THE ETIOLOGY OF TETANY—METABOLIC AND CLINICAL STUDIES *

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Most authors who have written on the subject of infantile tetany connect the cause with a disturbance of the calcium metabolism, the greater number believing it to be due to a deficiency of calcium in the tissues. Stoeltzner¹ and his co-workers believe there is a stagnation of calcium in the tissues. Cybulski² and Schabad³ are confirmed that the calcium excretion is not regularly increased in tetany; yet the latter finds that on giving cod liver oil and phosphorus, there is a gradual reduction of electrical irritability with simultaneously an increased calcium retention. Schwarz and Bass⁴ failed to find any lessening of calcium retention. MacCallum and Voegtlin⁵ observed that in parathyroidectomized dogs the injection of calcium and magnesium salts stops all symptoms of tetany and that the injection of sodium and potassium salts has the opposite tendency. In addition to this they found a reduction of the calcium content of the tissues and blood during tetany and increased excretion of calcium in the urine and feces while the tetany is developing. At the same time they found that the ammonia in the blood and urine was also increased. Rosenstern⁶ reduced the electrical irritability by giving calcium salts in large amounts per mouth.

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* Read by invitation before the Kent County Medical Society, Grand Rapids, Michigan.

1. Stoeltzner: *Jahrb. f. Kinderh.*, 1906, lxxiii, 661; *Neurol. Centralbl.*, 1908, xxvii, 58.

2. Cybulski: *Monatschr. f. Kinderh.*, 1906, v, 409.

3. Schabad: *Monatschr. f. Kinderh.*, 1910, ix, 25.

4. Schwarz and Bass: *AM. JOUR. DIS. CHILD.*, iii, 1, 15.

5. MacCallum and Voegtlin: *Jour. Exper. Med.*, 1909, xi, 118.

6. Rosenstern: *Jahrb. f. Kinderh.*, 1912, lxxii, 154.

Similar use of sodium chlorid resulted in the production of electrical irritability, provided that enough was given to cause a rise in temperature. In addition to these observations he further found that the tetanoid symptoms were reduced on the withdrawal of whey from the food and conversely the symptoms were produced on the addition of it. He did not find sodium and potassium salts as effective in increasing electrical irritability as was whey containing the same amount of sodium and potassium.

Grulee⁷ was unable to confirm Rosenstern's findings, except in regard to the experiments with whey. He introduced sodium and calcium salts by injection with negative results. However, the doses used were smaller than those employed by Rosenstern.

Finkelstein⁸ says probably some substance in the whey is responsible for the disturbance resulting in tetany. Grulee reports a considerable number of cases of tetany in which a cure was effected by giving a food free from whey curds and barley water, with or without additional carbohydrate.

Zybell⁹ in 1913 concluded that experimental results showed no agreement as to the effect on infants suffering from tetany, of long continued feeding of small or large doses of calcium, although occasionally one finds a slight reduction in the electrical irritability in the employment of large doses of this salt. He does not believe in any specific salt therapy.

One of the most important observations from our standpoint has been the observation by Lust¹⁰ in 1913 in which he gave only a clinical report of an infant suffering from severe general edema and typical tetany. The electrical irritability disappeared with the edema. On two successive occasions the edema accompanied by tetany returned and both conditions disappeared as on the first occasion. Of equal interest is Kehrers's¹¹ report of six cases of tetany of the new-born, in two of which, the mothers suffered from nephritis with edema. Reiss¹² in 1911 stated that he believed that the tetanoid condition depended on the relation between sodium and potassium, on the one hand, and calcium and magnesium on the other. Grulee in further investigations was unable to demonstrate any definite variation in the salts.

Thus it is seen from previous and somewhat extensive observations that there is little uniformity of opinion. By far the greatest number of observations have been devoted towards the detection of the cal-

7. Grulee: *Arch. Pediat.*, 1912, xxix, 24; *AM. JOUR. DIS. CHILD.*, 1913, v, 205.

8. Finkelstein: *Lehrbuch der Sauglings Krankheiten*, 1909.

9. Zybell: *Jahrb. f. Kinderh.*, 1913, lxxviii, 29.

10. Lust: *München. med. Wehnschr.*, 1913, vi, 93.

11. Kehrers: *Jahrb. f. Kinderh.*, 1913, lxxvii, 624.

12. Reiss: *Ztschr. f. Kinderh.*, 1911, iii, 1.

cium, and no observations either clinical or chemical have proved any definite variations in the balance of the body salts. It might be stated in passing that the trend of opinion goes to show that the parathyroids do not play any definite part in the etiology of this disease, except in assisting generally in the metabolic processes in the body. Many autopsies have shown hemorrhages into the parathyroids, yet the cases clinically have no symptoms of the tetanoid type.

Owing to the observation made by one of us that in several cases of tetany there developed diarrhea, in the course of which the tetanoid group of symptoms spontaneously disappeared, it seemed justifiable to associate the diarrhea with the relief of the tetany. On further investigation it was found that in diarrheal stools the output of sodium and potassium may be eight to ten times that of the normal, while the change in the calcium and magnesium is but slight. Bearing this in mind, it was repeatedly noticed that when the stools of infants suffering from tetany became loose there was an amelioration of the symptoms, depending of course on the fluidity of the movements. Contrary

TABLE 1.—RATIO OF INTAKE TO EXCRETION AND PER CENT. OF INTAKE LOST IN STOOLS

	Normal Stools		Loose Stools		Very Loose Stools	
Fat	12.4		23.1		40.5	
Protein	7.7		14.9		25.2	
Total ash...	40.0	Urine	46.6	Urine	84.3	Urine
CaO	67.2	Trace	70.2	Trace	79.0	Trace
MgO	56.7	Trace	66.0	Trace	100.0	Trace
P ₂ O ₅	36.9	36.7	41.4	36.0	48.3	41.7
Cl	3.7	79.0	17.7	70.2	52.9	17.0
K ₂ O	15.4	54.9	37.9	37.9	83.7	26.6
Na ₂ O	12.3	67.5	37.0	28.2	103.0	5.7

to this, it was also noted that infants afflicted with tetany, either mild or severe, were constipated and that doses of castor oil invariably produced a reduction in the patient's irritability.

At this juncture it is interesting to note what a tremendous output of salts, especially sodium and potassium, takes place in diarrheal stools and for this purpose I have reproduced the table (Table 1) from work done by Courtney and Fales¹³ at the Babies' Hospital, New York. Here it will be observed that the output of sodium is a little over eight times the normal while that of the potassium is over five times that of the normal. The calcium and magnesium are influenced only to a much less degree.

It is a general belief, and one which has been most specifically formulated by Reiss,¹² that the calcium and magnesium salts act antagonistically to the sodium and potassium salts, the former tending

13. Courtney and Fales: *AM. JOUR. DIS. CHILD.*, 1915, ix, 213.

to allay nervous irritability, the latter to increase it. In other words, the formula $\frac{\text{Na}}{\text{Ca}} \frac{\text{K}}{\text{Mg}}$ would more accurately represent the proposition. When there is a relative increase of calcium and magnesium over sodium and potassium one would expect, if we follow the reasoning on this subject, to have a decreased nervous irritability, while the opposite proposition would also be true.

From what has already been said it will be seen that no observation has yet shown any definite relation between the inorganic salts, on the one hand, and the symptomatology of tetany on the other.

It has been our object to see that if by changing the various food elements, tetany could be produced with a fair degree of certainty, and in addition to this to note if possible any change in the inorganic salts during the onset, height and curing of the condition and what substances were responsible for the ultimate healing.

Our observations have been made on a series of thirty cases of definite tetany and in addition one hundred infants who were thought to be free from tetany were carefully tested, electrically and mechanically, for any evidence of spasmophilia.

METHODS OF OBSERVATION

The clinical methods employed were divided into mechanical and electrical tests. Under the former classification were grouped the various irritability signs, such as Chvostek's, Trousseau's, Schultz, carpopedal spasm, laryngospasm and convulsions. The degree of intensity of each particular sign was denoted by + or + + +, etc. In this manner a fair degree of accuracy was obtained. The electrical tests were made with a galvanic, dry-cell battery equipped with a switch for reversing polarity, a rheostat for controlling the strength of the current and a balanced milliamperemeter measuring from 0.2 to 10 milliamperes.

In every instance the peroneal nerve muscle group was employed, the negative electrode being placed over the upper abdomen and the positive electrode over the peroneal nerve as it winds around the head of the fibula.

The patient to be tested is laid with feet pointing to the right of the observer whose right hand controls the positive electrode placed on the peroneal group. The left hand supports the infant's right foot in such a manner as to detect the slightest twitch occurring in the flexors of the ankle or toes. In this way slight responses are detected which would be imperceptible to the eye. The negative electrode is held in position by an assistant while the observer controls the handle of the rheostat with his elbow. It is essential that all tests should be begun with a current of sufficient strength to produce a good muscular

response, and from this point gradually reduce to a point where the slightest twitch is lost. If the reverse is attempted the lowest contraction point will be invariably passed before response occurs. It is of importance that the reading be made at the point to which the needle on the balanced milliamperemeter swings and not at its highest fluctuation.

The skin resistance varies directly with the amount of subcutaneous fat and reduces rapidly as the operation progresses, the latter fact being apparently due to the congestion developing under the electrodes, thus increasing the skin conductivity. Due allowance should be made for this individual skin resistance so as not unnecessarily to disturb the patient.

It seems to be well supported that electrical irritability may be present when one or all of the symptoms of what is called mechanical irritability are lacking; while, on the other hand, one or more of the latter may be observed without the other mechanical signs or without the electrical reaction.

The most accurate method of estimating the nervous irritability in infants is by the electrical reaction measure by a reliable machine. Escherich in 1909 definitely determined that in infants suffering with spasmophilia KOC is less than 5 ma., while AOC is less than ACC. Speaking more specifically, it requires less than 5 milliamperes of current to produce the cathode opening contraction, while the anode opening contraction is produced by less than is the anode closing contraction. Extensive observations lead us to believe that in the majority of cases of distinct tetany, KOC is not obtained less than 5, but that AOC is always reached before the ACC, which reaction may be spoken of as anodal irritability, and was found to be present in all the cases of the series; in fact in only one instance was KOC noted to be less than 5 ma.

One hundred infants were tested for evidence of mechanical or electrical irritability. Of this group there were only three instances of anodal irritability, in none of which was there a response to a current of less than 2.0 ma. None of this group showed any evidence of mechanical irritability; in other words there was nothing to suggest even a latent tetany. The type of child for control test was chosen at random on admission from a service of sixty beds treating children under 2 years of age.

A diagnosis of tetany was never made when electrical hyperirritability was the only evidence, and further, only variations of 0.2 ma. were considered significant, for below that a personal factor (susceptibility to slight twitch) undoubtedly entered into consideration.

The chemical observations were conducted on a metabolism bed slightly modified from that employed at the Babies' Hospital in New

York. The amount of food taken each day was measured and a proportionate part used for analysis. The urine and feces were collected separately. The specimens dried and ashed by Bunge's method. Sodium and potassium were separated by platinic chlorid and weighed as chlorids. The calcium and magnesium were, according to McCruden's method, weighed as calcium oxid and magnesium pyrophosphate. In cases in which only the urine was examined the amount of sodium chlorid was estimated according to Volhardt's method.

INCIDENCE OF TETANY

From the accompanying Figure 1 it is seen that tetany occurs almost solely in the fall, winter and spring months; in other words, at a season of the year when there is no tendency towards diarrhea and

Fig. 1.—Showing monthly incidence of tetany (blocked) in comparison with mortality (curve) from diarrhea.

at which period the general inclination is towards constipation. In contrast to this, one sees no tetany in July and August, during which months the largest number of diarrheal cases occur. This may be explained by the fact that during diarrhea the inorganic salts are constantly eliminated, especially sodium and potassium, as previously noted, and hence the tendency towards irritability, from the storing up of these salts, is removed. On the other hand, during the colder months the infants tend towards constipation; hence elimination and internal combustion is less complete and we have a tendency towards a storing up of sodium and potassium, according to the nature of the food intake. Thus it is seen that the danger of tetany is removed in

the summer months, while the tendency increases at the approach of the cold season.

NATURE OF THE PREVIOUS FEEDING

From Figure 2 it is seen that 78 per cent. of the cases of our series of tetany occurred while being fed on proprietary and cooked foods, while 43 per cent. developed tetany on the former alone. It is worthy of note to see that five cases of the series of tetany occurred while being fed breast milk only. The remaining two cases had been fed various dilutions of pasteurized whole milk mixtures. Whether the milk had been heated beyond the 145 degrees or not it is impossible to state. Figures 3 and 4 depict the percentage of carbohydrate fed to two infants extending over a period of six weeks in one case (Fig. 3) and three months in the other case (Fig. 4); at the expiration of these

No. of Cases	Whole milk dilutions	Breast milk	Cooked foods & high carbohydrate	Proprietary foods
12				
11				
10				
9				
8				
7				
6				
5				
4				
3				
2				
1				

Fig. 2.—Showing the relation of the number of cases of tetany to the previous feedings.

respective periods each infant showed typical electrical and mechanical irritability. The average carbohydrate fed during these periods was 9 per cent., the lowest 4 per cent. and the highest 11 per cent. The fat and protein in each instance were normal for infants of their age. The only other departure from the plain milk feedings was that in each instance the food was cooked for thirty minutes. Both infants gained rapidly in weight and exhibited at the end of the periods of observation a slight degree of craniotabes. We have on record four other such cases fed in identically the same way, and in each case after a period of a few weeks exhibited, as in these two cases, typical signs of tetany and varying degrees of craniotabes.

It is an established fact that infants fed, over extended periods of time, large percentages of carbohydrates (as is contained in the proprietary foods) develop a water retention and are frequently spoken

of as "water babies." Their resistance is lower than the average child and they succumb rapidly to intercurrent infections and at the onset of diarrhea lose weight in an astonishingly rapid manner. The main increase in weight in carbohydrate fed infants is due chiefly to the fact that they are storing up in their tissues water which is in combination with sodium as sodium chlorid. Whether this ability to store water is due to the fact that the glycogen demands two molecules of water in the tissues, is not yet an established fact.

Another link in the chain of evidence of sodium chlorid retention in the tissues is the fact that when these infants lose their fluid the output of sodium chlorid is eight to ten times the normal. Infants presenting what is known as metabolism edema (due to improper

Fig. 3.—T. S. Premature infant. During a six weeks' period, following birth, fed high percentages of carbohydrates and at the end of the period developed tetany. During this period gained 3 pounds and 11 ounces.

feeding) fall into this same class, presenting definite chlorid retention, which rapidly disappears on the subsidence of the edema. In two such cases we have detected definite tetany, the symptoms of which vanished on the disappearance of the edema, coinciding with the increased chlorid output. In support of this evidence might be mentioned Kehr's¹¹ observation on five new-born infants developing tetany shortly after birth; the mothers of two of whom had nephritis with edema; and Lust's case of edema and tetany in which the tetanoid symptoms disappeared on the subsidence of the edema and recurred again as the edema reappeared.

It is thus seen that children fed on cooked foods with a high percentage of carbohydrate (as is present in the proprietary foods) show the greatest susceptibility to tetany; in other words, they exhibit a higher water content than normal infants, which water retention is chiefly in the form of sodium chlorid. The sodium and potassium ions, as previously cited, are direct excitants to the nervous tissues. Why it is that infants develop tetany on breast milk is not yet fully determined. It is possible to conceive of the fact that the metabolism of the carbohydrates of the mother's milk is incomplete in these cases, thus favoring a sodium or potassium retention, or on the other hand the total sodium or potassium content of the milk may be abnormally high. We hope to report on this in the near future.

Fig. 4.—Premature infant during a three months' period following birth, fed high percentages of carbohydrates, and at the end of the period developed tetany. During this period gained 2 pounds and 11 ounces.

METABOLISM OBSERVATIONS

The case we have to report in detail presented an excellent opportunity for observation, first, during a period in which the symptoms were severe, and second, during a period of pronounced improvement, ultimately ending in complete cure. A preliminary report of this case with observations and comments has been made in the *Archives of Internal Medicine* by Dr. Almon Fletcher.¹⁴

14. Fletcher: *Arch. Int. Med.*, 1915, xvi, 382.

REPORT OF CASES

CASE 1.—G. McK., male, aged 13½ months, was admitted Jan. 7, 1915. Had been partly breast fed for nine months, supplemented with Allenbury's food and arrowroot biscuits, while for about one month previous to admission he had had Horlick's malted milk. Throughout, the child was constipated and up to the time of admission the bowel movements were obtained only by means of enemata; the stools being described as small and hard. For the last few weeks previous to his entrance to the hospital he had been cross and irritable. On December 15 he experienced a stiffening of the body accompanied by spasm of the hand and foot, characteristic of tetany. One week later a more severe attack occurred, during which time the child became cyanosed and seemed to struggle for breath. From then on similar convulsions occurred at frequent intervals until the time of admission.

Examination showed only a fairly well developed and nourished child with a moderate amount of subcutaneous tissue of diminished turgor. Enlargement of the epiphyses of the long bones, palpable spleen and a moderate degree of craniotabes were the evidences of rickets.

The child cried continuously, with occasional crowing inspiration. Feet and hands were in the typical position of carpopedal spasm. Chvostek's and Trousseau's signs were strongly positive. Deep tendon reflexes readily elicited, pronounced acetone odor on the breath. The electrical reactions showed distinct anodal irritability KCC = 0.8 ma.; AOC = 1.5 ma.; ACC = 2.2 ma.

We endeavored to approach the same type of feeding that the child had been having previous to admission, in order to eliminate as many extrinsic factors as possible, so, for this reason he was given a mixture containing approximately, fat 2 per cent.; starch 2.5 per cent.; sugar 4 per cent., and protein 1.8 per cent. This combination was obtained by employing evaporated milk, 300 c.c.; barley flour, 45 gm.; lactose, 30 gm., and water, 900 c.c. This was cooked in a double boiler for thirty minutes and water added to make up the loss. He was offered 240 c.c. every four hours for five feedings. A good deal of this was at first refused on account of his extreme irritability.

On January 10 he was put up in a metabolism bed and observed up to January 15. During these five days he had but three constipated movements produced in each instance by castor oil. His irritability consistently increased so that at the end of the period his electrical irritability had increased from KCC 1.0 to 0.4 ma.; AOC 2.0 to 1.0 ma. and ACC 2.5 to 1.8 ma. on the 10th. All his mechanical evidences of irritability showed a corresponding increase. Thus, as well as could be estimated clinically, his tetanoid symptoms had increased considerably, so that on the 15th he might be said to be at the height of the disease. During this period he passed very little urine, although the amount increased toward the end. See Figure 5. During this first stage of observation the child gained 300 gm. in weight.

It had been observed previously that infants fed a high protein diet, such as albumin or protein milk, had an enormous urinary output, sometimes as much as 8 to 10 times the normal. This observation led us to use urea as a diuretic which, being organic in composition, did not interfere with the inorganic estimations such as the other diuretics might have. Since these observations, however, we have found it to be much the superior diuretic for infants.

From January 16 to January 18 the infant was taken out of the observation bed and given 1.0 gm. of urea in the daily quantity of food, to stimulate diuresis, which had already begun. From January 18 to January 22 he was again put up in the observation bed. During this period a striking change occurred (see Fig. 4). The general condition improved, he took more food and seemed to be more contented. The bowels moved without the use of castor oil and seemed more free. The urine increased in quantity from an average of 182 c.c. per diem in the first period to 600 c.c. per diem in the second period.

In other words, a little over three times the amount of urine was excreted during the second period. The electrical irritability decreased from KCC 1.2 ma., AOC 1.4 ma., ACC 3 ma. on January 18 to KCC 2 ma., AOC 2.7 ma., ACC 3 ma., on January 22. The carpopedal spasm entirely disappeared. Trousseau's sign could not be obtained and only a slight Chvostek sign was all that remained of the mechanical irritability. During this period there was a gain of 120 gm. Subsequently the child continued to improve and made a complete recovery.

The daily average estimations for the two periods are represented in Table 2.

From this table it is seen, in Period 1, that there is an abnormal retention of all the salts except magnesium, which, in turn, accompanied a gain in weight due to the retention of fluid. Magnesium is retained in only small amounts. In Period 2 the retained potassium has been cut in half, a daily balance of 0.4464 gm. being reduced to 0.2202 gm. The sodium retention has actually increased 0.002 gm., but the percentage of the intake retained has been reduced from 81.6

TABLE 2.—SALT INTAKE AND OUTPUT IN PERIODS 1 AND 2
Period 1

	Intake	Feces	Urine	Loss	Balance
K ₂ O	0.5460	0.0387	0.0609	0.0996	+ 0.4464
Na ₂ O	0.1754	0.0194	0.0129	0.0323	+ 0.1431
CaO	0.4686	0.0779	0.0017	0.0796	+ 0.3896
MgO	0.0324	0.00761	0.02155	0.02916	+ 0.0032

Period 2					
K ₂ O	0.8331	0.0770	0.5359	0.6129	+ 0.2202
Na ₂ O	0.2706	0.0099	0.1157	0.1256	+ 0.1450
CaO	0.6948	0.2478	0.0081	0.2559	+ 0.4389
MgO	0.1136	0.0279	0.0149	0.0428	+ 0.0706

per cent. to 53.2 per cent. It is of equal interest to note that there has been an increase of 0.049 gm. retention of calcium while the magnesium retention has increased twenty times over that of Period 1.

The striking changes are readily seen in Table 3. Here it is to be observed that both the sodium and potassium retention in percentage of the intake has been reduced, respectively, from 81.6 per cent. and 81 per cent. in the first period to 53.2 per cent. and 26.4 per cent. in the second period. On the other hand the percentage of calcium has decreased from 83.1 per cent. to 63.2 per cent., while there has been a most striking increase in the magnesium balance from 9.8 per cent. in the first period to 62.1 per cent. in the second period.

A mere casual glance at these figures serves to show how calcium estimations alone could not account for either the development or production of tetany. The high magnesium balance is likewise noteworthy in view of its specific action on nerve tissue. This observation

alone in conjunction with those made by Berend¹⁵ and Holt, Courtney and Fales,¹⁶ led us to the employment of subcutaneous injections of a magnesium sulphate solution to control the irritability. So far our results have been most gratifying.

A point of most practical interest is the fact that in Period 2, 88 per cent. of the excretion of sodium and potassium was excreted by the kidneys alone, which excretion occurred simultaneously with an increased flow of urine. In the first period, when the alkalies were retained, the kidneys were remarkably inactive. This observation has been of practical value, for, as will be shown later, the estimation of the sodium chlorid content of the urine alone is of decided diagnostic and prognostic import. In addition it offers a safer method than the production of diarrhea, to rid the body of the offending alkalies.

TABLE 3.—SALT RETENTION, ETC., IN PERIODS 1 AND 2

Period 1			Period 2		
	Retention in Grams	Percentage of Intake Retained		Retention in Grams	Percentage of Intake Retained
K ₂ O	+ 0.4464	81.0	K ₂ O	+ 0.2202	26.4
Na ₂ O	+ 0.1431	81.6	Na ₂ O	+ 0.1450	53.2
CaO	+ 0.3896	83.1	CaO	+ 0.4389	63.2
MgO	+ 0.0032	9.8	MgO	+ 0.0706	62.1

The association of suppressed urine and constipation in tetanoid infants is most common; in fact in every one of our cases in which we obtained reliable information, either one or the other and frequently both were prominent symptoms. The association of fluid retention and gastro-intestinal disturbance (constipation) observed in the first period is seen not infrequently in children and the former seems to depend directly on the digestive disturbance, since observation has shown that it can be controlled by changes in the diet and disappears as an improvement in the digestion or general metabolism occurs.

CLINICAL OBSERVATIONS

These observations we have divided into four groups:

1. Showing the effects of diuresis.
2. Showing the effects of purgation.
3. Showing the effects of cod liver oil and phosphorus.
4. Showing the effects of a combination of the above three methods.

15. Berend: Monatschr. f. Kinderh., 1913, xii, 269.

16. Holt, Courtney and Fales: AM. JOUR. DIS. CHILD., 1915, ix, 318.

It must be borne in mind that all the severe cases received one or more doses of magnesium sulphate in order to tide them over the danger period and to enable the instituted treatment to exert some influence in lowering the irritability and thus remove the patient from the danger zone, when the injections were stopped. A detailed report of these injections will be presented at a later date.

Fig. 5.—Case 1. G. McK. Showing the disappearance of the tetanoid symptoms accompanying the increased urinary output and sodium chlorid excretion.

Group 1: Effect of Diuresis

CASE 1.—G. McK., aged 13 months, admitted January 7. This case has already been referred to under metabolism observations. A brief reference to Figure 5 shows the increasing irritability accompanied by kidney inactivity, and vice versa, at the commencement of increased kidney secretion, which began without a diuretic two days previous to the institution of treatment, but was augmented on the administration of 1 gm. of the organic diuretic urea and 6 c.c. of castor oil. Two days following the commencement of treatment there was complete loss of all irritability which did not again recur. The chlorids had

increased from 0.025 gm. in twenty-four hours to 0.622 gm. at the time of the loss of irritability, a total increase of 96 per cent. over the excretion on admission. As the child improved the chlorid excretion increased until two weeks following cure it was found to be approximately 200 per cent. more than on admission, when the irritability was at its highest. At the time of the administration of urea, cod liver oil and phosphorus treatment was commenced, with the idea according to Schabad's observation, of increasing the calcium retention. It should be noted that observations with the administration of cod liver oil and phosphorus show that there is practically no change in the calcium

Fig. 6.—Case 2. W. S. Comparing the electrical irritability with the sodium chlorid excretion.

retention till a period of about ten days or two weeks has been reached, so it is obvious that its administration had no effect on the rapid cure of this patient, but undoubtedly aided in the permanent healing which resulted. This plan has been followed more or less in all of our observations.

CASE 2.—W. S. (Fig. 6), aged 5 weeks, admitted Jan. 11, 1915, showed pronounced electrical and mechanical irritability. No treatment other than urea was instituted, except subcutaneous injections of magnesium sulphate solution to control the convulsions. Under the exhibition of urea, curiously, the chlorid excretion dropped from 0.235 gm. to 0.075 gm. over a period of nine days; it

was then discontinued and small doses of cod liver oil and phosphorus commenced. In ten days' time the chlorids had reached 0.822 gm. per day, this being coincident with a loss of all irritability as indicated on the chart. This phenomena has been occasionally observed, namely: after the discontinuance of the urea the chlorids increase. We do not think in this instance either that the cod liver oil could have had any such effect, as it was given only in 20 minimum doses, and the response was too rapid. It will be noted on reference to Figure 6 that at the period during low chlorid excretion the irritability was at its height.

CASE 3.—J. S. (Fig. 7), aged 15 months, was admitted April 13, 1915, with edema of face and extremities, in addition to which there were pronounced signs of tetany, including extreme electrical irritability. The child was given a plain milk and water mixture and put up in the observation bed. Unaided

Fig. 7.—Case 3. Comparing the electrical irritability with the sodium chlorid excretion.

a diuresis immediately set in to such an extent that at the end of two weeks he had lost 1,060 gm. in weight, during which time his edema gradually disappeared. The changes that occurred at the same time were, (a) gradual reduction in his irritability, and (b) gradual increase in the sodium chlorid excretion. On admission he was found to be excreting 0.342 gm. in all the first day, and 0.258 gm. the second day; the output gradually rose till eight days following admission when he excreted 1.364 gm. in twenty-four hours or an increase of nearly five times the output at the height of the irritability. In this instance urea had practically no effect in increasing the urinary output as it had already begun and was well established when the diuretic was added. Throughout, the stools averaged one to two a day and were well digested. At the height of the chlorid excretion cod liver oil and phosphorus were given in 3 c.c. doses three times a day which completed the cure twenty-three days following admission. This child then exhibited a tremendous chlorid retention

as manifested by his edema, and later the loss of chlorids. At the height of the edema the tetany was at its worst, the signs disappearing as the chlorids increased.

Group 2: Effect of Purgation

CASE 4.—W. E., aged 6 months, was admitted for convulsions and found to have pronounced mechanical and electrical irritability. During a period of one week the irritability remained practically unchanged with no treatment; at the expiration of this time the child developed a severe diarrhea with seven to eight watery stools a day. In forty-eight hours there was complete absence of all the tetanoid group of symptoms. Many other instances might be cited, only not to such a striking degree. So convinced are we that we do not fear the onset of tetany as long as the bowels are moving freely.

Group 3: Effect of Cod Liver Oil and Phosphorus

To this group belong the cases whose symptoms are not severe and in which it is safe to wait a period of ten days or two weeks before any curative results may be expected.

CASE 5.—F. M., aged 15 months, was admitted April 9, 1915, with fairly pronounced mechanical and electrical tetany. The child was given a diet consisting of whole milk, cereals, beef juice and fruit juice and at the same time 3 c.c. of cod liver oil and phosphorus three times a day. In one week the irritability had slightly diminished and at the end of the following week had entirely disappeared. Throughout, the digestion remained perfect and the stools averaged one a day. The anodal irritability on admission was 1.2 ma., at the end of the first week, 2.8 ma., at end of the second week greater than 3 ma. with no mechanical signs of tetany.

CASE 6.—E. G., aged 8 months, was admitted March 8, 1915, and given a plain milk and water mixture in addition to 1 c.c. of cod liver oil and phosphorus three times a day. The child was suffering from a moderate degree of tetany, the anodal irritability being 2.5 ma. At the end of six days there was a slight increase to 2 ma. The medication was increased to 2 c.c. three times a day. In four more days there was complete loss of all mechanical and electrical irritability.

Group 4: Effect of a Combination of all the Above Three Groups

By this we mean an initial dose of castor oil to clear out the intestinal tract, the administration of urea and cod liver oil and phosphorus. To this group belong the most dangerous and severe type of cases, our idea being primarily to eliminate as much as possible of the stored up sodium and potassium in the feces by purgation, and to continue this elimination by activating the kidneys through the exhibition of urea and then endeavoring to increase the calcium retention through the administration of cod liver oil and phosphorus.

CASE 7.—H. T., aged 6 months, admitted Feb. 2, 1915, with a history of spasms extending over two months, showed pronounced electrical and mechanical irritability, in fact, the child was on the verge of convulsions. Both the mother and nurse volunteered the information that during the past few days the patient had passed very little urine. The infant was immediately given a dose of castor oil to relieve the constipation, urea gm. 1 in the total days' food, which consisted of protein milk, and at the same time cod liver oil and phosphorus 1.5 c.c. three times a day. For the first three days injections of magnesium sulphate were given subcutaneously to control the spasms, which as previously mentioned, were very severe. In three days following admission there was a decided reduction in both mechanical and electrical irritability, and in six days the AOC had risen from 1.2 ma. on admission to 3 ma. There was complete loss of all irritability on the tenth day. The child went on to complete recovery. Although the daily quantity of urine was not measured, a close watch was kept, the nurse in charge reported a great increase in the

urine after the first twenty-four hours, which continued as long as the urea was administered.

CASE 8.—M. S., aged 9½ months, admitted March 2, 1915, suffering from severe convulsions over a period of two weeks, showed on examination severe mechanical and electrical irritability. The same treatment was instituted as in Case 7 of this group. After the first twelve hours there were no more convulsions and on the third day there was a slight reduction in the electrical irritability. On the thirteenth day there was a decided reduction, the AOC having risen from 1.2 ma. on admission to 2.5 ma. Two days later there was complete loss of both mechanical and electrical irritability. The child made a complete recovery.

In these two cases the symptoms had lasted over a period of from two weeks to two months, during which there was ample opportunity for the establishment of a severe salt disturbance, which was evidenced by the convulsions and severe spasms in each case. In both a cure was effected within two weeks from the institution of treatment, and in each case the healing was permanent. All avenues of excretion were utilized and the retention of the sedative salt increased through the administration of cod liver oil and phosphorus.

SUMMARY

An extensive review of the literature reveals the fact that there is little uniformity of opinion as regards the etiology of tetany. Most authors who have written on the subject have associated the disturbance with a lack of calcium in the system and only one author has suggested the possibility of a general salt disturbance, but has cited no definite proof. Metabolism observations on patients suffering from diarrhea reveals the fact that in severe water loss through the bowel the output of sodium and potassium is eight to ten times the normal.

The production of tetany is probably due to the fact that the organism has been storing up fluid in the tissues, which fluid is in combination with sodium and potassium salts. This phenomena is brought about by the feeding of improper foods composed of high carbohydrates which have been subjected to heat. The association of fluid retention and gastro-intestinal disturbances (constipation) is seen not infrequently in children, and the former seems to depend directly on the gastro-intestinal disturbances, since observations have shown that it can be controlled by dietetic changes, and disappears as the digestion improves.

As previously mentioned, carbohydrate and the salts of sodium and potassium are especially liable to induce these changes and may well be reduced when there is any reason to believe that fluids are being retained. Taking away part of the whey from the food, as is sometimes done in the treatment of tetany, is a means of lowering the sodium and potassium intake; the calcium remains in the curd.

Apparently the sodium chlorid estimation in the urine is an index of the irritability, and as the kidney function improves the irritability lessens or disappears. The production of diuresis is a much safer method of elimination than that of purgation. Undoubtedly calcium estimations alone do not account for the nerve irritability in tetany, but would seem to support the hypothesis that the tetany results from a disturbance of the concentration equilibrium of the salts and such salt changes are probably associated with gastro-intestinal disturbances and decreased flow of urine, and, as improvement in the function of these two systems occurs, restoration of the normal salt equilibrium ensues.

CONCLUSIONS

1. Tetany may be produced by high carbohydrate foods which have been subjected to heat up to or over the boiling point.

2. The monthly incidence of tetany is probably due to a disturbance of the gastro-intestinal tract (constipation), decreased internal combustion and the comparative safety from diarrhea in feeding high carbohydrate foods during the cold months.

3. A diagnosis of tetany is suggestive when there is manifest kidney inactivity in constipated infants fed heated foods of high carbohydrate content.

4. As a result of this improper feeding there is produced a disturbance of the body salts. At the height of the disease there is an almost complete retention of sodium and potassium (the irritating salts) and a great loss of magnesium. As improvement ensues there is an increased flow of urine accompanied by a relief of the constipation, during which the stored up sodium and potassium are rapidly lost.

5. This salt disturbance may be remedied first by purgation, second by diuresis, third by the administration of cod liver oil and phosphorus to build up the calcium content, and fourth by a change of diet.

6. The severe spasms or convulsions may be temporarily relieved by subcutaneous injections of a solution of magnesium sulphate.

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