

THE RELIABILITY OF THE ELECTRICAL DIAGNOSIS OF TETANY

WITH ESPECIAL CONSIDERATION OF THE ELECTRICAL VALUES FOUND IN
NORMAL CHILDREN *

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The first electrical diagnoses of tetany in children were made on well marked clinical cases. The electrical values obtained in these were much lower than those found in children free from tetany. It was later discovered that some children who showed no clinical evidences of tetany gave electrical values nearly if not quite so low as those found in cases of clinical tetany. Such children were said to suffer from latent tetany, the diagnosis being based wholly on the electrical reactions.¹

With this extension of the conception of tetany as an active and as a latent disease of infancy and childhood, the diagnosis of it has, especially with older children, come to rest on a less secure foundation. There have been no electrical standards established for normal children beyond the period of infancy, it having apparently been assumed that the values established for infants are applicable to older children as well. A study of the reactions in older children shows almost at once that this assumption is unjustifiable.

Even with infants, also, the determination of what is normal and what is abnormal offers at times great difficulties. Therefore, I have studied the reactions of infants and older children with and without tetany in order to determine the reliability of the electrical diagnosis of this disease and, especially with older children, to establish the standards for the normal and the deviations from this which enable us to recognize the presence of tetany.

The Development of the Conception of Tetany.—Many of the symptoms which we now recognize as belonging to tetany were first described in infants that were teething. Increased irritability, abnormal

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1. The chief justification for this conception and diagnosis of latent tetany is to be found in the fact that some of these children with low electrical values later develop unmistakable clinical symptoms of tetany.

contractions of the muscles, transient spasms, and, finally, convulsions, were thought to be more or less normal accompaniments of dentition. It was not until a century ago that physicians studied certain of these symptoms more carefully and began to recognize their abnormal character. One by one they were described, at first as independent entities and then as different manifestations of one underlying disease.

James Hamilton² in 1809 gave a beautiful description of spasm of the larynx and spoke of it as the most formidable symptom, except convulsions, which occurs during dentition. In 1816 George Kellie³ of Leith wrote at some length on a form of swelling of the backs of the hands and feet and on a spasmodic affection of the thumbs and toes which commonly accompanied it. Underwood, he said, had earlier described this condition, regarding it as of no importance, since it went away upon the eruption of the teeth; but to Kellie it seemed rather to constitute "a part of a disease of a somewhat more serious and striking nature." In the next year James Johnson⁴ of Philadelphia applied the term "carpopedal spasm" to this condition. It occurred, in his case, in association with transient spasmodic affections of the muscles of respiration.

In 1819 J. Cheyne⁵ differentiated clearly between hydrocephalus and laryngospasm. He said: "The pathognomonick of this disease is a crowing inspiration, with purple complexion, not followed by cough. In some cases . . . attended, not merely with a permanent clenching of the hand upon the thumb, but also with a very remarkable fixed spasm of the toes, particularly the great toe, which gives a look of swelled deformity to the upper part of the foot." He spoke also of the associated convulsions.

John North⁶ referred to the syndrome as one generally recognized, and Marshall Hall⁷ described the symptoms in a complete manner and attributed their appearance to reflex irritation of the central nervous system from teething and the presence of indigestible food residue in the gastro-intestinal tract.

The names of the earlier workers are, it will be noted, all British or American. Their views seem to have had little influence on French teaching; they were, however, accepted in Germany and there further elaborated. Then attention became centered upon details of symptomatology and etiology and the broader view that grouped together under

2. Hamilton, James: *Hints on the Treatment of the Principal Diseases of Infants*, 1813.

3. Kellie, George: *Notes on the Swelling of the Tops of the Hands and Feet, etc.*, *Edinburgh Med. and Surg. Jour.*, 1816.

4. Johnson, James: *Med.-Chir. Jour.*, Philadelphia, 1817, iii, 448.

5. Cheyne, J.: *Essays on Hydrocephalus, or Water in the Brain*, Ed. 2, 1819.

6. North, John: *Practical Observations on the Convulsions of Infants*, 1826.

7. Hall, Marshall: *Diseases and Derangements of the Nervous System*, 1842.

one head the conditions of laryngospasm and nonepileptic convulsions of childhood was almost forgotten for many years.

It is to Cheadle⁸ and those working with him that we owe the reestablishment of the old views of tetany after they had remained in obscurity for many years. "Laryngospasmus, tetany and convulsions," said Cheadle in 1887, "are different expressions of the same constitutional morbid state, are associated especially with the first two years of life, with the period of rickets and with the period of dentition." He designated this morbid constitution as "a state of erethism," in which the central nervous system is in a condition of abnormal excitability. He considered this condition and tetany of adults one and the same disease, with, however, this difference: in the adult muscular contraction predominates in the picture, in childhood convulsions and laryngospasm predominate. Abercrombie⁹ had noted "facial irritability" as a new symptom. Stewart,¹⁰ an American, reported in 1889 the presence of increased electrical excitability (Erb's phenomenon) in the tetany of childhood.

Escherich¹¹ (1890) found that mechanical excitability of the nerves, especially the facial phenomenon, was regularly present in laryngospasm, and that Trousseau's sign and spontaneous contractions seldom failed. In association with von Wagner, he demonstrated at that time the presence in the infant of galvanic electrical hyperirritability of the nerves, similar to that found in the tetany of adults. Moreover, he found that this electrical hyperirritability came and went with the attacks of laryngospasm and that as the attack passed away the spontaneous contractures disappeared first, then the Trousseau phenomenon, next the laryngospasm, and finally the electrical hyperexcitability.

The views of Escherich met at first with much opposition, but they were soon confirmed by reports from other sources. In the next year (1891) Escherich reported his observations on nearly three hundred cases. Since that time the contributions have dealt, for the most part, with details of diagnosis, etiology and treatment, and need not be mentioned here.

The Electrical Diagnosis of Tetany.—The presence of increased electrical excitability in the nerves of adults suffering from tetany—the so-called Erb's phenomenon—was noted by Erb in 1878. The first

8. Cheadle: Pathology and Treatment of Laryngismus, Tetany and Convulsions, Lancet, London, 1887, i, 919.

9. Abercrombie: On Tetany in Young Children, London, 1880.

10. Stewart: Tetany, Am. Jour. Sc., December, 1889, cited after Escherich.

11. Escherich: Idiopathische Tetanie im Kindesalter, Wien klin. Wchnschr., 1890, iii, 769; Begriff und Vorkommen der Tetanie im Kindesalter, Berl. klin. Wchnschr., 1897, xxxiv, 861; Die Tetanie der Kinder, Vienna and Leipsic, 1909, p. 10.

report of the presence of similar heightened electrical excitability in children suffering from tetany came from the American physician, Stewart, in 1889.

The first extensive study of Erb's phenomenon in the tetany of children under three years of age was made in the clinic at Graz, in 1890, by Escherich and his associate von Wagner. Ganghofner,¹² Hauser,¹³ Kalischer,¹⁴ Burkhardt,¹⁵ von Pirquet,¹⁶ and others supplemented these studies. The nerves most commonly selected for examination have been the median nerve (stimulated in the bicipital fossa) and the peroneal nerve (stimulated near the head of the fibula—Erb's point). The earlier investigators anesthetized their patients, thinking that restlessness might interfere with satisfactory readings; later workers have not found this necessary. As the change in the electrical excitability of the nerves in tetany is a general one, affecting all the peripheral nerves,¹⁷ it is possible, by examining one nerve, to determine the condition of the peripheral nervous system as a whole. It is necessary, however, to have some table of the values to be expected in normal children for use as a comparison.

Stintzing¹⁸ in 1886 prepared tables showing the range of values found for each of the peripheral nerves in normal adults, but no similar table has been compiled for infants and children. The Stintzing tables for adults give the cathodal closing (C. C. C.) values only. That the determination of the cathodal closing value alone is not sufficient in the case of infants and young children is shown by a brief review of the development of our knowledge of galvanic electrical reactions in children. The work of Escherich, Ganghofner, Burkhardt, Kalischer, Thiemich and Mann,¹⁹ and finally of von Pirquet, is of especial interest.

Escherich found what he considered abnormally low values for the C. C. C. (cathodal closing contraction) and the C. C. Te. (cathodal closing tetanus) in the few patients he examined in 1890. He spoke also of the occasional appearance of anodal opening tetanus, though the strength of current required to produce it was not given.

12. Ganghofner: Ueber Tetanie im Kindesalter, *Ztschr. f. Heilk.*, 1891, xii, 447.

13. Hauser: Ueber Tetanie der Kinder, *Berl. med. Wchnschr.*, 1896, xxxiii, 782.

14. Kalischer: *Jahrb. f. Kinderh.*, 1896, xlii, 386.

15. Burkhardt: Die Tetanie im Kindesalter, *Cor.—Bl. f. schweiz. Aerzte*, 1893, xxiii, 23.

16. Von Pirquet: Die Anodische Uebererregbarkeit der Säuglinge, *Wien. med. Wchnschr.*, 1907, lvii, 14.

17. This assertion, though commonly accepted, is questioned by some authors; consult Borrutau-Mann: *Handbuch der electro-medizinische Technik*, Leipzig, 1909, ii, 384.

18. Stintzing: Ueber elektrodiagnostische Grenzwerte, *Deutsch. Arch. f. klin. Med.*, 1886, xxxix, 76.

19. Thiemich and Mann: *Monatschr. f. Psychiat. u. Neurol.*, 1899, vii, 14; *Jahrb. f. Kinderh.*, 1900, li, 99.

Ganghofner examined thirteen cases and found the cathodal closing values low in all, with a return to higher values as the symptoms of tetany vanished.

Burkhardt in 1893 reported a typical case of tetany in a 2½ year old child, with increased galvanic excitability.

Hauser in 1896 was the first to dispense with chloroform anesthesia. He examined 280 children, ages not given, with various diseases, and testing the median and ulner nerves for the cathodal closing contraction and cathodal closing tetanus, found C. C. C. values ranging from 0.2 to 0.5 milliamperes and C. C. Te. from a few ma. to 16 ma. As a result of his study he asserted that increased electrical excitability of the nerves was the most constant and important symptom of tetany. Oddly enough, he did not observe this phenomenon in most of the cases of laryngospasm that he examined. Kalischer reported similar findings in the same year.

In 1897 Escherich published the results of later examinations made by him without anesthesia. He found what he considered to be an increased electrical excitability in all cases of tetany examined by him, and found, also, that this heightened electrical excitability preceded the appearance of spasms, and lasted weeks or months after these had disappeared. Especially important appeared to him the lowering of the C. C. Te. values. The nerve examined in this study is not mentioned.

In the same year (1897) Thiemich made an important contribution to the subject by determining what he considered the normal values for children in what we may call the tetany age, and by calling attention to the significance of the early appearance of cathodal *opening* contractions (C. O. C.). Stintzing had already determined the normal range of values for the cathodal closing contraction (C. C. C.) in adults. The Westphals,²⁰ father and son, studying the C. C. C. only, had shown that much higher values obtain in newly born infants. Thiemich and Mann examined fifty-six children whom they believed free from tetany and, averaging their findings, obtained the following results:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Children under 8 weeks of age.....	2.6	2.9	5.1	9.3
Children over 8 weeks of age.....	1.4	2.2	3.6	8.2

The nerve examined was the median, the point of stimulation being at the end of the bicipital fossa just above the bend of the elbow. The ages of the children were not given, nor were the actual findings from which the averages were obtained. There is evidence that the

20. Westphal, A.: Die electrischen Erregbarkeitsverhältnisse des peripheren Nervensystems des Menschen im jugendlichen Zustande und ihre Beziehungen zu dem anatomischen Bau desselben, Arch. f. Psychiat., 1894, xxvi, 1; Westphal, C.: Neurol. Centralb., 1886, v, 6.

children were all under three years of age. Thiemich and Mann thus obtained results that were more precise than any that had previously been recorded.

They then examined children of this age who were suffering from tetany, latent and active, and recorded similarly the electrical values found in them. They noted, in addition to low values for the C. C. C. (cathodal closing contraction), a preponderance of A. O. C. < A. C. C., anodal opening contractions appearing with less current than anodal closing contractions, and especially the appearance of C. O. C. with a current of less than 5 ma.

This last observation, the appearance of C. O. C. under 5 ma., Thiemich thought characteristic of tetanoid conditions of the nervous system; indeed he emphatically insisted that such a reaction was necessary for the diagnosis of tetany.

Ganghofner in 1904 reported the results of a few examinations. In the main he confirmed Thiemich's conclusions, but he believed that cases of undoubted clinical tetany may exist in which the cathodal opening contraction may be above 5 ma. (C. O. C. > 5 ma.), and that he had seen children (ages not stated) in whom the C. O. C. occurred with a current less than 5 ma., yet who neither before nor after the examination ever presented any clinical signs of tetany.

In reviewing the reports of all the earlier observers the reader is struck with the fact that the ages of the children examined are rarely given. In some instances one may infer that the age was under three years, for example, in Thiemich and Mann's work; as a rule the reader is left in doubt. Much more precise is the statement of the next contributor of importance, von Pirquet.

Von Pirquet in 1907 made systematic and repeated examinations on twenty-four children in the infant section of the Vienna clinic, through periods ranging from one month to a year. The oldest of these children appears to have been under two years of age. Two of the twenty-four developed definite signs of clinical tetany at some time during the year. As the result of his study von Pirquet offered the following corrections to the work of Thiemich and Mann, and gave as normal values for infants under 2 years of age as follows:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
3	>5	>5	>5
(exceptionally 1 to 5)	or <5		

These values were obtained from the peroneal nerve.²¹ As is indicated, von Pirquet found that the value of the anodal closing contrac-

21. Von Pirquet stated that he made comparative studies on the peroneal and median nerves and that his results showed approximately equal values for the opening contractions on the two nerves, and distinctly lower values in the median nerve for closing contractions.

tion varied and that it often fluctuated from day to day. The anodal opening value, on the other hand, he found remarkably constant:

Von Pirquet drew the following conclusions:

1. Normal infants present only closing contractions under 5 ma. when examined with the galvanic current.
2. The appearance of an anodal opening contraction under 5 ma., when unaccompanied by a cathodal opening contraction or cathodal closing tetanus under 5 ma., is characteristic of a low grade of hyperexcitability that may be termed anodal hyperexcitability.
3. Anodal hyperexcitability is a precursor of cathodal hyperexcitability, which is indicated by the appearance of cathodal closing tetanus or a cathodal opening contraction under 5 ma.

This work is the last important contribution to the development of the subject. In addition to giving a more precise statement regarding the electrical values in children under 2 years of age, von Pirquet introduced the conception of anodal hyperexcitability. Anodal hyperexcitability, he found, preceded the appearance of cathodal hyperexcitability, accompanied it, and was present for a time after the disappearance of the latter. It was present during the late spring of one year in one half of the infants in the Vienna Hospital, and it was in this group that the two cases of clinical tetany appeared; therefore, he regarded this condition, anodal hyperexcitability, as a sign of latent tetany.²² The development of active clinical, or manifest, tetany in his two cases was accompanied by the appearance of cathodal hyperexcitability (C. C. < 5 ma.).

Von Pirquet stated distinctly that his observations were made upon infants. He believed that the values for normal infants are approximately those given by Thiemich and Mann for children in the first

22. The term "latent tetany" seems to have been first used by Erb. In his chapter on Tetany in Ziemssen's Handbuch it is stated that repeated examination by him of two cases had shown that there existed a condition of increased electrical excitability, a fact earlier affirmed by several observers, notably by Benedict and Kussmahl; and that "the greatest increase of excitability coincided with the time of the best marked and most frequent attacks of tetany and there was a decrease in the excitability as they became less frequent; and finally, when the patient had completely recovered, the electrical excitability was found to be approximately normal. A distinct parallelism could thus be demonstrated to exist between the occurrence of spasms and the increase of electrical excitability" . . . and, it was added, as a footnote: "It is probable that exact electrical investigation, as well as Trousseau's symptom, would afford a means of recognizing a *latent condition of the disease, or that condition in which no attacks of tetany are present, though the disease is not entirely cured. The persistent increase of faradic, and especially of galvanic, excitability would constitute the characteristic symptoms of this condition.*" (The italics are mine.)

In the same paper it was observed that "the period of latency, in particular, may last for a long time, and apparent relapses are certainly often only indicative of the fact that the disease had not entirely run its course."

eight weeks of life, and that the values given by Thiemich and Mann for children over 8 weeks of age are too low for children between 8 weeks and 24 months of age. He gave as the values for normal children under two years of age:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
3	$\frac{5}{2}$	$\frac{5}{2}$	$\frac{5}{2}$
(exceptionally 1 to 5)	or $\frac{5}{2}$		

No mention was made of the values for children over two years of age.

Thiemich had determined the values in cases of tetany in children under three years of age, and for these had given the formula:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Tetany, manifest....	0.63	1.14	0.55	1.94

These figures were obtained by averaging the actual values found. They stand in sharp contrast with the normal values as given by Thiemich for children over 8 weeks of age, and in still greater contrast with the normal values given by von Pirquet for infants under 2 years of age.

The values found in Thiemich's cases of latent tetany in children were:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Tetany, latent.....	0.70	1.45	0.95	2.93

Here, also, neither the highest nor the lowest values actually found are given, but only the average of them all. It will be noticed that Thiemich's phenomenon, or the occurrence of cathodal opening contractions under 5 ma., is present, and the anodal opening is lower than the anodal closing value, in the formulas both for latent and active tetany. Taken in all, the values of the formulas given by Thiemich for latent and active tetany are so nearly alike that we may regard the two formulas as practically the same. There is a very great difference between them and the normal and very little danger of confusion.

Von Pirquet's observations, however, made it apparent that in cases of latent tetany particularly figures not deviating so far from the normal are to be expected and, as outlined above, he identified anodal hyperexcitability with latent tetany, and cathodal excitability with active, manifest tetany. However, he stated distinctly that his observations were made upon infants.

Many writers have not hesitated to utilize the data obtained upon infants and young children and consider them applicable to older children. Yanase,²³ for example, working in Vienna, applied the formulas obtaining in infancy to children of 5 and even 8 years of age, and finding in them anodal, and occasionally cathodal, hyperexcitability,

23. Yanase: *Jahrb. f. Kinderh.*, 1908, lxvii, 57.

made diagnoses of tetany. Peritz²⁴ (1912) says specifically that Esch-erich's value of 5 ma., for the anodal opening contraction as an expres-sion of heightened excitability certainly applies to older children; and, further, that the early appearance of anodal opening contractions (that is, A. O. C. <5 ma.) seems pathognomonic of tetany in older children.

More recently Sedgwick²⁵ has examined the mothers of children that he thought spasmophilic and has been surprised at finding in the mothers values that compared with the formulas of infancy are abnor-mally low. Low values, as tested by the same standard, were found also in fathers and older brothers and sisters of such children. From these findings he has drawn far-reaching conclusions regarding spas-mophilic families, in which the hereditary taint manifests itself in the children in the form of repeated absences or mild epileptiform attacks.

Now Stintzing has shown us that the value for the C. C. C. (catho-dal closing contraction) for the peroneal nerve in adults ranges from 0.2 ma., which he calls the lower limiting value, to 2 ma., the higher limiting value. The Westphals, Mann and Thiemich, von Pirquet and others have shown that much higher values are to be expected in nor-mal infants and, indeed, in children up to the third year. It is evident that a transition from the high normal values of infancy to the rela-tively low values of adult life occurs somewhere between the second year of life and puberty. When and how these changes occur has not been hitherto reported.

The recent clinical development of the conception of latent tetany forces this lack of knowledge upon our attention. The clinician who attempts to diagnosticate tetany or latent tetany in older children at once finds himself hampered by the inadequacy of published data regarding the course of galvanic excitability of the peripheral nerves in normal children. Ibrahim²⁶ has well said, in criticizing Sedgwick's paper on repeated absences, that it cannot be accepted as proved that the values that are pathognomonic for infants have the same diagnostic importance in older children and adults. Control examinations of normal children are very much to be desired.

It has seemed wise for these reasons to investigate the range of galvanic electrical values in a large number of children from birth up to thirteen years of age, and to record not only the average values, but also the highest and lowest values found in normal children of each year of life, together with any changes in the reactions that might be of importance.

24. Peritz: *Nervenkrankheiten*, Berlin, 1912, p. 444.

25. Sedgwick, Julius Parker: *Spasmophilia with Especial Reference to Familial Reactions and Repeated Absences*, *AM. JOUR. DIS. CHILD.*, 1914, vii, 140.

26. Ibrahim: *Ztschr. f. Kinderh.*, 1914, *Referate*, viii, 22.

The results of such an examination of a large number of average dispensary and hospital patients are herewith presented in tabular form.

The clinical material for examination was obtained from all patients admitted to the wards of the Harriet Lane Home from November, 1913, to April, 1914. These patients were tested as part of the first routine examination, and the test was repeated, as a rule, at intervals of a week or ten days thereafter during the patient's stay in the hospital. As many cases as time permitted were selected at random each day from the children in the outpatient department, and when a patient had been once tested an effort was made to repeat the test upon several subsequent visits. This practice applied also to former hospital patients.

Such patients are admittedly not normal children in the strictest sense of the word. The expression "normal children" is here used to designate those entirely free from evidences of clinical or latent tetany. Some of them were perfectly normal; some of them were brought for minor ailments, while others were suffering from, or convalescent from, severe illnesses. A few were epileptic or mentally retarded. There was no reason to suppose that any were not normal so far as their electrical reactions were concerned.

Four hundred and thirty-four patients were examined in all. Thirty-four of these were felt to be definitely abnormal, from the point of view of the study in hand, and were excluded from the present tabulation.

Of the thirty-four patients excluded from tabulation, thirteen were patients with latent or active tetany. The majority of them were admitted to the hospital for further study. In the other twenty-one cases the values obtained upon examination (first or subsequent) differed so widely from those of the ordinary child of the same age that it was thought best to exclude them from the series. Among them were three cases of hydrocephalus (with spasticity of the lower extremities) and other cases of abnormalities of the central nervous system, some of which will be discussed at the close of the paper.

The Technic of Examination.—With the child on his back, the examiner stood on the child's right and supporting the right knee and leg with his left hand, applied the stimulating electrode with his right hand.²⁷

An assistant, standing opposite the examiner and holding the indifferent electrode in place on the epigastrium with one hand, controlled the electrical apparatus with the other.

27. With the examiner standing in the position here described, slight movements of the foot, toes and tendons may be seen, and minimal contractions in the muscles of the lower leg may be felt, particularly in infants, by the fingers of the left hand as they rest on them. Voluntary movement of the leg is also restrained.

The apparatus was a silver chlorid battery of thirty-five cells, with the amperemeter in the direct circuit and reading fifths up to ten milliamperes.

The stimulating electrode consisted of a spherical metal ball of 1 cm. diameter mounted on a wooden handle bearing a make-and-break key, and the indifferent electrode of a metal disk 4 cm. in diameter. Both electrodes were covered with a thin layer of sponge to retain moisture and were moistened in warm water for use. In young infants the stimulating electrode was held firmly in the popliteal space—maximum contractions for minimal strength of current may be thus obtained in infants. In well-grown infants, and in children over 1 year of age, the point of maximum sensitiveness (Erb's point for the peroneal nerve) was sought, and being found, was retained throughout the examination.

The cathodal closing values were first sought by using a current sufficient to provoke a contraction. The strength of current was then diminished as rapidly as possible until contractions just ceased to appear. The reading at the appearance of minimal contractions, the needle always being allowed to come to rest, was recorded.

After waiting a few moments the anodal values were sought, beginning, as a rule, with about 5 ma. of current, diminishing it, and noting, as before, at what point minimal contractions appeared.

After again waiting, the cathodal opening value was similarly sought. The early appearance of cathodal closing tetanus sometimes prevents one obtaining a cathodal opening contraction; and in such cases cathodal closing tetanus alone was recorded.

The facial phenomenon (Chvostek), if present, was recorded in terms of its grade.²⁸

In no case was an anesthetic used and, save in two instances, it was never found impossible so to accustom the child to the procedure that a successful examination was possible. Infants were frequently examined while sleeping, without awakening them.

Rickets.—Tetany is no longer regarded as a symptom of rickets; but both are generally believed to be related in some way to disturbances in calcium metabolism. It is therefore necessary to review the conditions under which rickets appeared in the 400 children whose electrical values are here tabulated.

The number of cases (thirty-six) in which the presence of rickets was noted as other than the principal diagnosis—it was recorded as the principal diagnosis in seventeen cases—may appear small in comparison with the total number of cases tabulated (400); but this seeming disparity disappears when comparison is made with the number of individuals (100) examined between the sixth month and the third year, the period of active rickets. Then, too, the majority of cases of clinical tetany found during the period of study (see above) also presented signs of rickets, and the exclusion of these from the present table further reduces the percentage of rickets recorded therein. Possibly more cases suffered from rickets in some slight degree but not sufficiently to be clinically recognizable.

Examination of those individual cases in each age group which gave electrical values below the average for that group, showed that rickets was present with frequency only in Group 1 to 6 months and Group 1 to 2 years. In the former group it was present in 37 per cent. of the cases showing electrical values

28. Escherich records the Chvostek phenomenon in three grades, thus: Grade 1: Slight twitching at the angle of the mouth or of a small muscle bundle in the nose or forehead, following tapping with a percussion hammer or bent finger on a point midway between the pons zygomaticus and the angle of the mouth, over the facial plexus; Grade 2: A strong lightning-like twitch at the corner of the mouth, alae nasi, orbicularis, or frontalis muscles; Grade 3: A definite twitch in all the muscles supplied by the facial nerve upon tapping over it in front of the external auditory canal.

notably lower than the average. In the latter group it was present in 65 per cent. of the cases showing noticeably low values, and the lowest values included in the statistics for that group occurred in three cases of florid rickets.

In examining the tabulated results it is seen that the children are grouped according to age, and the number of children examined in each age group is given, together with the total number of examinations. The values obtained on galvanic electrical examination are presented

TABLE 1.—AVERAGE ELECTRICAL VALUES OF NORMAL CHILDREN OF DIFFERENT AGES

Age of Child, Years	Number of Children Examined	Average of Values Obtained in Normal Children				A. O. C. Less than A. C. C. %	Chvostek Phen., %	Total Number Examined
		C. C. C.	A. C. C.	A. O. C.	C. O. C.			
Under 1 mo.	29	>5	>5	>5	>5	0	..	39
1 to 6 mos.	56	3.9	4.9	>5	>5	8	0	157
½ to 1	38	3.3	4.7	4.6	>5	20	0	68
1 to 2	41	2.9	4.6	4.6	>5	36	0	78
2 to 3	20	2.5	4.2	4.3	>5	30	5	31
3 to 4	24	2.3	4.2	*4.2	>5	40	0	42
4 to 5	20	2.1	3.8	4.1	>5	40	0	25
5 to 6	22	1.9	4.1	3.7	>5	67	14	43
6 to 7	20	1.8	3.9	3.0	4.9	75	5	36
7 to 8	20	1.9	3.7	3.2	4.9	65	5	22
8 to 9	30	1.7	3.9	3.5	>5	60	16	41
9 to 10	20	1.8	3.8	3.2	4.9	55	25	38
10 to 11	20	1.8	3.6	3.5	4.9	50	20	28
11 to 12	20	1.5	3.5	3.1	5.0	40	25	24
12 to 13	20	1.7	3.6	2.3	5.0	55	20	28

under three heads: (1) the average values;²⁹ (2) the highest values discovered, provided those did not exceed 5 ma.; and (3) the lowest values found in children who did not present other signs of latent

29. In computing the average values, values >5 ma. were treated as 5 ma, and the appearance of cathodal closing tetanus was regarded as the equivalent of a cathodal opening contraction of the same number of milliamperes; that is, C. C. Te=4.2 ma. was regarded as the equivalent of C. O. C.=4.2 ma. Now since A. C. C. >5, for example, may, in a given instance, stand for A. C. >6 or 8 or 10, it is clear that such a method of computing may give an unduly low average value, particularly in infants, in whom the A. O. C. and C. O. C. values often range far above 5 ma.; yet, since it is not desirable to test for contractions with current of greater strength than 5 ma., some such method of computing must be employed. In the data for older children this source of error is practically excluded, since in them the prevailing values are below 5 ma.

tetany. Under each group is indicated also the frequency with which there appeared anodal opening contraction with a current less than that causing anodal closing contractions, that is A. O. C. < A. C. C., the so-called anodal hyperexcitability of von Pirquet.³⁰ The number of cases in which a positive Chvostek phenomenon appeared is also noted.

These are the average electrical values of normal children, obtained and computed in the manner described. Stintzing has shown, however,

TABLE 2.—EXTREMES OF ELECTRICAL VALUES IN APPARENTLY NORMAL CHILDREN

Age, Years	Lowest Values Found in Apparently Normal Children				Highest Values			
	C. C. C.	A. C. C.	A. O. C.	C. O. C.	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Under 1 mo.	3	4.2	>5	>5	>5	>5	>5	>5
1 to 6 mos.	1.6	3.4	>5	>5	>5	>5	>5	>5
½ to 1	1.9	2.0	2.9	>5	>5	>5	>5	>5
1 to 2	1.2	2.4	2.1	>5	>5	>5	>5	>5
2 to 3	1.2	2.8	2.5	>5	>5	>5	>5	>5
3 to 4	1.2	2.9	2.4	>5	4.5	>5	>5	>5
4 to 5	1.4	2.8	2.7	>5	2.9	>5	>5	>5
5 to 6	0.5	2.1	1.4	3.8	>5	>5	>5	>5
6 to 7	1.0	2.6	1.8	4.3	3.0	>5	>5	>5
7 to 8	1.1	2.2	1.7	4.9	2.8	>5	>5	>5
8 to 9	0.5	1.9	1.5	3.8	3.0	>5	>5	>5
9 to 10	1.1	2.7	2.1	4.7	3.0	5.0	>5	>5
10 to 11	1.1	2.0	2.0	4.7	3.0	>5	>5	>5
11 to 12	0.9	1.8	2.0	4.9	3.3	>5	>5	>5
12 to 13	0.3	1.8	1.5	>5	1.7	>5	>5	>5

how wide may be the range of electrical values in normal adults—the C. C. C. may be 0.2 to 2 ma. for the peroneal nerve at Erb's point, the average being 1 ma. There are analogous variations in infants and children. They may not be so great, but they exist.

There are presented here two other columns of figures, one showing the highest values discovered during the examination of the children in each age group, the other showing the lowest values found in children that were not subjects of active or latent tetany, so far as could be determined by careful examination, questioning, and by the observations of their subsequent symptoms.

30. See page 7.

It is difficult to know what interpretation to put on low electrical reactions in apparently normal children. There was sometimes found one figure, for example a C. C. C. value, which was very low, while all the other figures were high; but in general when one figure was high all were high, and vice versa. The low figures in Table 2 were found in individual patients, and are not compiled from isolated observations in several patients.

It can be understood that it is often exceedingly difficult to differentiate between the normal and the abnormal by electrical reactions alone, and it is frequently impossible to determine at the first examination whether younger children presenting low values are really suffering from a low-grade latent tetany. Later on, illustrative cases will be given, but the danger of including improper cases in the table of averages has led me to discard all those with unusual, isolated and unexplained low electrical values.

From these tables certain conclusions stand out clearly:

1. There is a gradual transition from the high electrical values of early infancy to the relatively low values of adult life.

2. Values below 5 ma., other than cathodal closing values, are rare in the first six months of life, but appear with increasing frequency thereafter.

3. Cathodal opening contractions with a current of less strength than 5 ma. are of infrequent appearance in normal children of any age; they probably do not occur in normal children under 5 years of age. The same may be said of cathodal closing tetanus. The occasional appearance of either after 5 years is not, per se, pathognomonic of tetany, but such children should be carefully examined for other evidences of tetany.

4. The presence of anodal opening contractions with a current less than that causing anodal closing contractions and under 5 ma. (anodal hyperexcitability) occurs with gradually increasing frequency from the first half-year of life upward, reaching its maximum frequency at 6 or 7 years. The infrequency of its occurrence in infants under 6 and 12 months of age (incidence 8 and 20 per cent., respectively) renders its appearance in them of considerable diagnostic importance, since this inversion of the usual sequence, as has been shown by others, may be, in cases of tetany, a forerunner of that cathodal hyperexcitability which usually accompanies manifest tetany. After the second or third year the presence of anodal opening contractions under 5 ma. in itself affords little help in diagnosis.

5. The facial phenomenon (Chvostek) is rarely met with in normal children under 5 years of age; it appears with increasing frequency thereafter.

6. There appears to be a rather abrupt transition toward adult values at the fifth to sixth year of life. In the age group 5 to 6 it is seen (*a*) that much lower values than hitherto were obtained in apparently normal cases; (*b*) that inversion of the earlier relation of anodal opening and anodal closing contractions appears in the formula of aver-

age values, and (c) that the facial phenomenon (Chvostek) appears with much increased frequency.

Knowing the galvanic electrical values that may be expected in normal children in each year of life, one can now proceed with some confidence to a critical examination of the electrical reactions that have been held by various authors to indicate the presence of tetany in infancy and childhood.

It should be emphasized that one low electrical value, no matter how low, is not in itself evidence of tetany. This is true especially of a low cathodal closing value. A low anodal value is of greater importance. If such appears to be present, the fact should be verified by a second examination a few minutes later. In clearly defined cases of tetany all values will, as a rule, be lower than usual.

In his earlier studies (1890 and 1897) Escherich stated that he found increased electrical excitability in all cases of tetany examined by him, and emphasized the early appearing cathodal closing tetanus as evidence of this. He considered hyperexcitability of the peripheral nerves the most important symptom of infantile tetany, which he defined as tetany occurring in children under 3 years of age, and said that at this age if electrical hyperexcitability were absent the diagnosis of infantile convulsions due to tetany could not be made, while certain conclusive conditions could only be recognized by its presence.

More precise statements were made by him in his monograph of 1909, or after the work of Thiemich and Mann, and von Pirquet. These will be considered later.

Escherich's earlier conclusions are sufficiently broad in their nature to admit of acceptance. Cathodal closing tetanus of anything more than the most momentary duration has not been found, in my study, in normal children under 5 years of age. The statement that electrical hyperexcitability is the most constant phenomenon in tetany of infancy has been generally accepted.³¹ The question is, what values exactly indicate the presence of abnormal hyperexcitability, that is, what figures indicate overstepping the limits of normal variation?

Thiemich and Mann, at the conclusion of their studies, declared that in cases of tetany the values for cathodal closing contractions are lower than in normal infants, that there is an almost uniform occurrence of anodal opening values less than anodal closing values ($A. O. C. < A. C. C.$), and that cathodal opening contractions ($C. O. C.$) appear under 5 ma. (Thiemich's phenomenon). This last phenomenon they considered characteristic of tetany.

31. This is not to imply that electrical excitability (electrical values) may not rarely be perfectly normal in cases of clinical tetany at the time of making any single observation (see page 18).

In considering Thiemich's views it is well to examine the actual figures given by him.³²

Thiemich and Mann's figures (averages) for cases of tetany are as follows:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Tetany	0.63	1.14	0.55	1.94
Latent Tetany.....	0.73	1.45	0.95	2.93 ³³

Their averages for normal children under eight weeks of age are as follows:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
2.61	2.92	5.12	9.28

Children over eight weeks of age:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
1.41	2.24	3.63	8.22

It has been thought by some later workers that certain children who suffered from less marked and unrecognized tetany must have been included in Thiemich's series of normal children, with consequent reduction of the averages. This seems evident from my figures for normal children, in comparison with which it appears that Thiemich and Mann's figures for normal children under eight weeks of age represent better the lowest figures found in normal children one year of age, and the average figures given by them for normal children over eight weeks of age are nearly as low as the lowest figures that I have found in normal children under a year of age, and lower than my average figures under five years. Not only are the figures given by Thiemich and Mann for normal averages too low, but the most infrequent occurrence of A. O. C. < A. C. C. (30 per cent. in the third year) is not indicated.

The lowest values tabulated by me for normal children under three years of age are as follows:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
1.20	2.80	2.50	> 5

The average values are much higher:

C. C. C.	A. C. C.	A. O. C.	C. O. C.
2.50	4.20	4.30	> 5

There is thus seen to be a wide difference between Thiemich's averages for active and for latent tetany and the lowest figures founded by me in normal children.

32. Due allowance should be made for the fact that Thiemich and Mann utilized the median nerve in their study. Later investigators have used the peroneal nerve (see page 6).

33. The figures for the two conditions are so nearly alike that they may practically be regarded as the same.

Though it is true that most cases of active, clinical tetany give findings that are much below the normal, and thus resemble Thiemich's findings more or less closely, yet there are other cases occasionally met with of undoubted clinical tetany which at no time in their course give findings as low as those of Thiemich and Mann for active and latent tetany.

If Thiemich and Mann's figures are made criteria of the presence of tetany, few erroneous diagnoses of tetany will be made, but many less-marked examples of clinical tetany will escape diagnosis, and most instances of latent tetany in which the electrical phenomena alone are present will pass unrecognized.

Von Pirquet stated his results very definitely and offered the conclusions given on page 7. He confined his study to infants, or children under two years of age. He divided them into three classes: (1) the normal; (2) those with latent tetany, and (3) those with manifest tetany. Those of the first class present only closing contractions under 5 ma.; those of the second class present anodal opening contractions under 5 ma.; while those of the third class (clinical tetany) give, in addition, cathodal opening contractions, or cathodal closing tetanus, under 5 ma.

Von Pirquet's conclusions are open to criticism. Anodal opening contractions under 5 ma. are frequently met with in infants under one year of age, and more frequently in children between one and two years of age. Anodal opening contractions under 5 ma. and under the value for the anodal closing contraction in the same patient, an even stricter definition of anodal hyperexcitability than is von Pirquet's, occur among normal children³⁴ with a frequency that increases progressively with the ages of the children until, in older children and in adults, it is a very common, if not regular, finding.

The phenomenon is met with in a considerable percentage of apparently normal infants under a year of age—probably about 10 per cent. It is not permissible, without further evidence, to say that such infants have latent tetany. They may show merely the early appearance of a phenomenon that is encountered with increasing frequency as age increases. The change is apparently one that accompanies normal growth, and one that finds several analogies, as, for example, the appearance of plantar flexion in response to plantar stimulation, a phenomenon seldom found in infants, more frequently met about the third year, and normally present in older children and adults.

Diagnostic significance would appear to be attached to the appearance of anodal hyperexcitability in infants, in children in whom it had not previously existed, or in connection with other suspicious condi-

34. See page 10 and Table 1.

tions. Its presence then becomes of diagnostic significance, and this significance is the greater the younger the child.

Escherich's later conclusions in his monograph, in 1909, were that there was as yet no general agreement as to the normal electrical values; that the values of von Pirquet were to be considered normal for the first year and indeed longer, though no exact studies for the later years of childhood had been made. Escherich accepted von Pirquet's three types of galvanic response in infancy, but questioned whether the milder grades of hyperirritability (von Pirquet's table) always indicate latent tetany.³⁵

With the publication of the tables in the first part of this paper, there are now available tables showing the electrical values found in normal children, tables that show both the average values and the extremes between which lie the actual values from which the average values are computed. The figures show that normal children present various degrees of galvanic electrical irritability. There is a wide normal variation that must be taken into account. The interpretation of electrical reactions must vary with the age of the subject examined. At no age is it possible to draw a sharp line between normal and abnormal reactions.

Certain broad statements, however, may be made for use in clinical work:

Electrical hypersensitiveness is the most common and constant phenomenon in tetany of infancy and childhood.

Whether tetany may exist without essential change in the electrical reactions of an infant or child cannot be dwelt upon here. Frankl-Hochwart and Chvostek are said to have noted such occurrences in the adult. Thiemich suggested such a possibility for the child. All the other phenomena of tetany have frequently been reported absent in individual cases of tetany. And we may ask, why not the electrical phenomena? Certainly, in their more marked grades they may be absent at the time of any given observation.³⁶ The essential relation between electrical hyperexcitability and the clinical manifestations of tetany cannot be said to be known. Nor can the cause of the frequent and sometimes daily variations (Case 8) in electrical hyperexcitability during the course of tetany be said to be known.

Cathodal opening contractions and cathodal opening tetanus, of anything more than momentary duration, with a current of less than 5 ma., do not occur among normal children under 5 years of age. If certain organic diseases, such as hydrocephalus, spastic paraplegia, and cerebral sclerosis can be excluded, the presence of C. O. C. < 5 ma. in

35. Escherich found a slight increase in electrical irritability in rachitis and organic nervous diseases, and Thiemich in microcephalus and cerebral sclerosis; in these cases the cathodal opening value lay above 5 ma.

36. See Case 8, January 5; Case 9; and Case 12, December 2 and 5.

children under 5 years indicates tetany. In children over 5 years, such is not necessarily the case.

The following cases show the value of C. O. C., and C. C. Te., < 5 ma. in diagnosis. One or two cases are also included to show that perfectly typical tetany may be present with the C. O. C. always greater than 5 ma.

CASE 1.—D. G., white girl, aged 8 months,³⁷ born in difficult, noninstrumental labor, was breast fed for three months, then given condensed milk mixture; during the last three weeks she was given cow's milk mixture, one half dilution. The child was born "blue" and remained so more than twenty-four hours. Jaundice appeared at birth and lasted six weeks. At the age of 5 months attacks "of getting blue and thumping of the heart" appeared. These came on without coughing, lasted five to ten minutes, and occurred three or four times a day at intervals of two or three days for one month. During the last two months the attacks were ushered in by sudden shortness of breath. First convulsion appeared eleven days before admission and lasted five minutes. The body became stiff, hands clenched and arms flexed; the tongue was bitten. Three similar attacks followed in the next three days, but were less severe.

The child was well developed and well nourished. There was slight epiphyseal enlargement. The spleen was not palpable. There was an inspiratory stridor. The thumbs were flexed on the palms, and there was a tendency to plantar flexion. The Trousseau phenomenon was present. The neck was rather short and thick. Roentgenography showed an enlargement of the heart and a probably enlarged thymus.

The child remained in the hospital twenty days and had no further convulsions until the last day. Her weight increased for ten days, then fluctuated, and during the last three days fell rapidly. The temperature at this time rose steadily from normal to 103.5. In the early morning the child was found hiccoughing, cyanotic, and making convulsive movements of the tongue and facial muscles, with the respirations irregular. There was no obstruction to the passage of air. Chloroform inhalations relieved the convulsions. The abdomen was much distended. The rapid heart sounds became weaker and weaker, and the cyanosis increased until death occurred.

Electrical examinations in Case 1:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.		
Feb. 13.....	0.3	2.9	1.2	3.1	Ch. 1 ³⁸	Trousseau +
Feb. 15.....	0.9	1.9	1.4	3.9	Ch. 1	Trousseau +
Feb. 16.....	0.5	1.2	0.9	1.5	Ch. 1	
Feb. 17.....	0.7	2.6	1.2	3.8	Ch. 3	
Feb. 18.....	1.5	2.9	1.5	3.0	Ch. 3	
Feb. 20.....	0.9	2.7	1.3	3.2	Ch. 3	
Feb. 24.....	0.9	1.9	1.0	2.8		
Feb. 28.....	0.9	3.2	1.2	2.7	Ch. 2	
Mar. 3.....	1.4	3.5	1.8	4.8	Ch. 2	

A diagnosis was made of tetany, status lymphaticus, rachitis. The necropsy report showed general lymphatic hyperplasia, slightly enlarged thymus, cardiac hypertrophy and dilatation and a beginning bronchopneumonia.

This was a typical case of tetany. Even during the periods of freedom from attack there could be no question concerning the electrical values. They were much lower than the lowest values found in nor-

37. The age is always that at the time of making the first electrical examination.

38. Abbreviation for Chvostek, Grade 1, etc., see Footnote 28.

mal children of this age, and there was cathodal and anodal hyper-irritability, as well as the presence of the Trousseau and Chvostek phenomena.

CASE 2.—L. D. J., girl, age 8 months, of normal birth, was breast fed. During the first days of the patient's life the mother noticed that the child twitched and shook in her crib, and breathed noisily and with difficulty. Convulsions became more frequent and severe after the sixth month, and when received the patient was having from five to eight daily. During attacks, the child "got stiff," "worked" in the crib, twitched, breathed with difficulty, became dark around the mouth and eyes, and the anterior fontanel bulged. Attacks were said to last a half hour, after which the child fell asleep. The child was well nourished. The Chvostek phenomenon was negative, and no signs of rickets were present. The diagnosis was epilepsy.

Electrical examinations in Case 2:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Mar. 26.....	3.2	4.4	3.7	>5.0
May 2.....	3.6	5.0	4.4	>5.0
June 25.....	4.0	>5.0	>5.0	>5.0

This case stands in sharp contrast to Case 1. It seems clearly a case of epilepsy. The values obtained, while below the average for this age, are not lower than those frequently found in apparently normal children. All clinical signs of tetany were absent.

CASE 3.—G. W., colored boy, aged 20 months, of normal birth, was breast fed for fourteen months, with table food in addition. Five or six weeks before admission to the hospital, the child was croupy and had attacks of spasms. Croupy cough reappeared a week before admission, accompanied by spasms in which the child lost his breath and grew stiff for two minutes. These attacks occurred from twelve to fifteen times daily, more commonly at night, and were accompanied by carpopedal spasm.

The child was well developed and moderately well nourished. There was enlargement of the costochondral junctions and of the epiphyses. The spleen was not palpable. On the second day after admission the child had three general and severe convulsions, with several minor convulsions following during the night. Dyspnea developed, and laryngeal examination showed the epiglottis and cords greatly swollen and edematous. The child became cyanotic, but an intubation tube could not be passed, and tracheotomy was performed, with immediate relief. After tracheotomy the patient's temperature rose and remained elevated. Death followed an attack of dyspnea and cyanosis on the eighth day.

Electrical examinations in Case 3:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	Ch. 2
March 19.....	0.9	2.1	2.0	3.5	

This case is one of severe tetany. The history is distinctive; the presence of a Chvostek phenomenon at this age almost always indicates tetany; and the electrical findings, especially C. O. C. < 5 ma., are conclusive.

CASE 4.—W. B., boy, white, aged 20 months, with past history not obtainable from the foster parents, five days before admission to the hospital was found "throwing himself about" and was cyanosed. He soon became stiff. The attack lasted in all about five minutes. Two similar attacks followed on succeeding days. They were preceded by a crowing sound, and always appeared when the

child was irritated. He seemed to bring them on by holding his breath. His thumbs were turned into his palms much of the time. He was a stout child with a short, thick neck. The superficial lymph glands were somewhat enlarged, and the tonsils were large. The spleen was palpable. The morning after admission, the child suddenly became cyanotic and dyspneic. This attack passed off, but a convulsion followed shortly with dyspnea, cyanosis and death, artificial respiration being unavailing.

Electrical examinations in Case 4:

C. C. C.	A. C. C.	A. O. C.	C. O. C.	Ch. 3
1.4	2.4	1.6	2.9	

The clinical diagnosis was tetany and status lymphaticus, with an anatomical diagnosis of status thymicolymphaticus, lymphoid hyperplasia, beginning rickets.

CASE 5.—A. L. S., girl, white, aged 7 years, breast fed until 9 months old, said to have had whooping cough at 4 years, moderately severe attack of measles six months before admission, and three attacks of tonsillitis in past, had always been well otherwise and had never had convulsions.

Following tonsillectomy under ether at 10 a. m., on September 26, the child complained of severe cramps in the feet and legs at 4 a. m., September 27. At this time her hands and feet were in the characteristic tetany position. Trousseau and Chvostek phenomena were present. As the result of sedatives and a hot bath, the child slept the greater part of the day, and in the late afternoon the cramps in the hands and feet had passed away, though the Trousseau and Chvostek phenomena remained present. Recovery was uncomplicated. There was no sign of rachitis.

Electrical examination in Case 5:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	Ch. 3
September 27, p. m.	0.8	2.6	1.8	3.3	

Remarks: This child had been under the observation of Dr. Howland for six years. At no time previous to the above attack had she had any symptom suggestive of tetany. The attack came entirely unexpectedly, following a surgical operation. The child was seen in the following spring. At this time her reactions were as follows:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	Ch. 2
March 21.	1.3	2.8	2.3	> 5.0	

She had no symptoms of tetany in the interim, and had been otherwise well.

The above case is an excellent example of clinical tetany following surgical manipulation of the neck in a 7-year-old girl. Its occurrence calls to mind all the theories of the Vienna school regarding the parathyroids and the supposed etiologic importance of disturbances of the blood supply due to prolonged assumption of unusual postures. The electrical values obtained, while typical of tetany at a younger age, were not lower than are found in some normal children of 7 years. Occurring in combination with undoubted clinical evidence of tetany, they scarcely admit of other interpretation.

CASE 6.—B. D., girl, colored, aged 2½ years, of normal birth, was breast fed for nine months, bottle fed for two months, then given table diet. After a normal infancy the patient suddenly developed carpopedal spasm (May 10), and on the same day had a convulsion, falling down, becoming stiff, and frothing at the mouth. On the night before admission to the hospital, June 5,

contractures of the hands and feet were present for one and a half hours, reappearing the next morning.

The patient was a well-developed and moderately well-nourished child. Rickets was marked. There was a persistent carpedal spasm. A bloody nasal discharge, with thick, mucopurulent secretion in the posterior rhinopharynx, was present. Throat culture was negative for *Bacillus diphtheriae*. The contractures of the hands disappeared on the second day after admission, and those of the feet on the third day. The Chvostek phenomenon had disappeared by the thirteenth day.

When seen again in November, the Chvostek phenomenon was elicited with difficulty, and the electrical reactions were not abnormal, but approached the lower limits of normal values.

Electrical reactions in Case 6:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
June 5.....	0.4	2.0	0.6	> 5
June 5.....	0.3	4.0	1.8	> 5
June 5.....	0.4	3.0	1.8	> 5
Nov. 21.....	2.0	2.9	2.4	> 5
Dec. 3.....	1.8	5.0	2.3	> 5

This case of clinical tetany in an older child (2½ years) shows that C. O. C. < 5 ma. is not necessarily present during the height of manifest tetany, a fact noted by Ganghofner in 1904.

The following cases are included to show that electrical reactions identical with those in tetany may be met in cases of hydrocephalus and spastic paraplegia.

CASE 7.—H. L., boy, white, aged 10 months, of normal birth, was breast fed for one month, then given proprietary foods and condensed milk and later cow's milk dilutions with sugar. At the age of 3 weeks the child suffered from a general convulsion, followed by stupor lasting for several hours. There had been no further convulsions, but at times the child had become rigid.

He was admitted to the hospital, April 18, as a poorly developed, poorly nourished infant, irritable, and somewhat spastic. The cranium was relatively enlarged and asymmetrical and the face small. There was fine nystagmus and a mild degree of choked disk. The reflexes were increased. The child was unable to sit alone and there was a rachitic rosary. The von Pirquet and Wassermann reactions were negative. There was little change in condition for one week; then there was rapid gain in weight (2 pounds, 12 ounces), and he was discharged May 28. He was treated thereafter in the outpatient department and did well.

Electrical examinations in Case 7:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	C. C. Te.
April 25.....	0.9	3.2	1.9	....	4.0
May 22.....	3.1	> 5.0	4.1	> 5.0	
June	3.1	> 5.0	4.0	> 5.0	

In this case the Chvostek phenomenon was negative. A diagnosis of malnutrition and hydrocephalus was made. There was marked electrical excitability, without any other evidence of tetany, but with hydrocephalus.

Von Ranke³⁹ in 1894 noted the clinical resemblance to tetany⁴⁰ of early cases of hydrocephalus, with spasticity. The presence of cranial

39. Von Ranke: Zur Diagnose d. chronischen Hydrocephalus in dessen Anfangstadien bei noch nicht vorhandener Vergrosserung des Schädels, Wiener Naturforscher-Versammlung, Sept. 26, 1894, cited from Kalischer, Footnote 14.

40. See historical sketch, J. Cheyne, in early part of this paper.

enlargement, nystagmus and choked disk, and the absence of the usual clinical signs of tetany, are to be noted here.

CASE 8.—B. C., girl, white, aged 3½ years, of normal birth, was breast fed for nine months, then weaned, and carefully fed thereafter. Slight convulsive movements had occurred before the child was 9 months of age, then numerous convulsions, until the time of admission. There had gradually developed paralysis on the right side, and eventually on the left side, with progressive mental and physical deterioration and spasticity of the extremities, but with no adductor spasm. There was slight Chvostek phenomenon.

After admission to the hospital, December 29, there were numerous clonic convulsions, sometimes ushered in by a cry, and there was marked rigidity. Rickets was not present. The von Pirquet was negative, Wassermann positive in both blood and spinal fluid. The child improved somewhat, and then declined, under vigorous antisyphilitic treatment. She was discharged unimproved.

Electrical examinations in Case 8:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	C. C. Te.
Dec. 31 (right).....	1.9	1.9	2.0	> 5.0	
Dec. 31 (left).....	1.9	2.9	2.5	> 5.0	
Jan. 5.....	1.7	1.9	> 5.0	> 5.0	
Jan. 12.....	0.7	2.9	3.6	....	4.0 +
Jan. 21.....	3.1	> 5.0	> 5.0	> 5.0	
Jan. 24.....	2.0	4.0	> 5.0	> 5.0	
Jan. 29.....	1.9	2.9	1.0	> 5.0	
Feb. 9.....	2.2	3.0	> 5.0	> 5.0	
Feb. 18.....	1.5	1.9	1.7	....	4.0

This is an example of typical electrical reactions of tetany, appearing in a case of spastic paraplegia due to hereditary syphilis.

Anodal opening contractions appearing with a current less than that causing anodal closing contractions, and less than 5 ma., during the first six months of life are pathognomonic of tetany in almost all cases; their appearance with a current less than 2 ma. is probably pathognomonic of tetany up to the fourth or fifth year; thereafter their appearance alone is of little significance.

With anodal hyperexcitability we are undoubtedly dealing with a lower grade of excitability than with cathodal and with one which is rather indefinitely separated from the normal. This follows from the wide range of galvanic excitability found in normal children. The range of normal variation appears to become greater as children increase in age, and therefore the difficulty of determining abnormal degrees of excitability is increased in older children.

In practice the difficulty is not so great as it might seem. The majority of cases of clinical tetany present values that are evidently far below the normal (for example, Cases 1 and 4). Furthermore, the great majority of cases of true clinical tetany in childhood occur during infancy, the period when the difficulty of electrical diagnosis is slightest.

As a rule the electrical diagnosis of tetany can be readily made, provided the child be examined early enough and frequently enough. By

frequently enough is meant daily examination for a short period. Cases 9 to 12 serve to illustrate these points.

CASE 9.—A. M., boy, white, aged 5 months, of normal birth, was breast fed for two months and then given cow's milk and various infant foods. He was poorly nourished. There were no symptoms of tetany. He was admitted to the hospital September 27, and gained weight satisfactorily. He was treated in the outpatient department after December 5, and did well.

Electrical examinations in Case 9:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	C. C. Te.
Oct. 22.....	4.8	> 5.0	> 5.0	> 5.0	
Nov. 4.....	3.0	3.8	5.0	> 5.0	
Jan. 26.....	2.7	> 5.0	3.0	> 5.0	
Jan. 29.....	1.5	2.4	1.9	....	4.3
Feb. 10.....	0.7	3.0	1.9	....	4.0 +
Feb. 27.....	1.4	3.0	1.8	3.5	
Mar. 12.....	2.9	> 5.0	3.0	> 5.0	
April 6.....	4.5	> 5.0	> 5.0	> 5.0	
May 18.....	3.1	> 5.0	> 5.0	> 5.0	

The Chvostek phenomenon was doubtful, and there was no evidence of rickets found. The patient was an artificially fed infant in whom electrical hyperexcitability developed while under observation.

The case is to be regarded one of latent tetany in which recovery took place without developing symptoms of manifest, or clinical, tetany. The appearance of anodal hyperexcitability (January 26) in an infant of 7 months in whom this had not previously existed was the first evidence of the presence of heightened excitability of the nervous system. This was followed quickly (January 29) by cathodal hyperexcitability and the condition of increased excitability persisted for a month, and then disappeared without the development of any symptoms.

CASE 10.—R. B. A., boy, colored, aged 5 months, breast fed, with supplementary feedings later, was a healthy infant, well nourished, with no symptoms of tetany, but with beginning rickets.

Electrical examinations in Case 10:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Oct. 25.....	2.0	5.8	3.0	> 5.0
Nov. 6.....	2.0	3.8	2.7	> 5.0
Nov. 18.....	2.2	> 5.0	> 5.0	> 5.0
Dec. 3.....	2.2	> 5.0	2.4	> 5.0
Dec. 26 (right).....	2.0	4.5	2.8	> 5.0
Dec. 26 (left).....	2.1	4.3	3.0	> 5.0
Dec. 30 (right).....	1.0	3.1	1.2	4.7
Dec. 30 (left).....	1.2	2.5	1.4	4.8
Jan. 3.....	2.8	3.1	3.1	> 5.0
Jan. 12.....	2.7	4.0	2.9	> 5.0
Jan. 21.....	3.1	3.9	3.9	> 5.0
Jan. 30.....	2.7	> 5.0	3.5	> 5.0
Feb. 7.....	2.1	> 5.0	3.0	> 5.0
Mar. 26.....	1.7	2.4	2.4	> 5.0
May 15.....	1.7	3.0	3.0	> 5.0

The Chvostek phenomenon was positive after the eighth month. The diagnosis of latent tetany is justified by the presence of anodal and cathodal hyperexcitability and a Chvostek phenomenon of moderate grade in a child with rickets.

Children suspected of tetany should be examined a number of times. Variations in electrical excitability are common during the course of the disease. In the above case the evidence of increased excitability was discovered during a routine examination (October 25), persisted for a time, and then disappeared entirely (November 18), only to return in more marked degree during the succeeding weeks.

CASE 11.—D. B., girl, colored, aged 18 months, of noninstrumental birth, but infant blue and respiration established with great difficulty, was breast fed for nine months, then given condensed milk and cereal. On January 10 the mother noticed that the child could no longer stand up when placed on her feet and that the feet and legs were swollen. There was fever. These symptoms continued until admission to the hospital. The child cried out in pain at times and drew her feet up. The swelling of the feet increased and the hands became clenched. Convulsive attacks appeared with increasing frequency.

She was a well-nourished child, with distinct evidences of rickets. There was slight bowing of the tibiae and lateral retraction of the chest wall. A condition of situs inversus of the viscera existed, but there was no general glandular enlargement. The spleen was just palpable. The Chvostek phenomenon was very marked, the very slightest touch producing marked contraction of the facial muscles. Typical carpopedal spasm existed. The child was admitted to the hospital February 2. The condition improved slowly, with no convulsions and no carpopedal spasm after February 5. Trousseau's sign was present until February 14. Chvostek phenomenon was less active after this date, but still marked.

Electrical examinations in Case 11:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Feb. 2.....	1.2	3.0	1.8	7.5 (5.2)
Feb. 3.....	0.4	3.0	1.1	2.1
Feb. 5.....	0.8	2.2	1.6	4.0
Feb. 9.....	0.8	2.2	1.4	4.0
Feb. 13.....	1.5	2.0	2.0	3.0
Feb. 20.....	2.1	2.4	2.3	4.5
Feb. 18.....	1.8	3.0	3.5	5.0
Feb. 26.....	2.0	3.0	3.5	? (near 4.5)

The rapid appearance of cathodal opening values below 5 ma. is here interesting. It was preceded by marked symptoms and signs of tetany and by anodal hyperexcitability (February 2) which in this case was but little more marked than that found in a few apparently normal children (see Table 2). The appearance of cathodal hyperexcitability next day (February 3) was coincident with the cessation of convulsions.

CASE 12.—J. W., boy, colored, aged 11½ months, of full-term, noninstrumental birth, no cyanosis at birth, was breast fed for ten months, then given supplementary feedings of cow's milk. There was an indefinite history of convulsive attacks when the child was 9 days old, but otherwise he was apparently healthy. At four months he had whooping-cough with "nervous twitchings" of the hands. On the night of December 1 the child (then 11 months old) was feverish, restless and breathed very loudly, but there was no cough. Early next morning the child had a convulsion. In the afternoon the child had another convulsion, lasting three minutes.

He was a well-nourished child, temperature 102, throat slightly injected, with adenoids and a marked high-pitched inspiratory stridor. There were marked rachitic rosary and Harrison's grooves, and superficial glandular enlargement. The abdomen was slightly distended, spleen not palpable, reflexes difficult to obtain. No spasticity or paralysis was present. Chvostek and Trousseau phenomena were present.

Electrical examinations in Case 12:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	
Dec. 2 (right) ...	2.4	4.5	3.5	>5	Ch. +
Dec. 2 (left)	2.8	4.8	3.8	>5	
Dec. 3 (right) ...	3.5	>5	>5	>5	
Dec. 3 (left)	3.7	>5	4.7	>5	Ch. 0
Dec. 4 .....	...	...	...	...	Ch. +; Trousseau, suggestive
Dec. 5, 12 m.	3.4	>5	>5	>5	Ch. very faint
Dec. 5, 2 p. m....	2.4	>5	2.1	>5	
Dec. 7	2.0	3.5	2.2	>5	Ch. +; Trousseau +
Dec. 7 (later) ...	3.2	>5	3.1	>5	Ch. +

During the next four weeks there were no signs of tetany, with Chvostek doubtful:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Jan. 14	>5	>5	>5	>5

There was striking daily variation of signs during the course of the tetany.

The case is of importance in showing the undoubted occurrence of normal electrical values during the course of tetany in infancy. The period of apparently normal electrical values was preceded by one of low electrical values, and followed by yet lower values. The presence at various times of all the other characteristic signs of tetany established the diagnosis. A single examination in this case, for instance, on December 3, might have led to an entirely erroneous diagnosis if the electrical examinations alone had been considered.

Tetany in Older Children.—By the term "older children" is here meant children of more than 3, and, more especially, of more than 5 years of age. In them the electrical diagnosis of tetany becomes difficult. The electrical standards of infancy certainly do not apply to older children. Formulas that in the infant would indicate the presence of tetany are common in healthy and apparently normal older children. Anodal hyperexcitability in its strictest definition becomes a frequent occurrence about the third year (40 per cent. in our series—see Table 1), and after the fifth year becomes the prevailing condition (67 per cent., in the fifth year, and 75 per cent. in the sixth year). Some children preserve the infantile formula as late as puberty, and physiologists differ as to which condition prevails in adult life. The occurrence of cathodal hyperexcitability (Thiemich's phenomenon) is not unusual in normal children over 5 years of age. The Chvostek phenomenon occurs frequently and in its lower grades (see Footnote 28) appears to be generally without significance.

The standards that have proved useful in infancy become less serviceable with increasing age. In children over 5 years of age it is necessary in making a diagnosis of tetany to adhere more closely to the criteria generally accepted for the diagnosis of tetany in adults.⁴¹

The electrical diagnosis of tetany, or even latent tetany, in older children by the standards of infancy rests on the most insecure foundation. Cases 13 and 14 will serve to illustrate the correctness of these statements.

CASE 13.—E. McK., boy, white, aged 8 years, of instrumental birth, was reared on diet poorly chosen, but not unusual. There were no symptoms of tetany. There was complaint of the presence of tapeworm. The child had never had convulsions, but there was a history of pertussis (1909), chicken-pox (1911), measles (1913), of an operation for abscess of neck (1910), and of otitis following measles. The present trouble began in 1911, and the child was treated with anthelmintics on two or more occasions. He was admitted to the hospital for three days, November 10. After treatment the patient passed seven feet of *Taenia saginata* segments. The Wassermann test, which was made because of suggestive family history and enlarged spleen and epitrochlear glands, was markedly positive. Antisyphilitic treatment was begun, and the child did well. He was readmitted to the hospital on January 28 because of the appearance of segments in the stools, and after treatment he passed six feet of worm.

Electrical examinations in Case 13:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
Nov. 10.....	0.3	1.4	1.2	2.4
Nov. 13.....	1.0	2.2	1.9	4.2
Jan. 28.....	0.25	2.1	1.9	4.8

The Chvostek phenomenon was not present at any time and no evidence of rickets was found.

This case is mentioned because of the extremely low electrical values found during the course of a routine examination. The patient was without suggestive history or symptoms. The reason for the occurrence of such low values in this child is not known. He was excluded from the series of normal reactions.

CASE 14.—A. R., girl, white, aged 9 years, with a mentally deficient Jewess as a mother, with a noninstrumental, but prolonged and difficult birth, was breast fed for eighteen months. The child is said to have suffered from "spasms" (abdominal cramps?) until 1 year old, but to have had none thereafter. She was brought to the outpatient department for treatment because of hyperesthesia and fleeting body pains that were occasionally sharp. She was poorly nourished and habitually constipated. The treatment from November 6 to February 14 consisted of tonics, better hygiene, half-time schooling, and correction of an error of refraction. The child improved steadily in appearance and her complaints became fewer, though there were occasional bad days.

On February 14 she was admitted to the hospital for closer observation, with complaint of pain in the right axilla, over the thorax, and around the heart. Examination showed normal temperature and pulse, carious teeth, palpable left thyroid lobe and exaggerated reflexes. The von Pirquet test was positive. The patient was discharged after five days, nothing further of importance having been found.

41. See standard texts, such as Oppenheim's Lehrbuch.

Electrical examinations in Case 14:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.	C. C. Te.
Nov. 6.....	<0.3	1.8	1.7	4.5	5.2
Nov. 8.....	0.6	2.1	1.5	3.2	3.5—4.5
Nov. 15.....	0.8	4.4	2.0	>5.0	
Nov. 20.....	0.9	3.0	1.9	4.4	
Dec. 2.....	1.1	4.2	2.0	>5.0	
Jan. 17.....	0.7	2.7	1.6	5.0—>5.0	
Feb. 18.....	1.0	2.9	2.1	4.7	

The Chvostek phenomenon was present, but not marked. Rachitis was not present. The diagnosis was neuropathic constitution.

It is not easy properly to classify this case. Many authors have enumerated such complaints as those described as symptoms of latent tetany, or, more commonly, of the so-called spasmophilic diathesis. At first glance it might be thought that electrical findings like the foregoing support such a hypothesis, but closer examination renders this at least doubtful. The electrical values found in this patient are low, but they are not lower than those found in many children of her age (see Tables 1 and 2—seventy children between 8 and 11 years of age). The Chvostek phenomenon, also, occurs not infrequently in children of this age (25 per cent.; see Table 1). Vague complaints like those enumerated are not uncommon among children of the patient's race and generally disappear with improved environment. They are probably not due to latent tetany.

Escherich's views regarding the electrical findings in puerile tetany may here be mentioned. He defined puerile tetany as tetany occurring in children over 3 years of age. His views may be summarized as follows:

The recognition of latent symptoms is determinative, their value with certain limitations, being the same as in infantile tetany. Presence of the Chvostek phenomenon, if in high grade (Grade 3), is probably pathognomonic, and the Trousseau phenomenon is unqualifiedly pathognomonic, if hysteria is excluded. Studies in the electrical values are lacking (1906) for this age, and the normal values have not been ascertained. It may be assumed, however, that the high values of infancy gradually approach the Stintzing values for adult life; and that the C. C. C. lies within from 1 to 1.5 ma., while the other values are higher. That outspoken electrical hyperexcitability will express itself in the C. C. C. sinking to 1 or less than 1 ma., the appearance of opening contractions under 5 ma., and the early appearance of tetanus, especially C. C. Te.

Some doubt was expressed whether the electrical signs alone will suffice for the diagnosis at this age of tetany and tetanoid conditions. Actual observations in cases of puerile tetany, as cited by him are as follows:

	C. C. C.	A. C. C.	A. O. C.	C. O. C.
At 7 years.....	0.4	0.8	0.6	0.8
	0.8	2.8	2.8	2.4
	0.1	1.4	1.4	<5
	1.0	2.0	1.0	<5
At 13 years.....	0.5	3.0	1.0	3.0

Also at 10 years C. C. Te. at 2.0 ma., and at 7 years A. O. Te. at 4 ma.

It is not felt that a diagnosis of tetany or latent tetany is warranted in either of the last two cases.

CONCLUSIONS TO CLINICAL PART

1. The appearance of cathodal opening contractions under 5 ma. (and in the absence of certain conditions already mentioned) in children under 5 years of age is pathognomonic of tetany. Cathodal opening contractions are, however, not infrequently absent in cases of clinical tetany.

2. The appearance of anodal opening contractions with less current than that causing anodal closing contractions, and under 5 ma. during the first 6 months of life is probably pathognomonic of tetany in all cases; their appearance with less current than that causing anodal closing contractions and under 2 ma. is probably pathognomonic up to the fourth or fifth year; thereafter it is of little significance.

3. The appearance of a Chvostek phenomenon under 2 years, in the absence of birth trauma, indicates tetany; under 4 or 5 years of age it is highly suggestive of tetany; its appearance in the highest grade (Grade 3, Escherich) is suggestive throughout childhood. After 3 years the Chvostek phenomenon is not infrequently found in milder grades in apparently normal children.

4. The occurrence of any one of these symptoms in association with a clinical history of tetany is to be considered conclusive evidence of tetany.

5. The determination of the electrical values is an extremely useful, but not always an infallible, means of diagnosing active or latent tetany in childhood. It is most useful in infancy. Like other clinical tests, this one has definite limitations that must be recognized.