9.3	0.127 ^c
TG (D2)	34.7 ± 5.0	48.5 ± 20.3	0.253 ^c	30.5 ± 15.7	0.676 ^c
Retrieved LN ≥ 15	48 (98.0)	317 (98.8)	0.511 ^c	123 (93.2)	0.291 ^c
Retrieved LN < 15	1 (2.0)	4 (1.2)		9 (6.8)	

Values in parentheses are percentages

LN lymph node, STG subtotal gastrectomy, TG total gastrectomy

*P*₁, robotic gastrectomy in elderly patients versus robotic gastrectomy in younger patients

*P*₂, robotic gastrectomy in elderly patients versus laparoscopic gastrectomy in elderly patients

* Values are mean ± SD

^a Chi square test

^b Fisher's exact test

^c Student's *t* test

gender was the only universal risk factor for postoperative complications. Male patients were older, had more comorbidity, and thus had higher ASA score than female patients in the robotic groups and underwent total gastrectomy more frequently in the elderly groups in the current study (data not shown). These findings were similar

to the results of a multicenter retrospective analysis in which Korean patients underwent laparoscopic gastrectomy for gastric cancer [29]. In our study, the elderly robotic group, as well as the elderly laparoscopic group, showed significantly worse overall survival than the younger robotic group. However, disease-specific survival

Table 4 Short-term outcomes

Variables	Robotic gastrectomy in elderly patients (<i>n</i> = 49)	Robotic gastrectomy in younger patients (<i>n</i> = 321)	<i>P</i> ₁	Laparoscopic gastrectomy in elderly patients (<i>n</i> = 132)	<i>P</i> ₂
Complication			0.639 ^a		0.659 ^a
Yes	7 (14.3)	38 (11.8)		24 (18.2)	
No	42 (85.7)	283 (88.2)		108 (81.8)	
Complication grade			0.633 ^b		0.311 ^b
Grade I	2 (28.6)	19 (50.0)		15 (62.5)	
Grade II	2 (28.6)	8 (21.1)		4 (16.7)	
Grade III	3 (42.9)	10 (26.3)		3 (12.5)	
Grade IV	0	1 (2.6)		1 (4.2)	
Grade V	0	0		1 (4.2)	
Mortality			N/A		1.000 ^b
Yes	0	0		1 (0.8)	
No	49	321		131 (99.2)	
Gas passage (POD)*	2 [2–5]	2 [1–17]	0.123 ^c	2 [2–4]	0.768 ^c
Soft diet (POD)*	4 [3–177]	4 [3–26]	0.994 ^c	4 [3–30]	0.118 ^c
Hospital stay (POD)*	5 [5–203]	5 [5–175]	0.179 ^c	6 [5–33]	0.156 ^c

Values in parentheses are percentages

N/A not available, *POD* postoperative day

*P*₁, robotic gastrectomy in elderly patients versus robotic gastrectomy in younger patients

*P*₂, robotic gastrectomy in elderly patients versus laparoscopic gastrectomy in elderly patients

* Values are median [range]

^a Chi-square test

^b Fisher's exact test

^c Mann–Whitney *U* test

in the elderly groups, respectively, was comparable to that in the younger robotic group.

Longer operative time and prolonged exposure to pneumoperitoneum are major concerns during surgery on elderly patients, who exhibit higher rates of cardiovascular and pulmonary comorbidities that can be adversely affected by longer anesthesia and pneumoperitoneum. Nevertheless, previous studies on laparoscopic gastrectomy in elderly patients have shown that longer operative time has no harmful effect on surgical outcomes [26, 27, 30, 31]. In this study, mean operative time in the robotic elderly group was significantly longer than that in the laparoscopic elderly group, by more than 50 min. However, as in the aforementioned studies on laparoscopic gastrectomy, the prolonged operative time and pneumoperitoneum in the elderly patients did not affect surgical outcomes (e.g., postoperative complications measured by Clavien–Dindo classification). As well, although the operative times for the robotic gastrectomies were longer than those for the laparoscopic gastrectomies, changes in serum hs-CRP levels after surgery were not statistically different between the elderly robotic gastrectomy and laparoscopic gastrectomy groups, indicating that the longer operative times of robotic surgery did not induce greater surgical stress or

invasiveness in the studied patients. Therefore, although robotic gastrectomy requires a longer operative time, compared to laparoscopic gastrectomy, the lesser surgical manipulation during robotic surgery may lead to less surgical stress in the patients.

For reasons of the limitations in surgical performance, laparoscopic surgeries tend to retrieve fewer lymph nodes than open conventional surgeries [10, 32, 33]. Meanwhile, robotic surgery, which allows for more well-defined dissection under a three-dimensional surgical view, has been shown to facilitate the retrieval of a larger number of lymph nodes than laparoscopic procedures, while minimizing blood loss [34]. In the present study, the number of retrieved lymph nodes was higher and the amount of blood loss during the operation was smaller in the elderly robotic group than in the elderly laparoscopic group, although the differences were marginal. However, the higher yield of lymph nodes in the robotic elderly group compared to the laparoscopic elderly group was not shown in the subgroup analyses that were performed according to the surgical extent, probably because of the small number of cases in the subgroups. The issue should be scrutinized by prospective study with a sufficient number of patients.

Table 5 Multivariate logistic regression analysis of risk factors for postoperative complications

Variable	Overall complications				Major complications			
	Robotic gastrectomy in younger and elderly patients		Robotic and laparoscopic gastrectomy in elderly patients		Robotic gastrectomy in younger and elderly patients		Robotic and laparoscopic gastrectomy in elderly patients	
	OR (95 % CI)	P	OR (95 % CI)	P	OR (95 % CI)	P	OR (95 % CI)	P
Procedure								
Laparoscopic (ref)								
Robotic	–	–	0.58 (0.20–1.66)	0.310	–	–	5.33 (0.14–204.44)	0.368
Age								
Younger (ref)			–	–			–	–
Elderly	1.04 (0.40–2.69)	0.943			0.94 (0.07–12.42)	0.964		
Sex								
Female (ref)								
Male	2.35 (1.04–5.33)	0.040	5.53 (1.64–18.65)	0.006	N/A		0.14 (0.00–4.15)	0.258
BMI								
kg/m ²	1.10 (0.98–1.24)	0.104	1.18 (1.02–1.36)	0.023	0.92 (0.66–1.27)	0.598	0.67 (0.41–1.08)	0.097
Comorbidity								
No (ref)								
Yes	0.69 (0.33–1.47)	0.336	1.17 (0.41–3.37)	0.766	0.90 (0.14–5.67)	0.910	1.71 (0.09–34.13)	0.726
ASA								
1 or 2 (ref)								
3 or more	2.96 (1.15–7.63)	0.025	0.81 (0.23–2.83)	0.743	0.51 (0.05–5.23)	0.591	0.82 (0.02–28.75)	0.912
Operative time								
Minute	1.00 (0.99–1.01)	0.880	1.00 (0.99–1.01)	0.605	1.01 (0.98–1.04)	0.587	1.01 (0.99–1.03)	0.430
Resection								
Subtotal (ref)								
Total	1.59 (0.69–3.68)	0.274	2.52 (0.90–7.04)	0.079	1.32 (0.18–9.79)	0.783	2.13 (0.07–65.04)	0.664
LN dissection								
D1 + or less (ref)								
D2	1.57 (0.78–3.17)	0.206	1.53 (0.63–3.68)	0.344	0.38 (0.05–3.13)	0.371	10.57 (0.38–293.55)	0.165
T classification								
EGC (ref)								
AGC	1.35 (0.60–3.02)	0.466	1.33 (0.47–3.76)	0.586	5.37 (0.47–60.93)	0.175	7.82 (0.35–173.05)	0.193
N classification								
N negative (ref)								
N positive	1.68 (0.73–3.86)	0.222	0.66 (0.18–2.34)	0.515	0.25 (0.02–3.21)	0.286	0.23 (0.00–15.35)	0.489

ref reference, BMI body mass index, ASA American Society of Anesthesiologists, LN lymph node, EGC early gastric cancer, AGC advanced gastric cancer, OR odds ratio, CI confidence interval

In general, in the present study, robotic gastrectomy in elderly gastric cancer patients was not inferior to laparoscopic gastrectomy, except for the longer operative time and higher costs. Nevertheless, in light of the results of this study, we suggest that robotic gastrectomy may hold potential benefits for elderly patients: retrieval of a larger number of lymph nodes will increase staging accuracy, and reduced intraoperative blood loss might help prevent tumor cell dissemination in the peritoneal cavity during the

operation [35]. Additionally, a shorter learning curve in robotic surgery, as suggested in previous studies, could enable surgeons lacking experience with minimally invasive surgery to perform complicated procedures of this kind more readily in higher-risk patients [36–38].

As far as we know, our report is the first to evaluate robotic gastrectomy for elderly patients in a relatively large cohort, assessing long-term oncological outcomes over a sufficient follow-up period. Additionally, we compared two

Fig. 1 Kaplan–Meier disease-specific survival curves for the elderly robotic, younger robotic, and elderly laparoscopic gastrectomy groups (log rank; $P = 0.222$, between the elderly and younger robotic groups; $P = 0.569$, between the elderly robotic and laparoscopic groups)

different minimally invasive techniques for treating elderly patients with gastric cancer. However, the main limitation was that our findings were derived from a single high-volume center. Data from multicenter randomized study are required to generalize the safety and efficacy of robotic gastrectomy in the elderly. Additionally, this retrospective analysis is limited by its lack of cost analyses. Results from an ongoing multicenter study (NCT01309256) will help further elucidate the role of robotic gastrectomy, in terms of cost-effectiveness, quality of life, and acute inflammatory reaction, in comparison to laparoscopic gastrectomy.

Herein, we showed that application of robotic surgery in elderly gastric patients is safe and feasible, by demonstrating that the short- and long-term outcomes thereof are comparable to those in younger robotic gastrectomy patients and elderly laparoscopic gastrectomy patients. Thus, for treating elderly patients with gastric cancer, we suggest that robotic gastrectomy is an acceptable alternative to laparoscopic gastrectomy.

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Conflict of interest The authors declare no conflicts of interest.

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