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

Shinji Homma

Division of Organ Physiology, Department of Regenerative and Transplant Medicine, Institute of Medicine and Dentistry, Niigata University, Academic Assembly, Japan

Submitted December 2, 2013; accepted in final form January 14, 2014

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 \((r)\) 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 \(MDT^r\) 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)
during MDT stress in a numerical comparison of the power content ratio of the MDTr–1 and topographic EGG mapping of MDTr–1 (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–1 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–1 and a high cut of –12 dBoct–1, (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–1 for each channel. Table 1 lists the figures for the epigastric 2, 5 and 8 channels and the infraumbilical 10–16.
Anxiety and electrogastrography

---

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 infraumbilical 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

| Channel  | Slope (α) | P     | r²     |
|----------|-----------|-------|--------|
| 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 (α) = 1.61, P = 0.046, and r² = 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 r² = 0.123.
Discussion

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, $\text{MDTr}^{-1}$ (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 $\text{MDTr}^{-1}$ 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 $\text{MDTr}^{-1}$ and the absolute power ratio of $\text{MDTr}^{-1}$ 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 $\text{MDTr}^{-1}$ 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 $\text{MDTr}^{-1}$ was not calculated in channel 2 (ch2) alone, and the mean of $\text{MDTr}^{-1}$ 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 $\text{MDTr}^{-1}$ (12). A significant linear correlation with a positive slope was also found in the $\text{MDTr}^{-1}$ 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 $\text{MDTr}^{-1}$ (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 $\text{MDTr}^{-1}$ 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 is 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.

**Conflict of interest**

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

**References**

1. Holtmann G, Enck P. Stress and gastrointestinal motility in humans: A review of the literature. J Gastrointest Mot. 1991; 3(4): 245–54.
2. Musial F, Enck P. An illustrated Guide to gastrointestinal motility. 2nd ed. Kummar D, Wingate D, editors. London: Churchill Livingstone; 1993. Stress and gastrointestinal motility; p. 104–17.
3. Smout AJPM, Van Der Schee EJ, Grashuis JL. What is measured in electrogastrography? Dig Dis Sci. 1980; 25(3): 179–87.
4. Mintchev MP, Bowes KL. Do increased electro-gastrographic frequencies always correspond to internal tachygastria? Ann Biomed Eng. 1997; 25(6): 1052–8.
5. Homma S. Local differences in electrogastrograms recorded on thoraco-abdominal surface at 16 locations. J Smooth Muscle Res. 2009; 45(6): 299–306.
6. Homma S. Local differences in electrogastrographic responses to the stress of the mirror drawing test (MDT) as determined by multichannel electrogastrography. J Smooth Muscle Res. 2012; 48(2–3): 47–57.
7. Homma S, Hasegawa J, Maruta T, Watanabe N, Matsuo H, Tamiya Y, Nishimaki T, Suzuki T, Muto T, Hatakeyama K. Isopower maps of the electrogastrogram (EGG) after total gastrectomy or total colectomy. Neurogastroenterol Motil. 1999; 11(6): 441–8.
8. Homma S. The effects of stress in response to mirror drawing test trials on the electrogastrogram, heart rate and respiratory rate of human subjects. J Smooth Muscle Res. 2005; 41(4): 221–33.
9. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand. 1983; 67(6): 361–70.
10. Mykletun A, Stordal E, Dah AA. Hospital anxiety and depression (HAD) scale: factor structure, item analyses and internal consistency in a large population. Br J Psychiat. 2001; 179: 540–4.
11. Homma S. Isopower mapping of the electrogastrogram (EGG). J Auton Nerv Sys. 1997; 62(3): 163–6.
12. Homma S. Correlations between the responses of electrogastrograms, heart rate and respiratory rate to the stress of the mirror drawing test in human subjects. J Smooth Muscle Res. 2006; 42(1): 9–19.
13. Welgan P, Meshkinpour H, Hoehler F. The effects of stress on motor and electrical activity in irritable bowel syndrome. Psychosom Med. 1985; 47(2): 139–49.
14. Muth ER, Koch KL, Stern RM, Thayer JF. Effects of autonomic nervous system manipulation on gastric myoelectric activity and emotional responses in healthy human subjects. Psychosomatic Med. 1999; 61(3): 297–303.
15. Fedor JH, Russel RW. Gastrointestinal reactions to response-contingent stimulation. Psychol Rep. 1965; 16: 95–113.
16. Fone DR, Horowitz M, Maddox A, Akkermans LM, Read NW, Dent J. Gastrointestinal motility during the delayed gastric emptying induced by cold stress. Gastroenterol. 1990; 98(5 Pt 1): 1155–61.
17. Riezzo G, Porcelli P, Guerra V, Giorgio I. Effects of different psychophysiological stressors on the cutaneous electrogastrogram in healthy subjects. Arch Physiol Biochem. 1996; 104(3): 282–6.
18. Koch KL, Stern RM. An illustrated guide to gastrointestinal motility. Kumar D, Wingate D, editors.
Anxiety and electrogastrography

London: Churchill Livingstone; 1988. Electrogastrography; p.290–307.

19. Chen JDZ, Macallum RW. Electrogastrography. Principles and applications. Chen JZ, McCallum RW, editors. New York: Raven Press; 1994. Electrogastrographic parameters and their clinical significance; p.45–73.

20. Pezzola F, Riezzo G, Maselli MA, Giorgio I. Electrical activity recorded from abdominal surface after gastrectomy or colectomy in humans. Gastroenterol. 1994; 97, 313–20.

21. Riezzo G, Pezzola F, Maselli MA, Giorgio I. Electrical activity recorded from abdominal surface before and after right hemicolecetomy in man. Digestion. 1994; 55(3), 185–90.

22. Homma S, Shimakage N, Yagi M, Hasegawa J, Satoh K, Matsuo H, Tamiya Y, Tabnaka O, Muto T, Hatakeyama K. Electrogastrography prior to and following total gastrectomy, subtotal gastrectomy, and gastric tube formation. Dig Dis Sci. 1995; 40(4): 893–900.

23. Kaiho T, Shimoyama I, Nakajima Y, Ochiai T. Gastric and non-gastric signals in electrogastrography. J Auton Nerv Sys. 2000; 79(1): 60–6.

24. Amaris MA, Sanmiguel CP, Sadowski DC, Bowes KL, Mintchef MP. Electrical activity from colon overlaps with normal gastric electrical activity in cutaneous recordings. Dig Dis Sci. 2002; 47(11), 2480–5.

25. Fukudo S, Suzuki J. Colonic motility, autonomic function, and gastrointestinal hormones under psychological stress on irritable bowel syndrome. Tohoku J Exp Med. 1987; 151(4): 373–85.

26. Chaudhary YNA, Truelove SC. Human colonic motility: a comparable study of normal subjects, patients with ulcerative colitis, and patients with the irritable colon syndrome. I. Resting patterns of motility. Gastroenterol. 1961; 40: 1–17.

27. Narducci R, Snape WJ, Battle WM, London RL, Cohen S. Increased colonic motility during exposure to a stressful situation. Dig Dis Sci. 1985; 30(1): 40–4.

28. Rao SSC, Hatfield RA, Suls JM, Chamberlain MJ. Psychological and physical stress induce differential effects on human colonic motility. Am J Gastroenterol. 1998; 93(6): 985–90.

29. Welgan P, Meshkinpour H, Beeler M. Effect of anger on colonic motor and myoelectric activity in irritable bowel syndrome. Gastroenterol. 1988; 94(5 Pt 1):1050–6.

30. Gorard DA, Gomborone JF, Libby GW, Farthing MJ. Intestinal transit in anxiety and depression. Gut. 1996; 39(4): 551–5.

31. Lorena SL, Tinois E, Brunetto SQ, Camargo E, Mesquita MA. Gastric emptying and intragastric distribution of a solid meal in functional dyspepsia: influence of gender and anxiety. J Clin Gastroenterol. 2004; 38(3): 230–6.

32. Monnikes H, Schmidt DG, Raybould HE, Tache Y. CRF in the paraventricular nucleus mediate gastric and colonic motor response to restraint stress. Am J Physiol. 1992; 262(1 Pt 1): G137–43.

33. Tache Y, Monnikes H, Bonaz B, Rivier J. Role of CRF in stress-related alteration of gastric and colonic motor function. Ann NY Acad Sci. 1993; 697: 233–43.

34. Tache Y, Martinez V, Million M, Wang L. Stress and the gastrointestinal tract III. Stress-related alterations of gut motor functions: role of brain corticotropin-releasing factor receptors. Am J Physiol. 2001; 280(2): G173–7.

35. Bhatia V, Tandon RK. Stress and the gastrointestinal tract. J Gastroenterol Hepatol. 2005; 20(3), 332–9.