THE SIGNIFICANCE AND ORIGIN OF LACTIC ACID IN THE GASTRIC CONTENTS

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It is generally accepted that hydrochloric acid is the chief acid of the gastric juice, but that organic acids may be found, of which the chief is lactic acid. The significance and origin of this lactic acid is still a matter of considerable doubt; a brief survey of the published work makes this evident.

As long ago as 1824 it was established by Prout that the acidity of the gastric juice was due to hydrochloric acid, and this was shortly afterwards confirmed by Children and by Braconnot. This finding was not, however, universally accepted at that time, as it was believed that such a strong acid as hydrochloric could not be present without damaging the stomach wall. Blondlot in 1843 suggested that the acidity was due chiefly to acid calcium phosphate, with mere traces of hydrochloric and phosphoric acids. In the following year a new view was put forward by Bernard and Barreswil. They considered that lactic acid, which they consistently found to be present, despite changes in the diet, was chiefly responsible for the acidity of the gastric juice. This view was immediately endorsed by Pelousse, and in 1845 by Thomson. Two years later Lehmann, in supporting the lactic acid hypothesis, explained the traces of hydrochloric acid which were found as resulting from interaction between the lactic acid and chlorides present in the gastric contents. Despite the considerable support which the lactic acid theory received it did not long remain unchallenged. Bidder and Schmidt reverted to the view that hydrochloric acid was the chief acid, but admitted that during digestion gastric juice contained lactic acid also. From this time onwards hydrochloric acid has always been recognized as the important factor in the causation of the acidity of the gastric contents.

As regards the origin of the lactic acid which undoubtedly is frequently present, Brücke appears to have been the first to suggest that it resulted from bacterial action on carbohydrates. Many subsequent observers were of the same opinion, but Halliburton pointed out that lactic acid might be present even when there had been no carbohydrate in the meal. Landwehr in 1886 held that it was produced by the action of a ferment on the mucus of the gastric glands, the mucus being decomposed, and lactic acid liberated from its carbohydrate moiety. An entirely different view, that the lactic acid is due to the specific action of carcinoma cells, has recently been advanced, and is referred to below. It is, however, almost generally accepted that this acid results from carbohydrate fermentation. Consideration of bacterial action in the stomach recalls the Boas-Oppler bacillus, for long considered pathognomonic of gastric carcinoma, which was presumed to be capable of producing lactic acid. Many other organisms having a similar action have since been described. Herter considered that the two chiefly concerned were the *B. acidilactici* and the *B. lactis aërogenes*.

Although it is now recognized that hydrochloric and lactic acids may be found together in gastric contents there has been much uncertainty as to the significance of the presence of the latter. Ewald and Boas stated that it was never present except in association with gastric disturbance. Herter agreed with this view, and considered

that lactic acid fermentation was very liable to occur when there was delay in emptying, especially if carbohydrates were freely eaten. Pavlov was of the opinion that Nature constantly endeavoured to prepare lactic acid in the stomach as well as hydrochloric acid, as an aid to digestion. This, however, is scarcely in agreement with the statement of Schafer in his textbook of 1897 that lactic acid, when it occurred, never persisted longer than half an hour, nor with the view taken by Noël Paton, who stated that lactic acid could be considered a normal constituent of the gastric contents during the first half-hour of digestion, but that its presence at a later period was to be considered abnormal. The most recent work on the subject which we have found is that by Moore and Roberts, who state that the presence of lactic acid is not only at all times abnormal, but is pathognomonic of gastric carcinoma. They considered its origin as probably resulting from the specific action of cancer cells on the glucose of the tissues.

Even at the present time, therefore, there is considerable divergence of opinion regarding the significance and origin of lactic acid in the gastric contents. Its presence has been variously described as being normal, as normal during the first half-hour of digestion and abnormal thereafter, and as abnormal at all times; and while the fermentation theory of its origin is generally accepted, doubts still exist as to the accuracy of this theory. The present investigation has accordingly been undertaken with a view to discovering, first, whether lactic acid is of common occurrence in the gastric contents and what significance can be attached to its appearance, and, secondly, what factors are involved in its production.

OCCURRENCE OF LACTIC ACID IN TEST MEALS

In the course of the routine examination of fractional test meals it appears that tests are seldom applied for the detection of lactic acid. Possibly this is accounted for by the difficulty of obtaining sufficient gastric contents for its determination in addition to that of free and total acidity. Probably, however, it is not considered essential to devote time to this estimation when its significance appears to be so uncertain. The present investigation consisted in the examination of test meals from fifty patients. In addition to the estimation of free and total acidity the presence of lactic acid was followed throughout the course of digestion in each case.

Methods Employed.—A gruel test meal was given and samples were withdrawn every quarter of an hour by the usual fractional method until the stomach emptied. These were examined for acidity by the titration method, and also tested for lactic acid. After the second hour the quantities obtained were frequently insufficient for both purposes, and alternate specimens were then used for the estimation of acidity and for the lactic acid test. The method employed for the latter was MacLean's modification of the thiophene test, which was found to be quite satisfactory, giving a definite positive reaction with a concentration of lactic acid of 0.02 per cent. in gastric contents, and more suitable than the original Hopkins test, with which charring occurred very readily. In our opinion, MacLean's method is more reliable than either the Uffelmann or the ferric chloride tests, although the principal difficulty with the thiophene method, as indeed with the others, is the interpretation of the result in the presence of bile. We have, however, found it possible to overcome this difficulty by extracting with ether and shaking the extract with animal charcoal. Mention must be made of the method recently described by Dodds and Robertson; this is undoubtedly more accurate, being a quantitative method, but its complexity debars it from clinical use.

Cases Investigated.—All these test meals were carried out on patients in the medical wards of the Glasgow Western Infirmary. Over 50 per cent. were receiving treatment for some gastric condition, while the remainder showed, clinically, no evidence of any such trouble. The patients were of both sexes, but the large majority were males. From the type of curve obtained when the gastric acidity was charted the cases were divided into four groups: (a) showing no free hydrochloric acid; (b) showing a very low concentration of hydrochloric acid; (c) showing isosecretory or normal curves; (d) showing hypersecretory or "climbing" curves.

The average ages were: Group A, 43 years; Group B, 33; Group C, 29; and Group D, 37.

The results were as follows:

TABLE I

Group	Number of Cases in Group	Number with Gastric Symptoms (a)	Number without any Gastric Symptoms (b)	Cases showing Lactic Acid throughout Meal	
				(a)	(b)
A	10	6	4	6	4
B	9	3	6	3	6
C	15	7	8	6	4
D	16	12	4	4	4

From this table it will be seen that lactic acid was found throughout the various fractions of the test meal in thirty-seven out of the fifty cases, and that its presence in the stomach was not necessarily associated with gastric symptoms. In Groups A and B every case was found to show lactic acid, while the gastric and non-gastric cases were practically equal in number. A similar distribution of cases according to symptoms is seen in Group C, but of the ten cases in which lactic acid was found only in six was a gastric condition diagnosed. In the last group the cases from which lactic acid was obtained were equally divided between the two categories.

A summary of the details of the test meals carried out is given in the following table.

TABLE II

Group	Number of Cases in Group	Fasting Juice		Lactic Acid Present throughout Test Meal, per cent.	
		Average Quantity, c.cm.	Mucus Present, per cent.	++	+
A	10	24.7	80	100	—
B	9	23.4	77	23	77
C	15	19.5	73	20	46.6
D	16	28.0	75	6.25	43.75

The average quantity of fasting juice varied a little, being least in the isosecretory, and greatest in the hypersecretory group. Lactic acid was present in the fasting juice in all cases in which it was detected throughout the course of gastric digestion. Mucus was present in a large proportion of the cases, the proportion in all four groups being almost identical.

It is apparent from Table II that increasing acidity of gastric contents is associated with a diminution in the frequency of occurrence of lactic acid. In the hyposecretory groups lactic acid was present in 100 per cent. of the cases, in the isosecretory in 66 per cent., while in the hypersecretory group the percentage fell to 50. Not only does frequency of occurrence of lactic acid vary inversely with gastric acidity, but there is, in addition,

a decline in the actual amount of lactic acid when that acid is present. It must be understood, of course, that the estimation of quantity was simply relative. When the concentration was high the reaction appeared much more quickly, often before the test had been completed—that is, as soon as the thiophene solution was added and before the usual heating in the water bath. Such a relatively high concentration determined in this way is indicated in the table as ++. In Group A all the cases fell into this category; in Group B, although in all cases lactic acid was found, only in two (23 per cent.) was a strongly positive reaction obtained. With the higher gastric acidity in Groups C and D both the incidence and the amount of lactic acid fell considerably, but perhaps the remarkable feature is that it was found to be present in so many cases. The hypersecretory group showed only 6.25 per cent. of cases giving the rapid reaction of relatively high concentration, but even in this group lactic acid was found throughout the course of gastric digestion in half the cases. Cases of the isosecretory type, Group C, were intermediate, both as regards incidence and quantity, between those of low and of high gastric acidity.

While lactic acid was not of such frequent occurrence where the gastric acidity was normal or high, our results were, nevertheless, in distinct contrast to the opinion, commonly found in textbooks, that the discovery of lactic acid in achlorhydria is pathognomonic of carcinoma. Herter found that the organisms which he considered responsible for the production of lactic acid in the stomach were more active in a neutral or slightly acid medium, although they grew quite well in the presence of hydrochloric acid in a concentration of 0.7 per cent. The results of the present investigation are capable of explanation by these facts.

PRODUCTION OF LACTIC ACID

From these results it is apparent that lactic acid frequently occurs in the stomach when there is no reason whatsoever to suspect carcinoma. The theory that its production is due to the specific action of cancer cells therefore appears untenable.

As the long-accepted view that lactic acid resulted from bacterial fermentation seemed very probable, it appeared to us to be of interest to investigate the source of the causative organisms—that is, whether these existed normally in the stomach or were introduced with the food. There is, of course, the further possibility that lactic acid might be produced wholly or in part as the result of enzyme action. In order to discover whether these organisms were present in the gruel test meal, several such meals were investigated under varying conditions. Freshly prepared gruel was kept at room temperature and specimens examined at intervals of a few hours, but even after twenty-four hours no lactic acid was detected. Evidently, then, the lactic acid found in the present series of cases must have been produced in the stomach. Next, samples of gruel test meals were incubated at body temperature for twenty-four hours. Neither gruel alone, nor gruel to which peptic extract and hydrochloric acid had been added, showed any trace of lactic acid, even at the end of that period. We concluded, therefore, that the organisms were not commonly introduced with the meal.

The possibility that they might exist in the stomach was next investigated. "Fasting gastric juice" which had been found to contain no lactic acid (this was obtained in each case from perfectly healthy individuals exhibiting no evidence of gastric disorder) was added to a gruel test meal and incubated at 37° C. Another meal, to which some boiled fasting juice had been added, was

placed under the same conditions, and samples of each were examined at hourly intervals. In the former, lactic acid was found after incubation for one hour, and the amount increased in each subsequent specimen examined. In the latter no lactic acid was found in any specimen up to four hours, when the experiment was discontinued. This procedure was repeated on several occasions, and identical results were obtained. This would suggest that organisms capable of producing lactic acid exist in the normal stomach, and that these can be destroyed by boiling.

These findings did not, however, exclude the possibility of enzyme action, as an enzyme would be similarly affected by boiling. Several specimens of fasting gastric juice, free of lactic acid, were passed through a Seitz filter. These were then added to the usual gruel meal and incubated, controls, in which the juice added had not been filtered, being put up at the same time. It was found that after the process of filtering the gastric juice no longer possessed the power of producing lactic acid, whereas in the unfiltered controls abundant lactic acid was produced as previously. We concluded, therefore, that lactic acid in the gastric contents was derived from carbohydrate fermentation brought about by non-filter-passing organisms ordinarily found in the healthy stomach. The hypothesis of enzyme action was discarded, since there is no reason to believe that an enzyme would fail to pass through a Seitz filter. This bacterial action takes place best in a neutral or slightly acid medium, but may go on, though generally to a considerably less extent, in the acidity commonly found in a case of hyperchlorhydria—namely, 0.3 to 0.4 per cent. hydrochloric acid.

THE CAUSATIVE ORGANISM

We next tried to discover whether an organism capable of producing lactic acid fermentation could be obtained from a normal healthy stomach. A sample of fasting gastric juice was obtained from a perfectly healthy subject showing an isosecretory curve. This sample contained no lactic acid, but, when added to a gruel meal and incubated, lactic acid was produced. With this gastric juice McConkey's neutral red lactose medium and sterile litmus milk were inoculated. At the end of twenty-four hours acid and gas production was observed in both media, and these showed a variety of organisms. These cultures were then submitted to Dr. Ernest Dunlop, clinical bacteriologist to the Western Infirmary, for further investigation. We are greatly indebted to him for his report and for furnishing us with pure cultures of the organisms. He isolated four types: (1) a bacillus showing all the characteristics of *B. acidi lactici*; (2) *B. coli*; (3) a streptococcus; and (4) a yeast. Of these it was found that only the first fermented lactose to an appreciable extent, although slight fermentation was produced by the *B. coli*. Therefore we concluded that the production of lactic acid in gastric contents was probably due to the presence of *B. acidi lactici*.

Finally, we thought it desirable to compare the action of the pure culture of this bacillus with the action of fasting juice when added to a gruel test meal in the incubator. We could not, of course, use the usual lactose culture medium, since this would have involved adding lactic acid to the meal; we therefore obtained a suitable growth on agar. A saline suspension of a forty-eight-hour culture was added to a test meal in exactly the same way as with the fasting gastric juice. At the end of four hours' incubation the thiophene test showed that a large quantity of lactic acid was present. This was considerably in excess of the amount found on incubation with fasting juice.

SUMMARY

1. An investigation of test meals from fifty subjects, pathological and normal, showed the presence of lactic acid in 74 per cent. While occurring more frequently in cases of hyposecretion, it may be present even in hypersecretion. The presence of lactic acid had apparently no clinical significance.

2. The production of lactic acid was almost certainly due to the action of *B. acidi lactici*, which was found to be present in the perfectly normal stomach.

Since this paper has been prepared for publication a very interesting historical monograph, entitled *Gastric Acidity*, by Dr. J. D. Robertson, has appeared. This contains a particularly full account of the relevant literature. A bibliography has therefore been omitted from the present communication.

JEJUNOSTOMY AND WITZEL'S OPERATION IN THE TREATMENT OF VICIOUS CIRCLE VOMITING

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Vicious circle vomiting, which was something of a burning question in the early days of the operation of gastro-jejunosomy, is now an uncommon condition. It still occurs from time to time, however, its incidence being probably between 2 per cent.¹ and 0.4 per cent.² The following three cases are recorded because an apparently sound treatment failed for no very evident reason in the first case, and because the second patient seemed to have been saved by a method which is easy, was sponsored by Witzel,³ and, if it has not been completely discarded, is at least little heard of. It is unusual for one surgeon to be called upon to operate on three patients suffering from this condition in three months—perhaps I may be forgiven for saying that on only one was the first operation done by myself.

CASE I

A postman, aged 43. Two years' history of indigestion; radiograph showing duodenal deformity. *Operation 1* (July 10th, 1931).—Infolding of ulcer and posterior no-loop gastro-jejunosomy. Eight days later 45 oz. of bile-stained fluid was vomited. Gastric lavage, small feeds, etc., were begun, with temporary improvement. Onset of severe tetany on October 25th. *Operation 2* (October 25th).—Jejunostomy 12 inches below stoma under local anaesthesia; immediate feed. The tetany, which had not improved with intravenous calcium chloride or subcutaneous salines, disappeared in one hour. However, the patient's condition, which had forbidden any major procedure at the time of operation, gradually and steadily deteriorated. He rapidly wasted; five days after operation he developed a purpuric eruption and haematuria; two days later he became febrile; and nine days after operation he died. Most of this time he had frequent fluid stools containing curds. His diet was constructed on the basis of the experimental work of Armour and others,⁴ and consisted of six pints of pancreatized milk with added glucose, salt, and peptone. He was also given three pints of saline, subcutaneously, daily. The following urine and blood changes were noted after the second operation: his urine excretion was kept up to between 30 and 40 oz. a day; it constantly contained albumin; chlorides were noted to be present on several occasions; acetone was noted the day after operation; sugar appeared once. His blood calcium just before operation was 7.6 mg. per 100 c.cm.; three days later it was 8.6. His blood urea was 340 mg. per 100 c.cm. two days after operation; five days later it was 510. Post mortem, the significant findings were: considerable dilatation of the stomach without pyloric stenosis, no peritonitis, normal kidneys, suppurative broncho-pneumonia.