INVESTIGATION OF pH OF CONTENTS OF THE GASTRO-INTESTINAL TRACT BY A RADIOTELEMETRIC METHOD

V. I. Dedlovskaya

UDC 612.331.014.462.6-088.621.398

A radiocapsule was used to study the pH of the contents of the gastro-intestinal tract of 15 heatlhy persons. The pH values recorded in the stomach 1-1.5 h after a test meal (one cup of tea, 15 g sugar, 70 g white bread) varied from 1.7 to 1.3, in the proximal part of the small intestine it was 6.5-4.2, in its terminal portion 9.0-7.8, and in the large intestine 6.0-4.0. When gastric acidity curves are plotted it must be remembered that the true pH value corresponds not to the maximal, but to the minimal level of fluctuations associated with peristaltic contractions.

Although the radiotelemetric method of investigation of functions of the gastro-intestinal tract is still undergoing technical modification and does not yet provide the desired accuracy of measurement, the results obtained by this method are nevertheless interesting to physiologists and clinicians.

In this paper we describe pH values for the contents of the stomach and various parts of the intestine obtained by means of a radiocapsule, the design and working principles of which were described by E. B. Babskii and A. M. Sorin [2].

During familiarization with the technique and in the course of preliminary experiments we found that pH of the gastric contents determined by the radioprobe method, when converted into customary titration units of acidity, frequently do not correspond to the accepted clinical norms. Evidently a special series of investigations was required to determined the normal pH values of the contents of the stomach and various parts of the intestine, and to establish methods of analysis of pH curves obtained on the recording system of the apparatus.

EXPERIMENTAL METHOD

We used the acidity radiocapsule to carry out 22 investigations on 15 apparently healthy young persons (men and women aged from 18 to 32 years) with no complaints concerning the state of the gastro-intestinal tract. The radiocapsule was charged and coated 12-15 h before the investigation began. Calibration of the capsule was carried out for 3-4 h in the morning, radio signals from the capsule being recorded when immersed in jars containing buffer solutions with pH 9.0, 7.0, 3.0, 2.0, and 1.0 kept in an incubator. Throughout the calibration period, a careful check was made of the temperature of the buffer solution by means of a thermometer kept in the same jar as the capsule. In the morning the subject took his usual breakfast, and at 2 p.m. a test meal in the middle of which he swallowed the radiocapsule. The test meal consisted of one cup of tea, 15 g sugar, and 70 g white bread. The temperature of the tea was 38-39°. The pH curve was recorded in the sitting position for 3 h after the test meal, and then for 30-40 min after an interval of 4-5 h, during which time the subjects took an ordinary meal. On subsequent days signals from the capsule were recorded periodically 3-4 times daily until it emerged from the intestine. In four cases, in order to record the pH 15-16 h after the beginning of the investigation without disturbing the subject's sleep, we postponed the start of the radioprobe examination until later in the day, to 6-7 p.m.

EXPERIMENTAL RESULTS

Segments of the pH curve recorded while the radiocapsule was in the stomach, the proximal portion of the small intestine, and the large intestine are given in Fig. 1. The presence of fast (2-3/min) fluctuations in the level of the pH curve of the gastric contents makes it difficult to give a numerical value to the acidity. These fluctuations may be due to contact between the capsule pick-up during peristaltic contractions and layers of food masses of different acidity. However, during digestion, as the gastric contents

Department of Normal Physiology, Sverdlovsk Medical Institute (Presented by Academician V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 66, No. 11, pp. 121-123, November, 1968. Original article submitted February 9, 1967.

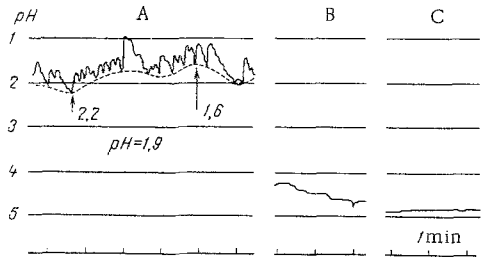

Fig. 1. pH Curves of contents of stomach (A), proximal portion of small intestine (B), and large intestine (C).

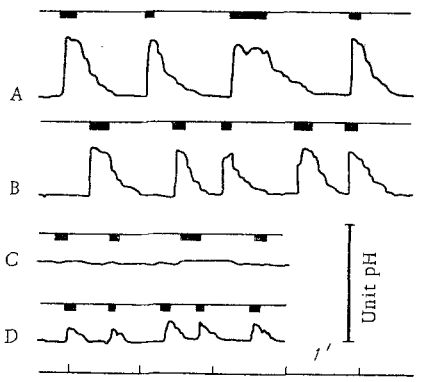

Fig. 2. Recording of radiocapsule signals from incubator while immersed in buffer solutions stationary or in movement relative to capsule pick-up. A-D) Buffer solutions of pH 1.0, 3.0, 7.0, and 9.0 respectively. Black rectangles denote periods of movement of solution; upward deflection of curve corresponds to decrease of pH.

are mixed and the secretory process gradually diminishes, these fluctuations in the curve would be expected to become smoothed out and to disappear, but in fact this often is not observed. It is evident that there must be some other reason for these fluctuations on the pH curve. We assumed that one such reason is not an actual change in the pH of the medium, but the rapid displacment of the liquid gastric contents relative to the radiocapsule pick-up during peristaltic waves.

This hypothesis was tested in special experiments in which signals were recorded from the radiocapsule placed in an incubator. The buffer solution in which the capsule was immersed was periodically set in motion. The results of these experiments are illustrated in Fig. 2. They show that while the buffer solution was stationary, a constant pH value was recorded; at times of movement of the solution relative to the capsule, the curve shifted toward the acid side, and these deflections, simulating an increase in acidity, were more marked the higher the hydrogen ion concentration in the tested medium. In a neutral medium, for instance, movement of the solution was not reflected in the frequency of signals from the radiocapsule, but in a solution of pH 1.0 it caused changes in the frequency of the signals simulating a pH change from 1.0 to 0.5. For the reasons given above, during analysis of the results for the pH of the gastric contents we took as our reference point the lower level of the fluctuations of the curve (Fig. 1, broken line), corresponding to the actual pH value. In addition, for each 5-min interval we determined the mean of two pH readings: maximal and minimal.

Analysis of data for the free hydrochloric acid concentration in the gastric contents and the reaction of the medium in different portions of the intestine gave the following results. During the first minutes after the test meal a weakly acid reaction was recorded, the pH of the medium being 4.0-5.0 (Fig. 3). After 30 min the pH of the gastric contents fell to 2.5-1.6 (median 1.75), corresponding to 4-21 titration units of acidity. From 1 to 1.5 h after the beginning of the investigations we usually obtained pH values between 1.7 and 1.3 (median 1.6), i.e., 20-50 titration units. As a rule, after this time a marked change in pH toward the acid side was observed: the recorded pH values varied from 1.5 to 1.0 (median 1.4) as the average of results for 5-min intervals, corresponding to 32-100 titration units of acidity. Sometimes pH values below 1.0 were recorded.

We consider that the reason for obtaining these high acidity readings is that the evacuatory process is practically complete 1.5-2 h after the beginning of the investigation and the capsule pick-up is able to remain in close contact with the gastric mucous membrane and with newly formed portions of hydrochloric acid which has not yet become diluted or neutralized with mucous. In a control series of experiments on dogs with fistulas, in which the acidity of the gastric juice was recorded simultaneously by the radiotelemetric method and by titration of the escaping juice, we found that the discrepancy between the results obtained by these two methods does not exceed 10 titration units. We therefore consider that there are no grounds for regarding the high acidity values at the end of the stay of the capsule in the stomach as incorrect. Changes in temperature at the end of the digestive process in the stomach (an increase in temperature changes the frequency of signals from the radiocapsule, just like an increase in hydrogen ion concentration) may play a role here, but final conclusions regarding this can be drawn only if pH and temperature are recorded simultaneously.

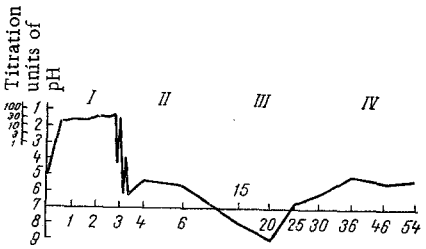

Fig. 3. pH of contents of stomach and various parts of intestine of healthy persons as given by radiotelemetric measurements. Location of radiocapsule: I) Stomach, II) small intestine; III) ileocecal region; IV) large intestine. Abscissa: time (in h).

In our investigations the radiocapsule passed from the stomach into the duodenum usually 3-3.5 h, and in rare cases 2 h, after they began. Like a particle of high specific gravity, the radiocapsule evidently remained for a long time in the fundus of the stomach and was evacuated last by means of more powerful peristaltic contractions. If we wished to hasten evacuation of the capsule, 3 h after the beginning of the investigation the subject lay on his right side. If the subject took food again before the capsule was evacuated from the stomach, it was retained there for a long time. Movement of the capsule into the duodenum, where it encountered portions of intestinal juice, was accompanied by sharp fluctuations in pH from 1.0 to 6.0, which gradually became smaller in amplitude, so that 1 h after entry of the capsule into the intestine pH values were 6.0-3.7 (medium 4.8). Bearing in mind that the temperature in the small intestine is almost 1° higher than in the stomach [1], and introducing the appropriate temperature correction, the actual pH of the medium in the duodenum was 6.5-4.2 (median 5.3). A weakly acid reaction in the small intestine was also recorded 2-3 h after departure of the capsule from the stomach, after which it changed to neutral, and 15-16 h after the beginning of the investigation, when the capsule was presumably in the terminal portion of the small intestine, the reaction of the median was alkaline: the pH varied, allowing for the temperature correction, from 8.5 to 7.8 (median 8.0). An even stronger alkaline reaction was found 19-20 h after the beginning of the investigation.

In the ileocecal region the pH began to change toward the acid side, and in the large intestine we usually recorded pH values between 6.0 and 4.0 (median 5.0). The weakly acid reaction of the contents of the large intestine is probably due to bacterial activity. It should be noted that we estimated the position of the capsule in the intestine on the basis of data in the literature [1] regarding the velocity of passage of the radiocapsule through the gastro-intestinal tract. Most frequently in our investigations the capsule was discharged from the intestine at the beginning of the 3rd day.

LITERATURE CITED

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2. E. B. Babskii and A. M. Sorin, in: Recent Advances in Medical Engineering [in Russian], Moscow (1965), p. 38.