A STUDY OF THE BLOOD IN PERTUSSIS *

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The number of investigations into the state of the blood in pertussis is comparatively small, but there exists a striking uniformity in the results obtained, though accuracy in a review of such investigations is, unfortunately, in some details difficult, because of the varying classifications of the leucocytes which have been adopted.

While the blood changes in pertussis are interesting in themselves, the diagnostic value of the interpretation placed on these changes by the various authors lends additional interest to this study.

With few exceptions, a leucocytosis and lymphocytosis have been noted early in the disease, and diagnostic value has been attributed to their presence. Recently more careful study has well-nigh established a definite series of blood changes in this disease and has demonstrated the value of a blood examination in the early diagnosis of pertussis.

The following is merely a brief review, the literature having been quite well covered recently by Barach.¹

In 1897 Fröhlich,² the first to call attention to the blood changes in whooping cough, found a leucocytosis in 55 cases and a lymphocytosis in the fifteen differential counts made. The next year Meunier³ found a leucocytosis in 30 cases, and, from ten differential counts, concluded that all forms of leucocytes were affected in this disease except the eosinophiles. De Amici and Pacchioni⁴ in a study of 18 cases, Stengel and White⁵ of 3, Muggia and Bertolotti⁶ of 25, Grulee and Phemister⁷

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1. Barach, J. H.: Morphology of the blood in pertussis. *THE ARCHIVES INT. MED.*, 1908, i, 602-604.

2. Fröhlich: Beitrag zur Pathologie des Keuchhustens. *Jahrb. f. Kinderh.*, 1897, xliv, 53.

3. Meunier, H.: De la leucocytose dans la coqueluche. *Compt. rend. Soc. de biol.*, 1898, 103-105.

4. De Amici, G., and Pacchioni, D.: Sulla leucocitosi nella pertosse. *Clin. Med.*, 1898, xxxviii, 51-61. La leucocytose dans la coqueluche. *Rev. mens. d. mal. de l'enf.*, 1900, xviii, 58. (Abstr.) Ueber leucocytose beim Keuchhusten. *Arch. f. Kinderh.*, 1902, xxxiv, 305-306.

5. Stengel, A., and White, C. Y.: Blood in infancy and childhood. *Univ. Penn. Med. Bull.*, 1902, xiv, 310-325.

6. Muggia (A.) et Bertolotti (M.): Ozonoterapie e reperti ematologici nei bambini affetti da pertosse. *Pediatrics*, Napoli, 1904, Series 2, ii, 875-889.

7. Grulee, C. G., and Phemister, D. B.: The leucocytes in whooping cough. *Arch. Pediat.*, N. Y., 1905, xxii, 595-599.

of 15, Churchill⁸ of 28, Barach¹ of 30 cases, and Crombie¹⁵ in an analysis of 112 cases, all found a leucocytosis and lymphocytosis, beginning in the catarrhal stage, increasing in severity with the paroxysmal and then decreasing until the normal was reached.

Mosenthal⁹ found the leucocytes approximately double the normal in the catarrhal stage, with less marked changes in the convulsive period. Cabot¹⁰ reported two cases of pertussis-pneumonia which, from the high leucocytosis and lymphocytosis, led him to believe the cases atypical pertussis. Steven¹¹ reports a similar case.

Cima¹² found a higher leucocytosis in pertussis than in other infectious diseases. On the other hand, Carriere¹³ found a higher leucocytosis in bronchitis, and Wanstall¹⁴ found an absence of leucocytosis in 5 cases in the catarrhal stage of pertussis, but, in 11 out of 14 cases, demonstrated the presence of a lymphocytosis.

During the latter part of the summer and early autumn of 1908, I had the opportunity of studying 27 cases in St. Vincent's Home and Maternity Hospital from the beginning to the end, having full control of my patients. Two cases were fortunately, though by accident, examined in the precatarrhal stage. It was soon evident that there occurred an appreciable change in the blood formula early in the disease. But, in order that these changes may be considered as possessing diagnostic value, it was necessary to determine a more or less normal standard for institutional children where hygienic conditions generally are not so good as in private homes and where the children are more likely to be poorly developed and anemic. Accordingly the object of my study was:

1. To determine what may be considered as a working standard for the total number of leucocytes and the various proportions of the leucocytic elements in the blood of institutional children of various ages.

8. Churchill, F. S.: Diagnostic value of the leucocyte formula in pertussis. *Jour. Am. Med. Assn.*, 1906, xlv, 1506.

9. Mosenthal, H. O.: Leucocyte count of normal "institutional" children and those suffering with pertussis. *Arch. Pediat.*, xxv, 1908, 831.

10. Cabot, R. C.: *Clinical Examination of the Blood*; ed. 5, New York, Wood, 1904, p. 220.

11. Steven, A.: Bronchopneumonia. *Lancet*, London, xx, 791.

12. Cima, F.: *La Pediatria*, 1899, vii, 261.

13. Carriere, G.: Le sang dans la coqueluche et dans l'adénopathie trachéo-bronchique. *Gaz. hebdom. de méd. et de chir.*, 1902, xlix, 127.

14. Wanstall, A.: Pertussis with special reference to its early diagnosis, from the blood findings. *Am. Med.*, 1903, v, 62-65.

2. To ascertain if it were possible to diagnose whooping-cough, with some degree of certainty, early in its course and in atypical cases by a study of the blood.

3. To study the blood in conditions resembling the catarrhal stage of whooping-cough to ascertain if the blood changes peculiar to this infection occur in them also. The opportunities in this direction were limited mainly to bronchitis and laryngitis.

4. To study the blood in cases of pertussis modified by complications. The opportunities in this direction comprised two cases of pneumonia and two cases of convulsions, and one case, each, of impetigo contagiosa, ecthyma and Vincent's angina.

It is plain that if we could by some means diagnose whooping-cough early in the catarrhal stage, which is generally impossible by the symptoms alone, it would be of great advantage especially from the standpoint of prophylaxis. It is most desirable to isolate children suffering with pertussis as early as possible, for without doubt the disease is very infectious during the catarrhal stage¹⁵ and scarcely less so during the paroxysmal stage. The importance of early diagnosis and isolation is emphasized in institutions for children where the inmates are more or less closely associated and the spread of the infection correspondingly facilitated. Again, many cases pursue an atypical course in which there is either no whooping or else a paroxysmal stage of short duration. Such cases were found to occur most frequently in infants. When we remember how disastrous pertussis is among the young and how helpless we are in ameliorating the symptoms and preventing fatal complications, it behooves us to avail ourselves of every means whereby the disease may be early diagnosed and its victims promptly isolated.

Due care was exercised in avoiding digestive leucocytosis, which especially affects the lymphocytes. Wright's stain was used throughout, being very simple and quite satisfactory. In most instances two leucocyte counts were made and two smears examined in each case at every examination.

CONTROL CASES

Early in this work I was impressed with the fact that a hazy idea of what constituted the normal blood picture in children, especially children of the type we were examining, would not suffice if one was to attempt making an early diagnosis of whooping-cough by an examination of the blood. It was necessary to know with some definiteness what constituted normal limits and what to regard as pathologic. I knew in a general way that the blood of institutional children and those

raised amid poor surroundings, as in the slums of a large city, differs from the blood of children reared in our better private homes. Such common affections as rickets, chronic glandular enlargements, intestinal disorders and congenital syphilis tend to upset the leucocytic formula, mainly affecting those cells with which we are most interested, the lymphocytes. As a general rule most institutional children suffer with rickets of varying degree of severity, many have variously sized glandular enlargements and intestinal disorders are very common, especially in artificially fed infants. With all these things to be remembered one would naturally think that blood examinations were not worth while. I believe their importance, however, with the exception of age, is a little exaggerated. This appears, at any rate, to be true of the following cases which were selected more or less at random from the children of St. Vincent's Home and belong to the usual institutional type. We believe that the results of these blood examinations would apply also to children as met in the ordinary dispensary practice.

TABLE I.—BLOOD EXAMINATION OF NORMAL INSTITUTIONAL CHILDREN; AGE, 3 TO 12 MONTHS

No.	Age, Mos.	Leucocytes.	Lymphocytes.		Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
			Small.	Large.				
1	3	7,800	44	15	3.57	36.42	1.07	.0
2	3	9,360	47.5	14.1	3.2	32.6	2.5	.1
3	6	8,800	54.88	11.2	3.12	26.4	4.4	.0
4	6	16,880	48.86	6.81	1.59	41.14	1.59	.0
5	6	10,240	26.81	24.09	3.63	43.25	2.22	.0
6	6	9,680	59.62	13.33	0.74	25.57	0.74	.0
7	6	10,640	44.52	9.65	0.34	42.07	3.1	.34
8	7	12,000	27.39	14.21	1.35	53.55	3.57	.0
9	12	12,000	42.31	16.61	1.23	38.01	1.23	.0
10	12	12,000	58.82	10.29	1.47	28.24	0.88	.29
Av'ge.	5½	10,900	45.47	13.53	2.02	36.78	2.13	.07

TABLE II.—BLOOD EXAMINATION OF NORMAL INSTITUTIONAL CHILDREN; AGE, 1 TO 2 YEARS

No.	Age, Yrs.	Leucocytes.	Lymphocytes.		Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
			Small.	Large.				
1	1½	10,160	37	11	2	48.33	1.66	.0
2	1¼	8,720	22.22	22.96	1.11	51.85	1.85	.0
3	1½	10,900	31.83	13.03	1.81	51.51	1.51	.3
4	2	14,000	48	11	.5	39.5	2	.0
5	1½	11,200	48.33	16.66	.66	34.01	.66	.0
6	1	12,000	58	10.85	1.42	28.72	1	.0
7	2	9,800	48.12	15.79	3.15	30.52	2.1	.32
8	2	12,000	54	9.75	1.25	43.5	1.5	.0
9	2	17,000	40.66	11.66	2.33	45	.34	.0
10	1½	10,500	27.42	15.92	1.11	53.7	1.85	.0
Av'ge	1½	11,600	41.55	13.86	1.53	42.66	1.45	.03

TABLE III.—BLOOD EXAMINATION OF NORMAL INSTITUTIONAL CHILDREN; AGE, 2 TO 3 YEARS

No.	Age, Yrs.	Leucocytes.	Lymphocytes. Small.	Lymphocytes. Large.	Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
1	3	11,880	42.22	8.88	.83	45.56	2.5	.0
2	2	14,000	27.1	7.54	.52	63	1.84	.0
3	2½	12,160	38.41	12.38	1.58	48.81	3.17	.63
4	3	16,000	27	10.25	1	59.5	2	.25
5	2	10,880	44.37	12.91	1.45	34.54	2.29	.02
6	3	16,100	29.19	7.14	.4	61.63	1.63	.0
7	1½	12,500	32.89	11.31	1.31	52.13	2.1	.26
8	3	14,320	40.9	7.57	.6	48.78	2.14	.0
9	1¾	11,900	38.15	9.47	1.84	49.45	1.05	.03
10	2	12,100	35.4	15.6	.8	47.4	.8	.0
11	2	10,600	27.93	7.58	1.72	57.24	5.52	.0
12	2	11,200	36.03	11.85	1.11	50.26	.74	.0
13	1¾	11,750	25	9.54	1.81	61.81	3.18	.0
14	3	12,100	40.33	7	.66	50	2	.0
15	1¾	11,500	45.55	22.58	1.48	28.53	1.48	.37
16	3	12,200	37.02	8.37	.54	52.72	.54	.81
17	3	11,800	35.76	10	1.15	49.63	3.45	.0
18	2	11,600	33.33	10.6	.6	53.34	2.12	.0
19	2½	11,400	35.92	8.63	1.36	48.18	5.9	.0
20	2½	12,300	36.01	10	1.33	50	2.66	.0
21	2½	11,400	35.55	21.11	1.11	41.48	.74	.0
22	3	10,900	31.31	10.87	.71	55.87	1.42	.0
23	2½	14,200	39.59	16.32	.83	40.81	2.44	.0
24	1¾	11,600	47	12.08	.41	40	.41	.0
25	1¾	11,900	27.27	9.09	1.21	58.8	3.03	.6
Av'ge	2¼	12,300	35.57	10.73	1.15	49.93	2.3	.01

TABLE IV.—BLOOD EXAMINATION OF NORMAL INSTITUTIONAL CHILDREN; AGE, 3½ TO 5 YEARS

No.	Age, Yrs.	Leucocytes.	Lymphocytes. Small.	Lymphocytes. Large.	Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
1	3½	14,080	18.93	12.8	.53	62.68	4.53	.53
2	3½	10,500	27.41	11.63	.64	58.06	2.26	.0
3	3	10,400	23.01	9.81	.75	63.04	2.64	.75
4	3	9,500	27.77	13.33	.55	55.55	2.24	.55
5	4	12,800	30.86	8.69	.43	56.10	3.91	.0
6	4	16,400	12.22	9.63	.74	75.52	1.85	.04
7	4	6,400	35.43	6.31	.68	56.14	1.4	.03
8	4	9,760	39.66	6.66	.66	51	2.02	.0
9	4	11,500	36.08	7.8	.73	52.44	2.92	.02
10	4	9,600	25.72	7.5	1.07	62.5	3.21	.0
11	4	10,200	25.66	6.66	.33	65	3	.33
12	4	9,760	16.66	7.71	1.11	72.3	2.22	.0
13	4	11,800	23.45	10	1.17	64.20	1.18	.0
14	4	11,000	27.54	13.89	.61	55.93	2.03	.0
15	4	10,800	28.5	8.6	.5	58.2	4.1	.0
16	4	10,500	31.31	9.33	1.33	52.33	5.66	.33
17	4	9,900	25	7.85	.71	62.28	3.57	.58
18	5	10,560	28.34	4.33	1	65	1.33	.0
19	5	9,520	30.21	5.71	.35	61.22	2.5	.0
20	5	11,400	38.57	12	1.13	45.91	2	.28
21	5	11,120	25.28	5.66	.66	67.03	1	.0
22	5	11,400	38.5	5.65	.80	51.33	3.71	.0
23	5	10,100	24.52	10.64	.32	61.61	2.9	.0
24	5	9,900	29.35	12.9	.64	54.85	2.25	.0
25	5	12,250	30.67	11.46	.73	54.14	2.92	.48
Av'ge	4¼	10,846	27.62	9.06	.72	59.37	2.73	.15

TABLE V.—SUMMARY OF BLOOD EXAMINATION IN CONTROL CASES

Age, Yrs.	Leucocytes.	Lymphocytes. Small.	Lymphocytes. Large.	Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
3-12 mos.	10,900	45.57	13.53	2.02	36.78	2.13	.07
1-2 yrs.	11,600	41.55	13.86	1.53	42.66	1.45	.03
2-3 yrs.	12,300	35.57	10.74	1.15	49.94	2.3	.01
3½-5 yrs.	10,800	27.62	9.06	.72	59.37	2.73	.15

One must examine the tables and not the averages to appreciate the range of variability in the percentages of the various leucocytic elements. Tentative examination will show the following points:

1. The number of leucocytes does not change materially with age up to five years. One is apt to find a lower count in an artificially fed infant than he would in a healthy breast-fed infant of the same age. No. 4, Table 1, was from a well-nourished breast-fed baby. I myself do not consider any such young children to have a leucocytosis unless the count is over 12,000 leucocytes per cubic millimeter.

2. The percentage of lymphocytes, both the small and large varieties, decrease as age advances. In well-marked cases of rickets a large percentage of large lymphocytes were found. Comparison with the blood of healthy private home children shows, as a general rule, a lower percentage of lymphocytes than is found in the blood of less fortunate children.

3. A fair percentage of basophiles or "mast" cells were found. Ewing has stated that these cells are generally absent in the blood of healthy children.

No blasts were encountered; a few phlogocytes or irritation forms of lymphocytes were seen, as were also many bilobate and "basket" cells.

While it is well to remember the range of variability in the percentages of the different leucocytes even at the same age, one must adopt a more or less arbitrary working standard. The percentage of lymphocytes is of most interest in relation to pertussis. The percentages used in this work are those given in the summary of the control cases.

PERTUSSIS CASES

The aim was to have cases of coughing reported at once and a blood examination made. Consequently most patients were examined quite early in the catarrhal stage. In a few instances the lymphocytosis was slight and a provisional diagnosis made. In the majority of cases there was an early and well-marked leucocytosis mainly affecting the small lymphocytes. At first there is an absolute increase in all the leucocytic elements. Soon the percentage of lymphocytes become higher and higher as the disease progresses. This early lymphocytosis is of most importance and, I believe, possesses a distinct diagnostic value many days before the true nature of the infection has asserted itself. The changes in the blood formula, while in most instances appreciable, were not so great but that a careful examination and due consideration of age and other modifying influences were necessary. Two patients were fortunately examined in the precatarrhal stage. Patient 8 was examined

for a slight cough, which cleared up entirely shortly afterward. About ten days later he recommenced coughing and an examination justified a diagnosis. In about eleven days he began to whoop. Patient 12 was examined to ascertain the presence of an eosinophilia in a suspected lumbricoides and oxyurides infection. This accounts for the large percentage of eosinophiles in this case.

All patients, except one, were examined in the catarrhal stage. Another examination was made during the height of the paroxysmal stage. A third count was made in the period of marked improvement when the children were coughing hard, but not whooping. A final examination was made on the average of about two months from the time of the paroxysmal stage.

TABLE VI.—BLOOD EXAMINATION OF PERTUSSIS PATIENTS IN PRECATARRHAL STAGE

No.	Name of Patient.	Age, Yrs.	Leucocytes.	Lymphocytes.		Transi- tionals.	Poly- morpho- nuclears.	Eosino- philes.	Mast Cells
				Small.	Large.				
8	John L.	4	14,000	45.24	6.76	2.7	41.24	3.9	.15
12	Jennie McB. ..	5	15,600	42.78	3.71	.75	37.9	14.72	.13
Average			14,800	44.91	5.23	1.72	39.57	9.31	.14

TABLE VII.—BLOOD EXAMINATION OF PERTUSSIS PATIENTS IN CATARRHAL STAGE

No.	Name of Patient.	Age, Yrs.	Leuco- cytes.	Lymphocytes.		Transi- tionals.	Poly- morpho- nuclears.	Eosino- philes.	Mast Cells
				Small.	Large.				
1	Annie Q.	1½	16,000	52.9	18.62	3.91	20.62	3.9	.05
2	Lewis M.	Not taken							
3	Leo W.	4½	15,000	35.29	11.76	1.96	47.05	3.92	.02
4	Martin F.	2	14,000	46.11	16.43	2.02	31.5	3.5	.43
5	Katie D.	3	14,500	49.04	10.46	1.56	36.13	2.03	.89
5	(7 days later) ..		16,000	63.98	3.62	3.88	35.13	2.59	.8
6	Etta D.	3		48.97	10.46	1.56	36.13	2.03	.89
7	Francis S.	1	13,000	46.76	5.88	2.94	42.45	1.47	.49
8	John L.	4	16,000	54.6	10.9	1.04	29.97	3.4	.08
9	Sophie R.	2½	28,000	61.39	3.62	.51	31.09	2.33	1.03
10	Margaret	2	19,000	57.51	9.56	2.87	27.65	1.43	.89
11	Eliz. M.	1½	17,500	48.75	10.61	3.4	33.71	2.47	1.05
12	Jennie McB. ..	5		54.22	6.36	1.81	28.4	9.09	.03
13	Francis	1½	15,000	46.07	6.	1.27	43.7	2.	.9
14	Walter	2	16,900	48.94	9.71	3.41	34.8	2.63	.5
15	Tossie	2	12,500	46.93	5.75	2.12	38.52	5.45	.21
16	Eliz. B.	2	Not taken.						
17	Katie P.	2¼	13,500	47.81	6.87	2.47	35.	7.81	.04
18	Alice.	1	Not taken.						
19	Leo B.	2	14,900	47.94	6.78	1.48	37.51	5.41	.87
20	Charles L.	2	21,520	44.4	8.7	1.	39.3	6.2	.3
20	(3 da. later) ..		22,600	49.14	10.71	2.67	32.14	4.46	.89
21	Edith	3½	16,000	52.42	9.65	.69	35.17	2.07	.0
22	Cath. H.	2	17,800	34.7	10.3	.69	51.	3.3	.0
23	Ikey	5/6	18,000	51.62	14.32	2.43	29.73	1.62	.27
24	Francis D.	1¼	14,500	48.17	15.44	1.97	33.8	.28	.28
25	Francis H.	4	15,200	44.64	13.39	1.96	36.6	2.7	.71
26	John M.	3	19,000	47.69	10.79	1.28	37.69	1.79	.76
27	Jno. McC.	5/12	Not taken.	Out	patient	department.			
Average			16,800	49.19	9.83	2.03	34.98	3.35	.53

TABLE VIII.—BLOOD EXAMINATION OF PERTUSSIS PATIENTS IN PAROXYSMAL STAGE

No.	Age.	Leuco- cytes.	Lymphocytes.		Transi- tionals.	Poly- morpho- nuclears.	Eosino- philes.	Mast Cells
			Small.	Large.				
1	1½ yrs.	25,000	63.4	6.4	1.4	27.4	.8	.6*
1	(2 da. later)	26,240	80.35	3.57	1.56	11.17	2.9	.37
2	1 yr.	24,900	61.07	9.01	2.34	24.07	2.39	1.21**
3	4½ yrs.		70.41	9.31	1.48	14.53	3.4	.86
4	2 yrs.	29,000	63.9	10.16	2.47	21.13	1.46	.87
5	3 yrs.	16,000	63.98	3.62	3.88	25.13	2.59	.8
6	3 yrs.	17,000	62.5	8.34	3.05	22.83	2.94	.33
7	1 yr.	22,000	60.38	14.08	1.81	21.76	1.07	1.†
8	4 yrs.	23,000	71.84	9.77	2.29	11.49	3.45	1.15
9	2½ yrs.		69.41	5.3	3.4	18.5	2.36	1.02
10	(Taken home.)							
11	1½ yrs.	21,000	60.	6.06	2.43	29.4	2.03	.06
11	(4 da. later)	20,000	65.6	8.	1.5	20.4	3.5	1.
12	5 yrs.	19,000	58.5	8.3	.6	29.	3.5	..
13	1½ yrs.	25,000	66.07	6.	1.27	23.7	2.	.9
14	2 yrs.	23,000	65.09	6.95	1.52	24.35	1.52	.65
15	2 yrs.	21,600	59.31	7.51	3.01	27.61	2.46	.09
16	2 yrs.	24,700	62.89	8.62	1.47	23.48	3.46	.08
17	2¼ yrs.	23,700	67.41	5.71	1.02	23.	2.38	.46
18	1 yr.		65.41	6.41	1.78	24.01	2.38	.19
19	2 yrs.	26,500	71.04	5.89	2.63	17.53	1.89	1.01
20	2 yrs.	28,900	59.56	5.31	1.46	32.25	2.31	.09
21	3½ yrs.	11,000	52.4	10.	.8	34.	2.4	.4
22	2 yrs.	24,500	69.33	8.27	1.03	19.65	1.72	.0
23	10 mos.	28,500	75.47	9.54	.68	12.5	1.81	.0
24	1¼ yrs.	14,400	54.46	12.22	1.66	28.33	3.33	.0
25	4 yrs.	22,000	47.15	9.77	.88	40.88	.44	.88
26	3 years.	14,000	45.34	10.22	1.33	38.22	4.	.88
27	5 mos.	19,200	57.14	15.23	.95	24.36	2.38	.0
Average		22,000	63.19	8.19	1.77	23.92	2.35	.53

* Died of bronchopneumonia.

** Convulsions; death.

† Died of lobar pneumonia.

TABLE IX.—BLOOD EXAMINATION OF PERTUSSIS PATIENTS IN STAGE OF MARKED IMPROVEMENT

No.	Age.	Leuco- cytes.	Lymphocytes.		Transi- tionals.	Poly- morpho- nuclears.	Eosino- philes.	Mast Cells
			Small.	Large.				
3	4½ yrs.	13,000	39.53	4.65	1.05	49.12	3.5	.2
3	(1 wk. later)	13,760	33.18	18.18	1.36	44.09	2.26	.9
4	2 yrs.	19,800	36.	8.	2.1	47.	5.6	1.2
4	(1 wk. later)	13,920	33.75	6.66	.83	51.	6.35	.41
5	Taken home.							
6	3 yrs.	12,000	41.59	4.56	1.05	49.12	3.5	.2
6	(1 wk. later)	13,900	40.58	14.7	2.05	40.88	.88	.88
8	4 yrs.	13,500	50.6	4.24	1.51	42.12	1.21	.3
8	(1 wk. later)	20,320	25.2	12.	.8	59.2	2.4	.4
9	2½ yrs.	23,500	46.01	6.51	1.88	38.76	5.98	1.35
9	(1 wk. later)	15,100	32.07	13.2	2.61	48.69	2.64	.75
11	Taken home.							
12	5 yrs.	14,900	43.94	9.21	.52	42.1	3.42	.78
13	1½ yrs.	35,600	32.51	12.82	1.02	51.28	1.79	.51
14	2 yrs.	21,120	41.43	11.91	2.28	39.05	5.24	.09
15	2 yrs.	19,520	36.22	7.97	.32	52.9	2.26	.32
16	Taken home.							
17	2¼ yrs.	17,500	45.55	3.33	.55	42.33	7.07	1.11
17	(1 wk. later)	15,680	37.02	13.61	2.55	39.14	7.23	.42
18	Taken home.							
19	2 yrs.	14,900	34.48	15.51	1.03	46.55	1.03	1.38
20	2 yrs.	14,500	32.26	5.21	1.3	47.42	6.51	1.3
20	(1 wk. later)	14,800	34.08	18.86	1.72	40.24	4.75	.34
21	3½ yrs.	11,000	32.5	8.12	1.87	55.09	2.5	.02
22	Died. Convulsions and Vincent's angina.							
23	10 mos.	17,700	46.42	11.42	.36	40.	1.79	.0
24	1¼ yrs.	14,900	43.75	25.	1.25	26.	5.75	.25
Average		16,800	38.30	10.6	1.34	45.09	3.71	.55

TABLE X.—BLOOD EXAMINATION OF PERTUSSIS PATIENTS IN THE POST-PAROXYSMAL STAGE, TWO MONTHS

No.	Age, Yrs.	Leucocytes.	Lymphocytes.		Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
			Small.	Large.				
3	4½	16,000	37.5	14.16	1.66	41.66	5	.0
4	2	12,400	43	7.91	1.25	45.83	2.08	.0
6	3	12,800	34	17.14	1.78	46.35	.71	.0
8	4	8,000	40.48	10.64	1.23	47.17	.85	.0
9	2½	19,000	32.62	9.23	1.23	55.38	1.23	.3
12	5	11,700	33.28	7.64	1.11	47.64	9.41	1.11
13	1½	15,000	35	12.6	.8	50	1.2	.4
14	2	15,000	40	6.75	.62	50.12	2.5	.0
15	2	20,000	41.66	12.5	2.08	42.09	.83	.83
17	2¼	13,000	27	12.5	.5	51.5	7	1.5
19	2	12,500	34.53	10.32	.32	53.54	1.29	.0
20	2	12,000	45.88	12.35	1.76	37.06	2.94	.0
Av'ge	..	14,000	37.07	11.14	1.19	47.36	2.92	.34

TABLE XI.—SUMMARY OF BLOOD EXAMINATIONS IN PERTUSSIS CASES

Stage.	Leucocytes.	Lymphocytes.		Transi- tionals.	Polymorpho- nuclears.	Eosino- philes.	Mast Cells.
		Small.	Large.				
Precatarrhal	14,800	44.01	5.23	1.72	39.57	9.31	.14
Catarrhal	16,800	49.19	9.83	2.03	34.98	3.35	.53
Paroxysmal	22,000	63.19	8.19	1.77	23.92	2.35	.53
Marked improvement..	16,800	38.39	10.6	1.34	45.09	3.71	.55
Two months after....	14,000	37.07	11.14	1.19	47.36	2.92	.34

It may be well to note a few of the more important points demonstrated in the tables.

1. There is a slight leucocytosis and an absolute increased percentage of all forms even in the precatarrhal stage, judging from the examinations in the two cases. The number of leucocytes steadily increases in the catarrhal stage, reaches the climax in the paroxysmal stage and then falls by lysis. Barach¹ states that they reach normal proportions in a little over three months.

2. The lymphocytes follow a similar course. I do not think that one could always appreciate an increase in the precatarrhal stage, but certainly a lymphocytosis will be found in the catarrhal stage in the great majority of cases. This lymphocytosis reaches its climax in the paroxysmal stage and then gradually falls. The increased percentage of lymphocytes is absolute and not simply relative, as is frequently found in rickets. The cause of this phenomenon has been attributed to a congestion of the tracheobronchial glands.

3. The large lymphocytes run a more irregular course. In most cases a large percentage was found when the number of small lymphocytes was high. It will be noted that their percentage usually remains high for a time after the small lymphocytes begin to decrease.

4. The transitionals run a very irregular and unimportant course.

5. The percentage of polymorphonuclear neutrophiles is in most instances actually increased, but relatively they decrease as the lymphocytes go up. It is interesting to note how this relationship is changed in the complications of pertussis, notably lobar pneumonia, and in secondary infections.

6. The eosinophiles run a more typical course. During the catarrhal stage they are usually present in normal proportions, are relatively decreased in the paroxysmal stage, and in the postparoxysmal stage a mild eosinophilia sets in.

7. I have found that the basophiles begin to distinctly increase in the catarrhal stage and that the percentage remains higher than normal throughout the disease.

8. Many bilobate and "basket" cells were found, especially in the presence of a high lymphocytosis. No myelocytes were encountered.

DIFFERENTIAL DIAGNOSIS

Quite generally whooping-cough is not diagnosed early in its course, because it resembles an ordinary cough without expectoration, accompanied by a little fever. It may go on in this manner for a week to ten days, and even longer, before one's suspicion is aroused by a more incessant cough, injection of the conjunctiva and a tendency toward paroxysms of coughing. A few observers assert that the disease is most contagious in this period. Those who have had experience with many children living together, as in an institution, are well acquainted with the coughs that spring up every now and then, practically unaccompanied by systemic symptoms and often without positive signs on physical examination. Often such a cough clears up without treatment, and about just as often it hangs on for a long time despite treatment. I call particular attention to the table composed of such cases in which one examination was made and a negative diagnosis given. When the danger of whooping-cough infection is present, it is just such cases that arouse one's anxiety to know if they are ordinary coughs or genuine pertussis or if pertussis is developing during the course of such a chronic cough. The other cases were diagnosed by the subjective symptoms and physical examination. Case 3, diagnosed as one of bronchitis, is interesting in that the small lymphocytes kept on increasing and then began to fall. The child never whooped. It is debatable whether this case was not one of an atypical pertussis, as it is not infrequently encountered in very young children.

TABLE XII.—BLOOD EXAMINATION IN CASES OF COUGHS OTHER THAN PERTUSSIS

CASE 1.—BRONCHITIS										
No.	Date.	Name of Patient.	Age, Yrs.	Leuco-cytes.	Lymphocytes, Small.	Lymphocytes, Large.	Transi-tionals.	Poly-morpho-nuclears.	Eosino-philcs.	Mast Cells.
1	9/16	Eliz. E.	4	11,000	40	3.5	.5	53.5	1.5	1
	9/28			9,500	40.9	9.54	1.36	40.9	6.86	.45
	10/2			9,500	35.93	14.37	.62	45.32	3.12	.62
CASE 2.—LARYNGITIS										
2	9/17	Kelly	1 1/6	9,000	39.79	7.19	1.25	50	1.56	.3
	9/20			9,500	40	6.5	1.5	48.53	3.4	.06
CASE 3.—BRONCHITIS										
5	9/19	Mary F.	11/12	9,000	22.22	7.12	1.94	61.11	6.68	.96
	10/24			21,200	54.44	29.45	2.44	10	3	.66
	10/26			20,000	69.74	13.33	1.28	14.1	1.54	.0
	11/1			10,000	57.82	19.13	.86	20.88	1.3	.0
CASE 4.—BRONCHITIS										
7	9/22	Nick	4	9,960	31.06	6.13	1.11	57.72	3.4	.58
	9/25			9,000	29.5	7.2	.9	57.8	4.5	.09
CASE 5.—BRONCHITIS										
9	9/24	Alice	3 1/4	10,000	42.86	7.41	.96	46.77	1.29	.64
	10/2			14,800	35.25	12.5	1.75	46.75	3.12	.62
CASE 6.—BRONCHITIS										
14	9/25	Willie Y. . . .	3	10,600	21.66	5.66	1.66	60.66	10	.33
	10/3			9,300	21.42	11.42	1.42	60.28	5.03	.42
CASE 7.—BRONCHITIS										
16	9/30	Harry S. . . .	2 1/2	12,720	26.19	17.14	3	51.78	1.42	.47
	10/2			12,000	20.49	16	2.33	58.63	2	.33
CASE 8.—BRONCHITIS										
19	10/2	Mary McC. . . .	3	12,080	40.61	10.46	3.38	43.38	1.84	.3
	10/17			14,500	40.17	9.04	1.42	46.04	2.86	.47
	10/26			10,500	43.12	7.5	.62	45.31	2.19	1.25
MISCELLANEOUS COUGHS										
1	10/12	Eliz. E.	4 1/2	11,000	40.93	14.37	1.36	45.32	3.12	.62
2	9/17	John N.	3	12,900	33.33	15.15	3.33	46.97	.7	.5
4	9/19	Gert. A.	4	9,000	25.52	5.26	1.05	63.15	4.94	.05
6	9/20	John J.	3 1/2	9,500	45.61	7.85	.95	42.76	1.9	.71
8	9/22	Joseph G.	5	9,910	38.44	6.75	.54	51.35	1.62	1.3
10	9/24	Thomas H. . . .	4	10,800	14.47	2.25	.64	75.8	6.16	.64
11	9/23	John H.	4	10,000	20.02	2.66	1.66	73.33	2	.33
12	9/23	William H. . . .	5	10,500	28.18	5.24	2.03	63.63	.61	.3
13	9/23	George B. . . .	2 1/2	11,600	36.10	13.25	2.5	46.15	1.75	.75
15	10/2	Daniel O'C. . . .	3	13,900	36.29	16.29	5.18	38.52	3.59	.11
17	10/2	James O'C. . . .	3	14,800	35.25	12.5	1.75	48.25	1.5	.5
18	10/2	Annie N.	4	10,000	26.55	8.46	.38	64.23	.38	.0
20	10/31	John N.	5	11,800	18.5	11.5	1	65	3.5	.5
21	10/31	Clara E.	4	14,600	27.2	6.64	1.25	62	2.91	.0

A study of Table XII will show that in such cases there is little change in the blood. One notes in most instances a slight leucocytosis. Once in a while lymphocytes are slightly increased, and it is in such cases that a provisional diagnosis is made and the child isolated for a day or so, when a second examination is made. Quite generally there is a slight rise in the percentage of the eosinophiles, and I also draw attention to an appreciably increased percentage of mast cells.

COMPLICATIONS

A study of these presents much that is of interest.

Pneumonia

Bronchopneumonia is one of the most frequent complications. There was one typical case; another commenced as a bronchopneumonia, but soon developed into a lobar; both were fatal. Both cases developed at the close of the paroxysmal stage. The results of the blood investigations in the two cases are given together for comparison. Autopsies were held in both cases.

TABLE XIII.—BLOOD EXAMINATION OF PNEUMONIA PATIENTS

CASE 1.—BRONCHOPNEUMONIA										
No.	Date.	Name of Patient.	Age, Yrs.	Leuco-cytes.	Lymphocytes.		Transi-tionals.	Poly-morpho-nuclears.	Eosino-philes.	Mast Cells.
1	8/12	Annie Q...	1¼	25,000	63.4	6.4	1.4	27.4	.8	.6
	8/13			29,700	68.40	3.36	1.41	21.27	5.47	.09
	8/14			26,240	80.35	3.57	1.56	11.17	2.9	.39
CASE 2.—LOBAR PNEUMONIA										
7	9/10	Francis S..	1	22,000	60.38	14.08	1.81	21.76	1.07	1.
	9/12			24,000	34.78	10.43	2.6	48.26	2.6	1.3
	9/20			27,000	24.26	11.56	2.18	60.1	1.25	.62

In both cases an increased leucocytosis will be noted, especially marked in the lobar case. In the case of bronchopneumonia the small lymphocytes are absolutely increased, whereas in the case of lobar pneumonia the percentage of lymphocytes, on the other hand, steadily decreased while the polymorphonuclear neutrophils were increasing.

Convulsions

There were two cases. In the first the convulsions succeeded on a violent paroxysm of coughing. Three hours later the child died. At autopsy the meninges on both sides were found much congested, and that was all.

TABLE XIV.—BLOOD EXAMINATION OF PATIENT WITH CONVULSIONS (CASE 1)

No.	Date.	Name of Patient.	Age, Yrs.	Leuco-cytes.	Lymphocytes.		Transi-tionals.	Poly-morpho-nuclears.	Eosino-philes.	Mast Cells.
2	7/25	Lewis M...	1	24,900	61.07	9.01	2.34	24.07	2.39	1.21
	7/27			29,000	59.56	5.31	1.46	32.25	1.31	.09

One blood count was taken during a quiet period shortly before death. The last count preceding the onset of the convulsions is given for comparison. It will be observed that with the convulsions there was an increased leucocytosis and a slight increase in the polymorphonuclears.

The second case was the one also complicated by a severe Vincent's angina. The gum of the upper jaw was ulcerated so badly that all the incisor and bicuspid teeth either dropped out or were pulled. Two incisors and a bicuspid of the lower jaw were also picked out.

TABLE XV.—BLOOD EXAMINATION OF PATIENT WITH CONVULSIONS AND VINCENT'S ANGINA

No.	Date.	Name of Patient.	Age, Yrs.	Leucocytes.	Lymphocytes.		Transi- tionals.	Poly- morpho- nuclears.	Eosino- philes.	Mast Cells.
					Small.	Large.				
22	10/17	Cath. H...	2	28,500	75.47	9.54	.68	12.5	1.81	.0
	10/24			49,600	70.64	10.41	1.87	15.83	1.25	.0
	10/26			47,500	48.69	15.79	1.31	32.89	1.31	.0
	10/28			65,000	50	7.69	.76	39.24	1.92	.38

All examinations were made in the paroxysmal stage. As one would expect in the presence of a necrotic condition, the leucocytes kept on steadily increasing, with a relative decrease in the lymphocytes and an absolute increase in the polymorphonuclears. The case, however, was progressing quite favorably under applications of formalin and a 5 per cent. solution of copper sulphate when, without warning, the child was seized with a minor convulsion. At first it responded quite promptly to treatment, but soon fell into a deep coma. Lumbar puncture was performed for a diagnostic purpose to ascertain the presence of cerebral abscess or a meningitis on account of the ulcerous necrotic condition in the mouth. The result was negative. The clear fluid flowed quite freely and 15 c.c. were removed, following which the patient's breathing was much easier and more regular. The convulsions had a unilateral tendency, especially affecting the left side. Ten hours later the patient died. Autopsy was performed shortly afterward. There was no extra-cerebral hemorrhage. Dr. William G. Spiller very kindly sectioned and examined the brain for me. He reports:

The right parietal and occipital lobes and the left occipital lobe are greatly congested, but no hemorrhages are found in the cortex or white matter.

Microscopic Examination: The pia of the left paracentral lobule is not thickened, but shows a considerable degree of round-cell infiltration, especially in the fissures. The vessels of the pia and of the cortex are much distended with blood, and those of the latter present a slight perivascular round-cell infiltration. The congestion of the vessels in the right paracentral lobule is about as intense as in the left paracentral lobule, but the round-cell infiltration of the pia is not so distinct.

The optic nerves and chiasm are full of holes, as though many nerve fibers had degenerated and dropped out. The pia of the optic nerve shows some round cell infiltration. A slight round-cell infiltration is found also in the pia of the medulla oblongata. The vessels of the medulla oblongata are distended with blood but not so much as those in the cerebral cortex.

The round cells are such as are often found in meningitis, consisting of small cells with a single nucleus.

The condition is one of moderate meningoencephalitis.

The last blood count was taken during the height of the convulsions and shows nothing more than a higher leucoctosis.

Impetigo Contagiosa

The lesions developed in the period of marked improvement. A slightly increased leucoctosis with an absolute increased percentage of polymorphonuclears and a slight eosinophilia toward the end will be noted.

TABLE XVI.—BLOOD EXAMINATION OF PATIENT WITH IMPETIGO CONTAGIOSA

No.	Date.	Name of Patient.	Age, Yrs.	Leuco-cytes.	Lymphocytes.		Transi-tionals.	Poly-morpho-nuclears.	Eosino-philes.	Mast Cells.
					Small.	Large.				
13	9/7	Francis . . .	1½	15,100	32.07	13.2	2.61	48.69	2.64	.75
	9/5			17,000	28.5	6	2	67.7	5.4	.3

Ecthyma

The lesions developed during the paroxysmal stage. The last count was taken in the period of marked improvement. Changes similar, but more marked, to those found in the case of impetigo will be noted, as one would expect, in the presence of a more severe pustular infection.

TABLE XVII.—BLOOD EXAMINATION OF PATIENT WITH ECTHYMA

No.	Date.	Name of Patient.	Age, Yrs.	Leuco-cytes.	Lymphocytes.		Transi-tionals.	Poly-morpho-nuclears.	Eosino-philes.	Mast Cells.
					Small.	Large.				
20	8/16	Chas. L. . . .	2	28,900	59.56	5.31	1.46	32.25	1.31	.09
	8/20			30,000	46.5	4.6	.9	44.23	3.7	.06
	9/25			14,500	38.26	5.21	1.3	47.42	6.51	1.3

DIAGNOSTIC VALUE

Each will have to decide this question more or less for himself from the various reports available. Certain it is that there is present in whooping-cough a leucoctosis and an absolute as well as a relative lymphocytosis. When I began this work I was quite skeptical as to its practical value, but gradually was convinced of its worth. It requires a careful examination with a counting of a large number of leucoctes and due consideration of the child's age. In two cases, Nos. 3 and 22, examined early in the catarrhal stage, there was no lymphocytosis and a negative diagnosis was made. These cases afterward proved to be genuine whooping-cough. In a few instances provisional diagnoses were made, but in each case a second examination cleared up the doubt either in a positive or negative way. Unfortunately the busy practitioner may have no opportunity for an examination that takes considerable time. Yet I believe that it will pay to take time, especially if the practitioner

is connected with institutions, hospitals and dispensaries where the disease is rapidly spread. The differential count is of more importance than the leucocyte estimation. The numbers of leucocytes vary a great deal in different cases, and the best methods of counting are still far from being accurate and absolutely reliable. I do not wish to underrate the value of a leucocyte count in conjunction with a differential count, but of the two the latter is of more importance and, I believe, of great interest and much value in aiding an early diagnosis of pertussis.

I wish to express my thanks to Drs. S. McC. Hamill, John M. Cruice and Charles Fife for their kind interest and to the Sisters of Charity, who by their unvarying courtesy and aid made the work both possible and pleasant.

St. Agnes' Hospital.