

2016 Gastric Cancer: Global view

Robot-assisted surgery for gastric cancer

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Abstract

Minimally invasive surgery for gastric cancer is a relatively new research field, with convincing results mostly stemming from Asian countries. The use of the robotic surgery platform, thus far assessed as a safe procedure, which is also easier to learn, sets the background for a wider spread of minimally invasive technique in the treatment of gastric cancer. This review will cover the literature published so far, analyzing the pros and cons of robotic surgery and highlighting the remaining study questions.

Key words: Gastric cancer survival; Robotic surgery; Gastric cancer surgery; Lymphadenectomy; Minimally invasive surgery

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Core tip: An important problem remains regarding the selection of the appropriate technique for a given gastric cancer case. Encouraging results are being published using the robotic technique, but the lack of homogenous study groups in terms of staging, comorbidities and adjuvant and neoadjuvant therapies makes it hard to establish a clear indication for the robotic gastrectomy in gastric cancer. Carefully weighing the treatment options is especially important since there are more and more groups publishing acceptable results with the robotic technique.

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INTRODUCTION

Surgery is unanimously considered the mainstay curative treatment in gastric cancer. Technically, the possibilities range from open surgery to minimally invasive methods like laparoscopy or robotic surgery. However, the newer laparoscopic techniques have only proven their effectiveness in early gastric cancer^[1]. The current challenge for robotic surgery in gastric cancer is to prove its benefit as a treatment option, ideally in the form of a survival advantage. Up until now studies only proved its non-inferiority compared with existent techniques.

Technologic progress has clearly had an impact in medicine and surgery, in particular. However the newest developments in the field of technology are not always the best ones and examples can easily be found in the last decades. Rejecting a new technique altogether is, however, not an option in the field of surgery. It would possibly mean closing the roads to a new development that could allow for patients to benefit from procedures which are not easily or not at all undertaken at the moment.

MINIMALLY INVASIVE SURGERY FOR GASTRIC CANCER

The existence of so many treatment options for gastric cancer suggests that currently there is no consensus regarding the adequate therapeutic conduct. Thus far, the following objectives for gastric cancer surgery have been made clear and should be pursued in any case: (1) If surgery can be performed, it must proceed, usually as a part of multimodal cancer treatment^[1]. The surgical approach is based on the Virchow-Halsted theory of centrifugal dissemination of carcinomas. This mechanistic theory dating from the end of the 19th century is based on the fact that cancer was believed to begin in the target organ and then spread in an orderly fashion through lymphatic drainage routes invading lymph nodes along the way^[2,3]; (2) The tumor must be resected according to oncological safety limits^[1]; and (3) An adequate lymphadenectomy must be performed. Its extent varies depending on the location and stage of the tumor^[1]. Reaching these objectives correlates with a higher survival rate and a lower rate of recurrence^[4,5].

Modern day gastric cancer treatment was definitely impacted by technological progress. The laparoscopy revolution was quickly introduced in this field, with the first laparoscopic gastrectomy performed by Kitano *et al*^[6]. Experience accumulated with bariatric surgery must not be neglected either, as it led to an improvement

in the technique required to perform intracorporeal anastomoses. The consequence was a rapid development of laparoscopic surgery for gastric cancer beginning, of course, with the early stages. On the other hand, the treatment options for gastric cancer were also enriched by the development of endoscopy, which limited the indications for video-assisted surgery.

Nonetheless, minimally invasive surgery failed to disseminate with great speed worldwide owing mostly to the fact that it is a technically demanding procedure. It is currently particularly favored in Asian countries^[7,8] where it is gaining terrain as a treatment for early gastric cancer, but it is interesting to note that laparoscopic surgery for gastric cancer is still an investigational procedure even in countries like Japan^[1]. To advance this type of surgery into the category of standard procedures, results of large randomized controlled studies like KLASS-01^[9], KLASS-02^[10] and JCOG 0912^[11] comparing the results of open and laparoscopic surgery are still awaited.

At the moment, the benefits of laparoscopy are still being debated, despite all the published studies which seemingly accrue "pro" arguments at a constant rate. In our opinion, the main objection is that these studies presenting good postoperative as well as oncological outcomes, mostly come from highly experienced large-volume surgical centers, which offer a standard of care that is not easily reproducible everywhere in the world.

ROBOTIC SURGERY

The robotic technologies were brought about to circumvent some of the difficulties of laparoscopic surgery. The laparoscopic procedures for gastric cancer have indeed been associated with improved postoperative outcomes and oncological results^[12-15], but the platform itself imposes a series of technical shortcomings. The two-dimensional views coupled with the fulcrum effect and the inherent tremor reduce the surgical range of motion and prolong the learning curve especially for large scale procedures such as gastrectomy. The robotic system comes with a three-dimensional view enabling depth perception, the EndoWrist[®] technology which allows for seven degrees of freedom and tremor filtration. Additionally, images can be enlarged enabling the performance of delicate steps such as lymph node dissection along great vessels which are essential in achieving a D2 dissection, suturing or knotting. These features could enable the performance of relatively complicated procedures such as function-preserving gastrectomy or extended resections for advanced gastric cancer using a minimally invasive method. Nonetheless this technique also has its disadvantages: Costs, duration of the procedures, the necessary trainings.

The use of the robotic platforms in general surgery did not enjoy the same success as it did in urologic surgery, and the field of gastric cancer is no exception. There are a series of shortcomings of the robotic platform explaining this situation. First of all the lack of robotic staplers and robotic seal and cut devices like

LigaSure™ is a considerable inconvenience. Second, due to the costs, the robotic platform cannot be used to cover the whole spectrum of procedures normally performed by a general surgeon^[12].

Current status of robotic surgery in early gastric cancer

Studies evaluating robotic surgery for early gastric cancer alone are scarce and stem mostly from Asian countries. The higher incidence of gastric cancer in these countries, together with the wide extent and increased efficacy of the national gastric cancer screening programs fueled the search for minimally invasive treatment modalities for the early stages of the disease. This led not only to the development of endoscopic resection, but also to a large pool of surgeons well versed in minimally invasive gastrectomies. The encouraging results published in small non-randomized comparative studies of laparoscopic vs open surgery for early gastric cancer^[13-15] were followed by the increased use of laparoscopy in clinical practice. Japan reports that at least 20% of the gastrectomies for early gastric cancer in its hospitals are now being performed laparoscopically^[1]. The need for better statistical evidence supporting the minimally invasive treatment of early gastric cancer was answered by starting two major randomized controlled trials which are now underway in Japan and South Korea comparing laparoscopy and open surgery^[9,11].

Following the foot-steps of laparoscopic surgery, robotics was first introduced in the treatment of early stage patients by the same surgeons who had acquired experience in the field of laparoscopic gastrectomies. After the first robotic gastrectomy reported in 2003 by Hashizume *et al*^[16], a series of encouraging reports on robotic surgery for gastric carcinomas began to appear in literature (Table 1).

In keeping with the trends of gastric cancer incidence in the eastern and western continents, Asian studies focus on mixed cohorts of gastric cancer patients with a high prevalence of the early stages or on early gastric cancer patients alone (Table 1). The largest cohort of early-stage gastric cancer to date was published by Woo *et al*^[17]. A total of 827 patients were included in this nonrandomized comparative study of robotic (236 patients) and laparoscopic surgery (591 patients) for stage Ia and Ib gastric carcinomas. The total operative time was significantly increased for the robotic procedures compared with laparoscopy (219.5 min vs 170.7 min, $P < 0.001$), but the robotic group also showed a lower estimated blood loss (91.6 mL vs 147.8 mL, $P = 0.02$). The length of hospital stay was slightly in favor of the laparoscopic group (7 d vs 7.7 d, $P = 0.004$) and there were no differences regarding morbidity and mortality. In terms of oncological principles, the number of retrieved lymph nodes was not different and all the patients in the robotic group had negative resection margins^[17].

Other studies comparing robotic surgery to laparoscopy in the treatment of gastric cancer show the same operative outcomes. The operative times are always

significantly longer for the robotic group (Table 2). This has been attributed to longer docking times necessary for the robot. However, a learning curve effect can be derived from the two studies separating the laparoscopic surgery group into an initial and a recent subgroup^[18,19]. The operating times reported for the initial laparoscopic technique subgroup are even longer than those of the robotic subgroup. That is no longer the case for the recent laparoscopy subgroup which yields the shortest operating time between the three subgroups (Table 2). In the study of Song *et al*^[19] the difference between these mean operative times were 289.5, 230 and 134 min, respectively with a statistically significant difference. The decrease of the mean operative times between the initial and the latter robotic cases (231 min vs 208 min) in the large cohort published by Woo *et al*^[17] indicates that shortening the operating times is also a matter of exercise, as was the case when the laparoscopic gastrectomies were introduced.

Regarding the estimated blood loss and the number of retrieved lymph nodes, there are conflicting results stemming from most of the cohorts comparing laparoscopy to robotic surgery (Table 2). A meta-analysis performed by Shen *et al*^[20] including the studies which also appear in our retrospective tables (Tables 1-3) comparing robotics and laparoscopy also found no statistically significant difference on the number of retrieved lymph nodes. However, a significantly lower blood loss was found in favor of the robotic group.

Current status of robotic surgery in advanced gastric cancer

Papers stemming from Europe, on the other hand, have a large prevalence of advanced gastric cancer cases in their study groups. In the largest study up to date (5839 patients) comparing robotic (436 patients), laparoscopic (861 patients) and open surgery (4542 patients) performed for stage I, II and III gastric cancer by Kim KM *et al*^[47], overall safety of these three types of surgery was the main focus. The overall complication rate was the same between the three groups (OG 10.7% LG 9.4% and RG 10.1%, $P = 0.494$) and so was their severity ($P = 0.424$). However, robotic surgery was prone to complications related to leaks ($P = 0.017$), whereas ileus and abscesses were more prevalent in open surgery ($P = 0.001$, $P = 0.013$ respectively). The authors explain that stapling lines were not reinforced with sutures in minimally invasive surgery, as opposed to open surgery and that the patients included in the open surgery group were mainly patients with more advanced disease for whom the complexity of the resections was higher. The robotic group showed a faster recovery with a shorter time to starting the soft diet and a shorter postoperative stay ($P < 0.001$ for both parameters) (Table 3). This study also showed an increased duration of the procedure compared to laparoscopic and open surgery (224 min vs 176 min vs 158 min, $P < 0.001$) combined with a lower estimated blood loss for the robotic group ($P < 0.001$). The

Table 1 Summary of studies reporting use of robotic surgery for gastric cancer

Ref.	Year	Type of study	Type of surgery	Stage ¹	Type of resection	No. of patients			
						Total	R	L	O
Patriti <i>et al</i> ^[21]	2008	CS	R	6 patients I , 6 patients II , 1 patient III	8 DG, 4 TG, 1 PG	13	13		
Lee <i>et al</i> ^[22]	2011	CS	R	I	DG	12	12		
D'Annibale <i>et al</i> ^[23]	2011	CS	R	17 patients I , 6 patients II , 1 patient III	11 TG, 13 DG	24	24		
Isogaki <i>et al</i> ^[24]	2011	CS	R	N/A	46 DG, 14 TG, 1 PG	61	61		
Kim <i>et al</i> ^[25]	2013	CS	R	11 patients I , 1 patient III	N/A	12	12		
Liu <i>et al</i> ^[26]	2013	CS	R	26 patients I , 32 patients II , 46 patients III	38 DG, 54 TG, 12 PG	104	104		
Park <i>et al</i> ^[27]	2013	CS	R	178 patients I , 22 patients II or more advanced	154 STG, 46 TG	200	200		
Tokunaga <i>et al</i> ^[28]	2014	CS	R	I A	18 DG	18	18		
Anderson <i>et al</i> ^[29]	2007	CS	R	Early GC	7 STG	7	7		
Song <i>et al</i> ^[30]	2009	CS	R	Early GC	67 STG, 33 TG	100	100		
Hur <i>et al</i> ^[31]	2010	CS	R	N/A	5 STG, 2 TG	7	7		
Uyama <i>et al</i> ^[32]	2012	CS	R	18 patients I A, 7 patients II A to III C	25 DG	25	25		
Yu <i>et al</i> ^[33]	2012	CS	R	N/A	29 DG, 12 TG	41	41		
Jiang <i>et al</i> ^[34]	2012	CS	R	24 patients I , 28 patients II , 68 patients III ²	62 DG, 35 TG, 23 PG	120	120		
Hyung <i>et al</i> ^[18]	2007	NC	R vs L	N/A	N/A	30	10	20	
Song <i>et al</i> ^[19]	2009	NC	R vs L	R: 20 patients I , L: 37 patients I , 3 patients II	R: 20 DG, L: 40 DG	60	20	40	
Pugliese <i>et al</i> ^[35]	2010	NC	R vs L	37 patients early GC, 33 patients advanced GC	64 STG	64	16	48	
Woo <i>et al</i> ^[17]	2011	NC	R vs L	827 patients I a or I b	R: 172 DG, 62, 2 CT; L: 481 DG, 108 TG, 2 CT	827	236	591	
Eom <i>et al</i> ^[36]	2012	NC	R vs L	R: 25 patients I , 3 patients II , 2 patients III, L: 56 patients I , 6 patients II	DG both groups	92	30	62	
Park <i>et al</i> ^[37]	2012	NC	R vs L	R: 27 patients I , 3 patients II ; L: 108 patients I , 11 patients II , 1 patient III	DG both groups	150	30	120	
Yoon <i>et al</i> ^[38]	2012	NC	R vs L	R: 29 patients I , 7 patients II , L: 55 patients I , 7 patients II , 3 patients III	TG both groups	101	36	65	
Kang <i>et al</i> ^[39]	2012	NC	R vs L	R: 82 patients I , 11 patients II , 7 patients III	R: 84 STG, 16 TG	382	100	282	
Hyun <i>et al</i> ^[40]	2013	NC	R vs L	R: 30 patients I , 5 patients II , 3 patients III; L: 67 patients I , 9 patients II , 7 patients III	R: 29 DG, 9 TG; L: 65 DG, 18 TG	121	38	83	
Noshiro <i>et al</i> ^[41]	2014	NC	R vs L	R: 18 patients I , 3 patients II -IV, L: 113 patients I , 47 patients II -IV	DG both groups	181	21	160	
Han <i>et al</i> ^[42]	2014	NC	R vs L	R: 59 patients I , 8 patients II , 1 patient III, L: 66 patients I , 2 patients II	PPG both groups	136	68	68	
Junfeng <i>et al</i> ^[43]	2014	NC	R vs L	R: 29 patients I , 36 patients II , 55 patients III, L: 115 patients I , 98 patients II , 181 patients III	R: 92 DG, 26 TG, 2 PG; L: 261 DG, 118 TG, 15 PG	510	120	394	
Kim <i>et al</i> ^[44]	2014	NC	R vs L	R: 145 patients I , 27 patients II and III; L: 422 patients I , 59 patients II and III	N/A	653	172	481	
Kim <i>et al</i> ^[45]	2010	NC	R vs L vs O	Lower than cT2N1M0	STG all groups	39	16	11	12
Huang <i>et al</i> ^[46]	2012	NC	R vs L vs O	R: 29 patients I , 7 patients II , 3 patients III; L: 55 patients I , 9 patients II , O: 198 patients I , 106 patients II , 282 patients III	R: 32 STG, 7 TG; L: 57 STG, 7 TG; O: 407 STG, 179 TG	689	39	64	586
Kim <i>et al</i> ^[47]	2012	NC	R vs L vs O	R: 3 patients O, 350 patients I , 51 patients II , 32 patients III; L: 8 patients O, 714 patients I , 96 patients II , 43 patients III, O: 28 patients O, 2376 patients I , 823 patients II , 1313 patients III	R: 327 DG, 109 TG, L: 703 DG, 158 TG; O: 3309 DG, 1232 TG	5839	436	861	4542
Pernazza <i>et al</i> ^[48]	2006	NC	R vs O	R: 2 patients O, 20 patients I , 12 patients II , 5 patients III, 6 patients IV	R: 21 DG, 24 TG	90	45	0	45
Caruso <i>et al</i> ^[49]	2011	NC	R vs O	R: 13 patients I , 9 patients II , 4 patients III, 3 patients IV, O: 57 patients I , 18 patients II , 33 patients III, 12 patients IV	R: 16 DG, 12 TG, 1 PG; O: 83 DG, 37 TG	149	29	0	120
Procopiuc <i>et al</i> ^[50]	2015	NC	R vs O	R: 9 patients II , 9 patients III, O: 15 patients II , 14 patients III	R: 7 DG, 10 TG, 1 PG; O: 6 DG, 23 TG	47	18		29

¹Data as reported by the authors from preoperative evaluation; ²Postoperatively obtained staging. CS: Clinical series; NC: Nonrandomized comparative study; R: Robotic surgery; L: Laparoscopic surgery; O: Open surgery; TG: Total gastrectomy; STG: Subtotal gastrectomy; DG: Distal gastrectomy; PG: Proximal gastrectomy; CT: Completion total gastrectomy; PPG: Pylorus-preserving gastrectomy; GC: Gastric cancer.

Table 2 Main operative outcomes in studies reporting use of robotic surgery for gastric cancer

Ref.	OP time (min)	Estimated blood loss (mL)	No. of harvested lymph nodes	Conversions
Patriti <i>et al</i> ^[21]	286	103	28.1	0
Lee <i>et al</i> ^[14]	253	135	46	0
D'Annibale <i>et al</i> ^[23]	267.5	30	28	0
Isogaki <i>et al</i> ^[24]	TG > DG 520 > 388	TG > DG 150 > 61.8	TG approximately equal DG 43 approximately equal 42	0
Kim <i>et al</i> ^[25]	234.7	46.4	42.4	
Liu <i>et al</i> ^[26]	272.52	80.78	23.1	1.8
Park <i>et al</i> ^[27]	248.8	146.1	37.9	3.5
Tokunaga <i>et al</i> ^[28]	331.5	32.5	40	0
Anderson <i>et al</i> ^[29]	420	300	24	0
Song <i>et al</i> ^[30]	231.3	128.2	36.7	0
Hur <i>et al</i> ^[31]	205			
Uyama <i>et al</i> ^[32]	361	51.8	44.3	0
Yu <i>et al</i> ^[33]	TG > DG 285 > 225	TG > DG 180 > 150	34.2	4.8
Jiang <i>et al</i> ^[34]	245	70	22.5	
Hyung <i>et al</i> ^[18]	Initial L > R > Recent L 337 > 253 > 164	-	Recent L > R > Initial L 37.8 > 34 > 29.2	0
Song <i>et al</i> ^[19]	Initial L > R > Recent L 289.5 > 230 > 134 ss	R > Recent L 94.8 > 39.5	Recent L > R > Initial L 42.7 > 35.3 > 31.5	0
Pugliese <i>et al</i> ^[35]	R > L 344 > 235 ss	L > R 148 > 90 ss	L > R 31 > 25	L > R 3 > 2
Woo <i>et al</i> ^[17]	R > L 219.5 > 170.7 ss	L > R 147.9 > 91.6 ss	R > L 39 > 37.4	0 = 0
Eom <i>et al</i> ^[36]	R > L 229.1 > 189.4 ss	R > L 152.8 > 88.3	L > R 33.4 > 30.2	
Park <i>et al</i> ^[37]	R > L 218 > 140 ss	R > L 75 > 60	R approximately equal L 34 approximately equal 35	0
Yoon <i>et al</i> ^[38]	R > L 305.8 > 210.2 ss		R > L 42.8 > 39.4	
Kang <i>et al</i> ^[39]	R > L 202 > 173 ss	L > R 173.4 > 93.2 ss		
Hyun <i>et al</i> ^[40]	R > L 234.4 > 220	R approximately equal L 131.3 approximately equal 130.4	R approximately equal L 32.8 approximately equal 32.6	0 = 0
Noshiro <i>et al</i> ^[41]	R > L 439 > 315 ss	L > R 115 > 96	R > L 44 > 40	R = L 0 = 0
Han <i>et al</i> ^[42]	R > L 258 > 193 ss		L > R 36.5 > 33.4	0
Junfeng <i>et al</i> ^[43]	R > L 234.8 > 221.3 ss	L > R 137.6 > 118.3 ss	R > L 34.6 > 32.7 ss	
Kim <i>et al</i> ^[44]	R > L 206.4 > 167.1 ss	L > R 134.9 > 59.8 ss	R approximately equal L 37.3 approximately equal 36.8	R = L 0 = 0
Kim <i>et al</i> ^[45]	R > L > O 259.2 > 203.9 > 126.7 ss	O > L > R 78.8 > 44.7 > 30.3 ss	O > R > L 43.3 > 41.1 > 37.4	0 = 0
Huang <i>et al</i> ^[46]	R > L > O 430 > 350 > 320	O > L > R 400 > 100 > 50 ss	O > R > L 34 > 32 > 26	
Kim <i>et al</i> ^[47]	R > L > O 226 > 176 > 158 ss	O > L > R 182 > 112 > 85	O > R > L 40.5 > 40.2 > 37.6 ss	
Pernazza <i>et al</i> ^[48]	R > O 293.8 > 224.6		R 34.2	
Caruso <i>et al</i> ^[49]	R > O 290 > 222	O > R 386.1 > 197.6	O > R 31.7 > 28	
Procopiuc <i>et al</i> ^[50]	R > O 320.83 > 243.36 ss	O > R 564.62 > 208.26 ss	O > R 25 > 22	0

R: Robotic surgery; L: Laparoscopic surgery; O: Open surgery; TG: Total gastrectomy; DG: Distal gastrectomy; ss: Statistically significant.

number of harvested lymph nodes was no different between open and robotic surgery.

In the experience of our group, the robotic platform is a versatile tool in the surgical approach of advanced gastric cancer. Our study^[50] enrolled 47 patients who were exclusively advanced gastric cancer patients and went on to receive either open (*n* = 29) or robotic (*n* = 18) surgery. Significantly longer mean operating times (320.83 min vs 243.36 min), but significantly lower blood loss (208.26 mL vs 546.62 mL) and shorter hospital stay (11.04 d vs 8.1 d) were obtained for the robotic group (Table 3). We found no difference in the number of retrieved lymph nodes or the rate of complications. After a mean follow up time of 31.66 mo for the open surgery group and a 24.72 for the robotic surgery group, the Kaplan-Meier analysis of the survival data revealed no statistically significant difference between the two cohorts (*P* = 0.177).

The authors consider that special emphasis needs to be placed on the long-term results of robotic surgery in advanced gastric cancer. The MAGIC trial^[51] published

in 2006 showed a survival benefit for gastric cancer patients receiving epirubicin, cisplatin and fluorouracil perioperatively when compared with patients treated with surgery alone. But the study also reported that 34% of the patients enrolled in the perioperative chemotherapy group, were unable to receive the regimen after surgery owing, among others, to postoperative complications. This creates a need for less invasive surgery like robotic surgery even in the treatment of the advanced gastric cancer patients. Patients would be thus enabled to receive the complete chemotherapy regimen, which would positively impact their survival prognosis^[51].

Another reason to investigate robotic surgery in the treatment of advanced gastric cancer would be the imperfect staging systems currently available. Studies report a considerable amount of patients staged as EGC perioperatively who turn out intraoperatively to suffer from advanced gastric cancer^[52,53]. Given these numbers Pugliese *et al*^[35] even proposed that all gastrectomies be performed including a D2 lymphadenectomy regardless

Table 3 Main postoperative outcomes in studies reporting use of robotic surgery for gastric cancer

Ref.	Time to first flatus (d)	Time to oral feeding (d)	Postoperative hospital stay (d)	Morbidity (%)	Mortality (%)	Follow up time (mo)
Patriti <i>et al</i> ^[21]			11.2	41.4	0	12.2
Lee <i>et al</i> ^[22]	2.4	4.6	6.6	8.3	0	
D'Annibale <i>et al</i> ^[23]		5	6	2	0	48
Isogaki <i>et al</i> ^[24]				4	1	
Kim <i>et al</i> ^[25]			6	0	0	
Liu <i>et al</i> ^[26]	2.5	4.1	6.2	11.8	0	
Park <i>et al</i> ^[27]			8	19	1	
Tokunaga <i>et al</i> ^[28]			8	22.22		
Anderson <i>et al</i> ^[29]		4 (2-8)	4 (3-9)	14.3		
Song <i>et al</i> ^[30]	2.9 ± 0.5	4.2	7.8	13	0	
Hur <i>et al</i> ^[31]						
Uyama <i>et al</i> ^[32]		3.56	12.1	8	0	11
Yu <i>et al</i> ^[33]	3.1	3.7		4.8	0	11
Jiang <i>et al</i> ^[34]			6.3	5	0	
Hyung <i>et al</i> ^[18]	Recent L > Initial L	Initial L > Recent L	Initial L > R = Recent L 6.9			
	> R 3.3 > 3.1 > 2.9	> R 4.8 > 4.3 > 4	> 6 = 6			
Song <i>et al</i> ^[19]	Recent L > Initial L	Initial L > Recent L	Initial L > Recent L > R 7.7	Recent L > Initial L = R 10 > 5 = 5		
	= R 3.25 > 3 = 3	> R 4.95 > 4.1 > 4	> 6.2 > 5.7			
Pugliese <i>et al</i> ^[35]			R = L 10 = 10	L > R 12.5 > 6.2	R > L 6.2 > 2	53
Woo <i>et al</i> ^[17]			R > L 7.7 > 7 ss	L > R 13.7 > 11	R approximately equal L 0.3 approximately equal 0.4	
Eom <i>et al</i> ^[36]	R = L 3.4 = 3.4		R approximately equal L 7.9 approximately equal 7.8	R > L 13 > 6		
Park <i>et al</i> ^[37]				R > L 17 > 7.5	R = L 0 = 0	
Yoon <i>et al</i> ^[38]	L > R 4.9 > 4.2		L > R 10.3 > 8.8	R > L 16.7 > 15.4		
Kang <i>et al</i> ^[39]			R > L 9.8 > 8.1 ss	R > L 14 > 10.3	R = L 0 = 0	
Hyun <i>et al</i> ^[40]			L > R 11.9 > 10.5	R > L 47.3 > 38.5	R = L 0 = 0	
Noshiro <i>et al</i> ^[41]			L > R 13 > 8 ss	L > R 10 > 9.5	0	
Han <i>et al</i> ^[42]		L > R 5 > 4.4	L > R 9.1 > 8.6	L > R 22.1 > 19.1	R = L 0 = 0	R > L 22.7 > 19.3
Junfeng <i>et al</i> ^[43]	L > R 3.3 > 3.1	L > R 4.1 > 3.9	L approximately equal R 7.9 approximately equal 7.8	R > L 5.8 > 4.3	R > L 32.2 > 30.1	L > R 19 > 15
Kim <i>et al</i> ^[44]			R > L 7.1 > 6.7	R > L 5.2 > 4.2	L > R 0.6 > 0	
Kim <i>et al</i> ^[45]	L > O > R 3.6 > 3.4 > 3.2		O > L > R 6.7 > 6.5 > 5.1 ss		R = L 0 = 0	
Huang <i>et al</i> ^[46]				L > R > O 15.6 > 15.4 > 14.7		
Kim <i>et al</i> ^[47]		O > L > R 5.7 > 4.7 > 4.4 ss	O > L > R 10.2 > 7.8 > 7.5 ss	O > R > L 10.7 > 10.1 > 9.34	0.4 ND	
Pernazza <i>et al</i> ^[48]				R > O 24.5 > 13.3	O > R 8.9 > 4.4	R = O 26 = 26
Caruso <i>et al</i> ^[49]			O > R 13.4 > 9.6	O > R 42.5 > 41.4	O > R 3.3 > 0	O > R 44 > 25
Procopiuc <i>et al</i> ^[50]			O > R 11.04 > 8.1 ss	O > R 27.58 > 22.22	O = R 0 = 0	O > R 31.6 > 24.7

R: Robotic surgery; L: Laparoscopic surgery; O: Open surgery; TG: Total gastrectomy; DG: Distal gastrectomy; ss: Statistically significant; ND: No statistical difference.

of the initial tumoral staging.

TECHNICAL ASPECTS

Combined resections

There has been a lack of studies specifically focused on the possible benefits of robotic multivisceral resections for advanced gastric cancer. Previous research by surgeons experienced in minimally invasive surgery suggests that the precision offered by the robotic platform might be of more use in large, technically-challenging procedures like multivisceral resections, rather than in cases requiring less complex surgery^[54,55].

Lymphadenectomy

To put forth robotic surgery as a viable surgical tech-

nique in gastric cancer treatment, its contribution to performing an extended lymphadenectomy needs to be made clear.

In laparoscopy, one of the major sources of intraoperative bleeding was shown to be lymph node dissection, especially when occurring around the large vessels^[56,57]. In our experience with the robotic platform owing to the elimination of physiologic tremor, the 3D steady view, and the 7 degrees of freedom of the EndoWrist® instruments lymph node dissection along the celiac trunk, the left gastric artery and the hepatic pedicle which are usually associated with increased bleeding, are now performed in a more precise and safe environment^[50].

The cohorts of Hyung^[18] and Song *et al*^[30] both included an initial and a recent laparoscopy group thus

allowing the assessment of the evolution of surgery parameters along the learning curve for this type of surgery and their comparison to the initial experience in robotic surgery. Although not statistically significant, recent laparoscopy showed the highest number of retrieved lymph nodes, with initial robotic cases coming second, in front of the initial laparoscopic cases. This comes to support the view that laparoscopy has a steeper learning curve than robotic surgery and that even inexperienced surgeons may obtain easily reproducible, high quality results faster with the robotic platform. This difference between the two techniques may not be important in the east, where experienced laparoscopic surgeons show no difficulties in quickly adjusting to the robotic platform, but it could bring a significant advantage to the western surgeons who simply cannot benefit from the same training in laparoscopy for gastric cancer due to the particular epidemiology of this disease.

The majority of the studies listed in Tables 1-3 show a higher number of retrieved lymph nodes for robotic procedures, which is an encouraging result given the extent of the preoperative under staging reported until now and the probable need to perform D2 lymphadenectomies for all patients until a reliable method for precise preoperative staging is introduced.

Digestive tract reconstruction

Key moments for the anastomosis are as follows: (1) closure of the duodenal stump; (2) closure of the stomach stump in subtotal gastrectomy or that of the esophageal stump in total gastrectomy; and (3) preparing the jejunum for the gastro-jejuno anastomosis or the eso-jejunoanastomosis. We generally opt for a Roux-en-Y anastomosis^[58].

The reconstruction solutions after total or subtotal gastrectomy can be grouped into two large categories. First, the extracorporeal anastomoses by the robot-assisted surgery require the performance of a minilaparotomy (smaller than 6 cm) through which the ends that need to be anastomosed are brought out and continuity of the digestive tract is reestablished, usually using circular stapler. This technique is not suitable for obese patients for whom the incision may need to be larger than 6 cm to perform the proximal resection and the purse-string suture on the esophageal stump.

To fully take advantage of the minimal invasiveness provided by the robotic platform, several techniques for intracorporeal anastomoses have been developed. They avoid the laparotomy and imply sectioning the esophagus under video control and then performing the anastomosis with a specific technique not requiring an abdominal incision. One option is using the OrVil™ device (Covidien, Mansfield, MA, United States). This consists of a foldable stapler anvil forming a 170° angle with the adjoining PVC tube. The OrVil™ device is introduced through the mouth and into the esophageal stump at which point the anvil is unfolded and connected to the circular stapler introduced abdominally. For this technique our team uses a 21 mm anvil followed by

a Roux-en-Y reconstruction with good postoperative results^[58]. Similar to this is the technique described by Hiki *et al*^[59] in which the anvil of a circular stapler is attached to a nasogastric tube using sutures and then introduced trans-orally. Another technique was described by Inaba *et al*^[60] and involves the creation of a side-to-side anastomosis using a linear stapler. Yet another option would be the manual sewing of the anastomosis, which we do not recommend, since it would prolong operating times unnecessarily, given the fact that the available mechanical devices are reliable alternatives.

The role of the assistant surgeon

In a study published by our team^[61], we assessed the role of the patient-side surgeon in robotic surgery. We found obvious benefits for the team when highly-trained assistants were involved in the procedure. Remarkable improvements were seen in handling the robot (docking and undocking times), the speed and precision in manipulating laparoscopic devices like the LigaSure or clip applier devices. Our data show that maintaining the same members of the team throughout more procedures and including assistants who undertook a structured, formal training program are more likely to warrant for fast and safe interventions.

OPEN QUESTIONS OF RESEARCH

An important problem remains regarding the selection of the appropriate technique for a given gastric cancer case. Thus far indications for robotic gastrectomy were: (1) a diagnosis of early gastric cancer without evidence of lymph node involvement; (2) T1 cancer with perigastric lymph node involvement; and (3) serosa-negative gastric cancer without lymph node metastasis. However, many of the patients were understaged preoperatively. This raises the need to study the outcomes of robotic surgery on large patient cohorts in randomized prospective studies not only for early gastric cancer, but also for tumors possibly requiring the D2 lymphadenectomy.

A recently published study surveying gastric cancer surgery techniques in United States academic medical centers^[62] shows that the number of robotic gastrectomies for gastric cancer has remained constant in 2011, 2012 and 2013. The study also mentioned that the robotic technique was utilized in the patients with the highest risk of mortality and severity of illness, in keeping with the fact that minimally invasive surgery has a lower impact on patient performance status and immune response mechanisms postoperatively^[62-64]. Therefore, extending the indications of robotic surgery to advanced gastric cancer is also a valid study point, especially in the West.

The option between endoscopic, laparoscopic, robotic or open surgery must be made based on well-established diagnostic criteria. This is not easy and one must take into account the caveats of evidence based

medicine and randomized controlled trials. The case of the results published by Bonenkamp *et al.*^[65] and Cuschieri *et al.*^[66,67] regarding the survival benefit of the D2 lymphadenectomy and the controversies thereafter have marked a decade of debate regarding the strategies for gastric cancer treatment. Carefully weighing the treatment options is especially important since there are more and more groups publishing acceptable results with the robotic technique.

CONCLUSION

Encouraging results are being published using the robotic technique, but the lack of homogenous study groups in terms of staging, comorbidities and adjuvant and neo-adjuvant therapies makes it hard to establish a clear indication for the robotic gastrectomy in gastric cancer.

Robotic surgery has proven to be safe and feasible thus far, but more convincing large volume prospective studies are needed to put it on the treatment list of early and advanced gastric cancer.

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