Reliability of Percent Distribution of Power of the Electrogastrogram in Recognizing Gastric Electrical Uncoupling

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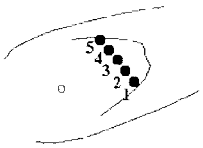
Abstract—**The aim of this study was to examine the reliability of percent distribution of electrogastrographic (EGG) power in recognizing gastric electrical uncoupling. Sixteen anaesthetized dogs underwent laparotomy and implantation of six pairs of stainless-steel wire electrodes. Distal stomach was measured and three sections with approximately equal lengths were defined. Two pairs of electrodes were implanted in each section. Eight-channel EGG was also recorded. Three separate half-hour recordings were made: in the basal state; after a full circumferential separation of the distal antral section from the rest; after a second circumferential cut completely separating the middle from the proximal sections. EGG digital power spectra were split into three frequency ranges and dynamics of percent distribution of power was statistically examined. After the first cut, changes in the percent distribution of EGG power in the normal range were not significant ($p = 0.2$). Significant changes in the low range were noted ($p < 0.05$) and changes in the high range were borderline nonsignificant ($p = 0.056$). After the second cut, changes in percent distribution in the normal and the high range became significant ($p < 0.01$) while changes in the low range were insignificant ($p = 0.075$). Severe uncoupling was reflected in EGG by significant changes in the high-frequency range without internal tachygastria necessarily being present.**

Index Terms—**Electrogastrophy, gastric electrical uncoupling.**

Cutaneous Canine EGG:

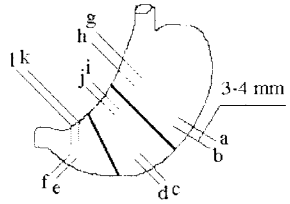
Channel	Electrode Combination
7	1-2
8	2-3
9	3-4
10	4-5
11	1-3
12	1-4
13	2-5
14	1-5



(a)

Internal Canine GEA:

Channel	Electrode Combination
1	a-b
2	c-d
3	e-f
4	g-h
5	i-j
6	k-l



(b)

Fig. 1. (a) Cutaneous and (b) internal electrode configurations used in the canine experiments. Internal electrodes a to f were implanted on the anterior gastric wall from the serosal side; electrodes g–l were implanted on the posterior wall. The first circumferential cut was performed along the line between electrode pairs e-f/l-k and c-d/i-j separating the distal from the proximal section. The second cut separated the electrode pairs a-b/g-h (the proximal section) from the middle section.

I. INTRODUCTION

The dynamics of the percent distribution of the frequency components in the electrogastrographic (EGG) power spectra was claimed to be a reliable representation of the dynamics of gastric electrical activity (GEA, [1]–[3]). However, no comparative study has been conducted to explicitly show that a shift of the EGG percent distribution toward higher or lower frequencies definitely means increased internal tachygastria or bradygastria [4], [5]. Moreover, it has been assumed that the dynamics of percent distribution would represent the dynamics of internal GEA frequency changes only. Gastric electrical uncoupling [6], a phenomenon which is far more likely to be related to an abnormal gastric function than occasional or even persistent frequency changes, could not be quantitatively evaluated from cutaneous EGG.

The aim of this study was to examine the reliability of percent distribution of EGG power in recognizing gastric electrical uncoupling. The study explored also the possibility that higher EGG frequency range could be affected by gastric electrical uncoupling alone, without higher-frequency GEA being present internally.

II. METHODS

Sixteen anaesthetized dogs underwent laparotomy and implantation of six pairs of internal stainless-steel wire electrodes. Gastric antrum was measured and three sections with approximately equal lengths were defined. Two pairs of electrodes were implanted in each section, one on the anterior and one on the posterior gastric wall from the serosal side. Eight-channel EGG was also recorded (Fig. 1). Three separate half-hour recordings were made: in the basal state; after a full circumferential separation of the distal antral section from the proximal stomach; after a second circumferential cut completely separating the middle from the proximal sections. EGG recordings were amplified, bandpass filtered (0.01–0.2-Hz, 2-pole Butterworth analog active filter), and digitized with 10-Hz sampling frequency using a locally designed multichannel electronic system. After the data acquisition, additional digital filtering was performed in the same frequency range and a new, lower sampling frequency of 2 Hz was introduced. Fast Hartley transform (a real-number equivalent of the fast Fourier transform, [7]) and a locally designed software system were used to convert successive 256-s intervals (75% overlap) from the time-domain EGG signals into frequency domain. EGG power spectra were split into three frequency ranges: low (0.1–3 cpm), normal (3–7 cpm), and high (7–18 cpm, Fig. 2). The percentage distribution of frequency power in the kth frequency range ($k = 0$ for the low-frequency range, $k = 1$ for the normal range, and $k = 2$ for the high-frequency range) was calculated for each spectrum according to the following expression:

$$D_k = \frac{\sum_{i=r_{0k}}^{r_{Lk}} S_i}{\sum_{j=r_{00}}^{r_{L2}} S_j} \cdot 100\% \tag{1}$$

Manuscript received October 11, 1996; revised June 12, 1997. *Asterisk indicates corresponding author.*

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Publisher Item Identifier S 0018-9294(97)07605-2.

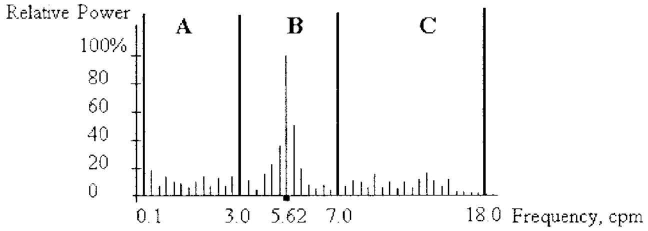


Fig. 2. Typical canine EGG power spectrum in the basal period. EGG power spectra were split into three frequency ranges—A (low), B (normal), and C (high). Typical canine EGG power spectrum in the basal period.

where D_k was the percent distribution value of a given EGG channel in the kth frequency range, r_0 and r_L were the indices of the first and the last frequency component in a given range k ($k = 0, 1,$ or 2), and S represented a given power spectrum component. Note that the distributions were normalized with respect to the total power in all three ranges. The averaged percent distribution of all EGG channels of the jth dog in the kth frequency range was calculated with

$$\mathrm{AD}_{kj} = \frac{\sum_{i=0}^{M-1} D_{kji}}{M} \tag{2}$$

where M is the number of EGG channels and D_{kji} is the percent distribution value of the ith EGG channel in the kth range for the jth dog. Using (2) one averaged spectrum was obtained from each dog every 256 s. The number of successively calculated spectra P per dog per condition (basal, after the first cut, and after the second cut) is given with

$$P = \frac{T * 60}{I - I * OVL} \tag{3}$$

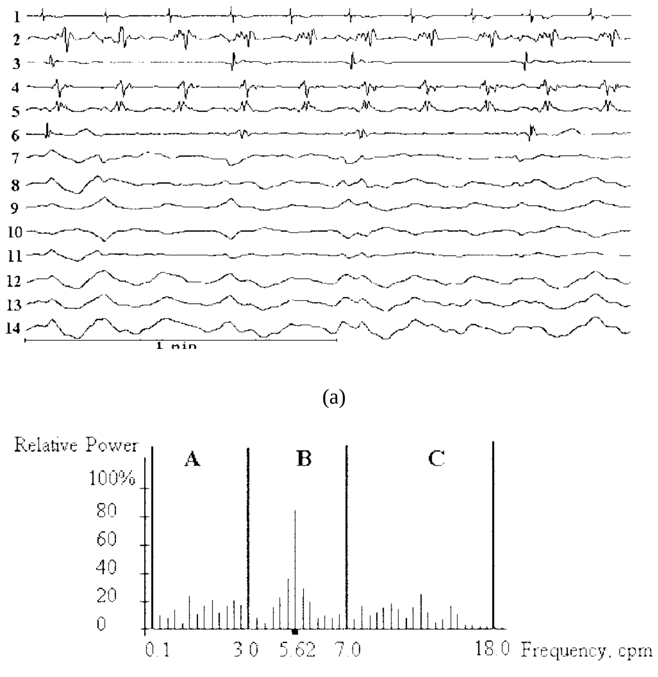
where T is the duration of the test per condition in min (30), I is the duration of the time segment from which a given spectrum has been calculated (256 s), and OVL is the percentage of the overlap used. With an overlap of 75%, this gave 28 spectra per dog, per condition (basal, after the first cut, and after the second cut). The respective percent distributions were averaged once again, this time according to the following equation for the jth dog:

$$\mathrm{AAD}_{kj} = \frac{\sum_{l=0}^{P-1} \mathrm{AD}_{kjl}}{P}. \tag{4}$$

Percent distribution values AAD_k-B (for the low, normal, and high frequency ranges, $k = 0, 1,$ or 2) obtained in the basal state from all 16 dogs were considered expected values, giving a degree of freedom 15 for the statistical evaluations. Percent distribution values AAD_k-1 and AAD_k-2 after each of the two circumferential cuts were statistically compared to the sets of expected values AAD_k-B using a standard Chi Square test for significance (8, MS Excell versus 5.0, Microsoft Corp., Redmond, WA).

III. Results

The first circumferential cut uncoupled the distal antral segment from the rest (Fig. 3) and in the majority of the time (over 90%) the frequency of the uncoupled segment was lower (Table I, see Channels 1–6). Change in the percent distribution of EGG power in the normal range was not significant $(p = 0.2)$. However, significant changes in the percent distribution in the low-frequency ranges were noted $(p < 0.05)$, and changes in the percent distribution in the high-frequency range were borderline nonsignificant $(p = 0.056)$.



(a)

(b)

Fig. 3. Electrical uncoupling of the distal antral segment (electrode pairs f-e and l-k, Channels 3 and 6) from the rest after the first circumferential cut. Channels 7–14 are (a) EGG; (b) corresponding averaged EGG spectrum is shown.

TABLE I

Typical Mean Value (MV) of the Dominant Spectral Peaks Calculated Every 256-s (75% Overlap) and Their Standard Deviation (sd) After the First Circumferential Cut. Channels 1–6 Measured Internal GEA, 7–14 Were EGG

Change	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MV [cpm]	5.2	5.2	4.7	5.3	5.2	4.6	5.1	4.2	3.7	3.7	4.3	5.1	4.8	5.0
sd [cpm]	0.1	0.1	1.2	0.2	0.1	1.4	0.2	1.6	1.7	1.7	1.7	0.3	0.3	0.4

TABLE II

Typical Mean Value (MV) of the Dominant Spectral Peak Calculated Every 256-s (75% Overlap) and Their Standard Deviation (sd) After the Second Circumferential Cut. Channels 1–6 Measured Internal GEA, 7–14 Were EGG. Increased sd in the EGG Channels Is Clearly Evident

Change	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MV [cpm]	5.6	4.7	3.6	5.7	4.6	3.8	5.7	6.2	5.9	5.3	6.1	5.8	5.3	5.6
sd [cpm]	0.2	0.4	1.4	0.2	0.3	1.2	1.5	2.0	2.1	1.8	2.1	1.7	1.6	1.3

After the second circumferential cut, which resulted in three distinct internal frequencies with the frequency of the most distal segment being the lowest (Fig. 4, Table II, see Channels 1–6), the change in percent distribution of power in the normal range became significant $(p < 0.006)$, while changes in the low-frequency range became insignificant $(p = 0.075)$. The most dramatic change was in the significant increase of the power distribution in the high-frequency range after the second cut $(p < 0.001)$, implying that the EGG spectral components shifted remarkably to the right of the frequency spectra after introducing severe electrical uncoupling internally.

Table III represents a summary of the changes in the averaged percent distributions of EGG power in the basal state and after the first and the second circumferential cuts in all dogs.

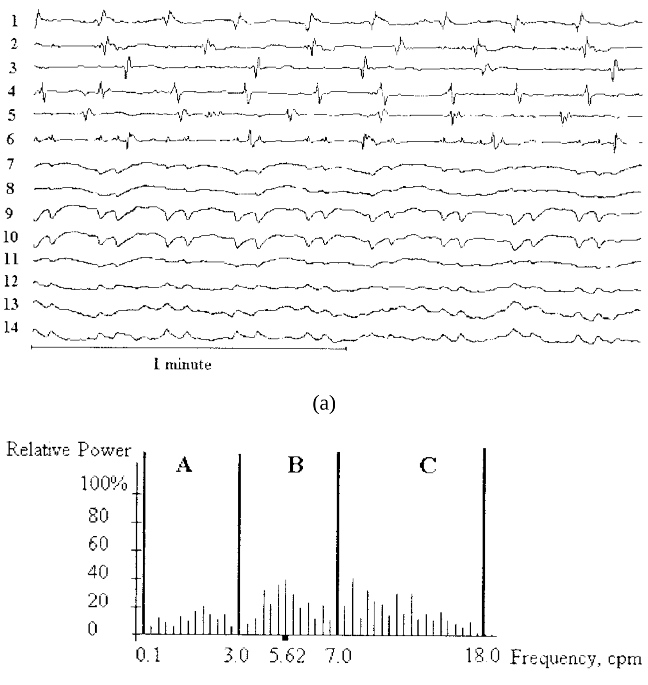
TABLE III
CHANGES IN THE AVERAGE PERCENT DISTRIBUTIONS OF EGG POWER IN DIFFERENT FREQUENCY RANGES AFTER THE FIRST AND THE SECOND CIRCUMFERENTIAL CUT

Dog	Condition	Average percent distribution in the low range (%)	Average percent distribution in the normal range (%)	Average percent distribution in the highrange (%)
1	Basal	7.8	69.4	22.8
1	After the first cut	6.9	64.7	28.4
1	After the second cut	8.1	8.1	8.1
2	Basal	9.8	58.3	31.9
2	After the first cut	15.1	54.6	30.3
2	After the second cut	13.5	48.3	38.2
3	Basal	17.5	51.4	31.1
3	After the first cut	14.1	65.9	65.9
3	After the second cut	18.2	35.5	46.3
4	Basal	10.9	63.6	25.5
4	After the first cut	17.4	54.2	28.4
4	After the second cut	14.3	58.4	27.3
5	Basal	10.1	63.8	26.1
5	After the first cut	7.3	52.3	40.4
5	After the second cut	12.1	51.8	36.1
6	Basal	8.3	43.2	48.5
6	After the first cut	7.4	60.4	32.2
6	After the second cut	16.5	44.4	39.1
7	Basal	14.1	64.1	21.8
7	After the first cut	15.3	58.7	26.0
7	After the second cut	17.8	49.6	22.6
8	Basal	19.7	39.0	41.3
8	After the first cut	13.0	41.2	45.8
8	After the second cut	11.0	38.9	50.1
9	Basal	11.8	68.7	20.5
9	After the first cut	15.4	15.4	22.2
9	After the second cut	16.9	53.9	29.2
10	Basal	7.6	53.3	39.1
10	After the first cut	9.2	56.8	34.0
10	After the second cut	9.6	52.8	37.6
11	Basal	15.3	48.8	35.9
11	After the first cut	15.7	42.5	42.5
11	After the second cut	15.0	41.5	43.5
12	Basal	8.8	49.4	41.8
12	After the first cut	17.1	43.8	39.1
12	After the second cut	13.0	35.2	51.8
13	Basal	12.0	47.9	39.1
13	After the first cut	11.8	53.9	34.3
13	After the second cut	10.4	54.9	34.7
14	Basal	6.8	50.7	42.5
14	After the first cut	10.9	54.4	34.7
14	After the second cut	10.5	47.9	41.6
15	Basal	9.0	55.3	35.7
15	After the first cut	13.5	50.1	36.4
15	After the second cut	11.4	47.2	41.4
16	Basal	11.7	59.4	28.9
16	After the first cut	10.0	58.5	31.5
16	After the second cut	11.1	60.6	28.3

IV. DISCUSSION

Jokerst *et al.* [3] performed a theoretical study suggesting that monitoring the dynamics of percent distribution of EGG power is a reliable quantitative technique for evaluating EGG. In the present study we examined the ability of this method to recognize gastric electrical uncoupling. Interestingly, we observed that the percent distribution in the low-frequency range (labeled by Jokerst *et al.* as “bradygastria,” [3] significantly increased after the first circumferential cut $(p < 0.05)$, but did not change beyond the significance level $(p = 0.05)$ after the second cut, although more lower-frequency gastric signals were present internally because of the dual uncoupling. The percent distribution in the high-frequency range after the second cut, however, was significantly higher compared to the basal recording $(p < 0.001)$.

The fact that severe (after the second cut) gastric electrical uncoupling resulted in such significant increase of the percent distribution of EGG power in the high-frequency range without internal tachygastria necessarily being present indicates that cutaneously recorded “tachygastrias” could be a result of a simple mixture of internal uncoupled signals from multiple sites, each of which might oscillate at lower frequency. This possibility is amplified by the high level of significant difference (or, in other words, the very low p-value) between the percent distributions of the basal EGG spectra in the high-frequency range and the percent distributions of the spectra in



(a)

(b)

Fig. 4. (a) Severe electrical uncoupling was clearly seen in the internal (1–6) channels after the second circumferential cut. (b) Corresponding averaged spectrum is shown.

that range calculated after the second circumferential cut. The changes in the high-frequency range after the first cut were also close to being significant $(p = 0.056)$. Therefore, if percent distribution of EGG power is the only quantitative EGG technique used, genuine gastric dishythmia would be hardly separable from gastric electrical uncoupling, particularly if it is a multisite uncoupling. In such situations terms like "tachygastria" and "bradygastria" could be misleading.

Monitoring the dynamics of percent distribution of EGG power in the normal frequency range could probably reliably indicate severe gastric electrical uncoupling. However, the changes in the high- and low-frequency ranges should be considered with caution keeping in mind that EGG represents a nonlinear mixture of all internal GEA events.

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