Tokunaga *et al*. *J Cancer Metastasis Treat* 2018;4:40
DOI: 10.20517/2394-4722.2017.80

Journal of Cancer Metastasis and Treatment

Review

Open Access

Robotic gastrectomy for gastric cancer

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How to cite this article: Tokunaga M, Watanabe M, Sugita S, Tonouchi A, Kaito A, Kinoshita T. Robotic gastrectomy for gastric cancer. *J Cancer Metastasis Treat* 2018;4:40. http://dx.doi.org/10.20517/2394-4722.2017.80

Received: 21 Nov 2017 **First Decision**: 23 Jan 2018 **Revised**: 13 Feb 2018 **Accepted**: 14 Jul 2018 **Published**: 30 Jul 2018

Science Editors: Lucio Miele, Masayuki Watanabe **Copy Editor**: Jun-Yao Li **Production Editor**: Cai-Hong Wang

Abstract
Robotic gastrectomy (RG) is increasingly performed, particularly in East Asia. With articulated devices, surgeons are able to perform every procedure more comfortably and meticulously, which makes RG ideal from the surgeon's standpoint. However, it is still unclear whether it is a suitable treatment strategy from the patient's viewpoint, due to the lack of solid evidence obtained from randomized controlled trials. The feasibility of RG has been demonstrated in many retrospective comparative studies, which showed similar trends, including relatively less estimated blood loss and longer operation time with RG than laparoscopic gastrectomy (LG), equivalent number of harvested lymph nodes and similar length of postoperative hospital stay between RG and LG. However, considering the higher medical expenses associated with RG, its superiority in terms of long-term survival outcomes will need to be confirmed for it to be accepted more widely.

Keywords: da Vinci, robot, gastric cancer, robot assisted gastrectomy, laparoscopic gastrectomy

INTRODUCTION
Minimally invasive surgery (MIS) for gastric cancer has been increasingly performed in the East, where incidence of the disease is high and approximately half of cases are diagnosed at an early stage[1-3]. The non-inferiority of laparoscopic gastrectomy (LG) for early gastric cancer comparing to open gastrectomy in terms of short- and/or long-term outcomes has been confirmed by randomized controlled trials, and that for advanced gastric cancer is under investigation and may be shown in the near future[4-7]. However, LG has several shortcomings which include limitation in the movement range of forceps and the two-dimensional surgical view available to operating surgeons, and it will be necessary to overcome these issues for MIS to be accepted more widely.

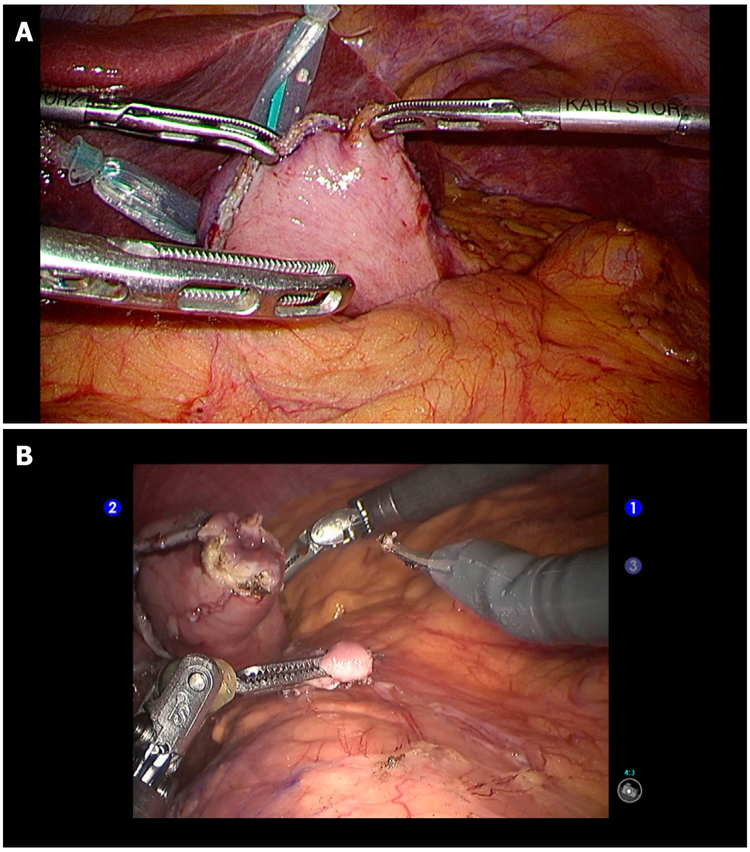

Figure 1. (A) Surgical field during LG: straight devices without articulation are used; (B) surgical field during RG: articulated devices are used

Using the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA, USA), a system for robotic surgery, surgeons are able to attain a three-dimensional view, instrument flexibility, tremor suppression, and improved ergonomics, which are thought to be advantages of robotic gastrectomy (RG)[8-11]. With these advantages, theoretically, RG enables surgeons to perform more precise surgery with less trauma, which could result in superior outcomes over LG. However, the number of comparative prospective studies between RG and LG is quite limited, and therefore, solid evidence supporting RG does not yet exist[12-16].

Herein, we would review the comparative retrospective and prospective studies which have investigated the differences in short- and long-term surgical outcomes between RG and LG.

Clear advantages of RG over LG

There are several clear benefits of RG which contribute to reducing invasiveness and trauma compared with LG. Articulated devices, which are only available in RG, make each surgical technique more meticulous and precise, and are thought to be one definitive advantage of RG [Figure 1][8-13]. Other apparent advantages include a tremor suppression function, which is helpful to keep a stable surgical field and effective to reduce organ injury, and a three-dimensional image, which has become available in LG although special equipment is necessary. With these clear advantages, RG is expected to have advantages over LG. Clear and possible advantages and disadvantages of both procedures are summarized in Table 1.

Clear disadvantages of RG

Because RG requires expensive machines and devices, cost effectiveness is an intriguing issue for surgeons, and seems to be an absolute disadvantage of RG. In Korea and Japan, where more than half of reports have

Table 1. Advantages and disadvantages of RG *vs*. LG are summarized

Articulated devices	RG favor
3D image	RG favor
Tremor suppression	RG favor
ergonomics	RG favor
Intraoperative blood loss	Equivalent
Morbidity rate	Equivalent
Mortality rate	Equivalent
Medical expense	LG favor
Operation time	LG favor

RG: robotic gastrectomy; LG: laparoscopic gastrectomy

been published, the cost for RG is not yet reimbursed by government, and therefore patients or hospitals have to pay additional fees[17]. In contrast, medical expense for LG is partially covered by national insurance systems, and the cost burden on patients and hospitals is obviously less than for RG. The additional fee for RG differs between surgeries depending on how many disposable and re-usable instruments are used. Previously, some comparative studies investigated the difference in medical expense between RG and LG and reported that RG expenses were approximately twice as great[18-21]. In a prospective comparative study conducted in Korea, significantly higher total cost in the RG group (US$13,432) than the LG group (US$8090) was also reported[14]. However, if medical expenses associated with RG decrease in the future, they will no longer be an absolute disadvantage of RG.

COMPARISON OF SHORT-TERM SURGICAL OUTCOMES BETWEEN RG AND LG

Short-term surgical outcomes between RG and LG have been compared in many retrospective and a few prospective studies[9,14-20,22-44]. Among short-term surgical outcomes, intraoperative blood loss, the duration of surgery, the number of retrieved lymph nodes, the incidence of postoperative complications, and the length of postoperative hospital stay are thought to reflect surgical quality, and were assessed in most studies.

Intraoperative blood loss was generally equivalent or less during RG than LG [Table 2]. The magnified fine three-dimensional view attained in RG enables surgeons to recognize even very small vessels, and with articulated devices, they can surely stanch bleeding. However, the reported statistically significant differences in intraoperative bleeding between LG and RG were generally less than 100 mL except for one report from Korea[38], and it is unclear whether the difference is clinically significant of not. Statistically significant more blood loss in RG was also reported in two Japanese studies, but the differences were less than 20 mL[33,41].

The duration of surgery is significantly longer in RG than in LG in all report, and the difference was statistically significant in most series [Table 3]. Although the difference ranged from 14 to 124 min, it took RG generally approximately 60 min more operation time than LG. There are several probable explanations for longer operation time in RG. Firstly, it takes 15 to 30 min, known as docking time, to prepare before an operator begins the surgery at a console. Secondly, during RG, a surgeon uses four robotic arms, which is less than the average number of five ports used during conventional LG. Although an additional port for an assistant can be used in RG, it is under the assistant's not the surgeon's control, and is sometimes useless due to collisions with robotic arms. As a result, it becomes difficult to make a fine surgical field, particularly in patients with high visceral fat volume or advanced disease, and therefore might cause longer operation time.

The number of retrieved lymph nodes was reported to be almost equal between RG and LG. The duration of postoperative hospital stay was also similar, although a few investigators reported that it was shorter following RG than LG.

Table 2. Comparison of blood loss

Author	Year	Country/area	Approach	Number of patients (n)	Blood loss (mL)
Kim *et al.*[30]	2010	Korea	ODG *vs.* LDG *vs.* RDG	12 *vs.* 11 *vs.* 16	[a]79 *vs.* 45 *vs.* 30**
Caruso *et al.*[22]	2011	Italy	OG *vs.* RG	120 *vs.* 29	[a]386 *vs.* 198**
Woo *et al.*[42]	2011	Korea	LG *vs.* RG	591 *vs.* 236	[a]148 *vs.* 92**
Huang *et al.*[25]	2012	Korea	OG *vs.* LG *vs.* RG	586 *vs.* 64 *vs.* 39	[a]400 *vs.* 100 *vs.* 50**
Kim *et al.*[29]	2012	Korea	OG *vs.* LG *vs.* RG	4542 *vs.* 861 *vs.* 436	[a]192 *vs.* 112 *vs.* 85**
Uyama *et al.*[41]	2012	Japan	LDG *vs.* RDG	25 *vs.* 225	[a]81 *vs.* 52**
Huang *et al.*[19]	2014	Taiwan	LG *vs.* RG	73 *vs.* 35	[a]116 *vs.* 80**
Junfeng *et al.*[27]	2014	America	LG *vs.* RG	394 *vs.* 120	[a]138 *vs.* 118**
Kim *et al.*[28]	2014	Korea	LDG *vs.* RDG	481 *vs.* 172	[a]135 *vs.* 60**
Lee *et al.*[32]	2015	Korea	LDG *vs.* RDG	267 *vs.* 133	[a]87 *vs.* 47**
Seo *et al.*[37]	2015	Korea	LDG *vs.* RDG	40 *vs.* 40	[a]227 *vs.* 76**
Suda *et al.*[40]	2015	Japan	LG *vs.* RG	438 *vs.* 88	[a]34 *vs.* 48*
Nakauchi *et al.*[17]	2016	Japan	LG *vs.* RG	437 *vs.* 84	[a]33 *vs.* 44*
Procopiuc *et al.*[36]	2016	Romania	OG *vs.* RG	29 *vs.* 18	[a]564 *vs.* 208**
Shen *et al.*[38]	2016	China	LG *vs.* RG	330 *vs.* 93	[a]213 *vs.* 177**
Yang *et al.*[43]	2017	Korea	OG *vs.* LG *vs.* RG	241 *vs.* 511 *vs.* 173	[a]149 *vs.* 66 *vs.* 53**
Song *et al.*[9]	2009	Korea	LDG (early) *vs.* RDG	20 *vs.* 20	-
			LDG (later) *vs.* RDG	20 *vs.* 20	40 *vs.* 94**
Eom *et al.*[18]	2012	Korea	LDG *vs.* RDG	62 *vs.* 30	88 *vs.* 153**
Park *et al.*[20]	2012	Korea	LDG *vs.* RDG	120 *vs.* 30	60 *vs.* 75*
Hyun *et al.*[26]	2013	Korea	LG *vs.* RG	83 *vs.* 38	131 *vs.* 131**
Noshiro *et al.*[33]	2014	Japan	LDG *vs.* RDG	460 *vs.* 21	115 *vs.* 96**
Son *et al.*[39]	2014	Korea	LTG *vs.* RTG	58 *vs.* 51	211 *vs.* 153**
Park *et al.*[35]	2015	Korea	LG *vs.* RG	622 *vs.* 148	146 *vs.* 171**
Cianchi *et al.*[23]	2016	Italy	LDG *vs.* RDG	41 *vs.* 30	119 *vs.* 100**
Okumura *et al.*[34]	2016	Korea	OG *vs.* RG	132 *vs.* 49	157 *vs.* 85**

*median; **mean. [a]$P < 0.05$. LDG: laparoscopic distal gastrectomy; LG: laparoscopic gastrectomy; LTG: laparoscopic total gastrectomy; RDG: robotic distal gastrectomy; RG: robotic gastrectomy; RTG: robotic total gastrectomy; ODG: open distal gastrectomy; OG: open astrectomy

The incidence of postoperative complication was compared between the approaches [Table 4]. Many investigators have thought that RG could be safer than LG, because articulated devices, the three-dimensional image, and the tremor suppression function could make recognition of anatomical structures much easier and lymphadenectomy much safer. However, unexpectedly, significantly lower morbidity rate was reported only in two reports, and the difference, even if morbidity rate was lower in RG than LG, was not statistically significant in other reports[33,41]. Considering the current status of LG, which is already a well-established safe procedure, it seems to be very difficult to show that RG could further improve the safety. Mortality rate was not statistically significant between RG and LG in any of the studies, and therefore, both RG and LG seem to be safe procedures in terms of postoperative morbidities and mortality.

Long-term outcomes between RG and LG

The number of reports focusing on long-term survival outcome is quite limited [Table 5]. Three Korean series, which were from a single institute with different study populations, and one Japanese series, reported long-term outcomes with a median follow up period of at least three years[32,33,35,40]. In the Korean series, Lee *et al.*[32] focused on patients undergoing D2 distal gastrectomy, Son *et al.*[39] included patients undergoing spleen-preserving total gastrectomy, and Okumura *et al.*[34] compared long-term survival outcomes of elderly (70 years old or older) patients between RG and LG. None of these studies showed significant survival differences. The Japanese series by Nakauchi *et al.*[17] compared three-year overall and recurrence free survival between RG and LG, and reported that no statistically significant difference was found even after stratification by pathological stage. However, the lack of the results of prospective comparative studies focusing on long-term survival makes it difficult to obtain any conclusive result in terms of long-term survival outcomes.

Table 3. Comparison of operation time

Author	Year	Country/area	Approach	Number of patients (*n*)	Operation time (min)
Song *et al*.[9]	2009	Korea	LDG (early) *vs*. RDG	20 *vs*. 20	[a]290 *vs*. 203**
			LDG (later) *vs*. RDG	20 *vs*. 20	[a]134 *vs*. 203**
Kim *et al*.[30]	2010	Korea	ODG *vs*. LDG *vs*. RDG	12 *vs*. 11 *vs*. 16	[a]127 *vs*. 204 *vs*. 259**
Caruso *et al*.[22]	2011	Italy	OG *vs*. RG	120 *vs*. 29	[a]222 *vs*. 290**
Woo *et al*.[42]	2011	Korea	LG *vs*. RG	591 *vs*. 236	[a]171 *vs*. 220**
Eom *et al*.[18]	2012	Korea	LDG *vs*. RDG	62 *vs*. 30	[a]189 *vs*. 229**
Huang *et al*.[25]	2012	Korea	OG *vs*. LG *vs*. RG	586 *vs*. 64 *vs*. 39	[a]320 *vs*. 350 *vs*. 430**
Kim *et al*.[29]	2012	Korea	OG *vs*. LG *vs*. RG	4542 *vs*. 861 *vs*. 436	[a]158 *vs*. 176 *vs*. 226**
Park *et al*.[20]	2012	Korea	LDG *vs*. RDG	120 *vs*. 30	[a]140 *vs*. 218*
Yoon *et al*.[44]	2012	Korea	LTG *vs*. RTG	65 *vs*. 36	[a]210 *vs*. 306**
Huang *et al*.[19]	2014	Taiwan	LG *vs*. RG	73 *vs*. 35	[a]330 *vs*. 358**
Junfeng *et al*.[27]	2014	America	LG *vs*. RG	394 *vs*. 120	[a]221 *vs*. 235**
Kim *et al*.[28]	2014	Korea	LDG *vs*. RDG	481 *vs*. 172	[a]167 *vs*. 206**
Noshiro *et al*.[33]	2014	Japan	LDG *vs*. RDG	460 *vs*. 21	[a]315 *vs*. 439**
Son *et al*.[39]	2014	Korea	LTG *vs*. RTG	58 *vs*. 51	[a]210 *vs*. 264**
Han *et al*.[24]	2015	Korea	LPPG *vs*. RPPG	69 *vs*. 68	[a]194 *vs*. 258**
Lee *et al*.[32]	2015	Korea	LDG *vs*. RDG	267 *vs*. 133	[a]171 *vs*. 218**
Park *et al*.[35]	2015	Korea	LG *vs*. RG	622 *vs*. 148	[a]189 *vs*. 255**
Suda *et al*.[40]	2015	Japan	LG *vs*. RG	438 *vs*. 88	[a]361 *vs*. 381*
Cianchi *et al*.[23]	2016	Italy	LDG *vs*. RDG	41 *vs*. 30	[a]262 *vs*. 323**
Kim *et al*.[31]	2016	Korea	LDG *vs*. RDG	288 *vs*. 87	[a]230 *vs*. 248**
Nakauchi *et al*.[17]	2016	Japan	LG *vs*. RG	437 *vs*. 84	[a]361 *vs*. 378*
Okumura *et al*.[34]	2016	Korea	OG *vs*. RG	132 *vs*. 49	[a]174 *vs*. 227**
Procopiuc *et al*.[36]	2016	Romania	OG *vs*. RG	29 *vs*. 18	[a]243 *vs*. 320**
Shen *et al*.[38]	2016	China	LG *vs*. RG	330 *vs*. 93	[a]226 *vs*. 257**
Yang *et al*.[43]	2017	Korea	OG *vs*. LG *vs*. RG	241 *vs*. 511 *vs*. 173	[a]193 *vs*. 174 *vs*. 202**
Uyama *et al*.[41]	2012	Japan	LDG *vs*. RDG	25 *vs*. 225	345 *vs*. 361**
Hyun *et al*.[26]	2013	Korea	LG *vs*. RG	83 *vs*. 38	220 *vs*. 234**
Seo *et al*.[37]	2015	Korea	LDG *vs*. RDG	40 *vs*. 40	224 *vs*. 243**

*median; **mean. [a]$P < 0.05$. LDG: laparoscopic distal gastrectomy; LG: laparoscopic gastrectomy; LTG: laparoscopic total gastrectomy; LPPG: laparoscopic pylorus preservingl gastrectomy; RDG: robotic distal gastrectomy; RG: robotic gastrectomy; RTG: robotic total gastrectomy; RPPG: robotic pylorus preservingl gastrectomy; ODG: open distal gastrectomy; OG: open gastrectomy

Considering the total medical expense of RG, long-term outcomes of RG need to be better than those of LG, and should be confirmed by future prospective trials.

PROSPECTIVE STUDIES

Although quite a few retrospective studies already exist, the number of prospective studies, particularly that of prospective comparative studies, is extremely limited so far[12-14,16].

Kim *et al*.[14] reported the results of a prospective non-randomized comparative study. In their study, a total of 423 patients selected either RG or LG after they received a comprehensive explanation of each procedure, and were matched according to surgeon, extent of gastric resection, and sex. Similar early surgical outcomes including morbidity and mortality rate, except for longer operation time in the RG group were reported.

The results of a single-center prospective randomized trial, in which patients were allocated to either open (n = 153) or robotic (n = 158) gastrectomy groups, were reported by Wang *et al*.[16]. Similar complication rates between the groups, and less estimated blood loss, longer duration of surgery, and shorter postoperative hospital stay in the robotic group than the open group were reported.

Table 4. Compararison of postoperative morbidy and mortality

Author	Year	Country/area	Approach	Number of patients (*n*)	Morbidity rate	Mortality rate
Huang *et al.*[19]	2014	Taiwan	LG *vs.* RG	73 *vs.* 35	[a]8% *vs.* 13%	1.4% *vs.* 1.4%
Suda *et al.*[40]	2015	Japan	LG *vs.* RG	438 *vs.* 88	[a]11% *vs.* 2%	0.2% *vs.* 1.1%
Nakauchi *et al.*[17]	2016	Japan	LG *vs.* RG	437 *vs.* 84	[a]12% *vs.* 2%	-
Yang *et al.*[43]	2017	Korea	OG *vs.* LG *vs.* RG	241 *vs.* 511 *vs.* 173	[a]25% *vs.* 12% *vs.* 5%	0.8% *vs.* 0.4% *vs.* 0%
Song *et al.*[9]	2009	Korea	LDG (early) *vs.* RDG	20 *vs.* 20	5% *vs.* 5%	0% *vs.* 0%
			LDG (later) *vs.* RDG	20 *vs.* 20	10% *vs.* 5%	0% *vs.* 0%
Kim *et al.*[30]	2010	Korea	ODG *vs.* LDG *vs.* RDG	12 *vs.* 11 *vs.* 16	17% *vs.* 9% *vs.* 13%	0% *vs.* 0% *vs.* 0%
Caruso *et al.*[22]	2011	Italy	OG *vs.* RG	120 *vs.* 29	43% *vs.* 41%	3.3% *vs.* 0%
Woo *et al.*[42]	2011	Korea	LG *vs.* RG	591 *vs.* 236	14% *vs.* 11%	0.3% *vs.* 0.4%
Eom *et al.*[18]	2012	Korea	LDG *vs.* RDG	62 *vs.* 30	7% *vs.* 13%	0% *vs.* 0%
Huang *et al.*[25]	2012	Korea	OG *vs.* LG *vs.* RG	586 *vs.* 64 *vs.* 39	15% *vs.* 16% *vs.* 15%	1.4% *vs.* 1.6% *vs.* 2.6%
Kim *et al.*[29]	2012	Korea	OG *vs.* LG *vs.* RG	4542 *vs.* 861 *vs.* 436	11% *vs.* 9% *vs.* 10%	0.5% *vs.* 0.3% *vs.* 0.5%
Park *et al.*[20]	2012	Korea	LDG *vs.* RDG	120 *vs.* 30	8% *vs.* 17%	0% *vs.* 0%
Uyama *et al.*[41]	2012	Japan	LDG *vs.* RDG	25 *vs.* 225	11% *vs.* 17%	0% *vs.* 0%
Yoon *et al.*[44]	2012	Korea	LTG *vs.* RTG	65 *vs.* 36	15% *vs.* 17%	0% *vs.* 0%
Hyun *et al.*[26]	2013	Korea	LG *vs.* RG	83 *vs.* 38	39% *vs.* 47%	0% *vs.* 0%
Junfeng *et al.*[27]	2014	America	LG *vs.* RG	394 *vs.* 120	4% *vs.* 6%	-
Kim *et al.*[28]	2014	Korea	LDG *vs.* RDG	481 *vs.* 172	4% *vs.* 5%	0.6% *vs.* 0%
Noshiro *et al.*[33]	2014	Japan	LDG *vs.* RDG	460 *vs.* 21	10% *vs.* 10%	0% *vs.* 0%
Son *et al.*[39]	2014	Korea	LTG *vs.* RTG	58 *vs.* 51	22% *vs.* 16%	0% *vs.* 2.0%
Han *et al.*[24]	2015	Korea	LPPG *vs.* RPPG	69 *vs.* 68	22% *vs.* 19%	0% *vs.* 0%
Lee *et al.*[32]	2015	Korea	LDG *vs.* RDG	267 *vs.* 133	13% *vs.* 11%	-
Seo *et al.*[37]	2015	Korea	LDG *vs.* RDG	40 *vs.* 40	30% *vs.* 28%	-
Park *et al.*[35]	2015	Korea	LG *vs.* RG	622 *vs.* 148	8% *vs.* 8%	0.5% *vs.* 0%
Cianchi *et al.*[23]	2016	Italy	LDG *vs.* RDG	41 *vs.* 30	12% *vs.* 13%	4.9% *vs.* 3.3%
Kim *et al.*[31]	2016	Korea	LDG *vs.* RDG	288 *vs.* 87	9% *vs.* 6%	0.3% *vs.* 1.1%
Okumura *et al.*[34]	2016	Korea	OG *vs.* RG	132 *vs.* 49	18% *vs.* 14%	0% *vs.* 0%
Procopiuc *et al.*[36]	2016	Romania	OG *vs.* RG	29 *vs.* 18	28% *vs.* 22%	0% *vs.* 0%
Shen *et al.*[38]	2016	China	LG *vs.* RG	330 *vs.* 93	10% *vs.* 10%	-

[a]$P < 0.05$. LDG: laparoscopic distal gastrectomy; LG: laparoscopic gastrectomy; LTG: laparoscopic total gastrectomy; LPPG: laparoscopic pylorus preservingl gastrectomy; RDG: robotic distal gastrectomy; RG: robotic gastrectomy; RTG: robotic total gastrectomy; RPPG: robotic pylorus preservingl gastrectomy; ODG: open distal gastrectomy; OG: open gastrectomy

Table 5. Studies which provided long-term survival outcomes

Author	Year	Country/area	Approach	Number of patients (*n*)	Median Follow up period (months)	5y-OS (%)	5y-DFS (%)
Son *et al.*[39]	2014	Korea	LTG *vs.* RTG	58 *vs.* 51	[a]70	[a]91.1 *vs.* 89.5	[a]90.2 *vs.* 91.2
Lee *et al.*[32]	2015	Korea	LDG *vs.* RDG	267 *vs.* 133	[a]75	[a]N.S.	-
Okumura *et al.*[34]	2016	Korea	OG *vs.* RG	132 *vs.* 49	[a]58	[a]N.S.	-
Junfeng *et al.*[27]	2014	America	LG *vs.* RG	394 *vs.* 120	19 *vs.* 15	69.9 *vs.* 67.8 (3y)	-
Han *et al.*[24]	2015	Korea	LPPG *vs.* RPPG	69 *vs.* 68	19 *vs.* 23	-	-
Nakauchi *et al.*[17]	2016	Japan	LG *vs.* RG	437 *vs.* 84	42 *vs.* 41	88.8 *vs.* 86.9 (3y)	86.3 *vs.* 86.9 (3y)
Procopiuc *et al.*[36]	2016	Romania	OG *vs.* RG	29 *vs.* 18	32 *vs.* 25	N.S.	-

[a]median follow up period longer than 3 years. N.S.: statistically not significant difference; LDG: laparoscopic distal gastrectomy; LG: laparoscopic gastrectomy; LTG: laparoscopic total gastrectomy; LPPG: laparoscopic pylorus preservingl gastrectomy; RDG: robotic distal gastrectomy; RG: robotic gastrectomy; RTG: robotic total gastrectomy; RPPG: robotic pylorus preservingl gastrectomy; OG: open gastrectomy

DISCUSSION

RG has several absolute advantages, which include articulated devices, tremor suppression function, and a fine three-dimensional view, and surgeons can perform operations comfortably with these technologies. However, these advantages are from the surgeons' perspective, and it is unclear whether these technologies applied to RG are also advantageous from the patients' viewpoint. Theoretically, the more meticulous and precise surgeries are, the better the outcomes will be. However, for RG to be more widely accepted, advantages from the patients' side should be demonstrated in clinical trials, ideally in prospective randomized trials.

Short-term surgical outcomes such as intraoperative bleeding, surgical time, duration of postoperative hospital stay, and postoperative morbidity and mortality rate are thought to reflect surgical quality, and some of them directly affect patients' quality of life. Therefore, these factors are frequently compared between surgical procedures, when investigators need to show superiority or non-inferiority of a newly emergent procedure. Indeed, they have been compared in many studies of RG and LG. However, it seems difficult to conclude that RG is a superior procedure to LG in terms of short-term surgical outcomes, because RG is a more time-consuming procedure, but does not show any obvious benefits. Although some have reported that RG is associated with less bleeding, the differences, which were generally less than 100 mL, seem not to be clinically meaningful. It might be difficult to demonstrate that RG could further improve short-term surgical outcomes, because LG is already a well-established and satisfactorily safe procedure.

The number of studies focusing on long-term surgical outcomes is quite limited, due to insufficient follow-up period in each study. So far, similar long-term survival outcomes between RG and LG have been reported, and we need to wait for the results of currently ongoing studies to reach any conclusions about long-term survival outcomes.

Interpretation of the results of comparative studies should be done carefully because of possible selection bias. In most comparative studies, surgical approaches were selected by the patients themselves after thoughtful explanation of both procedures, but the possibility of selection bias should be taken into account. To overcome this issue, well designed prospective, hopefully randomized controlled, trials are necessary, and we have to at least wait for the results of prospective non-randomized comparative studies[14].

To demonstrate the feasibility of RG, the surgical outcomes of RG are usually compared with those of LG. However, considering that both surgeries were developed on the concept of being minimally invasive, the differences between RG and LG might be marginal, even if RG is truly a superior procedure to LG. In addition RG is, so far, obviously the more expensive surgical procedure. Therefore, it seems unrealistic for RG to completely replace LG with all surgeries in the very near future. However, if the cost of RG decreases dramatically and high medical expense is no longer a problem, it may be a different story with RG becoming further widespread.

So far, RG seems to be as feasible as LG in terms of short- and long-term surgical outcomes. However, RG is an expensive procedure at present, and it is unclear whether RG is superior to LG from the patients' standpoint. The results of well designed prospective comparative studies are awaited to obtain conclusive results on this issue.

DECLARATIONS

Authors' contributions

Analysed and interpreted the data: Tokunaga M, Watanabe M, Sugita S, Tonouchi A, Kaito A, Kinoshita T
Read and approved the final manuscript: Tokunaga M, Watanabe M, Sugita S, Tonouchi A, Kaito A, Kinoshita T

Availability of data and meterials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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