Digestive Diseases and Sciences, Vol. 45, No. 3 (March 2000), pp. 517–524

Comparison of Gastric Electrical Activity and Gastric Emptying in Healthy and Dyspeptic Children

GIUSEPPE RIEZZO, MD, MARISA CHILOIRO, MD, VITO GUERRA, Dipl. Stat., OSVALDO BORRELLI, MD, GENNARO SALVIA, MD, and SALVATORE CUCCHIARA, MD

To assess and compare gastric electrical activity and gastric emptying recorded from dyspeptic and healthy children, cutaneous electrogastrography and ultrasound examination of the gastric emptying were simultaneously performed in 52 children with nonulcer dyspepsia and 114 healthy children. Symptoms were scored from 0 (none) to 6 (severe). A higher percentage of tachygastria, a higher instability of gastric power, and a lower post/preprandial ratio were present in dyspeptic children than healthy children. As regards the ultrasound parameters, the fasting antral area and $T1/2$ were similar in dyspeptic children and controls. Only 32% of dyspeptic children had a normal gastric emptying time vs 66% of healthy children. Marked postprandial antral dilatation was found in the dyspeptic children, which correlated with the total symptom score. Electrogastrographic and gastric emptying parameters show specific differences in dyspeptic children with respect to controls, both fasting and after a meal. The postprandial antral distension correlates with the severity of the symptoms.

KEY WORDS: gastric electrical activity; electrogastrography; gastric emptying; nonulcer dyspepsia; healthy children.

Functional or nonulcer dyspepsia (NUD) is an ill-defined condition characterized by the presence of chronic intermittent symptoms of epigastric pain and fullness, early satiety, nausea and/or vomiting, but no mucosal lesions or structural abnormalities of the gastrointestinal tract (1). Several studies in adults and pediatric patients have demonstrated the presence of gastrointestinal motor abnormalities in nonulcer dyspepsia; findings include decreased antral and/or antroduodenal contractile response to meal, uncoordinated and/or nonpropagated duodenal–jejunal motor waves, and increased perception of intraluminal stimuli (2, 3). Altered gastric electrical activity has been suggested to play an important role in the etiology of functional dyspepsia. Myoelectrical abnormalities of the stomach have been recorded in patients with unexplained nausea and vomiting, during pregnancy or motion, and in patients with anorexia nervosa (4–9).

Gastric electrical activity can be recorded noninvasively by cutaneous electrogastrography (10). Simultaneous recordings of serosal and cutaneous or mucosal and cutaneous electrical activity have confirmed that the dominant EGG frequency corresponds to that of the gastric slow waves (11–13). Gastric emptying is usually assessed by scintigraphy, but recently ultrasonography has been introduced as a noninvasive technique, which may be particularly suitable for young patients (14–16). Normal ranges of EGG and

Manuscript received October 12, 1998; accepted July 25, 1999.

From the Laboratory of Experimental Pathophysiology and the Laboratory of Epidemiology and Biostatistics, Scientific Institute of Gastroenterology, Castellana Grotte, Bari, Italy; and the Department of Pediatrics, 2nd School of Medicine, University of Naples, Naples, Italy.

This study was supported by grant from Ministero della Sanità ICS 9.1/RF93.80.

Address for reprint requests: Dr. Giuseppe Riezzo, Laboratorio di Fisiopatologia Sperimentale, Istituto Scientifico Gastroenterologico, Via F. Valente, 4, I-70013 Castellana Grotte (Bari), Italy.

0163-2116/00/0300-0517$18.00/0

TABLE 1. MEAL ADMINISTERED IN DIFFERENT AGE GROUPS*

Age (yr)	*Bread (g)*	*Ham (g)*	*Butter (g)*	*Fruit juice (ml)*
6–9	60	55		212.5
9–12	100	55	5	127

* Calorie content: bread, 290 kcal/100 g; ham, 412 kcal/100 g; butter, 750 kcal/100 g; fruit juice, 56 kcal/100 ml.

gastric emptying parameters have not yet been established because healthy children have not been enrolled. In fact, only recently have the availability of ultrasonography for studying gastric emptying and portable EGG enabled enrollment of large groups of healthy volunteers and the calculation of normal ranges of EGG data in adults (16, 17).

Aim of this study was to assess and compare EGG and gastric emptying parameters in healthy and dyspeptic children.

MATERIALS AND METHODS

Patients. Fifty-two children with nonulcer dyspepsia (22 boys and 30 girls; mean age 8.5 ± 3 years) entered the study. Inclusion criteria were: (1) a history of continuous or intermittent dyspeptic symptoms lasting at least one year; (2) no digestive organic disease; no systemic, metabolic, or neurologic disease; and no previous abdominal surgery; and (3) absence of mechanical or inflammatory obstruction evaluated endoscopically. Infectious diseases were also excluded and no patient had serologic evidence of cytomegalovirus infection.

Controls. One hundred fourteen healthy children without gastrointestinal symptoms (60 boys and 54 girls, mean age 8.5 ± 2.0 years) entered the study. To assess demographic data, gastrointestinal symptoms, medical, and/or surgical history, and medical treatments, each participant's parents completed a detailed questionnaire. The following criteria had to be met: (a) absence of gastrointestinal symptoms; (b) no history of prior gastrointestinal surgery or drug administration; and (c) no history of reflux disease, peptic ulcer, or irritable bowel syndrome.

Study Design. After overnight fasting, the EGG recordings were performed by means of portable equipment, together with ultrasound examination of gastric emptying, before and at 30-min intervals for 240 min after a meal, and all children were free to move around the room. Evaluation of gastric motor function was performed using a standard solid–liquid meal (55% carbohydrate, 30% protein, and 15% fat). Table 1 shows the meal administered to the different age groups. The meal was consumed within 15 min. Two silver–silver chloride bipolar electrodes (Clear Trace, ConMed, Utica, New York) were sonographically placed on the cleaned abdominal surface overlying the antropyloric axis to obtain a signal with the best signal–noise ratio. The reference electrode was placed forming an equilateral triangle (8). Written informed consent was obtained from each child's parent, and the study was approved by the scientific committee of our institute.

EGG Recordings. Electrogastrography was performed using a portable EGG recorder (Synetics Medical AB, Stockholm, Sweden). All recordings were made at a sampling frequency of 1 Hz. The internal high- and low-pass filters were set at 1.8 and 16 cpm, respectively. After recording, the electrogastrogram data were fed into a personal computer (Vectra RS 20 Hewlett Packard Company, Palo Alto, California) and analyzed by means of a dedicated software program (ElectroGastroGram Version 6.30, Gastrosoft Inc., Synetics Medical). In addition to the analysis available in ElectroGastroGram, we used Redtech GiPC software to perform further data filtering and analysis of the EGG data. The following parameters were evaluated for each subject (10):

1. Mean frequency and power of the EGG: The frequency (DF) and power (DP) of the gastric peak were determined by the absolute peak value, and the mean frequency/power were computed by averaging the individual spectra.
2. Instability coefficient: This specifies the stability of the gastric electrical peak visible on the running spectra plot. It was calculated as the percentage ratio of the frequency standard deviation to the mean gastric frequency (DFIC) and the percentage ratio of the power standard deviation to the mean gastric power (DPIC).
3. The percentage of DF in ranges defined as normal, bradygastric, and tachygastric: A rhythmic gastric electrical activity ranging from 2.0 to 4.0 cpm was considered as normal. Tachygastria was considered to be present when the running spectra had a dominant peak in the 4.0 to 9.0-cpm range, and bradygastria when the dominant peak was <2.0 cpm.
4. The power ratio: Since the absolute values of EGG power are influenced by several factors (skin conductance, distance between electrodes and the wall of the stomach, variable shape of the stomach, etc), EGG power can be evaluated only as relative changes. The power ratio is the ratio of postprandial to fasting EGG power values. To assess whether the postprandial power increase depends on the expanded gastric wall being nearer to the abdominal surface, this distance was recorded sonographically before and after the meal, and the postprandial minus preprandial skin–antrum wall distance (Δd) was calculated.

The EGG signal was visually inspected to verify that no artifacts were present in any recording period. Periods containing these motion artifacts were deleted before computer analysis. EGG parameters were obtained by means of running spectral analysis. Currently, spectral analysis is the method most commonly used to analyze the EGG, and since Van der Schee et al introduced running spectral analysis in the EGG, frequency and amplitude analysis has been possible (11). With this procedure, using a fast Fourier transform (FFT), the frequency components of 256-sec epochs of EGG signal are calculated, overlapped by 75%, and displayed as a three-dimensional frequency plot.

GE Recording. The ultrasound examination of gastric emptying was performed using a real-time apparatus (Sigma 20-Kontron Instrument) equipped with a 3.5-MHz linear probe. The probe was positioned at the level of the transpyloric plane for simultaneous visualization of the antrum, the superior mesenteric vein, and the aorta. The antral measurements were always taken from the outer profile of the wall. The cross section of the gastric antrum,

TABLE 2. EGG PARAMETERS IN CHILDREN WITH NONULCER DYSPEPSIA AND CONTROLS RECORDED PRE- AND POSTPRANDIALLY*

	Controls (N = *114*)	*Dyspeptic children* (N = *52*)	*Mann-Whitney U test*
Preprandial			
Dominant frequency (cpm)	3.0 (2.1–3.5)	3.2 (2.4–4.7)	0.007
Instability coefficient of dominant frequency (%)	26.0† (6.7–54.5)	30.0 (11.5–64.4)	NS
Dominant power (μV^2)	547.3‡ (275.4–1061.7)	612.7 (195.4–1900.8)	NS
Instability coefficient of dominant power (%)	70.0 (35.7–136.7)	116.5 (41.5–275.4)	0.0001
Normal slow waves (%)	81.5 (59.3–100)	73.5 (42.0–100)	NS
Bradygastria (%)	3.7 (0.0–22.2)	2.6 (0.0–16.0)	NS
Tachygastria (%)	9.4 (0.0–38.7)	22.3 (0.0–54.2)	0.02
Postprandial			
Dominant frequency (cpm)	3.0 (2.1–3.7)	3.3 (2.7–4.8)	0.0001
Instability coefficient (%)	30.0 (11.0–60.7)	29.5 (7.6–60.0)	NS
Dominant power (μV^2)	2181.3 (1210.8–3402.0)	849.7 (338.5–2457.6)	0.0009
Instability coefficient of dominant power (%)	64.5 (32.5–111.0)	106.0 (48.2–236.6)	0.0001
Normal slow waves (%)	76.9 (54.4–97.2)	78.1 (46.0–100)	NS
Bradygastria (%)	4.9 (0.0–29.3)	2.7 (0.0–17.2)	0.01
Tachygastria (%)	11.8 (0.0–35.0)	20.3 (0.0–50.5)	0.02
Power ratio	3.6 (0.8–19.7)	1.3 (0.2–8.1)	0.0001

* Median and 5th–95th percentiles are presented.
† $P = 0.03$ pre- vs postprandially.
‡ $P = 0.0001$ pre- vs postprandially.

corresponding to the sagittal plane passing through the superior mesenteric vein, is elliptical in shape, so its area can be calculated by measuring the longitudinal (L) and anteroposterior (AP) diameters and using the formula $\pi L \times AP/4$ (16). Sonography was always performed by the same investigator; antral measurements were made before and subsequently at regular 30-min intervals up to 240 min after the start of the meal. The emptying curve was established by plotting the cross-sectional area of the gastric antrum against time. In addition, the antral area was calculated as the area ratio (AR) of postprandial values versus the basal value and plotted against time. One of the main problems affecting ultrasound time studies of gastric emptying is that it is quite cumbersome and time consuming. To overcome these problems, intermediate parameters such as *AR*240 and *T*1/2 emptying were evaluated. In each patient, the emptying time (in minutes) was expressed as the half-emptying time (*T*1/2), corresponding to the time when the cross-sectional area of the antrum had an intermediate value with respect to the basal value and the maximum value recorded after a meal. *T*1/2 was calculated by linear regression analysis of the linear part of the emptying curve (17, 18).

Symptom Evaluation. Gastrointestinal symptoms such as vomiting, abdominal fullness, early satiety, and abdominal pain or burning were evaluated in each patient. The severity of symptoms was graded from 0 (none) to 6 (severe) as reported in a previous work (19). The final score was the sum of the individual scores, for a total possible score of 24.

Statistical Analysis. Data were expressed as median and 5th and 95th percentiles. Data from different recording periods in the same subject were compared using Friedman's ANOVA test; in the case of significance, a Wilcoxon matched-pair test was applied. The Mann-Whitney U test was used to compare data between patients and controls. The Spearman correlation test was performed to calculate the relationship among EGG, gastric emptying, and symptoms. The Youden test was used to calculate the best discriminant value between normal and delayed gastric emptying. $P < 0.05$ was considered as statistically significant.

RESULTS

Effects of Test Meal in Healthy Children

Electrogastrographic Findings. The EGG parameters obtained from the group of normal children in the pre- and postprandial periods are reported in

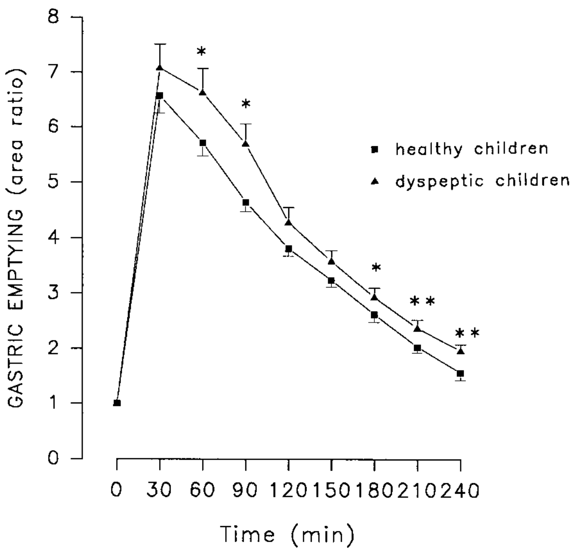

Fig 1. Gastric emptying curves recorded from dyspeptic and healthy children. Data are expressed as mean ± SEM. A significant difference is present in postprandial antral dilatation (* $P < 0.05$; ** $P < 0.001$).

Table 2. The DF did not differ in pre- and postprandial periods, but the DFIC was significantly higher after a meal ($P = 0.03$). Gastric power significantly increased after a meal ($P = 0.0001$) but its instability coefficient did not change. The percentage of normal slow-wave activity was 81.5%, with a slight decrease after the meal. The percentage of normal slow-wave activity was predominant both in pre- and postprandial states, and bradygastria and tachygastria were significantly less frequent ($P = 0.001$). The ingestion of the meal induced increased EGG power as expressed by the power ratio (PR) [3.6 (0.8–19.7)].

Gastric Emptying. Ultrasound examination of gastric emptying showed that the antral area before meal was 3.6 cm^2 (1.9–7.7 cm^2), the *AR*240 was 1.3 (0.6–4.3), and the *T*1/2 was 114.8 min (75.8–163.5 min). Figure 1 shows the gastric emptying curve expressed as the area ratio over time obtained in normal children.

Effects of Test Meal in Dyspeptic Children

Electrogastrographic Findings. The DF did not differ between pre- and postprandial periods, and the DFIC was not modified by the ingestion of the meal (Table 2). After the meal, the gastric power did not increase and its instability coefficient did not change. The percentage of normal slow-wave activity was 73.5%, with no evident changes after meal. The percentage of normal slow-wave activity was predominant both in pre- and postprandial states, and bradygastria and tachygastria were significantly less frequent ($P = 0.001$). Tachygastria was higher than 20% both in pre- and postprandial periods. Ingestion of the meal induced a small increase in the EGG power expressed as a power ratio (PR) [1.3 (0.2–8.1)] (Table 2).

Gastric Emptying. Ultrasound examination of gastric emptying showed that the antral area before meal was 3.4 cm^2 (1.8–8.5 cm^2), the *AR*240 was 1.8 (1.0–3.7), and the *T*1/2 was 121.4 min (76.3–186.0 min). Figure 1 shows the gastric emptying curve expressed as the area ratio over time obtained in dyspeptic children.

Comparison of EGG and Gastric Emptying in Healthy and Dyspeptic Children

Electrogastrographic Findings. Before the meal, the dominant frequency was statistically different in the two groups (Table 2). In normal children, the 5th and 95th percentiles were 2.1 and 3.5 cpm, respectively, while in dyspeptic children they were 2.4 and 4.7 cpm ($P = 0.007$). No difference was found in the instability coefficient of the dominant frequency. Gastric power was similar in the two groups but the instability coefficient of gastric power was significantly higher in dyspeptic than in normal children ($P = 0.0001$). The percentage of normal slow waves was similar in the two groups. The percentage of tachygastria was 22.3% in dyspeptic vs 9.4% in normal children ($P = 0.02$). After the meal, the dominant frequency was statistically different in the two groups (Table 2). In normal children, the 5th and 95th percentiles were 2.1 and 3.7 cpm, respectively, while in dyspeptic children they were 2.7 and 4.8 cpm ($P = 0.0001$). No difference was found in the instability coefficient of the dominant frequency. Gastric power was significantly lower ($P = 0.0009$) and the instability coefficient of gastric power was significantly higher in dyspeptic than in normal children ($P = 0.0001$). The percentage of normal slow waves was similar in the two groups but the percentage of tachygastria was 20.3% in dyspeptic vs 11.8% in normal children ($P = 0.02$), while the percentage of bradygastria was lower in dyspeptic children ($P = 0.01$). Also in the latter, the power ratio was significantly lower ($P = 0.0001$) (Table 2).

Gastric Emptying. As regards the ultrasound parameters, there were no statistically significant differences in preprandial antral area and *T*1/2 between the two groups. Comparison of the curves for gastric emptying time expressed as the area ratio over time showed significant differences at 60–90 min and 180–

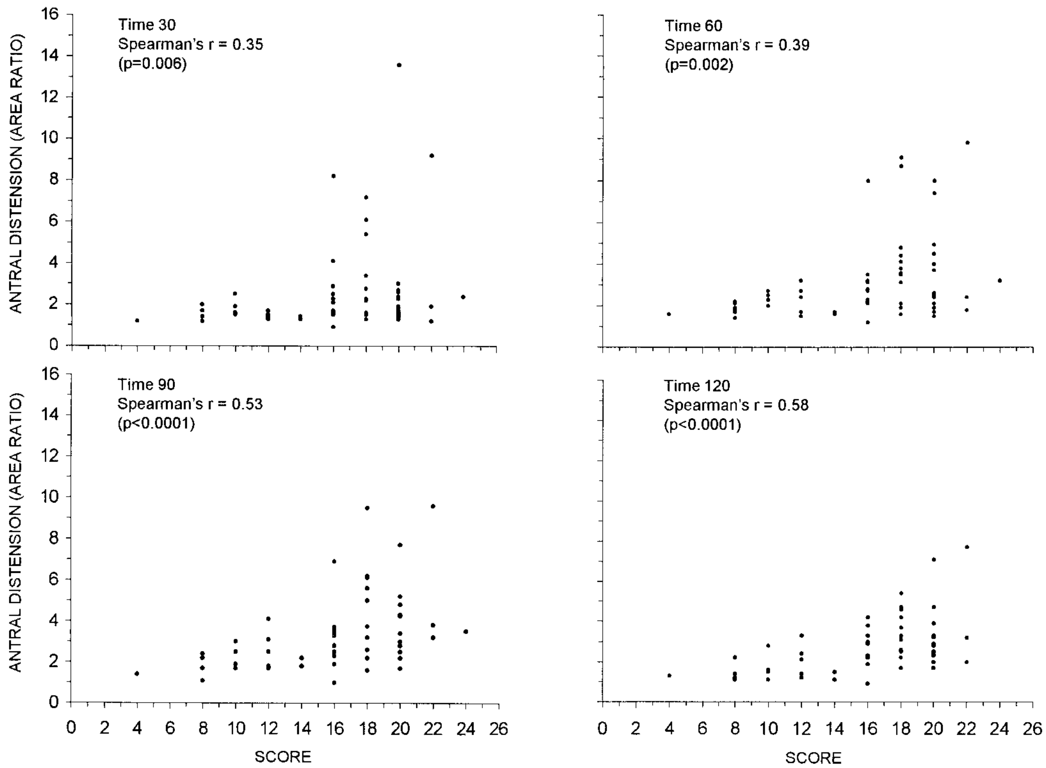

Fig 2. Correlation between dyspeptic symptom score and antral distension 30, 60, 90, and 120 min after feeding. Antral distension was calculated as postprandial values versus the basal value (area ratio).

240 min. The best discriminant value between normal and delayed gastric emptying was found to be $AR240 = 1.5$ (sensitivity = 0.62; specificity 0.61; diagnostic accuracy = 0.62). Sixty-six percent of healthy children vs 32% of dyspeptic ones had an area ratio below 1.5.

Correlation Data

No correlation was found between PR and Δd (Spearman's $r = 0.0045$; $P = 0.97$). The correlation between dyspeptic symptom score and the distension of the gastric antrum, measured by ultrasound, was found to be significant at 30, 60, 90, and 120 min after the administration of the meal (Figure 2). As regards EGG and gastric emptying, the correlation between the power ratio and gastric distension expressed as the area ratio at 240 min showed only a trend toward significance ($r = -0.28$; $P = 0.07$). No correlation was found between the power ratio and $T1/2$ or the power ratio and the symptom score.

DISCUSSION

In this study, a specific EGG and gastric emptying pattern was found to be present in dyspeptic children with respect to controls. The EGG pattern included frequency alterations (percentage of tachygastria and bradygastria) and power alterations (reduced post/preprandial ratio). The gastric emptying pattern consisted of marked postprandial antral dilatation and a higher percentage of subjects with a delayed gastric emptying rate. The severity of symptoms correlated with the antral dilatation observed in the early gastric emptying time.

EGG and gastric emptying studies were performed simultaneously, in children aged 6–12 years, and the EGG parameters were calculated pre- and postprandially. These include the frequency, the power, and the instability coefficient of the frequency and power. The instability coefficient reflects variation of EGG frequency or power over time and is not subject-dependent. In healthy children, the dominant preprandial frequency ranged from 2.1 to 3.5 cpm, and normal slow-wave activity was predominantly in the 2.0 to 4.0-cpm range. Bradygastria and tachygastria percentages were below 10%. The normal values of dominant frequency are consistent with previously published data in adults (20, 21). The postprandial EGG signal has been found to be characterized by an increase in frequency and power due to gastric peristaltic activity (10, 22, 23). In our study, the dominant frequency did not change in the postprandial period, but the DFIC, an index of subtle changes in the gastric slow waves, increased. The percentage of normal slow waves was in the 2.0 to 4.0-cpm range both during fasting and postprandially, and its postprandial reduction reflects a more unstable postprandial rhythm. As regards EGG amplitude, a significant increase in the postprandial EGG power was found. An increased electrical power has been attributed in part to distension, causing the stomach to move nearer the recording electrode (23, 24). In our study, the distance between the abdominal surface and the antral wall was calculated. The absence of any correlation between the power ratio and the skin–antrum distance confirms that a postprandial increase in EGG power is due to the contractile activity of the stomach.

The gastric emptying rate of solids in children is difficult to evaluate because the available methods are either invasive or induce a substantial radiation burden. A good correlation between scintigraphic and ultrasound parameters has been found using either liquid or solid meals (16, 17). Hence, in our study, the gastric emptying test was performed by means of a real-time ultrasound examination. The *T*1/2 emptying obtained from healthy children was found to be similar to that reported in a previous study (23) and *AR*240 was below 1.5 in 66% of healthy children.

In agreement with prior studies (7, 18, 25), this study demonstrated specific EGG and gastric emptying patterns in dyspeptic children. EGG findings included chronotropic dysfunction (gastric dysrhythmias: bradygastria and tachygastria) and inotropic dysfunction (decreased postprandial–fasting power ratio). Both pre- and postprandially, gastric frequency was higher and its range wider, the percentage of tachygastria was above 20%, and the percentage of bradygastria was lower than in controls. Abnormal gastrointestinal motor patterns have been recorded in a variety of dyspeptic syndromes, both idiopathic and secondary to organic, systemic and metabolic diseases. In particular, antral hypomotility alone or in combination with intestinal motor abnormalities has been described in nonulcer dyspepsia (2). The electrical counterpart of these motor alterations is the occurrence of tachygastria (26–29). Tachygastria may not only abolish gastric contraction, but also disrupt the temporal and spatial relationship between contractions, necessary for trituration and propulsion (30). The correlation between bradygastria and gastric motility is not yet clear. Some authors have observed that bradygastria was correlated with strong antral contractions (31) while others indicated the correlation of bradygastria with antral hypomotility (28) or absence of antral contractions (32). Recently, a superimposed low-frequency component has been observed (29, 33). Unlike bradygastria, the low-frequency component is not an alteration of the gastric electrical rhythm but a concurrent frequency component associated with antral or intestinal contractions (29). It was observed in healthy volunteers after eating and after cisapride (33). The high percentage of bradygastria observed in dyspeptic children could be explained by the presence of a concurrent low-frequency component calculated by the built-in software as bradygastria. Another interesting finding is the reduced increment of postprandial amplitude, expressed as absolute or relative changes. A possible cause for a decrease in the power ratio is the change in gastric slow waves, due either to decreased amplitude or to degradation of its regularity, or both. In our study, a wider range of dominant frequency, a higher percentage of tachygastria, and a reduced power ratio characterized the EGG signal recorded in dyspeptic children. Moreover, the simultaneous study of EGG and gastric emptying enabled us to find a negative correlation between the power ratio and the antral area expressed as the area ratio at 240 min. This confirm the hypothesis that a reduced power ratio may be considered an index of postprandial motility disorder (10).

Delayed gastric emptying is considered an important aspect in the pathophysiology of functional dyspepsia. Delayed gastric emptying of solids has been demonstrated in dyspeptic patients, and the gastric emptying of a radiolabeled meal was found to be delayed in 30–80% of patients (34). In addition, marked postprandial antral dilatation was reported to be a particular finding in the gastric emptying pattern of dyspeptic patients, associated with abnormal intragastric distribution of the meal and delayed gastric emptying (35, 36). Some authors found that greater antral distension could be related to the severity of symptoms (19, 36). Using the *AR*240 value as the cutoff between normal and delayed emptying, we demonstrated that 68% of dyspeptic children had delayed gastric emptying, while the comparison of gastric emptying curves showed a significant difference in the early gastric emptying time, with greater antral distension in dyspeptic than in healthy children. As in adults, in dyspeptic children there was a clear correlation between the symptom score and the antral area expressed as the area ratio. However, the gastric emptying rate expressed as $T1/2$ failed to show a significant difference in the two groups of children.

In conclusion, specific alterations in gastric electrical activity and gastric emptying are present in dyspeptic children. Cutaneous electrogastrography and ultrasonography are useful methods for studying the motor abnormalities observed in functional dyspepsia.

ACKNOWLEDGMENTS

We wish to thank Simone Montanaro for his excellent technical assistance and Dr. Victoria Pragner for her help in the English translation of the manuscript.

REFERENCES

1. Barbara L, Camilleri M, Corinaldesi R, Crean GP, Heading RC, Johnson AG, Malagelada J-R, Stanghellini V, Wienbeck M: The definition and investigation of dyspepsia. Dig Dis Sci 34:1272–1276, 1989
2. Stanghellini V, Ghedini C, Ricci Maccarini M, Paparo GF, Corinaldesi R, Barbara L: Fasting and postprandial gastrointestinal motility in ulcer and non ulcer dyspepsia. Gut 190:184–190, 1992
3. Greydanus MP, Vassallo M, Camilleri M, Nelson DK, Hanson RB, Thomforde GM: Neurohormonal factors in functional dyspepsia: Insight on pathophysiological mechanisms. Gastroenterology 100:1311–1318, 1991
4. Abell TL, Malagelada J-R, Lucas AR, Brown ML, Camilleri M, Go VLW, Azpiros F, Callaway CW, Kao PC, Zimmaister M, Huse DM: Gastric electromechanical and neurohormonal function in anorexia nervosa. Gastroenterology 93:958–965, 1987
5. Koch KL, Stern RM, Vasey MW, Botti JJ, Creasy GW, Dwyer A: Gastric dysrhythmias and nausea of pregnancy. Dig Dis Sci 35:961–968, 1990
6. Koch KL, Stern RM, Stewart WR, Vasey MW: Gastric emptying and gastric myoelectrical activity in patients with diabetic gastroparesis: Effect of long-term domperidone treatment. Am J Gastroenterol 84:1069–1075, 1989
7. You CH, Lee KY, Chey WY, Menguy R: Electrogastrographic study of patients with unexplained nausea and vomiting. Gastroenterology 79:311–314, 1980
8. Rothstein RD, Alavi A, Reynolds JC: Electrogastrography in patients with gastroparesis and effect of long-term cisapride. Dig Dis Sci 38:1518–1524, 1993
9. Stern RM, Koch KL, Stewart WR, Lindblad IM: Spectral analysis of tachygastria recorded during motion sickness. Gastroenterology 92:92–97, 1987
10. Chen JZ, McCallum RW: Electrogastrography: Principles and Applications. New York, Raven Press, 1994
11. van der Schee EJ, Smout AJPM, Grashuis JL: Application of running spectrum analysis to electrogastrographic signals recorded from dog and man. *In* Motility of the Digestive Tract. M Wenbeck (ed). New York, Raven Press, 1982, pp 241–250
12. Hamilton JW, Bellahsene BE, Reicherlderfer M, Webster JH, Bass P: Human electrogastrograms. Comparison of surface and mucosal recordings. Dig Dis Sci 3:33–39, 1986
13. Familoni BO, Bowes KL, Kingma YJ, Cote KR: Can transcutaneous recording detect gastric electrical abnormalities? Gut 32:141–146, 1991
14. Mintchev MP, Kingma YJ, Bowes KL: Accuracy of cutaneous recordings of gastric electrical activity. Gastroenterology 104:1273–1280, 1993
15. LiVoti G, Tulone V, Bruno R, Cataliotti F, Iacono G, Cataiano F, Balsamo V: Ultrasonography and gastric emptying: Evaluation of infants with gastroesophageal reflux. J Pediatr Gastroenterol Nutr 14:397–399, 1992
16. Bolondi L, Bortolotti M, Santi C, Colletti T, Gaiani S, Labò G: Measurement of gastric emptying time by real-time ultrasonography. Gastroenterology 89:752–759, 1985
17. Bolondi L, Santi V, Bortolotti M, Li Bassi S, Turba E: Correlation between scintigraphic and ultrasound assessment of gastric emptying. Gastroenterology 90:1349–1354, 1986
18. Riezzo G, Cucchiara S, Chiloiro M, Minella R, Guerra V, Giorgio I: Gastric emptying and myoelectrical activity in children with nonulcer dyspepsia. Effect of cisapride. Dig Dis Sci 40:1418–1434, 1995
19. Cucchiara S, Minella R, Iorio R, Emiliano M, Az-Zeqeh N, Vallone G, Bali MA, Alfieri E, Scoppa A: Real-time ultrasound reveals gastric motor abnormalities in children investigated for dyspeptic symptoms. J Pediatr Gastroenterol Nutr 21:446–453, 1995
20. Parkman HP, Harris HD, Miller MA, Fischer RS: Influence of age, gender, and menstrual cycle on the normal electrogastrogram. Am J Gastroenterol 91:127–133, 1996
21. Pfaffenbach B, Adamek RJ, Kuhn K, Wegener M: Electrogastrography in healthy subjects. Evaluation of normal values, influence of age and gender. Dig Dis Sci 40:1445–1450, 1995
22. Koch KL, Stewart WR, Stern RM: Effect of barium meals on gastric electromechanical activity in man. A fluoroscopic-electrogastrographic study. Dig Dis Sci 32:1217–1222, 1987
23. Chen J, McCallum RW: The response of electrical activity in normal human stomach to water and solids meals. Med Biol Eng Comput 29:351–357, 1991
24. Stern RM, Crawford HE, Stewart WR, Vasey MW, Koch KL: Sham feeding: Cephalic–vagal influences on gastric myoelectrical activity. Dig Dis Sci 34:521–527, 1989
25. Koch KL, Medina M, Bingaman S, Stern RM: Gastric dysrhythmias and visceral sensation in patients with functional dyspepsia. Gastroenterology 102:A469, 1992
26. Code CF, Marlett JA: Modern medical physiology: Canine tachygastria. Mayo Clin Proc 49:325–332, 1974
27. Telander RL, Morgan KG, Kreulen DL, Schemalz PF, Kelly KA, Szurszewki JH: Human gastric atony with tachygastria and gastric retention. Gastroenterology 75:495–501, 1978
28. Bortolotti M, Sarti P, Barbara L, Brunelli F: Gastric myoelectrical activity in patients with chronic idiopathic gastroparesis. J Gastrointest Motil 2:104–108, 1990
29. Chen J, Richards R, McCallum RW: Frequency components of the electrogastrogram and their correlations with gastrointestinal motility. Med Biol Eng Comput 31:60–67, 1993
30. Szurszewski JH: Electrical basis for gastrointestinal motility. *In* Physiology of the Gastrointestinal Tract, Volume 1, 2nd ed. LR Johnson (ed). New York, Raven Press, 1987, pp 383–422
31. van der Schee ET, Grashuis JL: Contraction-related, low frequency components in canine electrogastrographic signals. Am J Physiol 245:G470–G475, 1983
32. Abell TL, Malagelada J-R: Glucagon evoked gastric dysrhythmias in humans shown by an improved electrogastrographic technique. Gastroenterology 88:1932–1940, 1985

33. Koch KL, Birgaman S, Sperry N, Stern RM: Effect of cisapride on gastric electromechanical activity in healthy volunteers: A double-blind, placebo controlled study. Gastroenterology 100:A459, 1991
34. Malagelada J-R: Gastrointestinal motor disturbance in functional dyspepsia. Scand J Gastroenterol 26(suppl 182):29–32, 1991
35. Bortolotti M, Bolondi L, Santi V, Sarti P, Brunelli F, Barbara L: Pattern of gastric emptying in dysmotility-like dyspepsia. Scand J Gastroenterol 30:408–410, 1995
36. Troncon LEA, Bennett RJM, Ahluwalia NK, Thompson DJ: Abnormal intragastric distribution of food during gastric emptying in functional dyspeptic patients. Gut 35:327–332, 1994