

Robotic gastrectomy for gastric cancer – an American perspective

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Contributions: (I) Conception and design: Y Woo; (II) Administrative support: Y Woo; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: Y Woo; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Gastric cancer is a challenging surgical disease in the United States. Most patients present with advanced disease, curative resection requiring radical gastrectomy with D2 lymphadenectomy within a multimodality treatment approach. Minimizing surgical trauma is imperative to the goals of long-term survival and a good quality of life for our gastric cancer patients. The patient's early recovery from surgery with the ability to return to normal daily activities and to receive timely adjuvant treatment is an essential part of the comprehensive treatment for locally advanced gastric cancer. Therefore, limiting the surgical insult while maximizing the oncologic efficacy is a major consideration when deciding on the surgical approach. Robotic radical gastrectomy with its favorable outcomes is a promising option for expanding the currently limited role of minimally invasive surgery for gastric cancer in the United States. The minimally invasive approach to gastric cancer surgery offers patients improved clinical outcomes without compromising the oncologic efficacy of the operations in comparison to the open approach. These proven benefits for early gastric cancers have led to several large-scale prospective investigations of laparoscopic surgery for advanced gastric cancer in East Asia. While awaiting their conclusive results, many experienced gastric cancer surgeons have already extended their indications for minimally invasive surgery to include advanced gastric cancer. Conceptually, no detrimental differences in long-term survival outcomes are expected for minimally invasive radical gastrectomy when properly performed. To do so require achieving negative margins, evaluating sufficient number of lymph nodes, and dissecting the appropriate level of lymph node stations. Unfortunately, the technical difficulty and the challenges of D2 lymphadenectomy in advanced gastric cancer patients will continue to impede the adoption of laparoscopic surgery for relatively lower volume surgeons in the United States. Robotic radical gastrectomy using the Da Vinci Si/Xi Surgical Systems (Intuitive Surgical, Sunnyvale, CA, USA) promises to facilitate the adoption of minimally invasive surgery for gastric cancer worldwide. In the United States, the surgeon's ability to control four robotic instruments and capitalize on the 3-dimension (3D) magnified operative view, the Endowristed capability with 7-degree of articulation, and the tremor filtering of the instrument movements, may prove especially useful to overcoming the steep learning curve of this complex oncologic operation. The critical translation of these and other new robotic surgical tools into appropriate clinical practice for the ultimate benefit of our gastric cancer patients will determine the future of robotic surgery; not only in gastric cancer, but for all complex abdominal operations.

Keywords: Robotic gastrectomy; gastric cancer; robotic surgery; United States

Submitted Sep 25, 2015. Accepted for publication Oct 10, 2015.

doi: 10.3978/j.issn.2224-4778.2015.10.07

View this article at: <http://dx.doi.org/10.3978/j.issn.2224-4778.2015.10.07>

Introduction

Robotic surgery is the most innovative surgical approach for the treatment of gastric cancer. Surgeon pioneers have judiciously embraced the robotic surgical technology, currently only available as the Da Vinci Surgical Systems (Intuitive Surgical, Sunnyvale, CA, USA), by critically evaluating its safe application, its' potential advantages, and defining how robotic gastrectomy will fit into a comprehensive surgical strategy for the treatment of our gastric cancer patients (1). In the United States, the adoption of robotic surgery for gastric cancer, like many other complex abdominal operations, is in its nascent stages (2-7). The optimum role of robotic gastrectomy for gastric cancer is being critically defined based on the substantial body of literature mostly from South Korea and growing number of individual surgeon's training and experiences.

The goals of robotic radical gastrectomy for our gastric cancer patients are the same as for open or laparoscopic approaches: to achieve long-term survival and to preserve quality of life after surgery. In the United States indications for the robotic approach for gastric cancer operations have included those patients who met a spectrum of the clinical criteria for curative resection (*Figure 1*) (2,3). The extent of surgical resections and the lymph node dissections has been consistent between the robotic approaches to the curative resection and the open operations, adhering to the oncologic principles of gastric cancer surgery (8-10). In South Korea and Japan, robotic gastrectomies were initially performed only on early stage lesions and expanded to advanced disease with growing robotic surgery expertise (11,12). However, robotic surgery experience for gastric cancer in the United States as well as Italy and China, has included mostly patients with locally advanced disease (13).

For the American gastric cancer patient population, the ability to expand minimally invasive radical gastrectomy with D2 lymphadenectomy to an increasing number of patients with surgical resectable advanced gastric cancer is one of the most appealing perceived advantages of the robotic surgical approach. The decision to integrate robotic surgery for gastric cancer patients as a part of the surgical armamentarium is built on the growing body of evidence, which supports its oncologic safety and the outcomes studies which demonstrate equivalence to laparoscopy in its patient benefits over open operations (14-16). Robotic radical gastrectomy with D2 lymphadenectomy is a minimally invasive option especially well suited for the surgical treatment of gastric cancer in the United State, where there

are low hospital volumes, advanced stage of disease at the time of diagnosis, and a relatively limited surgeon experience with gastric cancer surgery (17). As surgeons better define the role of robotic surgery for gastric cancer, guidelines to direct the optimum application of robotic surgery in the overall strategy for gastric cancer treatment should be developed. Concurrently, proper robotic gastrectomy training, prerequisite to the safe and advantageous integration of robotic surgery into practice, will need to be considered.

Within the global context

Within the last decade, robotic radical gastrectomy has emerged as an oncologically sound surgical approach for the treatment of early gastric cancer (15,18). In 2002 and 2003 pioneering surgeons from Japan (Hashizume *et al.*) (19) and the United States (Giulianotti *et al.*) (3) independently reported the initial safety and feasibility of robotic gastrectomy for cancer. Subsequently, South Korea, Japan, and Italy experienced early adoption of robotic gastrectomy (20-22). The single institutional safety and feasibility studies were quickly followed by comparative evaluations, which demonstrated the robotic advantages of minimally invasive surgery for gastric cancer patients (23-25). Most of the robotic gastrectomy experience comes from South Korea who have the highest number of published studies, whereas the largest number of patients evaluated in one study was from the first reported Chinese experience (*Table 1*). Moreover, most robotic gastrectomies in South Korea, Japan, and Taiwan have been performed in early gastric cancer patients while those of the United States, Italy, and China were performed for advanced gastric cancers. This trend reflects the relatively rapid dissemination of minimally invasive surgery for the treatment of early gastric cancer in the former countries and limited number of early stage cases in China and the West.

The largest experience of robotic radical gastrectomy comes from Yonsei University Severance Hospital in South Korea where 948 robotic gastric cancer operations were achieved between 2005-2014 (1). Moreover, the largest study overall and the only multiinstitutional prospective comparative study, which included surgeons from Yonsei University, was also conducted in South Korea (31). Of the total of 434 patients enrolled, 185 patients in the robotic treatment group were compared to the 185 patients in the laparoscopic group. While the results of this prospective trial concluded that the surgeon perceived advantages of

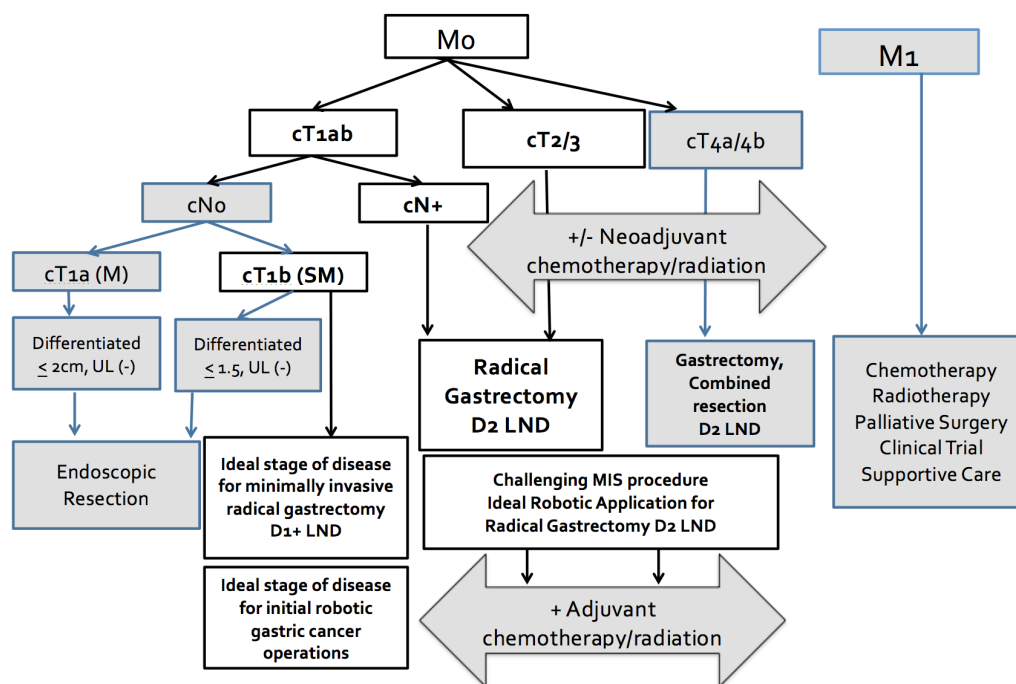


Figure 1 Decision Making Algorithm—Gastric cancer patients who meet criteria for curative surgical resection without evidence of serosal involvement are considered for robotic gastrectomy (white boxes).

Table 1 Comparative studies reflect robotic gastrectomy volume and experience

District	# of studies	Total # of patients*		Average # LN retrieved
		TG	DSG	
China (26)	1	120	394	35
Italy (18,27,28)	3	36	56	28-35
Japan (21-30)	3	30	104	40-43
South Korea (15,16,25,31-36)	11	355	685	30-43
Taiwan (37,38)	2	8	64	30
United States	0	0	0	NA

*Calculations were made taking into consideration potential duplicated patients within multiple studies. Abbreviations: TG, total gastrectomy; DSG, distal subtotal gastrectomy; LN, lymph nodes.

superior operative environment of robotic surgery did not translate into clinical outcomes, it did support the previous findings of the smaller retrospective studies. It demonstrated robotic gastrectomy for gastric cancer to provide the same minimally invasive benefits to the patient as laparoscopic surgery over the open approach.

The minimally invasive benefits of robotic radical gastrectomy are clearly defined and include less intraoperative blood loss, shorter hospital stay, decreased use of pain medicine, and earlier return of gastrointestinal

function when compared to open operations (18,23,27,32). There are no significant differences in the average number of lymph nodes retrieved, percentage of positive surgical margins, or long-term survivals representing adherence to oncologic principals during surgery without compromise in oncologic outcome (14). While longer operative times and higher operative costs have been the consistently reported disadvantages of the robotic approach for gastric cancer, the durations of the robotic gastrectomy operations appear to improve with the surgeons' increasing experience (37,38). A

cost analysis found the robotic approach not to have a higher financial impact on the cost of gastric cancer treatment in the United States (4).

The adoption of robotic radical gastrectomies by American general surgeons and surgical oncologists remain in its nascent stages of development. The majority of the gastric cancer operations, like most complex abdominal cancer surgery, are performed using the traditional open approach. In major academic centers, approximately 10% of radical gastrectomies are performed minimally invasively with an estimated 2.3% done using robot-assistance (4). These statistics are not surprising, considering that a combination of 1,490 different community, teaching and comprehensive cancer hospitals treated the relatively limited number of 37,124 gastric cancer patients over a 5 years period between 2001-2006. In this study 7,470 patients were treated at the highest volume hospitals which performed >13 cases/year. Another 7,229 patients received their surgery at hospitals with <3 cases/year volume. Moreover, only a few hospitals in the United States have a gastric cancer surgical volume exceeding 100 cases per year, with a limited number of surgeons having sufficient number of gastric cancer operations to readily overcome the learning curve of laparoscopic radical gastrectomy with D2 lymphadenectomy (39).

This snapshot of the United States gastric cancer surgical practices belies the lack of large volume studies in minimally invasive surgery for gastric cancer. It also speaks to the difficulty of obtaining sufficient training and experience to provide our gastric cancer patients with the most oncologically appropriate minimally invasive operations. The robotic surgical option adds another layer of complexity and decision making in the treatment of gastric cancer patients that requires both expertise in gastric cancer surgery and robotic operations; and preferably, robotic gastrectomy with D2 lymphadenectomy. The comparative outcome studies in the United States should provide a better understanding of the challenges of a radical gastrectomy with D2 lymphadenectomy particularly using the laparoscopic approach and the potential advantages of the robotic features specific to certain more complex portions of procedure. This should provide insight into how American surgeons can capitalize on the superiority of the robotic surgical systems.

The challenges of laparoscopic surgeons & advantages of the specific robotic features

The minimally invasive techniques of both the subtotal

distal gastrectomies and the total gastrectomies with D2 lymph node dissections have been well described in detail in previously published studies and in textbooks (25,40). First, the standard laparoscopic radical gastrectomy and D2 lymphadenectomy is performed using five access ports and requires two assistant surgeons, one to control the camera and another to help provide the proper exposure during the procedure (41). Second, at least one of the assistants is preferably an experienced advanced laparoscopist and must provide prolonged and steady retraction of various organs including the stomach, pancreas, and major vasculature for proper and timely exposure. Thirdly, the D2 lymphadenectomy requires steady and precise dissection along the head of the pancreas (#6 lymph node station), the vessels in the porta hepatis (#12 lymph node station), the common hepatic artery (#8 lymph node station), the celiac axis (#9 lymph node station), the left gastric artery (#7 lymph node station) the splenic artery (#11 lymph node station), and at times in the splenic hilum (#10 lymph node station). Fourthly, the camera operator must provide a clear and steady view of the operative field with directed movements while using challenging angles in the suprapancreatic area, posterior to the stomach, and within the esophageal hiatus for total gastrectomies. Most importantly, the laparoscopic radical gastrectomy with D2 lymphadenectomy has a steep learning curve, which is difficult to achieve without a high volume practice (41-44).

Control of four instruments

The Da Vinci Surgical System (Si and Xi) possesses key robotic features to address these challenges during a robotic radical gastrectomy. The robotic arms are docked on the four of the five access ports used during the procedure. This gives the surgeon control of four robotic arms leaving one port for the bedside assistant. Only one assist surgeon is needed to help change the robotic instruments, suction, or staple, and to provide the safety of a surgeon who is scrubbed at the patient side. At the operative console, the primary surgeon controls the camera and three additional instruments. This provides almost complete control of the operative environment allowing the surgeon to provide timely and appropriate repositioning of the camera and third arm retraction throughout the operation without delay and irrespective of the assistant's skill level. This feature maybe especially useful in situations where two assistants are difficult to obtain for a single operation and especially in teaching

hospitals or academic centers where the assistant is a trainee.

Steady and magnified 3-dimensional view of the operative field

Another distinct advantage for the surgeon is the 3D view of the operative field. The 3D magnified robotic visualization provides the improved depth perception superior to that of the laparoscopic flat 2-dimensional images, with the option of 30° angulation offering a high definition view of the operative field not readily observed during an open operation. The camera remains steady without unwanted movements since the robotic camera arm does not fatigue as a human assistant would and moves with the same steadiness and accuracy. This permits a well-coordinated steady 3D magnified operative view, which is especially useful during the D2 lymphadenectomy when numerous angles around the vessels can be very helpful during the dissection.

Tremor filtered precise operative movements

Besides the camera, the surgeon controls three additional robotic arms, which can be fitted with several different robotic instruments as per surgeon preference, all with more precise and tremor filtered capabilities. A feature to shift control between two arms allows the surgeon to alternate the use of two different instruments on one side of the dissection. For example, the surgeon can position one of the left sided arms for retraction and help improve exposure prior to dissection of a certain area using the two other instruments. During the suprapancreatic lymphadenectomy, the third robotic arm holding a Cardiere forceps can be used to gently and precisely retract the pancreas for improved exposure of the celiac axis and splenic artery. The exposure can be maintained without movement, allowing a tremor filtered precise dissection, identifying the major vessels and retrieving the soft tissues along these vessels without unwanted injury. The Cardiere grasper is often used for the third arm retraction while the harmonic (or the hook electrocautery) in the left arm and a Maryland bipolar forceps on the right arm. Although no direct correlation can be made, the precision of these dissections may correspond to the statistically less blood loss during robotic operations compared to both laparoscopic and open operations.

Endowrist instruments

Another useful advantage of the robotic gastrectomy is

derived from the robotic Endowrist capability, which allow for angled dissection and ease of suturing. The Large Needle Driver and the Mega™ Suture Needle Driver are Endowristed with 7-degrees of articulation facilitating ease of intracorporeal suturing of the gastrojejunostomy during a distal gastrectomy, the jejunojunostomy during a total gastrectomy, the oversewing of staple lines, or gaining quicker and more precise control of bleeding vessels. The robotic skills required to perform these complex minimally invasive maneuvers and perform the robotic gastrectomy safely and without compromise to oncologic techniques, require specific training in robotic surgery and gastric cancer operations along with the necessary operative experience.

Robotic surgery certification and specific hospital privileges for robotic surgery are uniformly required prior to performing an operation using the robot. Moreover a formal robotic surgical training curriculum, which includes gastric cancer procedures, is necessary and actively being developed in the United States. The robotic surgery curriculum will incorporate the currently available simulation and dry lab experience along with the hands on porcine and cadaveric training provided by Intuitive Surgical, along with structured practical experience to take into account the learning curve patterns of the robotic gastrectomy.

The learning curve in robotic gastrectomy for cancer

The technical difficulty of performing an extended lymphadenectomy recommended for all surgically resectable patients with Stage II or greater gastric cancer is well recognized even in open operations (45,46). The learning curve for laparoscopic radical gastrectomy with extended node dissection for even experienced gastric cancer surgeons are steep (40-100 cases), with differences in operative time and postoperative patient outcomes between surgeons who have reached their plateau and those who have not (47,48). In contrast, the learning curve of robotic radical gastrectomy demonstrate a quicker adaptation with most studies reporting 11 to 25 cases to be sufficient for experienced gastric cancer surgeons (*Table 2*) (24,33,49-51). This very important advantage can provide an increasing number of surgeons the opportunity to achieve proficiency in minimally invasive gastric cancer operations and offer the benefits of the robotic approach to the gastric cancer patients in the United States.

Table 2 Learning curve of robotic gastrectomy for gastric cancer

District/year	Author	Method of analysis	# of cases
China, 2015 (49)	J. Zhou	CUSUM	14-31
Korea, 2012 (33)	B. H. Kang	Outcomes comparison of the first 20 cases versus after 20 cases	20
Korea, 2012 (50)	S. S. Park	Nonlinear least-squares	18
Italy, 2011 (24)	A. D'annibale	ANOVA to test the variance of operative time and docking time and curve regression	20-24
Taiwan, 2012 (37)	K. H. Huang	Outcomes comparison of the first 20 cases versus 20 cases after	25

Conclusions

Robotic surgery is a promising surgical approach for the treatment of gastric cancer patients in the United States. Surgeons with a thorough understanding of the principles of gastric cancer treatment, including strict adherence to the proper oncologic technique and proper training in robotic gastric cancer surgery can provide an oncologically sound minimally invasively operation for our gastric cancer patients. Minimizing surgical trauma enhances postoperative recovery, essential to the long-term survival and quality of life of gastric cancer patients, and should be weighed heavily in the surgeon's selection of the operative approach. As expertise in robotic gastric cancer treatment grows, the optimal role of the ever-evolving robotic surgical technology for the treatment of gastric cancer will be better defined.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Goldner B, Woo Y. Robotic gastrectomy for gastric cancer—an American perspective. *Transl Gastrointest Cancer* 2015;4(6):453-460. doi: 10.3978/j.issn.2224-4778.2015.10.07