A STUDY OF THE POTENTIAL DIFFERENCE COMPONENT OF THE ELECTROGASTROGRAPH

by

J. Donald Longley B.A., M.D., C.M.

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PREFACE

This project, the study of the potential difference component of the electrogastrograph, was done under the supervision of Dr. H. S. Morton of the Royal Victoria Hospital and McGill University. Dr. Morton has done much of the original research on the electrogastrograph since he started work on the problem with the late Professor Babkin. Dr. Morton has been one of the first to study the direct current component of the electrogastrograph. I am greatly indebted to Dr. Morton for his supervision, encouragement, and interest in this study.

Other research workers who have been associated with this project are Dr. H. H. Jasper, Dr. W. S. Martin, Dr. J. F. Davis, and Dr. L. S. Allen. Dr. Davis was responsible for the design and maintenance of the equipment. I am grateful to Dr. Davis not only for this but also for advice on electrical problems.

I should like to thank Dr. D. R. Webster, Chairman of the Department of Experimental Surgery, not only for allowing me to work in his department during the year, but also for his encouraging me to undertake this project.

All the secretarial work and many of the recordings were done by the technician Mrs. Markland. My appreciation goes to her and to Mrs. Sledge for advice on statistical matters. My appreciation also goes to Mrs. Mayhood and Mrs. New for the final typing.

The clinical work was carried out at the Royal Victoria Hospital. The use of the facilities on Ward G, the operating room, and the x-ray department are gratefully acknowledged.

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CHAPTER I

INTRODUCTION

Historical

The realization that electricity was closely associated to living matter was reported in 1773 when Hunter (21) described the electrical potentials of the Torpedo fish. A few years later Galvani (17) produced a muscle contraction in the frog with a zinc-copper couple. Further research showed that electrical currents were associated not only with animal life but also with plant life. Plants have a potential which is most marked in the growing parts, as near a root tip. There is even a potential associated with an apple skin (9).

The measurement of a potential difference across the stomach wall had to wait for Donné in 1834 (14). This was about twenty years before the electrical activity of the heart was discovered by Kölliker and Muller (24). Further work was done in 1860 by Dubois-Reymond (15) and a little later by Rosenthal (46). Rosenthal also studied the skin potentials of the frog. He proposed that they were due to sweat gland activity.

Much of the pioneer work with the electrogastrograph was done by Alvarez (2). He published the first human recording in 1922 (3). Unfortunately he delayed work for a while

by suggesting diffusion potentials[1] would prevent the recording from ever becoming accurate. This not only caused him to lose interest but also discouraged other workers for about thirty years.

Not all work ceased, however. In 1932 Berkson and Balder under the leadership of Alvarez (8) published an article on work done correlating mechanical movements with the changes in electrical potential. Berkson (7) continued this work and in 1933 published a paper showing that the origin of the wave is in the structure of the intestine and not in the extrinsic nervous system. It was also shown by Berkson that the observed wave originated in the potential variations at the site of the electrode attachments to the intestine and not in changes of electrical resistance of the tissue.

Much of the recent work has been done by Rehm (34 to 42 inclusive) with experimental animals. He has gone into the mathematical treatment of the electrical currents that have been measured (42 and 43). Goodman (12 and 20) has studied the effect on the electrogastrograph of drinking milk in cancer and ulcer patients. Rehm (40) showed that these changes were due to diffusion potentials. Morton (26 to 33 inclusive) has correlated gastric physiology and pathology with the potential difference component, as well as the alternating current component, of the electrogastrograph. Ingram (22) in 1953 reported

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[1]Diffusion potential has been used synonymously with liquid junction potential in this text.

some similar work done on a study of gastric pathology and potential difference. These workers have all used the skin as the location of the reference electrode and have therefore measured the skin potential as well as the gastric potential.

Statement of the Problem

The problem was to measure the gastric potential component of the electrogastrograph as accurately as possible. To do this all other potentials had to be eliminated or short circuited. Also a loss of voltage due to the internal resistance of the various parts of the circuit had to be kept low.

Gastric potential, which one wishes to measure in the electrogastrograph, has been shown to arise between the mucosa and submucosa of the stomach by Rehm (37). Rehm also showed that the submucosa and serosa were about the same electrical potential. This work was done in laboratory animals. In man the reference lead cannot be placed on the submucosa or serosa except during an operation. This is not justified for a diagnostic procedure. In man the reference electrode is placed on the skin of the arm. By placing the reference electrode on the skin of the arm a skin potential is measured as well as the gastric potential.

One of the problems during the year was to study methods of overcoming or short-circuiting the skin potential. The magnitude and orientation of the voltage was determined. The amount of variation of skin potential was studied in an effort

to see how it would affect the gastric potential measured using the skin as a reference. A method of short circuiting the skin potential was investigated. The diagnostic accuracy of the direct current component of the electrogastrograph was compared using this new technique where the skin potential was short circuited rather than the old method of using the skin as the location of the reference electrode.

Other potentials which could have made the measured gastric potential inaccurate were the non-biological potentials. The electrode and diffusion potentials are the most important of these. Streaming potentials are much smaller and hence less important.

Alvarez (2) thought that diffusion potentials would prevent the electrogastrograph from ever becoming an accurate instrument. Special electrodes have been described by Davis and Morton (12) for use in the electrogastrograph in order to minimize the electrode and diffusion potentials. The ability of these electrodes to overcome the electrode and diffusion potentials was studied and confirmed during the year.

There is a loss of voltage due to the internal resistance of various parts of the circuit. This may be kept low by keeping the resistance and the current low. Resistance of mammalian cells is of the order of 100 ohms/cm. (10) and cannot be changed. However, other resistances of the external circuit were kept to a minimum. Current drawn from the subject was always less than 0.1 microamperes since an amplifier with an input impedance of 1 megohm was used.

After these various procedures had been studied to measure the gastric potential as accurately as possible the gastric potential itself was studied. The gastric potential was investigated in certain physiological, pharmacological and pathological states.

Instrumentation

The apparatus consists of four basic parts: electrodes, a calibrator and zero-suppression unit, an amplifier, and a recorder.

The metallic electrodes which are used in electrocardiograph and electroencephalograph recordings are not suitable for the measurement of direct current biological potentials. They are not suitable because of the large "battery-effect" which they exhibit. Where the direct current or potential difference component of electrical activity must be accurately measured, as is the case in the electrogastrograph, the practice is to use "non-polarizable" balanced electrodes. Examples of such electrodes are: calomel half-cell, zinc-zinc sulphate half-cell, and silver-silver chloride half-cell.

At this institution the silver-silver chloride electrodes are used for a number of reasons. The silver-silver chloride electrode is a sturdier and more mechanically stable form of electrode than the zinc-zinc sulphate and therefore more practical for routine daily use (47). The calomel half-cell electrode employs more toxic and more irritating electrolytes.

In addition the calomel half-cell is a more difficult structure to build to a scale suitable for intubation.

The choice of silver-silver chloride electrodes is also desirable because it makes possible the use of physiological saline as the conducting electrolyte. Almost any chloride could be used as the electrolyte; however, physiological saline is used at this institution for a number of reasons. Physiological saline is readily available in the sterile form which is necessary for operating room use. Physiological saline is less irritating to the mucosa of the pharynx and oesophagus than the other chlorides.

Figure 1 shows the skin-type electrode. A solution of N/6 NaCl is held next to the electrode by a cellulose sponge. Figure 2 shows the gastric-type electrode.[2] Here the solution of N/6 NaCl is held next to the electrode by a vinylite sleeve. This sleeve is detachable for cleaning and chloriding the electrode. An agar barrier could be used as it is more permanent; however, the type with the saline solution is more simply assembled and cleaned.

The basic reason for the present type of electrode was that it was the type standardized as a routine in the department by Martin (27). However, it was chosen at first for the above reason of durability and simplicity. A study of the characteristics of the gastric-type electrode was carried out and the results have been recorded in Chapter II.

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[2]Gastric-type electrode refers to this certain type of electrode as compared with a gastric electrode which is any electrode in the stomach.

The bucking or zero-suppression feature of the input circuit is necessary because steady potentials of the order of 20 to 100 millivolts are often encountered while the variable part of the potential, which must be examined in detail, may be of the order of 1 or 2 mv. A large part of the incoming signal, therefore, must be bucked out before it reaches the differential amplifier input. Calibration voltages of 1, 4 and 8 mv. can be applied to the amplifier in the form of square waves.

The amplifier employed is a modified Sanborn Direct-Current type. There is also a preamplifier (12AX7) with a battery-stabilized heater voltage which is of the balanced-differential type and has an input impedance of one megohm.

The recorder is a Sanborn Industrial model of the direct-writing hot stylus variety. In conjunction with the above modified Sanborn Direct-Current amplifier the final deflection sensitivity is 4 mv. per cm.

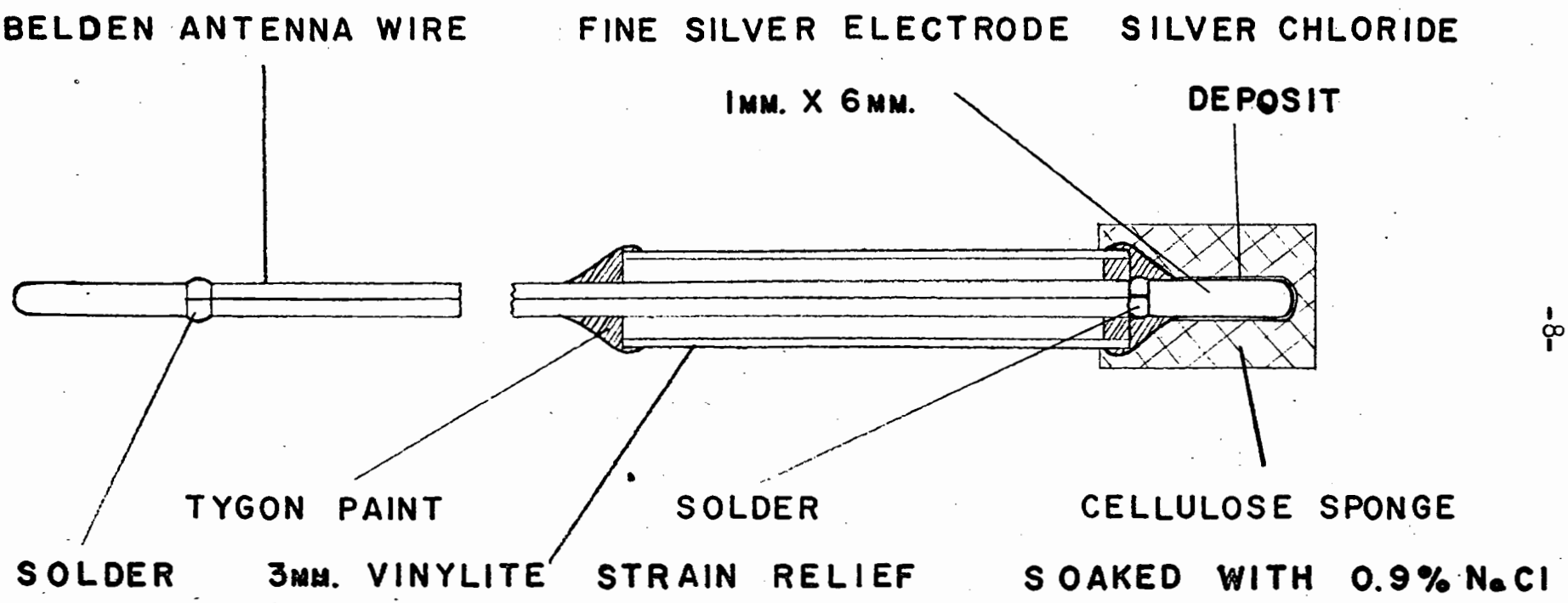


Figure 1. Skin-Type Electrode

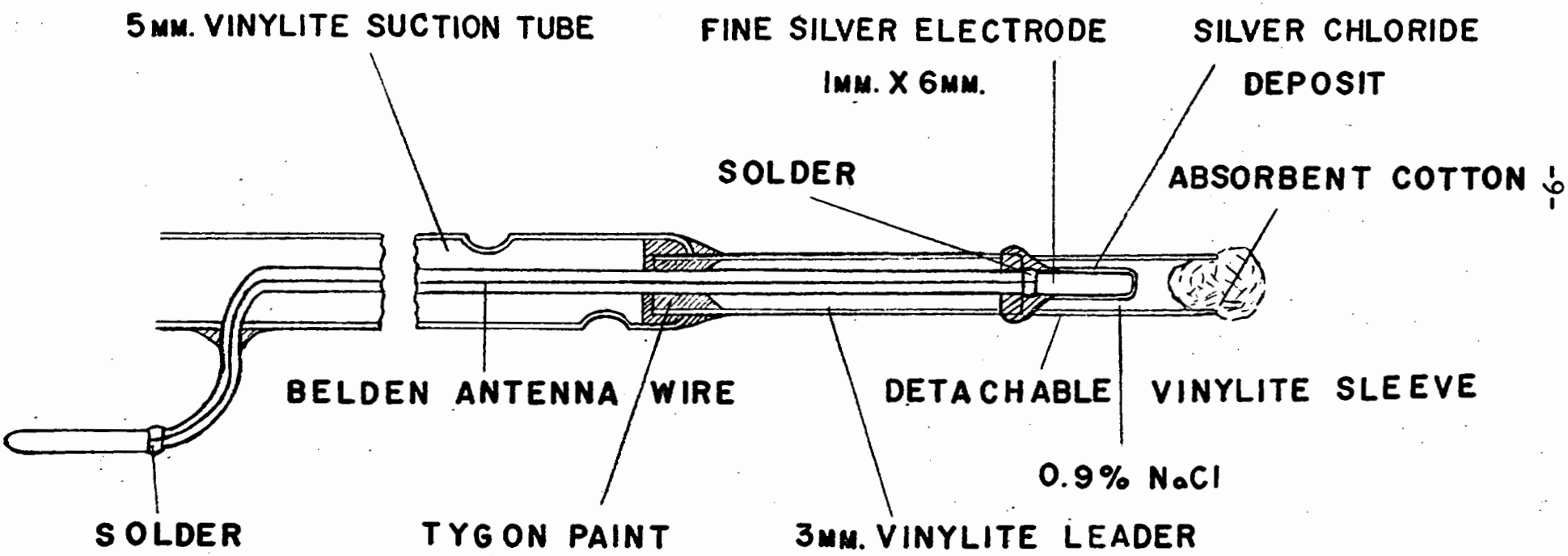


Figure 2. Gastric-Type Electrode

CHAPTER II

NON-BIOLOGICAL POTENTIALS AND THE GASTRIC-TYPE ELECTRODE

This chapter relates the work of a series of in vitro experiments designed to determine the ability of the gastric-type electrode to measure an electrical potential without interference from changes in temperature and various non-biological potentials. The effect of the acidity will be discussed in Chapter IV. These non-biological potentials are of little importance when only the alternating current component is studied as in the electroencephalograph or the electrocardiograph.

The most important non-biological potentials are the diffusion and electrode potentials. Other non-biological potentials as streaming potentials are much smaller and hence less important. A diffusion potential, or liquid junction potential as it is sometimes called, is that potential which exists between two electrolytes which are in contact with each other. It varies with the composition and concentration of the two electrolytes as well as their absolute temperature. The electrode potential exists between an electrode and its surrounding electrolyte solution. It varies not only with the composition, concentration and temperature of the electrolyte, but also with the material and temperature of the electrode and its surface deposit if any.

Alvarez (2) was the first to point out the importance of the electrode and diffusion potentials. Alvarez suggested that the voltage produced by slight differences in the concentration of acid bathing the instrument would be so great as to prevent the electrogastrograph from ever becoming a useful diagnostic tool.

While doing tracings Goodman (18) put the reference electrode in NaCl and the active electrode in HCl. By doing this the electrode potentials at the two ends of the circuit were different and, hence, the electrode potential was being measured as well as the gastric potential.

Davis and Morton (12) described a method of having both electrodes made of the same material and in the same electrolyte solution. By balancing the two ends of the circuit the diffusion potential exists at the reference end of the circuit between the saline solution of the sponge and the electrolytes of the skin. On the gastric end of the circuit there exists a diffusion potential across the cotton pledget between the gastric contents and the saline solution in the sleeve of the gastric-type electrode. Similarly there are diffusion potentials across all the various electrolyte solutions between the skin of the arm and the gastric contents. These all balance out since the electrolyte (N/6 NaCl) was the same at each end of the external circuit (12).

The absolute value of the electrode potentials was not important in the electrogastrograph. The question was to

determine the ability of the gastric-type electrode to resist infiltration of the gastric contents. After the gastric-type electrode had been in the stomach for a period of time there was a diffusion of electrolytes across the cotton pledget leading to a change of solution around the electrode. As the electrolytes in the gastric sleeve change in composition from that around the reference electrode, the electrode potentials at the two ends of the circuit become different. The electrodes then no longer balance.

The ability of the gastric electrode to remain balanced may be studied in vitro with gastric contents or with varying concentration of hydrochloric acid. Knowledge of the ability of the gastric electrode to overcome the electrode potential is of interest not only with N/6 NaCl but also with other concentrations of saline, or other salts such as potassium chloride.

As the two electrodes are at a different temperature this could cause a slight degree of imbalance between the two electrode potentials. The effect of having the active electrode at body temperature and the reference electrode at skin temperature was studied in vitro.

Method

Tests were undertaken to study the electrode potential between the gastric-type electrode and the contents of the stomach. These experiments were done with various concentrations of hydrochloric acid as well as with gastric contents.

The gastric-type electrode has been described fully in the introduction. The electrode potential is that potential between the electrode and its surrounding electrolyte solution. In the case of the gastric-type electrode the silver-silver chloride and the salt solution around the silver-silver chloride are taken as one unit. The electrode potential in this case being between the silver of the electrode and the electrolyte just outside the absorbent cotton diffusion barrier. In order to study the effectiveness of the gastric-type electrode, potentials must be compared having the sleeve both on and off.

These tests were carried out by having the gastric-type electrode in a beaker of hydrochloric acid or gastric contents. This beaker was called the active beaker (Figure 3). The reference electrode was in another beaker termed the reference beaker, which contained a salt solution. The two beakers were connected by a vinylite tubing containing the salt solution to act as an electrolyte "bridge".

Four series of experiments were carried out using different electrolytes in the sleeve of the gastric-type electrode. N/1 NaCl, N/6 NaCl, N/1 KCl, and N/6 KCl were the electrolytes used in the four series of experiments. These electrolytes were used not only in the sleeve but also in the vinylite "bridge" and the reference beaker.

The four series consisted of six experiments each, making 24 experiments in all. Each of the six experiments in a

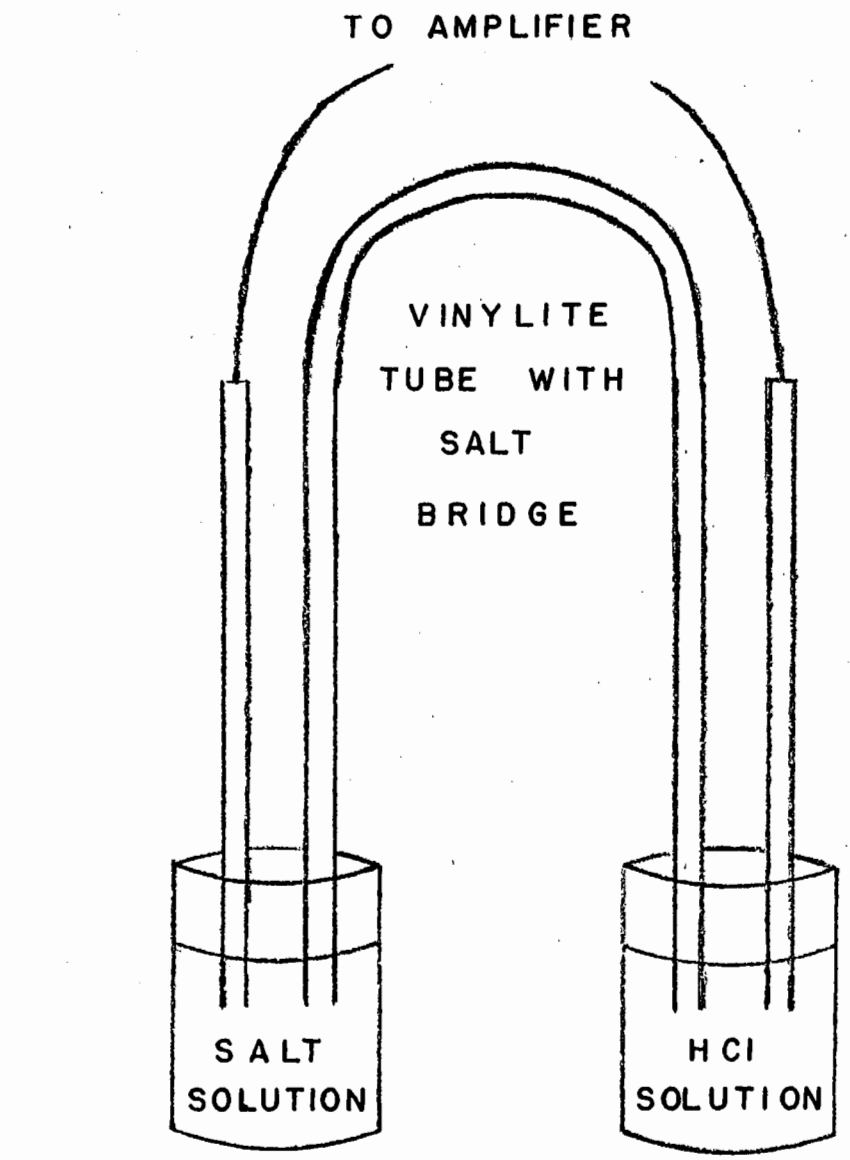


Figure 3. Apparatus for In Vitro Experiment

series had a different concentration of hydrochloric acid or gastric juice in the active beaker. These electrolytes in the active beaker were N/1 HCl, N/3.2 HCl, N/10 HCl, N/32 HCl, N/100 HCl, or gastric contents which titrated 15 units free acid and 23 units total acid.

The first experiment of the first series was carried out in the following way. The reference beaker was filled with N/1 NaCl. Both electrodes were then cleaned and a layer of silver chloride deposited as described by Martin (27). The skin-type electrode was placed in the N/1 NaCl of the reference beaker. The beakers were of the 60 cc. size and were filled to the top. The sleeve of the gastric-type electrode was filled with this same N/1 NaCl. An absorbent cotton plug soaked in N/1 NaCl was inserted into the end of the sleeve to hold the electrolyte in the sleeve. Next the vinylite tube was filled with N/1 NaCl. Absorbent cotton plugs were inserted into the tubing at the ends to prevent streaming potentials. The last step in preparation was to fill up the active beaker with N/1 HCl to the same level as the reference beaker. These beakers were allowed to stand for a few hours to reach room temperature. While standing both ends of the vinylite "bridge" were in the N/1 NaCl.

After this initial preparation the actual experiment was started. First the gastric-type electrode and one end of the vinylite "bridge" were placed in the active beaker. The potential difference was measured between the skin-type

electrode in the reference beaker and the gastric-type in the active beaker at the beginning and at 15 minute intervals for 120 minutes. Following the last measurement the sleeve of the gastric-type electrode was removed. This was done outside the beaker so that the contents of the sleeve would not change the composition of electrolyte in the active beaker. Then the measurement was repeated. That is, the potential difference between the two electrodes was measured with the skin-type electrode in the reference beaker of N/1 NaCl and the gastric-type electrode devoid of its sleeve in the N/1 HCl. This last measurement therefore gave the potential difference which would have been recorded if the sleeve of the gastric-type electrode had not been used. This potential difference is the error which would be recorded in the gastric potential measurement if the gastric-type electrode was not used.

The second experiment of the first series was carried out using N/1 NaCl in the reference beaker, vinylite "bridge", and in the sleeve of the gastric-type electrode. N/3.2 HCl was used in the active beaker. Again measurements were made at 15 minute intervals over a period of two hours. At the end of this time the sleeve was removed from the gastric-type electrode and the potential difference measured. This gave the error which would have been recorded all along had not the sleeve of the gastric-type electrode been used.

In the third experiment of the first series the N/1 NaCl was used in the reference beaker, in the vinylite"bridge", and

in the sleeve of the gastric-type electrode as before. The concentration of the hydrochloric acid in the active beaker was again changed. It was changed this time to N/10 HCl. After the series of measurements over the two-hour period, the sleeve was removed from the gastric-type electrode. The measurement taken with the sleeve off is the error which would have been produced if the gastric-type electrode had not been used.

The fourth and fifth experiments of the first series were similar to the previous three in that the N/1 NaCl was used in the reference beaker, the vinylite "bridge", and in the sleeve of the gastric-type electrode. However, in these experiments the concentration of hydrochloric acid used was again changed. In the fourth experiment N/32 HCl was used in the active beaker and in the fifth experiment N/100 HCl was used. Again in these experiments, as before, the sleeve of the gastric-type electrode was removed to show the error which would have been recorded without the gastric-type electrode.

In the sixth experiment of the first series there was one other variation besides the concentration of the acid. The N/1 NaCl was put in the reference beaker, in the vinylite "bridge", and in the sleeve of the gastric-type electrode as before. These were all allowed to stand for two hours in each case, as before, to reach room temperature. The variation in this experiment was the use of actual gastric juice which had been removed by Levine tube from a patient a short time previously. This gastric juice was not only of different

composition than the previous contents of the active beaker, but also was at a different temperature. It was maintained at 37° C. by setting the beaker in a water bath at this temperature. The concentration of the gastric juice was such that it titrated 15 units free acid and 23 units total acid. These conditions were established to duplicate as closely as possible the actual in vivo test situation. Again at the end of the two hours the sleeve of the gastric-type electrode was removed. The potential was then measured between the silver-silver chloride electrode of the skin-type in the N/1 NaCl of the reference beaker at room temperature and the silver-silver chloride electrode of the gastric-type without a sleeve in the active beaker at 37° C. This measurement gave the error of potential which would have been recorded if the gastric-type electrode had not been used.

In the second series of experiments the concentration of saline was changed to N/6 NaCl in the reference beaker, the vinylite "bridge" and sleeve of the gastric-type electrode. In the first experiment of the second series N/1 HCl was used in the active beaker. Measurements were taken at 15-minute intervals over a period of two hours. At the end of that time the sleeve was removed and the measurement recorded between the skin electrode in the N/6 NaCl and the gastric-type electrode without sleeve in the N/1 HCl.

The second, third, fourth, and fifth experiments of the second series were carried out in the same manner, using the

N/6 NaCl in the reference beaker, in the vinylite "bridge" and in the sleeve of the gastric-type electrode as before. The concentration of hydrochloric acid in the active beaker was N/3.2, N/10, N/32 and N/100 respectively in the second, third, fourth and fifth experiments. In each case at the conclusion of the experiment the sleeve of the gastric-type electrode was removed and the measurement made to show what the error would have been had not the gastric-type electrode been used.

In the sixth experiment of the second series the N/6 NaCl was used in the reference beaker, the vinylite "bridge" and in the sleeve of the gastric type electrode as before. However, the contents of the active beaker were varied as in the sixth experiment of the first series. That is, actual gastric contents kept at 37° C. were used in the active beaker. The sleeve was removed at the end of the two-hour period of testing as before.

In the third series, N/1 KCl was the electrolyte used in the reference beaker, in the vinylite "bridge" and in the sleeve of the gastric-type electrode. In all other respects this third series was the same as the first and second series. That is, the first five experiments used the five different concentrations of hydrochloric acid (N/1, N/3.2, N/10, N/32, and N/100) in the active beaker. Again all these were at room temperature as were the contents of the reference beaker. In the sixth experiment of this third series the gastric contents at 37° C. were used in the active beaker. In all three

experiments of the third series, as in the first and second, the sleeve of the gastric type electrode was removed at the end of the experiment and a further final measurement made.

The fourth series of six experiments was carried on the same as the preceding three except for the electrolyte to be tested. In this fourth series N/6 KCl was the electrolyte used in the reference beaker, the vinylite "bridge" and in the sleeve of the gastric-type electrode. The electrolyte of the active beaker was again the five different concentrations of hydrochloric acid (N/1, N/3.2, N/10, N/32 and N/100) as in the first five experiments of each of the other series. Again in the sixth experiment of the fourth series, as in the first three, the electrolyte used in the active beaker was gastric contents at 37° C. These were part of the same gastric contents and so as before titrated 23 units of total acid and 15 units free acid. Again in each experiment the sleeve of the gastric-type electrode was removed at the end of the experiment for the last measurement.

A series of experiments was carried out to study the effect of temperature on the electrode potential. In these experiments all conditions of both beakers were the same except for the temperature. Both the reference and active beaker contained N/6 NaCl and a skin-type electrode. The two beakers were connected by a vinylite "bridge" of N/6 NaCl. The reference beaker and its contents were kept at 20° C. whereas the temperature of the active beaker was varied between 20 and 40°C. Measurements were taken at 2° C. intervals. An average was

taken of four runs.

Results

The data show that the gastric-type electrode satisfactorily overcame the electrode potential in the range of hydrochloric acid found in the stomach. This was not true in the more concentrated acid. These data of the tests of the gastric-type electrode have been shown in Tables 1, 2, 3, and 4.

The variation of electrode potential due to temperature was approximately a linear relationship over the range measured. The electrode potential increased 0.287 mv. for each degree centigrade rise. This variation has been shown in Table 5.

Discussion

In vitro experiments showed that the gastric-type electrode with N/6 NaCl as used here overcame the electrode potential adequately. The last row of figures in Tables 1, 2, 3, and 4 show the electrical potential which was recorded when the sleeve was removed from the gastric-type electrode. This was the amount of error which would have been recorded if the gastric-type electrode had not been used. It can be seen from the data that, as the hydrochloric acid diffused through the absorbent cotton into the sleeve, the electrode became more unbalanced. The measurement deviated in the same direction

Table 1

DURABILITY OF THE GASTRIC-TYPE ELECTRODE

WITH N/1 NaCl

Time in Minutes	Potential in mv. Using the Following Solution in the Active Beaker					
	HCl in the Following Concentrations at Room Temperature					Gastric* Contents at 37° C
	N/1	N/3.2	N/10	N/32	N/100	
Potential with sleeve 0	0	0	0	0	0	0
15	-1	0	0	+1	0	+3
30	-2	0	+1	+2	+1	+2
45	-3	0	+2	+3	+1	+3
60	-3	0	+2	+3	+2	+2
75	-3	0	+3	+5	+3	+2
90	-4	-1	+3	+5	+3	+2
105	-3	-1	+3	+5	+3	+2
120	-4	-1	+4	+5	+3	+3
Potential without sleeve	-91	-45	+26	+44	+57	+17

*Gastric juice titrated 15 units free acid and 23 units total acid.

Note: The reason for comparing the gastric-type electrode with and without a sleeve is fully discussed in the text.

Table 2

DURABILITY OF THE GASTRIC TYPE ELECTRODE

WITH N/6 NaCl

Time in Minutes		Potential in mv. Using the Following Solutions in the Active Beaker					
		HCl in the Following Concentrations at Room Temperature					Gastric* Contents at 37° C
		N/1	N/3.2	N/10	N/32	N/100	
Potential with sleeve	0	0	0	0	0	0	0
	15	0	0	0	0	0	+3
	30	0	0	0	0	0	+2
	45	-1	-1	0	0	0	+2
	60	-3	0	0	0	0	+2
	75	-5	-2	0	0	+1	+2
	90	-9	-3	0	0	+1	+2
	105	-13	-4	-1	0	+1	+2
	120	-17	-5	-1	0	+2	+1
Potential without sleeve		-142	-78	-18	+8	+24	-2

*Gastric juice titrated 15 units free acid and 23 units total acid.

Note: The reason for comparing the gastric-type electrode with and without a sleeve is fully discussed in the text.

Table 3

DURABILITY OF THE GASTRIC-TYPE ELECTRODE

WITH N/1 KCl

Time in Minutes		Potential in mv. Using the Following Solutions in the Active Beaker					
		HCl in the Following Concentrations at Room Temperature					Gastric * Contents at 37°C
		N/1	N/3.2	N/10	N/32	N/100	
Potential with sleeve	0	0	0	0	0	0	0
	15	-2	0	0	+1	0	+2
	30	-3	0	-1	+1	0	+3
	45	-2	0	0	0	+1	+2
	60	-2	0	0	0	+1	+2
	75	-3	-1	0	+2	+1	+2
	90	-3	-1	0	+2	+1	+3
	105	-4	-1	0	+2	+1	+3
	120	-4	-2	0	+1	+1	+3
Potential without sleeve		-47	-8	+26	+45	+58	+34

* Gastric juice titrated 15 units free acid and 23 units total acid.

Note: The reason for comparing the gastric-type electrode with and without a sleeve is fully discussed in the text.

Table 4

DURABILITY OF THE GASTRIC-TYPE ELECTRODE

WITH N/6 KCl

Time in Minutes		Potential in mv. Using the Following Solutions in the Active Beaker					
		HCl in the Following Concentrations at Room Temperature					Gastric * Contents at 37° C
		N/1	N/3.2	N/10	N/32	N/100	
Potential with sleeve	0	0	0	0	0	0	0
	15	-2	0	+1	+1	0	+2
	30	-3	0	-1	+1	0	+2
	45	-7	-1	0	+2	0	+2
	60	-8	-1	+1	+1	-1	+2
	75	-10	-2	0	+2	-1	+1
	90	-12	-2	0	+1	-1	+2
	105	-14	-3	+1	+1	-1	+2
	120	-16	-4	+1	+1	-1	+2
Potential without sleeve		-94	-59	-10	+16	+27	+2

* Gastric juice titrated 15 units free acid and 23 units total acid.

Note: The reason for comparing the gastric-type electrode with and without a sleeve is fully discussed in the text.

Table 5

THE EFFECT OF TEMPERATURE ON THE

ELECTRODE POTENTIAL

Temperature of Electrode and NaCl in Degrees Cent. Reference	Active	Potential of active Electrode in mv.
20	20	0.0
20	22	0.55
20	24	0.97
20	26	1.50
20	28	1.87
20	30	2.33
20	32	2.83
20	34	3.57
20	36	4.43
20	38	5.10
20	40	5.73

Table showing the effect of temperature on the potential measured between two electrodes. Figures were an average of four measurements. Standard deviation of the last figure of 5.73 was 1.57.

as that without any sleeve. When doing recordings the gastric-type electrode was always balanced at the end as well as the beginning of the test. The balance was seldom out as much as 2 mv. This acted as a check to see how the gastric-type electrode could withstand infiltration by the gastric contents.

In vitro studies suggest that normal potassium chloride might have been slightly better as an electrolyte than the N/6 sodium chloride in very strong acid. However, in the range of acid found in the stomach they were about the same. In practice the N/6 sodium chloride gave adequate results, was easier to procure in sterile form, and was less irritating to the nasal and pharyngeal mucosa.

Difference in the temperature between the skin electrode and the gastric electrode tended to cause a small variation in the gastric potential measured. However, this was not only small but also fairly constant. The gastric electrode remains at body temperature of 37°C. The skin electrode in the sponge varied in a range of 25 ± 5° C. These temperature changes would cause a potential variation of ± 1.5 mv. which is an allowable degree of error.

The last column of figures in Tables 1, 2, 3, and 4 also show the effect of temperature. The last column of Table 2 shows the results of the in vitro experiment which most nearly duplicated the actual testing situation. This experiment showed that the gastric-type electrode warmed up completely within 15 minutes. Thereafter the effect of temperature was constant at 2 mv.

CHAPTER III

THE PROBLEM OF SKIN POTENTIALS AND THE TECHNIQUE OF PIERCING THE SKIN

The skin surface has been used as the location for the reference electrode in the electrogastrograph. By using the skin as the location of the reference electrode a skin potential is measured as well as the gastric potential. The skin potential is the potential between the surface of the skin and the underlying tissues or mesosomal isopotential continuum of Davis (13). This concept of an isopotential continuum has been developed further in the discussion. The skin potential varies between 5 and 25 mv. in different people. It varies with sweat gland activity (4), circulation, and skin temperature (9 and 50). The skin potential is oriented in such a manner that the skin surface is negative to the underlying tissues and hence tends to cause the measured gastric potential to be less negative than the true gastric potential.

Not only does the skin potential change the average gastric potential but also it causes an extra variable in the gastric potential measurement which increases the variance of a group of like cases. That is, a group of cases which normally all had about the same gastric potential, would have an increased range of potential measurements when an extra variable as the skin potential is added.

Only recently has it been realized that the skin potential was a source of error in the gastric potential measurement. Alvarez (2) in 1922 used the skin of the epigastrium as the location of the reference electrode. This caused a large source of error as the epigastrium has a very fluctuating skin potential.

More recent workers are aware of the problem of the skin potential but have done little to correct the situation. Goodman (20), as recently as 1955, mentioned the problem as one of the sources of error but gave no suggestions of how to overcome it. Sawyer (44) "scarified" the skin but did not state whether this overcame any or all of the skin potential.

Work in this center has been directed first of all at finding a stable skin area. Allen (1) suggested that the skin of the right delto-pectoral groove would be good as a location for the reference electrode of the electrogastrograph because sweat gland activity was minimal in this area. He was able to show that the skin potential was more stable in this area than the other areas tested. However, even this area was variable.

In this thesis the term skin potential refers to the electrical potential of the surface of the skin measured with a pierced skin as a reference. The procedure of piercing is described in the next section under "Method". This same technique of piercing was also used to overcome the skin potential in the work on gastric potential.

This procedure of piercing the skin was described by Forbes (16) in 1936. He used it at the reference electrode

to eliminate only the variability of the skin potential. Richter and Woodruff (44) used the pierced skin technique. This was used at the reference electrode to overcome the skin resistance. Neither of the above measured the skin potential. Barnes (4) took the skin surface as the reference point and described a positive "injury potential" at the site of the active electrode due to piercing. What he was doing in effect, by piercing the skin, was overcoming the skin potential at the active electrode and measuring the negative skin potential at the reference point. Instead, he should have had the reference electrode over the piercing and the active electrode on the skin surface.

The object of the experiments in this section was to determine whether piercing the skin could short-circuit the skin potential. Various techniques of piercing were studied. The durability of the short circuit during the period of the recording was also determined. The skin potential itself was studied using the pierced-skin as a reference point.

Method

The technique of piercing consisted first of all in sterilizing the area to be pierced with 70% alcohol. The skin was held taut with the thumb and fore-finger of the left hand. All layers of the skin were then pierced three times with a number 21 hypodermic needle. The depth of piercing was about 3/16 of an inch. There was seldom any blood as a result of

this procedure. The electrode was placed over the piercings and over this again was some gauze soaked in saline. The whole was held in place with adhesive tape. This technique was followed for the first three series. Later, for the fourth series, the technique was varied by placing a small wad of absorbent cotton soaked in saline between the electrode and the piercing. In the fifth series the electrode was placed within a cellulose sponge soaked in saline.

These five series were varied by changing not only the technique but also the location of the skin and pierced-skin electrodes. Areas where either thermal or psychic sweating were known to be of high activity, as the palmar, plantar, and forehead skin, were purposely avoided (25 and 52). In the first series the forearm skin was pierced and the skin potential of the arm was measured. In the second series the arm was pierced. In the third, fourth, and fifth series both arm and forearm were pierced using alternating right and left sides.

There were some cases in which two piercings were done at the same time and in other cases, the second piercing was done an hour after the first. This was to test the durability of the piercing. By durability was meant the ability of the pierced-skin to short-circuit the skin potential over a period of time.

Studies were undertaken to determine whether misplacement of the electrode over the area of piercing would affect

the potential measured. The reference electrode in this experiment was a regular pierced skin. The active electrode was placed at varying distances from a second piercing. Both electrodes were of the standard skin type. The active electrode was connected to the second piercing with a saline bridge of varying degrees of dryness. In one series there was no bridge at all.

In those cases in which the two pierced skins differed from each other by more than 5 mv. it was assumed that the technique was at fault. The technique in some of these cases was checked to ascertain where the fault lay.

Results

It was shown that as long as there was a moist saline "bridge" between the piercing and the electrode, the distance between the two did not matter up to about one inch. However, with a drier bridge the distance was less before the skin potential overcame the short-circuit caused by piercing. These data are shown in Table 6.

Table 7 gives the electrical potential between pierced skins at different locations. In some of the cases in which the two pierced skins were out 5 mv. or more the technique was studied. It was found, in cases no. 116-55, 70-56, 71-56, 85-56, 90-56, and 99-56, that by tightening the adhesive tape and by adding more saline around the electrodes the two pierced skins came much closer together. In none of these cases was the skin repierced.

Skin potential was different in the various parts of the body studied. It may be seen from Tables 8 and 9 that the skin potential of the forearm was greater than that of the arm. The data of these tables and Table 12 show that the skin potential became more negative during the course of the test. When no drug was given, the skin potential became on the average more negative by 3.9 mv.

The durability of piercing was tested by comparing a piercing done at the beginning of the recording with one done an hour later. This data has been given in Table 10. With the new pierced skin as a reference the old pierced skin measured 1.3 $\pm$ 3.7 mv. in ten cases. That is, after an hour, the piercing was less able to overcome the skin potential by 1.3 mv.

The mean skin potentials with various degrees of acidity and with various diseases were calculated. The skin potential changes as a result of giving various drugs were also determined. These data have been shown in Tables 11, 12, and 13. The most interesting finding of these experiments was that the skin potential in patients with hypothyroidism was significantly less than normal while in those with hyperthyroidism it was significantly greater than normal.

Table 6

EFFECT OF MISPLACEMENT OF THE ELECTRODE

WITH RESPECT TO THE SKIN PUNCTURE

Distance of Active Electrode from the Piercing in Inches	Potential of the Active Electrode in mv. with the Following Degree of Saline Bridging			
	Nil	Moist	Wet	Very Wet
0	0	0	0	0
1/2	-21	-3	1	3
1	-19	0	-1	-1
1 1/2	-18	-9	-4	3
2	-22	-17	-6	-3

All readings were an average of two or more readings.

The table is fully explained in the discussion.

Table 7

POTENTIALS BETWEEN PIERCED SKINS IN DIFFERENT LOCATIONS AND WITH DIFFERENT TECHNIQUES

Series	Electrodes Reference	Active	No. of Cases	Mean Potential in mv.
1	lfps	rfps	24	-1.7 ± 6.7
2	laps	raps	12	0.3 ± 7.0
3	rfps	raps	25	-3.0 ± 6.7
	lfps	laps	27	-3.3 ± 6.6
4	rfps	raps	13	1.4 ± 6.8
	lfps	laps	18	-2.3 ± 4.5
5	rfps	raps	5	0.4 ± 1.4
	lfps	laps	5	2.6 ± 3.3

Notes: A list of all the abbreviations is given in Appendix A. The lfps stands for left forearm pierced skin, the raps stands for right arm pierced skin.

In the first three series the electrode was over the piercing. In the fourth series there was absorbent cotton between the electrode and the piercing. In the fifth series the electrode was in a cellulose sponge. The cotton and sponge were in all cases soaked with saline.

None of the above means is significantly different from zero by the "T" test. The standard deviations became progressively better as the technique improved.

Table 8

SKIN POTENTIALS MEASURED USING THE PIERCED-SKIN AS THE LOCATION OF THE REFERENCE ELECTRODE AND THE SKIN SURFACE AS THE LOCATION OF THE ACTIVE ELECTRODE

Series	Electrodes		No. of	Mean Potential in mv.	
	Reference	Active	Cases	Beginning	End
1	rfps	ras	24	-8.2±5.5	-11.4±7.3
	lfps	las	24	-9.9±8.1	-11.0±8.7
3	rfps	rfs	25	-10.0±11.3	-12.4±10.2
	lfps	lfs	27	-10.3± 9.7	-10.6±12.3
	raps	ras	25	-3.4± 6.3	-3.6± 7.7
	laps	las	27	-4.0± 5.5	-4.6±13.2
4	rfps	rfs	13	-9.5± 5.0	-11.6± 3.7
	lfps	lfs	18	-9.6± 7.4	-9.9± 7.4
	raps	ras	13	-6.7± 6.9	-11.2± 9.8
	laps	las	18	-3.4± 4.2	-9.2±10.4
5	rfps	rfs	4	-5.5± 5.9	-11.0±10.1
	lfps	lfs	5	-5.4± 9.1	-9.6±10.5
	raps	ras	4	-7.5±11.4	-10.3±12.7
	laps	las	5	-4.6± 5.7	-11.0±11.6

A list of abbreviations is given in Appendix A. The rfps refers to the right forearm pierced skin. The ras stands for the right arm skin. The significance of this data is discussed in the text.

Table 9

DIFFERENCE OF SKIN POTENTIALS MEASURED BETWEEN VARIOUS AREAS OF THE ARMS

Series	Electrodes Reference	Active	No. of Cases	Mean Potential in mv.
1	las	ras	24	2.6 ± 5.4
3	rfs	ras	25	4.1 ± 7.5
	lfs	las	27	2.3 ± 6.5
4	rfs	ras	13	5.4 ± 4.7
	lfs	las	18	2.1 ± 5.8
5	rfs	ras	5	2.4 ± 4.2
	lfs	las	5	7.7 ± 4.7

A list of abbreviations is given in Appendix A. The different areas of the skin vary more between each other than do the various pierced-skins as shown in Table 7. The significance of these figures is discussed in the text.

Table 10

THE DURABILITY OF PIERCING OVER

A PERIOD OF TIME

Case No.	Time in Minutes Between Piercings	Potential in mv. of Old Piercing with New Pierced-Skin as Reference
106-55	60	4
108-55	60	-2
117-55	60	-5
121-55	15	-5
50-56	60	-3
50-56	60	3
50-56	60	2
112-56	60	-1
113-56	60	1
115-56	90	-7
Mean		-1.3 ± 3.7

The mean potential change has been calculated including the two cases in which the time interval was not 60 minutes. The change in potential was about the same as the difference in potential between two pierced-skins as given in Table 7.

Table 11

A CORRELATION OF SKIN POTENTIAL AND

GASTRIC ACIDITY

Acidity	Number of Cases	Mean Skin Potential in mv.
No free acid with stimulant	16	-6.0 ± 7.6
Free acid only after stimulant	18	-8.4 ± 6.1
Free acid in fasting specimen	19	-5.4 ± 4.2

The gastric stimulant used was alcohol, histamine priscoline, or insulin. These means are not significantly different. Therefore, there is no correlation between skin potential and the ability of the stomach to produce acid.

Table 12

CHANGE IN SKIN POTENTIAL AS A RESULT OF CERTAIN DRUGS

Drug	No. of Cases	Mean Change in Skin Potential in mv.
30 cc. of 7% Alcohol	11	-2.2 ± 3.9
25 mg. Priscoline	12	-2.4 ± 6.0
0.5 mg. Histamine	10	-3.8 ± 5.1
No drug	54	-3.9 ± 4.2

These means are not significantly different.

Table 13

A CORRELATION OF SKIN POTENTIAL WITH

VARIOUS DISEASES

Diagnosis	Number of Cases	Mean Skin Potential in mv.
Hypothyroid	4	-1.1 ± 1.3
Duodenal ulcer	12	-4.8 ± 5.3
Pseudocontrol	12	-5.0 ± 4.9
Pernicious anemia	4	-6.0 ± 8.1
Gastric ulcer	9	-7.9 ± 4.1
Psychoneurotics	3	-8.0 ± 7.2
Carcinoma	18	-8.4 ± 4.9
Acute gastritis	6	-8.7 ± 8.9
Normal	10	-9.0 ± 4.2
Hyperthyroid	5	-13.5 ± 4.2

The means of the hyperthyroid and hypothyroid patients are significantly different from normal.

Discussion

In the studies of misplacement of the electrode it was shown that misplacement from the piercing up to an inch did not cause any appreciable change in potential measured. It is improbable that the electrode was ever so far misplaced in routine testing. The important factor was maintenance of a moist saline bridge between the piercing and the electrode.

In considering those cases in which the technique was poor it was found that either the adhesive tape had been attached loosely or that the sponge around the electrode was not sufficiently moist. It would appear that the piercing itself was never at fault since it was found that, with improved technique of applying the electrodes, no further trouble was encountered.

In the cases in which the skin was repierced at the end of the test period, to study the durability of the first piercing, it was found that the older piercing was less able to short-circuit the skin potential by 1.3 mv.

Skin potential was more negative on the forearm than the arm. It was more negative on the left arm than on the right. Snodgrass (51) found the skin surface of the left arm negative to that of the right. He reported a difference of 1.7 mv. in 14,000 measurements. Barton (6) showed that it was the hand dominance of an individual which determined the negativity. The dominant hand was less negative. He, like Snodgrass, did not measure skin potential, but rather compared the surface of the skin of the two arms.

The skin potential increased in negativity on an average of 3.9 mv. over the period of testing when no drug was given. This change in skin potential was probably a result of an adaptation to the test situation through physiological and psychological mechanisms. This increase in negativity was less with no drug than with each of the three gastric stimulants given. These drugs, alcohol, priscoline, and histamine, are known to increase the skin circulation which would modify the other factors tending to increase the negativity of the skin potential. The second measurement of skin potential was made against the pierced-skin which itself had changed in a negative direction by an average of 1.3 mv. Therefore, with no drugs the skin potential had actually become more negative by 5.2 mv. The pierced skin was, therefore, four times as stable as the skin during the period of the tracing. Also the standard deviation of the pierced-skin change at 3.7 mv. was less than that for the skin at 4.2 mv. This finding about the pierced-skin was most important.

This change of skin potential was substantiated by the data of gastric potentials. The mean gastric potentials measured against the skin became less negative by an average of 6.1 mv. during the period of testing (Table 15). This was due to the change of the skin potential which was also measured when the skin was used as a reference. The mean gastric potential only changed 2.3 mv. on the average when the pierced-skin was used as a reference. This is comparable to a change of 1.3 mv.

in the pierced-skin measurement during the period of tracing. It can be seen that this change of gastric potential confirmed the thesis that the pierced-skin was more stable as a reference than the skin surface.

Note: It must be remembered that the skin potential is oriented in the opposite direction to the gastric potential in the external circuit when comparing these changes.

The whole point of piercing the skin is to overcome the skin potential and therefore to use the mesosomal isopotential continuum of the body as a reference point. This is the only sound potential to use as reference in bioelectric measurements (13).

CHAPTER IV

GASTRIC POTENTIALS

The object of the experiments described in this section was the study of the direct current component of the electrogastrograph. This gastric potential was studied using both the skin and pierced-skin as a reference. Gastric potential was measured using the pierced-skin as a reference in an effort to overcome the skin potential. The two gastric potential measurements were compared in various diseases and with various degrees of mucosal activity.

Gastric potential has been shown to arise between the submucosa and mucosa in laboratory animals by Rehm (37). In the laboratory it is measured between the serosa and the mucosa as the mucosa is almost the same electrical potential as the submucosa (37). The mucosa is always negative to the serosa (14). It has been shown to vary with mucosal activity in laboratory animals (38 and 43).

Rehm (38) has studied extensively the relationship between mucosal activity and electrical potential. He has shown that the E.M.F's of the mucosa send electrical current across the canalicular border of the parietal cells in the direction of the canaliculi. This flow of current in the presence of a gastric stimulant results in the production of hydrogen ions.

Rehm has also shown that the flow of current can control the production of hydrogen ions without furnishing a major portion of the free energy needed for the osmotic work involved in the formation of hydrogen ions.

Most of the work in man has been done on the alternating current component of the electrogastrograph. Work on the direct current component of the electrogastrograph has been done by Morton (32 and 33). Even with the skin as a reference, Morton was able to show that there were variations in gastric potential with various diseases. This work has been confirmed by Ingram and Richards (22). These workers also measured the skin potential along with the gastric potential.

The gastric potential was studied with various degrees of mucosal activity. The mucosal activity was determined not only by the acidity of the stomach but also as the result of giving various drugs and as a result of vagotomy and sympathectomy. The mean gastric potential was found in hypothyroidism and hyperthyroidism to determine whether a general change in metabolism would affect the gastric mucosal metabolism. The mean gastric potential associated with various gastric lesions was determined.

Method

About one hundred and eighty records were done in which both the skin and the pierced-skin were used as a reference. These cases included a large variety of gastric diseases. In

about half of the cases a gastric analysis was done concurrently with the electrogastrograph recording. These patients were fasting while those who did not have a gastric analysis had usually eaten about two hours previous to the test.

First the gastric electrode was inserted through the patient's nose into the stomach. In a few cases in which the patient would not tolerate it in the nose, it was inserted by mouth. The distance the electrode was down was recorded. In some cases the position was also checked by radiography. Next the skin and pierced-skin electrodes were applied as described in the section on skin potentials.

During the first part of the recording, data were collected about skin potentials. The skin potentials were usually repeated at the end of the recording. After the skin potentials were taken, the record was set to run measuring gastric potential using the pierced-skin as a reference. The usual routine was to develop a baseline potential for 10 or 15 minutes. In those cases in which a gastric analysis was done, a fasting specimen was taken and 30 cc. of 7% alcohol were given via the gastric electrode. Further specimens were taken at 15 minute intervals. If there was no free acid after the second specimen another drug was given. In some cases 0.5 mg. histamine was used as a stimulant; in other cases 25 mg. of priscoline was given intravenously. In one patient, at two different times, two different doses of insulin were given.

The effect of vagotomy on the gastric potential was studied by doing electrogastrographs before and after the

vagotomy. Some of these tracings were done by a previous worker, the results of which are analysed here. The effect of a sympathectomy was studied during an epidural xylocaine block.

The control cases were divided into two groups on the basis of symptoms. Those cases with no pathology and no symptoms were called normal. Those patients who complained of gastric symptoms but in whom no pathology was found were put in a group designated pseudocontrols. In some cases a pathology report was not available. In these cases the discharge diagnosis was accepted as final, if it was clinically well established.

Results

Mean gastric potentials recorded in the various series with different reference points are given in Table 14. The means are about 10 mv. more negative when measured against the pierced-skin rather than the skin. This is to be expected as the skin potential is about 10 mv.

Mean gastric potential correlated with different degrees of gastric activity is given in Table 15. The activity in this table has been determined by the ability of the stomach to produce acid. The more active stomachs, capable of producing more acid, had the more negative potential.

The mean change of gastric potential occurring with a change of mucosal activity as a result of giving various drugs

is given in Table 16. As the stomach mucosa becomes more active in response to histamine, it becomes less negative. Insulin, if given in an adequate dosage to lower the blood sugar, also causes a decrease of negative potential. These data have been represented in Table 17.

The change of gastric activity, as shown by changes in gastric potential, with interruption of the nerve supply is given in Tables 18 and 19. Vagotomy results in a more negative potential, while xylocaine epidural sympathectomy makes the gastric potential less negative.

The data of mean gastric potential in various diseases are given in Table 20. Those diseases associated with an active gastric mucosa as gastritis, and duodenal ulcer have gastric potentials which were significantly more negative than normal. Gastric ulcer, pernicious anemia, and cancer have a less negative potential.

The mean gastric potential and change of potential were also calculated using two different methods of selection. Tables 21, 22, and 24 show the data with those cases in which the technique was considered to be poorly eliminated; that is, those cases with a pierced-skin to pierced-skin potential of more than 5 mv. Tables 23 and 24 show the difference in the standard deviation as a result of selection of cases to eliminate those who had eaten a short while before testing.

Table 14

MEAN GASTRIC POTENTIALS MEASURED FROM DIFFERENT REFERENCE POINTS

Series	Reference Electrode	No. of Measurements	Mean Gastric Potential in mv.
1	ras	23	1.4 ± 19.0
	lfps	23	-7.8 ± 23.0
2	laps	12	-13.4 ± 12.3
	lfs	12	2.8 ± 15.8
	rfs	12	1.0 ± 31.5
	raps	12	-14.2 ± 31.6
3	ras	25	-5.8 ± 14.8
	las	27	-3.6 ± 15.8
	rfps	25	-14.1 ± 15.5
	lfps	27	-11.8 ± 11.6
4	ras	13	-0.5 ± 12.8
	las	18	-5.1 ± 13.8
	rfps	13	-8.6 ± 10.7
	lfps	18	-15.6 ± 12.2
5	ras	4	4.7 ± 7.7
	las	4	0.4 ± 3.2
	rfps	4	-15.0 ± 9.6
	lfps	4	-21.0 ± 5.4

It may be noted that the gastric potential measured is more negative by about 10 mv. when the skin potential is eliminated by piercing. A list of abbreviations used is given in Appendix A.

Table 15

A CORRELATION OF GASTRIC POTENTIAL WITH

THE ABILITY TO PRODUCE ACID

Acidity	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
No free acid with stimulant	18	4.7 ± 10.4	-4.8 ± 10.9
Free acid only after stimulant	19	-1.2 ± 11.8	-16.0 ± 16.6
Free acid in fasting specimen	21	-7.0 ± 12.8	-18.6 ± 25.9

It may be noted that those stomachs which were more active, as shown by their ability to produce acid, had the more negative potential. This correlation is with the mucosal activity and not with the gastric contents. This point is most important and has been dealt with in detail in the discussion.

Table 16

CHANGE OF GASTRIC POTENTIAL AS A RESULT OF CERTAIN DRUGS

Drug	No. of Cases	Change in Gastric Potential in mv. with skin	with pierced-skin
30 cc. 7% Alcohol	11	-2.0 ± 11.8	-4.1 ± 9.8
No drug	30	6.1 ± 14.5	2.3 ± 13.2
25 mg. Priscoline	12	4.9 ± 16.3	3.7 ± 14.8
0.5 mg. Histamine	10	13.4 ± 7.3	7.4 ± 4.3

The change of gastric potential is significantly greater with Histamine than with the other drugs. When using the skin as reference the mean gastric potential became 6.1 mv. more positive. This was because the skin potential, which is included in this measurement, had changed by an average of minus 5.2 mv.

Table 17

CHANGE OF GASTRIC POTENTIAL AS A RESULT OF GIVING INSULIN

Record No.	Dose of Insulin	Lowest Blood Sugar	Highest Total Acid	Duration of Recording	Change of Gastric Potential in mv. with skin	with pierced-skin
147-55	10 units	65 mg.	5 units	90 min.	-6	1
152-55	20 units	39 mg.	12 units	60 min.	7	5

Both of these recordings for the effect of insulin were done on the same patient. Using the pierced-skin as a reference, there was a minimal change of measured gastric potential with the 10 units of insulin even after 90 minutes. However, with the larger dose, the patient had a response in both gastric potential and blood sugar after 60 minutes.

Table 18

CHANGE OF GASTRIC POTENTIAL AS A RESULT OF VAGOTOMY

Recording No.		Gastric Potential with the Skin in mv.		
Before	After	Before	After	Change
151-53	159-53	15	17	2
197-53	206-53	8	-15	-23
174-53	225-54	14	15	1
18-55	19-56	-10	-13	-3
162-55	17-56	8	6	-2
55-56	66-56	22	13	-9
Mean				-5.7 ± 9.3

Some of these recordings were done by a previous worker. Although the standard deviation is high, this data suggests that the potential becomes more negative with section of the vagus nerve.

Table 19

DATA FROM CASE NO. 80-56 SHOWING CHANGES IN GASTRIC POTENTIAL DUE TO A XYLOCAINE EPIDURAL SYMPATHECTOMY

Time	Status	Gastric Potential in mv. with pierced-skin
12:30	original xylocaine	-72
2:00	sympathectomy wearing off	-76
2:30		-80
3:00		-90
3:15	Sympathectomy of xylocaine	-92
3:30	repeated	-90
4:00		-88
4:15		-88

A sympathectomy appears to cause a decrease of negative potential.

Table 20

A CORRELATION OF GASTRIC POTENTIAL WITH

VARIOUS DISEASES

Diagnosis	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
Gastric ulcer	9	8.2 ± 13.4	0.6 ± 14.8
Hyperthyroidism	5	9.8 ± 15.0	-1.6 ± 22.0
Carcinoma	22	0.1 ± 12.9	-6.5 ± 13.6
Pernicious anemia	4	-3.3 ± 8.3	-10.7 ± 13.5
Neurotic	4	-0.3 ± 6.2	-10.8 ± 6.1
Normal	10	-3.6 ± 8.1	-11.5 ± 9.1
Hypothyroidism	3	-8.4 ± 17.0	-14.3 ± 10.8
Duodenal ulcer	14	-2.8 ± 10.6	-17.2 ± 7.5
Gastritis	6	-11.6 ± 7.1	-19.5 ± 14.1
Pseudocontrol	12	-12.6 ± 12.1	-19.9 ± 11.1

These diagnoses are in order of their mean gastric potentials measured with the pierced-skin as reference.

Table 21

A CORRELATION OF GASTRIC POTENTIAL WITH THE ABILITY TO PRODUCE ACID

CASES SELECTED SO THAT THE DIFFERENCE OF POTENTIAL OF THE TWO PIERCED-SKINS WAS 5 mv. OR LESS

Acidity	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
No free acid with stimulant	10	5.3 ± 9.7	-2.5 ± 10.9
Free acid only after stimulant	11	-2.1 ± 10.5	-12.0 ± 12.7
Free acid in fasting specimen	18	-6.0 ± 10.9	-17.3 ± 7.2

The standard deviations in this table were less than those of Table 15. The reason the variance was smaller is that those cases which in retrospect the technique was considered poor have been eliminated. These were the cases in which the two pierced skins differed by more than 5 mv.

Table 22

A CORRELATION OF GASTRIC POTENTIAL WITH VARIOUS DISEASES

CASES SELECTED SO THAT THE DIFFERENCE OF POTENTIAL

OF THE TWO PIERCED-SKINS WAS 5 mv. OR LESS

Diagnosis	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
Gastric ulcer	5	14.0 ± 12.7	5.4 ± 4.8
Carcinoma	10	6.6 ± 13.9	-4.4 ± 12.6
Pernicious anemia	3	0.6 ± 3.1	-5.6 ± 9.1
Normal	5	-2.0 ± 8.1	-8.6 ± 11.4
Hypothyroidism	3	-8.4 ± 17.0	-14.3 ± 10.8
Hyperthyroidism	3	-2.7 ± 4.1	-16.0 ± 9.7
Duodenal ulcer	12	-3.2 ± 11.2	-17.5 ± 7.2
Pseudocontrol	11	-14.6 ± 12.7	-19.4 ± 10.4
Gastritis	3	-12.6 ± 8.2	-19.6 ± 14.7

These cases were selected in the same manner as those of Table 21. That is, only cases with good technique were used. This table should be compared with Table 20. This comparison shows the standard deviations to be decreased by using only those cases in which the piercing technique was adequate. This is of course only those readings in which the pierced skin was used as a reference.

Table 23

MEAN GASTRIC POTENTIALS IN FASTING AND NON-FASTING PATIENTS

Status	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
Eaten within two hours	58	-1.7 ± 14.8	-9.2 ± 16.0
Fasting	59	-1.4 ± 11.3	-12.1 ± 11.6

This table shows the data of the decreased standard deviations as a result of having the patients fasting. This fact may also be brought out by comparing the data of Table 24 with that of Table 22.

Table 24

A CORRELATION OF GASTRIC POTENTIAL WITH VARIOUS DISEASES

CASES ALL FASTING AND SELECTED AS IN TABLE 22

Diagnosis	Number of Cases	Mean Gastric Potential in mv. with skin	with pierced-skin
Gastric ulcer	4	8.5 ± 2.6	4.3 ± 2.7
Pernicious anemia	3	0.6 ± 3.1	-5.6 ± 9.1
Carcinoma	8	3.6 ± 14.9	-5.9 ± 13.5
Pseudocontrol	7	-10.0 ± 8.6	-17.6 ± 5.6
Duodenal ulcer	9	-3.9 ± 12.7	-20.1 ± 4.6

The standard deviations of this data should be compared with those of Table 22. It may be determined from the data of these tables that the variance within the various groups is decreased by taking the recordings of only those patients who were fasting.

Discussion

The data show that there are significant differences in mean gastric potential with differences in gastric activity. Many people have thought that a change of potential was synonymous with a change of gastric acidity and have even gone so far as to suggest that the electrogastrograph was a pH meter. This is definitely not true. The electrogastrograph is not a pH meter.

A group of workers led by Rovelstad (48) who tried to measure the pH of gastric contents found that they could not do so because of the electrical potentials involved. Their apparatus recorded 3 per minute waves of 5 pH units amplitude. This frequency is the same as that measured by the electrogastrograph. Obviously the pH of an electrolyte cannot vary 5 pH units three times per minute.

Most research workers when they start on the electrogastrograph somehow have the misconception that the instrument is a pH meter. They soon, however, publish a paper showing that this is not true. Katzka (23) in one of his earlier papers came to the conclusion that the electrical potential measured intragastrically was specific for the stomach and independent of the gastric contents. Rice (43) showed that there is a change of potential difference with drugs if acid is not produced or is buffered out. Crane et al (11) showed that the gastric potential difference was dependent on an adequate blood and oxygen supply and was abolished at the moment of death.

However, it is true that those stomachs with an active mucosa and a more negative electrical potential have a higher free fasting acid. When they are stimulated to produce acid the potential becomes less negative, or more positive. The data in Table 16 show this change, using the pierced-skin as a reference, as 7 mv. with histamine. Katzka (23) gave a value of 14 mv. when using the skin as a reference. Table 16 shows a value of 13 mv. when the skin potential is included in the gastric potential measurement. This is comparable to the 14 mv. found by Katzka.

Priscoline is also a gastric stimulant (45). However, it does not produce a change of gastric potential as great as histamine. The data of this drug are shown in Table 15.

In one patient in whom 10 units of insulin was given subcutaneously the blood sugar only dropped to 65 mg.% and there was only 1 mv. change of gastric potential after 90 minutes. However, in this same patient when the dose of insulin was increased to 20 units intravenously the blood sugar dropped to 39 mg.%. With this blood sugar response the pierced-skin to gastric potential became less negative 5 mv. after about 60 minutes. This was about the time required for the blood sugar to lower. Similar results were found by Mack, Allen and Morton (26).

Vagotomy resulted in the record becoming more negative. The one case of sympathectomy suggested that this procedure results in the record becoming less negative. This was what

one would expect from the function of these nerves. The vagus stimulates the stomach to more activity. Loss of vagal tone due to vagotomy would, therefore, cause less activity of the stomach and a more negative potential. Loss of sympathetic tone appears to work in just the reverse manner.

As may be seen from the data the gastric potential was more negative than normal in those cases associated with an active mucosa and a high acid secretion as duodenal ulcer and gastritis. On the other hand, those conditions which were associated with an atrophic mucosa and a low mucosal activity as gastric ulcer, pernicious anemia, and carcinoma of the stomach had a less negative potential.

Pseudocontrols were patients who complained of symptoms but in whom no pathology was found. For the most part they were nervous people. They were often diagnosed as functional dyspepsia or hypersecreters. Their electrical potential was high, of the same order as the duodenal ulcer and the acute gastritis.

A tentative conclusion was reached during the course of the year that the technique was poor in some of the earlier cases in which the potential between the two pierced skins was more than 5 mv. The means and standard deviations of the various groups were recalculated using only those cases in which the difference between the two pierced skins was 5 mv. or less. Tables 21, 22, and 24 show that the standard deviations of the pierced-skin to gastric potentials were improved by the elimination of those cases in which the technique was, in retrospect,

considered poor.

The means and standard deviations were also calculated for the different diseases using only the data of those patients who had been fasting. These data are presented in Table 24. It was found that this selection decreased the standard deviation especially in the pierced-skin to gastric group. This would suggest that better diagnostic accuracy could be achieved by having all the patients fasting.

It was shown in the study on skin potentials that the pierced-skin was about 4 times as stable as the normal skin during the period of testing. These data may be compared to those of Table 16 showing the average change in measured gastric potential during the course of the test giving no drugs. When using the skin as a reference the average measured gastric potential changed 6.1 mv. This was comparable to a change of skin potential on the average of 5.2 mv. On the other hand, with the pierced-skin as a reference the change of gastric potential was only 2.3 mv. This change was similar to the pierced-skin change of 1.3 mv. during the course of the test. These data substantiate the thesis that the pierced skin was much more stable than the skin during the course of the test.

CHAPTER V

POTENTIALS STUDIED DURING OPERATION

The object of the experiment described in this section of the work was to compare gastric potential, measured with the pierced-skin as a reference, to the gastric potential, measured with the serosa as a reference. That is, a comparison was made of the gastric potential measured in the regular work laboratory with the true gastric potential between serosa and mucosa.

In all the work done on laboratory animals the serosa has been used as a reference, whereas in all the work done on humans, the skin has been used as a reference. The work in this section was to correlate these two groups of work.

It has been assumed that changes of gastric potential due to gastric pathology arise on the mucosal side of the stomach wall. The electrical potential of the serosa overlying a carcinoma was compared with that of serosa of normal stomach and other viscera.

It was found, in most cases, that readings taken in the operating room were completely outside the range of expected values. The measurements varied not only in magnitude but also in polarity. Accordingly, steps were taken to determine the cause of these questionable measurements. An attempt was made to duplicate the operating room situation in the regular

work laboratory. Studies showed that the main electrical difference was that in the operating room the patient was connected to ground. The patient was grounded by several pathways including intubation, nasal-gastric suction, intravenous fluid therapy, and moist dressings. A series of tests in which the various electrodes were shorted to ground gave values similar to those found in the operating room.

Method

In the operating room standard skin-type electrodes were applied to the skin in the usual way. The gastric electrode was inserted through the patient's nose about an hour before operation. The electrodes used for the serosa and subcutaneous tissue were of the standard gastric-type with the following modifications. They were more strongly constructed and were sterilized before assembly. The serosal electrode was held in place in a fold of serosa. The subcutaneous electrode was put into a forceps-made tunnel at the side of the incision. Measurements were made between all combinations of the five electrodes.

A study of the effect of shorting the various electrodes to ground was done in the regular work laboratory, as well as in the operating room, so that the short to ground could be varied at will. Following this, each of the electrodes was in turn shorted to ground with a gastric-type electrode. The electrode in the stomach was shorted to ground by a N/6 saline

bridge in the lumen of the gastric electrode. This "bridge", therefore, connected together the two gastric-type electrodes; that is, the one in the stomach to the grounding electrode outside.

Tests were also done in the operating room on shorting to ground. The regular silver-silver chloride leg ground was disconnected temporarily and the change was noted. The change was also noted due to grounding the patient with intubation, the establishment of nasal-gastric suction, and the starting of intravenous fluid therapy.

In one case, No. 111-56, the serosa to subcutaneous potential was zero. In this case the position of the serosal lead was varied to determine if the potential of the serosa varied in different places.

A gastrectomy specimen, of a case of carcinoma, was examined electrically upon removal from the abdomen. The reference electrode was of the gastric-type and was put on the serosal surface. The active or exploring electrode was also of the gastric-type. This was moved around to the different parts of the mucosa and the potentials recorded. The reference electrode was also varied in its position on the serosa.

Results

The data of the operating room cases are given in Table 25. Case No. 105-56 was one in which algebraic summation gave approximately equal results. The data of this case are presented graphically in Figure 4.

A.B. 105-56

MAY 26

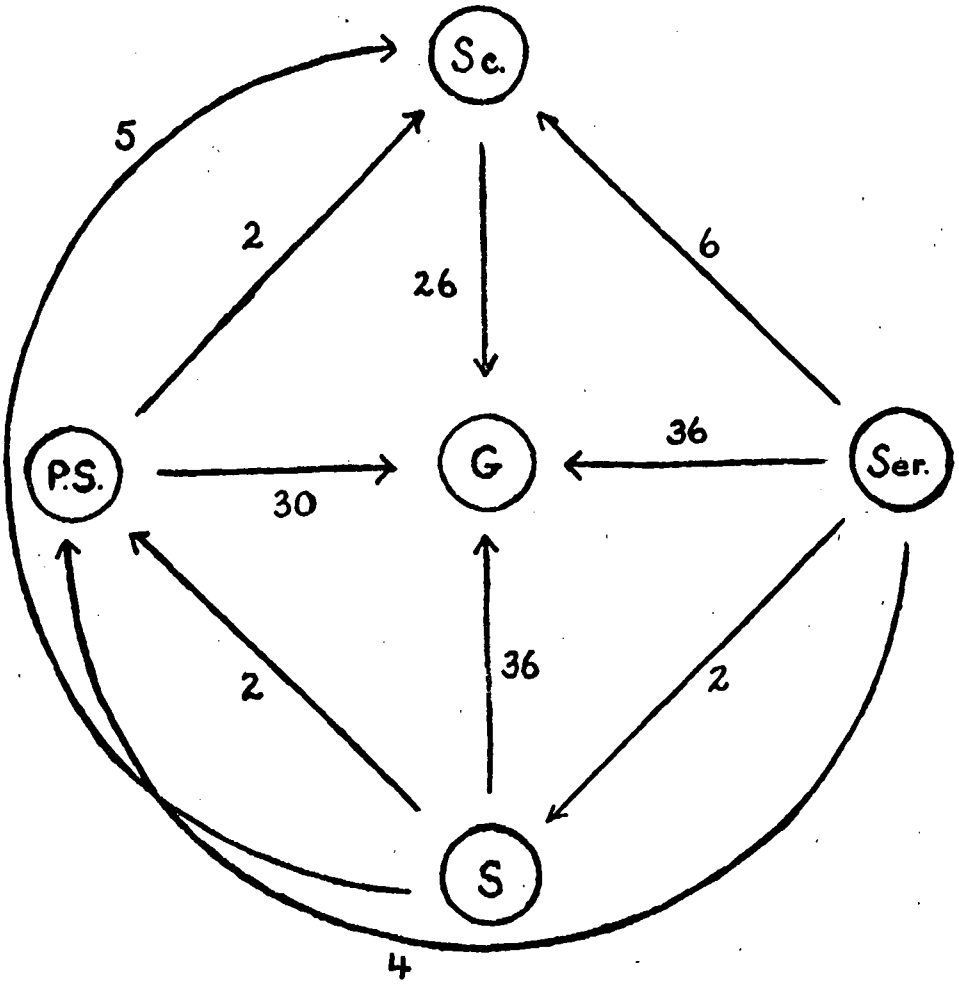


Figure 4. Algebraic Summation in Case No. 105-56

The results of shorting the various electrodes to ground by the gastric-type electrode in the regular work laboratory were inconstant in magnitude. However, there was a definite pattern to the polarity. In those cases in which the reference electrode was grounded, the reading became more positive. When the active electrode was grounded, the reading became more negative. These data are given in Table 26.

The potential changes in the operating room due to grounding were quite complicated. There was no change on removing the ground electrode from the leg skin. The change as a result of grounding the patient in the operating room depended on whether the reference or active electrode was most directly connected to ground. In the skin to gastric reading the measurement became more negative with intubation. In the pierced-skin to skin measurement the reading became more positive with this operating room grounding. In the recovery room with the intubation disconnected the measurement of the skin potential became negative, whereas in the operating room it was almost always positive. The pierced skin to gastric measurement became slightly more positive on operating room grounding. These data have been shown in Table 27.

The results of comparing the electrical potential of the various parts of the serosa suggest that the subcutaneous tissue and the various parts of the serosa, even over the carcinoma, are of equal potential. These data have been shown in Table 28.

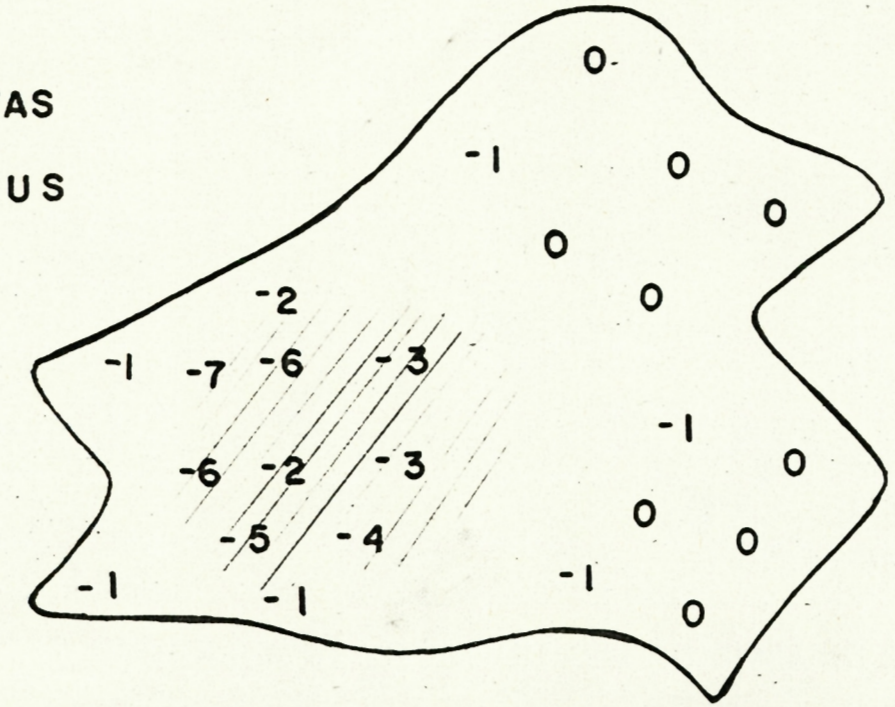
The results of comparing various parts of the stomach

mucosa 15 minutes after removal have been shown in Figure 5. Changing the position of the reference lead on the serosa caused no change in the measured potential. The active lead was moved to the various parts of the mucosa including over the neoplastic area. This caused changes in the measured potential as recorded in Figure 5. These potentials slowly decreased to zero over the ensuing 15 minutes.

ELECTRICAL POTENTIALS

OF NORMAL AND CARCINOMATOUS GASTRIC MUCOSA

15 MINUTES AFTER REMOVAL



POTENTIALS WERE RECORDED

WITH SEROSA AS REFERENCE

Figure 5.

Table 25

DATA FROM OPERATING ROOM CASES SHOWING

TYPICAL MEASUREMENTS

Case No.	Electrodes: Reference/Active									
	s* g	ps s	ps g	sc s	sc ps	sc g	ser s	ser ps	ser sc	ser g
99-55	-29			-59		-65	72			16
151-55			-10			-30				
4-56			-40			-20		-20	-2	-30
82-56	0	12	37	17	6	80				
84-56	-37	-2	-43	17	20	-22	-44	-53	-70	-70
88-56	-45	5	0	45	36					
92-56	-48	29	-20	22	4	-20	22	4		-32
95-56	-29	-60	-18	18	114	-14	10	92	-7	-11
105-56	-36	2	-30	5	2	-26	-2	-4	-6	-36
111-56	-82	82	-20	1	-3	-22	80	-3	0	-22
114-56	-9	137	3	71	-37	-49	106	-2	86	-13

* See Appendix A for a list of these abbreviations.

Table 26

CHANGE OF MEASURED POTENTIAL DUE TO SHORTING THE VARIOUS ELECTRODES TO GROUND

Location of Electrodes	Measured Potential in mv. with the Following Electrodes Short-Circuited to Ground					
	nil	aps	as	fps	fs	g
fps-aps*	2	-10	3	15	7	14
fps-fs	-7	2	-2	11	-11	8
fps-as	-15	148	-96	160	140	57
aps-as	-14	160	-111	142	130	49
fs-as	-3	142	-15	149	169	-3
as-g	6	-10	210	-10	-6	-58
fps-g	-20	-22	-20	-14	-22	-22

* The first mentioned electrode location is the reference and the second the active. For a list of these abbreviations see Appendix A. It may be determined from this data that if the reference electrode was shorted to ground the reading became more positive. On the other hand, if the active electrode was shorted the reading moved in a negative direction.

Table 27

DATA FROM CASES NO. 80-56 AND 111-56 SHOWING POTENTIAL CHANGES DUE TO GROUNDING IN THE OPERATING ROOM

Case No. and Degree of Grounding	Potential Recorded in mv. s/g	ps/s	ps/g
Case No. 80-56			
At start of operation	-42	3	-45
After intubation	-100	20	-80
Intubation discontinued	-70	-15	-86
Case No. 111-56			
At start of operation with leg ground	-33	32	-2
At start of operation without ground	-26	26	-4
After intubation without ground	-94	90	22
After intubation with leg ground	-83	87	20

The data of this table show that the change of measured potential, due to a short-circuit to ground, was the same in the operating room as in the regular work laboratory.

Table 28

DATA FROM CASE NO. 111-56 SHOWING POTENTIAL LEVELS OF THE VARIOUS PARTS OF THE SEROSA

Part of Serosa Over Which Reference Electrode Lay	Potential Measured in mv. With the Active Electrode at			
	s	ps	sc	g
Over normal stomach	78	-4	0	-23
Over cancer of the stomach	80	-3	0	-22
Over small bowel	78	-4	0	-23

The data of this table show that the serosa is of the same electrical potential in the places measured.

Discussion

It was shown, during the work on the skin, that piercing was able to short-circuit the skin potential. It was also shown that, using the pierced-skin as a reference, the gastric potential measurements were more negative, and therefore more in line with results of animal experimentation (43). The experiments, done during operation, were to show that the pierced-skin was about the same electrical potential as the serosa. However, it was shown that as a result of multiple shorts to ground in the operating room, the potential recorded was not a true potential difference. If the reference electrode were grounded the reading moved in a positive direction and if the active electrode were grounded the recording moved in a negative direction. Even though the polarity of these shifts was completely consistent, the magnitude of the shifts was somewhat unpredictable. These varying magnitudes were probably due to factors both in the metal involved in the various grounds and the variable resistance of the pathways to ground.

It was shown in the operating room that removal of the leg ground had little effect, showing that the patient was already grounded by other means. On the other hand, there were marked changes due to intubation and the establishment of nasal-gastric suction, suggesting that these were some of the short-circuits to ground.

In spite of the effect of grounding, the pierced-skin to gastric data were not too dissimilar from the serosa to

gastric data. In case No. 111-56 the two measurements as well as the subcutaneous to gastric were almost the same. In the case No. 105-56 in which algebraic summation was most accurate, it was assumed that the effect of the short to ground was minimal. This case also suggested that the pierced skin and serosa were of equal electrical potential.

The skin potentials were almost all positive in the operating room instead of negative as was usually found. Being more positive it would suggest that the pierced-skin was being grounded more than the skin surface. This was to be expected as the skin surface is a poor conductor of electricity.

The one case in which a specimen was studied outside the body suggested that the negative mucosal potentials continue for a while after the blood supply has ceased. Crane (11) found that in situ the negative mucosal potential decreased to zero within a half hour after clamping off the arterial supply to the stomach. It is suggested that in this particular case the normal mucosa had died, hence the negative potential had gone. However, the carcinoma cells remained alive and able to keep up their negative potential for a longer period of time after removal.

The data suggest that the pierced-skin was approximately the same electrical potential as the serosa. However, this could not be conclusively established because the studies in the operating room were hampered by the electrodes being shorted to ground.

Dr. Davis has proposed that there is a mesosomal isopotential continuum of the body (13). The serosa and peritoneal cavity generally are at this isopotential continuum. The work of this chapter and Chapter III shows that the potential measured with this pierced-skin technique is also at this mesosomal isopotential continuum. It is suggested that the pierced-skin technique is the only practical method of establishing a reference electrode at this mesosomal isopotential continuum.

CHAPTER VI

RECTAL POTENTIALS

Introduction and Method

A pilot study of rectal potentials was carried out during the year. The rectal potential was studied in much the same way as the gastric potentials. Skin-type electrodes were put on two reference points, a skin and a pierced-skin. A gastric-type electrode was used in the rectum. If a lesion was known to exist in the rectum the electrode was inserted to that level. In all other cases the electrode was inserted six inches.

Results and Discussion

The data of rectal potentials show that ulcerative colitis has the least negative potential. Cancer has a potential more negative than normal. Diverticulitis was much more negative than normal. These data of rectal potentials are given in Table 29.

Table 29

A CORRELATION OF RECTAL POTENTIAL WITH VARIOUS DISEASES

Diagnosis	Number of Cases	Mean Rectal Potential in mv. with skin	with pierced-skin
Ulcerative colitis	2	9.5 ± 17.7	-5.0 ± 15.5
Normal	5	-13.4 ± 20.3	-21.8 ± 21.9
Cancer of the rectum	3	-8.0 ± 6.0	-26.0 ± 6.2
Cancer of the colon	5	-25.0 ± 20.6	-28.4 ± 30.0
Diverticulitis	2	-33.0 ± 1.4	-40.0 ± 18.4

This table shows the variations in rectal potential with different diseases.

SUMMARY

Before the gastric potential itself could be studied, other potentials, which caused errors in the gastric potential measurement, were eliminated. These were electrode potentials, diffusion potentials, and skin potentials.

The special gastric-type electrode, when used in conjunction with a skin electrode of the same material, was shown to be able to overcome the electrode and diffusion potentials in the range of hydrochloric acid found in the stomach. By using these electrodes the measured gastric potential did not vary with changes in gastric acidity. The apparatus should not therefore be confused with a pH meter.

A method is described for piercing the skin to short-circuit the skin potential and therefore use the mesosomal isopotential continuum of Davis (13) as the potential of the reference electrode. It was shown that this pierced-skin gave a more stable reference point than the skin. The pierced-skin to gastric potential was shown to be closer to the serosa to gastric potential than the skin to gastric potential. The use of the pierced-skin as the location for the reference electrode was also studied in the operating room. With these facts it was concluded that the pierced-skin was a better location for the reference electrode than the skin surface.

After these variable potentials were eliminated the gastric potential itself was studied. It was found to vary

significantly with gastric activity. The gastric activity was determined by the fasting free acid and was varied with different gastric stimulants such as histamine, insulin, alcohol, and priscoline. The mean gastric potential for various diseases was determined. It was shown that the variance within the various groups could be decreased not only by using the pierced-skin as a reference, but also by having all the patients fasting.

A pilot study of rectal potentials was carried out. It was shown that there were significant differences in rectal potential with differences in rectal pathology.

CONCLUSIONS

Electrode and Diffusion Potentials

The gastric-type electrode was able to overcome the electrode potential adequately in the range of hydrochloric acid found in the stomach. It was shown that the electrogastrograph was not affected by changes in pH. and was definitely not a pH meter. The difference in electrode potential due to a difference in temperature was small and constant enough that it can be considered in the range of experimental error.

Skin Potentials

The skin potential was short-circuited by piercing. The skin potential was significantly higher in the forearm than in the arm. It was significantly higher in hyperthyroidism and lower in hypothyroidism than normal. The skin potential did not vary significantly with disease nor with the giving of histamine, alcohol, or priscoline.

The pierced-skin as a reference point was much more stable than the skin surface during the period of testing.

Gastric Potentials

The mean gastric potential varies significantly with different degrees of gastric activity as determined both by fasting free acidity and gastric stimulants. The gastric potential was more negative in duodenal ulcer and gastritis

than normal. It was of low negativity in pernicious anemia, gastric cancer, and gastric ulcer. The gastric potential became significantly less negative with histamine than with alcohol or priscoline.

The variance of the various gastric potential means was decreased by using only the data on those patients who were fasting at the time of testing. The variance of the pierced-skin to gastric potentials within the various groups was decreased by taking the data from only the patients on which, in retrospect, the technique was considered to be good.

A comparison of the gastric potentials, using the two different reference points and no drugs, reaffirmed the thesis that the pierced-skin was more stable than the skin as a reference point.

Potentials Studied During Operation

Potentials studied in the operating room were variable due to the various electrodes being short-circuited through the patient to ground. In spite of these short-circuits, the evidence that was accumulated suggested that the pierced-skin was of the same electrical potential as the serosa.

Rectal Potentials

There were variations in the rectal potential with different diseases which could be an aid in diagnosis.

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APPENDIX A

List of Abbreviations

List of Abbreviations

a	arm
Ca	cancer
D.U.	duodenal ulcer
f	forearm
g	gastric or gastric-type electrode usually in the stomach, occasionally elsewhere if so stated.
I	interference
l	left
mv.	millivolts
N.Y.D.	not yet diagnosed
P.C.	pseudocontrol
ps	pierced skin
r	right
s	skin
sc	subcutaneous
ser	serosa

APPENDIX B

Tables of Original Data

Notes of the Tables of Original Data

In series 1, 2, and 3 the electrode was placed right over the site of the piercing. In the 4th series a wad of absorbent cotton was placed between the electrode and the site of the piercing. The electrode was placed inside a cellulose sponge in the 5th series.

When two sets of figures are given in the following data, the first set was taken at the beginning of the record and the second at the end of the record. The average record was about 60 minutes.

The letter "g" normally refers to the gastric electrode in the stomach. However, if a rectal, colostomy, or other type of record was done, it then refers to a gastric-type electrode in the part being measured.

The two piercings were done at the same time unless otherwise stated.

The figures are all in millivolts. At the top of each column of numbers, the reference electrode has been given first, and the active electrode has been given second.

DATA OF SERIES NO. 1

Case No.	rfps ras	ras g	rfps g	lfps las	lfps rfps	lfps ras	las ras	Diagnosis and Remarks
98-55	-16	2	-21					P.C. Second piercing after
			5	-7	-28	-17	6	x-ray
99-55	O.R. case. See Table 25.							
100-55	-9	2	-12					N.Y.D. Colostomy tracing
101-55	3	5	15					Chronic D.U.
102-55	-7	3	-8					Ca. Second piercing after
			-11	-29	-12	-7	14	x-ray
103-55	-15			-7	0	-20	6	Normal. Skin only
	-8			-3	-1	-12	7	
104-55	-8	3	-6	-12	-11	-15	-3	Normal
105-55	-19	1	-30	-15	-18	-9	-4	N.Y.D. Pierced 60 min. apart
106-55	-5	-14	-24	-5	45	42	2	Ca. of rectum. Rectal tracing. Pierced apart
107-55	-14	-8	-32	-4	-2	-22	-14	Ca. of rectum. Rectal tracing.
	-14	-14	-34	-24	-3	-26	-2	Pierced 60 min. apart
108-55	-4	30	28	-18	-2	-14	-18	N.Y.D.
	-13	50	38					
109-55	-8	-52	-64	-20	-2	-9	7	Ca. of colon. Rectal tracing
	-6	-46	-59	-22	-5	-14	7	
110-55	-15			7		-6		Normal. Skin only
	-16			7		-4		
111-55	-5			-9		-17	-1	Normal. Skin only
	-7			-12		-19	-4	
112-55	-15	-5	-20	-28	-9	-31	-3	Ca. of colon. Colostomy
	-15	18	-5	-26	-2	-27	-3	tracing
113-55	-10	-45	-55	-9	-14	-14	8	Tuberculosis. Rectal tracing
	-1			-18	5	6	9	

DATA OF SERIES NO. 1 (continued)

Case No.	rfps ras	ras g	rfps g	lfps las	lfps rfps	lfps ras	las ras	Diagnosis and Remarks
114-55			-40	-4	19	-5	1	Normal rectal tracing
	-23	-21	-38	-35	18	-4	4	
115-55	1	-14	-2	-12	-18	-18	-1	Ca. Pierced 60 min. apart
	-1			-15	-17	-18	1	
116-55	-9	6	7	-24	-12	-35	-5	N.Y.D. Pierced 60 min. apart
	-3	23	17	-21	-8	-11	12	
117-55	-7	-8	-10	-15	-5	-8	6	Hiatus Hernia. Pierced 60
	-7			-15	-3	-8	9	min. apart
118-55	-3			I	-16	-8	9	Cholecystitis. Pierced 60 min. apart
119-55	2	-2	0	-27	-10	-14	12	Cholecystitis. Pierced 60 min. apart
120-55	0			-1	8	6	6	Mild hypothyroid
	-2			-3	8	3	7	
121-55	-1			-20	-11	-11	11	P.C. Pierced 15 min. apart
	-8			-12	5	-5	11	
122-55	-14	1	-16	-13	4	-14	1	Schizophrenia
	-17			-24	-2	-21	2	
123-55	-16	-16	-24	-15	-5	-25	-4	Hydronephrosis
	-11			-12	1	-11	4	
124-55	-9			-23	-8	-18	7	Normal
	-13			-15	0	-16	-1	
125-55	-16	22	6	-4	11	-6	2	Rectal tracing. Ulcerative
	-42			-21	4	-41	-17	colitis
126-55	-4	-13	-29	2	6	1	4	Acute gastritis
	-30			-30	-2	-35	-1	
127-55	-7	-2	-12	-9	4	-9	0	Hiatus hernia
	-10			-4	8	-4	-4	
128-55	-15	37	30	-1	8	-8	-2	Basal metabolic rate plus 25.
	-15	23	30	-24	5	-16	-2	Second readings after x-ray

DATA OF SERIES NO. 1 (continued)

Case No.	rfps ras	ras g	rfps g	lfps las	lfps rfps	lfps ras	las ras	Diagnosis and Remarks
129-55	-4	-8	-13	-16	0	-5	8	Hysterical reaction
	-30			-24	-9	-40	-10	
130-55	-6	-29	-46	-3	6	-4	4	Digitalis intoxication
	-14			-10	4	-8	2	
131-55	-5	-30	-45	-4	7	-3	7	Pseudocontrol. Second reading
	-6	-28	-10	-14	17		-11	after x-ray
132-55	-5	36	12	-1	6	-5	0	Gastric ulcer. Second readings
	3		7	-6	4	3	24	after x-ray
133-55	-5	-6	-22	-8	-6	-17	0	Rectal tracing. Cancer of
	-12			-8	-4	-16	3	stomach
134-55	3	-8	-16	-4	-6	-4	4	Ulcerative colitis
	-2			-7	-2	-4	7	
135-55	-8	-14	-28	-6	1	-14	-3	Rectal tracing. Cancer of
	-16			-4	-1	-17	-13	sigmoid
136-55	-11	4	-7	-14	-4	-16	5	Repeat of 128-55
	-14			-22	-5	-18	5	
137-55	-2	-3	-16	-8	3	-2	9	Rectal tracing. Ulcerative
	-8			-9	7	-2	16	colitis
138-55	-7	4	-14	-19	-4	-16	5	Cancer of stomach
	-4			-17	4	0	16	
139-55	-7	13	27	-1	5	-7	0	Cancer of the stomach
	-34			-46	3	5	26	
140-55	-21	34	22	-22	-6	-23	1	Diabetes
	-14			-33	-16	-28	-1	
141-55	-4	-4	-13	-6	2	-4	4	Cancer of stomach
142-55								Special skin study data in second series
143-55	1	14	25	-14	-8	-10	3	Gastric ulcer
	-5			-16	-15	-24	2	

DATA OF SERIES NO. 2

Case No.	raps rfs	laps lfs	laps raps	laps rfs	lfs rfs	Diagnosis and Remarks
142-55	0	-20	-27	-28	-4	Normal skin. raps was not well
	4	-22	-27	-25	0	pierced
	laps raps	laps g	lfs g	rfs g	raps g	
144-55	1	-12	16	17	-8	N.Y.D.
	1	3	24	29	1	
145-55	-8	-19	3	3	-15	Severed common duct
	-6	4	27	27	14	
146-55	3	-13	3	3	-14	Duodenal ulcer
	-17	-14	0	4	4	
147-55	1	-12	18	1	-16	Post vagotomy. No free acid with
	-13	-8	5	-5	-15	10 units insulin sub-cutaneous
148-55	-5	-45	-32	-39	-49	Rectal tracing. Cancer of the
	-5	-46	-19	-21	-38	colon
149-55	3	-22	-16	-7	-24	Post vagotomy
	-9	15	40	23	24	
150-55	-2	-7	-3	2	-4	Cholelithiasis
	-1	-6	13	3	-4	
151-55	O.R. case. See Table 25.					
	raps rfs	laps g	lfs g	rfs g	raps g	
152-55	14	18	3	1	25	Repeat of 147-55. No free acid
	18	1	7	8	-20	with 20 units insulin I.V. See Table 16
153-55	-6	-7	0	4	-2	Cholecystitis
	-40	0	27	15	50	
154-55	-8	-18	23	7	-8	Nervous psychopath
	-14	-15	28	2	-9	

DATA OF SERIES NO. 2 (continued)

Case No.	raps rfs	laps g	lfs g	rfs g	raps g	Diagnosis and Remarks
155-55	-2	-8	-2	5	-16	Gastric ulcer. Free acid in-
	1	-19	-21	2	-30	creased from 6 to 18 with alcohol
156-55	-1	5	21	15	4	Cancer of stomach
157-55	9	-14	-8	2	-18	Duodenal ulcer. No fasting free
	1	-4	-2	2	-3	acid. Free acid 25 with alcohol

DATA OF SERIES NO. 3

Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
158-55	3	-5	-5	-8	2	9	3	Gastric ulcer. No fasting free
	-15	-15	-5	-2	14	-18	-20	acid. Free acid up to 53 with alcohol
160-55	-3	-1	-7	-3	-7	2	5	Acute cholecystitis
162-55	-1	-7	-6	-5	1	-8	-16	Duodenal ulcer
2-56	5	-8	-5	-8	1	-6	-16	Normal stomach. Given 25 mg.
	0	-21	-6	-6	10	-6	-37	priscoline
4-56	O.R. case. See Table 25.							
6-56	0	-13	-6	-5	7	-20	-28	Gastric cancer. Fasting free
	0	-20	-8	-8	15	-18	-32	acid 3. Free acid up to 5 with alcohol
8-56	-16	-34	-54	-38	-15	31	-25	Gastric ulcer. Free acid increased from 4 to 20 with alcohol
10-56	-1	-22	-8	-2	12	6	-7	Pernicious anemia. No free acid
	-7	-23	-18	-3	6	20	2	with 0.5 mg. histamine
12-56	-1	-4	0	2	4	6	4	Gastric ulcer. No free acid
	-2	-8	3	0	14	10	12	with 0.5 mg. histamine
14-56	-6	-5	-1	3	4	-31	-31	Cancer of the stomach
	-6	-22	0	6	-18	-28	-29	
16-56	-7	-21	-15	-8	5	14	1	Cancer of stomach. No free acid
	-9	-18	-13	0	5	15	2	with 0.5 mg. histamine
18-56	8	3	0	9	0	6		Duodenal ulcer
						34	22	
20-56	-5	-15	-19	-15	-3	-34	-53	Rectal record. Diverticulitis
	-5	-21	-25	-21	-4	-21	-43	
22-56	-3	-3	-9	-6	-6	7	-3	Colostomy record. Ulcerative
	-3	-4	-14	-9	-8	-2	-17	colitis
24-56	-1	-9	-9	-8	3	-6	-18	N.Y.D. Free acid increased
	-7	-19	-12	-2	7	-6	-27	from 6 to 13 with alcohol

DATA OF SERIES NO. 3 (continued)

Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
26-56	1	-17	-5	-7	13	7	-11	Pseudocontrol
	2	-23	-8	-14	13	21	-28	
28-56	-19	-46	-41	0	21	-3	-23	Cancer of stomach
	-26	-5	-21	-6	-9	-25	-23	
30-56	3	-4	-5	-8	-1	-3	-6	Pseudocontrol. No fasting free
	-2	-15	-18	-18	-3	21	3	acid. 25 mg. priscoline increased acid to 58
32-56	-9	-19	-8	3	16	0	-14	Cancer of stomach. Alcohol in-
	-25	-37	-18	8	23	-2	-20	creased free acid from 10 to 25
34-56	-7	-26	-20	-5	-3	-14	-37	Normal stomach
	-13	-19	-23	-6	-1	0	-22	
36-56	1	-2	0	0	2	-27	-28	Ulcerative colitis. Gastric
	0	0	-5	-5	-5	-22	-27	tracing
38-56	3	19	-1	-2	-9	4	4	Pernicious anemia. No free acid
	3	7	1	0	-2	17	17	with 25 mg. priscoline
40-56	1	-1	5	3	5	-12	-16	Pseudocontrol. Free acid in-
	3	-2	0	-2	2	-15	-26	creased from 53 to 77 with alcohol
42-56	-8	-6	0	9	9	1	0	Duodenal ulcer. Free acid 75.
	-4	-26	2	6	33	5	5	After alcohol dropped to 54
44-56	-17	-1	-8	12	-6	-10	-21	Cancer of stomach. No free acid
	-23	-22	-7	17	15	27	18	with 25 mg. priscoline
46-56	3	-2	4	2	7	-17	-22	Pseudocontrol. Free acid in-
	3	-5	-1	-3	6	-2	-6	creased from 16 to 50 with alcohol
48-56	3	-5	-6	-5	-1	28	20	Gastric cancer. No free acid
	-3	-4	-9	-5	-4	41	27	with 25 mg. priscoline
50-56	See data in Tables 6 and 10.							
52-56	-17	-16	-8	5	13	0	-2	4 years post op. left gastric
	-7	-15	-17	-7	-2	15	-5	sympathectomy

DATA OF SERIES NO. 3 (continued)

Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
54-56	-3	3	-2	1	5	-28	-21	Hypothyroid
	1	-2	-2	-3	4	-17	-20	
	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	
159-55	3	-2	-1	-1	-2	-22	-26	Stomal ulcer. No free acid
	-3	-5	-3	-1	1	0	-2	with alcohol
161-55	-1	1	0	7	0	-9	-12	Gastritis
	-8	-6	0	7	5	-17	-18	
163-55	5	6	8	5	-1	-22	-27	Cancer of the rectum. Rectal record
1-56	-2	-23	-3	-2	16	-2	1	Hiatus hernia
	0	-33	-3	-2	30	6	4	
3-56	-2	-1	0	2	0	2	2	Barbiturate overdosage. Given
	0	-21	9	9	31	6	16	25 mg. priscoline
5-56	-12	-15	-16	-1	-1	-15	-26	Pernicious anemia
	-19	-16	-20	0	-4	-5	-26	
7-56	-4	-38	-26	-8	17	-22	-32	Acute gastritis. No fasting
	-9	-51	-2	7	51	-24	-26	free acid. 16 units acid with alcohol
9-56	1	-13	-8	-13	-3	19	6	Cancer of the stomach
	-5	-7	-21	-16	-7	27	4	
11-56	-16	-26	-20	1	4	0	-10	Gastric ulcer
	-18	-26	-24	-6	2	18	-6	
13-56	-1	-15	2	4	17	-58	-56	Post gastrectomy syndrome
	-9	-18	4	16	25	53	50	
15-56	-1	-19	-8	-7	8	2	-7	Not yet diagnosed
	0	-19	-7	-8	9	-5	-15	
17-56	1	-8	-17	-19	-6	16	-7	Repeat of 4-56 after vagotomy
	2	-20	-17	-20	4	-4	-23	
19-56	0	-4	-1	-2	4	-13	-13	Regional enteritis. Post
	1	-9	-8	-8	-9	3	-8	vagotomy

DATA OF SERIES NO. 3 (continued)

Case No.	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	Diagnosis and Remarks
21-56						-18		Tuberculosis
23-56	-7	0	-5	0	-5	3	-3	Cancer. No free acid. 40 units
	-14	-7	-14	1	-5	21	8	acid with 0.5 mg. histamine
25-56	-14	-18	-15	-2	0	5	-12	Gastric ulcer. No free acid
	-17	-18	-28	-12	-10	25	0	with alcohol
27-56	-8	-22	-15	-5	5	7	-4	Cancer of the pancreas.
	2	-21	-34	-38	-18	23	7	Rectal record
29-56	5	-12	-14	-17	-3	0	-8	Cancer of sigmoid. Rectal
	1	-15	-18	-19	-2	14	-5	record
31-56						15		Repeat of 154-55. Psychopathic personality
33-56	-7	-16	-19	-7	3	-4	-35	Acute gastritis. No fasting
	-14	-19	-25	-9	1	5	-40	free acid. 122 units free acid with priscoline
35-56	-7	-16	-14	-1	5	22	8	Stomal ulcer. No free acid with
	-14	-22	-16	-12	5	20	4	25 mg. priscoline
37-56	-3	-9	-9	-6	0	-7	-20	Hyperthyroid
	-3	-9	-18	-14	-6	-6	-33	
39-56	5	5	3	-1	-2	-7	-5	Gastritis
	5	7	1	-4	-6	-2	-3	
41-56	0	-12	-5	-5	6	-10	-16	Duodenal ulcer. Free acid in-
	0	-15	-8	-8	7	-11	-21	creased from 4 to 85 with 25 mg. priscoline
43-56	7	-1	-1	-7	2	-5	-4	Gastritis. Free acid increased
	6	0	-1	-5	0	4	14	from 3 to 28 with alcohol
45-56	-4	-6	-3	-8	2	-2	-22	Cancer of rectum. Rectal
	-8	-12	-4	1	6	-8	-16	tracing
47-56	1	-1	0	0	1	0	0	Intra abdominal adhesions
	-4	-3	-7	-1	-8	16	5	

DATA OF SERIES NO. 3 (continued)

Case No.	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	Diagnosis and Remarks
49-56	-5	-2	-4	0	2	-13	-20	Pseudocontrol. Free acid increased from 6 to 45 with priscoline
	-2	0	-4	-2	-2	12	-1	
51-56	0	-2	2	0	5	4	0	Not yet diagnosed
	15	4	0	-14	0	6	7	
53-56	5	0	3	-1	5	-20	5	Cancer of large bowel. Rectal record
	4	-3	5	7	6	13	21	
55-56	-20	-15	-22	0	-5	20	-14	Stomal ulcer. No fasting free acid. 34 units acid with 25 mg. priscoline
	-27	3	-27	1	-13	25	-8	

DATA OF SERIES NO. 4

Case No.	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	Diagnosis and Remarks
57-56	3	-7	-9	-14	3	-1	-19	Pseudocontrol. No fasting free
	4	-18	-16	-19	5	1	-17	acid. 36 units acid with alcohol
59-56	-7	-8	-16	-8	-5	0	-20	Cancer. No fasting free acid
	-5	-9	-19	-14	-6	-1	-22	42 units free acid with alcohol
61-56	0	-4	-4	-3	5	-18	-23	Duodenal ulcer. Free acid in-
	-1	-7	-7	-6	5	-10	-18	creased from 14 to 43 with alcohol
63-56	1	-3	1	1	6	-35	-32	Repeat of 60-56. Pseudocontrol.
	3	-4	-2	-3	5	-27	-28	Normal stomach at operation
65-56	-4	-13	-2	4	-3	7	-27	Duodenal ulcer. Free acid in-
	21	0	22	-33	18	-9	-7	creased from 38 to 47 with alcohol
67-56	-6	-4	-2	4	1	-5	-9	Cancer of stomach. No free acid
	-15	-2	-6	9	-4	-2	-8	with 25 mg. priscoline
69-56	-14	-23	-23	-3	-1	4		Cancer of the pancreas
	-17	-23	-25	-7	-1	12	-19	
71-56	-5	-14	-9	-5	4	4	-6	Not yet diagnosed. No fasting
	-9	-15	14	-17	-15	24	0	free acid. 14 units acid with alcohol
73-56	3	1	-1	-3	1	15	-1	Record from an ileo-bladder
	5	-2	-3	-7	-1	10	5	
75-56						-36		Record of ileo-bladder for cancer of cervix
77-56	-6	-6	-5	1	-1	-13	-15	Hiatus hernia
	-16	-12	-9	7	3	10	1	
79-56	-1	-12	2	4	15	-18	-17	Cancer of pancreas. No free
	-10	-20	-10	0	12	-2	-13	fasting acid. 0.5 mg. histamine gave 82 units

DATA OF SERIES NO. 4 (continued)

Case No.	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	Diagnosis and Remarks
81-56	-2	-9	-4	-3	5	-2	-14	Pernicious anemia. No free
	2	-18	-11	-14	4	4	-10	acid with 0.5 mg. histamine
83-56	5	-5	-2	-6	4	6	2	Normal stomach. 48 units acid fasting. Free acid dropped to 32 with alcohol
85-56	-2	-9	-13	-7	-2	15	2	Cancer of stomach. No free acid
	5	-6	-1	-7	5	7	6	with 25 mg. histamine
87-56	5	-7	1	-5	9	12	8	Gastric ulcer. No fasting free
	-2	-8	3	2	9	15	11	acid. 21 units free acid with alcohol
89-56	-1	-26	-11	-9	-11	-23	-35	Not yet diagnosed
	1	-15	-14	-15	-14	18	8	
91-56	-3	-15	-10	-5	4	-2	-14	Cancer of stomach. No free acid
	-3	-12	-16	-13	-3	16	0	with 0.5 mg. histamine
93-56	-5	-20	-10	-3	7	-4	-15	Not yet diagnosed. No fasting
	2	-1	-11	-12	-9	-4	-19	free acid. 18 units free acid with alcohol
95-56	O.R. case. See Table 25.							
97-56	0	3	-3	-2	-6	-7	-13	Duodenal ulcer. Free acid rose
	-5	1	-14	-6	-15	14	0	from 18 to 22 with alcohol
99-56	10	-5	2	-7	6	-5	-5	Hyperthyroid. Repeat of 90-56
	3	-7	-8	-11	0	-1	-10	after two weeks in hospital
	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	
58-56	4	-8	-7	-9	6	12	-1	Diabetes
	4	-9	-10	-12	6	17	1	
60-56	-3	-5	-5	-2	5	-20	-22	Pseudocontrol. Free acid in-
	-3	-16	-3	0	15	-20	-25	creased from 36 to 64 with alcohol
62-56	13	-8	1	-12	10	-6	-4	Cancer of stomach. No free
	22	-7	-2	-24	5	6	2	acid with 25 mg. priscoline

DATA OF SERIES NO. 4 (continued)

Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
64-56	-11	-13	-15	-3	-1	-5	-23	Stomal ulcer. No fasting free
	-9	-13	-15	-4	0	-1	-19	acid. Up to 105 units acid with alcohol
66-56	12	-3	-3	-15	4	13	-3	Stomal ulcer. Repeat of 55-
	2	-14	-14	-15	5	4	-17	56 after vagotomy
68-56	4	-15	-9	-13	13	-4	-18	Pseudocontrol. Free acid rose
	-1	-15	-11	-7	6	1	-14	from 16 to 25 with alcohol
70-56	3	-14	-2	-4	12	1	-5	Hyperthyroid. Free acid in-
	5	-14	-12	-18	0	-2	-15	creased from 41 to 49 with alcohol
72-56	-4	-5	-4	1	4	2	-2	Hypothyroid
	-6	-7	-7	0	3	-14	-15	
74-56	4	-13	3	5	5	-26	-20	Duodenal ulcer. Fasting free
	-5	-15	2	7	18	-18	-16	acid 42. Free acid with alcohol 41
76-56						0		Tracing from ileo-bladder
78-56	-5	-12	-5	-4	5	7	2	Gastric ulcer. No free acid
	3	-6	-11	-13	-3	0	-10	with 0.5 mg. histamine
80-56	O.R. case. See Table 25.							
82-56	O.R. case. See Table 25.							
84-56	O.R. case. See Table 25.							
86-56	1	-9	-14	-14	-4	3	-20	Duodenal ulcer. Free acid in-
	2	-15	-19	-19	-3	7	-20	creased from 12 to 30 with alcohol
88-56	O.R. case. See Table 25.							
90-56	6	-17	-9	-16	7	20	10	Hyperthyroid. No fasting free
	-1	-12	-23	-10	10	-15		acid. 13 units free acid with alcohol
92-56	O.R. case. See Table 25.							

DATA OF SERIES NO. 4 (continued)

Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
94-56	4	-6	-3	-9	8			Gastric ulcer
96-56						10		Repeat of 94-56
98-56	0 4	-1 -8	-1 -12	-1 -16	5 5	-4 11	-6 -2	Cancer of the stomach. No free acid with 0.5 mg. histamine

DATA OF SERIES NO. 5

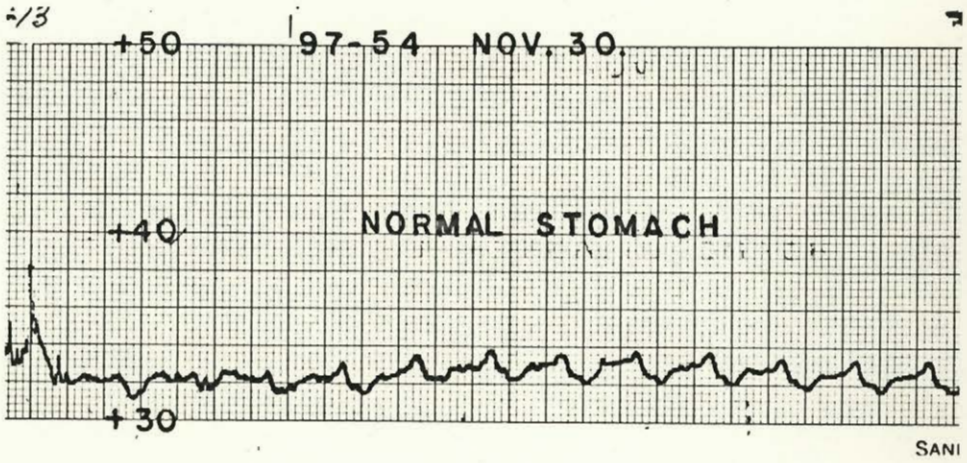
Case No.	rfps raps	rfps rfs	rfps ras	raps ras	rfs ras	ras g	rfps g	Diagnosis and Remarks
100-56	-1	-14	-4	-3	7	0	-24	Duodenal ulcer. No fasting free
	-2	-22	-5	-3	14	-13	-28	acid. 7 units of acid after alcohol
102-56	-1	-2	3	3	4	1	-20	Hypothyroid
	6	1	1	0	3	-1	-20	
104-56	1	-1	-6	-7	-5	15	-14	Duodenal ulcer. Fasting free
	2	-7	-15	-14	-3	6	-2	acid 44. 42 units free acid with alcohol
106-56	O.R. case. See Table 25.							
108-56	1	1	0	0	6	-1	-2	Anxiety state
110-56	2	-5	-22	-23	2	-127	-150	N.Y.D. Gastric electrode was
	2	-21	-25	-27	1	-119	-159	not balanced at end
112-56		-15				13	-6	N.Y.D. Two piercings done an
	-1	-32				25	-11	hour apart
114-56	O.R. case. See Table 25.							
	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	
101-56	0	0	-1	0	4	-4	-24	N.Y.D. No fasting free acid.
	1	0	-3	-2	3	-1	-15	36 units of acid with 0.5 mg. histamine
103-56	2	-5	0	-1	3	1	-24	Duodenal ulcer. Free acid rose
	11	-4	-6	-6	1	1	-28	from 4 to 42 with alcohol
105-56	3	-21	-7	-13	14	-2	-23	Hyperthyroid
	5	-26	-23	-25	4	4	-22	
107-56	0	3	1	1	5	-24	-55	Cancer of stomach. No fasting
	2	-6	-15	0	1	8	-14	free acid. Acid 21 with 0.5 mg. histamine
109-56	8	-4	-3	-7	13	3	-13	Cancer of stomach. No free acid
	2	-15	-20	-22	5	22	-5	with 0.5 mg. histamine

DATA OF SERIES NO. 5 (continued)

Case No.	lfps laps	lfps lfs	lfps las	laps las	lfs las	las g	lfps g	Diagnosis and Remarks
111-56	O.R. case. See Table 25.							
113-56		-3				-27	-57	Cancer of the stomach. Two
	1	-14				-55	-91	piercings done an hour apart. Gastric electrode broken on removal
115-56		-13				14	-13	N.Y.D. No free acid with 0.5
	-7	-16				2	-28	mg. histamine

APPENDIX C

Typical Records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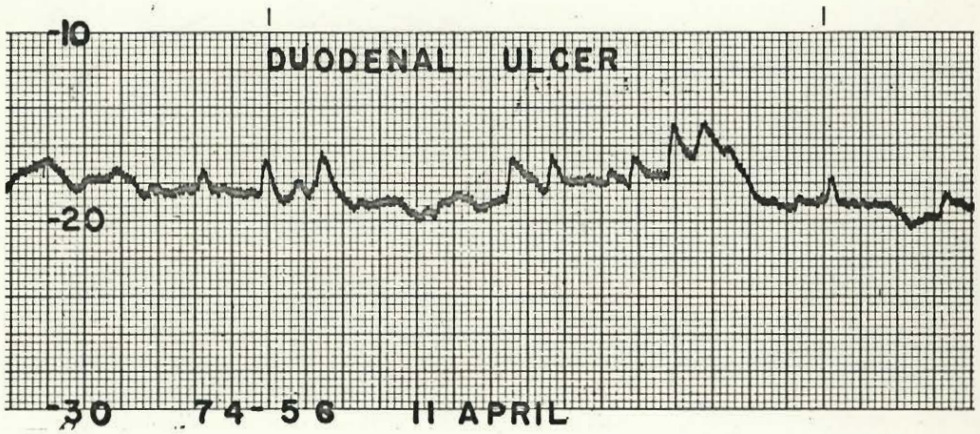
97-54 NOV. 30.
+40
NORMAL STOMACH
+30
SANI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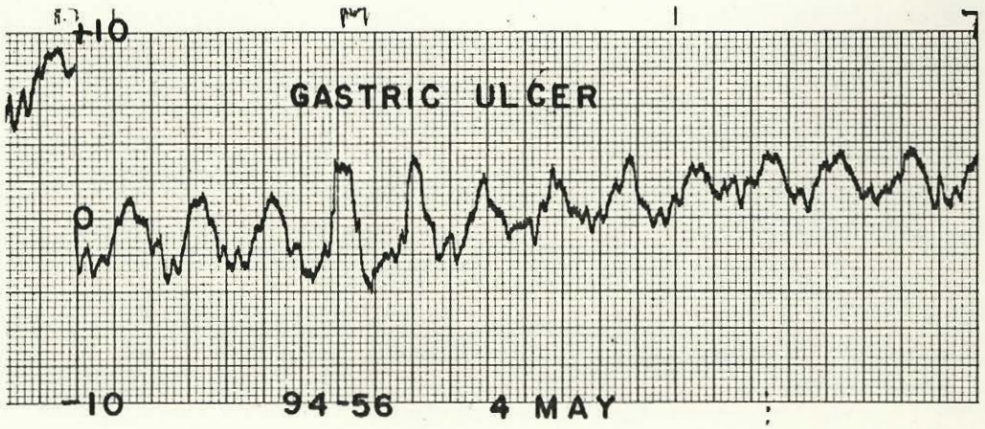
DUODENAL ULCER
-20
-30
74-56 11 APRIL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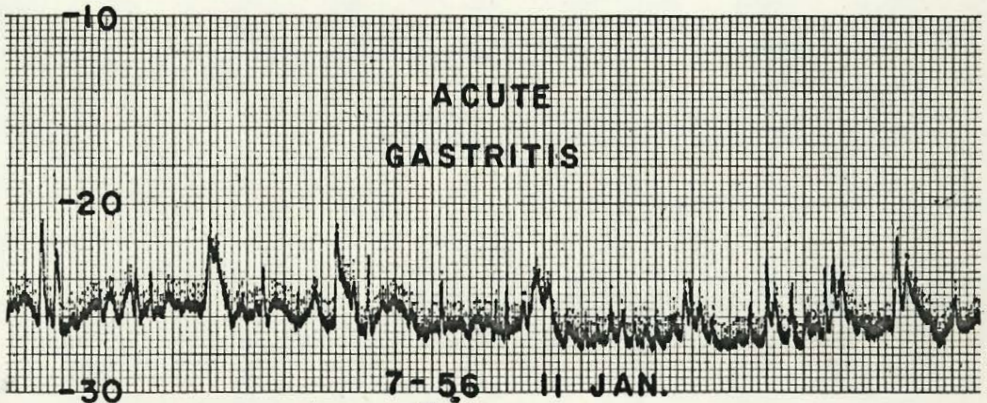
GASTRIC ULCER
0
-10
94-56
4 MAY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ACUTE
GASTRITIS
-20
-30
7-56 11 JAN.
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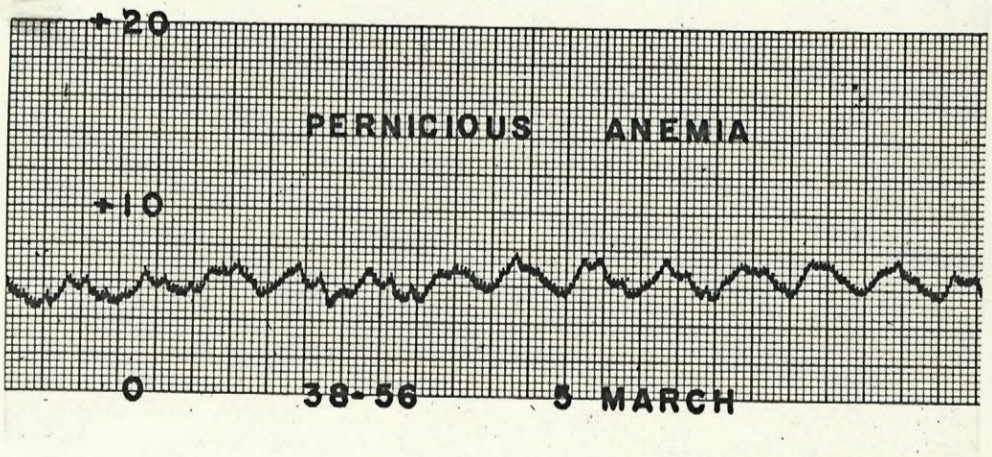
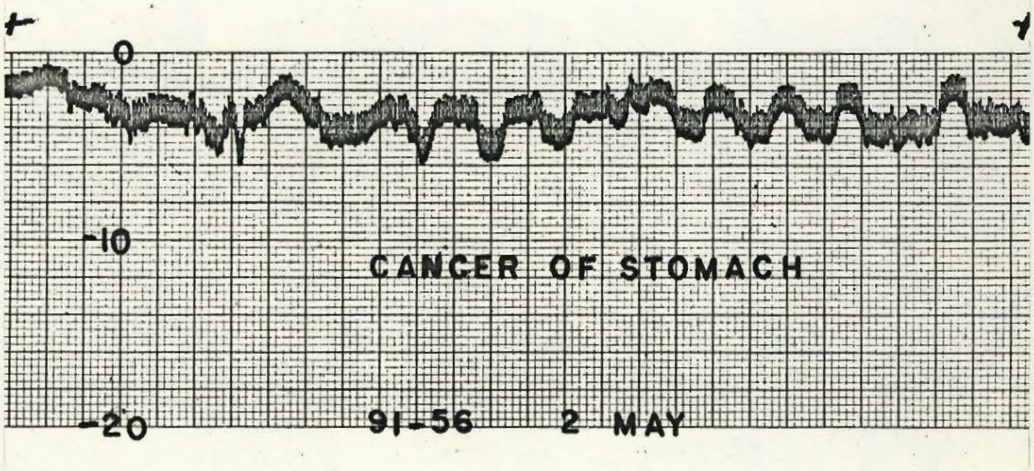

+20
PERNICIOUS ANEMIA
+10
0
38-56
5 MARCH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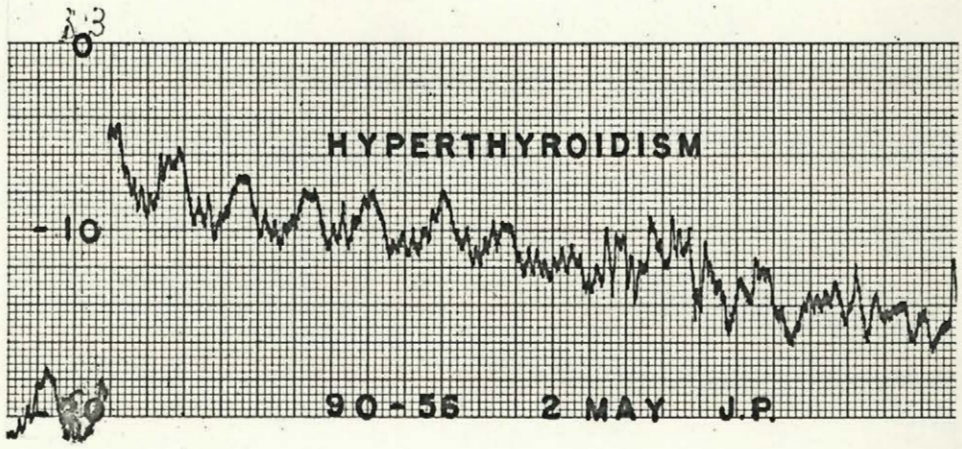
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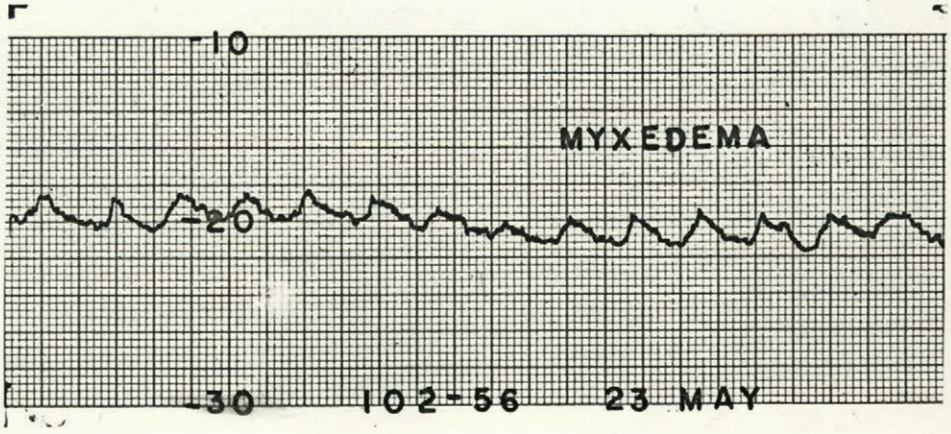
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MYXEDEMA
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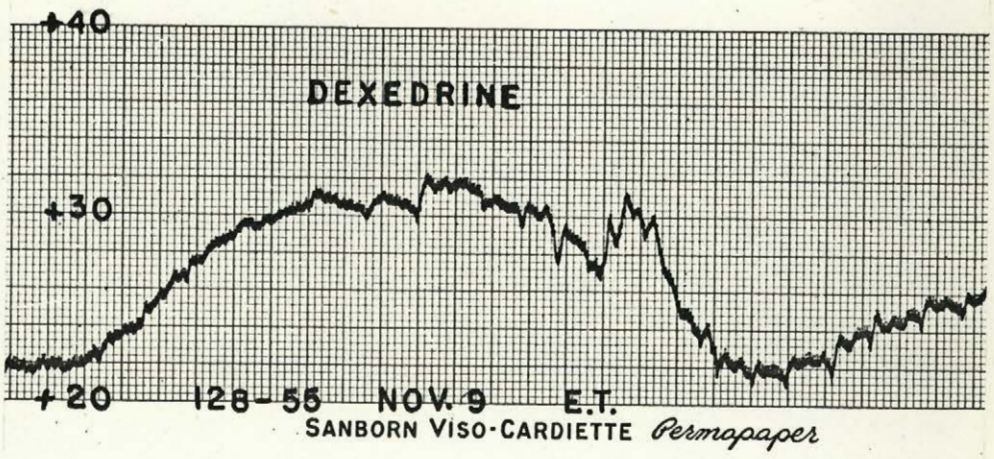
-30
102-56 23 MAY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DEXEDRINE
+30
+20
128-55 NOV. 9 E.T.
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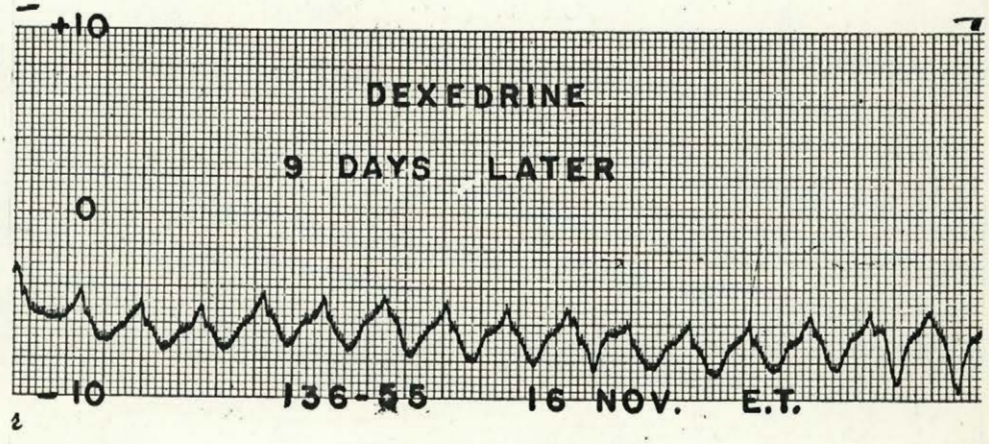
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9 DAYS LATER
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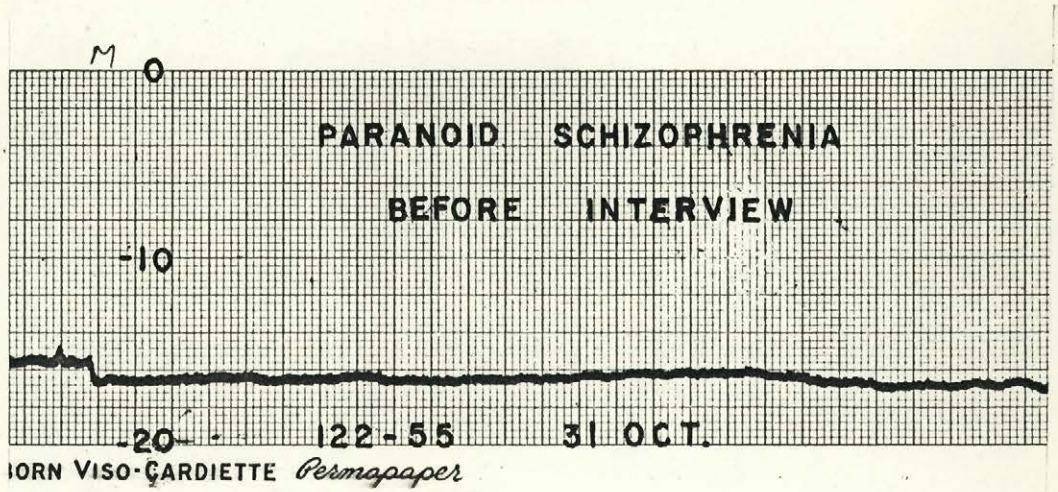
-10
136-55 16 NOV. E.T.



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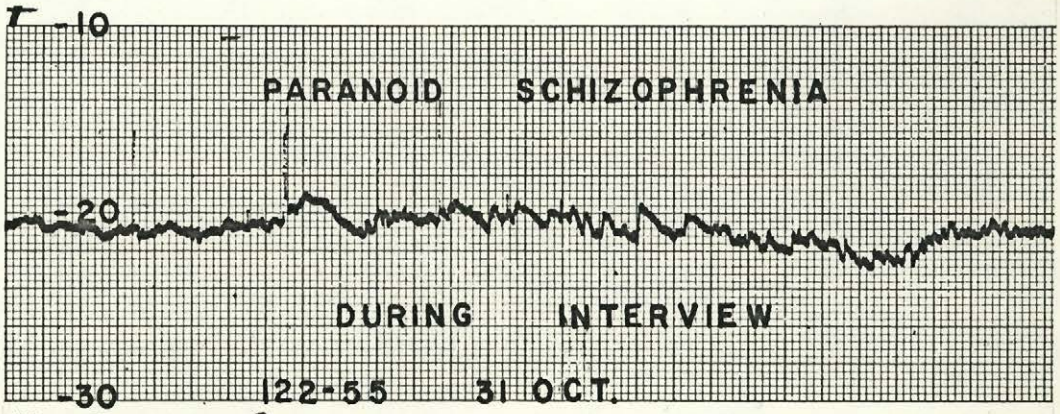

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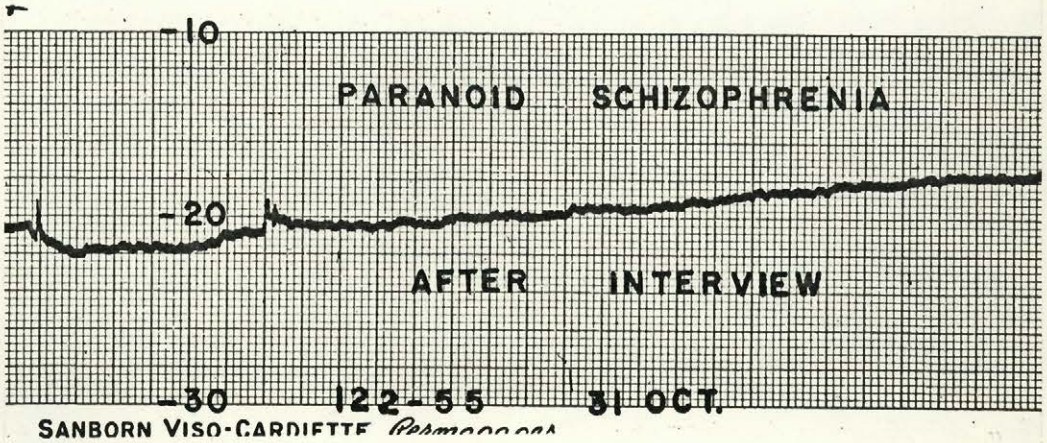

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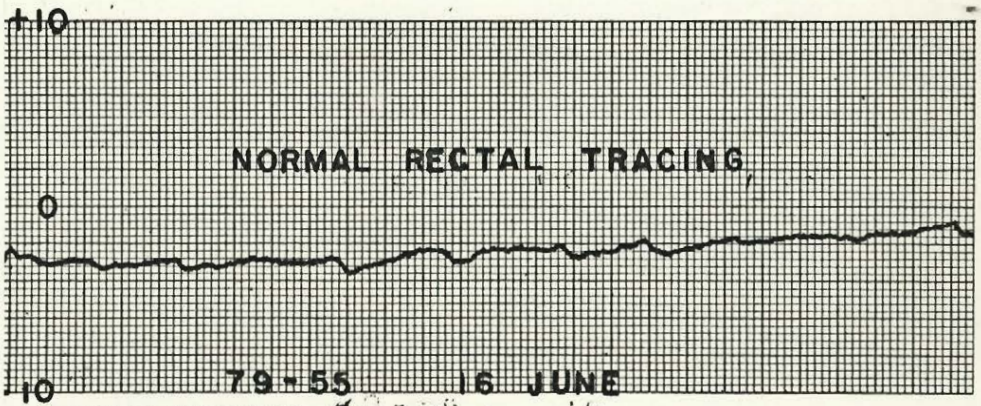
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79-55
16 JUNE
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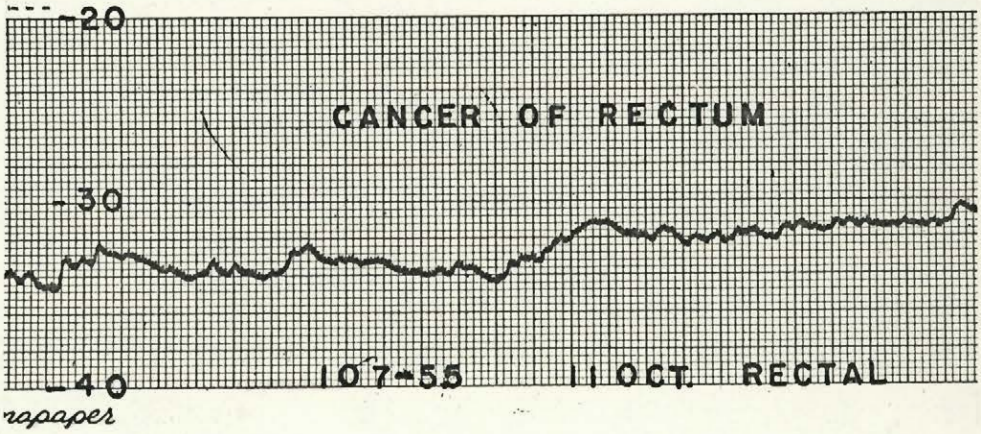
16



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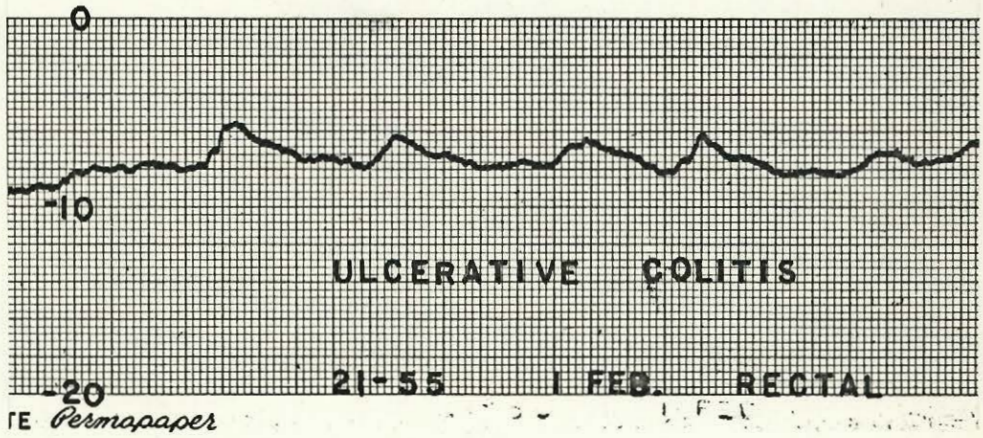
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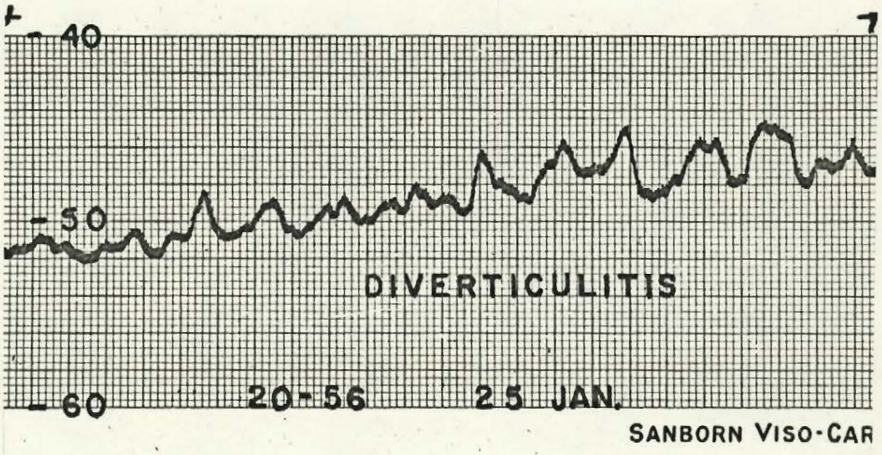
40
50
DIVERTICULITIS
60
20-56
25 JAN.
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