

The effects of stress during the mirror drawing test on electrogastrograms of subjects who underwent gastrointestinal surgery involving either total gastrectomy, distal gastrectomy, or total esophagectomy with colonic replacement

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Abstract

Electrogastrograms (EGGs) were recorded from 16 locations on the thoraco-abdominal surface to find the maximum absolute power foci during rest (RAP) and the maximum ratio of the % content during the mirror drawing test (MDT) compared to that during rest (%C-MDT/R) for both the 3 cpm (2.4–4.9) and 6 cpm (5.0–7.4) groups. The maximum foci were obtained from control subjects and those who received gastrointestinal surgery via total gastrectomy (TG), distal gastrectomy (DG), and total esophagectomy with colonic replacement (CR). The control mean of the infraumbilical channels 10–16 (I) expressed as %C-MDT/R of the 3 cpm group was higher than the mean of the supraumbilical channels 1–9 (S) ($I > S$, $P < 0.001$). The maximum focus of the 3-cpm %C-MDT/R was in the left umbilical area, while that of the 6-cpm %C-MDT/R was found bilaterally in the right epigastric and left umbilical areas, interposed by the lower %C-MDT/R gastric area. Therefore, the presence of gastric EGG inhibition and colonic facilitation are suggested to occur during MDT. In TG and DG, the foci of the %C-MDT/R in the 3-cpm group were located bilaterally in the right epigastric and left umbilical areas. The shifts of foci suggest colonic EGG facilitation. The mean S of the 3-cpm group was significantly higher than the mean I with CR ($S > I$, $P < 0.05$). The maximum foci of the 3- and 6-cpm groups were in the epigastrium. These results suggest colonic EGG facilitation in the epigastrium, as the stomach has been removed and the original gastric location is instead occupied by the transverse colon in CR.

Key words: electrogastrogram (EGG), mirror drawing test (MDT), gastrointestinal surgery, topographic EGG map

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Introduction

Various stressors are known to affect gastrointestinal motility (1, 2). In particular, stress inhibits gastric motility and facilitates colonic motility, via corticotropin releasing factor (CRF) (3, 4). We have previously demonstrated gastric inhibition and colonic facilitation with topographic electrogastrographic maps in normal subjects (5). Therefore, we examined whether or not it was possible to demonstrate colonic facilitation during acute stress with the mirror drawing test (MDT) even in subjects who had undergone gastrointestinal surgery of total gastrectomy (TG), distal gastrectomy (DG) or total esophagectomy with colonic replacement (CR) using electrogastrograms (EGG) and topographic EGG maps. In addition, we examined cases of total colectomy (TC) with an ileal W-pouch using similar methods.

Subjects and Methods

This project was conducted with the approval of the ethics committee of the Niigata University, Faculty of Medicine (project no. 179). Written informed consent was obtained from all volunteers. The ages of the 58 normal control subjects ranged from 20–38 years old. Data from the operated group in this study were obtained from volunteer outpatients after either TG, TC, DG, or CR at the Niigata Medical and Dental Hospital (6). The ages and time since surgery ranged widely in the patients, depending on the type of surgery: TG due to gastric cancer (67.6 ± 11.8 years old, 63.0 ± 67.0 postoperative months [POM], $n=9$), TC due to ulcerative colitis (39 ± 13 years old, 43.3 ± 29.3 POM, $n=10$), DG due to gastric cancer (Birlloth I, 72 ± 33 years old, 115 ± 31.7 POM, $n=12$), and CR due to esophageal and gastric cancer (66.2 ± 43 years old, 64.0 ± 33.7 POM, $n=5$).

The methods for recording and analyzing EGGs, and making topographical EGG maps were the same as those employed in previous studies (5–8). In brief, unipolar EGGs were recorded at 16 locations (channels) on the thoraco-abdominal skin surface, using reference electrodes on the right leg (Fig. 1). These 16 locations have been cited in previous papers (5–7). The amplifier was a modified electroencephalograph (EEG) amplifier (time constant = 5 sec, high cut = 0.5 Hz and -12 dB/oct, low cut = -6 dB/oct: Biotop 6R 12–4, NEC-Sanei, Japan). After cleaning the skin with ethanol, electrode cream was applied to 11 mm disc electrodes to obtain an EEG. The electrodes were fixed to the skin with surgical tape. Resting EGGs were recorded for about 20 min in fasted subjects with EGG samples obtained every 128 sec (1 file). After recording the resting control data, subjects were exposed to the acute stress of the MDT. The MDT involves using an electric pen to trace the cut image of a metal star reflected on to a mirror. The pen gives a click alarm whenever an error is made when the tracing runs off the edge of the star. Some subjects claimed they needed to stop the MDT due to the strong stress and difficulty of the MDT. A MDT trial usually takes 1 min and induces enough response in both the EGG and heart rate (7). Therefore, a 5 min MDT trial was considered to be sufficient to provide 2–3 files. Approximately 10 min after finishing the MDT test, a further 20 min of EGG recording (about 7 files) was collected to obtain a post-MDT spectrum. The stress effects on EGG and heart rate recovered after MDT within several min.

The ensemble means and piled running spectra were obtained after the analysis of the files using the maximal entropy method (MEM), and the spectral peaks of the spectral absolute power were determined (8). The spectral recordings were classified into 5 groups: the 1-cpm (0–2.4 cpm), 3-cpm (2.5–4.9 cpm), 6-cpm (5.0–7.4 cpm), 8-cpm (7.5–9.9 cpm) and 10-cpm (10.0–12.9 cpm). Examples of piled running spectra during rest and MDT were shown in a previous paper (7). The original raw EGG waves, and analyzed power spectral waves in the piled manner, both during rest, during the MDT, and in the post-MDT state were also shown in a previous paper including control and surgical groups of TG, TC, DG, and CR (5–7). The % at rest of a certain

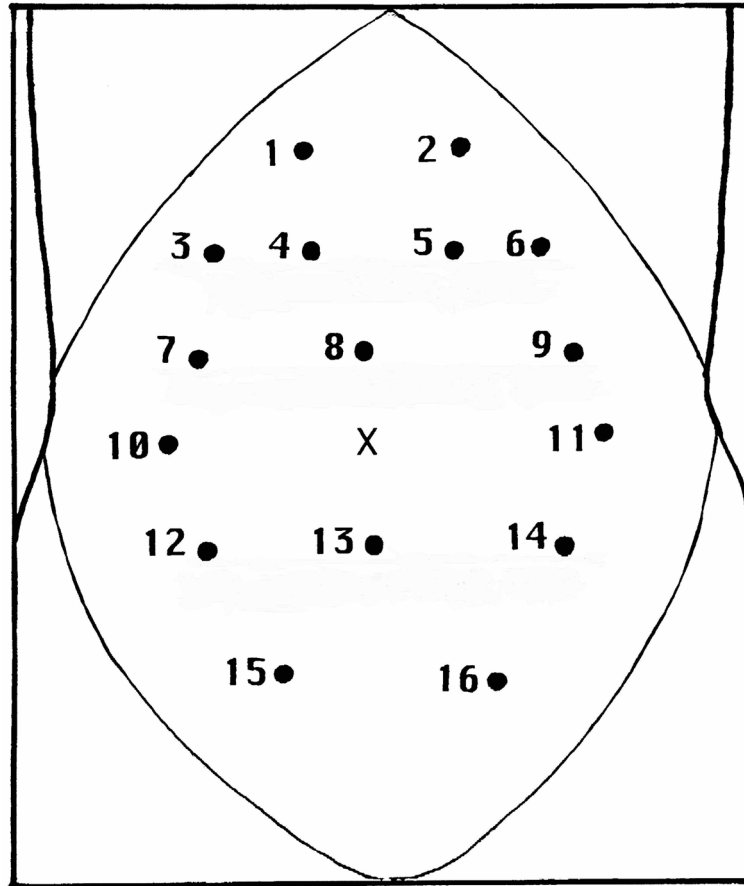


Fig. 1. Schematic location of 16 EGG electrodes (filled circles) on the body surface based on the xiphoid process, costal arch, and iliac line. X indicates the navel. The filled circles indicate the average location of each electrode. The Xmax was 27 cm and Ymax was 32 cm in this study.

frequency group was defined as the power area of a certain frequency group/total area of the spectrum, i.e., the area encircled by a spectrum envelope line and abscissa. The ratio of the % content during the MDT to the resting % content of a certain frequency is expressed as the %C-MDT/R. For numerical comparisons, channels 1–9 were defined as the supraumbilical channels, and channels 10–16 the infraumbilical channels (Table 3). In addition, as in the previous paper (5), the probable gastric channels of 5 and 8 were compared with the probable colonic channels from 10–16 (Tables 1 and 2).

To create the topographic EGG maps, the electrode positions were expressed by two dimensional standard coordinates, (X_i and Y_i), and the RAP and %C-MDT/R at a certain electrode was expressed as $Z_i = (X_i, Y_i)$. X_i and Y_i were usually 27–36 cm, with $X_{max}=27$ cm, and $Y_{max}=32$ cm in this study. The contour map program (9) was then applied, and topographic EGG maps were drawn for RAP and the % C-MDT/R.

Mapping the % C-MDT/R showed the MDT effect much more clearly on the topographic EGG map than mapping of the absolute power (AP) during the MDT (5). It is generally accepted that the main EGG activity is 3 cpm (10–12). The EGG activity of 3–6 cpm EGG mainly in the infraumbilical area reflects the colonic myoelectric activity of the EGG (8, 13–15). Therefore, the maps of the 3- and 6-cpm groups are shown in this study (Fig. 2). The mean and standard errors (SE) were calculated, and the Student's *t*-test was used to determine the statistical significance. *P* values below 0.05 were considered to be significant.

Table 1. %C-MDT/R (mean \pm SE) in 3-cpm group (2.4–4.9 cpm)

	C	TG	TC	DG	CR
ch5	0.90 \pm 0.054 (a)	0.98 \pm 0.11	0.99 \pm 0.085	1.01 \pm 0.19	1.49 \pm 0.27
ch8	1.01 \pm 0.066 (b)	1.02 \pm 0.18	1.25 \pm 0.15 (j)	1.09 \pm 0.14	2.20 \pm 1.14
ch10	1.11 \pm 0.071 (c)	0.93 \pm 0.07	1.15 \pm 0.19	0.96 \pm 0.16	0.95 \pm 0.11
ch11	1.36 \pm 0.14 (d)	1.03 \pm 0.18	0.95 \pm 0.13	1.32 \pm 0.19	1.25 \pm 0.19
ch12	1.22 \pm 0.09 (e)	1.04 \pm 0.09	1.00 \pm 0.17	1.16 \pm 0.14	1.26 \pm 0.37
ch13	1.21 \pm 0.074 (f)	1.04 \pm 0.20	1.10 \pm 0.14 (k)	0.99 \pm 0.13	0.90 \pm 0.12
ch14	1.30 \pm 0.12 (g)	1.02 \pm 0.14	1.09 \pm 0.076	1.24 \pm 0.12	1.35 \pm 0.20
ch15	1.17 \pm 0.076 (h)	0.95 \pm 0.12	1.13 \pm 0.11	0.81 \pm 0.10	1.23 \pm 0.24
ch16	1.19 \pm 0.092 (i)	0.79 \pm 0.09	1.10 \pm 0.12	1.05 \pm 0.12	1.35 \pm 0.15

C, control; TG, total gastrectomy; TC, total colectomy; DG, distal gastrectomy; CR, total esophagectomy with colonic replacement. Channels 1-9 were defined as S (supraumbilical) and channels 10-16 as I (infraumbilical). For the control channels, the infraumbilical MDT responses were significantly higher than the epigastric (ch. 5 and 8) MDT ones ($C_i > C_s$); $P < 0.05$ between a-i, b-e, $P < 0.01$ between a-d, a-f, a-g, a-h. For the TC (total colectomy) channels, the infraumbilical MDT response was lower than that of the epigastric ones; $P < 0.05$ between j-k.

Table 2. %C-MDT/R (mean \pm SE) in 6-cpm group (5.0–7.4 cpm)

	C	TG	TC	DG	CR
ch5	0.89 \pm 0.060	0.79 \pm 0.10	1.02 \pm 0.17	1.27 \pm 0.27	2.56 \pm 0.94
ch8	1.08 \pm 0.10	0.98 \pm 0.19	0.97 \pm 0.11	1.15 \pm 0.24	1.10 \pm 0.31
ch10	1.04 \pm 0.089	0.81 \pm 0.16	1.11 \pm 0.13	1.21 \pm 0.29	0.65 \pm 0.08
ch11	1.03 \pm 0.091	0.79 \pm 0.15	1.08 \pm 0.13	1.06 \pm 0.22	0.89 \pm 0.18
ch12	0.9 \pm 0.074	0.91 \pm 0.12	1.02 \pm 0.10	1.24 \pm 0.31	1.11 \pm 0.35
ch13	1.03 \pm 0.084	1.38 \pm 0.39	0.99 \pm 0.16	1.35 \pm 0.44	0.88 \pm 0.09
ch14	0.99 \pm 0.081	1.02 \pm 0.16	0.96 \pm 0.12	1.15 \pm 0.27	1.20 \pm 0.25
ch15	1.04 \pm 0.073	0.79 \pm 0.09	1.20 \pm 0.14	1.00 \pm 0.18	1.05 \pm 0.28
ch16	1.04 \pm 0.077	0.85 \pm 0.12	1.10 \pm 0.16	1.07 \pm 0.24	1.25 \pm 0.16

In control and operated subjects, the MDT infraumbilical 6-cpm responses were not significantly higher than the MDT the epigastric 6-cpm responses.

Table 3. Comparison of %C-MDT/R (mean \pm SE) between S and I

	Control	TG	TC	DG	CR
3 cpm, S	1.0 \pm 0.09	1.0 \pm 0.017	1.2 \pm 0.067	1.10 \pm 0.027	1.70 \pm 0.11
3 cpm, I	1.2 \pm 0.03	0.97 \pm 0.032	1.1 \pm 0.025	1.07 \pm 0.06	1.18 \pm 0.064
S/I	I > S, $P < 0.001$	NS	NS	NS	S > I, $P < 0.05$
6 cpm, S	1.0 \pm 0.04	0.87 \pm 0.037	0.99 \pm 0.035	1.27 \pm 0.15	1.30 \pm 0.15
6 cpm, I	1.0 \pm 0.011	0.93 \pm 0.071	1.1 \pm 0.028	1.15 \pm 0.10	1.00 \pm 0.071
S/I	NS	NS	NS	NS	NS

S, supraumbilical channels (ch. 1-9); I, infraumbilical channels (ch. 10-16).

Results and Discussion

1. A comparison of the %C-MDT/R values between supraumbilical region of channels 1–9 (S) and the infraumbilical channels 10–16 (I)

In control subjects during the MDT, the infraumbilical %C-MDT/R of the 3 cpm was significantly higher than the supraumbilical %C-MDT/R ($P < 0.05$ –0.01) (Table 1), and the mean infraumbilical %C-MDT/R (I) is

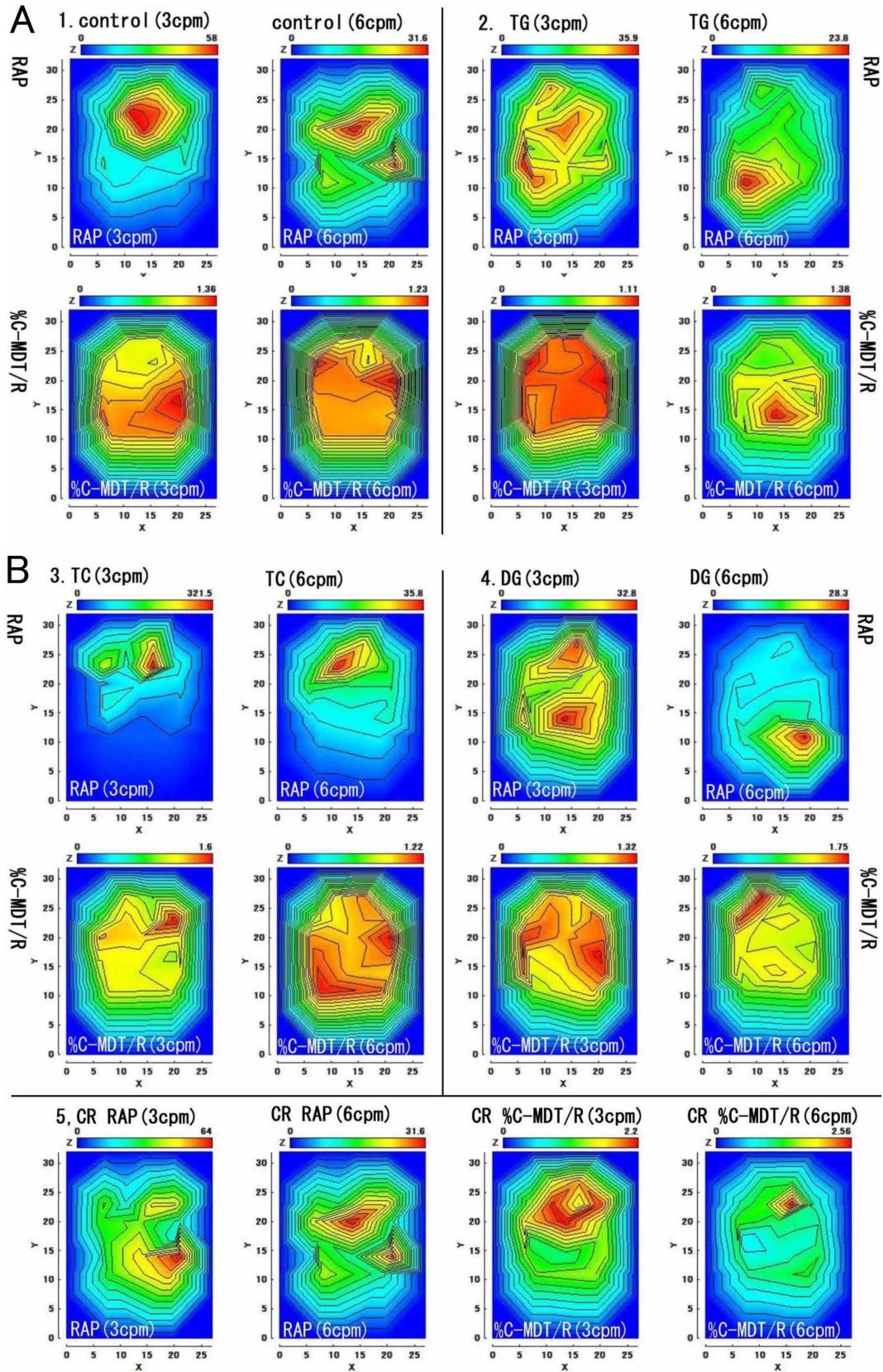


Fig. 2. Topographic electrogastrographic maps of controls subjects [1] and of subjects who received total gastrectomy (TG) [2] in A and those of subjects who received total colectomy (TC) [3], distal gastrectomy (DG) [4] and total esophagectomy plus colonic replacement (CR) [5] in B.

significantly higher than the mean supraumbilical one ($I>S$, $P<0.001$) (Table 3), suggesting colonic facilitation and gastric inhibition during the MDT as reported previously (5). These differences were not found in the 6-cpm group (Table 2), or in the subjects who had undergone TG, TC, or DG. However, in those who had CR, the supraumbilical mean %C-MDT/R of the 3 cpm (S) was significantly higher than the mean infraumbilical %C-MDT/R (I) ($S>I$), $P<0.05$) (Table 3). The original stomach space is replaced by the transverse colon in CR, so colonic facilitation may be exaggerated in the supraumbilical area. In addition, the supraumbilical replaced colon seems to have been more facilitated than the infraumbilical colonic loop, and the former may be closer to the skin surface than the latter, as the latter is formed by anastomosing the ascending and descending colon after removing the transverse colon.

2. A comparison of the %C-MDT/R of epigastric channels 5 and 8 with that of infraumbilical channels 10–16 of the 3- and 6-cpm groups

The infraumbilical %C-MDT/R of channels 10–16 in the 3-cpm group was significantly higher than the supraumbilical 3-cpm %C-MDT/R of channels 5 or 8 in control subjects ($P<0.05$ – 0.01) (Table 1), suggesting colonic facilitation and gastric inhibition, as reported previously (5). This finding was not noted in the control 6-cpm group (Table 2), nor in the subjects following TG, DG, or CR in the 3-cpm or 6-cpm groups (Table 2, 3). However, the topographic EGG maps of %C-MDT/R suggest colonic facilitation (section 3). Furthermore, in subjects following TC ($n=10$), the %C-MDT/R of epigastric channel 8 was significantly higher than that of the infraumbilical channel 13 ($P<0.05$), in contrast to the findings in the control subjects ($n=58$) (Table 1). The reason for this and the mechanism underlying this finding is puzzling. However, the mean supraumbilical %C-MDT/R of the 3-cpm group was not significantly higher than the mean infraumbilical %C-MDT/R (Table 3). Table 2 shows that no significant differences were noted between supraumbilical channels 5 or 8 and infraumbilical channels 10–16 in the 6-cpm group.

3. A comparison of the location of the maximum power foci by topographic EGG maps of the mean RAP and %C-MDT/R of normal controls and operated subjects

In control subjects, the maximum RAP focus of the 3-cpm group was located in the central epigastrium. The maximal focus of the control %C-MDT/R shifted to the left umbilical area during the MDT. The maximum RAP focus of the 6-cpm group was in central umbilical area and shifted to right and left epigastric areas, suggesting right and left colonic flexure, interposed by the lower %C-MDT/R area during the MDT (Fig. 1). These changes in the maximum RAP and %C-MDT/R foci during the MDT in both the 3- and 6-cpm groups seems to indicate colonic facilitation. As described in section 1, the infraumbilical %C-MDT/R was significantly higher than the supraumbilical %C-MDT/R (Table 1), and the mean infraumbilical %C-MDT/R (I) was significantly higher than the mean supraumbilical %C-MDT/R (S) in the 3-cpm group ($I>S$, $P<0.001$, Table 3), supporting these mapping results.

For subjects who had undergone TG, the maximal RAP focus of the 3 cpm group at the right infraumbilical area shifted to the right epigastric and left umbilical areas of %C-MDT/R during the MDT, as in the control 6-cpm group, interposed by the lower %C-MDT/R area. The maximum RAP focus in subjects who underwent TG in the 6 cpm group at the right infraumbilical area shifted to the central infraumbilical area of %C-MDT/R. These shifting foci during the MDT seems to indicate colonic facilitation.

The maximum RAP foci in subjects who underwent DG in the 3-cpm at the central epigastrium and infraumbilical areas shifted to the right umbilical and left infraumbilical areas of %C-MDT/R during the MDT, as in the control 6-cpm group and TG 3-cpm group, interposed by an epigastric focus of a lower %C-MDT/R

area. These foci may be indicating the colonic facilitation as in control subjects and TG subjects. The DG 6-cpm maximum focus in the left infraumbilical area shifted to the right epigastrium during the MDT. The maximum focus of %C-MDT/R in the 6-cpm group at the right epigastrium may suggest colonic facilitation near the right colonic flexure.

The maximum RAP focus in subjects who underwent CR in the 3-cpm group at the left infraumbilical area shifted slightly to the right epigastric area during the MDT of %C-MDT/R. The maximum RAP foci and %C-MDT/R of the 6-cpm group at the central epigastrium are found at closely similar locations. The stomach is replaced by the transverse colon in CR, so the stomach is entirely absent. It is therefore quite reasonable that the MDT stress facilitated the colon. The activity of the replaced transverse colon in the epigastrium in the 3-cpm group seems to have been more facilitated during the MDT than the infraumbilical remaining anastomosed colon, and the replaced transverse colon may be closer to the skin surface than the remaining anastomosed colon in the pelvic cavity.

The maximum RAP focus in subjects who underwent TC in the 3- and 6-cpm groups at the central epigastrium shifted to the left epigastrium in the 3-cpm group and to the left umbilical and right infraumbilical areas in the 6-cpm group during the MDT. The maximum focus in the 6-cpm group at the right infraumbilical area during the MDT did not originate from the colon, as the complete removal of the colon in the case of TC. The ileal W-pouch intraluminal pressure and myoelectric activity of EGG recorded from the parasacral region of the perineal surface was about 6–7 cpm (16). Therefore, the maximum %C-MDT/R focus in the 6-cpm group at the right lower infraumbilical area may be derived from the ileal-W pouch.

The intact colon in controls, and those who underwent TG and DG seems to have been facilitated by MDT stress. The replaced colon in CR may also be facilitated by MDT stress. The replaced colon in CR may also be facilitated by MDT stress, as the %C-MDT/R is over 1, indicating real motility facilitation. The EGG gastric inhibition and colonic facilitation is also basically found in subjects who received gastrointestinal surgery of TG, TC, DG and CR as in normal controls. It is speculated that CRF is also involved in this gastric inhibition and colonic facilitation in subjects of gastrointestinal surgery.

Conflict of interest

The author does not have any financial relationship with the organization that sponsored the research.

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