Antral Myoelectric Activity, Gastric Emptying, and Dyspeptic Symptoms in Diabetics

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Background: Electrogastrography (EGG) enables the cutaneous measurement of gastric electric activity. An association between electric abnormalities and gastrointestinal motility disorders has been shown. The primary objective of this study was to investigate whether diabetic gastroparesis could be predicted by EGG. *Methods:* EGG was performed in 18 insulin-treated type-II diabetics (9 female, 9 male; median age, 64 years; range, 45–76 years) with chronic dyspepsia. After an overnight fast, during 1 h in the fasting and 1 h in the fed state after ingestion of a liquid–solid test meal (370 kcal; liquid phase labeled with 0.5 mCi ^{99m}Tc-colloid) antral electric activity was captured by one pair of electrodes sonographically placed on the skin overlying the gastric antrum. Several EGG variables including dominant frequency (DF), percentages of DF in the normal range (2–4 cycles per minute (cpm)), bradygastria (<2 cpm), and tachygastria (4–10 cpm), dominant frequency instability coefficient (DFIC), and postprandial to preprandial power ratio (PR) were calculated by fast Fourier transform. The data were correlated to results obtained in 20 age- and gender-matched healthy subjects (10 female, 10 male; median age, 68 years; range, 53–90 years). In addition, the data were compared with the percentages of retention of the radionuclide in the stomach at 60 min, and lag times measured by simultaneous scintigraphy. *Results:* The EGG values obtained in diabetics did not differ significantly from those in healthy subjects and did not correlate with radioscintigraphy ($p > 0.05$). Moreover, the EGG values in diabetics with delayed gastric emptying (about 40%) did not differ from data in diabetics without gastroparesis. Furthermore, whereas dyspepsia correlated significantly with radioscintigraphy, no correlation with EGG could be found. *Conclusions:* Electrogastrography seems to be unsuitable for assessment of motility disorders in type-II diabetics.

Key words: Diabetics; electrogastrography; gastroparesis; radioscintigraphy

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Electrogastrography (EGG) enables the cutaneous measurement of gastric electric activity (1). Since its first application in the 1920s (2), several studies have shown an association of electric abnormalities with gastrointestinal motility disorders (3). However, some authors consider the EGG an assessment tool in the diagnosis of gastric motility disorders (4). Among different diseases associated with a disturbance of the gastrointestinal motility, concomitant abnormalities in the EGG have been observed in diabetics.

The aim of this study was to investigate whether EGG as a noninvasive method really could predict a gastric motility disorder in insulin-treated type-II diabetics with chronic dyspepsia.

SUBJECTS AND METHODS

Subjects and study protocol

Eighteen consecutive insulin-treated type-II diabetics (9 female, 9 male; median age, 64 years; range, 45–76 years; median body mass index, 27.5; range, 22–34) with chronic dyspepsia suggestive of gastroparesis entered the study. The median insulin dosage used by the patients was 28 U/day (8–64 U/day). The median duration of known diabetes mellitus was 16 years (0.5–39 years), and the median actual blood glucose level assessed by five measurements in the morning of the study day was 153 mg/dl (102–286 mg/dl). The median HbA1 level was 9.5% (6.2–13.7%) (normal value, 5–8%). The presence of gastrointestinal symptoms was assessed immediately before the measurements, using a standardized protocol. The symptoms, including retrosternal pain, epigastric pain, epigastric fullness, belching, nausea and vomiting, and abdominal pain, were rated with regard to severity (0 = not present, 1 = modest, 2 = moderate, 3 = severe) and frequency (1 = 2–3 times a month, 2 = once a week, 3 = 2–3 times a week, 4 = daily), resulting in a maximum possible total clinical score of 42 points. A minimum score of 3 points was required for entering the study. Autonomic nerve function was evaluated in five patients by standard cardiovascular reflex tests in accordance with a previous recommendation (5). Calculated from continuous ECG recording, parasympathic function was assessed by a) heart rate during rest: a heart rate more than 90/min was considered abnormal; b)

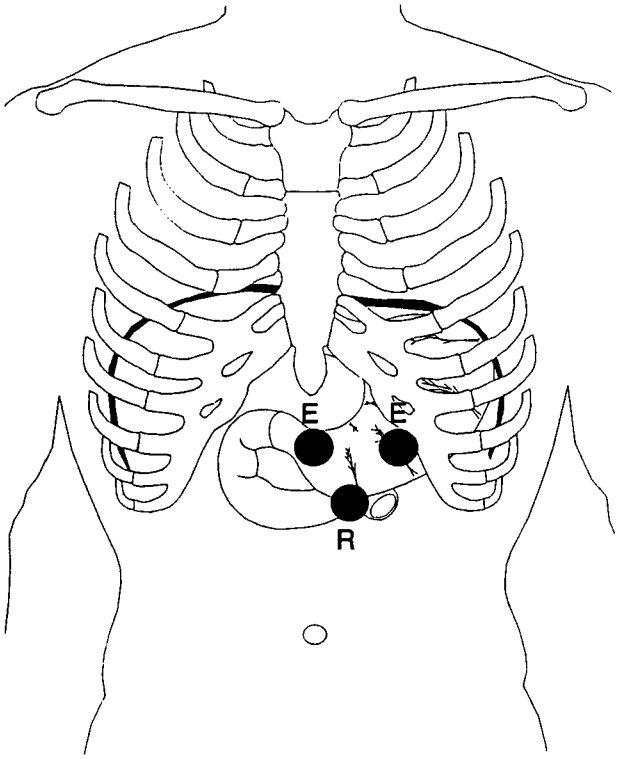

Fig. 1. Sonographic position of two surface electrodes (E) and one reference electrode (R) on the skin overlying the gastric antrum.

heart rate variation (R–R interval) during deep breathing (6 breaths/min): a mean difference of maximum and minimum heart rates less than 10 beats/min was considered abnormal; and c) immediate heart rate response to standing: the ratio of the shortest R–R interval at or around the 15th beat and the R–R interval at beat 30 after standing was calculated. A 30:15 ratio less than 1.0 was considered abnormal. Sympathetic function was assessed by the fall in systolic blood pressure in response to standing. A decrease of 30 mmHg or more was considered abnormal. Autonomic neuropathy was defined as having at least two abnormal test results (moderate degree, two abnormal results; severe degree, three and four abnormal results). Patients with laboratory evidence of pancreatic or liver disease, with either a history of endoscopically diagnosed peptic ulcer disease, a history of gastrointestinal tract surgery (except appendectomy and cholecystectomy), and serious systemic disorders (infections, malignancies) were excluded.

After an overnight fast electrogastrographic recordings were assessed at 0800 h continuously without disconnection of the electrodes during 1 h in the fasting and 1 h in the postprandial period after ingestion of a 370-kcal standardized test meal containing 45 g wheat bread, two scrambled eggs (130 g), 100 ml coffee labeled with 0.5 mCi ^{99m}Tc colloid, and 100 ml unsweeted orange juice. All meals were consumed within 10 min. Two silver/silver chloride bipolar surface electrodes (Red Dot, 2271, 3M, Ontario, Canada) were placed on the cleaned and shaved skin overlying the sonographically detected gastric antrum, which provides an appreciable signal detection (6). The third skin electrode for the reference lead was placed so as to form an isolateral triangle (Fig. 1).

Immediately after the test meal an anterior positioned gamma camera (Toshiba GCA 901A/SA, Toshiba Medical System, Neuss, Germany) recorded radionuclide counts over the upper abdomen at 1-min intervals over a total period of 60 min. A region of interest was selected including the area of the whole stomach. At the end of the data acquisition a correction for attenuation was performed (7). Using a computer, the percentage of nuclides remaining in the stomach at 60 min (t 60 values) after meal completion was calculated. We preferred the t 60 values to gastric half-emptying times because the former variable appears more reliable. Moreover, lag times were determined.

The electrogastrographic results were compared with EGG data obtained in 20 healthy volunteers without gastrointestinal symptoms (10 female, 10 male; median age, 68 years; range, 53–90 years). The measurements were done in exactly the same manner as in the diabetics. There was no difference in age, gender, and body mass index between control subjects and diabetics.

Table I. Electrogastrographic variables* obtained in healthy subjects and diabetics (median, percentiles)

	Healthy subjects (n = 20)	Diabetics (n = 18)	Wilcoxon Mann–Whitney U test
Preprandial period			
DF (cpm)	2.9 (2.1–3.3)	2.8 (2.1–4)	NS
DF in normal range (%)	90.0 (64.7–100)	81.5 (54.5–99.1)	NS
Bradygastria (%)	5.6 (0–23.9)	8.9 (0–27.2)	NS
Tachygastria (%)	3.5 (0–14.9)	2.7 (0–27.3)	NS
DFIC (%)	27.5 (8–53.5)	26.0 (7–46.5)	NS
Postprandial period			
DF (cpm)	3.1 (2.2–3.5)	3.1 (1.8–3.9)	NS
DF in normal range (%)	88.9 (65.8–100)	93.0 (71–100)	NS
Bradygastria (%)	4.5 (0–24.6)	2.9 (0–15.8)	NS
Tachygastria (%)	5.4 (0–21.1)	3.6 (0–20.2)	NS
DFIC (%)	22.0 (6.5–47.5)	17.0 (3.5–36.5)	NS
PR	3.2 (0.1–24.4)	3.2 (0.5–26.2)	NS

* DF = dominant electric frequency; DFIC = dominant frequency instability coefficient; PR = postprandial to fasting power ratio.

Table II. Correlation between electrogastrographic (EGG) variables* and gastric retention of the radionuclide at 60 min (t 60 values)

EGG in diabetics (n = 18)	Spearman rank correlation to scintigraphic t 60 values (%)
Preprandial	
DF (cpm)	$R = 0.1$; $p = 0.7$
DF in normal range (%)	$R = 0.3$; $p = 0.2$
Bradygastria (%)	$R = 0.2$; $p = 0.5$
Tachygastria (%)	$R = 0.3$; $p = 0.2$
DFIC (%)	$R = 0.3$; $p = 0.2$
Postprandial	
DF (cpm)	$R = 0.2$; $p = 0.5$
DF in normal range (%)	$R = 0.1$; $p = 0.6$
Bradygastria (%)	$R = 0.2$; $p = 0.4$
Tachygastria (%)	$R = 0.1$; $p = 0.6$
DFIC (%)	$R = 0.3$; $p = 0.3$
PR	$R = 0.1$; $p = 0.6$

* DF = dominant electric frequency; DFIC = dominant frequency instability coefficient; PR = postprandial to fasting power ratio.

Informed consent was obtained in all cases, and the study was approved by the local ethics committee of Ruhr University, Bochum, Germany.

Electrogastrographic recordings

Electrogastrography was performed with a 96-kb portable EGG recorder (Synectics Medical AB, Stockholm, Sweden). All recordings in the study were made at sampling frequencies of 4 Hz. After the measurement the EGG data were digitized and fed into an AT 80386 personal computer and analyzed by means of a commercially available software program (ElectroGastroGram Version 6.30, Gastrosoft Inc., Synectics Medical). Several variables, including dominant electric frequency (DF), the percentages of DF in the defined normal frequency range (2–4 cycles per minute (cpm)), bradygastric range (<2 cpm) or tachygastric range (4–10 cpm), the dominant frequency instability coefficient (DFIC), and postprandial to fasting power ratio (PR) were analyzed. DF higher than 10 cpm were separated from tachygastria, because they are assumed to arise outside the stomach.

The data were obtained by running spectrum analysis. By this technique, 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 are computed and displayed as a function of time, thus yielding frequency and amplitude information over the course of time (8). The DF (cycles per minute (cpm)) is calculated as the highest peak of the mean FFT line for the recording time (1 h). The DFIC (percentage) is a measure to ascertain the changes of DF during the period of data acquisition. It is defined as the coefficient of variation (percentage) (standard deviation/mean DF × 100%) of DF. PR is the ratio of the power (amplitude) of the postprandial to the fasting DF peak.

Statistical analysis

Statistical analysis was first carried out as a descriptive evaluation (median, 5/95 percentiles). Data from preprandial and postprandial periods within the same subject were compared using a Wilcoxon matched pairs test. A Wilcoxon Mann–Whitney U test was performed to compare data between the groups. Correlations were tested for significance with a Spearman rank test. The results were regarded as significant when the error probability was less than 0.05.

RESULTS

Electrogastrography in healthy subjects and diabetics

The EGG variables, including DF, percentage of DF in the normal range, bradygastria, tachygastria, DFIC, and PR, did not differ significantly between control subjects and diabetics (Table I). Both groups showed a predominance of DF in the normal frequency range. Bradygastrias and tachygastrias were significantly less common in both the preprandial and postprandial period in diabetics and controls ($p < 0.05$). In

Table III. Comparison of electrogastrographic (EGG) variables* in diabetics with delayed gastric emptying and diabetics with normal gastric emptying (median, percentiles)

	Diabetics with delayed gastric emptying (n = 7)	Diabetics with normal gastric emptying (n = 11)	Wilcoxon Mann–Whitney U test
EGG preprandial			
DF (cpm)	2.8 (2.1–3.18)	2.8 (2.1–3.3)	NS
DF in normal range (%)	84.1 (63.2–98.2)	71.9 (51.6–98.2)	NS
Bradygastria (%)	0 (0–15.9)	8.9 (0–25.8)	NS
Tachygastria (%)	0 (0–8.8)	3.5 (0–22.6)	NS
DFIC (%)	15.0 (5.0–29.0)	27.0 (9.0–38.0)	NS
EGG postprandial			
DF (cpm)	2.8 (1.9–3.3)	3.1 (1.6–3.5)	NS
DF in normal range (%)	78.9 (71.9–94.7)	94.7 (70.2–100)	NS
Bradygastria (%)	0 (0–14.0)	0 (0–5.3)	NS
Tachygastria (%)	1.8 (1.8–14.0)	0 (0–15.8)	NS
DFIC (%)	13.0 (4.0–34.0)	9.0 (3.0–29.0)	NS
PR	1.0 (0.7–4.1)	2.7 (0.4–24.1)	NS

* DF = dominant electric frequency; DFIC = dominant frequency instability coefficient; PR = postprandial to fasting power ratio.

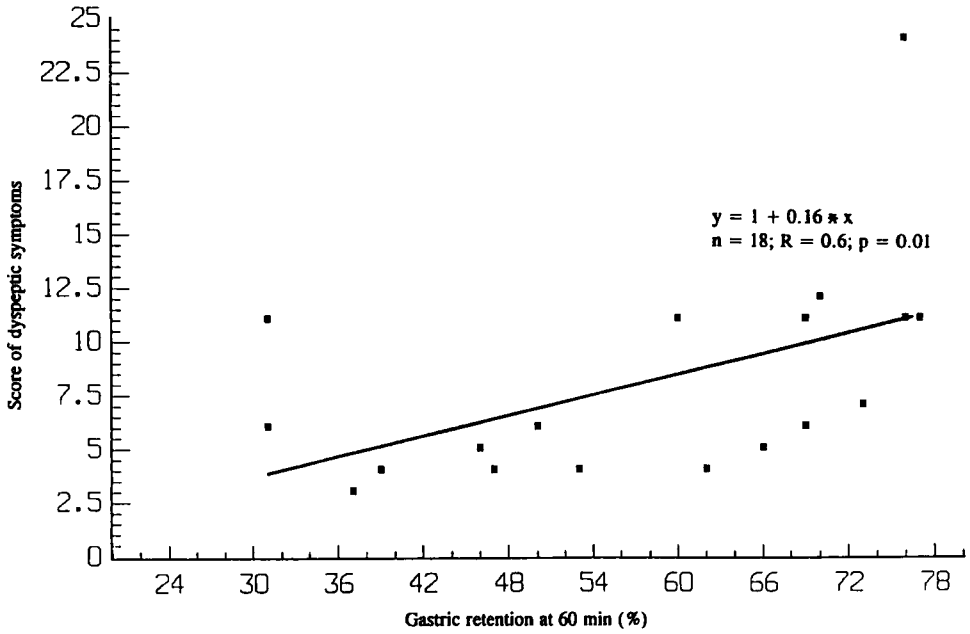

Fig. 2. Correlation between gastric retention of the radionuclide at 60 min and dyspepsia.

the postprandial electrogastrogram, an increase in DF and power and a decrease in DFIC could be considered in both groups. However, both the electric frequency and the power ratio showed a wide variation in controls and diabetics.

There was no significant correlation between EGG and clinical variables, including age, gender, body mass index, insulin dosage, duration of known diabetes mellitus, blood glucose, HbA1 level, and score of autonomic neuropathy.

Radioscintigraphy in diabetics

The scintigraphic t 60 values ranged from 31% to 77% (median, 61%). Compared with normal gastric emptying values previously reported (9) (upper limit for gastric retention at 60 min, 68%), seven diabetics showed a delayed gastric emptying (median t 60, 70%; 5/95 percentiles, 69–76%). The remaining 11 diabetics had a normal gastric emptying (median t 60, 46%; 5/95 percentiles, 31–62%). Gender, body mass index, insulin dosage, duration of known diabetes mellitus, blood glucose, HbA1 level, and score of autonomic neuropathy did not correlate significantly with t 60 values. However, age showed a moderate significant correlation with the t 60 values, with older diabetics having prolonged gastric emptying times ($R = 0.5$; $p = 0.02$). None of the clinical variables correlated with the lag times, ranging from 0 to 14 min (median, 0 min).

Electrogastrography and radioscintigraphy in diabetics

The variables DF, percentage DF in normal range, bradygastria, tachygastria, DFIC, and PR did not correlate significantly with the scintigraphic t 60 values ($p > 0.05$) (Table II). In addition, no correlation with lag times could be found. Moreover, the EGG values obtained in 7 diabetics with and 11 diabetics without gastroparesis did not differ significantly (Table III).

Correlation of dyspepsia with radioscintigraphy and electrogastrography

The median dyspeptic score in the diabetics was 6 points (range, 3–24 points). The median dyspeptic score in diabetics with delayed gastric emptying (11 points; range, 6–24 points) was higher than in those with normal gastric emptying (4 points; range, 3–11 points) ($p = 0.004$). There was a significant correlation between dyspepsia and scintigraphic t 60 values ($R = 0.6$; $p = 0.01$) (Fig. 2). In contrast, a significant correlation with the EGG variables could not be observed.

DISCUSSION

Pathologic findings in EGG have been associated with different gastrointestinal diseases. Gastric electric abnormalities like tachygastria, dysrhythmia, or disturbance of power have been considered in patients with dyspepsia (8, 10–12), diabetic gastroparesis (13, 14), hyperglycemia (15), gastric cancer (16), highly selective vagotomy (17), anorexia nervosa (18), and other conditions (19). Although the clinical significance of the electrogastrographic abnormalities is still uncertain, partly because EGG abnormalities have not been shown to be more than 'associated with' specific gastrointestinal diseases (3), EGG is by some authors accepted as providing useful information for clinical diagnosis (4). Others, however, feel considerable doubt about the clinical application of EGG at present (20).

Noninvasive EGG has been proposed for the diagnosis of diabetic gastroparesis (14), which has been increasingly recognized as a frequent phenomenon in patients with long-standing insulin-treated diabetes mellitus (21). Therefore, we investigated the clinical application of EGG in insulin-treated type-II diabetics with chronic dyspepsia by both comparison with healthy subjects and correlation to radioscintigraphy.

First of all, there was no significant difference in EGG between diabetics and healthy subjects. Both groups showed a predominance of the normal gastric electric rhythm in both the preprandial and the postprandial state. Nevertheless, as in healthy subjects (22), the percentages of normal frequency range, bradygastria, and tachygastria varied considerably in diabetics, indicating that, in contrast to the opinion of others, the existence of bradygastria and tachygastria alone cannot be considered a pathologic finding.

Like the controls the diabetics showing an increase in the electric frequency and a decrease in the instability of electric frequency in the postprandial state, which may reflect a normal antral myoelectric activity. In addition, as in healthy subjects, the amplitude (power) increased in the postprandial electrogastrogram in diabetics. Whereas in another study an absence of the normal postprandial amplitude increase in patients with unexplained nausea and vomiting was observed (8), we could not find this phenomenon. However, the power ratio showed an enormous variation both in controls and diabetics, which diminishes the diagnostic value of this variable. Moreover, it has previously been shown that the electric amplitude does not reflect gastric mechanical activity reliably (23, 24). The postprandial increase in electric amplitude obviously appears to be the result also of the gastric antrum approaching the abdominal surface. Therefore, in our opinion, the magnitude of the electric amplitude is not a useful EGG variable.

Besides lack of gastric electric differences between diabetics and control subjects the EGG variables did not correlate with radioscintigraphy. In the present study—making use of ^{99m}Tc colloid incorporated in the liquid phase, which becomes partially absorbed by the solid phase (up to 50%) (25)—gastric emptying rates thus reflect emptying of the aqueous phase and, in part, the solid phase (26, 27). Whereas about 40% of the diabetics had delayed gastric emptying, EGG could not provide electric abnormalities. Moreover, the EGG values in diabetics with gastroparesis did not differ from those obtained in diabetics with normal gastric emptying.

In agreement with other authors, we found a significant correlation of dyspeptic symptoms with a prolonged gastric emptying as evaluated by radioscintigraphy (21, 28). However, dyspepsia did not correlate with EGG.

In conclusion, EGG performed in insulin-treated type-II diabetics with dyspepsia, partly showing delayed gastric emptying, does not deviate from that in healthy subjects and does not correlate significantly with radioscintigraphy. Therefore, in agreement with Smout et al. (29), EGG is not a reliable tool for assessing gastric motility and emptying. A clinical application of electrogastrography in the diagnosis of diabetic gastroparesis cannot be recommended.

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