SPECTRAL EVALUATION OF GASTRIC FUNCTION

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Analysis of the results and measurements of the basic electrical rhythm of the stomach [1-5] has led to the identification of the state of the gastric function in terms of spectral and self-oscillating concepts of the electrical activity of the gastric muscles.

This paper describes spectral evaluation of the electrical rhythm of the stomach in clinically healthy young individuals and also Fourier transforms of gastric electromyograms of dogs undergoing selective proximal vagotomy (SPV), receiving various drugs, and undergoing electrical stimulation of the gastric muscles.

EXPERIMENTAL METHOD

The electric field of the stomach was measured by means of resistive–capacitive electrodes and standard electromedical equipment in 53 clinically healthy young persons [3, 4]. Gastric electromyograms were studied and electrical stimulation, controlled by the basic electrical rhythms of the stomach, was applied to the organ in 7 dogs in 38 chronic experiments [1, 5] and also in 6 dogs subjected to SPV in acute experiments; the same technique [2], however, was used in both series of experiments.

EXPERIMENTAL RESULTS

It was shown previously that information on the functional state of the gastric smooth muscle is contained in the internal structure of its basic electrical rhythm [3, 4]. Accordingly, an essential task is autoregression analysis of the basic electrical rhythm of the stomach, which is urgently required for use in extracorporeal electrogastrography [3]. The solution to this problem is complicated by the fact that the real gastric electrical signal is masked by electrochemical polarization potentials of the heart, intestine, and other organs. To increase the stability of the autoregression estimates, the electrogastrogram must be represented in the frequency region as an evident function of time. The random sequence of momentary values of the period T of the basic electrical rhythm having been transformed for this purpose into a regular set of discrete values of momentary frequency F ($F = 1/T$) a temporal series is obtained, which can be called the electrogastrorhythmogram (EGRG). The internal structure of the EGRG, satisfying the conditions of steadiness of state and ergodicity (with an error of the order of 10%), was shown to be described by an autoregression process of the second to the fourth order, with the stomach at rest, and the eighth to the eleventh order during peristalsis. Accumulation of Fourier transforms of the EGRG of clinically healthy young persons demonstrates the presence of significant peaks of spectral density at frequencies of the order of $0.5/T_0$, when the stomach is at rest, and at frequencies of the order of 0.001 Hz during activity, verified roentgenologically (Table 1), where T_0 is the mathematical expectation of the natural frequency of the basic rhythm.

The high informativeness of Fourier transforms of the EGRG served as the basis for undertaking a study of self-oscillating properties of the gastric electromyogram.

Representation of electrical activity of the gastric muscle by means of a nonlinear diffusion equation, the righthand side of which is represented by density of the transmembrane current as a function of potential supplied by a system of equations of the Hodgkin–Huxley class [1], shows that the spread of the basic electrical rhythm of the stomach under normal physiological conditions is a dispersion wave process.

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TABLE 1. Fourier Transforms of EGRG of the Human Stomach at Rest and during Peristalsis

Criterion of optimality	Maximum of spectral density, Hz		Probability of error	
	rest	activity	of type I	of type II
Bayes	0.0241	0.0079	0.009	0.013
Minimal risk	0.0198	0.0095	0.014	0.011

Legend. 1. Estimates given for training sample, electrogastrograms recorded during 1 h after test meal (150 g of stewed lean beef). 2. Calculations done by the SOMI package of applied programs on the EC-1045 computer.

TABLE 2. Spectral Evaluation of Gastric Electromyogram of Dogs Subjected to SPV, to Pharmacologic Blockade of Cholinergic and Adrenergic Structures, and to Muscle-Controlled Electrical Stimulation of the Stomach

	State or stimuli	Maximum of spectral density, Hz	Probability of error	
			of type I	of type II
1	Control	0.078		
	Myoelectrical stimulation	0.121	0.17	0.14
2	Atropine	0.055		
	Atropine + myoelectrical stimulation	0.128	0.06 –	0.05 –
3	Atropine + propranolol + phentolamine	0.052		
	Atropine + propranolol + phentoalamine + myoelectrical stimulation	0.131	0.05	0.05
4	SPV	0.058		
	SPV + myoelectrical stimulation	0.136	0.04	0.04
5	SPV + atropine + propranolol + phentolamine + myoelectrical stimulation	0.143	0.98	0.97
6	SPV + atropine + phentolamine	0.140	0.99	0.98

Legend. 1. Probability of errors calculated by Neyman–Pearson test. 2. Significance of maxima of spectral density determined by chi-square test.

The self-oscillating properties of the basic electrical rhythm of the stomach can be used with advantage in applied research and, in particular, in connection with vagotomy. Attention must therefore be paid to previous results [2, 5] indicating the myogenic nature of the phenomenon of binding and self-stabilization of the frequency of the basic gastric electrical rhythm during stimulation of the gastric muscle; this also is confirmed by Table 2, which gives estimates of the spectral density of the EGRG of dogs undergoing selective proximal vagotomy, or receiving blocking drugs or controlled myoelectrical stimulation. Blocking muscarinic cholinergic structures was shown to lead to a significant (by 1.5-2 times) increase in the period T of the basic electrical rhythm of the stomach. Blockage of α- and β-adrenoreceptors slowed the basic rhythm of the stomach only a little (by not more than 10%) if muscarine-sensitive receptors were inactivated beforehand (Table 2). SPV caused an increase in the period T of the basic electrical rhythm of the stomach, comparable in magnitude with the action of atropine (Table 2). Selective denervation of the acid-forming zone of the stomach (by SPV), against the background of blockade of muscarinic acetylcholine receptors, and also of adrenoreceptors, leads to a decrease in the frequency of the basic electrical rhythm of the stomach by about 1.7-2 times (Table 2). Analysis of the facts given above showed us that the effectiveness of denervation can be assessed by the technique of stimulation controlled by electrical activity of the gastric muscle.

Muscle-controlled electrical stimulation in fact causes the frequency of the basic rhythm to rise by 25-40% [1, 2, 5]; the rule discovered previously, moreover, is also found to apply under acute experimental conditions (Table 2). Myoelectrical stimulation with feedback, against the background of SPV, also causes a greater increase (by 5-10%) in the frequency of basic electrical rhythm of the stomach, which is only slightly increased (by about 5%) if it is preceded by pharmacologic blockade of cholinergic and adrenergic structures (Table 2).

The results of this investigation thus demonstrate the important role of the extramural nervous system in the regulation of the frequency of the basic electrical rhythm of the stomach. It must be emphasized, in this connection, that acetylcholine receptor blockade reduces the frequency of the basic electrical rhythm of the stomach by 1.5-2 times, whereas α- and β-blockers cause virtually no significant changes in the frequency of this rhythm.

When the applied aspect of this investigation is discussed, the potential importance of the methodology of controlled myoelectrical stimulation of the gastric smooth muscles in the evaluation of gastric function by measurements of the EGRG must be emphasized, especially for confirming the completeness of vagotomy.

LITERATURE CITED

1. V. N. Ustinov, Biofizika, 31, No. 5, 871 (1986).
2. V. N. Ustinov and M. P. Papazova, Fiziol. Zh. SSSR, 60, 831 (1974).
3. V. N. Ustinov, M. A. Trunin, and M. F. Stoma, Klin. Med., No. 4, 50 (1988).
4. V. N. Ustinov, Automated Electronic Systems for Mass Prophylactic Examinations of the Population [in Russian], Leningrad (1985), p. 16.
5. M. Papazova (Papasova), V. Ustinov, Z. Mizhorkova, et al., Acta Physiol. Pharmacol. Bulg., 2, 7 (1974).