Original Paper

The Effect of Different Frequency Electrical Acu-stimulation on Gastric Myoelectrical Activity in Healthy Subjects

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ABBREVIATIONS: Electrogastrography (EGG); Fast Fourier Transform (FFT); Power Ratio (PR); Dominant Frequency (DF)

ABSTRACT

Background/Aims: Acupuncture has been used to treat gastrointestinal symptoms in oriental countries for many years. The underlying mechanism is still not fully understood.

Methodology: Fifteen healthy male volunteers were enrolled into this study. A cutaneous electrogastrography recording was obtained. Two frequencies (2Hz and 100Hz) of electrical stimulation were applied to Zusnali or Shousanli point in different sessions. Another non-acu-point (2cm lateral to Zusanli) without electrical stimulation was used for a control study.

Results: There was a significant increase in the percentage of normal frequency during 2Hz of electrical stimulation on Zusnali (baseline *vs.* acupuncture, 82.49±12.87% *vs.* 93.18±8.40%, $p<0.01$). The percentage of normal frequency did not change significantly, during or after acupuncture, with 100Hz of electrical stimulation on Zusnali, or 2Hz and 100Hz of electrical stimulation on Shousanli. In addition, the percentage of tachygastric frequency and power ratio also changed significantly during 2Hz of electrical stimulation on Zusnali. However, the change in the percentage of bradygastria and dominant frequency was not statistically significant among all five study sessions during each stage.

Conclusions: The results of this study demonstrated that electrical stimulation, with a frequency of 2Hz, on Zusanli might enhance the regularity of gastric myoelectrical activity. The effect of acupuncture on gastric myoelectrical activity was acu-point-specific, and that effect was observed with 2Hz but not 100Hz electrical stimulation.

INTRODUCTION

The phasic contraction of the distal stomach is regulated by a rhythmic electrical depolarization, known as the pacesetter potential or gastric slow wave, which is generated in the proximal gastric body (1). Myoelectrical changes play an important role in the control of gastric motor activity. Under normal conditions, the slow wave oscillates at approximately 3cpm. Certain rhythm disturbances have been described in clinical disease, such as an overly fast rhythm (tachygastria), an overly slow rhythm (bradygastria), and an irregular rhythm (arrhythmia) (2). Tachygastria and bradygastria are found in many patients with diabetes gastroparesis (3-6). Electrogastrographic abnormalities have also been described in nausea and vomiting during pregnancy (7), motion sickness (8-10), anorexia nervosa (11), and chronic intestinal pseudo-obstruction (12,13).

Acupuncture has been used to treat gastrointestinal symptoms in oriental countries for many years. Studies published in the Chinese literature have reported the improvement of gastrointestinal motility and symptoms with acupuncture (14). However, the underlying mechanism is still not fully understood. Furthermore, there is no report in the literature concerning the effect of different frequencies of electrical acu-stimulation on gastric myoelectrical activity in healthy subjects. In this study, we applied two different frequencies (2Hz and 100Hz) of electrical stimulation on two different acu-points, one in the leg (Zusanli) and one in the forearm (Shousanli) in healthy volunteers. We expected that the effect of acupuncture on gastric myoelectrical activity might be acu-point-specific, and that each different frequency of electrical stimulation might convey a distinct effect.

METHODOLOGY

Subjects

Fifteen healthy male volunteers (aged 23-34 years, mean: 25.6±2.7 years) were enrolled for this study. None had previously participated in similar experiments. No subjects reported cardiovascular, pulmonary, or gastrointestinal disorders, and none had taken any medications for at least 2 weeks before the study. Screening for *Helicobacter pylori* infection was performed using a serologic test for IgG antibodies to *H. pylori* (Pylori ELISA II, Bio Whittaker, Walkersville, Maryland, USA), and all subjects tested nega-

tive for *H. pylori*. The subjects fasted for at least 8 hours before the experiment. Informed consent was obtained from each subject, and the study protocol was approved by the ethics review committee of Taichung Veterans General Hospital in accordance with the Helsinki Declaration.

Electrical Stimulation of Acupuncture Points

Electrical stimulation of acupuncture points was performed on the subjects using acupuncture needles. Studies were conducted with a low (2Hz) or a high (100Hz) frequency of electrical stimulation. For comparison, two acu-points, Zusanli and Shousanli, and a placebo non-acu-point were tested. Sessions were completed in a randomized order 3 days apart. Two acupuncture needles (0.3mm in diameter, 30mm long, Chian-Huei Acupuncture Appliance Co., Taipei, Taiwan) were inserted into the subject's legs at the Zusanli (St 36) point, or into his arms at the Sousanli (LI 10) point, and manipulated until a 'chi'-sensation was reported (a deep cramp-like sensation). The Zusanli points are located about 10cm below the patella and 2cm lateral to the anterior rest of the tibia, whereas the Shousanli points are located 6cm distal to the end of the lateral transverse elbow crease, when the forearm is flexed at a right angle to the upper arm. The acupuncture needles were connected to a 9-V battery-powered electrical acupuncture instrument (Model-04S, Gwo-Jih Medical Instrument Factory, Taipei, Taiwan). Biphasic, square electrical stimulation of 2Hz or 100Hz pulses and with a wave width for 0.16 ms duration at the maximal tolerated strength without discomfort was delivered for 30 min. The placebo stimulation on a non-acu-point was conducted as follows: Acupuncture needles were inserted subcutaneously 2cm lateral to the Zusnali point. No manipulation was performed. The leads to the needles were connected to an inactive channel of the acupuncture stimulator. The stimulator was turned on, but electrical pulses were delivered to an unconnected channel. Hence, the subject experienced the same audiovisual stimuli.

Electrogastrography (EGG)

Cutaneous EGG was performed in the morning after an overnight fast, for 30 min in the baseline state, 30 min during acupuncture, and for an additional 30 min after acupuncture. The subjects were positioned comfortably in a chair, and were requested to remain as still as possible to reduce motion artifacts. After gentle skin abrasion to enhance electrical condition, 3 Ag-AgCl electrodes (Accutac Diaphoretic ECG Electrodes; NDM, Dayton, Ohio, USA) were affixed to the abdomen. The first electrode, for one of the active EGG leads, was placed on the patient's left side about 1/3 of the distance from the ventral to the left axial midline and 1cm below the bottom rib. The second electrode, for the other active EGG lead, was placed on the patient's ventral midline about half way between the umbilicus and the xyphoid process. The third electrode, for the reference lead, was placed on the patient's abdomen, forming a triangle with three equal sides.

EGG was performed with a portable EGG recorder (Synetics Medical Inc., Irving, Texas, USA). All recordings in the study were made at sampling frequencies of 4Hz. After the measurement, the EGG data were digitized, fed into a personal computer and analyzed by means of a commercially available software program (ElectroGastroGram Version 6.30, Gastrosoft Inc., Synetics Medical). Motion artifacts (large amplitude deflections) on the original EGG recording were identified visually and deleted before analysis. To avoid any artifact during acupuncture needle insertion and the initiation of electrical stimulation, EGG analysis was conducted for 20 min during each period (to exclude the first and last 5 min from each 30 min period). The data were obtained by running spectrum analysis. Using a fast Fourier transform (FFT) algorithm of a 256-sec "window" of the raw data, power spectra of overlapping stretches of the electric signal were computed and displayed as a function of time, yielding frequency and amplitude information over the course of the study (15). Several variables, including the dominant frequency (DF), the percentages of DF in the defined normal frequency range (2-4 cycles cpm), the bradygastric range (0.5-2cpm) and the tachygastric range (4-9cpm) were analyzed. Any DF higher than 10cpm was separated from tachygastria, because it was assumed to arise from outside the stomach. The DF was calculated as the highest peak of the mean FFT line during the recording time. The DP during the acupuncture and post-acupuncture period was compared to the dominant power during the baseline period to yield the power ratio (PR) for the acupuncture and post-acupuncture period.

Statistical Analysis

Data were expressed as the mean ± SD. Statistical analyses were performed to investigate the effects of acupuncture on the EGG parameters defined above, using repeated measurement analysis of variance (ANOVA) and the Wilcoxon matched-pairs signed ranks test. A p value <0.05 was considered statistically significant.

RESULTS

The percentage of normal frequency of EGG during the baseline period among all five sessions was similar. When applying 2Hz of electrical stimulation on the Zusnali point, there was a significant increase in the percentage of normal frequency during acupuncture (baseline *vs.* acupuncture, 82.49±12.87% *vs.* 93.18±8.40%, $p<0.01$). The percentage of normal frequency after 2Hz of electrical stimulation on the Zusnali point was also increased, but it was not statistically significant when compared to the baseline (baseline *vs.* post-acupuncture, 82.49±12.87% *vs.* 88.72±10.85%, $p=0.11$, no significance) (**Table 1**). The percentage of normal frequency did not change significantly, during or after acupuncture, with 100Hz of electrical stimulation on the Zusnali point, or with 2Hz and 100Hz of electrical stimulation on the Shousanli point.

TABLE 1 Percentage of Normal EGG Frequency (2-4cpm) in Each Group at Baseline, during Acupuncture and Post-acupuncture

Session	Baseline (mean ±SD) %	Acupuncture (mean ±SD) %	Post-acupuncture (mean ±SD) %	*P* value
A	82.49±12.87	93.18±8.40	88.72±10.85	0.002*
B	85.67±12.25	85.63±13.09	82.55±14.92	NS
C	84.71±12.73	82.75±11.86	84.21±14.58	NS
D	89.41±13.00	81.96±17.57	80.95±13.98	NS
E	86.85±10.82	83.63±12.96	80.78±14.83	NS

A: 2Hz on Zusanli, B: 2Hz on Shousanli, C: 100Hz on Zusanli, D: 100Hz on Shousanli, E: non-acu-point, *: acupuncture *vs.* baseline; NS: no significance.

TABLE 2 Percentage of Tachygastric EGG Frequency (4-9cpm) in Each Group at Baseline, during Acupuncture and Post-acupuncture

Session	Baseline (mean ±SD) %	Acupuncture (mean ±SD) %	Post-acupuncture (mean ±SD) %	*P* value
A	6.57±7.85	1.94±4.48	5.78±9.48	0.028*
B	7.40±9.52	5.09±8.56	5.49±9.81	NS
C	3.92±6.90	5.09±10.87	4.32±5.66	NS
D	2.35±5.35	6.27±9.01	9.41±12.92	NS
E	2.53±4.60	8.60±12.97	5.10±8.64	NS

A: 2Hz on Zusanli, B: 2Hz on Shousanli, C: 100Hz on Zusanli, D: 100Hz on Shousanli, E: non-acu-point, *: acupuncture *vs.* baseline, NS: no significance.

TABLE 3 Percentage of Bradygastric EGG Frequency (0.5-2cpm) in Each Group at Baseline, during Acupuncture and Post-acupuncture

Session	Baseline (mean ±SD) %	Acupuncture (mean ±SD) %	Post-acupuncture (mean ±SD) %	*P* value
A	10.28±11.64	3.54±6.23	5.50±8.16	NS
B	7.60±11.89	9.27±12.64	11.89±10.80	NS
C	11.37±13.05	12.49±11.28	11.80±13.77	NS
D	8.23±11.07	11.38±17.44	10.03±11.53	NS
E	10.63±10.98	7.37±9.61	14.12±15.37	NS

A: 2Hz on Zusanli, B: 2Hz on Shousanli, C: 100Hz on Zusanli, D: 100Hz on Shousanli, E: non-acu-point, NS: no significance.

The percentage of tachygastric and bradygastric frequency of EGG during the baseline period among all five sessions was also similar. During acupuncture phase, there was a significant decrease in the percentage of tachygastria (baseline *vs.* acupuncture, 6.57±7.85 % *vs.* 1.94±4.48%, $p<0.05$) **(Table 2)**. There was a decrease in the percentage of bradygastria during and after 2Hz of electrical stimulation on the Zusnali point, but it was not statistically significant **(Table 3)**. In addition, the change in the percentage of tachygastria or bradygastria was not statistically significant with 100Hz of electrical stimulation on the Zusnali point or 2Hz and 100Hz of electrical stimulation on the Shousanli point.

The DP during the acupuncture and post-acupuncture period was compared to the dominant power during the baseline period to yield the PR for the acupuncture and post-acupuncture period. When applying 2Hz of electrical stimulation on the Zusnali point, there was a significant increase in the PR during acupuncture (baseline *vs.* acupuncture, 1.00±0.00% *vs.* 1.77±1.03%, $p<0.01$). The PR during the post-acupuncture period was increased as well, but it was not statistically significant when compared to the baseline (baseline *vs.* post-acupuncture, 1.00±0.00 % *vs.* 1.28±0.90%, no significance) **(Figure 1)**. The PR did not change significantly, during or after acupuncture, with 100Hz of electrical stimulation on the Zusnali point, or 2Hz and 100Hz of electrical stimulation on the Shousanli point.

The dominant frequency of EGG during the baseline period among all 5-study sessions was also similar. There was no difference in the dominant frequency among all 5-study sessions during each period (baseline, acupuncture, or post-acupuncture) **(Figure 2)**.

DISCUSSION

In this study we found that (a) electrical stimulation on Zusanli could enhance the regularity of gastric myoelectrical activity (including an increase in the percentage of normal frequency as well as PR), and (b) the effect of acupuncture on gastric myoelectrical activity was acu-point-specific, and the effect was observed with 2Hz but not 100Hz of electrical stimulation.

Acupuncture has been used to treat gastrointestinal symptoms in oriental countries for many years. The most commonly used acupuncture points for treating gastrointestinal symptoms are the Neiguan and Zusanli points (16). Acupuncture at the Neiguan point in patients who underwent gynecological surgery had a significant antiemetic effect on postoperative nausea and vomiting (17), and it could also decrease cisplatin-associated nausea and vomiting in cancer patients (18). Electrical acu-stimulation of the Neiguan point has reduced the severity of symptoms of motion sickness and decreased gastric tachyarrhythmia (19). The underlying mechanism is still not fully understood. In this study, we applied electrical stimulation on Zusanli to evaluate the effect of acupuncture on gastric myoelectrical activity. For comparison, another acu-point in the arm, Shousanli, from a different meridian was also tested to investi-

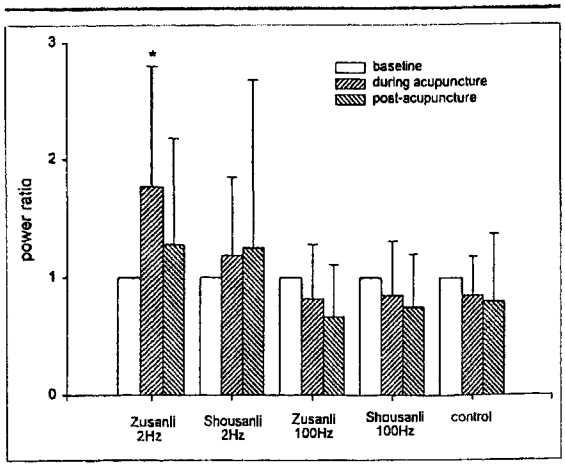

FIGURE 1 EGG power ratio in each group at baseline, during acupuncture and post-acupuncture. The power ratio in the Zusanli 2Hz group increased significantly during acupuncture. No significant change was noted in the other 4 groups.

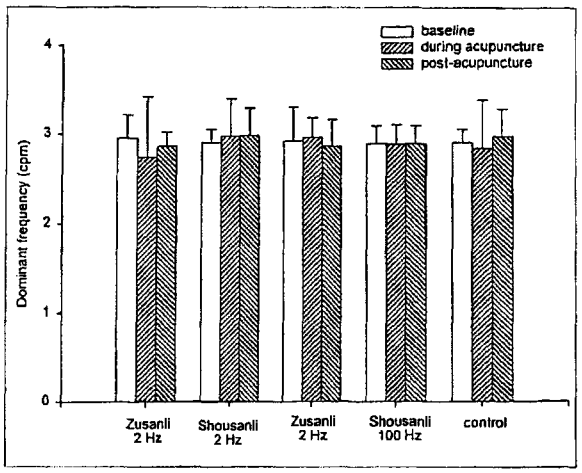

FIGURE 2 EGG dominant frequency (CPM) in each group at baseline, during acupuncture and post-acupuncture. No significant changes were noted in each group.

gate whether the effect of acupuncture on gastric myoelectrical activity is acu-point specific. The results revealed that the beneficial effects of acupuncture on gastric myoelectrical activity was observed with electrical stimulation on the Zusanli point, but not on the Shousanli point or on a non-acu-point. This phenomenon indicates that the effect of acupuncture on gastric myoelectrical activity is acu-point-specific.

The impact of acupuncture on gastrointestinal function is complex, and results depend upon the species studied, the acu-points employed, the methods of manipulation, and the underlying functional activity of the gut. Electrical stimulation of acupuncture points has been shown to enhance the regularity of gastric myoelectrical activity in healthy subjects (20). In our study, we applied 2 different electrical frequencies (2Hz and 100Hz) to further investigate the underlying mechanism for the effect of electrical stimulation of acupuncture points on gastric myoelectrical activity. Acupuncture analgesia studies suggest that the effect of acupuncture is due to release of the endogenous opioid peptides endorphin and enkephalin (21,22). High frequency electrical stimulation of acupuncture points predominantly produces local effects of short duration on pain perception/tolerance. Low frequency stimulation of 1-4Hz often produces effects that are less localized and of longer duration. Recent work has also demonstrated that opioid peptides have a wide range of actions on the alimentary tract (23). Several studies have shown that acupuncture decreases sham feeding stimulated acid output through naloxane-sensitive opioid mechanisms, involving vagal efferent pathways (24,25). The gastrointestinal actions of exogenous opioid peptides and those of acupuncture are similar (26). In cats, acupuncture at Zusanli stimulated antral peristalsis, as did an injection of morphine into the dorsal caudal medulla (27). However, enkephalins promote normal contractions, but inhibit drug-stimulated intestinal contractions (28); suggesting that acupuncture exerts a different effect on gastrointestinal motility, depending on the degree of underlying motor activity. The results of our study demonstrated that electrical stimulation, with a frequency of 2Hz, on Zusanli may enhance the regularity of gastric myoelectrical activity. However, no such effect was found with 100Hz of electrical stimulation. This phenomenon revealed that low and high frequencies of electrical stimulation may convey distinct effects on the gastric myoelectrical activity.

According to traditional Chinese medicine, needle stimulation should give rise to a specific needle sensation (in Chinese called *deqi*) which is experienced as numbness, heaviness and radiating paraesthesia, a sensation close to deep muscle pain when muscle points are stimulated. The sensation is a sign of the activation of thin myelinated nerve fibers, presumably A-delta fibers. Low frequency electrical stimulation of sufficient intensity causes muscular contractions, which activate mechano-receptors with low and high thresholds in the muscles. These receptors have a high threshold for mechanical stimulation and are innervated by A-delta fibers and possibly C-fibers. These receptors are physiologically activated by strong muscle contractions (29,30) and have been denoted as ergo-receptors. Whether neural and/or hormonal pathways are involved in the underlying mechanisms has not yet been fully explored. Further studies with neural and hormonal pathway parameters are needed.

In conclusion, in accordance with previous studies, electrical stimulation of acupuncture points may enhance the regularity of gastric myoelectrical activity in healthy subjects. Furthermore, the effect of acupuncture on gastric myoelectrical activity is acupoint specific, and the effect is observed with 2Hz but not 100Hz of electrical stimulation.

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