

## Correlations between anxiety and the stress responses of electrogastrography (EGG) induced by the mirror drawing test (MDT)

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### Abstract

Electrogastrograms (EGGs) were recorded at 16 locations on the thoraco-abdominal surface at rest and then both during and after the acute stress of performing the mirror drawing test (MDT). A significant linear correlation with a negative slope was found between the anxiety scores and the ratio of the power content during MDT to the power content at rest ( $r$ ) ( $MDTr^{-1}$ ) of the 3 cpm component from the epigastric channel 2 recording. In contrast, significant linear correlations with positive slopes were found between the anxiety scores and  $MDTr^{-1}$  of the 6 cpm component of the recordings from the infraumbilical channels (channels 13, 15, and 16). The epigastric 3-cpm EGG activity reflects gastric myoelectric activity, while the infraumbilical 3- and 6-cpm activity reflects that of the colon. Therefore, these results seem to further support the previous report of the inhibition of gastric EGG by stress and the stress-mediated facilitation of colonic EGG (Homma S, J Smooth Muscle Res. 2012; 48(2–3): 47–57).

**Key words:** electrogastrography (EGG), stress, anxiety, mirror drawing test (MDT), absolute power, power content

### Introduction

The facilitation or inhibition of gastrointestinal motility due to stress has been previously reported (1, 2). As gastrointestinal motility is partially reflected by EGG activity (3, 4), the effects of stress on the epigastric, supraumbilical and infraumbilical EGG data can be correlated with anxiety scores. Our previous study demonstrated that the local differences in the power content during 16-location EGG were more clearly shown at rest, during the postprandial state and during the mirror drawing test (MDT) (5). Furthermore, we demonstrated the epigastric EGG inhibition (seen in 3 cpm activity) and infraumbilical EGG facilitation (seen in 6 cpm activity)

**Table 1.** The EGG power content ratio of electrode locations

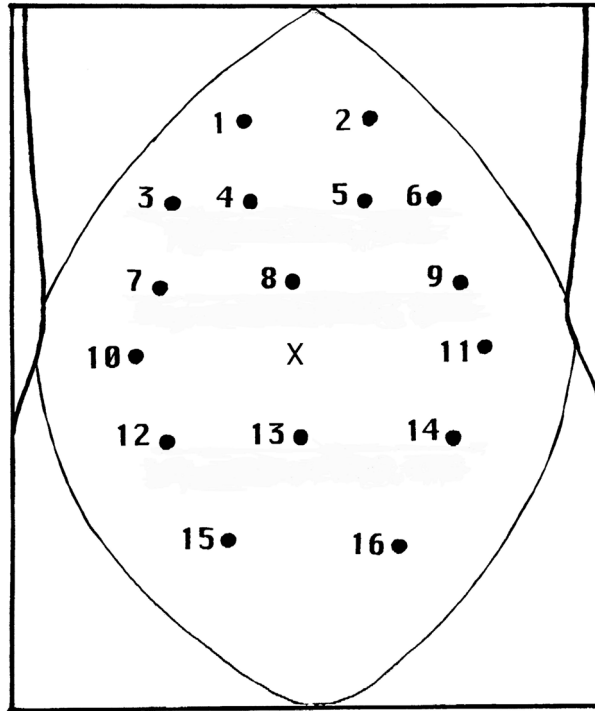
	1 cpm (0–2.4)	3 cpm (2.5–4.9)	6 cpm (5.0–7.4)	8 cpm (7.5–9.9)	10 cpm (10.0–12.9)
ch.2	2.17 ± .58	0.95 ± .59	0.52 ± .077 <sub>13</sub>	0.86 ± .064	0.86 ± .12
ch.5	1.95 ± .26 <sub>1</sub>	0.90 ± .054 <sub>4</sub>	0.89 ± .060 <sub>14</sub>	0.96 ± .089	0.84 ± .10
ch.8	1.71 ± .16	1.01 ± .066 <sub>12</sub>	1.08 ± .10 <sub>15</sub>	0.84 ± .073	0.83 ± .096
ch.10	1.76 ± .18	1.11 ± .071 <sub>5</sub>	1.04 ± .089 <sub>16</sub>	0.85 ± .078	0.76 ± .088
ch.11	1.59 ± .14	1.36 ± .14 <sub>6</sub>	1.03 ± .091 <sub>17</sub>	0.84 ± .091	0.64 ± .079
ch.12	1.64 ± .17	1.22 ± .090 <sub>7</sub>	0.96 ± .074 <sub>18</sub>	0.82 ± .088	0.67 ± .096
ch.13	1.63 ± .19	1.21 ± .074 <sub>8</sub>	1.03 ± .084 <sub>19</sub>	0.74 ± .076	0.66 ± .081
ch.14	1.48 ± .13	1.30 ± .109	0.99 ± .081 <sub>20</sub>	0.84 ± .12	1.28 ± .57
ch.15	1.32 ± .11 <sub>2</sub>	1.17 ± .076 <sub>10</sub>	1.04 ± .073 <sub>10</sub>	0.87 ± .10	0.79 ± .11
ch.16	1.34 ± .11 <sub>3</sub>	1.19 ± .092 <sub>11</sub>	1.04 ± .077 <sub>22</sub>	0.81 ± .073	0.69 ± .070

The effect of the MDT on the power content ratio (MDTr<sup>-1</sup>, *n*=52–58, means ± S.E.M.). Small number by the S.E.M., 1–2, 1–3, 4–5, 4–11, and 6–12, *P*<0.05. 4–6, 4–7, 4–8, 4–9, 4–10, and 13–14, *P*<0.01. 13–15, 13–16, 13–17, 13–18, 13–19, 13–20, 13–21, and 13–22, *P*<0.001. Channels 2, 5, 8 are epigastric and channels 10–16 are infraumbilical.

during MDT stress in a numerical comparison of the power content ratio of the MDTr<sup>-1</sup> and topographic EGG mapping of MDTr<sup>-1</sup> (power content during MDT/power content at rest) (6). Therefore, in the present study, we compared the effects of MDT-related stress on each of the 16 locations of EGG using the power content ratio of the MDTr<sup>-1</sup> to clarify the correlation between stress and EGG, which partially reflects gastrointestinal motility (3, 4, 6).

## Methods

This project was conducted under the approval of the ethics committee of Niigata University, Faculty of Medicine (project no. 179). Informed consent was obtained from all of the subjects after explanation about the informed consent immediately prior to the EGG recording. Data were obtained from healthy student volunteers. There were 58 subjects, (52 males and six females), with 23 of the subjects ranging in age from 20–38 years (23.1 ± 1.0, *n*=23), while the age of other 35 subjects was not known. The methods used for recording and analyzing EGGs were the same as those used in the previous studies (7, 8). Briefly, unipolar EGGs were recorded from 16 locations (channels, ch) from the thoraco-abdominal skin surface (Fig. 1), using a reference electrode on the right leg. The amplifier was a modified electroencephalographic (EEG) amplifier, with time constant set at 5 sec, with a high cut at 0.5 Hz, a low cut of –6 dBOct<sup>-1</sup> and a high cut of –12 dBOct<sup>-1</sup>, (Biotop 6R 12-4, NEC-Sanei, Japan). After cleaning the skin with ethanol, electrode cream was applied to the disc electrode for the EEG (diameter=11 mm). The electrodes were fixed on the skin with surgical tape. Resting EGGs were recorded for about 20 min, in subjects who had fasted for at least eight hours, and were sampled every 128 sec (1 file). After recording the resting control data, subjects were exposed to the stress of the MDT. The MDT involves tracing the cue figure of a metal star, reflected onto a mirror with an electric pen, which gives a click alarm when the tracing runs off the edge of the star (error). The MDT stress was applied for about 5 min to obtain 2–3 EGG files. Compiled running spectra were obtained after the files were analyzed using the maximal entropy method (MEM). The spectral frequency readings were classified into five groups: the 1-cpm group (0–2.4 cpm), 3-cpm group (2.5–4.9 cpm), 6-cpm group (5.0–7.4 cpm), 8-cpm group (7.5–9.9 cpm) and 10-cpm group (10.0–12.9 cpm). Ensemble means were obtained during rest, during the stress of the MDT, and after the MDT. With regard to the EGG parameters, this study focused on the power content ratio of MDTr<sup>-1</sup> for each channel. Table 1 lists the figures for the epigastric 2, 5 and 8 channels and the infraumbilical 12–16



**Fig. 1.** Location of the electrodes. Superimposed images of the body and the location of the 16 electrodes on the thoraco-abdominal body surface based on the xiphoid process, costal arch, and iliac line. X indicates the navel. The numbers (1–16) by the filled circles indicate the roughly averaged location of the electrodes. The length of  $X_0 \sim X_{\max}$  was assumed to be 32 cm, and that of  $Y_0 \sim Y_{\max}$  36 cm based on the superimposed body lines (5).  
(Reproduced from Homma S. *J Smooth Muscle Res.* 2012; 48(2–3): 47–57) (6).

channels found in our previous studies for simplicity (5, 6). The anxiety scores were estimated using the HADS (hospital anxiety and depression scales) (9, 10). The electrode positions were represented by two-dimensional standard coordinates,  $X_i$  and  $Y_i$ , and a spectral peak at a certain electrode position was expressed as  $Z_i = (X_i, Y_i)$  (7, 8, 11, 12).

The mean and standard errors (SEM) were calculated, and the Student's *t* test was used to determine the level of statistical significance. The simple linear regression line analysis was performed by a software Stat View. *P* values < 0.05 were considered to be significant.

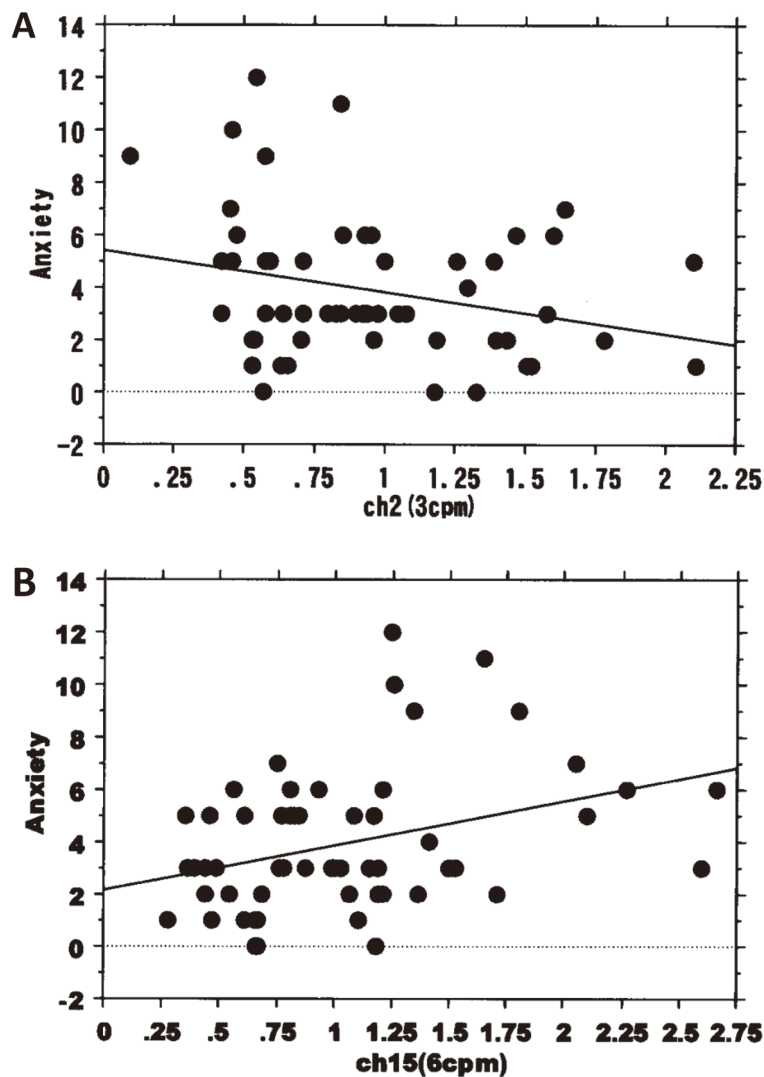
## Results

The epigastric (ch.2, 5 and 8) and infraumbilical (ch.12–16) power content ratio of the  $MDTr^{-1}$  of five spectral frequencies in addition to umbilical channels 10 and 11 are shown in Table 1. The power content ratio of  $MDTr^{-1}$  of 3- and 6 cpm in the epigastric channels was generally, significantly lower than that of the infra-umbilical channels. The significant linear correlations ( $P < 0.05$ ) between the anxiety scores and power content ratio of  $MDTr^{-1}$  are shown in Table 2 and Fig. 2A and B. The slope of the ch.2 correlation (3 cpm) was negative (Fig. 2A) and the slopes of ch.10, 11, 13, 15, and 16 (6 cpm) were positive (Fig. 2B).

**Table 2.** The linear correlation parameters

	$\alpha$	$P$	$r^2$
ch.2 (3 cpm)	-1.61	0.046	0.071
ch.10 (6 cpm)	1.31	0.013	0.11
ch.11 (6 cpm)	1.11	0.033	0.080
ch.13 (6 cpm)	1.18	0.037	0.077
ch.15 (6 cpm)	1.71	0.008	0.123
ch.16 (6 cpm)	1.28	0.038	0.076

Tabulation of the the significant linear correlation parameters ( $P < 0.05$ ) between the anxiety scores and the power content ratio of the MDT to that at rest ( $MDTr^{-1}$ ).



**Fig. 2.** A: The correlation between the anxiety scores and the EGG power content ratio of 3 cpm. The linear correlation between the anxiety scores (Y axis) and the power content ratio ( $MDTr^{-1}$ ) of 3 cpm of epigastric channel 2 (X-axis). Slope ( $\alpha$ ) = 1.61,  $P = 0.046$ , and  $r^2 = 0.071$ . B: The correlation between anxiety scores and the EGG power content ratio of 6 cpm. The linear correlation between anxiety scores (Y-axis) and the power content ratio ( $MDTr^{-1}$ ) of 6 cpm of infraumbilical channel 15 (X-axis). Slope = 1.71,  $P = 0.008$ , and  $r^2 = 0.123$ .

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## Discussion

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It is well known that EGG records gastrointestinal electrical activity or myoelectric activity, which reflects some of the motility as power content (3, 4). The power content ratio or the normalization of EGG change,  $MDTr^{-1}$  (power content during MDT/power content at rest) reflects the real change of the local EGG for each electrode as demonstrated in topographic EGG maps (6).

It is also well known that stress influences the gastric and colonic activity measured with EGG. In fact, stress induces dual excitatory and inhibitory effects that can be observed with EGG. Cold pressor test stress, interviews and performing arithmetic calculations increased the colonic EGG (13). Electric shock significantly decreased the percentage of the 3 cpm frequency and tachyarrhythmia (%) component of the EGG, but forehead cooling increased the percentage of the 3 cpm frequency (14). The induction of similar gastric inhibition or facilitation by stress has been reported using manometry (14, 15, 16, 17). We have previously reported the effects of the acute stress of MDT on the gastric and colonic facilitation or inhibition with EGG. However, MDT stress did not appear to exert effects on the intestinal EGG activity (6, 8, 12).

It is generally accepted that the normal gastric spectral activity of EGG is 3 cpm (3, 18, 19). However, the gastric and colonic EGG activity includes both 3- and 6- cpm EGG activity according to gastrectomy and colectomy studies (7, 20, 21, 22, 23, 24). Therefore, the infraumbilical 6 cpm EGG activity in this study is considered to reflect the colonic myoelectric activity.

Both colonic facilitation and inhibition were suggested by maximal power foci with topographic EGG maps (8). However, the finding of a significantly higher power ratio of the  $MDTr^{-1}$  of the infraumbilical 3 cpm than that in the epigastric recording during MDT suggested that the MDT stress inhibited gastric EGG and facilitated colonic EGG. In addition, topographic EGG maps drawn according to the power content ratio of the  $MDTr^{-1}$  and the absolute power ratio of  $MDTr^{-1}$  supported this idea (6). Similar findings of colonic facilitation have been reported with manometry (13, 25, 26, 27, 28, 29). MDT-related stress significantly increased bowel evacuation frequency, while it is known that depressed patients tend to be constipated (30).

Anxiety has also been reported to facilitate antral meal retention (31). This report suggests that anxiety induces gastric inhibition. In accord with this report, a linear correlation with a negative slope was found between the anxiety scores and the  $MDTr^{-1}$  of 3 cpm EGG of channel 2 in this study (Table 2, Fig. 2A). In a previous study, the correlation between the anxiety scores and the 3 cpm  $MDTr^{-1}$  was not calculated in channel 2 (ch2) alone, and the mean of  $MDTr^{-1}$  for channels 3, 4, 5, and 6 channels was defined as the epigastric CH1 (8, 12). A significant linear correlation was not found between the anxiety scores and the 3 cpm of CH1  $MDTr^{-1}$  (12). A significant linear correlation with a positive slope was also found in the  $MDTr^{-1}$  of 6 cpm of umbilical channels 10 and 11 (Table 2). Similarly, the infraumbilical CH3 was calculated using the mean of channels 12, 13, and 14 (12). However, a linear correlation with a positive slope was found between the anxiety scores and infraumbilical 6 cpm of CH3  $MDTr^{-1}$  6 cpm (12) and channel 13 (one of the CH3 substituents) in this study in addition to channel 15 (Fig. 2B) and channel 16 (Table 2). A significant linear correlation with a positive slope was also found in the  $MDTr^{-1}$  of 6 cpm of umbilical channels 10 and 11 (Table 2). The locations of channels 10 and 11 may correspond to the right and left flexure of the colon. The umbilical 6-cpm EGG activity might therefore reflect the colonic activity.

It has been suggested that various stressors depress stomach contractility and emptying, and facilitate colonic motility, transit and defecation through the limbic, hypothalamic and autonomic nervous system via RF-R2 (corticotrophin-releasing factor receptor and CRF-R1, respectively (32, 33, 34, 35). Our EGG findings in human subjects provide further supports for these studies (6).

Finally, the present results further support the idea that MDT stress inhibits stomach motility and facilitates colonic motility. Therefore, the MDT appears to induce anxiety.

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### Conflict of interest

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

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