STUDIES WITH THE ELECTROCARDIOGRAPH ON THE ACTION OF THE VAGUS NERVE ON THE HUMAN HEART.

II. The Effects of Vagus Stimulation on the Hearts of Children with Chronic Valvular Disease.*

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Plates 1–5.

During the study that forms the subject of the present communication, the methods and conditions were constantly similar to those described in our first paper (1). The electrocardiograms were always obtained by electrodes attached to the right forearm and left leg—the so-called second lead. The string of the galvanometer was adjusted so that its shadow moved one centimeter on the scale attached to the camera when a current of one millivolt passed through it.

The hearts of children suffering with so-called chronic endocarditis were found to be very susceptible to vagus stimulation by pressure. The study was carried out on a group of four children, in all of whom acute articular rheumatism can probably be held accountable for the heart lesions.

Case I. A girl of eight years, who first gave evidence of heart disease when six years old at the time of an attack of purpura. The diagnosis at the time of admission was mitral insufficiency, probably also aortic insufficiency and chronic pericarditis. The pulse rate ranged from 110 to 150 per minute while quiet in bed, and the blood pressure was estimated by the auscultatory method at systolic 105, diastolic 25 millimeters of mercury.

Case II. A boy of fourteen years, whose cardiac symptoms developed at the age of nine, two years after acute articular rheumatism. He suffered from mitral and aortic insufficiency. The pulse rate was from 100 to 126 per minute, and the blood pressure was systolic 110, diastolic 54 millimeters of mercury on admission, and on the next day the systolic pressure was 130.

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Case III. A girl of seven years, who first showed cardiac symptoms during her fifth year after tonsillitis and diphtheria. Later she had acute articular rheumatism and presented the signs of mitral insufficiency. Her heart rate was 110 per minute on admission.

Case IV. A girl of fifteen years, who, besides having had rheumatism, gave a positive Wassermann reaction and whose parents gave a definite history of syphilis. Her cardiac symptoms appeared during her ninth year and the diagnosis of mitral insufficiency and congenital syphilis was made. Her pulse rate was 75 to 85 while quiet in bed, and her blood pressure was systolic 98, diastolic 60 millimeters of mercury.

In each case, the heart was beating with sufficient force to give a very well defined apex impulse, and in the first three cases, in which the rate was abnormally rapid, the heart action may be described as thumping. All the cases showed a marked enlargement of cardiac dullness on percussion. It is, of course, impossible to say what myocardial changes were present, but it is reasonable to suppose that the heart muscle, especially in the case where both rheumatism and congenital syphilis had been present, was at least physiologically abnormal. All the curves to be presented were obtained when the patients were free from the effects of digitalis.

The curves will first be described and the various features of the entire group will then be discussed.

The electrocardiograms have been analyzed in order to determine how the vagus stimulation has affected the various cardiac properties—rhythmicity, conductivity, contractility, and excitability—and the results of the analyses have been tabulated as previously. The measurements are given in seconds, calculated from the markings of the Jacquet chronograph, except those of the heights of waves which are in millimeters. The duration of each ventricular cycle is determined by measuring the time elapsing between the first evidence of ventricular stimulation in the electrocardiograms. This time is designated Q–Q or R–R in the tables, depending on whether the initial ventricular stimulation produced a negative Q wave or a positive R wave. The conduction time is measured by computing the time elapsing from the onset of auricular stimulation, the foot point of the P wave, to the onset of ventricular stimulation. This time is therefore represented by P–Q or P–R in the tables. In the same way, the length of auricular cycles is designated as P–P. Ventricular systole is measured from the onset of the Q or R wave to the end of the T wave, while from this last point to the following Q or R point represents ventricular diastole.

Figures 1 to 6 are from case I. Figure 1 shows one cycle of the electrocardiogram obtained when the heart was beating at its usual rapid rate, 140 per minute, undisturbed by vagus stimulation. The other eight cycles in this curve are very similar, and the measurements average as follows:

$$Q\text{–}Q = 0.430, \quad P\text{–}Q = 0.152, \quad P = 3.6, \quad R = 18.2, \quad T = 3.2.$$

No comment is needed except to call attention to the rapidity of rate, which causes a partial fusion of the T and P waves, and the prominence of these waves.

Figure 2 shows the effect of pressure on the right vagus nerve, figure 3 on the left vagus. The measurements from these curves are given in the following tables.

FROM FIGURE 2.

Curve 27.1. Right Vagus Pressure.

Number of cycle.	*Q-Q.*	Systole.	Diastole.	*P-Q.*	*P.*	*R.*	*T.*
1	——	——	——	0.152	2.5	15.7	2.2
2	0.458	——	——	0.157	3.0	16.5	2.2
*3	0.422	——	——	0.162	2.7	14.5	2.0
4	0.400	0.282	0.218	0.162	2.7	15.5	2.0
5	0.972	0.282	0.690	0.151	2.2	15.0	2.5
6	0.997	0.323	0.674	0.161	1.5	15.0	2.5
7	0.782	0.298	0.484	0.150	1.0	15.3	2.5
8	0.653	0.304	0.349	0.164	1.2	16.0	2.5
9	0.590	0.297	0.293	0.150	2.0	15.5	3.0
10	0.575	0.297	0.278	0.165	2.0	—	3.0
11	0.537	0.290	0.247	0.157	2.2	16.0	3.0
12	0.532	0.292	0.240	0.161	2.5	15.5	2.7
13	0.500	0.294	0.206	0.158	2.5	15.5	2.5
14	0.495	0.297	0.198	0.149	2.5	16.0	2.3

* Vagus pressure was made at the point of the first asterisk and was released at the point of the second asterisk in all curves where the release is indicated.

FROM FIGURE 3.

Curve 27.2. Left Vagus Pressure.

Number of cycle.	*Q-Q.*	Systole.	Diastole.	*P-Q.*	*P.*	*R.*	*T.*
1	——	——	——	0.149	3.0	18.5	3.0
2	0.462	——	——	0.153	3.2	18.0	—
*3	0.446	——	——	0.160	3.5	17.5	3.0
4	0.454	——	——	0.160	3.5	17.2	3.0
5	0.478	——	——	0.168	3.3	18.5	3.0
6	0.497	——	——	0.186	3.5	18.2	3.0
7	0.546	0.301	0.245	0.249	3.5	19.0	3.0
8	0.629	0.288	0.341	0.227	3.3	18.5	3.0
9	0.710	0.298	0.412	0.249	3.5	21.5	2.5
10	0.654	0.309	0.345	0.264	3.5	21.5	3.0
11	0.626	0.314	0.312	0.228	3.5	19.5	2.5
12	0.643	0.299	0.344	0.246	3.0	—	3.0
*13	0.600	0.300	0.300	0.217	3.5	20.0	3.0
14	0.535	0.310	0.225	0.183	3.5	18.5	3.0(?)
15	0.541	0.310	0.231	0.169	3.5	19.5	3.5
16	0.526	0.304	0.222	0.165	3.0	20.0	3.5
17	0.503	0.309	0.194	0.162	3.0	20.5	3.0
18	0.495	0.290	0.205	0.150	3.0	19.0	3.0
19	0.475	0.299	0.176	0.145	3.5	19.0	3.0
20	0.490	——	——	——	3.5	—	—

On another occasion, pressure was made first on the right vagus and then on the left with practically similar results, as seen by the following measurements of the curves which are not reproduced.

CURVE NOT REPRODUCED.

Curve 24.2. Right Vagus Pressure.

Number of cycle.	*Q-Q.*	*P-Q.*	*P.*	*R.*	*T.*
1	——	——	——	17.8	3.2
2	0.432	0.142	2.5	16.5	3.5
3	0.433	0.148	2.5	16.5	2.8
4	0.433	0.147	2.5	——	3.8
*5	0.439	0.157	3.0	17.5	3.2
6	0.479	0.155	3.0	17.3	3.4
7	1.768	0.217	1.7	19.0	3.5
8	0.657	0.211	1.8	18.5	4.5
9	0.653	0.175	1.8	18.0	4.0
10	0.711	0.192	2.0	19.0	4.5
11	0.719	0.164	2.0	18.8	4.3
12	0.635	0.167	1.8	18.2	5.0
13	0.592	0.133	2.0	18.2	5.0
*14	0.597	0.158	2.0	18.5	4.5
15	0.530	0.135	2.5	18.5	5.0
16	0.511	0.155	2.5	18.2	4.5
17	0.492	0.154	2.5	18.6	4.5
18	0.488	0.158	3.0	18.0	4.2
19	0.467	0.158	2.7	17.6	—

CURVE NOT REPRODUCED.

Curve 24.3. Left Vagus Pressure.

Number of cycle.	*Q-Q.*	*P-Q.*	*P.*	*R.*	*T.*
1	——	0.152	3.0	18.0	3.5
2	0.433	0.148	2.7	18.0	4.0
3	0.438	0.152	3.0	18.5	3.5
*4	0.436	0.154	3.0	17.0	3.5
5	0.431	0.151	3.0	18.5	3.5
6	0.438	0.153	3.0	18.5	4.0
7	0.453	0.167	3.0	18.5	3.5
8	0.524	0.223	3.5	19.0	3.0
9	0.522	0.219	3.0	19.0	3.0
10	0.542	0.208	3.0	19.0	3.5
11	0.472	0.190	3.5	19.0	4.0
12	0.462	0.177	3.0	19.0	4.0
13	0.464	0.184	3.5	18.0	4.0
14	0.463	0.169	3.0	18.0	4.0
15	0.482	0.166	3.0	18.5	——
*16	0.459	0.160	4.0	18.5	4.0
17	0.474	0.173	3.5	18.0	4.0
18	0.464	0.169	3.0	18.0	4.0
19	0.462	0.163	3.5	18.0	4.0

It is seen from the measurements in both sets of curves that there has been a marked difference between the effect of stimulation of the right and left vagus. Right vagus pressure had a striking effect on the heart rate, apparently through its action on the sinus node, the normal "pace-maker" of the heart-beat. The slowing came on less than a second after pressure was made and caused the maximal lengthening of the cardiac cycle in the first or second slow

beat. Left vagus pressure caused but slight slowing, and the longest cycle in each curve was the seventh after the pressure was exerted, each occurring about three seconds after the initial pressure. The time of conduction of the heart-beat from auricles to ventricles, as indicated by the *P-Q* time, is, however, more influenced, both relatively to the heart rate, and absolutely, by stimulation of the left vagus than the right. In the curve 27.1 (figure 2) right vagus pressure produced no delay in conduction, although the slowing of the cardiac rhythm was marked. Pressure on the left vagus nerve caused marked delay in conduction on both occasions, in curve 27.2 (figure 3) with moderate, and in the unpublished curve, 24.3, with almost no change in rate. The changes in conduction occurred synchronously in the curves with the changes in rate. Right vagus stimulation caused a striking diminution in the size of the *P* wave, which was apparently unaffected by left vagus pressure. The *R* wave was usually increased, slightly more by left-sided pressure, and the *T* wave more by right-sided, but not until several beats after pressure was made.

On two occasions in case I, right vagus pressure produced a dissociation of auricles and ventricles, seen in figure 4. The measurements from this curve are as follows:

FROM FIGURE 4.

Curve 19.2. Right Vagus Pressure.

Number of cycle.	*Q-Q.*	*P-Q.*	*P-P.*	*P.*	*R.*	*T.*
1	0.421	——	——	——	——	3.5
2	0.424	0.149	0.424	4.0	19.5	3.5
3	0.434	0.149	0.435	4.0	18.0	3.5
4	0.420	0.148	0.419	4.0	18.0	3.3
5	0.420	0.149	0.420	4.0	19.0	3.0
6	0.433	0.149	0.431	3.8	19.5	3.3
*7	0.670	0.151	0.658	3.8	18.8	3.7
8	0.687	0.170	0.661	2.5	20.8	3.5
9	0.991	0.196	1.011	3.0	21.2	3.8
10	°0.853	0.176	0.991	1.8	20.0	4.4
11	°0.788	——	1.000	——	20.0	5.0
12	°0.794	——	0.700	——	22.8	4.0
13	°0.778	——	0.706	——	21.8	4.5
14	°0.780	——	0.674	——	24.0	5.0
15	0.635	0.137	0.596	——	21.3	5.2
16	0.556	0.133	0.640	3.3	21.5	5.0
17	0.517	0.141	0.509	3.3	20.0	5.0
18	0.489	——	0.493	3.0	20.0	4.3

° = independent ventricular cycles. Independent ventricular rate = 75.1.

It is seen that after definite slowing in rate, but without maximal delay (as compared to figure 3), the *R* and *P* waves occur in abnormal relations in cycles 11, 12, 13, 14, and 15. The relations of the waves then resume that seen before vagus pressure was exerted, except for a shortening in the conduction time. It seems evident that this temporary disturbance in the electrocardiogram results from a complete dissociation of auricles and ventricles. The ventricles take up their own pace at a rate of 75.1 beats per minute, but the first independent ven-

tricular cycle is longer than those that follow. Practically the same ventricular complex is seen during as before and after the dissociation. The changes in the *R* waves in this part of the curve seem referable to the coincidences of the *P* and *R* waves. Otherwise the changes in the various waves are similar to those previously seen, except that there is a well defined increase in the *T* wave.

Figures 5 and 6 are reproduced to show the effect that right vagus pressure had on the cardiogram, taken by means of an open funnel held over the apex beat. The child had a thin chest wall, and the violently beating heart produced a very well defined apex beat. In figure 5, the cardiogram is recorded synchronously with the electrocardiogram. Soon after the initial pressure over the right vagus, which took place between the fifth and sixth cardiac cycles, the cardiogram becomes diminished in height until the thirteenth cycle is reached, when it is seen to have almost disappeared. The appearance of the entire length of this curve and of a number of others that were taken, make it certain that respiratory movements are in no way responsible for this flattening out of the cardiogram. Greatly weakened ventricular contractions seem to be the only possible cause. The marked diminution in intensity of the cardiac sounds and murmurs, which invariably occurred, confirm this explanation. The late appearance of the maximal weakening of the ventricles is worthy of note. It occurs over four seconds after the initial pressure and does not accompany the maximal slowing or depression of conductivity. The measurements from the curve show, however, neither a marked decrease in rate nor much delay in conduction.

FROM FIGURE 5.

Curve 19.5, with Apex Beat. Right Vagus Pressure.

Number of cycle.	*Q-Q.*	*P-Q.*	*P.*	*R.*	*T.*
1	0.436	0.149	—	——	—
2	0.430	0.154	3.5	18.0	3.5
3	0.437	0.152	3.5	18.0	3.5
4	0.432	0.150	3.0	18.0	3.5
5	0.442	0.154	3.5	18.0	—
*6	0.470	0.161	—	18.3	4.0
7	0.550	0.171	4.0	17.5	3.5
8	0.582	0.174	3.0	18.0	—
9	0.652	0.169	2.7	20.0	4.0
10	0.652	0.165	2.8	20.0	4.0
11	0.731	0.155	2.8	19.5	4.3
12	0.670	0.157	2.4	19.5	4.5
†13	0.637	0.160	2.5	21.0	—
14	0.635	0.156	2.0	20.5	5.5 (?)
15	0.560	0.155	3.0	19.0	4.5
16	0.556	0.168	2.5	20.0	5.0
17	0.536	0.155	3.0	19.5	4.5
18	——	——	2.7	19.0	4.0

† Greatest decrease in size of apex beat.

It is also interesting to find that the *R* wave of the greatest height occurs with the most weakened beat, while the greatest depression of the *P* wave is seen in the following beat. The definite increase in the *T* wave is seen in the latter part of the curve, as in the others, when the right vagus was pressed upon.

Figure 6 shows tracings from the apex beat and brachial artery, recorded in the usual way on the smoked paper drum of a kymograph. Right vagus pressure made while the curve was being taken, produced the same diminution in the cardiogram. The slowing of the heart responds to right vagus stimulation in what seems to be the usual way, while it is the second beat after the longest pause that forms the smallest cardiogram. The explanation for the fact that the weakest beat and the longest pause do not occur synchronously here may lie in the fact that the long rest afforded the heart had caused a stronger ventricular beat than occurred when the rest was not so long. This reasoning, however, can hardly be applied to explain the non-parallelism in rhythmicity and contractility which is seen in figure 5. Only a part of a long graphic record is reproduced, but when the entire curve was studied, respiratory effects could be excluded as the cause of the depression of the cardiogram. Cold and then hot applications to the neck of this patient, for about an hour and a quarter each, failed to alter the heart rate or the susceptibility of the heart to vagus pressure.

Figures 7, 8, 9, and 10 are from case II. In the record obtained without vagus pressure (figure 7), it is seen that the *P*, *R*, and *T* waves are very well marked, the *T* wave being abnormally large. Measurements of the entire curve of eight cycles, of which only part is reproduced, average as follows:

$$Q\text{-}Q = 0.553, \quad P\text{-}Q = 0.174, \quad P = 2.3, \quad R = 21.6, \quad T = 4.5.$$

The rate was 109 beats per minute. A slight depression of conductivity is indicated by the *P*–*Q* time of 0.174.

The difference in the effects of stimulation of the right and left vagi is seen by comparing figures 8 and 9.

FROM FIGURE 8.

Curve 41.2. Right Vagus Pressure.

Number of cycle.	*Q*-*Q*.	*P*-*P*.	*P*-*Q*.	*P*.	*R*.	*T*.
1	0.511	0.503	0.172	2.5	21.5	4.0
2	0.512	0.523	0.184	2.5	21.5	5.0
*3	0.572	0.584	0.173	2.5	22.0	4.5
4	0.834	0.811	0.161	2.5	22.0	4.5
5	0.777	0.799	0.184	1.0	22.5	4.0
6	0.789	0.792	0.162	1.0	22.0	4.2
7	0.823	0.815	0.159	1.0	22.0	4.5
8	0.800	0.805	0.167	——	22.5	4.5
*9	0.796	0.794	0.162	0.5	22.5	5.0
10	0.601	0.608	0.164	1.0 (?)	21.5	5.0
11	0.595	0.582	0.157	1.0	22.0	5.0
12	0.561	0.564	0.170	2.0	21.5	4.5
13	0.543	0.546	0.167	2.0	22.5	5.0
14	0.515	0.498	0.164	2.0	22.5	5.0
15	0.497	0.505	0.181	2.0	23.0	4.7
16	0.508	0.508	0.173	2.0	23.0	4.5
17	0.535	0.600	0.173	2.5	23.0	4.5
18	——	——	0.157	——	——	——

FROM FIGURE 9.

Curve 41.6. Left Vagus Pressure.

Number of cycle.	*Q–Q.*	*P–P.*	*P–Q.*	*P.*	*R.*	*T.*
1	0.524	0.520	0.171	2.5	23.0	4.5
2	0.524	0.522	0.175	2.5	22.3	4.5
*3	0.560	0.576	0.177	2.5	21.0	4.5
4	0.512	0.502	0.161	2.3	22.5	4.5
5	0.706	0.714	0.171	2.5	21.5	4.5
6	0.530	0.516	0.163	2.3	21.5	4.0
7	0.628	0.667	0.177	2.5	22.0	5.2
8	0.530	0.527	0.148	2.0	23.0	4.5
9	0.514	0.488	0.141	2.5	23.0	4.5
10	0.524	0.513	0.167	2.5	23.0	4.5
*11	0.612	0.631	0.178	2.5	23.0	4.5
12	0.554	0.551	0.159	2.0	22.0	4.5
13	0.531	0.539	0.162	2.0	22.5	5.0
14	0.534	0.517	0.154	2.0	22.5	4.5
15	0.530	0.524	0.171	2.0	21.5	5.0

With right vagus stimulation (figure 8), definite slowing occurred, but in a somewhat irregular manner. At the same time, no delay in conduction is apparent, but the striking diminution of the *P* wave, which nearly disappears, may have masked any lowering of conductivity. In those cycles showing almost an absence of the *P* waves, the *R* and *T* waves remain practically unchanged, so that it is the auricular portion of the electrocardiogram which is especially disturbed.

Left vagus stimulation (figure 9) produced only slight changes in the heart-beat in the one instance obtained. The only apparent influence on conduction is indicated by shortening of the *P–Q* time seen in the eighth and ninth beats, an effect exactly opposite to that seen in case I with left vagus pressure. No changes of note are seen in the *R* and *T* waves and only slight diminution occurs in several of the *P* waves.

The main interest in this case lies in the phenomenon of dissociation which was produced by right vagus pressure. It is seen in figure 10 that following vagus stimulation, a moderately prolonged cardiac cycle occurred, followed by a greater lengthening. At the end of this second lengthened cycle, 1.6 seconds after the initial pressure, there is a slight movement upward in the curve resembling the beginning of a *P* wave, which is interrupted by an entirely new type of ventricular complex consisting of a somewhat diminished *R* wave, a much exaggerated negative *S* wave, and a much enlarged *T* wave. This complex occurs in a series of three beats, each preceded closely by a small wave, evident from its position and shape as at least part of the *P* wave. The close proximity of the beginning of these *P* waves to the *R* waves makes it also evident that the auricles are not, during these three beats, the pace-maker for the ventricles. The abnormality of the ventricular complexes indicates that the stimulus of cardiac contraction does not pass through the ventricles in the usual way from the atrioventricular bundle, but that some abnormal point in the ventricles has taken up the pace-making function. The auricles and ventricles are beating

independently, therefore, during the sixth, seventh, and eighth cycles, each portion of the heart at its own rate under the conditions produced by right vagus stimulation. From the measurements from this curve, it is seen that the ventricular rate is 78.5 per minute. Measurements from the rather poor brachial tracing and the electrical curve indicate that the length of systole is about the same, whether the ventricular beat is of normal or abnormal type.

FROM FIGURE 10.

Curve 41.3. Right Vagus Pressure. Dissociation.

Number of cycle.	*Q–Q.*	*P–P.*	*P–Q.*	*P.*	*R.*	*T.*
1	0.502	0.502	0.165	2.5	22.0	4.5
2	0.490	0.480	0.165	2.5	21.0	4.5
3	0.494	0.485	0.175	2.5	21.0	4.5
*4	0.562	0.592	0.184	2.5	22.0	5.0
5	°0.753	0.881	0.154	1.5	—	5.0
6	°0.764	0.750	—	—	13.0	7.0
7	°0.776	0.714	—	1.0	13.0	7.0
8	0.668	0.629	— (0.108)	1.0	14.0	7.0
*9	0.603	0.598	0.147	0.5	22.0	5.5
10	0.598	0.568	0.152	1.0	22.0	5.0
11	0.544	0.544	0.159	2.0	21.5	5.0
12	0.534	0.526	0.159	2.5	22.0	5.0
13	0.516	0.509	0.167	2.0	21.5	5.0
14	0.530	0.527	0.174	2.5	21.7	4.5
15	0.516	0.504	0.177	2.0	21.5	4.5
16	—	—	0.179	2.5	22.0	5.0

° = independent ventricular cycles. Independent ventricular rate = 78.5.

The brachial tracing gives no indication that these dissociated ventricular beats produce a weaker pulse than the others.

It should be noted that before the dissociation no appreciable delay in conduction is seen, while, when the auricles again resume their pace-making function, the conduction, as indicated by the *P–Q* time, is distinctly shortened, just as it is in figure 4. Here the flattening of the *P* waves, which is not seen in figure 4, may make this shortening only apparent, although it is quite reasonable to assume that the rest afforded the conducting system during the dissociation has rendered it capable of more rapid conduction than before.

The curves of especial interest from case III are those shown in figures 11 to 15. The undisturbed electrocardiogram (figure 11) is characterized by an especially prominent *T* wave. The heart rate calculated from the curve was 94.8 per minute, and a slight so-called sinus arhythmia is seen. The measurements average as follows:

$$R\text{–}R = 0.633, \quad P\text{–}R = 0.163, \quad P = 2.5, \quad R = 13.2, \quad T = 4.0.$$

Curves 66.2 and 66.4 (figures 12 and 13) demonstrate the difference in the effects of right and left vagus stimulation in this case.

FROM FIGURE 12.

Curve 66.2. Right Vagus Pressure.

Number of cycle.	*R-R.*	*P-P.*	*P-R.*
1	0.586	0.576	0.186
*2	0.642	0.663	0.188
3	°1.000	1.229	0.180
4	0.966	0.730	——
5	0.574	0.578	0.177
6	0.556	0.550	0.170
*7	0.597	0.608	0.176
8	0.576	0.568	0.165
9	0.597	0.592	0.173
10	0.598	0.603	0.178
11	0.592	0.592	0.173
12	0.593	0.586	0.173

° = independent ventricular cycle. Independent ventricular rate = 60 per minute.

FROM FIGURE 13.

Curve 66.4. Left Vagus Pressure.

Number of cycle.	*R-R.*	*P-P.*	*P-R.*
1	——	——	——
2	0.526	0.523	0.190
3	0.530	0.536	0.193
4	0.550	0.550	0.189
*5	0.541	0.527	0.194
6	0.544	0.544	0.208
7	0.544	0.570	0.208
8	0.549	0.534	0.182
9	0.550	0.555	0.197
10	0.550	0.558	0.192
*11	0.550	0.551	0.184
12	0.556	0.559	0.183
13	0.574	0.560	0.180
14	0.558	0.562	0.194

Again the difference in the action of the right and left vagus appears. Stimulation of the right nerve has slowed the heart rate and not affected conductivity; stimulation of the left nerve has produced exactly the reverse effect, although the delay in conduction is slight. No striking changes are seen in the sizes of the various waves in either curve.

Dissociation of auricles and ventricles occurs in the right vagus pressure curve. The *P* wave of the fourth cycle follows the *R* wave closely, falling between it and the *T* wave, thus indicating that auricular and ventricular systole occurred synchronously. Except for the distortion which this coincidence causes, and a slight increase in the height of the *R* wave, the ventricular complex retains its usual form, and it may be inferred, therefore, that the stimulus of ventricular contraction was propagated through the ventricles from the atrio-ventricular bundle in the normal course. The independent ventricular systole

occurs exactly one second after the preceding ventricular systole, showing an inherent ventricular rate of sixty per minute. The impairment of conductivity seen in the first part of the curve may be the result of a course of digitalis which had lasted nine days but had been discontinued five days before the curve was taken.

Another example of the difference in the effect of right and left vagus stimulation in this case is seen in curves 77.5 and 77.4 (figures 14 and 15).

FROM FIGURE 14.

Curve 77.5. Right Vagus Pressure.

Number of cycle.	*R-R.*	*P-P.*	*P-R.*	*R.*
1	0.526	0.557	—	9.0
2	0.529	0.517	0.163	9.0
3	0.501	0.507	0.175	9.3
*4	°1.081	1.389	0.169	9.0
5	1.060	1.175	—	10.0
6	0.475	1.144	—	10.0
7	°1.000	—	0.215	10.0
*8	0.988	0.894	—	9.5
9	0.697	0.684	0.142	9.0
10	0.626	0.624	0.155	9.0
11	0.562	0.562	0.157	9.0
12	0.547	0.530	0.174	9.0
13	0.539	0.537	0.176	9.0
14	0.526	0.525	0.175	9.0
15	0.537	0.544	0.168	9.0
16	0.549	0.557	0.160	9.0

° = independent ventricular cycles. Average length of independent ventricular beats = 1.047 seconds. Rate of independent ventricles = 57.3 per second.

FROM FIGURE 15.

Curve 77.4. Left Vagus Pressure.

Number of cycle.	*P-P.*	*P-R.*	*R.*
1	——	——	8.3
2	0.494	0.177	8.5
3	0.494	0.177	8.2
4	0.524	0.175	8.0
*5	0.528	0.180	8.0
6	0.542	0.187	8.2
7	0.558	0.185	8.0
8	0.545	0.172	8.3
9	0.554	0.180	9.3
10	0.580	0.197	8.7
11	0.584	0.184	9.0
12	0.548	0.163	9.0
*13	0.532	0.164	8.5
14	0.538	0.173	8.5
15	0.510	0.170	8.5
16	0.538	0.180	8.5
17	0.534	0.165	—

Although the electrocardiograms are somewhat unsatisfactory, the accompanying cardiograms from the apex beat make the curves of interest. The exceptionally pronounced apex beat gave very perfect records through the usual funnel receiver, so that it seems justifiable to consider the sudden decrease in size of the cardiograms as evidence of weakened ventricular contraction. The modifying influence of respiratory movements was excluded, and the diminution in intensity of heart sounds and murmurs lent further justification to our interpretation of the small cardiograms. Although no attempt is made to express numerically the difference between the cardiograms in the two curves, it is seen in the curves that left vagus pressure has caused apparently a greater decrease in the force of ventricular contraction than right vagus pressure. Consideration must be given to the fact, however, that left vagus stimulation has caused almost no effect on rate in distinction to the marked slowing that followed pressure on the right nerve. This difference in rate may be responsible for the difference in the cardiograms, for the long diastoles following right vagus pressure would allow time for recovery of the depressed contractility of the ventricles, which could not take place with the slightly reduced rate following left vagus pressure. Again it is seen, as pointed out in curve 19.5 (figure 5), that the R wave is increased in height in those beats where the greatest reduction in size of the cardiograms occurs, especially with left vagus pressure.

In the curve showing the striking dissociation (figure 14), the ventricles take up their own inherent rhythm in three beats and show a ventricular rate of 57.3 beats a minute, nearly the same as that seen in the curve (figure 12) taken two weeks previously. The ventricular rhythm is broken into by one beat coming through from the sixth auricular systole. The point on the curve when this auricular contraction occurs cannot be determined with certainty, but it seems to be coincident with the T wave of the preceding cycle and is followed after a long conduction time by the ventricular contraction. The length of conduction here probably results from the auricular contraction occurring toward the end of the preceding ventricular refractory phase. The ventricles, therefore, could not respond immediately to the stimulus from the auricles. That this lengthening is not the direct result of vagus stimulation seems probable, too, when it is observed that immediately after the dissociation, the conduction time is strikingly shortened and remains so for several beats. The conduction time is, however, lengthened in the left vagus pressure curve with almost no slowing of rate.

The curves from case IV (figures 16, 17, and 18) show a somewhat different type of reaction of the heart to vagus stimulation. Clinically the case differed from the others in that the rate was slower, the heart-beat less forcible, and the difference between systolic and diastolic blood pressure not so great. In curve 38.3 (figure 16), it is seen that the undisturbed electrocardiogram from this case differs distinctly from those of the preceding cases. The rate (75.7 per minute) is slower, and the P and T waves are distinctly less prominent. The measurements average:

$$R\text{–}R = 0.792, \quad P\text{–}R = 0.167, \quad P = 1.4, \quad R = 17.0, \quad T = 2.1.$$

Right vagus pressure (figure 17) produced moderate slowing of the heart

and slight lengthening of the conduction time, while the most striking feature of the curve is the great reduction and almost total disappearance of the *P* wave during the time of vagus stimulation. The *R* waves show a tendency to increase and the *T* waves to decrease in height during this time. After the removal of the pressure, the heart rate increases and the cardiac cycles become distinctly shorter than those seen before the pressure was made and than those in the curve unaffected by vagus stimulation (figure 16). At the same time, the *P* waves and the *T* waves are slightly higher than in the unaffected curve. This is seen especially in cycles 12 and 13, while in cycles 11 and 12 the *R* waves are slightly reduced.

FROM FIGURE 17.

Curve 38.4. Right Vagus Pressure.

Number of cycle.	*R-R.*	*P-R.*	*P.*	*R.*	*T.*
1	0.810	0.190	1.3	18.0	2.3
*2	1.264	0.178	1.0	18.0	2.0
3	1.200	0.184	?	18.3	1.0
4	1.257	0.192	?	19.0	2.0
5	1.306	0.203	?	18.0	2.0
6	1.069	0.193	?	19.0	2.0
*7	1.074	0.178	?	18.0	2.0
8	0.997	0.170	1.0	18.0	2.5
9	0.868	0.178	1.0	18.0	?
10	0.719	0.167	?	17.0	2.5
11	0.636	0.170	1.0	16.0	3.0
12	0.663	0.176	1.5	16.5	3.0
13	0.647	0.173	1.5	18.0	3.0
14	—	0.176	—	—	—

FROM FIGURE 18.

Curve 38.5. Second Lead. Left Vagus Pressure.

Number of cycle.	*R-R.*	*P-R.*	*P.*	*R.*	*T.*
1	0.740	0.155	2.0	16.0	2.8
2	0.766	0.169	1.0	16.0	2.0
*3	1.103	0.161	1.5	16.0	2.3
4	1.273	0.197(?)	?	17.0	2.0
5	1.162	?	?	16.0	1.5
6	1.018	0.183	1.0	16.5	1.5
*7	1.017	0.196	0.5	16.5	2.0
8	0.868	0.193	1.0	16.0	2.0
9	0.856	0.175	1.0	16.5	1.5
10	0.469	0.180	1.0	16.0	—
11	0.952	—	—	21.5	—
12	0.836	0.183	1.5	16.5	1.5

Left vagus pressure (figure 18) produced almost similar effects. The slowing is not quite so great, while the delay in conduction of the heart-beat from auricles to ventricles is about the same. The striking flattening of the *P* wave and the tendency for the *R* wave to be increased and the *T* wave to be decreased

in height are seen here also. After the removal of pressure, there is, however, no quickening of the heart rate and no increase in the P and T waves or decrease in the height of the R wave. Otherwise in this case in the curves presented and in several others, no definite difference could be made out in the effects from stimulation of the right and left vagus, although well marked effects were produced by pressure over each nerve.

DISCUSSION.

In the discussion of the curves that have been described, two features, the differences in the action of the right and left vagi and the significance of the dissociation of auricles and ventricles, demand special emphasis.

In two of these cases of so-called chronic endocarditis, a definite difference between the action of the two vagi has been constantly demonstrated. The control of rate predominated in the right vagus nerve, presumably through its inhibitory action on the normal pacemaker of the heart-beat, the sinus node. The control of conduction of the heart-beat from auricles to ventricles predominated in the left vagus nerve, presumably through its inhibitory action directly on the conducting system. It will be brought out later that the dissociations following right vagus stimulation depend primarily on the ability of this nerve to reduce auricular rate. The factor of heart rate must be reckoned with when the difference in the effect of the right and left vagi on conductivity is considered. The prolonged cardiac cycles resulting from right vagus stimulation afford an opportunity for recovery of the conductivity not given to the more rapidly beating heart when the left vagus is stimulated. An examination of the relation of the conduction times to the lengths of the preceding diastoles shows, however, that this difference in rate is at least only a contributing factor, and that the left nerve acts especially on conductivity.

There is sufficient evidence in the curves and in the auscultatory phenomena that accompanied the other vagus effects for the belief that in two of the cases vagus stimulation acted directly on the ventricles, causing a marked diminution in the force of their contractions. From the one case where a comparison of the effects of the two nerves on the contractility was made, no definite conclusions can be drawn as to their relative effectiveness, although

each nerve apparently lessened definitely the ventricular contractions. This effect of vagus stimulation was not studied in the other cases of this series. The curves furnish no evidence as to changes in the excitability or tonus of the heart.

The heart seems to respond not infrequently more quickly to stimulation of the right than of the left vagus. Often the maximal effects occur in the first or second beat after right vagus pressure becomes effectual, while they occur several beats later with left vagus pressure.

The influence which stimulation of the vagi has on the various waves of the electrocardiogram shows also a difference in the action of the two nerves. The most constant change in the form of the electrocardiogram is the reduction in the size of the *P* wave, which sometimes entirely disappears. The *R* wave is usually increased in height, and the *T* wave may be increased a number of beats after vagus stimulation has been made, or, as in one case, diminished synchronously with the diminution of the *P* wave. The *P* waves, which represent the auricular activity, were practically always more affected by right vagus stimulation than by left, while in the cases where the *R* waves, which represent the initial activity in the ventricles, were increased, this change was greater after left than after right vagus pressure. The greatest changes in the *P* and *R* waves usually occurred in the longest cardiac cycle or in the following cycle. It is noteworthy that in each of the three curves in which the cardiogram is also shown (figures 5, 14, and 15), the *R* waves reach their greatest heights in the heart-beats in which the weakest ventricular contractions are seen. This fact indicates that an increase in the *R* wave in the electrocardiogram cannot be taken to mean an increase in the force of contraction of the ventricles. The observation agrees with that of Hering (2), who found that when pulsus alternans was experimentally produced in animals, the weaker ventricular contractions gave a larger *R* wave than did the stronger contractions.

The difference in the action of the two vagi have not been constantly demonstrable by the somewhat uncertain method of vagus stimulation which we have employed. In case IV, pressure on each nerve produced striking but practically similar effects, and in an-

other case quite contrary results were obtained in the one comparison that was made of the difference in action of the two nerves. This patient was a man of twenty-nine years with chronic endocarditis. Left vagus pressure was followed by greater slowing of rate but by less delay in conduction than right vagus pressure. The effects of vagus pressure were comparatively slight in each instance. The significance of this finding is not clear, but it indicates that an investigation of many more patients is necessary to determine with what constancy differences in the action of the two vagi can be demonstrated in man by means of vagus pressure.

In our first communication, we described the effect of right vagus stimulation on hearts with auricular fibrillation, and showed that long ventricular pauses occurred without any appreciable change in the auricular fibrillation. This effect was attributed to a lowering of conductivity to such an extent that all the impulses which would ordinarily reach the ventricles from the fibrillating auricles were blocked. At first sight, it would seem that in these cases the right vagus was capable of very marked effect on the conductivity, but when it is remembered that a large majority of the rapidly formed impulses arising in the auricles are ordinarily blocked, it is reasonable to assume that complete blockage for several seconds may be produced by the slight further lowering of conductivity of which the right vagus is capable. No comparative studies of the two nerves were made in the fibrillating cases, so it is not possible to say whether stimulation of the left vagus could have been more effectual even than stimulation of the right. We wish to emphasize the fact, however, that in these cases with auricular fibrillation, marked effects of right vagus stimulation on the ventricular rate, probably due to changes in the conductivity of the heart, can apparently be demonstrated, while in them no opportunity is afforded for conclusions as to the influence of the nerve on the rhythmicity of the heart.

There are, therefore, facts which do not seem to agree entirely with the findings in the cases where differences in the two vagi are clearly demonstrated. However, it seems probable to us that usually in man, in healthy as well as in diseased hearts, the control of the rate of the heart-beat predominates in the right vagus, and

control of stimulus conduction predominates in the left vagus, not because of any specific activity in the nerves themselves, but, as Dr. A. E. Cohn has suggested to us, on account of a possible difference in the anatomical distribution of the two nerves.[1] The recent work of Garrey (3) on the comparison of the action of the two vagi on the turtle's heart has added weight to the suggestion. Rothberger and Winterberg (4) have pointed out differences in the action of the two vagi in dogs similar to those we have described in man, and curves published by Hering (5) and Rihl (6) have also shown them.

In three cases, dissociation between the auricles and ventricles has occurred after stimulation of the right vagus nerve. In other words, following pressure over the right vagus, the auricular rate has been slowed and the ventricular contractions have ceased to follow normally the slowed auricular rhythm, but have established their own rhythm for one, two, or more beats. The contractions of the two parts of the heart have occurred almost synchronously, for the *P* and *R* waves nearly coincide, and the rate of the ventricles has been, at least in the first beat of the dissociations, faster than that of the auricles. The independent ventricular rates in these cases were from 57.3 to 78.5 beats per minute.

The usual cause of complete dissociation of auricles and ventricles is complete heart-block, when the normal mechanism for the conduction of the heart-beat is so impaired, usually by an anatomical lesion, that the ventricles receive no stimuli from the auricles, and so the ventricular rhythm is established independently of the auricular activity. The inherent rhythmicity of the ventricles determines then the rate of their contractions. This rate is, as a rule, in adults about thirty beats a minute, although faster ventricular rates have been observed, as in the cases of Wenckebach (7) and Windle (8), in which the ventricles beat forty-six and sixty-six times per minute respectively.

In our cases, impairment of conduction seems to play no part in the production of the dissociations, as there is but slight delay

[1] As this subject is discussed by Dr. Cohn in his paper in this number of the *Journal of Experimental Medicine,* we shall not go further into it. For the same reason, we shall not attempt to show extensively the relation of our work to the results which have been obtained experimentally on animals.

in the conduction of the heart-beat from auricles to ventricles before the dissociation, a decrease in the conduction time immediately after, and no true blockage of the heart-beat is seen. It is the inherent high rate of ventricular rhythmicity in these cases which is the determining factor in the production of the auriculo-ventricular dissociations which follow right vagus stimulation. As soon as the vagus action slows the auricular rate below that at which the ventricles would contract by their own inherent rhythmicity, the ventricles cease to wait for the auricles as their pace-maker. They break through the pause, establish their own rhythm, and interrupt the normal course of the stimuli of the heart-beat. When vagus stimulation is discontinued, the auricular rate increases to a point where it is again sufficiently rapid to resume its pace-making function. An essential feature of the action of the right vagus in the production of these dissociations is its much greater inhibitory effect on the auricular rate relative to its effect on that of the ventricles, the rate of the inherent rhythmicity of the latter being apparently uninfluenced by stimulation of the right vagus nerve.

These patients in which dissociation followed right vagus stimulation had in common an abnormally rapid heart rate when at rest; an abnormally large pulse pressure occurred at least in two of the three cases; and in all, the heart action was thumping. The foregoing facts and the form of the undisturbed electrocardiograms from these cases have led us to the conclusion that the unusually high rate of the inherent ventricular rhythm, which has been the essential causative factor in the production of the dissociations, is the result of a hypertonus of the cardiac accelerator nerves. The undisturbed electrocardiograms from the cases showed very prominent *P* and *T* waves, resembling those obtained by Rothberger and Winterberg (9), after both vagi were cut. These authors conclude that the prominence of these waves in the electrocardiograms is typical of increased cardiac accelerator activity. The *P* and *T* waves are usually well marked in children, but in our cases a further abnormal exaggeration of them is seen. It is perhaps noteworthy that the fourth case, in which dissociation never followed vagus stimulation, also failed to show any of the signs which we have taken as indicative of accelerator over-action.

The question of accelerator tone is one which has not been very generally considered and little is known as to its normal occurrence. Hunt (10), however, who investigated the question extensively in dogs, reached the conclusion that the most important function of the accelerators, and perhaps their only demonstrable one, was their tonic activity.. Hunt has shown that the accelerators not only stand in antagonism to the vagi, but that stimulation of the right accelerator has apparently more effect on the heart rate than left accelerator stimulation. Rothberger and Winterberg (4) have confirmed this finding, and they also show that left accelerator stimulation raises the power of stimulus formation in certain regions, especially in the node of Tawara and in the left auricle. This action of the left accelerator nerve on the lower points of stimulus formation could not be demonstrated, as a rule, until the activity of the normal pace-maker, the sinus node, was depressed. They found that this depression could be accomplished not only by cooling and scarification but by vagus stimulation as well. It appears from their work (9) that the right accelerator predominates over the sinus node in the right side of the heart, while the left accelerator exerts a stronger action over the heart in the region of the atrioventricular bundle. There is some reason to believe then that each accelerator antagonizes each vagus more or less separately, and that there is a certain anatomical division between the innervation of the right and left side of the heart. This is probably only relatively true, however, as the nerves of the right side go over functionally into the domain of the nerves of the left side, and *vice versa.*

Rothberger and Winterberg (4) have shown that after section of all the heart nerves in dogs, simultaneous stimulation of the right vagus and left accelerator results in the establishment of subauricular autonomy. This phenomenon depends upon the fact that the hyper-accelerated rhythmicity of the atrioventricular node exceeded the rhythmicity of the vagus-slowed auricles, and so ultimately the atrioventricular node set the pace for both auricles and ventricles. Thus a true nodal rhythm is produced. During the transition between this nodal type and the usual rhythm, there occurred a time when the sinus node set the pace for the auricles and the atrioventricular node set the pace for the ventricles. Electrocardiograms

of this phenomenon in their dogs are very similar to those we obtained from our patients during the dissociations[2] described above. In our cases, we believe that both accelerators were in a state of increased activity or hypertonus. Although the left accelerator was exerting continuously its activity on the atrioventricular node, producing a heightened state of rhythmicity, this effect did not become apparent, for the right accelerator through its action on the sinus node sustained auricular rate at such a pace that ventricular autonomy could not assert itself. When, however, the action of the right accelerator was offset by stimulation of the right vagus, the rate of stimulus formation in the sinus node was reduced momentarily below that of the highly accelerated atrioventricular node. The atrioventricular node then asserted itself as the pace-maker of the ventricles, and complete dissociation resulted.

The form of the ventricular complexes in the electrocardiograms in two cases (Nos. I and III) is the same during the dissociation as when no dissociation exists. This indicates that in spite of the fact that the stimulus of the heart-beat no longer reaches the ventricles as a result of auricular contraction, it does arise in some point above the ventricles themselves. The stimulus reaches them and passes through them in a normal manner, for it is well known that stimuli arising in abnormal points in the ventricles, as in ventricular extrasystoles, give abnormal electrocardiograms. It seems probable that the point of origin of the ventricular stimuli is the atrioventricular node of Tawara. This node is considered on account of its specialized structure to have a higher rhythmicity than other points in the region of the ventricles, and Winterberg (11) has shown that electrical stimulation of the exposed heart in this region produces a normal ventricular complex in the electrocardiogram. In the third case (No. II), the independent ventricular complex in the electrocardiogram during the dissociation has an abnormal form, and here some other point in the ventricles has taken up the rhythm.

Left vagus pressure never produced dissociation in these cases, probably, on the one hand, because stimulation of this nerve never reduced the auricular rate sufficiently to allow the ventricular au-

[2] See especially figure 4*b*, *Arch. f. d. ges. Physiol.*, 1911, cxli, 355, and figure 1*e*, *ibid.*, 1910, cxxxv, 567.

tonomy to assert itself. Possibly, on the other hand, stimulation of the left vagus directly offset the tonic action of the left accelerator and so prevented the onset of that increased ventricular rhythmicity which would find expression in dissociation. Some other factor seems to operate besides the delay of the auricular rate in allowing the ventricular autonomy to assert itself, for in the same case dissociation sometimes occurred after cardiac cycles which were shorter than some after which no dissociation took place. This added factor might be considered to be the mechanical stimulation by pressure of the accelerator fibers which so often run in the vagus nerve; the well known, long latent period of the accelerator nerves, however, makes it very unlikely that this is the case.

It is our belief that in these three cases of so-called chronic endocarditis in which right vagus stimulation produced a dissociation between auricles and ventricles, hypertonus of the accelerator nerves is a striking and important feature in the pathological physiology. It is this factor that we consider responsible for the apparent overaction of the heart, as evidenced by the rapid rate, violent contractions, and the large difference between the systolic and diastolic blood pressure, indicating an abnormally large cardiac output per beat. It is this factor also that gives these cases the somewhat distinctive form of electrocardiogram and raises the inherent rhythmicity of the ventricles to such a point that they assume their own rhythm, independently of the auricles as soon as the auricular beats are reduced to a rate which is not excessively slow. The fact that the same characteristics are seen in the electrocardiogram and that the same type of dissociation may appear when the accelerators of the dog's heart are stimulated electrically, adds weight to this idea.

It is, of course, impossible to say why the hearts of patients such as these, who suffer from chronic cardiac disease after rheumatism, should show evidence of overaction of the accelerator nerves. There may be an increased susceptibility of the heart to the action of these nerves, there may be an absolute increase in their tonic activity, or there may be a relative hypotonic condition of the vagus inhibitory mechanism which allows the usually active tone of the accelerators (if such exists) to be abnormally effectual. It is possible that this hypertonus or constant overaction of the accelerators of the heart

represents a compensatory phenomenon which has gone beyond the limits of usefulness. On account of the valvular lesions, no doubt, it is necessary for the heart muscle to increase its work per beat and per minute in order to maintain the circulation properly, but the impression is gained by clinical examinations of these patients, that their hearts beat with unnecessary violence and rapidity and that there must be a constant fatiguing strain upon the myocardium. An increase of rest for the heart muscle by slowing the rate of its contractions is certainly an essential factor in restoring the compensation in many cases of heart disease. Besides rest in bed and such general measures as ice to the praecordium, there is often nothing of avail in reducing the heart rate, for in many cases digitalis and its allies fail, as do all other drugs and procedures, to produce any permanent benefit. If hypertonus of the accelerators is an important feature in the pathological physiology of these cases, as we believe it is, a rational therapy should be directed at lowering the activity of the cardiac accelerator nerves. This may require a new form of cardiac therapeutics.

SUMMARY.

The electrocardiographic records taken during vagus stimulation by pressure from children suffering with chronic heart disease have shown that the stimulation of the vagi in these cases is strikingly effectual. In some of the cases, a definite difference was demonstrated between the action of the right and left vagi. The control of the rate of the heart-beat seemed to predominate usually in the right vagus nerve, while the control of stimulus conduction from auricles to ventricles apparently predominated usually in the left vagus. This difference in the two nerves probably exists on account of the difference in their anatomical distribution, the right vagus going especially to that part of the heart which controls the rate of contraction, the sinus node above the right auricle, and the left vagus going especially to that part in which the conducting mechanism is found. Each nerve, however, has to a lesser degree the function which predominates in the other. The whole heart seems to respond, as a rule, more promptly to right than to left vagus pressure, and fairly constant differences have been seen in the effects which stimu-

lation of each nerve has on the various waves of the electrocardiograms. The stimulation of each vagus may influence directly the contractions of the ventricles, causing great diminution in their force.

Right vagus stimulation was followed at times by a complete dissociation of auricles and ventricles. The auricular rhythm was slowed sufficiently at this time to allow the ventricles, whose inherent rhythmicity is apparently unaffected by right vagus stimulation, to take up their own independent rhythm. The heightened ventricular rhythmicity in these cases allowed this to take place after only moderate slowing of the auricles. The independent ventricular rhythm was sometimes established in the region of the node of Tawara, for no disturbance of the ventricular portion of the electrocardiogram occurred. At another time, some other point in the ventricles inaugurated the stimuli of the independent ventricular contractions and an abnormal electrocardiogram resulted.

The resemblance of our curves, showing dissociation, to those obtained during right vagus and left accelerator stimulation in dogs is definite. That analogy, the clinical picture, and the form of the electrocardiograms of these cases have led us to the belief that an important feature in the pathological physiology of these cases is hypertonus of the cardiac accelerator nerves. This factor, as a cause of symptoms and as a hindrance to the establishment of cardiac rest, may prove of great importance, against which a new form of cardiac therapeutics must be directed.

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EXPLANATION OF PLATES.

PLATE I.

FIG. 1. Curve 19.4. Case I. Without vagus pressure.

FIG. 2. Curve 27.1. Case I. Without vagus pressure.

FIG. 3. Curve 27.2. Case I. Left vagus pressure.

FIG. 4. Curve 19.2. Case I. Right vagus pressure with dissociation of auricles and ventricles.

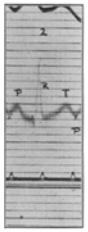

FIG. 1.

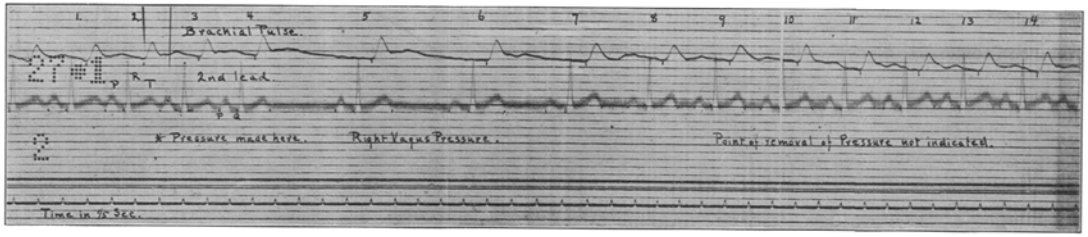

FIG. 2.

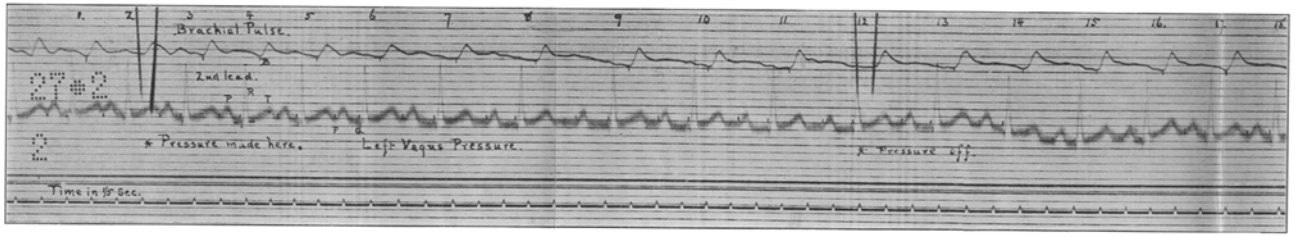

FIG. 3.

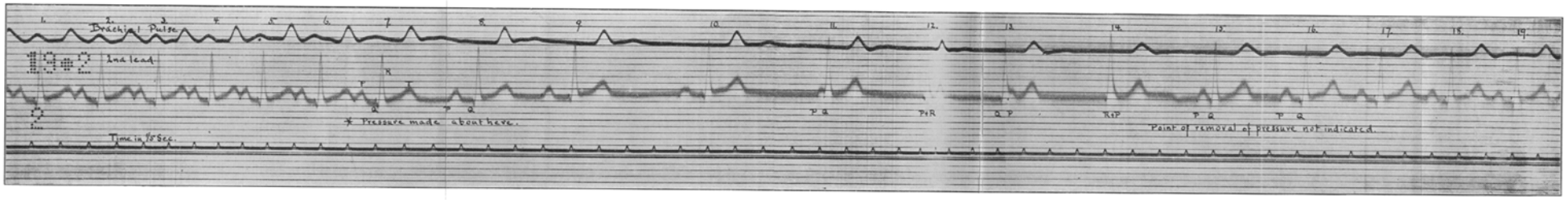

FIG. 4.

PLATE 2.

FIG. 5. Curve 19.5. Case I. Right vagus pressure. Cardiogram and electrocardiogram.

FIG. 6. Case I. Graphic record of the apex beat and brachial artery during right vagus pressure.

FIG. 7. Curve 41.4. Case II. Without vagus pressure.

FIG. 8. Curve 41.2. Case II. Right vagus pressure.

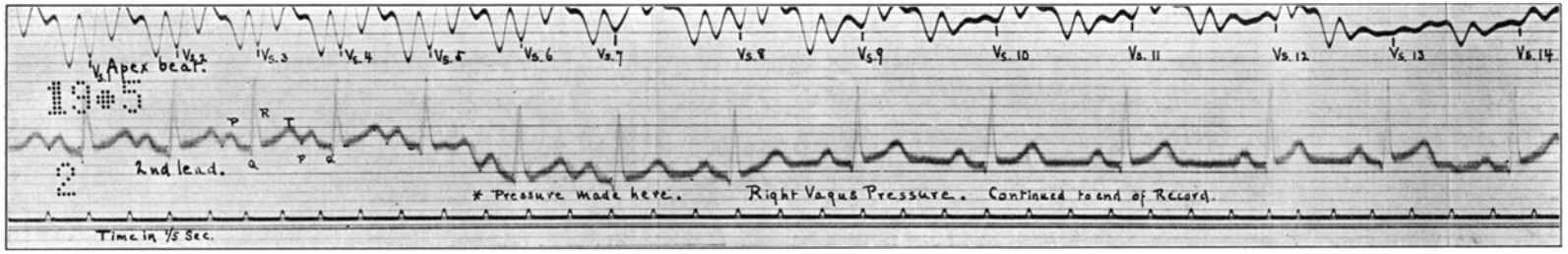

FIG. 5.

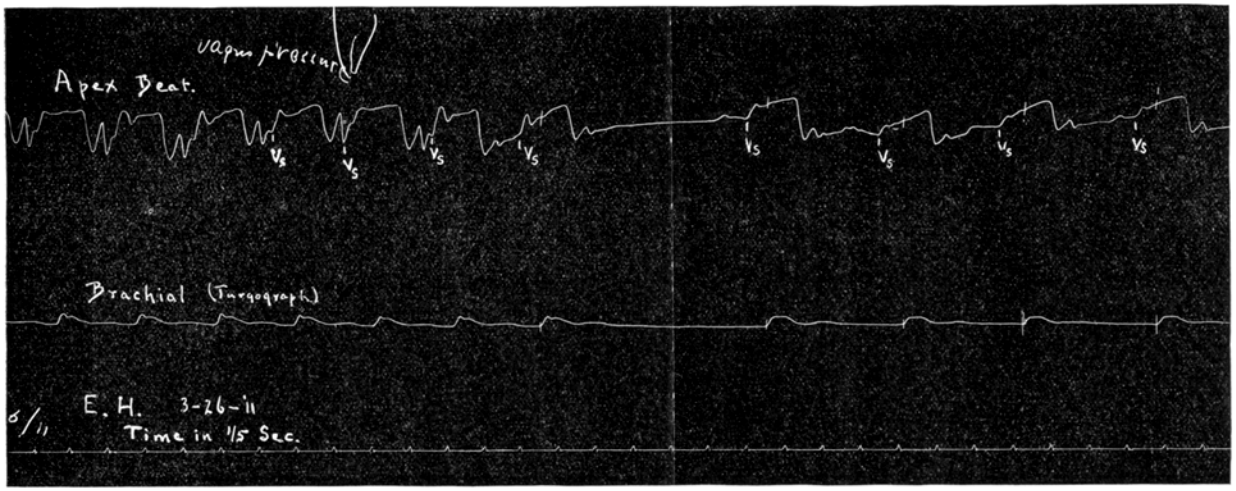

FIG. 6.

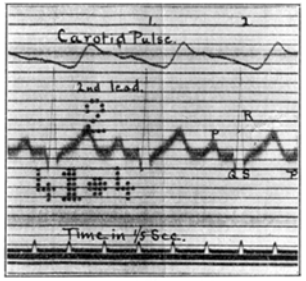

FIG. 7.

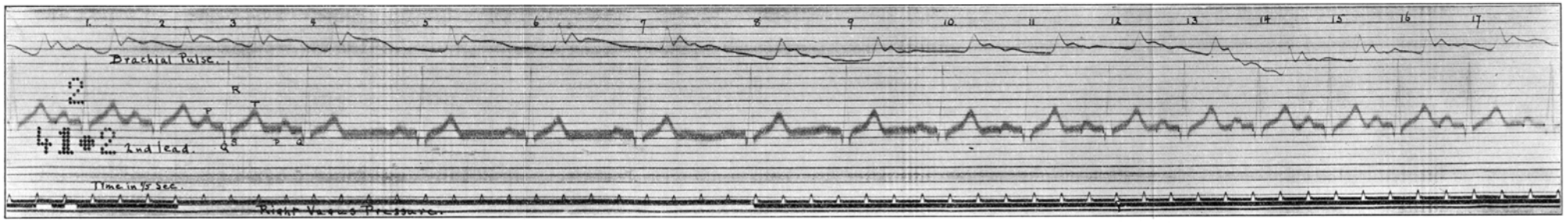

FIG. 8.

PLATE 3.

FIG. 9. Curve 41.6. Case II. Left vagus pressure.

FIG. 10. Curve 41.3. Case II. Right vagus pressure with dissociation of auricles and ventricles.

FIG. 11. Curve 47.1. Case III. Without vagus pressure.

FIG. 12. Curve 66.2. Case III. Right vagus pressure with dissociation of auricles and ventricles.

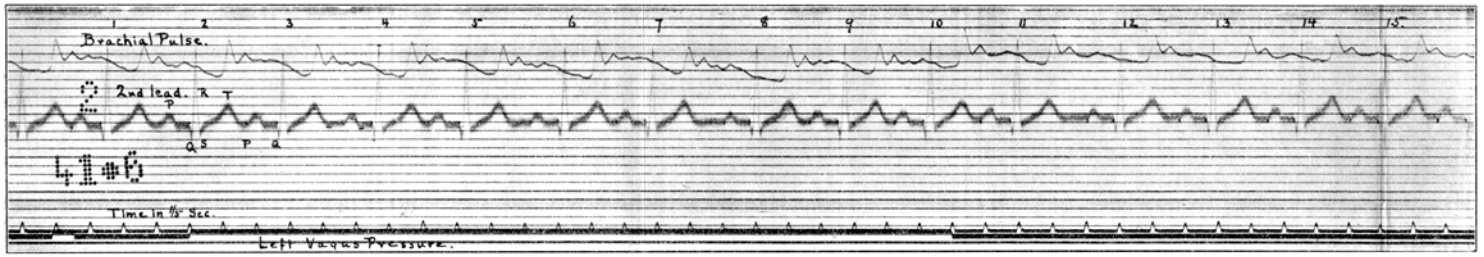

FIG. 9.

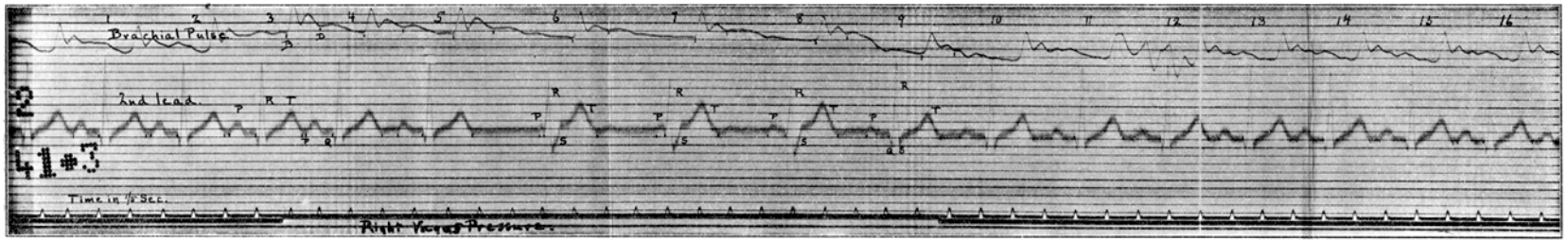

FIG. 10.

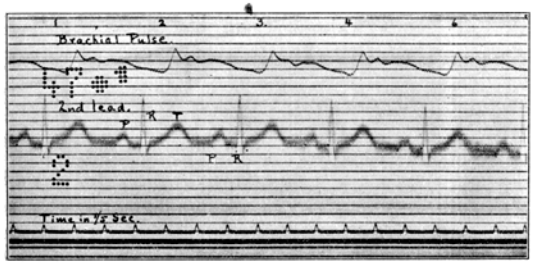

FIG. 11.

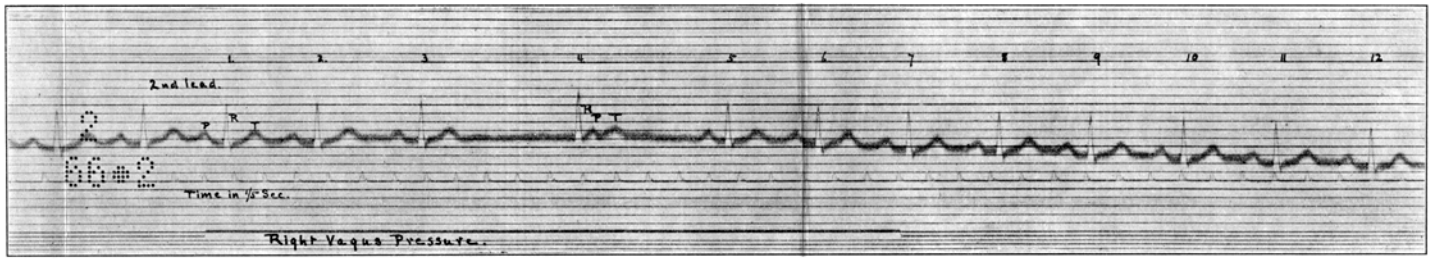

FIG. 12.

PLATE 4.

FIG. 13. Curve 66.4. Case III. Left vagus pressure.

FIG. 14. Curve 77.5. Case III. Right vagus pressure showing dissociation and the effect on the cardiogram.

FIG. 15. Curve 77.4. Case III. Left vagus pressure. Cardiogram and electrocardiogram.

FIG. 16. Curve 38.3. Case IV. Without vagus pressure.

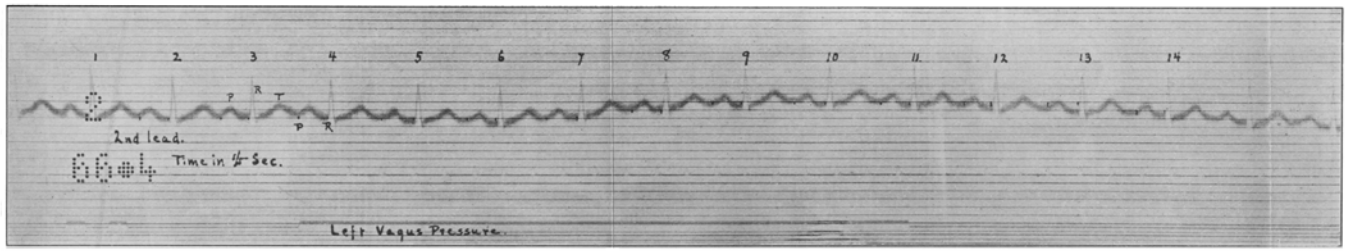

FIG. 13.

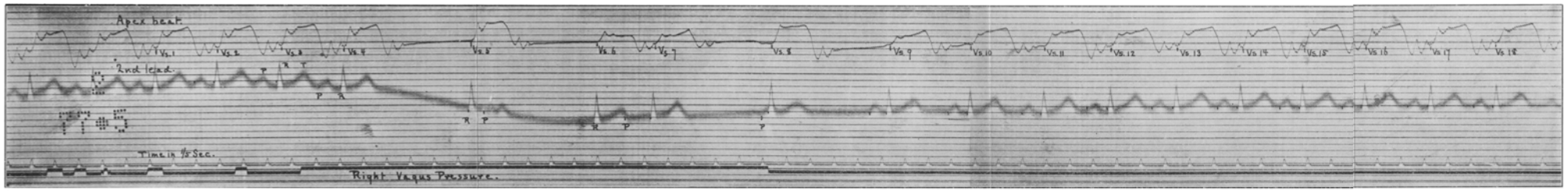

FIG. 14.

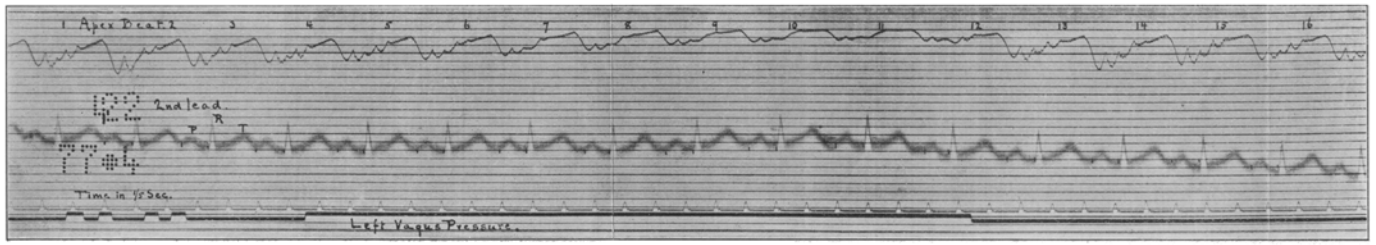

FIG. 15.

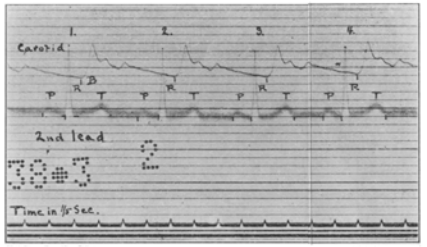

FIG. 16.

PLATE 5.

FIG. 17. Curve 38.4. Case IV. Right vagus pressure.

FIG. 18. Curve 38.5. Case IV. Left vagus pressure.

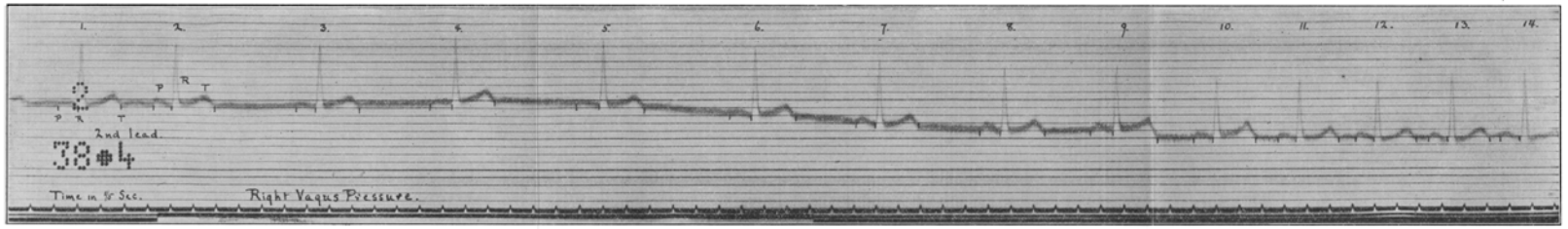
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14.
P R T
2nd lead.
38#4
Time in 5 Sec.
Right Vagus Pressure.

FIG. 17.

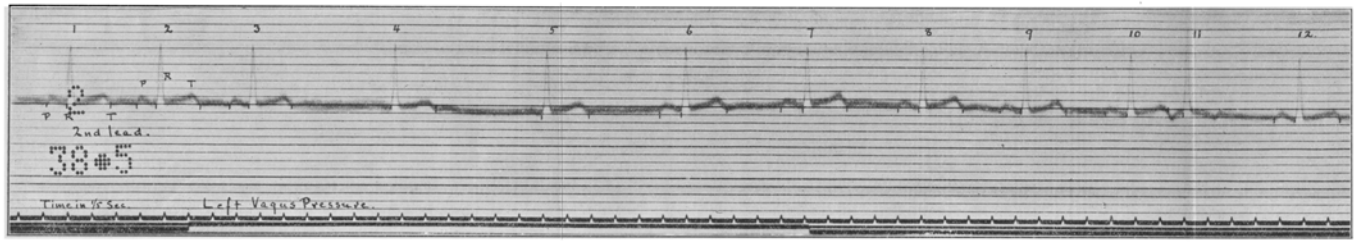
1 2 3 4 5 6 7 8 9 10 11 12.
P R T
2nd lead.
38#5
Time in 5 Sec.
Left Vagus Pressure.

FIG. 18.