Risk Factors of Postoperative Intra-Abdominal Infectious Complications After Robotic Gastrectomy for Gastric Cancer

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Abstract

Background

Robotic surgery is regarded as an evolved type of laparoscopic surgery. Few studies have undertaken detailed analysis of complications following robotic gastrectomy for gastric cancer.

Methods

This is a single-center retrospective study of 149 consecutive patients with gastric cancer who underwent robotic gastrectomy. It examines in detail the postoperative complications in robotic gastrectomy for gastric cancer, focusing on intra-abdominal infectious complications including anastomotic leakage, pancreatic fistula and intra-abdominal abscess. We also aim to identify the related risk factors.

Results

The median operation time was 299 min and median bleeding was 25 ml. The incidence of overall complications higher than grade II was 8.7%. Clinically serious complications higher than grade IIIa occurred in 6.7% of cases. The incidence of intra-abdominal infectious complications that were higher than grade II was 4.0%. Mortality in our consecutive series was zero. Multivariate logistic regression analysis indicated that postoperative intra-abdominal infectious complications were significantly associated with history of abdominal surgery ($P = 0.043$), with odds ratios of 17.890 (95 % confidence interval 1.092 – 293.150) and with non-curative resection ($P = 0.025$), with odds ratios of 58.629 (95 % confidence interval 1.687 – 2037.450).

Conclusion

Robotic gastrectomy was shown to be a safe and effective treatment for gastric cancer when performed by experienced surgeons. Attention should be paid to the risk of developing postoperative complications when performing robotic gastrectomy in gastric cancer patients with a history of abdominal surgery and in patients with advanced gastric cancer in whom there is expected to be difficulty in curative resection.

Introduction

Robotic surgery is regarded as an evolved type of laparoscopic surgery. The robotic system benefits from an articulated wrist swivel device, a stable operation platform, and a wider operative field via three-dimensional vision. The effectiveness and safety of robotic gastrectomy (RG) for gastric cancer (GC) have been widely reported, and RG group has been shown to have lower rate of complications than the laparoscopic gastrectomy (LG) group [1–4]. Conversely, other reports have argued that the technological benefits of robots do not necessarily lead to reduction in postoperative complications [5–7].

Few studies have undertaken deep analysis of complications following RG, although one report highlighted that elderly patients and insufficient surgeon experience were risk factors for morbidity in

robotic gastric cancer surgery [8].

The present study aims to evaluate the postoperative complications in RG for GC, focusing on intra-abdominal infectious complications including anastomotic leakage, pancreatic fistula and intra-abdominal abscess, and to identify the related risk factors.

Materials And Methods

Patients

This study was single-center retrospective analysis of prospectively collected data. This study was approved by the Institutional Review Board at the Wakayama Medical University Hospital (WMUH). The committee that approved the research confirmed that all research was performed in accordance with relevant guidelines/regulations. Written informed consent was obtained from all participants and all research was performed in accordance with the Declaration of Helsinki.

Between May 1, 2017 and March 31, 2021, 486 patients underwent radical gastrectomy for GC at WMUH. Of these, 152 patients underwent RG, 311 patients underwent LG, and the remaining 23 patients underwent open gastrectomy. Patients with GC that underwent RG were included as part of a clinical trial (UMIN000027969/000031536) [9]. Among the 152 patients that underwent RG, we excluded two patients that required conversion to laparoscopic surgery due to machine trouble, and one patient that required conversion to open surgery due to portal vein injury [9]. The remaining 149 consecutive patients were included in this retrospective study.

Tumor stage was classified by the International Union Against Cancer TNM criteria, Eighth Edition [10]. Operation time was defined as the time from the skin incision to skin closure, and console time was the overall surgery time at the console. All surgical and medical complications and mortality events were documented. Postoperative complications were analyzed according to Clavien-Dindo classification [11]. Complications higher than grade II were considered to be clinically significant [11]. Surgical complications were confined to events that occurred within 90 days after surgery; these included anastomotic leakage, pancreatic fistula, intra-abdominal abscess, intra-abdominal bleeding, intraluminal bleeding, ileus, cholecystitis, anastomotic stenosis, and wound infection [9]. Medical complications included pulmonary, cardiovascular, liver, urinary and thrombosis events [9]. Intra-abdominal infectious complications were defined as anastomotic leakage, pancreatic fistula, and intra-abdominal abscess [9]. Reoperation cases were defined as any reoperation connected with any surgery-related complications [9]. Mortality was defined as any death that occurred during the hospital stay [9].

Surgical procedures

Details of the RG procedures performed at WMUH have been previously described [9, 12, 13]. All RG procedures were performed using da Vinci S, Si or Xi Surgical System (Intuitive, Sunnyvale, CA, USA) with four articulating robotic arms; a central second arm for a 30° rigid endoscope, a first arm for fenestrated

bipolar forceps, a third arm for monopolar scissors, and a fourth arm for Cadiere forceps [9]. One additional port for assisting forceps was placed at the right umbilical level. D1 or D1+ dissection was applied for clinical stage IA tumors, while D2 or D2 plus para-aortic nodal dissection was performed for tumors higher than clinical stage IB [14]. We performed lymph node dissection using monopolar scissors and a Vessel Sealer. Lymph node dissection was completed intracorporeally [9, 12, 13]. Intracorporeal anastomosis was performed using linear staplers, such as gastroduodenostomy, gastrojejunostomy, or esophagojejunostomy [15-18]. All operations were performed or overseen by one senior surgeon (T.O.) as a console surgeon or instructor.

Statistical examinations

SPSS version 24.0 (SPSS, Chicago, IL) was used for all statistical analyses. Quantitative results are expressed as medians and ranges. To identify risk factors for postoperative intra-abdominal infectious complications, we analyzed univariate and multivariate logistic regression. In the multivariate analysis, risk factors with a univariate $P<0.20$ were included, and risk factors with a multivariate $P<0.05$ were defined as independent risk factors.

Results

Patient demographics and tumor characteristics

The detailed characteristics of the 149 patients are listed in Table 1; there were 93 males and 56 females with median age of 72 years. Forty-one patients (27.5%) had history of abdominal surgery. The median tumor size was 30 mm. Eighty-nine patients (59.7%) had a differentiated adenocarcinoma, while 60 (40.3%) had an undifferentiated adenocarcinoma. Ninety-eight (65.8%), 33 (22.1%), 14 (9.4%), and 4 (2.7%) patients had TNM Stages I, II, III, and IV, respectively.

Table 1
Patient demographics and tumor characteristics

Variables	n = 149
Patients demographics	
Gender, Male / Female	93 / 56
Age, yr, median (range)	72 (34–90)
BMI, kg/m^2, median (range)	21.9 (14.0–32.1)
ASA score, 1 / 2 / 3	49 / 93 / 7
Comorbidity	
Hypertension (%)	73 (49.0)
Diabetes (%)	28 (18.8)
Pulmonary (%)	12 (8.1)
Cardiovascular (%)	18 (12.1)
Renal (%)	4 (2.7)
Hepatic (%)	2 (1.3)
Cerebrovascular (%)	6 (4.0)
History of abdominal surgery, (%)	41 (27.5)
Laparoscopic or open cholecystectomy	5
Appendectomy	20
Colorectal surgery	4
Gynecological surgery	11
Hepatectomy	1
Nephrectomy	1
Smoking history (%)	83 (55.7)
Daily drinker (%)	62 (41.6)
Tumor characteristics	

BMI body mass index, *ASA* American Society of Anesthesiologists, *U* upper third of the stomach, *M* middle third of the stomach, *L* low third of the stomach, *W* whole stomach

[1] Japanese Classification of Gastric Carcinoma.

[2] UICC 8th edition

Variables	n = 149
Location, U / M / L / W	42 / 39 / 65 / 3
Size, mm, median (range)	30 (4–150)
Histological type[1], differentiated (%) / undifferentiated	89 (59.7) / 60 (40.3)
pStage[2], I / II / III / IV	98 / 33 / 14 / 4
BMI body mass index, *ASA* American Society of Anesthesiologists, *U* upper third of the stomach, *M* middle third of the stomach, *L* low third of the stomach, *W* whole stomach	
[1] Japanese Classification of Gastric Carcinoma.	
[2] UICC 8th edition	

Surgical Results And Postoperative Complications

The detailed surgical results of the patients are listed in Table 2.

Table 2
Surgical results

Variables	n = 149
Operative procedure, DG (%) / TG / PG	93 (62.4) / 43 (28.9) / 13 (8.7)
Lymph node dissection[1], D1 / D1+ / D2 / D2 + PAND	2 / 78 / 68 / 1
Reconstruction, BI (%) / BII / RY / EG / DT	51 / 20 / 65 / 4 / 9
Combined resection, yes (%)	19 (12.8)
Gall bladder / Spleen / Pancreas / Colon / Renal (Partial)	14 / 6 / 2 / 1 / 2
Robot type, da Vinci Xi / da Vinci Si / da Vinci S	100 / 29 / 20
Operation time, min, median (range)	299 (179–654)
Console time, min, median (range)	252 (134–586)
Blood loss, ml, median (range)	25 (5–475)
Intraoperative transfusion, yes (%)	1 (0.7)
No. of retrieved lymph nodes, median (range)	32 (10–103)
No. of involved lymph nodes, median (range)	0 (0–46)
R classification R0[1] (%)	145 (97.3)
DG distal gastrectomy, *TG* total gastrectomy, *PG* proximal gastrectomy, *PAND* para-aortic nodal dissection, *BI* Billroth-I reconstruction, *BII* Billroth-II reconstruction, *RY* Roux-en-Y reconstruction, *EG* esophago-gastrostomy, *DT* double-tract reconstruction	
[1] Japanese Classification of Gastric Carcinoma.	

Ninety-three patients (62.4%) underwent distal gastrectomy, 43 patients (28.9%) underwent total gastrectomy, and 13 patients (8.7%) underwent proximal gastrectomy. One hundred forty five patients (97.3%) underwent curative resection. Nineteen patients (12.8%) had simultaneous combined organ resection. The median operation time was 299 min and median bleeding was 25 ml.

Postoperative complications are listed in Table 3. The incidence of overall complications was 8.7%. Clinically serious complications higher than grade IIIa occurred in 6.7% The incidence of intra-abdominal infectious complications was 4.0%. Reoperations (grade IIIb) were required for two patients (1.3%); one patient underwent laparoscopic ileus repair and the other required laparoscopic resection of anastomotic site for refractory anastomotic ulcer. Mortality in our consecutive series was zero.

Table 3
Postoperative complications

Variables	n = 149
Overall complication[1] ≥ grade II (%)	13 (8.7)
Overall complication, ≥ grade IIIa (%)	10 (6.7)
Intra-abdominal infectious complication[2], ≥ grade II (%)	6 (4.0)
Intra-abdominal infectious complication, ≥ grade IIIa (%)	5 (3.4)
Reoperation[3], grade IIIb (%)	2 (1.3)
Mortality	0
Surgical complication	
Anastomotic leakage, ≥ grade II (%)	4 (2.7)
Anastomotic leakage, ≥ grade IIIa (%)	3 (2.0)
Pancreatic fistula, ≥ grade II	0
Intra-abdominal abscess, ≥ grade IIIa (%)	2 (1.3)
Intra-abdominal bleeding, ≥ grade II (%)	2 (1.3)
Intra-abdominal bleeding, ≥ grade IIIa (%)	1 (0.7)
Ileus, ≥ grade IIIa (%)	2 (1.3)
Cholecystitis, ≥ grade II	0
Stenosis, ≥ grade II	0
Wound infection, ≥ grade IIIa (%)	1 (0.7)
Medical complication	
Pneumonia, ≥ grade II (%)	1 (0.7)
Pneumonia, ≥ grade IIIa	0
Cardiovascular system, ≥ grade II	0
Liver system, ≥ grade II	0

[1] Complications were classified into five categories according to the Clavien–Dindo classification.

[2] Including anastomotic leakage, pancreatic fistula, and intra-abdominal abscess.

[3] One patient underwent laparoscopic ileus repair and the other underwent laparoscopic resection of anastomotic ulcer.

Variables	n = 149
Urinary system, ≥ grade II	0
Thrombosis, ≥ grade II	0
[1] Complications were classified into five categories according to the Clavien–Dindo classification.	
[2] Including anastomotic leakage, pancreatic fistula, and intra-abdominal abscess.	
[3] One patient underwent laparoscopic ileus repair and the other underwent laparoscopic resection of anastomotic ulcer.	

Univariable And Multivariable Analyses Of Risk Factors Influencing Intra-abdominal Infectious Complications

Univariable and multivariable analyses were performed to identify associative risk factors influencing the intra-abdominal infectious complications (higher than Clavien-Dindo grade II) in patients with GC who underwent RG. The 28 variables were univariately examined as potential associative risk factors for the six patients with complications compared with the 143 patients without complications (Table 4). In univariable analyses, seven of the 28 risk factors differed significantly between these groups (Table 4, $P < 0.20$), and were selected as significant associative risk factors. Multivariate logistic regression analysis indicated that postoperative intra-abdominal infectious complications were significantly associated with history of abdominal surgery (Table 4, $P = 0.043$), with odds ratios of 17.890 (Table 4, **95**% confidence interval 1.092–293.150) and with non-curative resection (Table 4, $P = 0.025$), with odds ratios of 58.629 (Table 4, **95**% confidence interval 1.687–2037.450).

Table 4
Univariable and multivariable analyses of risk factors influencing intra-abdominal infectious complication with higher than grade II

Risk factors	Variables	Univariate Analysis		Multivariate Analysis	
		P	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)
Gender	Female	0.827	1		
	Male		0.824 (0.146–4.652)		
Age, yr	< 72	0.337	1		
	≥ 72		0.429 (0.076–2.415)		
BMI, kg/m^2	< 25	0.690	1		
	≥ 25		0.641 (0.072–5.679)		
ASA	1	0.997	1		
	2 / 3		NE		
Hypertension	No	0.441	1		
	Yes		0.507 (0.090–2.856)		
Diabetes	No	0.892	1		
	Yes		0.859 (0.096–7.658)		
Pulmonary	No	0.442	1		
	Yes		2.400 (0.257–22.396)		
Cardiovascular	No	0.727	1		
	Yes		1.482 (0.163–13.458)		

CI confidence interval, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *NE* not estimated, *DG* distal gastrectomy, *TG* total gastrectomy, *PG* proximal gastrectomy, *PAND* para-aortic nodal dissection, *BI* Billroth-I reconstruction, *BII* Billroth-II reconstruction, *RY* Roux-en-Y reconstruction, *EG* esophago-gastrostomy, *DT* double-tract reconstruction, *M* middle third of the stomach, *L* low third of the stomach, *U* upper third of the stomach, *W* whole stomach

[1] Japanese Classification of Gastric Carcinoma.

[2] UICC 8th edition

Risk factors	Variables	Univariate Analysis		Multivariate Analysis	
		P	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)
Renal	No	0.999	1		
	Yes		NE		
Hepatic	No	0.999	1		
	Yes		NE		
Cerebrovascular	No	0.150	1	0.070	1
	Yes		5.520 (0.540-56.454)		29.695 (0.755-1167.344)
History of abdominal surgery	No	0.049	1	0.043	1
	Yes		5.730 (1.008–32.584)		17.890 (1.092–293.150)
Smoking history	No	0.774	1		
	Yes		0.788 (0.154–4.035)		
Daily drinker	No	0.676	1		
	Yes		0.692 (0.123-3.900)		
Operative procedure	DG	0.156	1	0.304	1
	TG / PG		3.500 (0.620-19.767)		0.154 (0.004–5.452)
Lymph node dissection[1]	D1 / D1+	0.101	1	0.982	1
	D2 / D2 + PAND		6.172 (0.703–54.173)		0.968 (0.061–15.409)
Reconstruction	BI / BII	0.480	1		

CI confidence interval, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *NE* not estimated, *DG* distal gastrectomy, *TG* total gastrectomy, *PG* proximal gastrectomy, *PAND* para-aortic nodal dissection, *BI* Billroth-I reconstruction, *BII* Billroth-II reconstruction, *RY* Roux-en-Y reconstruction, *EG* esophago-gastrostomy, *DT* double-tract reconstruction, *M* middle third of the stomach, *L* low third of the stomach, *U* upper third of the stomach, *W* whole stomach

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Risk factors	Variables	Univariate Analysis		Multivariate Analysis	
		P	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)
	RY / EG / DT		1.865 (0.331–10.506)		
Combined resection	No	0.770	1		
	Yes		1.389 (0.153–12.574)		
Robot type	da Vinci Xi	0.981	1		
	da Vinci Si / S		1.021 (0.181–5.777)		
Operation time, min	< 300	0.130	1	0.116	1
	≥ 300		5.362 (0.611–47.056)		43.464 (0.392-4824.197)
Blood loss, ml	< 25	0.749	1		
	≥ 25		1.326 (0.235–7.498)		
Tumor location	M / L	0.294	1		
	U / W		2.405 (0.466–12.400)		
Tumor size, mm	< 30	0.629	1		
	≥ 30		1.531 (0.272–8.629)		
Histological type[1]	Differentiated	0.725	1		
	Undifferentiated		0.733 (0.130–4.133)		
pT stage[2]	T1	0.039	1	0.113	1

CI confidence interval, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *NE* not estimated, *DG* distal gastrectomy, *TG* total gastrectomy, *PG* proximal gastrectomy, *PAND* para-aortic nodal dissection, *BI* Billroth-I reconstruction, *BII* Billroth-II reconstruction, *RY* Roux-en-Y reconstruction, *EG* esophago-gastrostomy, *DT* double-tract reconstruction, *M* middle third of the stomach, *L* low third of the stomach, *U* upper third of the stomach, *W* whole stomach

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Risk factors	Variables	Univariate Analysis		Multivariate Analysis	
		P	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)
	≥T2		9.896 (1.124–87.097)		20.465 (0.487-859.427)
Lymph node metastasis	No	0.313	1		
	Yes		2.326 (0.451–11.986)		
No. of retrieved lymph nodes	< 32	0.960	1		
	≥ 32		0.959 (0.187–4.912)		
Curative resection[1]	Yes	0.001	1	0.025	1
	No		32.250 (3.916-317.342)		58.629 (1.687-2037.450)

CI confidence interval, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *NE* not estimated, *DG* distal gastrectomy, *TG* total gastrectomy, *PG* proximal gastrectomy, *PAND* para-aortic nodal dissection, *BI* Billroth-I reconstruction, *BII* Billroth-II reconstruction, *RY* Roux-en-Y reconstruction, *EG* esophago-gastrostomy, *DT* double-tract reconstruction, *M* middle third of the stomach, *L* low third of the stomach, *U* upper third of the stomach, *W* whole stomach

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Discussion

The present study examined the surgical outcomes of RG for GC in a relatively large cohort of patients managed by a single surgeon. Robotic surgery for GC patients was a safe and feasible procedure with low frequency of postoperative complications. Risk factors for the development of intra-abdominal infectious complications after RG were history of abdominal surgery and non-curative resection.

In this study of 149 patients, the overall morbidity with higher than grade II was 8.7% and the intra-abdominal infectious complications including anastomotic leakage, pancreatic fistula, and intra-abdominal abscess was 4%. Our postoperative complication rate was lower than that of previous studies [1–8, 19, 20]. Notably, no pancreatic fistulas were found in our surgical series. A nationwide Japanese registry database indicated that pancreatic fistulas tend to increase in LG [21]. Laparoscopic ultrasonically activated devices (USAD) and assisting forceps may cause thermal damage and pressure injury to the pancreas [1, 12, 19]. Our study showed that RG procedure without a using USAD, which avoids contact with the pancreas, could result in reduced incidences of pancreatic fistulas. In addition,

robotic surgery is designed to overcome the drawbacks of laparoscopy in that forceps with articulated function can be used [1–8]. In RG using articulating forceps, it is possible to perform lymphadenectomy without contact with the pancreas.

History of abdominal surgery has been traditionally considered to be a relative contraindication for LG, and with high rate of conversion to open gastrectomy [22, 23]. With improvement of minimally-invasive surgery technology, recent studies have found no differences between patients with and those without a history of abdominal surgery in surgical outcomes following LG [24–26]. However, the feasibility of RG for patients with a history of abdominal surgery has not yet been demonstrated. RG is generally avoided for such patients because of the risk of injuring the gut during exfoliation of adhesions. In patients with a history of colorectal surgery, robotic exfoliation of ball-shaped jejuno-to-jejuno adhesions was especially difficult because the robotic system lacks tactile sensation. Patients after colorectal surgery who require robotic total gastrectomy and Roux-en-Y reconstruction might therefore have been at a high risk for intra-abdominal infectious complications.

We performed RG only on patients with GC undergoing curative-intent resection. However, 4 of the 149 patients underwent non-curative resection, and non-curative resection was an independent risk factor for complications. The incidence of postoperative complications in patients with GC that underwent non-curative resection was shown in previous reports to be about 30%, which was higher than that in patients that underwent curative resection [27–29]. Robotic extended lymph node dissection and gastrectomy with multiple organ resections are controversial for patients with locally advanced GC.

This study has several limitations, it was a retrospective study and conducted in a single institution. The medium sample size would decrease statistical power. In contrast with Western countries, the number of obese patients in our Japanese hospital was extremely small, which may have led to the frequency of postoperative intra-abdominal infectious complications being lower than reported in previous studies. In addition, we did not show the long-term oncological outcomes of patients who underwent RG, which might confirm the final impact of RG. A multi-center prospective study is required that would evaluate the benefits including consideration of postoperative complications, quality of life, or more long-term oncological outcomes in patients with GC treated with RG.

Conclusion

This retrospective study suggests that RG is a safe and effective treatment for GC when performed by experienced surgeons. Special attention should be paid to the risk of developing postoperative complications when performing RG on GC patients with a history of abdominal surgery and on patients with advanced GC who are expected to have difficulty in curative resection.

Abbreviations

RG

robotic gastrectomy
GC
gastric cancer
LG
laparoscopic gastrectomy
WMUH
Wakayama Medical University Hospital
USAD
ultrasonically activated devices

Declarations

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Authors' Contributions

T.O. designed the study and wrote the initial draft of the manuscript. T.O. and K.H. contributed to data interpretation and critical revision of the manuscript. All the other authors (J.K., A.T. and H.Y.) contributed to data collection and interpretation and critical review of the manuscript. All authors have read and approved the final version of the manuscript and have agreed to be accountable for all aspects of the study, ensuring that any queries related to the accuracy or integrity of any part of the work are answerable.

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Data availability / Availability of Data and Materials statement

The datasets generated and/or analyzed during the current study are not publicly available due to hospital regulations but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Wakayama Medical University Institutional Review Board. All procedures were undertaken in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Informed consent to be included in the study, or the equivalent, was obtained from all patients.

Consent for publication

Not applicable.

Competing Interests

The authors declare no competing interests.

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