Original Communications.

ON THE USE OF THE SPHYGMOGRAPH IN THE INVESTIGATION OF DISEASE.

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The advances made of late in the diagnosis of disease by means of instrumental contrivances, have been so many and so great, that they will hereafter doubtless be considered as forming the chief characteristic of the medicine of this age. The stethoscope has for years past been rendering our knowledge of certain diseases more exact, by enabling us to detect and follow changes in the condition of the thoracic viscera, that were, before its invention, hidden from us. The microscope has not only aided us in the diagnosis and prognosis of disease, but has wonderfully assisted in the elucidation of pathological change. Diseases of the eye, hitherto obscure, are now illuminated by the ophthalmoscope; and certain intracranial conditions promise to reveal themselves by the same means. The laryngoscope has thrown its light upon a region whose morbid conditions were before but vaguely understood, and has enabled us to treat locally the maladies of a tract into which, a few years back, it was doubted if an instrument could be passed.

The introduction of all these appliances has been followed, not only by a much more perfect knowledge of disease, but has also heralded a no less considerable advance in its treatment. Any new aid, then, that ingenuity can devise to enable us to recognise with precision conditions that escape our unaided senses, we should gladly hail with no small hope that by its means we may be able to extend the limits of our knowledge.

To-night I have to bring before this society an instrument invented originally for physiological research, but which has since been applied to pathological investigation with no small advantage. Its inventor (M. Marey), impressed with the idea that a sound knowledge of the laws which preside over a function in health, must precede any improved knowledge of the disorders of that function, has first carefully investigated experimentally the physiology of the circulation of the blood, and then applied the information thus obtained to its pathology. (*Physiologie Médicale de la Circulation du Sang.* Par le Dr. E. J. Marey. Paris: 1863.) In such inquiry, the arterial pulse presented a prominence that could scarcely fail to attract much attention; and, to assist in its investigation, the sphygmograph has been invented, or rather modified.

The value of the indications afforded by the pulse in disease has been much neglected of late years, probably on account of the many and more accurate means at our disposal for obtaining information as to the state of the circulation. Our knowledge of its physiology alsc has not been sufficiently advanced to render the attentive study of its morbid characters a fruitful subject; and, moreover, our means of appreciating its finer differences have been very imperfect. The finger placed on an artery perceives only the grosser peculiarities of the arterial movement, such as force, frequency, and regularity; the more subtle differences, from the fleeting character of the sensation experienced, escape our notice, or, when observed, convey no distinct or explicable impression to our minds. In order, therefore, that the pulse should yield valuable evidence in disease, we must first understand thoroughly its nature and causes; and secondly, we must so improve our means of investigating it, that we may recognise and retain a knowledge of its finer features.

The sensation of hardening and elevation felt by the finger placed over an artery, at each contraction of the heart, has been termed the arterial pulse. At each systole of the ventricle, we know that the blood driven into the arteries produces a varying amount of dilatation of the vessels. The arteries, distended by each new blood-wave, tend, by virtue of their elasticity, to contract upon their contents, and, while modifying by their recoil the ventricular force, they nevertheless drive the blood on in its course. The greater the distension of the vessels, the stronger will be this elastic recoil, or, in other words, the arterial tension. The phenomena of the pulse are thus intimately connected with the tension of the arteries, and may be said to be "a direct result of the changes which the arterial tension experiences under cardiac action." Whenever we place the finger on an artery situated in a position favourable to compression (*e.g.*, over an osseous plane), the alternations of elevation and depression of the vessel tell us the variations in the tension of the arterial wall. The hardness of the pulse is, to some extent, a measure of the arterial tension; a soft full pulse, on the other hand, points to feeble pressure within the vessels. The movement of the blood through its channels gives, according to its character, many variations to the pulse form, which escape our unaided senses, and can only be collected and appreciated by an improved method of investigation.

The sphygmograph of Marey* affords us the necessary aid; and by it we can gain not only a knowledge of the finer differences which escape our touch, but we can also preserve for inspection a distinct trace of these delicate peculiarities. The accompanying cut (Fig. 1), copied from Marey, shews us in the interior of the frame (Q R) the essential part of the instrument, which consists of a flexible steel spring (I), and which is covered on its under surface at its free extremity with a convex plate of ivory (K). This plate rests upon the artery to be examined, and, by virtue of the elasticity of the spring (I), exerts a certain pressure upon it. Each pulsation of the vessel raises the spring slightly at K, and the multiplication of this movement is obtained by means of a very light lever (A), which moves upon a pivot (C). The elevation of the spring is transmitted to the lever, very near to its centre of movement, by means of a bar of metal (B E), which moves round the point (E); this bar terminates by a vertical plate (B D), and is pierced by a screw (T). When the screw acts upon the spring, the connection is established between the spring and the bar, and the movements of the spring are transmitted to the bar, and through its vertical plate to the lever. In order to insure the transmission of the movement, the plate (B N) must be in contact with the under surface of the lever; by means of the screw (T) we can arrange this, and regulate the interval between the point of the plate (B D) and the

* To the kindness of Dr. Anstie, I owe my first acquaintance with the instrument; and to him we are, I believe, indebted for its first introduction to a medical society in this country.

under surface of the lever. In order that the lever should not be projected too much upwards by sudden movement, and also that it should overcome any slight friction experienced in the paper at its terminal point (A'), a small spring (Y) rests upon its fixed extremity, and presides over its descent. The screw (P) enables us to regulate the amount of pressure exercised upon the artery by the spring (I). The

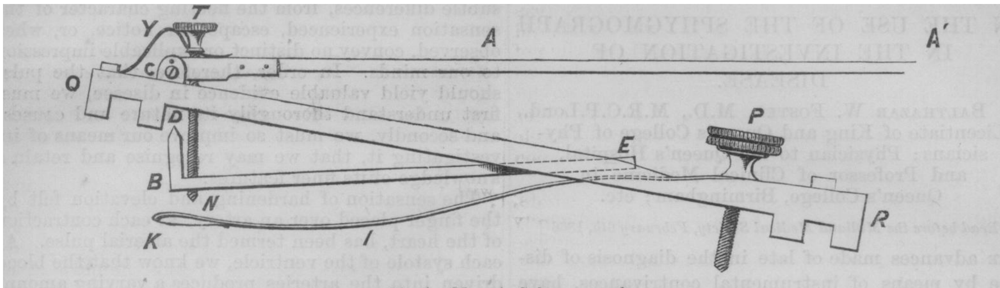

Fig. 1.—Marey's Sphygmograph.

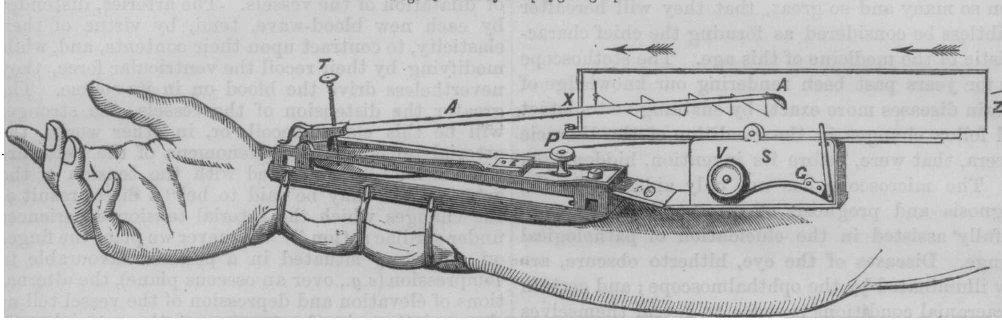

Fig. 2.—Sphygmograph applied to Arm.

woodcut (Fig. 2), modified from Marey, shews the instrument placed upon the arm over the radial artery in the position for use. The lever (A) is here seen to carry at its free extremity a little pen, which, filled with ink, registers its movements upon the paper which covers the plate (X Z); this plate is moved at an uniform rate in the direction indicated by the arrows, by means of watch-work placed beneath in the case (S). Ten seconds are occupied by the passage of the plate. The button (V) enables us to wind up the watch-work; and the small regulator (G) starts or stops the motion of the plate, as desired. The application of the instrument I have found much facilitated by the use of elastic bands, instead of a silk lace, as recommended by Marey. These bands embrace the arm, and are hooked on to the small projecting points on the metal framework, as seen in the diagram. The addition of a pad* to the under surface of the arm renders the instrument more comfortable to the patient, and prevents any pressure from the bands.

The instrument, when in action, enables us to obtain an exact representation on paper of the pulse form; it also tells us the frequency of the pulsations and their regularity. It enables us, in addition, to see at a glance any peculiarity in the entire series, or in any single pulsation. A trace, as seen below (Fig. 3), is com-

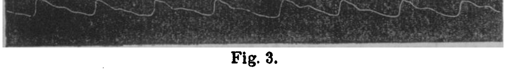

Fig. 3.

posed of a series of curves, each of which corresponds to a complete revolution of the heart, and is called a *pulsation*. On analysis, each pulsation is evidently composed of three parts: the line of *ascent*, the *summit*, and the line of *descent*. The line of *ascent* is caused by the flow of blood into the arterial system after each cardiac systole; and tells us, by its form, the manner in which the blood enters the vessels. The more rapid the afflux, the more quickly the pressure in the arteries will be elevated, and the more vertical will be the ascent of the lever. When the entry of the blood is slow, the line of ascent will be traced by the lever obliquely, or rather in a curved form. The line of ascent, in certain morbid conditions, exhibits a mixed form—the first part of the trace being vertical, the latter part curved. The *summit* of the pulsation corresponds to the duration of the arrival of blood in the artery, and designates the period during which the entrance balances the onward flow—in other words, the afflux and efflux are exactly equal. This period varies in length; it may be so short, that the summit becomes a mere mathematical point between the lines of ascent and descent, or it may have sufficient duration to render the summit a horizontal line of some length. In the latter case, the lever traces the horizontal line so long as the entry of blood into the vessel and its passage onwards mutually balance one another, and this line indicates the duration of the cardiac systole. The summit of the pulsation, when of any length, is not always horizontal; it may be formed by an ascending or descending plane, according as the afflux predominates over the onward flow, and *vice versâ*. In some cases a little hooked point may precede the summit; and this proves a very valuable diagnostic element in the trace, as we shall see further on. The line of *descent* corresponds to the fall of the pressure in the arterial system, and is synchronous to the interval between the closure of the sigmoid valves and the next ventricular contraction. This line, by its obliquity, marks the celerity of the fall of the pressure within the vessels, and indicates the facility with which the blood passes on in its

* I am indebted to my clinical clerk, Mr. Waters, for the suggestion of the pad.

course. The frequency and amplitude of the pulse are pointed out by the obliquity of this line. The form may vary very much; sometimes it is purely oblique, at others a curve convex upwards, and occasionally one or more undulations may be seen in it. This last peculiarity is often very marked, and in some cases is perceptible to the finger; it has been termed *dicrotism*. By this term, we should only understand undulations occurring in the line of descent. Similar peculiarities have been pointed out in organic diseases of the heart; but these refer to the period of ascent, and are due to very different causes. The sphygmograph here gives us valuable aid; for it enables us to recognise to which period the peculiarity belongs.

Marey, from a series of remarkable experiments, concludes that this phenomenon is due to purely physical causes, and depends on the quickness of the entrance of the blood into the vessels and the elasticity of the arterial walls, whence results an oscillation of the column of liquid in a direction alternately centrifugal and centripetal.* The dicrotism will bear, then, a close relation to the rapidity of the ventricular contraction and to the elasticity of the arteries. Thus, in certain cases in which the blood enters the aorta slowly and the line of ascent is curved, the dicrotism is absent. When the heart contracts suddenly and forcibly, the blood enters the vessels with much speed, then the rebounds are plainly seen.

The occurrence of dicrotism is favoured by whatever increases the elasticity of the arteries, and is opposed to whatever diminishes it. Thus, conditions which are associated with great elasticity of the arterial walls, as dilatation of the vessels and easy passage of blood through the capillaries, are marked by evident dicrotism in the line of descent. The trace (Fig. 4), taken during the perspiration of hectic,

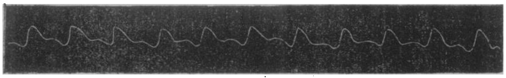

Fig. 4.

shows this characteristic. In the following trace (Fig. 5), the senile change in the vessels, and consequent loss of elasticity, is indicated by the absence of dicrotism—as well as by other characters to which we will hereafter refer.

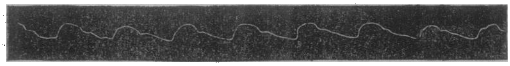

Fig. 5.

In examining a pulse-trace, one should note, in addition to the form of each pulsation, whether the summits of all of them can be joined by a horizontal line, and whether the bases can be also connected by a similar line parallel to the former. In some cases, this ceases to be the case, and a series of pulsations cannot be contained between such imaginary lines. The pulsations become irregular, and the line to join their summits or bases must cease to be horizontal.

The line joining the summits of a series of pulsations is the line of the maxima of *arterial tension*, and to it we will now confine ourselves. Its value as an indication is not absolute; it only tells us the variations that the arterial tension may undergo during the period of the observation; and it enables us to judge of the relative pressure within the vessels during any of the cardiac contractions registered. In the trace below (Fig. 6), by compressing the femoral artery during the first part of the trace, the tension was increased; and, on the compression being withdrawn during the latter half, the tension fell.

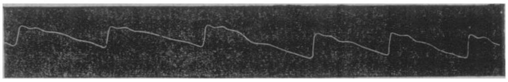

Fig. 6.

This line of greatest tension is of much value, and, with the corresponding line of least tension, should be observed in all cases, as these lines undergo generally parallel deviations, and a glance at either usually suffices to inform us of any change. Many influences act upon the pressure of the blood in the arteries; and of these, respiration is probably the most interesting, and will, when further investigated, yield much useful information to the physician.

The *frequency* of the pulse may be also studied by means of the sphygmograph; for, as the plate moves at an uniform rate and occupies exactly ten seconds in its passage, we can with ease calculate the pulse-rate. By this means, too, slight variations in frequency and irregularities are revealed to notice that would most probably escape the unaided touch. The frequency of the heart's action, according to the French physiologist, depends very much upon the state of the circulation in the vessels of the periphery; an easy passage of blood favouring the increased action, a difficult passage, by reason of the greater arterial tension, causing diminished frequency of the ventricular systole.

The law is laid down, that, in the majority of cases, "the frequency of the pulse is in inverse proportion to the arterial tension." (Marey, *op. cit.*, p. 209.) M. Marey has made a series of experiments in reference to this point, and some of them I have been able myself to confirm. By the compression of any of the large arterial trunks, we can easily elevate the tension of the other vessels, and so diminish the frequency of the pulsations. This is seen in a trace already figured (6), in which the femoral was compressed. With the fall of arterial tension, on the removal of the compression, we can notice the increased frequency of the beats. In the trace below (Fig. 7) also, during

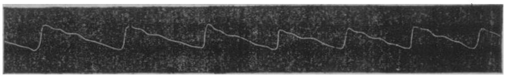

Fig. 7.

the first four pulsations, the arm and leg of the opposite side were elevated, and thus the arterial tension (as pointed out by Marey) increased; and, on the restoration of the limbs to the horizontal posture, during the remainder of the trace, increased frequency of the pulse, as registered, took place.

Of the following traces, the first (Fig. 8) was taken

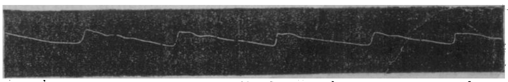

Fig. 8.

with the skin rather colder than usual; and the second (Fig. 9), twenty minutes afterwards, when,

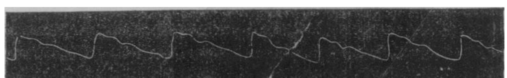

Fig. 9.

* Naumann has explained the dicrotism by the impact of the blood against the closed aortic valves, which, like the sudden stoppages of the flow through any set of tubes, produces a jarring impulse through the blood column. (*Vide* Carpenter's *Human Physiology*, 1864, p. 240.) I was inclined to prefer this explanation at one time to Marey's; but my observations on the occurrence of the dicrotism in certain diseases of the arteries and in cases of aortic insufficiency, have led me to accept the explanation given above.

from increased warmth, the vessels on the surface were relaxed. A comparison of the pulsations of each trace points to the greater rapidity of the circulation under influences which facilitate the passage of the blood.

The *force* of the pulse is indicated by the height of the pulsations. The greater the elevation of the lever, the greater the energy of the pulse-beat; and we may say that, in many cases, the strength of the ventricular contraction is expressed by the force of the pulse. This law, however, has many exceptions; and we find that the altitude of the pulse-trace depends on several other conditions.

I. The volume of the artery influences much the amplitude of the trace. This can be well seen in traces collected from old persons. In senile changes, the volume of the vessels is increased considerably, and the trace betrays great fulness. Marey believes this to be due, not solely to the hypertrophy of the ventricle which exists in the old, but also to the dilatation of the artery. (*Vide* trace, Fig. 5.)

II. The state of arterial tension modifies greatly the force of the pulse; and, as the tension is dependent on the state of the capillary circulation, it may be said that in most cases "the force of the pulse is not in relation with the energy of the ventricular systole, but that it is regulated by the state of the circulation in the ultimate ramifications of the vascular system." (Marey, *op. cit.*, p. 235.) By means of the manometer, in a great number of experiments, this law has been found to hold good; a feeble state of arterial tension giving to the finger and the instrument the sensation of increased amplitude. Marey, by means of the following diagrams (Figs. 10 and 11), illustrates this very well.

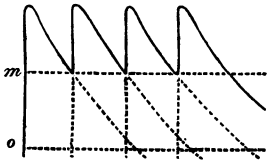

Fig. 10.

The first shows the form of pulsation in a state of feeble tension; the second, under a state of strong tension. The difference in the amplitude of the traces is very distinct. In the state of feeble tension, or easy passage of the blood onwards, the lever falls quickly to the point of least tension, and is ele-

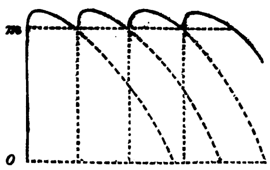

Fig. 11.

vated considerably at each pulsation. In the case of difficult passage of the blood through the capillaries, and consequently of great arterial tension, the lever descends slowly by a line convex upwards; and, long before it has reached a minimum tension equal to that in the former case, the lever is raised slightly by the next pulsation. While the lines of the maxima of arterial tension are the same in both cases, the lines of the minima are very different. On this depends the amplitude of the pulse-trace.

III. The duration of the interval which separates the pulsations has also a distinct influence on the amplitude of the trace. This is due to the fact that, during a long interval, the blood flowing continually onward lessens the pressure in the vessels, and thus favours the greater amplitude of the next pulsation. This is well seen in a trace (Fig. 12) taken from a patient of mine in the Queen's Hospital.

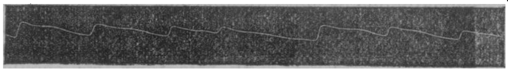

Fig. 12.

The condition of the vessel itself, as to permeability below the point observed, influences the force of the pulsation by altering the pressure within the artery. Marey has also pointed out that in some cases, where the pulse-beat is almost imperceptible to the finger, the sphygmograph records a considerable amplitude of trace; and *vice versâ*. I have been struck with this peculiarity in several instances; and the explanation appears to be, that we perceive changes in the artery more distinctly in proportion as they occur more suddenly. The cases in which the pulse has been almost imperceptible to the touch, but has nevertheless yielded a distinct trace, have been associated with a very slow distension of the vessels.

The foregoing remarks, based upon the work of the French author, will, I trust, by pointing out the meaning of the many forms of pulse-trace, and by setting before us the causes to which they are due, enable us to understand more clearly the changes exhibited by the arterial pulse-form in disease. The remainder of the paper I shall, with the permission of the Society, devote to a consideration of some few of the many pathological conditions in the detection of which the use of the sphygmograph renders us invaluable aid.

[*To be continued.*]

ON THE USE OF THE THERMOMETER AS A GUIDE IN THE DIAGNOSIS OF PYREXIAL DISEASES.

By F. W. Gibson, B.A., M.D.London, late House-Surgeon of the Taunton and Somerset Hospital, Taunton.

[*Concluded from page* 251.]

Typical Range of Temperature in different Diseases.

A knowledge of the range of temperature peculiar to each disease enables the observer, when he perceives any marked departure from the type, to pronounce either that his diagnosis is wrong, and that the disease is not what it appeared to be, or that some secondary lesion has supervened.

For example, the typical range or temperature in typhoid (Peyerian) fever, as established by Wunderlich, is as follows.

	Morning.	Evening.
First day	98.5 deg.	100.5 deg.
Second day	99.5	101.5
Third day	100.5	102.5
Fourth day	101.5	104
Second half of week	102	104

At the commencement of the second week, in mild cases, the temperature begins to decrease; for, although the evening temperature may be 104 deg., the morning is only 102 deg. In severe cases, on the other hand, the morning temperature is above 103 deg.; the evening above 104.5 deg., and may reach 106 deg. In the third week, remarkable vacillations of four to six degrees between the morning and evening temperature occur. The fever terminates