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HYPERTROPHIC STENOSIS IN INFANTS*

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The data which form the basis of this paper have been derived from a study of 133 cases of pyloric stenosis in infants who have been treated in the wards and private rooms of the Babies' Hospital in my own practice and that of my colleagues, and eight cases which I have seen with physicians outside the hospital, making 141 in all. Of the fatal cases, the stomach has been examined at necropsy in thirty-five. Microscopic examinations of the stomach have been made in twelve cases by Dr. Wollstein, pathologist to the hospital. Of the infants who recovered, three have been lost sight of; ten died subsequently from other conditions; the remaining sixty-four have been followed almost up to the date of writing, twelve of them for a period of four years or over.

Pyloric stenosis of infancy has been regarded by some writers as essentially a condition of tonic muscular spasm, hypertrophy when present being secondary. Others have considered the essential lesion to be a congenital hypertrophy with spasm superadded. Still others have argued that there are two distinct types of cases—one purely spasmodic, the other hypertrophic.

The clinical course and the uniform pathologic findings have convinced my colleagues as well as myself that a division of cases of pyloric stenosis of infants into spasmodic and hypertrophic types is not admissible. There are seen in early infancy a variety of gastric disturbances which may present some of the symptoms of hypertrophic stenosis, but careful observation shows that they are quite distinct from them. Cases of true hypertrophic stenosis, however, differ much in degree; in very few is the obstruction complete, but hypertrophy, undoubtedly congenital, is the essential lesion in all, spasm being added as a secondary condition. Dent¹ found the hypertrophy in a 7 months' fetus. It is inconceivable that the hypertrophy such as has been found by operation to exist two or three weeks after birth could have developed as a result of spasm. Furthermore, I hold that persistent spasm of the pylorus without hypertrophy has not yet been established.

Assuming that the hypertrophy is congenital, it might be expected that symptoms would begin to show themselves soon after birth. But this is almost never the case. Seldom (in only 4 per cent. of our cases) do they begin before the end of the first week, and more often not for two, three or four weeks, during which time the infant appears in every way normal. It does not appear that hypertrophy alone often produces sufficient narrowing to cause symptoms, at least not in infancy. Not until spasm is added do symptoms usually begin. What is it, then, which excites the muscular spasm on which the symptoms so largely depend? Regarding this we know as yet very little.

The great majority of the cases are among infants entirely breast fed, and comparatively few have shown previous evidence of any gastric disorder. But the stomach in early infancy is a highly sensitive organ, and just as disordered innervation of the intestine a few months later may excite intussusception, so now some trivial irritation may be sufficient to excite spasm of the pylorus. We have seen relapses or a recurrence of forcible vomiting and active peristalsis excited by disturbances of digestion after these symptoms had been absent for some weeks.

It is our firm belief from our observation of these patients in the early weeks that in all cases hypertrophy precedes the tonic spasm. That the hypertrophy continues long after the spasm has subsided we have absolute proof. We have repeatedly observed cases in which an unmistakable tumor could be felt for weeks after vomiting had subsided, the stools had been quite normal and peristalsis had entirely ceased.

The number of cases is now considerable in which the tumor has been found still present at necropsy in children who have died from other causes some time after operation or recovery without operation.

In Morse's⁷ case the tumor was still present at necropsy in a child who died of acute disease six and a half months after a successful gastro-enterostomy.

In Howland's⁸ case the tumor was present in a child who died four months after recovery without operation.

In Lewis and Grulee's⁹ patient, operated on by gastro-enterostomy at 2 months and dying eight and a half months later, the tumor was approximately of the same size and consistency as that found at operation.

In Walton's¹⁰ case, a child dying seven months after a gastro-enterostomy, the tumor was still hard and thick, and the pylorus impervious.

* Because of lack of space, this article is abbreviated in THE JOURNAL. The complete article appears in the author's reprints.

¹ Frederick A. Packard Lecture, delivered at Philadelphia, Feb. 13, 1917.

⁷ Dent, C. T., quoted by Cantley: Diseases of Children, 1910, p. 265.

⁸ Morse: Boston Med. and Surg. Jour., 1908, 158, 480.

⁹ Howland: Personal communication to the author.

¹⁰ Lewis, Dean, and Grulee, C. G.: The Pylorus After Gastro-Enterostomy for Congenital Pyloric Stenosis, THE JOURNAL A. M. A., Jan. 30, 1915, p. 410.

¹¹ Walton: Ann. Surg., 1914, 60, 342.

We are able to add four cases of our own in which late examinations have shown the persistence of the tumor. One child died of diphtheria six months after a gastro-enterostomy; a second died by accident two years and two months after a gastro-enterostomy, and a third of pneumonia twenty-one months after a gastro-enterostomy. In all these the tumor was still present at necropsy, and its condition was similar to that present at the time of the original operation. In the fourth case, a child returned to the hospital four years and seven months after a gastro-enterostomy for an operation on a ventral hernia, a sequel of the early laparotomy; the examination of the stomach in this case also showed the pyloric tumor to be still present.

CLINICAL PICTURE

An infant, usually breast fed, who has nursed well, gained normally in weight, has had sufficient and well digested stools and, in fact, has shown few or no signs of disturbance, begins to vomit persistently and forcibly. These symptoms have their most frequent beginning in the third or fourth week of life, and in most cases their onset is abrupt and without assignable cause. To the forcible vomiting are added marked constipation, steady loss in weight, and all the symptoms belonging to failing nutrition. Careful examination reveals definite gastric peristaltic waves, and in most cases a palpable tumor in the pyloric region.

So characteristic is the vomiting in these cases, as to the time of its occurrence, the manner in which it takes place and the matter vomited, that one can often make the diagnosis from this symptom alone. It differs markedly from the usual vomiting seen in young babies, in that it occurs soon after nursing, often while the child is still at the breast. It is forcible and projectile; the food is fairly shot out of the mouth, sometimes for a distance of 3 or 4 feet. It is in large amounts, usually the entire contents of the stomach, and generally it is repeated after each feeding. If the vomiting is infrequent, and does not occur after every feeding, the amount ejected at one time is often much larger than the amount taken at the last feeding. The frequent regurgitation of small amounts of food is seldom seen. The vomiting is unaccompanied by fever or pain, and in the beginning and usually for some time there is no impairment of appetite. Immediately after emptying the stomach the child may seem so hungry as to take a full feeding. Finally, the vomiting is persistent. Nearly every change of food has a surprising effect in temporarily lessening the vomiting, but in a day or two it returns and is as severe as ever.

The waves of gastric peristalsis have been so often described that a repetition is hardly necessary. Intestinal peristalsis may be mistaken for them, though rarely, indeed. Visible gastric peristalsis is, I believe, a constant symptom of these cases. In the great majority of cases the waves are typical and unmistakable, though in some they may not be observed unless the patient can be frequently seen and closely watched under the most favorable conditions, the most important one being that observations are made immediately after filling the stomach, and that the child is quiet. Slight atypical waves may be seen in a variety of conditions other than hypertrophic stenosis. But the deep, regularly recurring waves passing from left to right and frequently followed by vomiting are a conspicuous feature of nearly every case.

While a palpable tumor cannot be considered essential to the diagnosis, it will usually be found by a careful observer under favorable conditions. In fully three fourths of the cases it is unmistakable; but I have seen men of much experience unable to feel a tumor when one was afterward shown to be present, and I have known men to be quite sure that they felt a tumor when none could be demonstrated at necropsy or operation. The tumor is more distinct in the most severe cases. It may persist for months in cases in which recovery occurs without operation. The tumor is felt as a small movable mass about 2 cm. in diameter and 3 cm. long. It is most frequently found about 3 cm. to the right of the navel and a little above it, but there is liable to be considerable variation in position.

Abnormal gastric retention is easily estimated by emptying the stomach two, three or four hours after a test meal by means of a simple suction apparatus composed of a rubber catheter, a small laboratory wash bottle and a suction tube. The test meal which we have usually employed consists of 2 or 3 ounces of breast milk; diluted condensed milk answers the purpose; but one should not employ mixtures of unboiled cow's milk, as the coagulated milk in the stomach may block the tube. Simply passing the stomach tube is not enough; considerable suction must be employed to empty the stomach completely. In doubtful cases, several observations should be made or the retention determined even after each feeding. In few of these cases is the pyloric opening completely closed; but the determination of the amount of retention gives perfectly definite evidence to the extent of its occlusion, quite as reliable as the Roentgen ray after bismuth.

The secondary symptoms, constipation, wasting, scanty urine, etc., are simply a result of the vomiting. In the most severe cases the closure of the pylorus may be complete and the stools contain no fecal matter, resembling meconium. In most cases some food passes the pylorus, and the stools contain some solid fecal material.

Wasting is a constant symptom, and its rapidity is the best guide to the seriousness of the case. In the more marked types, the loss in weight frequently amounts to 2 or 3 ounces a day.

In the milder type of cases, though gastric peristalsis is marked, the vomiting may occur only two or three times a day, and occasionally there may be none for days together. The bowels move without medicine, and the stools are fecal, and often in normal amount. The weight may be stationary, or at times there may even be a slight gain. Gradually, in the course of from six weeks, but sometimes not till four or five months, the vomiting ceases altogether, the peristaltic waves are no longer seen, and the patient to all appearance has recovered. Even in these cases the typical tumor is often to be felt for several weeks, and in three of my patients it was noted as late as the sixth month.

In the severe cases the course is progressively from bad to worse. The vomiting is constant, little or nothing being retained; the bowels move only from enemas or medicine. The loss of weight may amount to a pound or more a week; the infants waste to skeletons, and when untreated usually die of inanition in from two to four weeks from the onset of symptoms. Between these extremes, cases of all degrees of severity are seen.

DIAGNOSIS

Enumerated in the order of their diagnostic importance I should place the points in this order:

1. The history, if obtained from a reliable mother or nurse.
2. Abnormal gastric retention, observations being repeated four or five times at least.
3. Peristaltic waves, not of diagnostic value unless typical.
4. The presence of a palpable tumor.
5. Wasting, constipation, scanty urine, etc.

I have placed tumor fourth in importance. Many would put it second. Though a palpable tumor is readily found in the great majority of the cases, there is in quite a considerable number a degree of uncertainty regarding it, and I have seen equally good observers differ often on this point. In any case, the diagnosis should not rest on the presence of a tumor, and, most of all, a decision regarding operation should not depend on it.

Stress has been laid by some writers on the value of the Roentgen ray in diagnosis. It does show whether the bismuth meal is passing through the pylorus, and the rapidity of its passage, and also whether or not the stomach is able to empty itself completely. In few of the cases is there complete obstruction at the pylorus. It is doubtful whether the Roentgen ray tells more than can be learned from careful observations of the gastric retention as described above. Furthermore, it must be remembered that these patients are very young, most of them in bad condition, and that they bear the manipulation incident to successive investigations with the bismuth meal badly. I have known one instance in which, after a series of such observations which occupied nearly twenty-four hours, the diagnosis was finally reached and the surgeon summoned, but the child was dead when the surgeon reached the bedside. While in some early cases, with the infants in good condition, useful information may be obtained by a series of Roentgen observations with the vast majority of infants it is extremely doubtful whether the results are commensurate with the risks incurred.

The principal difficulty in differential diagnosis is to distinguish cases of gastric indigestion with protracted vomiting from those of hypertrophic stenosis. This is especially difficult, as in the former gastric contraction and even small peristaltic waves may sometimes be observed; but these are usually slight and atypical, and are only occasionally seen even with the closest observation. The diagnosis is to be made by the absence of the other characteristic features of hypertrophic stenosis—the history, tumor and retention. The point should be emphasized that slight gastric peristalsis, even when accompanied by frequent vomiting, which at times may be forcible, does not warrant the diagnosis of hypertrophic stenosis.

There are certainly a number of conditions other than hypertrophic stenosis in which pyloric spasm is present. Pyloric spasm with gastric peristalsis has been repeatedly observed in infants with ulcer of the duodenum. Distinct gastric peristalsis was recently observed in the Babies' Hospital in an infant 4 days old with a congenital atresia of the esophagus. The introduction of food or water was followed in this patient by distinct gastric peristalsis, though the necropsy showed that the fluid never passed beyond the middle of the esophagus. The pylorus was normal. We have seen one instance in which pressure on the upper part of the duodenum by a congenital band gave rise to persistent, forcible vomiting and marked gastric

peristalsis, suggesting hypertrophic stenosis; but the vomiting began from the first days of life and was bilious in character. In another recent case, which an exploratory operation revealed to be one of tuberculous peritonitis with a normal pylorus, there had been frequent vomiting, at times forcible, and definite gastric peristalsis. There was a general matting together of the intestines from the tuberculous inflammation, but no definite pressure on the upper intestine.

It is evident, then, that there are quite a large number of different pathologic conditions in which gastric peristalsis and presumably pyloric spasm may be occasionally seen. To confuse these cases with hypertrophic stenosis, or to consider them as closely allied pathologic conditions just because they have one or two symptoms in common does not seem justifiable. It has greatly obscured the discussion of the subject. Hypertrophic stenosis should be regarded as a pathologic entity, though its symptoms vary greatly, according as the lesion is mild or severe.

MEDICAL TREATMENT

The medical treatment of hypertrophic stenosis consists in careful feeding and stomach washing. The gastric lavage should be practiced at first twice a day, and later at longer intervals; it serves the purpose of emptying the stomach thoroughly of mucus and fermented food; the water should be used warmer than usual, that is, up to 112 F. If it can be secured, breast milk is the preferable food, but one not rich in fat is desirable. The common practice of weaning as soon as symptoms develop is most unwise. In default of breast milk, a modified milk mixture low in fat should be employed.

With respect to quantities and intervals of feeding, cases respond differently. We have usually depended on from 1 to 3 ounces at three or four hour intervals, or small quantities and shorter intervals, especially if the food is breast milk. With the longer intervals, water should be given between feedings. In greatly prostrated patients, hypodermoclysis should be used daily; from 150 to 250 c.c. of 4 per cent. dextrose may be given in a saline solution at one time. Rectal feeding is of little assistance. The bowels are usually best moved by enema. I believe that drugs and local applications of heat over the epigastrium for the purpose of allaying the spasm are of little value. The weight should be carefully watched and taken daily, as it is the best guide to the patient's condition and progress.

SURGICAL TREATMENT

The first recorded operation for hypertrophic stenosis in infancy of which I can find record was that by Cordua¹¹ in 1893. The operation was a jejunostomy; the patient did not recover. I have found no more operations reported until 1898, when two done by Willy Meyer¹² of New York were reported, and a few weeks later one by Stern¹³ in Germany, the operation, however, having been done some months before. These three were all gastro-enterostomies, and in none did the patient recover. After the year 1900 the number of patients operated on steadily increases, though Shaw and Elting,¹⁴ writing in 1904, could find recorded up to that time, including their own case, but thirty-nine operations, with seventeen

11. Cordua, referred to by Grisson: *Deutsch. Ztschr. f. Chir.*, 1904, 75, 111.

12. Meltzer and Meyer: *Med. Rec.*, New York, Aug. 20, 1898.

13. Stern: *Deutsch. med. Wchnschr.*, 1898, 24, 601-604.

14. Shaw and Elting: *Arch. Pediat.*, 1904, p. 893.

recoveries. Only five of these operations had been done in this country.

In 1908, Dufour and Fredet¹⁷ collected published results in 135 operations which included the foregoing, and showed a mortality of 50 per cent.

This certainly was not a very encouraging showing, and the results led Heubner and Pfandler and others in Germany, and Hutchinson in London to inveigh against operation altogether, and to take the position that the great majority of the cases could be cured by medical means alone and that surgery was seldom if ever to be invoked.

With experience and improved technic during the next few years, surgeons in this country, particularly Scudder,¹⁸ Downes¹⁹ and Richter,²⁰ obtained much better results than those reported above; but still the general mortality attending operation was so high that physicians were loath to refer patients for operation, particularly when medical treatment was advocated by such high authorities as those mentioned.

In 1913, Rammstedt²¹ of Münster reported a successful case in which he simply divided the circular muscular layer of the pylorus by external incision. In his case, a typical one, the patient made an excellent recovery. He advocated this procedure as a substitute for the older operations—gastro-enterostomy, divulsion and pyloroplasty—then in vogue. The great advantages he claimed were that the stomach was not opened and the duration of the operation was much shortened. In his case it required only fifteen minutes,

TABLE 1.—RESULTS IN ONE HUNDRED AND THIRTY-FIVE OPERATIONS

Groups	Cases	Recoveries
Gastro-enterostomy	52	22
Divulsion	36	21
Pyloroplasty	22	13
Various modifications and combinations	25	12
Total	135	68

as compared with from thirty to fifty minutes needed for most of the other operations.

So far as I have been able to learn, this single case was the only one he has ever reported. But the operation was taken up by the surgeons of the Babies' Hospital, first by Dr. Alfred S. Taylor and then by Dr. William A. Downes, and now for over two years has been the only operation done in that institution.

In Table 2 are given the results obtained by medical treatment and by the older and the more recent surgical treatment in the patients who have come under my observation in private practice and those admitted to the Babies' Hospital in my own practice and that of my colleagues, Drs. Downes, Taylor, Kerley and Bartlett.

Rammstedt's operation of external muscle division has been done in the hospital up to January, 1917, in sixty-seven cases, all but one of these by Dr. Downes. Up to January, 1915, it was done occasionally, in all, on six patients. Since that date it has been done exclusively in the institution. In nineteen of the first twenty cases, in order to make sure that the constriction had been completely divided, the stomach was opened and a sound passed through the pylorus. This

was then decided by the surgeon to be quite unnecessary, and hence discontinued in the last forty-seven operations. It certainly adds to the operative risk.

The comparison of statistics of different men in different cities with different types of cases is not such conclusive evidence of the value of any plan of treatment as is a comparison of results in a single institution where the general run of cases is much the same, where all the operations have been done by the same surgeon and where the after-treatment followed was identical.

Including my private cases and the patients operated on at the Babies' Hospital, there were forty-one gastro-enterostomies with a mortality of 51 per cent.; of the twenty-eight cases in which operation was performed by Dr. Downes, the mortality was 43 per cent. Of the sixty-seven cases in which the Rammstedt operation was performed, the mortality was but 24 per cent.

The advantages of this operation are evident to one who has had experience with the other operations proposed. First in importance may be mentioned the time required. Seldom does the entire operation consume over fifteen minutes, and it is often completed in ten. The stomach is not opened, and the risks of nonunion, leakage and peritonitis from this cause are eliminated. Hemorrhage is seldom troublesome; no suturing is required, and a minimum handling of the viscera. So much for the surgical aspects. Our experience has shown that the shock is much less severe; the temperature reaction is less marked; food can be pushed more rapidly, and disturbances of digestion, particularly diarrhea, which has been so troublesome a symptom after gastro-enterostomy in more than half our cases, are much less frequent and less severe. This is undoubtedly due to the fact that the food passes normally into the duodenum instead of directly into the jejunum.²²

Experience has shown that there are some special dangers connected with this operation. The most important are the wounding of the mucous membrane, incomplete division of the constricting muscle, and hemorrhage. Wounding the mucous membrane occurred in but three cases in our series, two of them being among the first operations done. Both of these patients recovered. In one other this accident was followed by leakage, peritonitis and death. The incomplete division of the constriction happened but once in our series of sixty-seven consecutive operations. In one child, however, a previous operation in another hospital had not relieved the obstruction, and the symptoms continued; although the obstruction was relieved by the second operation and the vomiting ceased, the patient died of marasmus two weeks later. Both of the accidents mentioned will occur seldom in the hands of an experienced surgeon. The risk of hemorrhage is a slight one, but it should be kept in mind as a possible danger from the operation wound which is left. It has happened but once in the hospital series, and that the patient was a bleeder.

An analysis of the sixteen deaths in the Rammstedt cases is interesting. Six infants died from shock within a few hours after operation, but all of them were in extremely bad condition at the time of operation, and two of them almost moribund. In none had symptoms lasted for less than four and a half weeks, and in two they had lasted over ten weeks. One infant

17. Dufour and Fredet: *Rev. de Chir.*, 1908, p. 208.

18. Scudder: *Boston Med. and Surg. Jour.*, August, 1908; *Surg., Gynec. and Obst.*, 1911, 10, 275; *Ann. Surg.*, February, 1914.

19. Downes, W. A.: *Pyloric Obstruction in Infants*, *THE JOURNAL A. M. A.*, June 27, 1914, p. 2019; *Surg., Gynec. and Obst.*, March, 1916, p. 251.

20. Richter, H. M.: *Congenital Pyloric Stenosis*, *THE JOURNAL A. M. A.*, Jan. 31, 1914, p. 353.

21. Rammstedt: *Med. Klin.*, 1912, 8, 1702-1705; *Zentralbl. f. Chir.*, 1913, 11, 3.

22. For details regarding surgical technic, I would refer to the publications of Dr. Downes (Footnote 19).

had whooping cough when operated on, and died from bronchopneumonia on the sixth day. There remain nine deaths connected with the operation or due to the original condition which the operation did not relieve. Three were from peritonitis; one from hemorrhage; one from continued wasting; one from continuance of vomiting, the constriction not being entirely relieved; and in three, death occurred suddenly on the first, second and seventh day, respectively, no cause being discoverable.

Excluding the seven operations which were done under conditions which make it impossible to estimate the value of any operation, there remain sixty cases with nine deaths, a mortality of 15 per cent. This I believe, is the approximate mortality in these cases, taking them as they come. In a hospital like the Babies', where so many long-neglected cases are brought, it will be nearer 25 per cent. It should be remembered that these are chiefly hospital ward patients, and that they represent consecutive admissions. In only a single case in the last five years was operation refused on account of the child's condition. This patient when admitted was 3 months old and weighed, after eight weeks' medical treatment, but 3 pounds, 14 ounces; she lived only a few hours.

AFTER-TREATMENT

The success of operative measures in this condition is dependent in no small degree on the after-treatment. For a number of days after the operation the lives of these little patients often hang by a slender thread, and errors in judgment, especially with regard to feeding, often have the most disastrous consequences. It is, then, of the highest importance not only that the operation be done by a skilled surgeon, but also that the infant after the wound is closed be under the care of one equally skilled in the postoperative management.

From January, 1910, to January, 1917, there were 101 operations done at the Babies' Hospital. The postoperative management which has gradually been evolved as a result of the experience of the surgeons, the attending physicians and the resident medical staff has been fully detailed in a recent publication by Dr. Edward Morgan,²³ former resident physician. It will be given here only in outline.

It is to be borne in mind that practically all these infants are between 4 and 8 weeks old at the time of operation, and that they all have become much reduced in vitality as a result of loss in weight (often amounting to 3 or 4 pounds) and several weeks of protracted vomiting. It is of the first importance, therefore, that everything be done to conserve every particle of strength which the infant possesses. Exposure during operation should be the smallest possible. The room should be warm and the patient protected still further by artificial heat. Before the anesthetic is given, the stomach is emptied of food, gas and mucus. Stimulants during the operation are rarely called for. After removal from the table, the infant is wrapped in hot blankets and placed in a bed surrounded by hot water bags. The head of the bed is kept lowered until the effect of the anesthetic has passed off. As a means of introducing fluids into the tissues of these infants, often completely dehydrated as a result of the previous vomiting, nothing compares with hypodermoclysis. From 120 to 240

c.c. of a physiologic sodium chlorid solution are given, usually between the scapulae, and it is surprising how rapidly this is absorbed, even in some of the worst cases. Of stimulants given hypodermically, epinephrin has given us the most satisfactory results in doses of from 3 to 5 minims of the 1:1,000 solution. With the precautions mentioned, the small amount of shock to these patients from laparotomy is often amazing.

Feeding is usually begun as soon as the child has entirely recovered from the anesthetic. The position now used is with the head raised, sometimes to the semierect posture, so as to facilitate the expulsion of gas. Breast milk is indispensable, but it must be given at regular intervals and in carefully measured quantities, or serious disturbances of digestion may ensue, sometimes with fatal results, when everything previously has gone exceptionally well. The amount of food should be at first small, not over 2 or 3 teaspoonfuls of breast milk diluted with 1 or 2 teaspoonfuls of water. This is given with a medicine dropper and repeated in gradually increasing amounts every three hours. Water is given between the feedings in similar quantities. At the end of twenty-four hours, the infant is usually taking 4 or 5 teaspoonfuls of breast milk undiluted, and at the end of two days 1 ounce every three hours. These quantities are gradually increased to about 2 ounces by the fifth or sixth day, and at a week or ten days, but not before, the infant may be put to the breast. At first this should be for only two or three minutes. For the first month or two, artificial feeding presents unusual difficulties, and can seldom be successfully carried on except by one with much experience.

The administration of a teaspoonful of castor oil at the end of twenty-four hours is a routine practice whose beneficial results we seldom have had reason to doubt. It aids in the expulsion of gas and mucus, and seems to add much to the comfort of the patient. Often all disposition to vomit ceases as soon as the bowels have acted freely. Constipation after this is uncommon, but not infrequently diarrhea occurs. This was much more often seen when gastro-enterostomy was done than after the Rammstedt operation. In the former, particularly, it may be a most troublesome symptom for several weeks. The most successful measures for controlling this have been the substitution of protein milk (*Eiweissmilch*) for part of the breast milk, and the administration of moderate doses of bismuth and opium, since in the majority of the patients the chief factor in the diarrhea seems to be excessive peristalsis.

Some vomiting is to be expected during the first twelve to twenty-four hours. It is most frequently due to accumulation of gas in the stomach, and is relieved by posture or by passage of the stomach tube. It may be due to a too rapid increase in the food or sometimes apparently only from a persistence of the hyperesthesia of the gastric mucous membrane. Defects in the operation itself, when the obstruction has not been entirely relieved, may lead also to a continuance of the vomiting; finally, vomiting occurring after the third or fourth day may be due to peritonitis.

MEDICAL VERSUS SURGICAL TREATMENT

On the whole, is medical or surgical treatment of hypertrophic stenosis in infancy to be advised? It must be admitted that there appears to be considerable difference of opinion among those with some experience in this disease. To what is this difference of

23. Morgan, E. A.: The Postoperative Management of Pyloric Stenosis, *Am. Jour. Dis. Child.*, April, 1916, pp. 245-256.

opinion due? Are the physician and the surgeon talking about the same clinical and pathologic conditions? I do not believe that they always are. There are, I believe, a number of pathologic conditions in early infancy associated with vomiting which have many of the symptoms seen in hypertrophic stenosis, but which on close study are seen to be quite different. There are also different conditions in which there is visible gastric peristalsis. Even this symptom does not put the case in the same class with those we have been discussing. A large proportion of such patients recover with medical treatment only, as do also many of those of hypertrophic stenosis of the milder type, although probably in many of them the correct diagnosis is not made.

Let us drop these two groups of cases from our discussion and consider only the patients with hypertrophic stenosis as they are admitted to hospitals or as the pediatrician sees them. Such patients have usually been first in the hands of the general practitioner. Few of these cases have been recognized or received proper early treatment. They have generally been looked on as difficult feeding cases. In most of them the first thing done is to wean the baby, on the supposition that the mother's milk is at fault—usually the worst possible advice. Every conceivable change in food formula is made with the expectation of controlling the vomiting, but with no result, or at most only a temporary benefit. The average duration of the symptoms before the child is brought to the consultant or admitted to the hospital has been in our experience four weeks. Seldom are any but the most severe types seen as early as the second week.

The problem, then, of the infant with hypertrophic stenosis as the surgeon and the hospital physician sees it is that of a baby 7 weeks old, weighing 7 pounds, who has been vomiting for four weeks; such at least are our average figures. In some there is a history of continuous vomiting for two weeks or more and rapid loss in weight amounting to 2 or 3 ounces a day. In other cases, alternations of improvement and relapse have perhaps continued for two or three months.

The principal medical risk is of acute inanition, which may come on quite rapidly; and in the most severe type of disease, the infant may quickly sink to so low a point that it is impossible to save him by any means. In the less severe types there is the danger from slow marasmus, especially in hospitals and with patients in poor surroundings. In some of these cases the vomiting may be insignificant and the stools fecal, yet the child may slowly lose weight till his condition is hopeless, or he may die quite suddenly when apparently as well as for several days before. This is particularly apt to be the case unless the weight is closely watched and the actual amount of food retained is carefully recorded. In hospitals, risks of intercurrent disease are not to be ignored in patients with such feeble resistance as these infants. Finally, there must be considered the possibility of trouble in later life from these cases not treated surgically.

Certain surgical risks are unavoidable and belong to any operation as serious as a laparotomy. The chief one with these patients is shock, which in most cases is surprisingly little, considering the gravity of the operation and the tender age of the patients. Few infants who are in even a reasonably good condition die from shock; though with those in whom the disease has not been recognized or has been long neglected, this is important. All the surgical dangers—

shock, leakage, sepsis, hemorrhage—are greatly lessened by the substitution of the ten or fifteen minute operation proposed by Rammstedt for a gastro-enterostomy, which takes three or four times as long. After the Rammstedt operation also not only these grave dangers, but all the complications and sequelae are much less frequent and less severe. The reactionary temperature is not so high, and vomiting and diarrhea, both often troublesome after gastro-enterostomy, are relatively seldom seen; the food can be begun earlier and increased more rapidly, convalescence is altogether much shorter, and gain in weight in most cases begins by the end of the second week and thereafter proceeds as in normal infants.

If the child is seen in private practice with the possibilities of the best care and most intelligent feeding—particularly breast feeding—if the weight is stationary or the loss in weight is not great and the child still in good condition, if the vomiting is only two or three times a day, if the stools are fecal, waiting is to be advised.

On the contrary, if the weight has fallen to 6 pounds or below and the loss is still going on, if the vomiting is continuous, if there is marked gastric retention, if the stools contain no fecal matter, no time should be lost, but immediate operation advised, particularly in a hospital.

My early personal experience led me strongly to favor the medical treatment of these cases. I was greatly influenced by a few conspicuous successes in a few patients treated without operation, and also by the results of the first seven cases in which I saw operation done, five of the seven having been fatal. Increased experience has shown that the average case medically treated, unless it shows improvement in a few days, is liable to run a very prolonged course, even though the child may ultimately recover.

No better argument can be adduced for operative treatment than a comparison of our results at the Babies' Hospital in the three periods into which I have divided our experience (Table 2). During the first period, up to the end of 1911, our policy was operation only after a prolonged trial had been made of medical treatment, surgery being looked on as a last resort.

In the second period, comprising the years 1912, 1913 and 1914, operation was done in nearly every case within forty-eight hours, and the larger number within twenty-four hours, after admission.

During the third period, comprising the years 1915 and 1916, sixty-three cases were treated; sixty-one by operation, all Rammstedts, by Dr. Downes, with a mortality of 23 per cent.

These results have convinced not only myself but all my colleagues in the hospital that with the average infant admitted with hypertrophic stenosis, the immediate performance of the Rammstedt operation offers a better chance of life than any other method of treatment yet proposed.

FINAL RESULTS

It would seem rather remarkable if so marked a pathologic condition as exists in these cases should disappear in a few weeks. The symptoms, it is true, subside completely and, so far as one can positively say, permanently. At least none are seen for years. It is this fact that has led many to regard the essential condition as merely a pyloric spasm; believing that when this has disappeared the patient is well. To this view we cannot subscribe. We believe not only

that hypertrophy precedes the spasm but also that it continues long after the spasm has ceased. Proof of the latter point has already been cited. Most observations on this disease are still recent, and we cannot be quite certain yet in any case that symptoms may not appear later in life. It is true that they have rarely been noted in early childhood. But in the classical case of Beardsley (1788), marked symptoms were noted in the first week of life. They continued more or less severely, and at 2 years were described in language showing that they were typical. The child continued to suffer until his death at 5 years, the necropsy showing marked hypertrophy of the

to two and three quarter years, all were strong and healthy; but one suffered from vomiting attacks for nearly a year after operation. Roentgen observations in cases two or three years after gastro-enterostomy showed that the food was still passing through the operative wound. Judging from the histories of these patients, the operation of gastro-enterostomy in no wise interferes with the normal growth and development of children.

The Rammstedt cases (Table 3) have necessarily been observed for a much shorter time, but long enough to establish the fact that this operation does relieve the obstruction at once and completely. Of the

TABLE 2.—RESULTS OF MEDICAL TREATMENT AND THE OLDER AND THE MORE RECENT SURGICAL TREATMENT *

	Cases, No.	Recovered, No.	Died, No.	Mortality, Per Cent.	Average Age, Weeks	Average Weight Pounds
First Period, 1901-1911:						
Without operation	24	10	14	58	...	...
Operation (Gastro-enterostomy)	17	7	10	58	...	...
Total	41	17	24	58	7.3	7.6
Second Period, 1912-1914:						
Without operation	7	3	4	57	...	...
Operation (Gastro-enterostomy, 24; Rammstedt, 6)	30	17	13	43	...	...
Total	37	20	17	45.9	6.6	7.7
Third Period, 1915-1916:						
Without operation	2	1	1	50	...	...
Operation (Rammstedt)	61	47	14	23	...	...
Total	63	48	15	23.8	7.0	6.8

* In the first period, operation was performed generally after medical treatment; in the second period, usually soon after admission, and in the third period, always soon after admission. The average duration of symptoms on admission in each group was 4.2 weeks.

pylorus, considered by the author "scirrhus." The pyloric obstruction was so tight that only the "finest fluid" passed into the duodenum. More and more reports are constantly appearing of hypertrophic pyloric stenosis in older children and early adult life, which are ascribed to a congenial condition.

That hypertrophic stenosis may exist for years before it gives symptoms is shown by the case of Rosenheim,²⁵ in which a boy had no gastric symptoms until he was over 5 years old. An operation at 6½ years disclosed a hypertrophic stenosis. I have seen but one case of pyloric stenosis in an older child, a girl of 4½ years. In this the diagnosis was established by operation; but there was no history of protracted vomiting in infancy, and definite gastric symptoms did not begin until the patient was 3 years old.

In my own series of cases I have been able to follow for any length of time only seven patients who recovered without operation—one for eleven years, one for seven, three for six, one for five, and one for four years. All were in excellent health and only one had vomiting attacks after his initial recovery, and these ceased entirely at the age of 8 months. None who had been observed for shorter periods had shown any symptoms after the first year.

Turning now to the final results in the operative cases, I shall first consider those after gastro-enterostomy. Of the twenty patients who recovered, one died two weeks and one four weeks after operation, of enterocolitis; one died after four months, of diphtheria; one after two years from accident; and one, twenty-one months after from pneumonia, and one was lost sight of. The remaining fourteen patients have been followed up to the last few weeks. One seen after eleven and a half years is a well grown, normal boy. Four were followed for from four to five and a half years; all were then quite well, but one had suffered from occasional attacks of vomiting up to his third year. Of eight followed for from two

fifty-one infants who recovered, five died subsequently.

The remaining forty-six infants have been followed up to the last few weeks. The time elapsing from the operation to the date of last report was:

In four cases, between 2 years, 2 months, and 3 years.
In fourteen cases, between 1 year, 6 months, and 2 years.
In twelve cases, between 10 months and 15 months.
In eleven cases, between 5 months and 8 months.
In five cases, between 1 month and 4 months.

When seen, these children were almost without exception in the best of health; they were plump and rosy-cheeked, nearly all above average weight, and as fine a group as one would care to see.

TABLE 3.—RAMMSTEDT'S OPERATION AT BABIES' HOSPITAL.

	Cases, No.	Deaths, No.	Mortality, Per Cent.
Prior to 1915	6	2	33
1915	35	10	28.5
1916	26	4	15.3
	67	16	24

* Three patients died from gastro-intestinal conditions subsequently (4 weeks, 6 weeks, 7 weeks); one patient died from empyema (3 months) and one from pneumonia (4 months); forty-six have been followed and are well to date.

Our experience, I think, warrants the conclusion that the Rammstedt operation meets the indications in this condition. If this simple procedure does this, then there is no longer any justification for the other more serious surgical procedures which have been employed in the past.

CONCLUSIONS

1. Hypertrophic stenosis of the pylorus in infancy is a pathologic entity. It should not be confused with other pathologic conditions which may be accompanied by vomiting and occasional gastric peristalsis.
2. In many of the milder forms, the patients recover with only medical treatment.
3. All those who do not improve under such treatment in the course of two or three weeks should be

25. Rosenheim: Berl. klin. Wechnschr., 1899, 32, 703.

treated surgically; with the more severe types only a short delay is permissible.

4. The symptoms which indicate surgical intervention are rapid loss in weight, persistent, forcible vomiting, and active gastric peristalsis; the presence of a palpable tumor and abnormal gastric retention aids much in diagnosis.

5. The Roentgen ray reveals nothing of importance which cannot be discovered by a study of gastric retention, and without its dangers.

6. The patients who come under observation after four or five weeks of vomiting and marked loss in weight are best treated by operation as soon as the diagnosis is established.

7. The earlier operations of gastro-enterostomy, divulsion, pyloroplasty, etc., were unduly severe and prolonged; they should be abandoned for the simple external division of the circular muscular fibers proposed by Rammstedt.

8. Results by the same operator, on the same class of patients in the same institution and with the same after-treatment, show the great superiority of the Rammstedt operation to gastro-enterostomy and to medical treatment.

9. Skilled after-treatment is quite as essential to good results as good surgical technic.

10. Cases of gastro-enterostomy followed from four to eleven years indicate that growth and development are not impaired by the operation.

11. Cases followed two and three years after the Rammstedt operation show no interference with health and progress.

12. Patients not operated on usually show no symptoms after the first year. Yet the possibility that this condition may be the basis of pyloric obstruction in later life undoubtedly exists.

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ANAPHYLATOXIN AND ANAPHYLAXIS*

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It is our purpose to summarize the results of investigations which are published concurrently, under the same general heading, as a series of ten articles in the May and June numbers of the *Journal of Infectious Diseases*. For details, the reader must consult the experimental work there given. Although the problem primarily concerns a laboratory research, it nevertheless touches on matters of great importance in medicine. It will be realized that a new conception in physiology is inseparably bound up with problems in pathology and hence in disease. Thus, it is with the great questions of anaphylatoxin and anaphylaxis which, beginning with the observations of the French physiologist Richet, have claimed the attention of many workers, in many countries, during the past fifteen years. Many explanations have been brought forth to account for these reactions, and it would seem as if all possible interpretations had already been presented. Yet, as the result of an intensive study extending over a period of three years, we have arrived at an entirely different view, one which reveals these phenomena in a new light.

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We were led to take up this investigation through a series of observations made in the course of a study of certain tropical diseases of animals, namely, the trypanosomiasis, known as surra and nagana. In endeavoring to immunize against these diseases by injecting dead cultures of the trypanosomes, it was found frequently that severe toxic effects with marked hypothermia followed such injections. When these were repeated, chronic intoxication resulted which usually terminated fatally. For this reason it was not possible to secure a high degree of immunity, and it was clear that no progress could be made until a better understanding of this intoxication was reached. Laveran had encountered the same effects, and ascribed them to a "trypanotoxin." Similar effects have been known for a long time in connection with bacteria and led to the conception of "endotoxins."

PRODUCTION OF ANAPHYLATOXIN BY TRYPANOSOMES

The resemblance of the action of trypanotoxin to that of anaphylatoxin led us first to study the trypanosomes in their relation to anaphylatoxin production. Several investigators had already touched on this question. They found that if the *Trypanosoma brucei* was incubated with guinea-pig serum for two hours, and this mixture was then iced for from twelve to twenty hours, the serum thus treated was toxic in a dose of 3 c.c., because of the formation of something which is called anaphylatoxin. In our investigation, five different species of trypanosomes were employed, and it was possible to show that they all behaved in exactly the same way. Whether living or dead, on contact with serum they rendered it poisonous. Two fundamental facts were learned: first, that the rat serum was a most excellent reagent, better than any other serum hitherto used, and second, that the toxification occurred at great speed. Instead of incubating for hours, it was possible to render a serum fatally toxic in two or three minutes. Indeed, with rat serum it was possible to make this so toxic that in a dose of 0.25 c.c. it would kill guinea-pigs within three minutes after the injection. Never before had so powerful an anaphylatoxin been produced, or in so short a time.

A given mass of trypanosomes could be used to toxify different lots of serum, and in one experiment twenty consecutive tests were thus made without any apparent decrease in the ability of the organisms to make this poison. This study showed that the poison did not reside within the cells of the parasite, but that in some way it was produced out of a matrix present in the serum. The poison thus produced, when injected into animals, caused typical anaphylactic shock and death. It was shown that a ferment was not concerned in the production of this poison.

PRODUCTION OF ANAPHYLATOXIN BY AGAR

After it had been found that anaphylatoxin was produced by these organisms, it was in order to inquire as to what anaphylatoxin was, and how it was produced. This led us to study other agents which have been known to produce anaphylatoxin, and because of convenience we made use of agar. Bordet of Brussels had previously shown that when agar was incubated with guinea-pig serum for an hour or more, anaphylatoxin resulted. Accordingly, an extensive series of tests was made with agar. Various serums were employed, notably guinea-pig, rabbit and that of the rat. It was possible to show with all of these serums, that the reaction of poison production was