METHOD FOR ESTIMATING THE BLOOD FLOW IN THE ARM

PRELIMINARY REPORT

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Of the various factors entering into the problem of circulatory dynamics the most important is the rate of blood flow. This can be determined experimentally by Ludwig's *Stromuhr* or some of its various modifications. More recently T. G. Brodie¹ has estimated the blood flow in an organ by suddenly occluding its efferent vein and measuring the change of volume by an oncometer. Under these circumstances the arterial blood enters the organ with undiminished speed at first, but soon the flow is retarded by the rise of pressure in the veins and capillaries. The organ therefore swells rapidly at first and progressively more slowly. The earliest portion of this curve represents the rate at which the blood enters under normal conditions. Brodie has shown that this method gives as reliable results as the *Stromuhr*. It is applicable only to organs from which all efferent blood can be collected by a single vein.

We have used Brodie's principle in order to determine the rate of flow in the arm of man. A distensible cuff similar to that used for determining arterial pressure was placed about the upper arm and an attempt was made so to adjust the pressure in the cuff that the veins should be occluded and the arteries left open. The resultant changes in the volume of the arm were recorded by a plethysmograph and a Brodie volume recorder. Certain precautions are necessary in order to obtain uniform results. In the first place, the pressure cuff must be inflated very rapidly. This is accomplished by connecting it with a large bottle in which the pressure has previously been raised slightly above that desired for the cuff. When the stop-cock between the two is opened the pressure is applied to the arm almost instantaneously. In the second place, the inflation causes a damming back of fluids which lie in the tissues beneath the cuff. The wider the cuff and the nearer to the plethysmograph the larger is the amount of fluid forced back into the latter. For this reason we have used a narrow cuff, about 3 cm. wide,

1. Brodie (T. G.): The determination of the rate of blood flow through an organ. Reported at the Seventh International Physiological Congress, August, 1907.

and have placed it about 3 cm. from the opening into the plethysmograph. Under such conditions the increase of volume caused by the tightening of the cuff rarely exceeded 2 or 3 c.c. and was often less than this.

Another important question remains: Is it possible to occlude the outflow through the veins without affecting the arterial inflow? Theoretically this should be possible if the pressure applied to the tissues were in excess of the venous pressure and at the same time less than the diastolic arterial pressure. Under such conditions one should realize a parallel to Brodie's experiment. At first the blood would flow uninterruptedly into the arm, but after a time the distention of the veins, capillaries and surrounding tissues would impede the entrance of blood and the inflow would gradually lessen. We have recorded the volume changes after applying a series of gradually increasing pressure to the upper arm by means of the pressure cuff. Pressures below 30 or 40 mm. of mercury were usually insufficient to obstruct the veins even for short lengths of time, and the volume curve failed to rise uniformly after a few cubic centimeters of blood had entered. At somewhat higher pressures—usually from 40 to 80 mm. of mercury—all the volume curves from the arm were practically uniform. At still higher pressures the arteries were obstructed and the rate of inflow lessened until finally, at pressures above the arterial systolic pressure, the arteries were completely occluded and the only rise in the volume curve was due to the forcing of liquid back from beneath the pressure cuff. We believe that during the uniform series of curves obtained at various pressures (usually between 40 and 80 mm.) the veins were completely obstructed and the arteries open.

These curves show a gradually lessening rate of entrance of blood into the arm owing to the gradual increase of pressure in the veins, capillaries and surrounding tissues. The first portions of these curves show a nearly uniform rate of inflow, and usually about 10 c.c. of blood entered the plethysmograph without marked retardation (more than 20 per cent.). Sometimes only about 5 c.c. entered at a practically uniform rate, while again as much as 15 or 20 c.c. entered before retardation became marked. Up to the point when this occurs the swelling of the arm may be taken to represent approximately the normal rate of blood flow into the arm.

By this method the rate of flow was found to vary considerably in different individuals and to vary to a less extent in the same individual under different circumstances. The usual rate was from 3 to 5 c.c. per 100 grams of arm substance per minute, with extreme variations of

1.5 to 12 c.c. This agrees fairly well with the results obtained by Tschuewsky,² who used the *Stromuhr* on the legs of dogs and obtained inflows averaging 3.25 c.c. and varying from 1.93 to 4.77 under normal conditions, but increasing to as much as 11.8 after cutting the nerves and 6.89 after a brief obstruction of the artery.

At present we are measuring the rate in arms of patients with various pathologic conditions, but as yet have found no constant relation between certain diseases and the rate of flow. So far as we know, the only similar methods recorded for estimating the rate of flow in the arm are that suggested by O. Müller³ and that of A. Müller.⁴ Both these authors, however, stopped the circulation in the arm before measuring the rate at which the blood entered the plethysmograph. Consequently normal conditions were not approximated.

2. Tschuewsky (J. A.): Ueber Druck, Geschwindigkeit, und Widerstand in der Strombahn der Arteria carotis und cruralis sowie in der Schilddrüse und im Musculus gracilis des Hundes. Arch. f. d. ges. Physiol., 1903, xcvii, 210.

3. Müller (O.): Das absolute Plethysmogramm. München med. Wehnschr., September, 1908, lv, 1819.

4. Müller (A.): Methods zur Bestimmung von Schlagvolumen und Herzarbeit und deren Ergebnisse. Bed. ü. d. Verhandl. d. Kong. f. inn. Med., 1908, xxv, 325.