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Dynamics of Level of Randomness of Electrogastrograms Can Be Indicative of Gastric Electrical Uncoupling in Dogs

CLAUDIA P. SANMIGUEL, MD, MARTIN P. MINTCHEV, PhD, and KENNETH L. BOWES, MD

Gastric electrical uncoupling is the lack of electrical synchronization in different parts of the stomach. The aim of this study was to investigate the impact of gastric electrical uncoupling on the level of randomness of canine electrogastrograms (EGG). Electrogastrograms were obtained from 11 unconscious acute dogs. Gastric electrical uncoupling was produced surgically by performing two consecutive circumferential cuts through the entire thickness of the gastric muscle layer. Three separate 1/2-hr eight-channel bipolar EGGs were obtained from each dog in the basal state and after each cut. The signals were amplified using amplifiers with a flexible frequency range, digitized with 10-Hz sampling frequency, and 4.27-min portions of the digital EGGs were subjected to a turning point test for randomness. The number of turning points (NTPs) was determined from successive time intervals calculated from all EGG channels. Distributions of NTPs were calculated for each dog. An average NTPs (ANTP) for each dog in a given state (basal, after the first cut, and after the second cut) was calculated from the ANTPs of all channels. In six of 11 dogs the ANTP were greater after the first cut. The number rose to nine of 11 dogs after the second cut. In only 45% of the dogs were the ANTP distributions significantly different ($P < 0.01$) after the first cut (sensitivity 45%). After the second cut the sensitivity rose to 64%. In two specific EGG channels NTP distribution was significantly different ($P < 0.01$) in nine of 11 dogs (sensitivity: 82%) after the second cut. The dynamics of the level of randomness in EGG can be indicative of severe gastric electrical uncoupling. Some EGG channel configurations are more sensitive than others in recognizing gastric electrical uncoupling.

KEY WORDS: gastric electrical activity; electrogastrography; randomness; gastric electrical uncoupling.

Gastric emptying of solids depends mainly on coordination of propulsive movements in the distal stomach and on the antropyloroduodenal motor function (1–3). This mechanism is modulated by many factors, such as gastric electrical activity (GEA) and some hormones, but the principal influence seems to be exerted by intrinsic and extrinsic neural control (4–6). It has been shown that the disruption of the intramural innervation, gastric electrical uncoupling, causes important alterations of the gastric motor function (7–9). These alterations include disorganization of the coordination of contractions in the distal stomach and destabilization of the electrical rhythm, which along with other modifications induced by the electrical uncoupling cause delayed gastric emptying of solids and semisolids (9).

These findings clarify the important clinical value of assessing gastric electrical uncoupling. Several non-

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From the Departments of Surgery and Electrical Engineering, University of Alberta, Edmonton, and University of Calgary, Calgary, Alberta, Canada.

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Address for reprint requests: Dr. Martin Mintchev, Department of Electrical and Computer Engineering, University of Calgary, 2500 University Drive N.W., Calgary, Alberta T2N 1N4, Canada.

Cutaneous Canine EGG

Channel	Electrode Combination
7	1 - 2
8	2 - 3
9	3 - 4
10	4 - 5
11	1 - 3
12	1 - 4
13	2 - 5
14	1 - 5

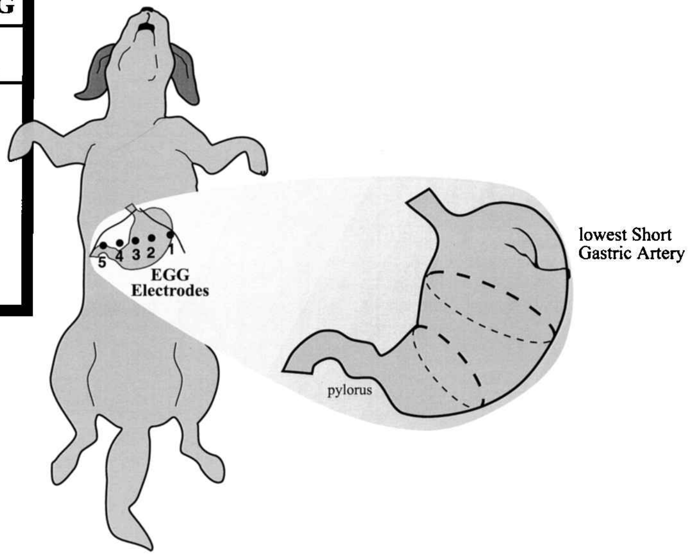

Fig 1. Channel combinations used for the canine recordings. An eight-channel bipolar EGG recording system was used to acquire the GEA signals using cutaneous electrodes placed on the abdominal wall. The electrode arrangement on the abdomen is depicted on the right as is the position of the circumferential gastric myotomies.

invasive methods to investigate this motor alteration have been studied. It was thought that measuring the time shifts in different electrogastrographic (EGG) channels could detect this alteration (10). It was shown later that time shifts recorded cutaneously were insignificant and inconsistent and, therefore, they could not be regarded as a reliable tool to detect gastric electrical uncoupling (11, 12). It was also suggested that EGG waveform dynamics could be an alternative procedure to investigate the propagation of GEA (13). Unfortunately, it was found that changes in the EGG waveform are seen sporadically in healthy volunteers and that many external factors could alter the morphology of the EGG without any significant internal alteration of the GEA (12). A recent study using a canine model revealed that severe gastric electrical uncoupling could be detected by an appropriate quantification of EGG frequency dynamics (14). In the present study we suggest a different approach for recognizing gastric electrical uncoupling based on the assessment of the EGG randomness dynamics in an acute canine model.

MATERIALS AND METHODS

After a 24-hr fast, 11 acute anesthetized dogs underwent laparotomy under Pentothal anesthesia (Abbott, Montreal, Quebec, Canada). The initial dosage of anesthetic was 30 mg/kg and was supplemented with 3 mg/kg as needed, based on monitoring the restoration of the blinking reflex. During the procedure, the distance from the pylorus to the gastroesophageal junction (GEJ) on the lesser curvature and the distance from the pylorus to the lowest short gastric artery were measured. At different times during the experiment, two circular myotomies of the whole gastric muscle layer around the entire circumference of the stomach were done at one third and two thirds of the above distances (Figure 1). The stomach was thus divided in three roughly similar portions by these cuts. The cuts were done using cautery, and the divided gastric portions were not reanastomosed but were left in their normal positions. During the procedure, gastric blood supply was carefully preserved. After each cut the abdominal wall was scrupulously closed and five neonatal ECG electrodes (Conmed, Andover Medical, Haverhill, Massachusetts) were positioned on the skin of the abdominal wall overlaying the stomach axis (Figure 1). During the EGG acquisition an eight-channel bipolar recording system was utilized, which allowed for investigation of GEA using short- and long-distance channels. Half-hour cutaneous EGGs were recorded in each dog during the basal state, after the first cut (distal to the GEJ), and after the second cut (proximal to the GEJ). The dogs rested quietly in the supine position during the EGG recording sessions, and the locations of the electrodes were maintained constant during all experiments.

EGG signals were filtered in the frequency band of 0.02–0.2 Hz. The signals were amplified and digitized with 10-Hz sampling frequency using a LABMASTER 20009 16-channel analog-to-digital converter (Scientific Solutions, Vancouver, British Columbia, Canada) controlled by an IBM PC 486-66 MHz using locally designed software. The signals were further filtered using digital Hartley filters (15) in adequate ranges allowing for a reduction of the sampling frequency to 2 Hz.

TABLE 1. TYPICAL EXAMPLE OF DISTRIBUTION OF NTP IN BASAL STATE AND AFTER FIRST AND SECOND CIRCUMFERENTIAL MYOTOMY*

	Number of turning points (±SD)			P	
Channel	*No cut*	*1 cut*	*2 cut*	*0–1 cut*	*0–2 cut*
7	89 (11.08)	116 (17.2)	158.3 (20.3)	0.01†	0.01†
8	87.3 (11.4)	108 (5.4)	210.8 (12.7)	0.005†	8.9×10^{-9}†
9	83.6 (10.5)	79 (9.1)	116.6 (5.7)	0.43	0.001†
10	82.5 (11.9)	79 (9.0)	119.6 (3.2)	0.58	0.0004†
11	96 (15.8)	121 (9.0)	116.5 (6.6)	0.01†	0.02
12	87.8 (11.5)	90.5 (10.7)	156.1 (29.1)	0.68	0.001†
13	101.8 (12.1)	103.5 (7.6)	168 (18)	0.78	4.6×10^{-5}†
14	98.5 (10.6)	112.3 (3.3)	134.8 (4.8)	0.02	0.0001†
Average	90.8	101.1	147.6		

* The increment in the NTP after each cut is evident. The percentage of statistically significant changes in the NTP distributions increased after the second myotomy.
† Statistically significant.

Dynamics of the level of randomness of digital EGG recordings were assessed using the turning point test (16, 17). A turning point is a peak or trough in every three consecutive digits of a given digital EGG wave. A software algorithm was developed to calculate the distributions of the number of turning points (NTPs) in each EGG channel in each dog during the three different states. The mean value of the NTP distribution for a given EGG channel was obtained from averaging the NTP calculated from successive 4.27-min time intervals. An overall average NTP (ANTP) distribution for each dog in a given state (basal, after the first cut, and after the second cut) was calculated by averaging the mean values of the NTP distributions of all channels.

The eight NTP distributions (one for each channel) and the single ANTP distribution obtained from each dog in each state were submitted to statistical analysis using a paired Student *t* test (MS Excel 97, Microsoft Corp., Redmond, Washington) (18). $P < 0.01$ was considered significant.

The study was approved by the University of Alberta Animal Welfare Committee.

RESULTS

In nine of the 11 dogs the NTP distribution in each EGG channel in the basal state showed low NTPs (108.4 ± 16.3). After the first antral cut, which uncoupled the antrum below the cut from the proximal part of the stomach, the NTP showed a tendency to increase (123.9 ± 32.7). After the second cut, which resulted in three uncoupled gastric regions, the increase in the NTP was more obvious (143.6 ± 29.1) and became significant ($P < 0.01$). A typical example of these findings is shown in Table 1.

In six of 11 dogs, the mean values of the ANTP distributions were greater after the first cut. The number of dogs with greater ANTP distributions compared to the basal state rose to nine of 11 after the second cut (Table 2, Figure 2a and 2b). In only five of 11 of the dogs were the ANTP distributions

TABLE 2. DISTRIBUTION OF ANTP IN ALL DOGS IN DIFFERENT STATES*

	Number of turning points (±SD)			P	
Dog	*No cut*	*1 cut*	*2 cut*	*0–1 cut*	*0–2 cut*
1	90.8 (7.09)	101.1 (16.4)	147.5 (32.6)	0.12	0.0002†
2	171.3 (5.7)	145.9 (14.8)	163.5 (16.9)	0.0004†	0.23
3	87.2 (26.9)	146.1 (38.1)	179.6 (19.5)	0.003†	1.7×10^{-6}†
4	134.5 (4.1)	164.6 (21.1)	153.9 (9.8)	0.001†	0.0001†
5	78.9 (18.8)	75.1 (17.3)	113.0 (10.9)	0.67	0.0005†
6	107.1 (14.6)	141.4 (20.1)	153.4 (7.54)	0.001†	1.4×10^{-6}†
7	140.2 (9.8)	153.9 (11.1)	162.8 (9.0)	0.027	0.0004†
8	118.5 (14.0)	105.8 (14.6)	133.7 (28)	0.09	0.19
9	134.2 (29.3)	126.6 (15.5)	155.6 (9.4)	0.52	0.068
10	165.6 (16.0)	109.9 (11.3)	114.4 (16.6)	1.3×10^{-6}†	2.0×10^{-5}†
11	85.6 (31.4)	92.8 (8.9)	102.2 (20.0)	0.54	0.22
Average	119.6	123.9	143.6		

* The tendency for increment in the ANTP after each myotomy is clearly seen. The ANTP distributions tended to increase their statistical significance after the second cut.
† Statistically significant.

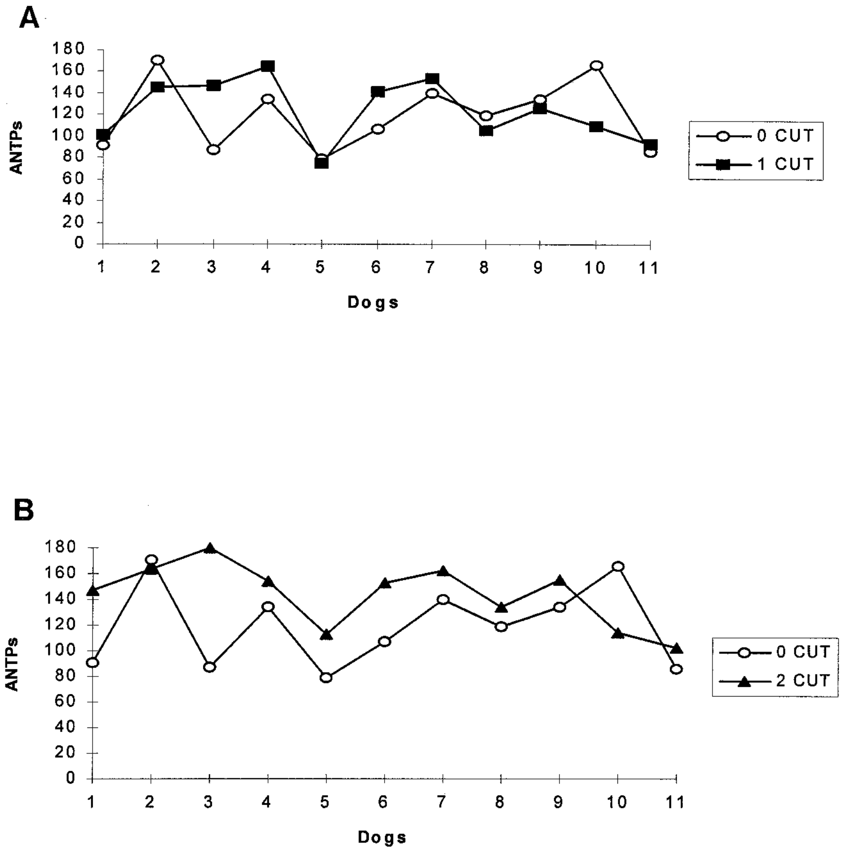

Fig 2. Typical distributions of the average of number of turning points (ANTP) in the basal state and after the first gastric myotomy (A) and in the basal state and after the second myotomy (B). The increment in the ANTP after the second cut is evident in most of the cases. After the first cut, however, the changes were marginal.

after the first cut significantly greater than the distributions in the basal state ($P < 0.01$), giving a sensitivity of detecting mild gastric electrical uncoupling of 45%. After the second cut the sensitivity of detecting severe gastric electrical uncoupling rose to 64% (seven of 11 dogs, Table 2).

In all dogs the average of the EGG channels in which the changes in the NTP distributions were statistically significant ($P < 0.01$) was five of eight during severe uncoupling (after the second cut). This average was lower during mild uncoupling (four channels). With the configuration of the EGG acquisition system used in this study, two EGG channels showed significant higher sensitivity in detecting gastric electrical uncoupling (channels 10 and 12, see Figure 1). In these channels, the NTP distributions were significantly different ($P < 0.01$) in nine of 11 dogs (sensitivity: 82%) after the second cut, while in another EGG channel (channel 14, see Figure 1) such significance was noted in only three dogs (27%) (Table 3). The configurations of the sensitive channels were different: one of them was a short-distance (2.5 cm) bipolar channel and the other was a long-distance (8.0 cm) bipolar channel.

DISCUSSION

This study explored a new approach to assess gastric electrical uncoupling investigating the dynamics of randomness in EGG. The suggested method is based on the calculation of the NTP in successive 4.27-min intervals and building their distribution in a given EGG channel during the entire period of recording. The method was previously applied to a comparative study of internal and cutaneous recordings of GEA in the basal state of dogs and humans (19). In the present study experimentally controlled uncoupling was introduced in dogs, and its impact on the level of randomness of EGG was quantitatively examined.

TABLE 3. RELIABILITY OF DIFFERENT CHANNEL CONFIGURATIONS IN DETECTING GASTRIC ELECTRICAL UNCOUPLING*

	Dogs in which NTP was significantly different (P < 0.01)	
EGG channel	*0–1 cut*	*0–2 cut*
7	3 (27%)	7 (67%)
8	7 (67%)	8 (73%)
9	6 (54%)	8 (73%)
10	7 (67%)	9 (82%)
11	6 (54%)	8 (73%)
12	6 (54%)	9 (82%)
13	7 (67%)	6 (54%)
14	8 (73%)	3 (27%)

* The percentage of detection of the alterations in GEA propagation was greater after the second myotomy (severe uncoupling). Some channel configurations were more sensitive than others.

This alternative method of analysis revealed that there is a tendency for an increase in the NTP after each circumferential gastric myotomy. We would suggest that these changes in the NTP were due to a lack of adequate GEA propagation and the generation of spontaneous slow wave activity by foci located distal to the myotomies. This hypothesis is supported by prior studies reported by Bedi et al (7) and Bauer et al (8), which showed the formation of these foci with different slow-wave frequencies after gastric myomectomy, and by a recent study that indicated gastric electrical uncoupling altered the EGG waveform, increasing its frequency without any genuine internal tachygastria (14).

When the mean values of the ANTP were used to detect gastric electrical uncoupling, the sensitivity was high (82%) after the second gastric myotomy compared to the basal state. This finding is similar to the conclusions obtained in a prior study in which gastric electrical uncoupling was detected with high sensitivity only in cases of severe gastric uncoupling (14). The low sensitivity (45%) in detecting mild uncoupling reduces the clinical utility spectrum of this method to cases with severe uncoupling abnormalities.

During this study we utilized a multichannel EGG acquisition system that combines short- and long-distance bipolar channels. Using this system, we were able to detect statistically significant changes in the NTP between the basal state and the second cut in at least two EGG channels (average: five channels). This finding is very encouraging because it suggests a high sensitivity of the EGG test in detecting gastric electrical uncoupling. Another interesting finding in this study was the presence of EGG configurations that were more sensitive in detecting gastric electrical uncoupling than other configurations. For example, channels 10 and 12 in our configuration (see Figure 1) proved to be the most sensitive in detecting alterations of the GEA propagation, and this might be related to their specific location. On the other hand, one EGG channel (channel 14) persistently showed reduced sensitivity in detecting uncoupling. This different sensitivity underlines the necessity for a multichannel EGG recording system and the use of a statistical approach in evaluating the recordings.

CONCLUSIONS

Our study showed that severe gastric electrical uncoupling can be detected with high sensitivity by studying the dynamics of randomness in specific EGG channels. It is also evident that some channel configurations can be more useful for this purpose than other configurations, and in such situations the benefits of multichannel EGG recordings could be significant.

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