EXPERIMENTAL METHODS FOR CLINICAL PRACTICE

Mechanisms of Generation of Slow Components of Bioelectric Activity in Diagnostics of Functional State of the Gastrointestinal Tract

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New electrophysiologic devices were used for the diagnostics of the state of excitable structures in the gastrointestinal tract and correction of their motor functions. Bioelectrical and biomechanical activities form the basis of functioning of internal organs. The mechanisms of generation of slow bioelectrical activity that are important for clinical and physiological studies are described. One of these mechanisms is a capacitance parametric transducer converting the energy of contractions into specific electric signals reflecting muscle functions. Another mechanism results from slow oscillations of resting potentials of interrelated excitable cells in large neuromuscular structures of internal organs. The elaborated procedure is efficient for preventing early postoperative paresis of the gastrointestinal tract.

Key Words: *electroenterogastrography; functional state of internal organs; electrostimulation*

Human gastrointestinal tract (GIT) generates near-sinusoidal electric waves (0.02 Hz frequency) without contractile activity [2]. Each portion of the GIT (stomach, duodenum, and small and large intestines) generates pulses of a certain frequency [7]. These data and the interrelation between mechanical and electrical activities suggest the presence of new mechanisms of generation of specific electrical signals by neuromuscular structures reflecting functional state of internal organs.

Specific bioelectrical activity and the mechanisms of generation of bioelectrical signals form the basis for construction of special electrophysiologic devices for gastroenterologic examinations in clinics [5] and elaboration of resonance electrical methods for stimulation of smooth muscles (SM) [6], diagnostics of the state of GIT, and correction of its functions.

It was shown that electrical bilayer at the phase interface creates potential difference between these media [3]. This bilayer possesses an electrical capacitance [3]. Muscle contractions of biological structures deform natural phase boundaries causing interphase capacitance oscillations. Thus, capacitance transducers are the sources of bioelectrical signals, which reflect the dynamics of contractions.

Bioelectric signals formed by natural parametrical transducers during coordinated rhythmic contractions reflect the functional state of organs. Such signals separated from the total electrical activity of the body carry diagnostic information.

The resting potential of SM cells varies from 30 to 70 mV [6]. In contractile structures of the GIT, SM cells are connected through ultrathin gaps (1500 E), and slow waves of depolarization and action potentials

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are transmitted from cell to cell without attenuation [1]. These data indicate that ultralow-frequency electrical waves can be produced by interrelated oscillations of resting potentials in SM cell population without generation of action potentials. These oscillations slowly propagate along excitable tissues and form bioelectrical waves in GIT organs.

Weak (no more than 0.25 mA) but long-lasting electrical impulse stimulation can gradually increase the amplitude of slow waves. Such effects are specific for examined organ and nonspecific to others, if the frequency of stimulating impulses corresponds to the frequency of the organ natural activity.

The goal of the present work was to study the effects of resonance electrical impulse stimulation on the state of neuromuscular structures in the stomach, duodenum, and small and large intestines and the possibility for correcting GIT functions in patients during the early postoperative period.

MATERIALS AND METHODS

We examined 265 patients aged 18-74 years supervised in intensive care and other departments of the A. V. Vishnevskii Institute of Surgery. The period between the operation and stimulation varied from 18 h to several days.

Examinations were performed using a selective electroenterogastrograph (SEEG) [5] and GIT stimulators [6]. Figure 1 shows block-schemes and amplitude-frequency characteristics of SEEG and standard devices for gastrography (EGS-3 and EGS-4m). SEEG separately records signals of all GIT portions, while in standard devices, this analysis is hampered by interference of various signals.

SEEG was connected to the lower and upper limbs of a patient. The diagnostics of the state of excitable structures of GIT organs and correction of their functions were performed with stimulators, which were connected to electrodes applied to the abdominal wall through saline-soaked gauze pads. Recovery of the contractile activity of GIT organs was controlled clinically by peristaltic sounds and using X-ray and ultrasound methods.

The initial activity of neuromuscular structures in GIT organs was recorded for 10-15 min, and then the state of the stomach, duodenum, and small and large intestines was studied against the background of 3-7-min stimulation of the abdominal cavity with short series of specific impulses. The state of excitable structures of each GIT division was determined by analyzing the response to specific and nonspecific stimuli and the dynamics of their spontaneous activity during the period (3-5 min) between 2 consecutive stimulation series. Taking into account these results, correction was performed by the series of electrical impulses of various duration, which depended on the type of reactions and corresponded to the state of neuromuscular structures.

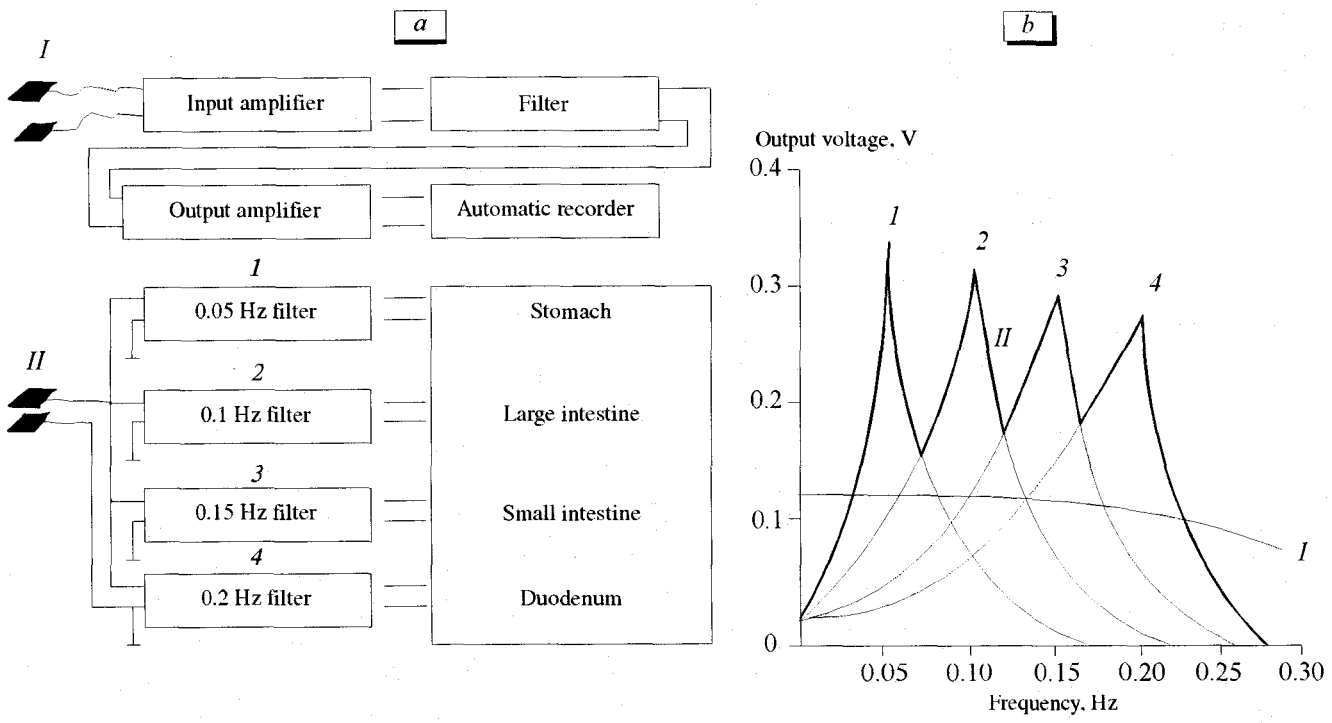

Fig. 1. Block-schemes of standard (*I*) and selective (*II*) electroenterogastrographs equipped with high-sensitivity filters instead of a broadband amplifier (*a*) and their amplitude-frequency characteristics (*b*): gastrograph (*1*), colograph (*2*), enterograph (*3*), and duodenograph (*4*).

RESULTS

Objective methods and clinical observations showed that long-lasting transcutaneous low-current electrostimulation of the abdominal cavity (no more than 0.25 mA) induced potent physiological effects on neuromuscular structures of GIT in 261 of 265 patients. Patients with severe postoperative paresis (1.1%) did nor respond to electrostimulation.

Ultralow-frequency specific and nonspecific stimuli induced a rapid or gradual increase in the intensity of recorded signals and were used for stimulation of GIT.

Reactions of neuromuscular structures to specific and nonspecific stimuli were different at various stages of therapy.

In patients with mild paresis of GIT, both specific and nonspecific electrostimulation caused rapid (5-10 min) excitation of SM structures of all organs, beats and peristaltic sounds appeared in all portions of the abdominal cavity, and motor and evacuation functions of GIT rapidly recovered (Fig. 2).

In patients with moderate postoperative paresis, the response was induced only by specific stimulation (Fig. 3), and bioelectrical activity increased gradually over 0.5-2.5 h. In this case, normalization of motor and evacuation functions took a longer period (3-7 h).

The extremely high sensitivity and peculiar reactions of neuromuscular structures of GIT to long-lasting electrical stimulation (for example, the appearance of beats) indicate the existence of both mechanisms of generation of characteristic bioelectric signals in GIT organs.

Hence, proposed methods and devices for the diagnostics and correction of the state of neuromuscular structures normalize motor functions of GIT. Resonance stimulation is a more potent method than drug therapy.

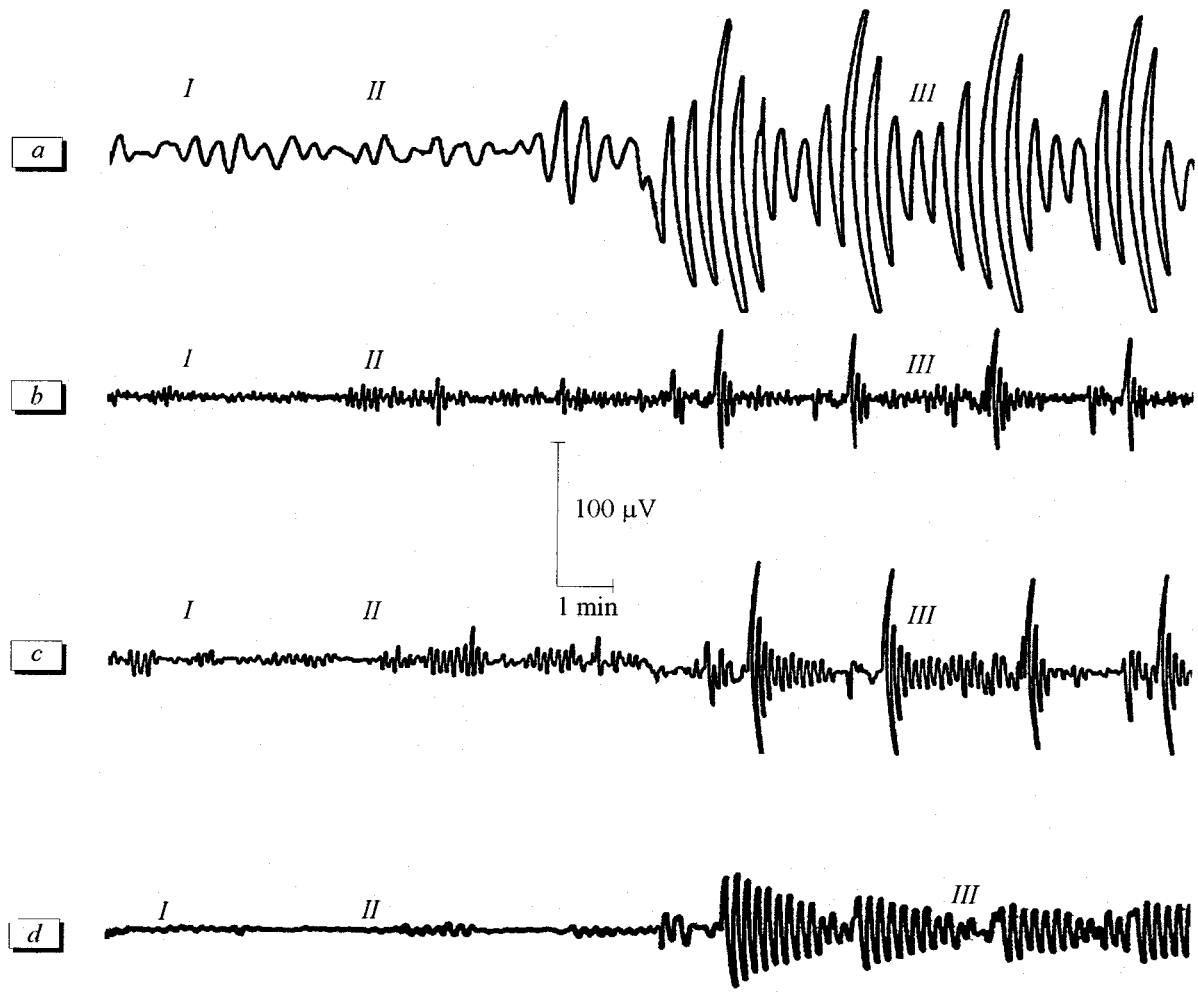

Fig. 2. Bioelectrical activity of neuromuscular structures of the gastrointestinal tract in a patient with mild postoperative paresis: gastrogram (*a*), duodenogram (*b*), enterogram (*c*), and cologram (*d*). Initial bioelectrical activity (*I*), electrostimulation of the abdominal cavity (*II*, 0.05 Hz pulse frequency and 0.11 mA current), and response of neuromuscular structures (*III*).

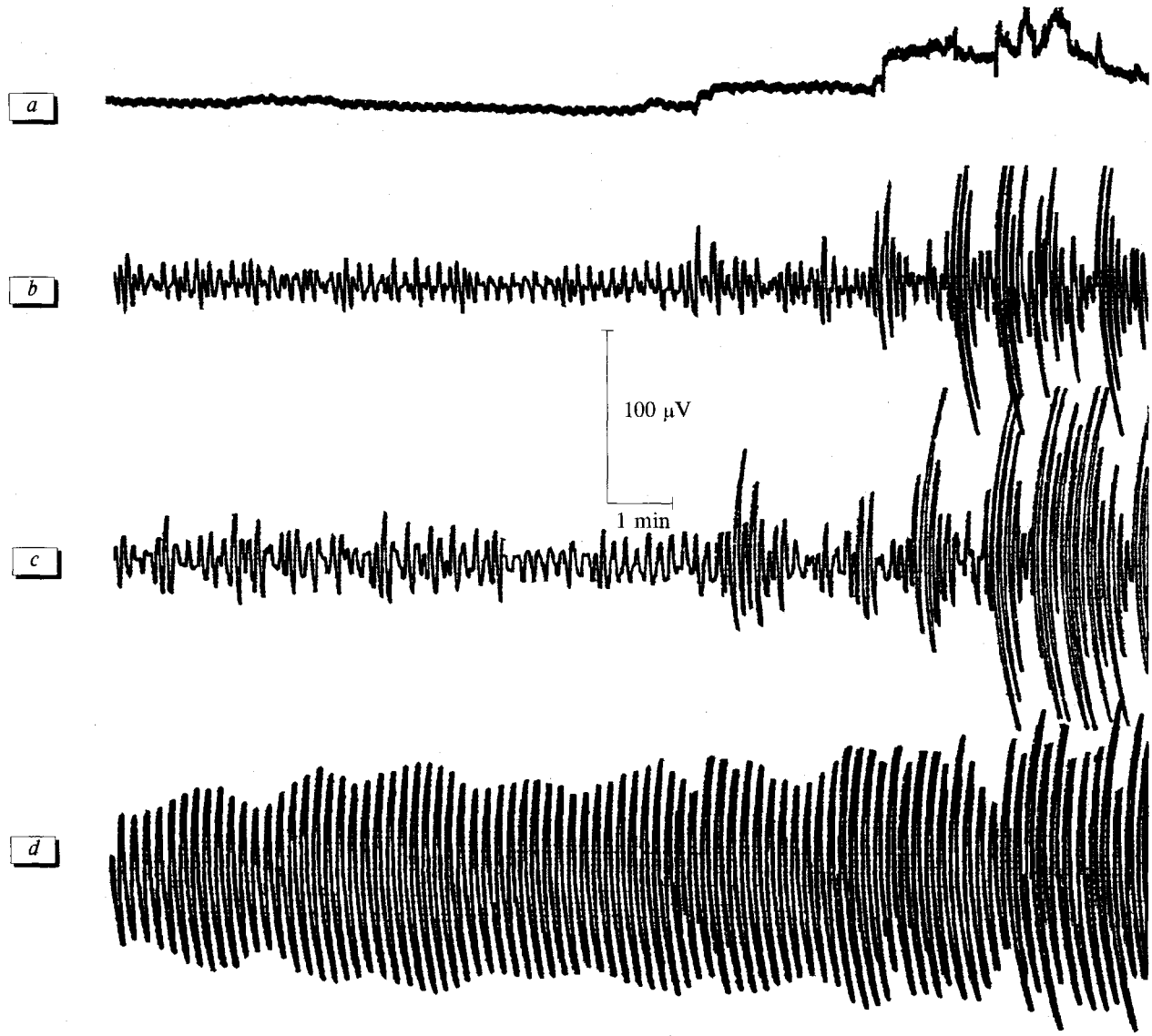

Fig. 3. Bioelectrical activity of neuromuscular complexes of the gastrointestinal tract and its correction in a patient with moderatepostoperative paresis: stomach (*a*, gastrogram), duodenum (*b*, duodenogram), small intestine (*c*, enterogram), and large intestine (*d*, cologram).

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