612.16

THE PULSE WAVE VELOCITY AND EXTENSIBILITY OF THE BRACHIAL AND RADIAL ARTERY IN MAN.

BY J. S. FULTON AND B. A. McSWINEY.

(*Department of Physiology, University of Leeds.*)

IN 1923, Bramwell, Hill and McSwiney(1) published the results of investigations on the transmission of the pulse wave by recording simultaneously the carotid and radial pulses. A series of seventy-four observations on normal subjects showed a definite relationship between age and velocity. About the same period, Bazett and Dreyer(2) demonstrated that the pulse wave velocity was lower in the brachial than the radial artery, which suggests a greater extensibility of the central artery. These observers were, however, primarily interested in the relationship of pulse wave velocity to blood-pressure, and endeavoured to correlate their results with the measurements made by Bramwell and Hill(3) on the pulse wave velocity in the isolated human artery with varying internal pressures. No systematic survey was made by Bazett and Dreyer of the velocity of the pulse wave or extensibility of the carotid and peripheral arteries in normal individuals. Hürthle(4), in 1923, showed that the femoral artery is normally less extensible than the carotid artery. This observer investigated the relation between internal pressure and volumetric expansion in living animals by applying a plethysmograph. Using a physical formula, which took into account the diameter and thickness of the vessel wall, Hürthle showed that there was a progressive decrease in the extensibility of the vessels in the arterial path. The present investigation was undertaken to establish the relationship of the pulse wave velocity and extensibility of the brachial and radial arteries with age and, if possible, with the blood-pressure.

METHOD.

The velocity of the pulse wave was recorded by use of the hot wire sphygmograph as previously described(1). Records were taken from the carotid, brachial and radial arteries of the right arm, with the subject sitting at rest in a chair. A small glass funnel was used to record the carotid pulse, and a tambour with stud attached, as mäde by Jacquet, for the radial pulse. For the brachial pulse, a hollow rubber bandage with an effective breadth of 2 cm. was strapped round the arm, just above the elbow, and attached to a Pachon oscillometer. A narrow bandage was chosen, as Bramwell, McDowall and McSwiney(5) had previously shown that, with a sphygomanometer bandage, 11 cm. in width, the velocity under the bandage varied according to the applied pressure. The pressure used in the narrow brachial bandage was never greater than 40 mm. mercury, as it was found that higher applied pressures altered the readings obtained from both the brachial and radial arteries.

To examine the accuracy of the technique, three separate records were made on bromide paper, using a double fibre case in the Einthoven galvanometer. Respiratory movements were recorded simultaneously with the pulse waves, in order that measurements might be made at similar phases of inspiration and expiration(6). The sum of the time intervals of the pulse wave in the brachial and radial artery was found to approximate extremely closely to the time interval obtained by recording the carotid-radial pulse with the brachial bandage removed. Measurements were made in some twenty subjects of different ages, and an average difference of 0·0016 of a second was obtained. As the presence of the brachial bandage, with pressures up to 40 mm. mercury, did not interfere with the results, the three pulse waves were recorded simultaneously in our later experiments. A small Salmanson galvanometer, with two metal strings, was placed in front of the Einthoven string galvanometer, which contained a single glass string.

To obtain the distance traversed by the pulse wave, three measurements were made:

(1) Sterno-calvicular joint to the centre of application of the carotid cup.

(2) Sterno-clavicular joint to the upper border of the hollow rubber bandage applied at the elbow.

(3) Sterno-clavicular joint to the point from which the record from the radial artery was taken.

It is possible, by subtracting the measurements between the sterno-clavicular joint and the carotid cup from the measurements along the subclavian-auxillary trunk, to calculate the length of artery traversed by the pulse wave during the time interval under consideration. Records were made on bromide paper, and the time intervals were measured by the apparatus devised by Elliott. The blood-pressure readings were taken from the brachial artery by the ausculatory method, immediately after the records were made.

EXPERIMENTAL RESULTS.

University students, workmen and school-children were used as subjects, care being taken to exclude those not in good health and incapable of taking muscular exercise. In Table I the pulse wave velocities obtained in fourteen subjects, ages 20 to 21, are given to illustrate the results obtained from the brachial and radial artery.

TABLE I. Pulse wave velocity.
(Metres per second.)

Age	Brachial	Radial	Whole arm	Blood-pressure
20	4·7	6·1	5·4	110/70
20	4·2	8·1	5·9	106/68
20	5·2	8·2	6·4	112/82
20	5·0	11·3	6·7	102/74
20	5·3	9·1	6·6	100/72
20	4·9	7·6	6·0	98/70
20	4·3	7·3	5·7	98/68
20	4·1	8·7	5·6	112/68
20	4·8	7·2	5·8	120/88
21	4·5	11·0	7·2	118/80
21	4·8	10·4	6·4	108/76
21	4·6	7·2	5·6	108/76
21	4·7	6·7	5·7	132/89
21	5·1	12·7	7·0	134/74
Average	4·7	8·7	6·1	
Minimum	4·1	6·1	5·4	
Maximum	5·3	12·7	7·2	

It will be observed that the pulse wave velocity is lower in the brachial than the radial artery. The measurements obtained from the brachial artery are fairly uniform, but the observations on the radial artery show considerable variation, probably owing to the local conditions of vaso-constriction or dilatation.

The results of our observations on the brachial artery are shown in Fig. 1. The ages of the 103 normal subjects varied from 5 to 80 years, and the pulse wave velocity from 3·1 to 6·6 mm. per sec. Sixty-four observations have been made on subjects under 30 years of age. A smaller number of observations is available over that age, but the results are in good agreement and fall close to the continuation of the mean curve. In Fig. 1 the pulse wave velocity is plotted against age, and a mean curve has been drawn through the observations. Of the 103 observations, 49 fall above, 49 below, and 5 on the mean line. The maximum deviation appears to be 1 m. per sec., and lines are drawn at that distance above and below the mean line. It will be observed that there is a progressive increase in the velocity of the pulse wave associated

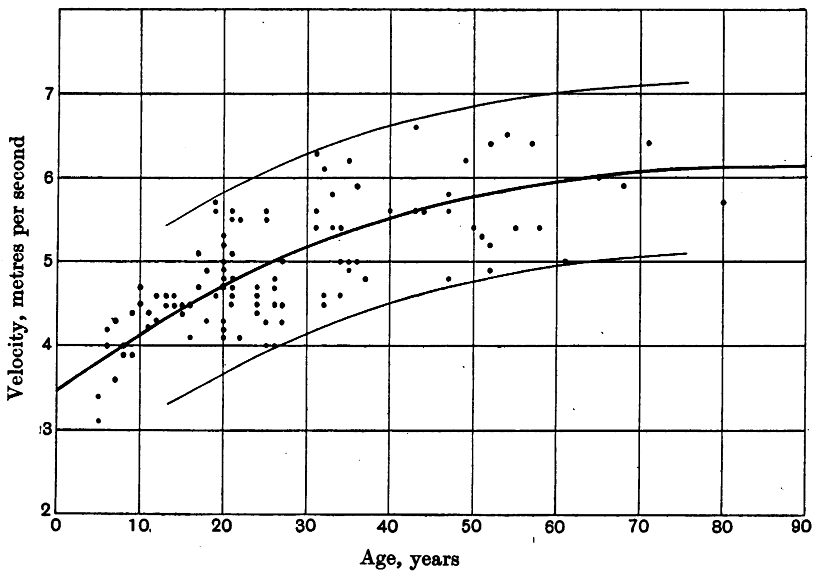

Fig. 1.

with increase in age; this change, however, is more marked in the age groups below 30. Above this age the increase in the pulse wave velocity is more gradual. Although there is a general increase in pulse wave velocity in the radial artery with age, it was found impossible to draw an accurate curve relating velocity to age, owing to the wide variation in the results. Observations made from the carotid and radial pulses showed better agreement, the maximum deviation from the mean line being 1·5 m. per sec. The mean pulse wave velocity in the whole arm represents, to some extent, the average of the velocities in the radial and brachial artery, and it is not surprising, therefore, to find that the results show a moderate degree of uniformity.

TABLE II. Average pulse wave velocity.
(Metres per second.)

Ages	Brachial	Radial	Whole arm
5–15	4·2	6·0	4·9
15–25	4·7	8·3	6·0
25–35	5·0	8·9	6·5
35–45	5·5	10·4	7·0
45–55	5·6	11·4	7·2
55–65	5·6	11·0	7·4
65–80	6·0	11·0	7·5

The average results of the pulse wave velocity obtained in the arteries of the arm in each age group are summarized in Table II.

TABLE III. Mean extensibility.

Ages	Brachial	Radial	Whole arm
5–15	0·70	0·35	0·53
15–25	0·57	0·18	0·35
25–35	0·51	0·15	0·30
35–45	0·42	0·12	0·26
45–55	0·40	0·10	0·24
55–65	0·40	0·11	0·23
65–80	0·38	0·11	0·22

The extensibility of the arteries, as shown in Table III, has been calculated from the average pulse wave velocities obtained for the different age groups. According to Bramwell and Hill (3), the percentage increase of volume for 1 mm. mercury rise in pressure is equal to $\frac{12{\cdot}7}{(\text{velocity of pulse wave})^2}$. The results obtained by Bramwell, Hill and McSwiney (1) showed the extensibility in the whole arm at age 5 to be 0·47, gradually decreasing with age, the value at 80 years of age being 0·17. These results agree reasonably well with the figures shown in Table III, column 3, for the brachial radial artery. In the brachial artery, however, the mean extensibility for the group 5 to 15 years of

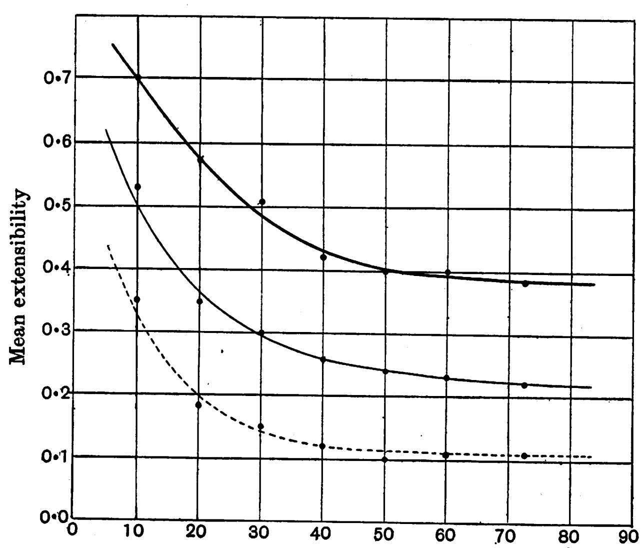

Fig. 2.

——— Brachial. ——— Whole arm. - - - - - - Radial.

age was 0·70, and 0·38 for the group 65 to 80 years of age. It is interesting to note that the extensibility of the brachial artery decreases from 0·70 to 0·42 up to 45 years of age, but with further increase in age there is little decrease in extensibility.

Fig. 2 shows the relationship of the extensibility of the arteries to age. Observations on the radial artery and the whole arm are included for comparison, as they have been previously used to demonstrate the decrease of extensibility with age.

Careful comparison of the pulse wave velocity in the brachial artery with the systolic pressure, the diastolic pressure and the pulse pressure in turn has failed to reveal any definite relationship. Bazett and Dreyer(2) found that the rate of transmission of the pulse wave varies with the blood-pressure and, in the large vessels, the figures were in good agreement with those obtained on excised vessels by Bramwell and Hill(3). We have applied results obtained from the brachial artery in a similar way, but were unable to confirm these observations. In the individual, however, there is a relationship between the blood-pressure and the pulse wave velocity, and an alteration in pressure will produce a change in the velocity depending on the extensibility of the vessel wall and the pressure in the vessel. Measurements of the velocity during inspiration and expiration, and with the limb in different postures(7) demonstrate the effect.

Summary.

By the use of the hot wire sphygmograph the velocity of transmission of the pulse wave in the brachial and radial artery may be measured with accuracy. A series of 103 observations in normal subjects shows that, with the brachial artery, there is a definite relationship between age and velocity. It is further shown that, between 5 and 80 years of age, the arterial extensibility decreases from 0·70 to 0·38. The pulse wave velocity was found to be always lower, and the extensibility higher, in the brachial than in the radial artery. The rate of transmission was much more variable in the peripheral than in the central artery. No relationship between pulse wave velocity and arterial blood-pressure could be established.

The expenses of this research have been defrayed in part by a grant from the Government Grant Committee of the Royal Society.

REFERENCES.

1. Bramwell, Hill and McSwiney. Heart, 10. p. 233. 1923.
2. Bazett and Dreyer. Amer. J. Physiol. 63. p. 94. 1922.
3. Bramwell and Hill. Proc. Roy. Soc. B, 93. p. 298. 1922.
4. Hürthle. Pfluegers Arch. 200. p. 49. 1923.
5. Bramwell, McDowall and McSwiney. Proc. Roy. Soc. B, 94. p. 450. 1923.
6. Hickson and McSwiney. This Journ. 59. Proceedings, p. v. 1924.
7. Hickson and McSwiney. Ibid. 59. p. 217. 1924.