

# Clinical Application of Electrogastrography in Patients with Stomach Cancer Who Undergo Distal Gastrectomy

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**Purpose:** Electrogastrography is a method of measuring action potentials of the stomach. The purpose of this study was to investigate early postoperative changes in the electrogastrography and determine the correlation between electrogastrography and quality of life of patients with stomach cancer who underwent distal gastrectomy.

**Materials and Methods:** This study analyzed 20 patients with stomach cancer who underwent electrogastrography and quality of life was measured 1, 12, and 24 weeks after the operation. Quality of life-C30 version 3.0 and quality of life-STO22, were used.

**Results:** Fasting and postprandial mean dominant frequency at 1 week after the operation was 2.7 and 2.7 cycles per minute, and 2.8 and 2.7 cycles per minute at 12 weeks, 2.6 and 2.8 cycles per minute at 24 weeks. Fasting and postprandial mean dominant power at 1 week was 36.5 and 36.4 dB, 36.3 and 40.1 dB at 12 weeks and 40.9 and 42.3 dB at 24 weeks. The percentage of tachygastria was increased whereas the percentage of bradygastria was decreased during the postoperative periods ( $P < 0.05$ ). Global health, physical, emotional and social functioning scales were improved, but role and cognitive functioning were not changed. Pain, insomnia, diarrhea and financial difficulties were significantly improved according to the postoperative periods ( $P < 0.05$ ). The correlation between the STO22 and electrogastrography parameters was not significant ( $P > 0.05$ ).

**Conclusions:** These may suggest that electrogastrography is a simple and noninvasive method and may be applied for evaluating motility and autonomic functions of the remnant stomach.

**Key Words:** Electrogastrography; Stomach neoplasms; Distal gastrectomy

## Introduction

The primary functions of the stomach are to mix secreted enzymes and peptides and store, grind, digest, and empty food into the duodenum. Multiple levels of neuronal mechanisms of the central, spinal, and enteric nervous systems are in place to coordinate the stomach's ordered movement.<sup>1</sup> The stomach muscle itself also exhibits myoelectrical activity that mediates stomach motility. Both

slow waves (electrical control activity) and spikes (electrical response activity) are well-known components of stomach myoelectricity.<sup>2</sup> In 1922, Alvarez<sup>3</sup> recorded a three-cycles per minute (cpm) sinusoidal wave using electrodes placed on the abdominal skin. Noninvasiveness is the greatest advantage of electrogastrographies (EGGs), which use surface-placed electrodes to record stomach myoelectricity.<sup>2,4-6</sup> Since Alvarez's report, a number of studies concerning EGG have determined that gastric electrical potentials break out from a pacemaker located on the upper gastric body along the greater curvature.<sup>7,8</sup> These potentials are related to an electrical pacing function and the power of gastric contraction.<sup>9-11</sup> The EGG result is a combination of gastric signals and noise. The gastric signal consists of normal slow waves (regular frequency, 2~4 cpm), tachygastria (regular frequency, 4~9 cpm), bradygastria

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(regular frequency, 0.5~2 cpm), and arrhythmia (irregular rhythmic activities). The noise is composed of respiratory and motion artifacts, electrocardiography, and electrical interference of the small intestine.<sup>9</sup> Gastric emptying (GE) is a function of the net inhibitory and excitatory results of antropyloroduodenal coordination among all portions of the stomach, pylorus, and duodenum.<sup>1</sup> Partial or total removal of the upper gastrointestinal organs impairs GE. In the present study, we investigated postoperative changes on the EGGs of patients with stomach cancer and analyzed the relationship between the EGG system and the quality of life (QOL) of patients with stomach cancer who were treated with distal gastrectomy.

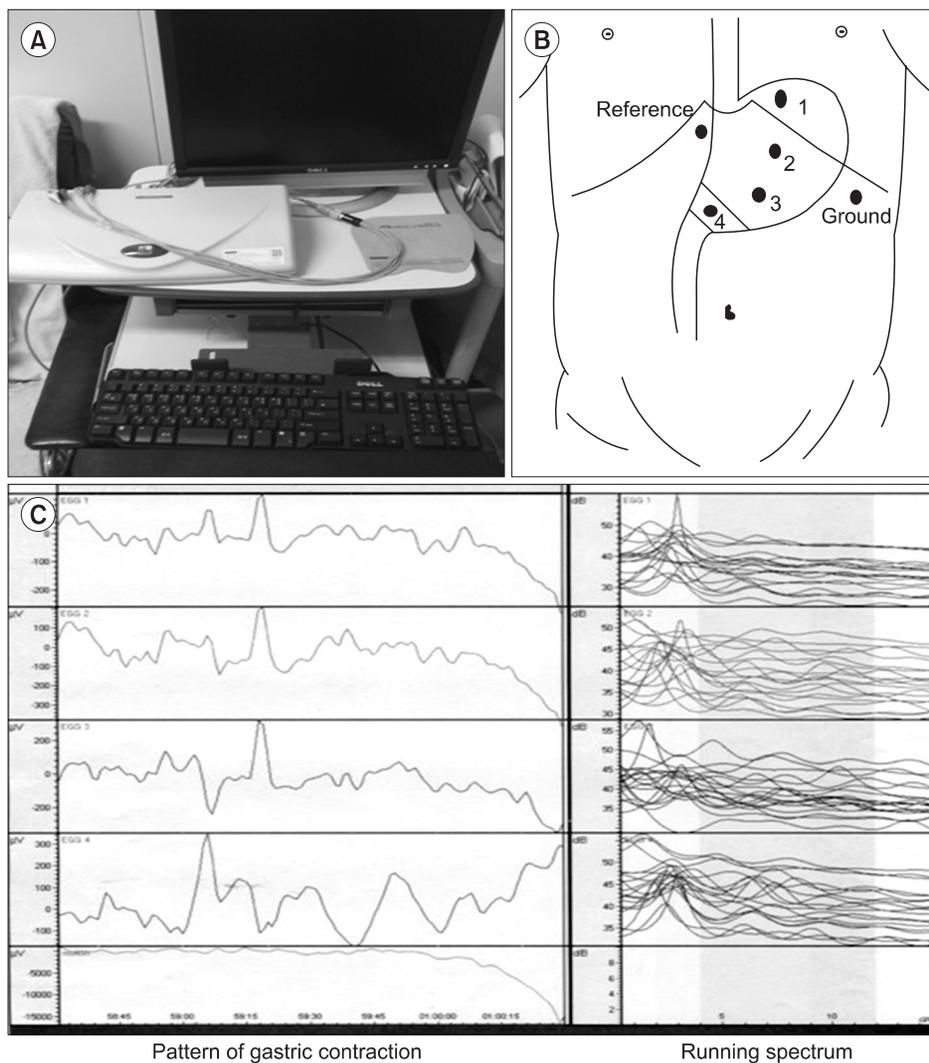
## Materials and Methods

### 1. Patients

Twenty individuals who underwent distal gastrectomy with

gastroduodenostomy for the treatment of stomach cancer at Kyung Hee University Medical Center between May and December 2010 were enrolled. Abnormal GE and associated dyspeptic symptoms are common in the early period after the operation, while GE may return to normal 12 months after surgery. In addition, some changes in EGG parameters occur in the early days after subtotal gastrectomy. Therefore, we enrolled patients with stomach cancer who were treated with distal gastrectomy to investigate postoperative EGG changes and analyzed the correlation between EGG findings and QOL.

The elapsed time after distal gastrectomy was obtained from chart reviews. However, we excluded subjects with distal gastrectomy who showed evidence of diabetes, tumor metastasis or recurrence, tumor-related terminal stages, dumping syndrome, obvious dyspepsia, or the current use of any medications known to alter gastrointestinal motility. An EGG was recorded for each of the



**Fig. 1.** Electrogastrography (EGG) system (POLYGRAM NET™) (A), electrode position (B), and EGG graphs (C).

20 patients with gastric cancer who underwent gastrectomy (15 men, five women; mean age  $\pm$  standard deviation [SD], 59.8 years; range, 28~74 years). All subjects were advised to accept endoscopy to confirm their distal gastrectomy and the absence of tumor recurrence. Our hospital's ethics committee approved this project. Informed consent was obtained from all patients before the study was conducted.

## 2. Electrogastrography system

Each EGG was recorded with a POLYGRAM NET™ (Medtronic A/S; Alpine Biomed ApS, Skovlunde, Denmark) (Fig. 1). Active electrodes for a four-channel EGG study were placed to follow the antral axis of the stomach. The electrodes were placed under abdominal ultrasonographic guidance. Pre-gelled electrodes were applied to prepared spots in the following sequence:

1. The channel 3 electrode was placed approximately 2 cm left of the midway point between the umbilicus and xiphoid process on the patient's ventral midline.

2. The channel 4 active electrode was placed approximately 5 cm right of the channel 3 electrode at the same level.

3. The channel 2 active electrode was placed approximately 5 cm left of and 45° to the channel 3 active electrode at the same level.

4. The channel 1 active electrode was placed approximately another 5 cm away and 45° to the channel 2 electrode.

5. A common reference electrode was placed just below the xiphoid process.

6. A ground electrode was placed approximately 10 cm left of ventral midline at the same level of the channel 3 electrode.

## 3. Electrogastrography measurement

After an overnight fast, the subjects rested quietly in the supine position and were asked not to move, sleep, or talk throughout the recording. A baseline EGG recording was obtained for 45 minutes in the supine position. After the basal recording was taken, the subjects were asked to consume a standard light meal including 180 ml of orange juice and a piece of cake (347 kcal) in a sitting position. We then recorded a postprandial EGG for 45 minutes.

## 4. Analysis

The results are expressed as mean  $\pm$  SD. Numerical data were analyzed with paired Student's *t*-test or an analysis of covariance test. Statistical analyses were performed with SPSS statistical software, version 17.0 (SPSS Inc., Chicago, IL, USA). Values of  $P < 0.05$  were considered statistically significant.

## Results

Table 1 illustrates the characteristics of the patients with gastric cancer. According to the tumor location, there were 10 cases (50%) in the body and 10 cases (50%) in the antrum. According to the Union for International Cancer Control 7th TNM classification (2010), there were seven cases (35%) of stage Ia, five cases (25%) of stage Ib, two cases (10%) of stage IIa, two cases (10%) of stage IIb, and four cases (20%) of stage IIIa. Open distal gastrectomy was performed in 11 cases (55%) and laparoscopic-assisted distal gastrectomy was performed in nine cases (45%). Twelve cases (60%) received adjuvant chemotherapy.

Table 2 illustrates the effect of the meal on EGG parameters during the postoperative period (~24 weeks). According to the effect of the meal on EGG parameters during the early postoperative period, between the fasting and postprandial recordings, there were no significance differences in dominant frequency (DF), dominant power (DP), and percentage of normal frequency, but there were significant decreases in the percentage of bradygastria and increases in the percentage of tachygastria ( $P < 0.05$ ). The percentage of bradygastria decreased significantly on the postprandial recordings between 1 week and 3 months, between 1 week and 6 months, but not between 3 months and 6 months. The percentage of tachygastria increased between 1 week and 6 months but not between 3 months and 6 months. The percentage of normal frequency was

**Table 1. Characteristics of patients with gastric cancer**

Gender (male : female)	14 : 6 (2.3 : 1)
Age (yr)	59.8 (28~74)
Stage*	
Ia	7 (35)
Ib	5 (25)
IIa	2 (10)
IIb	2 (10)
IIIa	4 (20)
Tumor location	
Body	10 (50)
Antrum	10 (50)
Surgery	
DG	11 (55)
LAGD	9 (45)
Chemotherapy	
Yes	12 (60)
No	8 (40)

Values are presented as number, median (range), or number (%). DG = distal gastrectomy; LAGD = laparoscopic-assisted distal gastrectomy. \*Union for International Cancer Control 7th TNM classification.

**Table 2. Effect of the meal on EGG parameters during the postoperative period (~24 weeks)**

EGG parameter	Fasting	Postprandial	P-value
Dominant frequency (cpm)			
1 week	2.7±0.1	2.7±0.3	0.432
12 weeks	2.8±0.4	2.7±0.5	0.704
24 weeks	2.6±0.4	2.8±0.5	0.101
Dominant power (dB)			
1 week	36.5±2.4	36.4±2.7	0.107
12 weeks	36.3±3.2	40.1±4.9	0.647
24 weeks	40.9±6.5	42.3±8.4	0.498
Percentage of normal frequency (2.7~3.4 cpm)			
1 week	18.1±13.4	23.6±14.2	0.003
12 weeks	19.4±5.6	22.5±8.8	0.077
24 weeks	21.9±9.1	23.3±10.2	0.170
Percentage of bradygastria (<2.7 cpm)			
1 week	58.5±15.9	41.8±13.9	0.000
12 weeks	48.2±14.8	37.0±11.0	0.000
24 weeks	48.0±14.9	36.5±9.3	0.001
Percentage of tachygastria (>3.4 cpm)			
1 week	21.9±7.4	33.8±11.5	0.000
12 weeks	28.9±10.7	37.9±10.1	0.001
24 weeks	26.6±9.8	37.7±12.2	0.000
Instability coefficient (DF)			
1 week	0.82±0.34	0.86±0.45	0.660
12 weeks	0.75±0.29	0.88±0.32	0.042
24 weeks	0.98±0.39	1.1±0.45	0.335

Values are presented as mean±standard deviation. EGG = electrogastrography; cpm = cycles per minute; DF = dominant frequency.

slightly increased in the postprandial recordings, but there were no significant differences except in postoperative week 1.

Global health status and physical, emotional, and social functioning scales were improved, but role and cognitive functioning were not changed. Most symptom scales were slightly improved, whereas pain, insomnia, diarrhea, and financial difficulties were significantly improved according to the postoperative periods regarding the European Organisation for Research and Treatment of Cancer (EORTC) quality of life questionnaire QOL-C30 version 3.0 ( $P < 0.05$ ) (Table 3). Comparison of QOL with the EORTC QLQ-STO22 questionnaire during the postoperative periods (~12 weeks) revealed no statistically significant differences ( $P > 0.05$ ) (Fig. 2), and the correlation between QOL and EGG parameters was not statistically significant ( $P > 0.05$ ) (Table 4).

## Discussion

Stomach surgery may influence gastric motor function. Even gastric restrictive surgery without resection in obese subjects leads to altered DF and DP but not power ratio.<sup>12</sup> Truncal vagotomy with

gastric resection for peptic ulcer disease impairs esophageal sphincter tone, food accommodation, and the grinding and emptying ability.<sup>13</sup> Distal gastrectomy is severely destructive to the stomach anatomy and its neighboring organs and may lead to poor motility.<sup>14-16</sup>

Debate persists regarding when to record postoperative EGG parameters. Abnormal GE and associated dyspeptic symptoms are common in the early days after an operation, while GE may require 12 months after stomach surgery to return to normal.<sup>1,15</sup> Some changes in EGG parameters occur in the early days after subtotal gastrectomy.<sup>17</sup> Lee et al.<sup>18</sup> enrolled subjects for distal robotic sleeve gastrectomy (RSG) who had undergone stomach surgery at least 1 year previously. Homma et al.<sup>19</sup> reported that a series of regular peaks of 3 cpm activity were not clearly visible in the EGGs running spectra recorded from patients who had undergone a distal gastrectomy with a short postoperative period (13~71 days in 13 subjects). Imai and Sakita<sup>20</sup> recorded postoperative EGGs in gastrectomy patients 3 to 5 weeks after surgery. Hayashi et al.<sup>21</sup> recorded EGGs at least 1 year after surgery. In our study, we recorded and analyzed EGGs in patients who had undergone distal

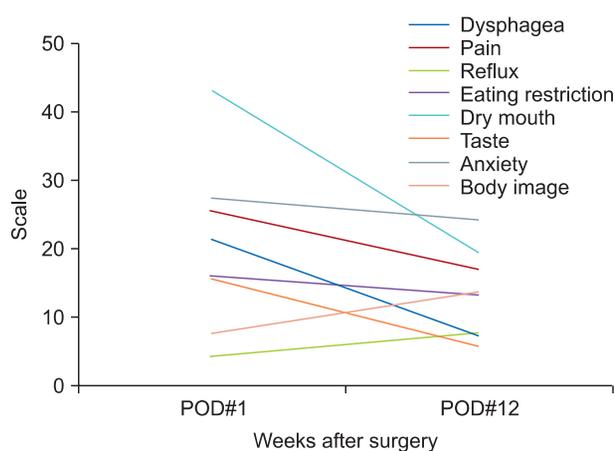
**Table 3. Comparison with the European Organisation for Research and Treatment of Cancer QOL questionnaire (QOL-C30 version 3.0) according to postoperative period**

	Postoperative 1 week	Postoperative 12 weeks	P-value
Global health status	49.2±38.0	60.8±30.1	0.000
Functional scales			
Physical functioning	63.9±26.9	76.8±13.4	0.046
Role functioning	67.1±33.4	81.6±21.8	0.118
Emotional functioning	78.5±18.5	90.4±12.2	0.025
Cognitive functioning	85.1±14.6	90.4±17.0	0.268
Social functioning	66.7±18.4	80.7±22.4	0.025
Symptom scales			
Fatigue	32.2±15.2	25.7±20.0	0.243
Nausea/vomiting	7.0±11.5	2.6±6.2	0.135
Pain	38.6±24.2	7.9±14.0	0.000
Dyspnea	14.0±20.2	8.8±15.1	0.187
Insomnia	21.1±25.4	5.3±12.5	0.008
Appetite	14.0±20.2	5.3±16.7	0.056
Constipation	12.3±22.8	15.8±17.1	0.494
Diarrhea	45.6±33.7	17.5±20.4	0.003
Financial difficulties	42.1±24.4	24.6±33.0	0.047

Values are presented as mean±standard deviation. QOL = quality of life.

gastrectomy over postoperative periods from 1 to 24 weeks to investigate postoperative changes according to the various time intervals.

Bradygastria (regular frequency, 0.5~2.0 cpm) is currently defined as values below the normal range (regular frequency, 2~4 cpm), whereas tachygastria (regular frequency, 4~9 cpm) is defined as values above the normal range.<sup>9,22,23</sup> Unfortunately, the normal



**Fig. 2.** Changes in mean quality of life score scales on the ST022 questionnaire during the postoperative period (~12 weeks). POD#1 = postoperative 1 week; POD#12 = postoperative 12 weeks.

**Table 4. Correlation between QOL questionnaires (QOL-C30 version 3.0 and ST022) and EGG parameters by postoperative period**

QOL	EGG parameters (P-value)									
	Postoperative 1 week					Postoperative 12 weeks				
	DF	DP	BR	NO	TA	DF	DP	BR	NO	TA
Global health status	0.44	0.40	0.59	0.91	0.38	0.95	0.61	0.88	0.62	0.55
Functional scales	0.13	0.04	0.01	0.13	0.39	0.63	0.18	0.46	0.40	0.35
Symptom scales	0.88	0.77	0.58	0.45	0.72	0.77	0.41	0.65	0.70	0.87
Fatigue	0.19	0.87	0.00	0.24	0.20	0.58	0.60	0.65	0.30	0.19
Nausea/vomiting	0.57	0.82	0.27	0.36	0.96	0.31	0.78	0.34	0.47	0.95
Pain	0.40	0.68	0.14	0.66	0.31	0.27	0.42	0.36	0.25	0.55
Dyspnea	0.05	0.63	0.12	0.18	0.98	0.84	0.72	0.59	0.27	0.33
Insomnia	0.70	0.22	0.07	0.01	0.10	0.76	0.28	0.04	0.05	0.18
Appetite	0.31	0.36	0.14	0.52	0.40	0.01	0.43	0.50	0.40	0.74
Constipation	0.30	0.99	0.78	0.39	0.27	0.58	0.13	0.17	0.68	0.99
Diarrhea	0.85	0.98	0.71	0.27	0.02	0.58	0.27	0.54	0.12	0.22
Financial difficulties	0.12	0.24	0.78	0.90	0.78	0.10	0.23	0.53	0.85	0.99
ST022	0.88	0.77	0.68	0.45	0.72	0.77	0.41	0.65	0.70	0.87

QOL = quality of life; EGG = electrogastrography; DF = dominant frequency; DP = dominant power; BR = bradygastria; NO = normogastria; TA = tachygastria.

range is very difficult to define due to variations in the recording system and a lack of standard analysis methods.<sup>24</sup> Moreover, the occurrence of tachygastria is influenced by electrode position and configuration.<sup>25</sup> However, the association between tachygastria and gastric motor disorders has been substantiated in other studies. For example, You et al.<sup>26</sup> observed tachygastria in a 26-year-old woman with persistent nausea, vomiting, and abdominal pain and severely impaired antral motor function. The correlation between bradygastria and gastric motility is not yet as clear. van der Schee and Grashuis<sup>27</sup> observed bradygastria in dogs and found that it was correlated with strong antral contractions.

In the present study, comparison of temporal changes in EGG parameters revealed no significant temporal differences for DF, DP, percentage of normal frequency, or percentage of tachygastria. However, it did reveal significant temporal differences in the percentage of bradygastria for postprandial recordings between 1 week and 3 months and between 1 week and 6 months but not between 3 months and 6 months. Unlike other studies that obtained a DF of ~3 cpm in the gastric remnant, Lee et al.<sup>18</sup> found that distal RSG patients had a lower DF value with an increased percentage of bradygastria (<2 cpm) irrespective of meal ingestion. Bracci et al.<sup>28</sup> observed the less common 3 cpm with an increased chance of bradygastria in children who underwent partial gastrectomy to augment bladder function. Although they lacked a clear definition of bradygastria, they suggested that this is the effect of the removal of stomach pacemaker cells.

Roux-en-Y reconstruction in previous gastrectomy patients also led to bradygastria, which was closely related to the time after surgery.<sup>29</sup> Hayashi et al.<sup>21</sup> pointed out that proximal subtotal gastrectomy subjects with more than half of the stomach resected had lower percentages of normal rhythm, DF, and even DP compared with those with greater stomach preservation. Lee et al.<sup>18</sup> suggested that removal of part of the main pacemaker in distal RSG patients leads to an increased percentage of bradygastria and that the ectopic pacemaker of the rest of the stomach in lower frequency values would replace the originally removed main pacemaker cells to dominate the gastric SW rhythm. Murakami et al.<sup>30</sup> reported that longer periods of normal gastric function (normogastria, 2.0~4.0 cycles min<sup>-1</sup>) were detected in channel 1 in the vagus nerve-preserving distal gastrectomy group (VP-DG) than in the standard distal gastrectomy without vagus nerve preservation group (DG) in either the fasted or fed state ( $P < 0.05$ ). The VP-DG group showed better preserved gastric myoelectric activity than the DG group.

Homma et al.<sup>19</sup> recognized serial 3 cpm peaks in the running spectra of EGGs recorded in patients who had undergone distal

gastrectomy 15 to 20 years previously and suggested that the reorganization of gastric pacemaker activity represents reorganization of the interstitial cells of Cajal in the remnant stomach of distally gastrectomized patients. According to the effect of the meal on EGG parameters during the early postoperative period, comparison of fasting to postprandial recordings revealed significant decreases in the percentage of bradygastria and increases in the percentage of tachygastria. According to time intervals, there was a significant decrease in the percentage of bradygastria in fasting and postprandial recordings between 1 and 12 weeks and between 1 and 24 weeks. The percentage of normal frequency was increased in the postprandial recording between 1 and 24 weeks. These results suggest that the decreased percentage of bradygastria and the increased percentage of tachygastria indicate a change in EGG parameters that represents reorganization of the interstitial cells of Cajal in the remnant stomach of distally gastrectomized patients.

In conclusion, these findings suggest that EGG may be a noninvasive method for evaluating the motility and autonomic functions of the remnant stomach after distal gastrectomy. However, the present study has shortcomings including its lack of a control group and preoperative baseline EGGs and its small number of patients.

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