apical infection a necessary corollary of dermatological or of constitutional effects? A good deal of light could be thrown on the subject by X ray investigation of every case where dental infection is suspected. But the reading of plates and prints—I write from a considerable experience of radiography during the war—requires an expert, who must be unbiassed.

3. Because in five cases dental sepsis would appear to have been the cause of certain skin manifestations, it would be unwise to argue that the types of skin lesions discussed are necessarily always associated with dental infection. It is, however, hardly open to denial that in dental infection of a certain type we may have hit upon one cause—and that an easily accessible one—for the production of urticaria, erythema multiforme, intractable furunculosis, and pruritus of otherwise unknown origin.

Every case must be investigated on its own merits, and this paper aims at no more than indicating a by-path in which valuable information may sometimes be found.

VELOCITY OF TRANSMISSION OF THE PULSE-WAVE

AND ELASTICITY OF ARTERIES.

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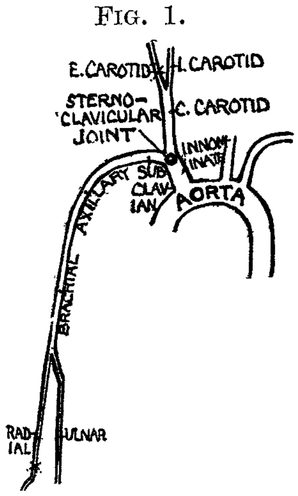
IN the course of an investigation in which we are at present engaged we have had occasion to make a considerable number of observations on the velocity of transmission of the pulse-wave, both in health and in disease. Since the technique is simple, and the records yield very accurate measurements, it seems likely that the method employed will not only be of service in the investigation of problems of purely scientific interest, but may also have a practical application in the field of clinical medicine.

Method Employed.

In order to determine the velocity of transmission it is necessary to measure the time taken by the pulse-wave to travel along a known length of artery. Most of our observations have been made on the upper limb. Synchronous sphygmograms of the right carotid and right radial pulses are recorded, and measurements made from the right sterno-clavicular articulation to the points in the neck and wrist from which the two records are obtained (Fig. 1). The right sterno-clavicular articulation corresponds to the point of bifurcation of the innominate artery. Hence the interval which elapses between the commencement of the carotid and radial deflections respectively is the time taken by the pulse-wave to travel from the sterno-clavicular joint to the wrist, less the distance from the same point to the carotid.

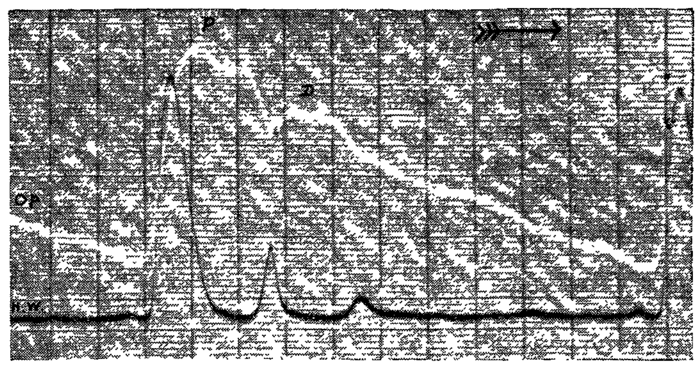
FIG. 1.



Anatomical diagram of measurements taken in estimating pulse-wave velocity in upper limb. Receivers are placed on the cartoid and radial arteries at points marked with a cross.

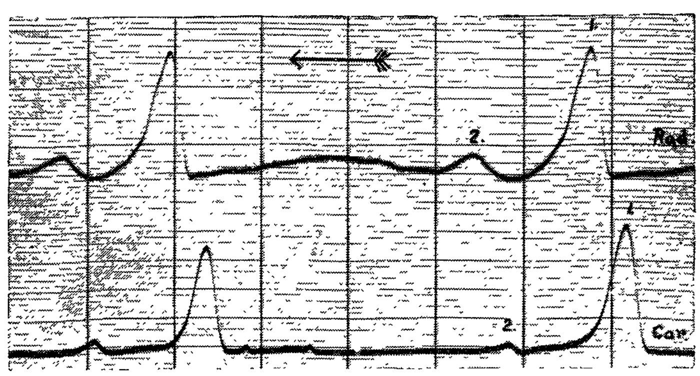
The general features of the hot-wire sphygmogram have previously been described.[1 2] The primary wave, with which alone we are concerned in the present paper, corresponds in time to the rapid rise of pressure which follows immediately on the arrival of the pulse-wave in the artery under investigation (Fig. 2). The radial and carotid pulses may be recorded separately by employing two bridges and two galvanometer strings (Fig. 3), or may be combined to form a single record by connecting the two hot wires in parallel to the same bridge, so that their alterations in resistance are recorded on the same string of the galvanometer (Fig. 4).

FIG. 2.



Synchronous optical and hot-wire sphygmograms obtained by connecting the two recording instruments in series to the same receiver. Thus, points on the two curves which fall in the same vertical plane are synchronous records of the same event in the carotid cycle. It will be seen that the primary wave of the hot-wire sphygmogram is synchronous with the upstroke of the percussion wave in the optical record. Op = Optical sphygmogram. H.W. = Hot-wire sphygmogram. P = Percussion wave. D = Dicrotic wave. Time intervals 0·099 sec. Record reads from left to right.

FIG. 3.



Radial and carotid sphygmograms recorded on separate strings. Time interval 0·2 sec. Record reads from right to left. 1. = Primary deflection. 2. = Secondary deflection. Rad. = Radial. Car. = Carotid.

Results Obtained.

Table I., which contains the results of a small number of observations on normal healthy individuals, shows that there is a general agreement between age and pulse velocity. The older the subject the more rigid are his arteries, and the higher the velocity of transmission of the pulse-wave. With a large number of observations it would be possible to plot a curve representing this relationship, and even the small number of figures in Table I. is sufficient to give some indication of the general disposition of this curve (Fig. 5).

Under pathological conditions, on the other hand, this relationship between age and pulse velocity is no longer present, as will be seen from Table II., which is compiled from observations on a miscellaneous collection of patients in hospital suffering from the various diseases mentioned. The data at our disposal are at present insufficient to enable us to draw any general conclusions with regard to the alterations in pulse velocity which are met with under different pathological conditions, but that such alterations do occur is already sufficiently evident.

Theoretical Aspect.

Elasticity of the arterial walls is a factor of fundamental importance to the circulatory mechanism. It is owing to this property that the arteries are able to

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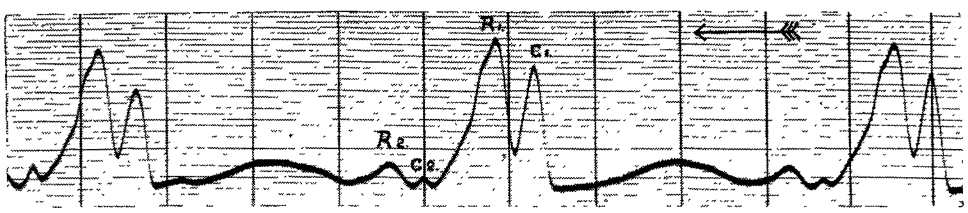
transform an intermittent cardiac output into a continuous capillary flow. The more perfect the elasticity of the arteries the greater will be the volume of blood which they are able to accommodate for a given rise of pressure. Now the amount of energy

TABLE I.—*Showing General Relationship of Age to Velocity of Transmission of Pulse-wave in Normal Healthy Individuals.*

Age (years).		Velocity (metres per sec.).	Age (years).		Velocity (metres per sec.).
6	......	4·7	32	......	7·2
20	......	6·0	35	......	6·6
24	......	6·7	51	......	7·4
28	......	7·5	66	......	8·5

expended by the heart per beat, as measured by its oxygen consumption or CO_2 output, has been shown to be proportional to the pressure developed;[3 4] hence the amount of energy which the heart has to expend per beat, other things being equal, varies inversely as the elasticity of the arterial system. Conversely, the more elastic the arteries the smaller will be

FIG. 4.



Radial and carotid sphygmograms recorded on same string. Time intervals 0·2 sec. Record reads from right to left. C^1 = Primary carotid deflection. C^2 = Secondary carotid deflection. R^1 = Primary radial deflection. R^2 = Secondary radial deflection.

the decrease in pressure for a given decrease in volume. Hence the difference between systolic and diastolic pressure, that is the pulse pressure, other things being equal, will vary directly as the rigidity of the arterial walls. In the interests of an efficient circulation it is obviously desirable that the amount of unproductive work which the heart is called upon to perform should be reduced to a minimum, and that the fall of pressure

TABLE II.

Velocity.	Age.	Disease.
5·5	18	Rheumatic fever, aortic incompetence.
6·2	33	Aortic incompetence.
6·5	35	Pernicious anæmia.
6·5	53	Thoracic aneurysm.
6·5	62	Thoracic aneurysm.
6·9	16	Rheumatic fever, aortic incompetence.
7·0	64	Complete heart-block.
7·3	50	Pernicious anæmia.
7·3	48	Thoracic aneurysm.
7·4	23	Neurasthenia.
8·3	48	Chronic lead poisoning.
8·5	36	Septic endocarditis, mitral stenosis.

in the arterial system, associated with the passage of blood to the capillary area, should be as small as possible. That is to say, *the greater the alteration in the volume of the arteries in response to a given alteration in pressure the more efficient will be the arterial mechanism.*

Now we have shown in a previous paper[6] that the velocity of transmission of the pulse-wave may be expressed by the formula :—

$$\text{Velocity (in metres per sec.)} = 3{\cdot}57 \Big/ \sqrt{\%\ \text{increase of volume per mm. Hg increase of pressure.}}$$

Hence, we may conclude that an artery is the more efficient the lower be the velocity of the pulse-wave in it. In other words, in the velocity of the pulse-wave we have a criterion of the efficiency of one very important factor in the circulatory mechanism.

Direct Measurements of Pulse Velocity in Isolated Human Arteries.

The relationship of volume to pressure in isolated human arteries was measured directly by Roy.[5] His experiments, however, are compromised by the fact that the volume changes were induced gradually; and, owing to the " elastic after-action " of the tissues, the rise of pressure was less than would have been the case if the alteration of volume had been brought about suddenly, as is actually the case in the living body. We have recently devised a method by which it is possible to estimate directly the velocity of transmission of the pulse-wave in isolated human arteries obtained from the post-mortem room, and so, if required, to deduce the percentage increase of volume per mm. Hg rise of pressure. Only a small number of experiments have been performed hitherto, but the results obtained by this method agree closely with the observations made in the living body with the hot-wire sphygmograph.

Application to Clinical Medicine.

When it is possible to palpate a thickened radial artery at the wrist, or to recognise the characteristic changes in the vessels of the retina, direct evidence

FIG. 5.

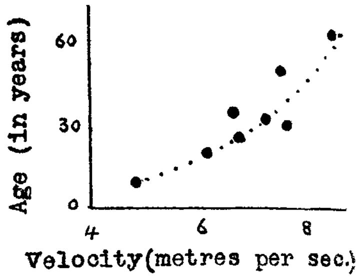


Diagram to illustrate relationship of age to velocity of transmission of pulse-wave in normal healthy subjects. Compiled from figures in Table I.

of arterio-sclerosis may be present; but in a large number of cases the diagnosis of this condition has to be based on circumstantial evidence such as that afforded by high blood pressure or by the presence of certain diseases known to be associated with arterio-sclerosis, in particular, chronic interstitial nephritis and gout. Under such circumstances direct evidence would be of considerable value; and this evidence may be obtained by measuring the velocity of transmission of the pulse-wave. Again, accurate measurements of the velocity of transmission of the pulse-wave may be of value in the diagnosis of aneurysm. In vessels involved in aneurysmal dilatation the progress of the pulse-wave is delayed. Such delay may be sufficiently obvious to be recognised by the finger; but in a large number of cases the delay is so small that it can only be demonstrated by instrumental methods.

Summary.

1. By means of the hot-wire sphygmograph it is possible to obtain accurate measurements of the velocity of transmission of the pulse-wave.

2. In health there is a relationship between age and pulse-wave velocity. This is not so in disease.

3. Pulse-wave velocity is an index of arterial elasticity, which is one of the most important factors in circulatory efficiency.

4. Direct measurements of pulse-wave velocity in isolated human arteries agree closely with the values obtained by means of the hot-wire sphygmograph in the living subject.

5. The measurement of pulse-wave velocity affords direct objective evidence in the diagnosis of arterio-sclerosis and aneurysm.

In conclusion, we wish to thank the physicians and assistant physicians of the Manchester Royal Infirmary for the facilities granted us for making observations on their patients.

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