A STUDY OF THE PRESPHYGMIC PERIOD WITH THE MICROGRAPH.*

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A series of tracings is given in text-figure 1, taken with films moving at the rate of 17.2 inches per second, in order to measure the time intervals with more accuracy than was possible with the lower speed. This speed is nearly three times that of the films from which the records were made in a former paper. 1 At this higher speed, approximately one cardiac cycle only is recorded on the length of film used. The vertical lines in the figure are spaced one tenth of a second apart. The line CC near the center of the figure is selected as a reference line at the one second mark, and marks the time of the beginning of the upstroke of the carotid pulse. Two curves were taken simultaneously in each case, the carotid always being one of the two. The series was obtained from the same subject as the set in text-figure 3 of a former paper, 2 and the apex tracing No. 24, text-figure 1, is very similar to tracings Nos. 2 and 3 in the figure referred to.

THE B-WAVE-GROUP.

The B-wave-group is very clearly marked in each of the pairs of simultaneous tracings Nos. 24 and 22, apex and carotid. Short vertical lines are drawn at the maximum and minimum points of the wave, and it will be seen that there is a fair approximation to regular periodicity. The period of the waves in the carotid, taking the average of a number of curves, is 0.0175 seconds, a distance of 0.3 inches in the figure; it represents a frequency of 57.4 complete waves per second. The period of the apex B-wave-group is a little

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less, 0.014 seconds, a distance of 0.24 inches in the figure, and a frequency of seventy-one complete waves per second.

The first wave of the B-wave-group in the carotid pulse, No. 24, at the point T, occurs 0.33 inches or 0.0192 seconds later than the corresponding first wave at Q of the B-group in the simultaneous apex tracing No. 24. The pair of curves, No. 22, carotid and apex, gives 0.41 inches, or 0.0238 seconds, for the same time interval, and the average of the two sets gives 0.37 inches or 0.0215 seconds as the difference in time of the B-wave-group in the carotid and apex curves.
The Presphygmic Period with the Micrograph.

If we assume that the B-wave-group in both the apex and the carotid tracings is caused by the closing of the semilunar valve, and also that the disturbance caused by the closing of the semilunar valve is propagated as a vibration through the aorta and the carotid artery, at the same rate of speed as the blood pressure waves travel from the heart to the brachial and the radial arteries, as previously determined, namely, 289 inches per second, it follows that the time interval, 0.0215 seconds, as above determined, corresponds to a distance of 6.22 inches travelled by the wave.

On our supposition that the disturbance starts from the closure of the semilunar valve, this time interval represents the difference between the two times of transmission from the semilunar valve to the carotid tambour and from the semilunar valve to the apex tambour at the positions where these tambours were located, the wave disturbance being propagated in different directions from the same origin. Hence the distance, 6.22 inches, represents the difference in the distances from the semilunar valve to the carotid tambour and to the apex tambour.

It should be stated that the length of the tube connecting the tambours with the interference instruments was the same for each, about four feet, and in taking differences the time of travel of a pressure wave through these tubes of the instrument may, therefore, be neglected, although the time is only 0.004 seconds.

The distance from the semilunar valve to the apex tambour may roughly be taken as five inches, and to the carotid tambour as eleven inches, making a difference of six inches in the two distances. This corresponds well with the distance, 6.22 inches, as measured above, and this coincidence, therefore, helps to confirm the supposition that the B-wave-group is caused by the closing of the semilunar valve.

THE PRESPHYGMIC PERIOD.

The two pairs of simultaneous tracings, Nos. 23 and 25, carotid and jugular, show that the B-wave-group appears in both tracings at very nearly the same time. The difference in the location of the jugular and carotid tambours was about two inches, and this distance corresponds to less than 0.01 seconds in the time of travel of the B-wave-group.
In comparing the jugular and the apex tracings, it is necessary to set the jugular back in time to allow for the time of travel of the waves along the vein. If the distance from the mitral valve to the jugular tambour is nine inches, the time required for the waves to travel this distance is 0.031 seconds, or a distance of 0.535 inches in text-figure I. The jugular tracing No. 23 is represented by the curve 23A in text-figure I, when it is moved backwards in time 0.031 seconds, and this curve may now be compared directly with the apex tracing No. 24.

It may be objected that the apex tracing should also be moved back about 0.017 seconds, or 0.3 inches, to allow for the time of travel of the liquid wave over the distance, five inches, from the valves to the apex tambour. This should no doubt be done when considering the B-wave-group as above, where a wave is actually transmitted through the blood in the ventricle to the apex tambour; but when considering the presphygmic wave, P, due to a contraction of the ventricle itself, which is almost in contact with the tambour at the apex, no time need be allowed for the travel of the waves. The two curves, apex No. 24 and jugular No. 23A, therefore, stand in their correct positions when the presphygmic period is to be considered.

The presphygmic wave at P in the apex tracing No. 24 is practically identical with this wave as shown at P, text-figure 3, in a former paper. The well known A-wave in the jugular tracing, due to auricular systole, is clearly marked beginning at the point F and finishing at D, 0.12 seconds later. It will be observed that the presphygmic wave, P, in the apex curve, begins at a point X a little before (0.0175 seconds) the close of auricular systole at D. This means that the mitral and tricuspid valves are open at the time the presphygmic contraction sets in, and the immediate effect of this contraction must be to close these large valves, and in so doing a sudden impulse must be transmitted back through the auricles to the veins, and we should expect to find some trace of this shock transmitted to the jugular tambour.

Waves of the nature of a sudden shock such as this will travel along a vein even though there are valves in the vein to prevent the

\[1\text{Jour. Exper. Med., 1911, xiv, 354.}\]
back-flow of a steady current. The impulse will easily pass through
the valve without the necessity of the passage of any blood.

The wave we should expect is seen as a very pronounced wave
which is marked the M-wave in the jugular record immediately
following the crest of the presphygmic wave, P, and is due to the
closure of the mitral valve. The crest of this M-wave in the jugu-
lar coincides almost exactly with the sharp depression marked M in
the apex tracing, and it may therefore be considered that the mitral
valve is closed at or near this lowest point in the apex curve, just
at the close of the presphygmic wave, P, and also at the beginning
of the large wave of ventricular systole, S.

When the real ventricular systole begins, therefore, at M it finds
the mitral and tricuspid valves already closed, and there is a
firm backing which serves as a good fulcrum to force the blood into
the arteries. The closure of the mitral valve at or near the point
M leaves the ventricles for a very short time as completely closed
chambers; for the pressure has not yet increased sufficiently to open
the semilunar valves. In this condition the pressure within the
ventricles must rise very rapidly until the semilunars open.

At the point A_0 on the apex curve, just after the sudden rise
from the bottom point, M, there is an abrupt jog, which is present
in all the apex curves, that is, a sudden change in the direction of
the rapid upstroke. It is conjectured that at this point the aortic
semilunar valve opens and admits blood to the arteries. That this
conjecture is well founded is proved by measuring the time interval
between A_0 and the line CC, or the beginning of the upstroke of the
carotid; for this interval of time must represent the difference be-
tween the times of travel of the blood pressure from the semilunar
valve to the carotid tambour, and the wave through the blood in the
ventricle to the apex tambour. This time interval we have meas-
ured when considering the B-wave-group above, which is due to the
closure of this same valve, the opening of which is now being con-
sidered. This interval is 0.37 inches in text-figure 1, or 0.0215
seconds, and is very nearly equal to the distance from the point A_0
to the line CC.

The time during which the ventricle is a completely closed cham-
ber is, therefore, probably the interval from the point M to the
point K, where the aortic semilunar valve begins to open, a distance of 0.34 inches or 0.0198 seconds. The valve is completely opened for the flow of blood at A. The time during which the chamber of the ventricle is closed is, therefore, approximately 0.02 seconds.

The direction of motion of the valves should also be considered. When the aortic valve opens it does so in a direction away from the apex of the heart and is recorded at K as a slight depression in the apex curve, rather than as an elevation. Similarly, when the mitral valve closes at M, it moves away from the apex and toward the jugular vein, and is recorded as a depression in the former and an elevation at M in the jugular tracing.

In the light of the foregoing description of the events connected with the presphygmic period, it may be said with some confidence that the presphygmic contraction of the ventricle is for the purpose of closing the large mitral and tricuspid valves just before the powerful ventricular systole sets in, in order to prevent the very sudden shock which these valves would receive if they were slammed shut by the sudden impact of blood backed up by the great pressure of systole. This provision makes for the smooth running of the heart without jar or undue strain.