A Single Surgeon's Experience with 3-Dimensional (3D) Laparoscopic Surgery for Gastric Cancer

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Abstract

Over the past twenty years, laparoscopic surgery has become increasingly popular for the treatment of gastric cancer. Since Kitano's first description of using laparoscopic surgery for gastric cancer resections **[1]**, countries in the Far East – namely Japan, Korea, and China – has readily adopted this evidence-based procedure, and it is now set to become an indispensable component in the armamentarium of oncological surgery worldwide. This evolution of surgical techniques has driven the relentless development of advanced equipment to assist surgeons approach their craft in the best way possible. A mark of this technological progress is appreciable in the advent of 3-dimensional (3D) laparoscopic surgery, which was developed in order to provide laparoscopic surgeons a more accurate portrayal of their visual field and allow for finer tissue handling due to enhanced depth perception. Because of the emerging status of this medium, further evidence of the potential benefits and safety of 3D laparoscopic surgery for gastric cancer is warranted. As such, this study was conducted in order describe these factors using a single surgeon's long-term experience with this technology.

Keywords: 3-dimensional, laparoscopic surgery, gastric cancer

Part 1: Introduction

Compared with open surgery, the feasibility and increased safety of laparoscopic surgery for the curative treatment of gastric cancer has been demonstrated through large-scale randomized controlled clinical trials **[2-5]**. As a result of the success found with laparoscopic surgery, a significant amount of technological innovation has been geared towards the development of laparoscopic equipment in order to optimize the patient's postoperative outcome and surgeon's operative experience - such as laparoscopic surgical staplers and high-definition video systems. A problematic issue that needed to be addressed was the difficulty of maneuvering in a 3-dimensional (3D) environment using a 2-dimensional (2D) display. Even with the introduction of systems that provided binocular disparity, this medium fell short of providing accurate visual information; surgeons were still required to rescale visual information to guide motor behavior **[6]**. With the development of 3D imaging, however, a perceptively precise portrayal of the surgeon's internal workspace is possible and is an emerging technology that can positively alter the landscape of laparoscopic surgery.

1.1 Clinical and in-training applications of 3D laparoscopy

Preliminary studies reported several benefits associated with the clinical and in-training implementation of 3D laparoscopic surgery when compared to 2D systems. These include reduced duration of operations in radical cystectomy, right-sided colectomy, radical hysterectomy, and pelvic lymphadenectomy **[7-9]** as well as a shorter length of hospital stay **[9]**. Additionally, 3D laparoscopic surgery has repeatedly been shown to improve performance of novice surgeons **[10-12]**. These benefits can be linked to the superior depth perception and spatial orientation 3D visualization systems offer **[13-14]**. Despite these encouraging results, a limited number of studies have been conducted to determine the benefits and safety of 3D laparoscopic surgery in gastric cancer surgery.

The purpose of this report is to address this issue and provide evidence to demonstrate the safety and feasibility of the clinical implementation of 3D laparoscopy in gastric cancer surgery.

Part 2: Methodology

Between September 2014 and September 2016, 240 patients received 3D laparoscopic gastric surgery by the chief surgeon (Dr. Young-Woo Kim) of the Gastric Cancer Branch at the National Cancer Institute - Korea. The inclusion criteria included pathologically proven adenocarcinomas and an ASA score of 1 to 4. Accordingly, we used STATA version 12.0 to conduct analysis of operative and short-term outcomes, such as surgical and non-surgical complications.

2.1 3D Laparoscopic System Setting (Sometech Inc.)

We used the Sometech 3D system to perform gastric cancer surgery. This system was designed with state-of-the-art specifications, such as 1920×1080P@60Hz for high-definition imaging and 3D stereoscopic imaging for depth perception. The main unit of this system was set with the following features:

- Convergence Control:
  With a basic working distance of 5 cm, the distance can also be adjusted between a range of 3 to 10 cm for close and long range visuals, respectively.

- Binocular Disparity Control:
  In the same way that human eyes view objects with binocular disparity, two cameras are used to display a 3D image. An adjustment jig allows for easy adjustments of this control after scope replacement. Adjustments can be set using a touch screen on the Binocular Disparity Control menu.

- White Balance Function:
  This function automatically adjusts the white balance of the camera image.

- High-Definition Multimedia Interfaces (HDMI)

  Totaling 4 HDMIs, 3 HDMI-outs are installed for 3D imaging and 1 HDMI-out for 2D imaging.

Part 3: 3D Laparoscopic surgery for gastric cancer is safe and feasible

3.1 Patient and tumor characteristics

Patient demographics can be found in Table 1. The majority of all 3D laparoscopic surgery was performed on patients with early gastric cancer (190 out of 237 patients; 80.2%) with an average tumor length of 3.35 cm ± 1.85 at the longest diameter (Table 2).

Table 1: Patient demographics

Characteristic	% or mean (SD)
Age	
26 – 87	60.88 (± 12.19)
Sex	
Male	155 (± 64.6)
Female	85 (± 35.4)
BMI	
17.5 – 33	23.9 (± 2.9)
ASA Score	
1	81 (± 34.75)
2	143 (± 59.6)
3	15 (± 6.25)
4	1 (± 0.4)
5	0
6	0
Alcohol Consumption	
Yes	130 (± 54.1)
No	110 (± 45.83)

Table 2: Tumor characteristics

Characteristic	% or mean (SD)
Diagnosis	
Early	190

Advanced	35
GIST*	9
Lymphoma	0
Others	3
Size (longest diameter)	
0.4 – 13 cm	3.35 (± 1.85)
Histology type	
Differentiated	145 (± 60.4)
Undifferentiated	81 (± 33.8)
N/A	14 (± 5.8)
Lauren Classification	
Intestinal	102 (± 42.5)
Diffuse	82 (± 34.17)
Mixed	30 (± 12.5)
Indeterminate	7 (± 2.92)
N/A	19 (±7.92)
Location	
Upper	28 (± 11.67)
Middle	64 (± 26.67)
Lower	106 (± 44.17)
Mid-lower	15 (± 6.26)
Whole	1 (± 0.42)
N/A	26 (± 10.83)
Invasion depth	
T1a	97 (± 40.42)
T1b	89 (± 37.08)
T2	20 (± 8.33)
T3	13 (± 5.42)
T4a	4 (± 1.67)
N/A	17 (± 7.08)
Stage	
1a	169 (± 70.42)
1b	28 (± 11.67)
2a	10 (± 4.17)
2b	11 (± 4.58)
3a	6 (± 2.5)
3b	1 (± 0.42)
4	2 (± 0.83)
N/A	13 (± 5.42)

- GIST, gastrointestinal stromal tumor

3.2 Outcome analysis of operative parameters

Table 3: Operative outcomes

Outcomes (n=240)	% or mean (SD)
Reconstruction method	
Billroth I (with stapler)	30 (± 13.27)
Billroth I (handsewn + stapler)	72 (± 31.86)
Billroth II	14 (± 6.19)
Roux-en Y	39 (±17.26)
Gastro-gastrostomy	37 (± 16.37)
Esophago-gastrostomy (double shouldering)	19 (± 8.41)
Double tract	2 (± 0.88)
Primary repair (wedge resection)	13 (± 5.75)
Lymphadenectomy	
SBD	15 (± 6.25)
D1+	186 (± 77.5)
D2	24 (± 10)
D2+	2 (± 0.83)
Resection of other organs	
Pancreas	0
Spleen	1
Liver	0
Colon	0
Residual Tumor Status	
R1	226 (± 94.17)
R2	2 (± 0.83)
N/A	12 (± 5)
Operative time	
45 – 480 mins.	219.14 (± 68.6)
Blood Loss	
5 – 2000 mL	96.13 (± 183.9)
Hospital Stay	
3 – 120 days	8.8 (± 8.3)
Harvested Lymph Nodes (LN)	
Number of LN	33.21 (± 13.6)
Positive LN	0.59 (± 2.5)
Resection Margins	
Proximal	4.1 (± 3.2)
Distal	4.4 (± 3.3)
Conversion	
STG to TG	6 (2.52%)
Open	3 (1.26%)
Intraoperative Complications	9 (3.75%)

Table 4: Comparison of operative procedures by outcome

Procedure Type	Number of Cases	Operative time Mean (SD)	Intraoperative blood loss Mean (SD)
1. Totally laparoscopic total gastrectomy (TLTG)	7 (2.95)	313.6 ± 46.8	125 ± 88
2. Laparoscopy assisted total gastrectomy (LATG)	3 (1.27)	401.7 ± 75.2	150 ± 70.7
3. Totally laparoscopic distal gastrectomy (TLDG)	125 (52.74)	221.16 ± 57.2	102.2 ± 221.9
4. Laparoscopy assisted distal gastrectomy (LADG)	17 (7.17)	204.7 ± 38.7	80 ± 44.7
5. Totally laparoscopic pylorus-preserving gastrectomy (TLPPG)	21 (8.86)	211 ± 36.4	46.25 ± 35
6. Laparoscopy assisted pylorus-preserving gastrectomy (LAPPG)	17 (7.17)	237.4 ± 39.3	101.1 ± 84.8
7. Totally laparoscopic proximal gastrectomy (TLPG)	19 (8.02)	237.6 ± 65.6	56 ± 37.6
8. Laparoscopy assisted proximal gastrectomy (LAPG)	2 (0.84)	372.5 ± 109.6	600
9. Laparoscopy wedge resection (LWR)	26 (10.97)	134.5 ± 60.3	36.5 ± 29.3

Table 5: Comparison of reconstruction methods by operative time

Reconstruction Method	Mean (SD)
Billroth I (with stapler)	167.1 ± 90.8
Billroth I (handsewn + stapler)	223.7 ± 57
Billroth II	225.7 ± 40
Roux-en Y	229.2 ± 69.5
Gastro-gastrostomy	216 ± 70.7
Esophago-gastrostomy (double shouldering)	241.3 ± 68.4
Double tract	269 ± 99
Primary repair (wedge resection)	215 ± 44

Table 6: Short-term postoperative outcomes

Outcome	Number of Patients (%)
Surgical Complications	
Anastomotic leakage	8 (3.3)
Anastomotic stenosis	6 (2.5)
Anastomotic bleeding	1 (0.42)
Wound-related complications	6 (2.5)
Delayed emptying syndrome	2 (0.83)

Intra-abdominal abscess	1 (0.42)
Total	24 (10)
Non-surgical complications	5 (2.18)
Mortality	0

Part 4: Discussion

Laparoscopic surgery is widely accepted for the treatment of gastric malignancies due to notable advantages and improved oncological outcomes. However, one of the biggest hurdles for surgeons – particularly novice surgeons – to overcome is hands-on maneuvering of a 3-dimensional space using 2-dimensional imaging. Surgeons lose depth perception and therefore experience higher visual and cognitive loads. In response to the need for an alternative approach to imaging, 3D laparoscopy is now a reality owing to a leap forward in technological innovation. Since its clinical introduction almost two decades ago, multiple studies have consistently confirmed the superiority of 3D systems both operatively and in training (e.g. endotrainer, experimental surgical models **[15]**).

Thus far, two studies have analyzed data comparing these two laparoscopic mediums concerning stomach-related procedures. Giuseppe Currò et al examined the efficacy of 3D laparoscopy bariatric surgery in 40 obese participants who were randomly assigned to receive either 3D or 2D laparoscopic mediums **[16]**. 3D imaging was shown to decrease the performance time of bariatric procedures due to the increased ease of completing technically-difficult tasks, such as suturing and intestinal measurement. Recently, an interim report was published concerning a phase III randomized controlled trial with 221 gastric cancer patients to evaluate short-term outcomes of 3D versus 2D laparoscopic surgery **[17]**. Results demonstrated a reduction in blood loss but did not indicate a decreased time of operation.

Additionally, the clinical application of 3D laparoscopic gastric surgery has been shown to improve surgical performance of trainees, as well as augment anatomical awareness. Significant improvement in performance time and reduction in error was particularly pronounced with complex tasks such as needle capping and knot typing **[12]**. Independent to surgical experience and procedural difficulty, utilizing a visual system configured to offer depth perception was found to increase task performance speed by 60-70% **[18]**. Meaning, efficient 3D optical systems can facilitate the completion of both simple and advanced laparoscopic procedures for experienced and inexperienced surgeons alike.

Because depth perception and hand-eye coordination are vastly improved using 3D imaging, accurate and swift dissections as well better intra-corporeal knotting possible. Especially for total gastrectomy, advanced technical maneuvers such as suturing and knot tying were difficult for surgeons to initially approach and execute. In this study, the mean operating time of intracorporeal knotting is lower than that of the extracorporeal group, except with distal gastrectomy. Y.W. Kim **[19]** et al reported the surgical outcomes of 2D LADG in a randomized clinical trial, where the mean operating time was determined to be 252.6 minutes – which is longer than this present study. As shown in a previous study, a 30-40% reduction in performance time was found using a 3D approach compared to 2D **[18]**.

There are several methods used for reconstruction during laparoscopic gastric surgery. Our results showed no difference in operating time between each reconstruction method. However, this result may be associated with the diversity of equipment utilized to complete this task.

Particularly for handsewing, suturing, and delicate needle handling, 3D was extremely useful and convenient compared with 2D laparoscopy.

During minimally invasive surgery, surgeons learn to interpret monocular depth cues from 2D displays to perform intricate movements that demand accurate handling of forceps. During laparoscopic cholecystectomy, a staggering 97% of bile duct injuries were reported to occur as a result of “visual perceptual illusions”; that is, cognitively derived illusions based on heuristic biases and uncommon anatomical configurations **[20]**. As such, the enhancement of depth perception using 3D imaging may improve the quality of laparoscopic surgery and patient safety **[14]**. In 2014, H.H. Kim **[21]** reported the surgical outcomes of 2976 patients treated with laparoscopic gastrectomy. Morbidity was found to be 12.5% in the laparoscopic groups, whereas a randomized controlled trial published in 2013 (COACT 0301) reported the rate of short-term complications after laparoscopic distal gastrectomy was 29.3% **[22]**. In our study, 10 out of 240 patients had complications. Although this is slightly more modest compared with other studies, the reported benefits of 3D laparoscopic surgery for gastric cancer in this study and others are promising nonetheless, and therefore 3D laparoscopic systems for gastric cancer surgery is worthy of further evaluation.

Conclusion

Due to increased spatial awareness 3D laparoscopic systems offer, improvements in the surgical outcome of patients receiving surgery for gastric cancer is expected due to decreases in operating time, intraoperative blood loss, and complication rates compared with the 2D surgical approach. In the realm of minimally invasive surgery, this study demonstrates that 3D technology improves the operator's visual field and allows for an improved surgical experience. However, a randomized controlled trial is necessary to determine the nature and extent of this niched surgical medium.

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