as a standard, but occasionally both radials are anomalous and we may be compelled to use the temporal or facial instead.

7. *The Condition of the Artery Walls.*

Arterio-sclerosis is manifested in the peripheral arteries in the following forms:

(*a*) Simple *stiffening* of the arteries without calcification.
(*b*) *Tortuosity* of the arteries.
(*c*) *Calcification.*

Simple stiffening without calcification is due to fibrous thickening of the intima and produces a condition of the arteries not always to be distinguished from high tension. The artery can be rolled under the fingers, stands out visibly between the heart's beats, but is not incompressible, has a smooth surface, and is not always tortuous. If it is tortuous as well as stiff, we may conclude that there is endarteritis at any rate, whether or not there is increased tension as well. In the vast majority of cases the two conditions are asssociated and do not need to be distinguished.

The normal radial artery is straight; hence any deviation is evidence of changes in its walls and is easily recognized as we run our fingers up and down the vessel.

Calcification of the radial produces usually a *beading* of its surface. As we move the fingers along the artery, quickly and with very slight pressure, a series of transverse ridges or beads can be felt. The qualities of the pulse wave within can usually be appreciated fairly well, in this type of artery, but in very advanced cases the calcification is diffuse and converts the radial into a rigid "pipe stem"—absolutely incompressible—unless we break the calcified coat—and easily mistaken for a tendon. In such an artery no pulse can be felt.

Such are the points to be observed in feeling the pulse. To enumerate the characteristics of the pulse in the many diseases in which it affords us valuable information is beyond the scope of this book. The qualities to be expected in the pulse in connection with the different diseases of the heart are described in the sections on

those diseases. Here it will suffice to enumerate some of the conditions in which vascular tension is usually increased or diminished.

Low tension is produced by moderate exercise, by warmth (*e.g.*, a warm bath), by food. Among pathological conditions we may mention especially debilitated states, mental worry, and fever.

High tension is produced by cold (*e.g.*, cold bathing, malarial chills), and by constipation (in some cases). As a rule, the tension of the pulse increases with age and is high after the fiftieth year. Hysteria and migraine are often associated with increased vascular tension. Most frequent among pathological conditions as causes of high tension are *chronic nephritis* and *arterio-sclerosis* with the various diseases in which arterio-sclerosis is a factor (gout, alcoholism, lead poisoning, diabetes of fat old people, chronic bronchitis with emphysema).

Among valvular heart lesions, aortic and mitral stenosis are especially apt to be associated with increased vascular tension.

Arterial Pressure and the Instruments for Measuring It.

Within the past few years a number of instruments have come into use, the object of which is to tell us with some approach to accuracy the lateral pressure in the peripheral arteries. We have long attempted to estimate this pressure, by simple digital compression and palpation, and no doubt these methods in the hands of skilled observers will always have a field of usefulness; but it seems to me clear that by the instruments about to be described we can obtain data in regard to the force of the heart's contractions and the tension of the peripheral arteries more accurate and more reliable than those furnished by digital examination. This is especially true of comparative records, as, for example, if one attempts to compare the tension of the pulse to-day with what it was yesterday, when one has felt many pulses in the interim. Another objection to estimates of pulse pressure based on digital examination results from the fact that the size of the artery itself is apt to be a confusing factor.

Among the many instruments introduced within the past few years we may distinguish (1) those which aim to estimate the

amount of compression which has to be exerted upon a given artery in order to arrest the onward flow of blood in it, and (2) those which seek to estimate the amount of pressure in a given artery at the moment when its wall makes the widest excursion or oscillation.

Instruments of the first type are said to measure *systolic pressure*, and those of the second type to measure *diastolic pressure*. Under the first heading I shall describe the Riva-Rocci and Gaertner instruments. Under the second that of Oliver and that of Hill and Barnard.

1. *Gaertner's Tonometer.*—The end of a finger is made bloodless by rolling up over it a tight rubber ring. Over the blanched finger tip one next applies a pneumatic ring, which can be inflated by means of a rubber bulb, while the tension within is measured by a manometer connected with it. The manometer may be either of the mercury or the spring type. To use the instrument we inflate the pneumatic ring until the pressure recorded in the manometer is considerably above what we expect in the case dealt with. (The tip of the finger all this time remains blanched.) Next we relax the tension within the pneumatic ring, by gradually releasing the pressure exerted upon the inflation bulb, until the red color reappears in the finger tip. Just as the color reappears we note the pressure in the manometer. This figure was supposed by Gaertner to represent the average or mean pressure in the arteries, but it has been very generally conceded by other observers that the figures given by this instrument are much nearer to those of *systolic* pressure, that is, to the pressure during the systole of the left ventricle or to the crest of the pulse wave.

The advantages of the Gaertner instrument are its compactness and portability. Its disadvantages are that (in this climate at any rate) it is very apt to get out of order, that it is not suited to estimating pressures in any of the dark-skinned races, and that its readings are very much affected by vasomotor influences, such as nervousness or cold. If the fingers are cold it may be almost impossible to make a satisfactory record with the instrument. Further, the spring manometer, like all instruments of this type, is very apt

to get out of order, and if the mercury manometer is employed the instrument loses its only advantage, namely, its compactness.

2. *The Riva-Rocci Instrument.*—This instrument consists essentially of an inflatable rubber armlet, so arranged that it can be fitted closely around the upper arm, a mercury manometer of the ordinary type, and an air-pump (see Fig. 70). The air forced from the

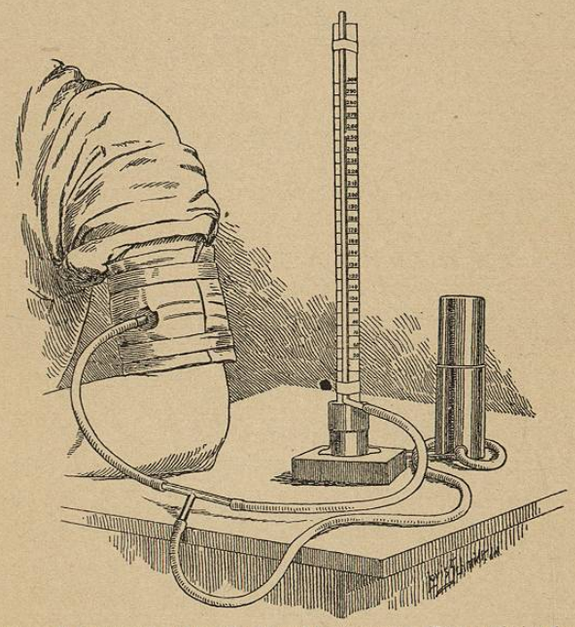

FIG. 70.—Stanton's Modification of the Riva-Rocci Instrument. (By permission from the University of Pennsylvania Medical Bulletin.)

pump is distributed into the rubber armlet and into the manometer at the same time, and experiments have shown that the actual pressure in the armlet is practically identical at any given time with that in the manometer. To use the instrument we pump in air until the radial pulse stops, and at that instant note the height of the mercury column. The reading thus obtained is

taken to represent the systolic or maximum pressure in the brachial artery.

It is true that the air within the rubber armlet has to overcome not only the pressure within the radial artery, but the resistance of the artery wall and the elasticity of the soft parts around it. The former factor has been shown to represent a pressure of not more than 2 or 3 mm. Hg, provided the artery walls are normal. If arterio-sclerosis is present, it has been estimated by von Basch that they may oppose a resistance equivalent to 5 or 6 mm. Hg. The amount of error thus introduced, however, appears to be of no importance, since there are physiological variations of 5 mm. Hg or more, occurring from moment to moment, and dependent on changes in the force of the heart beat and on the respiratory oscillations of pressure.

The resistance of the soft parts around the artery is a factor of considerable importance, provided the compressing armlet is as narrow as many of those supplied with Riva-Rocci instruments. But if an armlet of about three and one-quarter inches width is used, according to the recommendation of von Recklinghausen and Stanton, we find that the pressure is practically the same in a given individual whether the armlet is applied round the upper arm, round the forearm, or round the thigh. Now if the resistance of the tissues of the thigh exerts no greater influence than that of the upper arm or forearm, it seems safe to conclude that this factor may be neglected as a source of error in comparative measurements with arms of different sizes.

The instrument is a very simple and quick one to use, needing very little practice and not more than a minute or a minute and a half for a single reading. The chief objection to it is its bulk and fragility.

3. *The Instrument of Hill and Barnard.*—In essentials this instrument is like the Riva-Rocci, except that all the connecting tubes are rigid, and that in place of the mercury manometer a very delicate aneroid instrument is employed to record the pressures within the armlet (see Fig. 71). The delicacy of this form of manometer is so great that with rigid connections it is possible to register the

oscillations of the artery wall and to estimate the amount of pressure within the armlet at the time when the arterial oscillations are widest; in other words, when the arteries are slackest. The work of Howell and Brush has demonstrated to my satisfaction that the pressure at the time of the maximum oscillation corresponds to the minimum or diastolic pressure within the arteries.

The Hill and Barnard instrument, when in good order, seems to

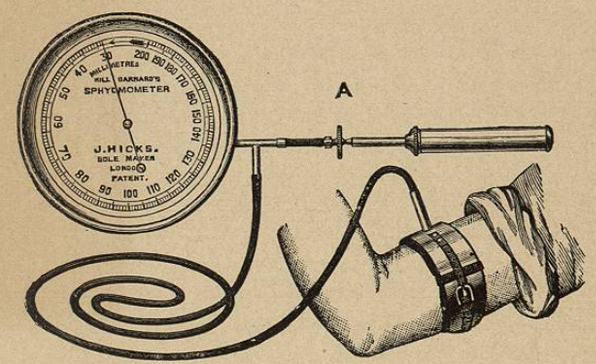

FIG. 71.—Hill & Barnard's Sphygmometer.

me on the whole the best among those that are clinically available for measuring diastolic pressure. The difficulty of reading it is less than with most other instruments designed for this purpose, and the only serious drawback to the instrument is the likelihood that the manometer will get out of order, a difficulty to which all instruments of this type are very prone.

4. *The Oliver Instrument.*—This instrument is intended, like the last, for estimating the pressure in the arteries during the period of maximum oscillation. This, as I have said, corresponds in my opinion to the diastolic and not to the average or mean pressure. A small rubber capsule filled with water is placed upon the radial artery, and through this the pulsations of the artery, under different pressures, are transmitted directly by a straight rod to a spring

manometer, where the oscillations and pressures are recorded in mm. Hg (see Fig. 72). The instrument is a very compact and simple one, and if it were not constantly getting out of order, would be, I think, of considerable value, although it is a difficult instru-

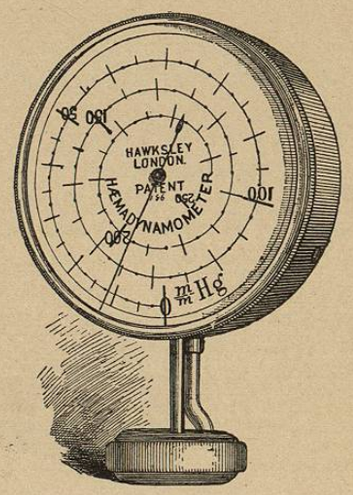

FIG. 72.—Oliver's Hæmodynamometer.

ment to use. Its readings, however, soon become inaccurate and cease to correspond with the mercury column.

Stanton (*University of Penn. Med. Bull.*, February, 1903) has succeeded in fitting a Riva-Rocci instrument with rigid connecting tubes, so that with this single instrument he can record both maximum and minimum pressures. The maximum or systolic pressure he records in the ordinary way. To get the minimum or diastolic pressure he clamps off the tube leading to the inflation bulb, and then lets out the air little by little until the mercury begins to oscillate in the tube. The oscillations increase in extent up to a maximum as the air is steadily let out, and then decrease again until they are lost. The reading for diastolic pressure is taken when the mercury shows the greatest extent of oscillation in the tube.

The Use of the Data Obtained by these Instruments.

The subject is still in its infancy, but in a general way one may say that whenever it is important that we should know the strength of the heart beat or the tension of the peripheral arteries, these instruments are of value. Just which instrument is likely to come into permanent use I cannot venture to prophesy, but it seems to me likely that the charts of pulse rate will be supplemented before long by charts of blood pressure taken at regular intervals as a matter of routine. Especially the investigation of diseases of the heart and kidney, diseases in which involvement of the suprarenal gland is suspected, intracranial hemorrhage or tumor and surgical shock, accurate record of blood pressure will be of value. Even the imperfect instruments now in use are capable of yielding us most important information, if applied in comparative measurements upon the same patient at different times, so that all the elements of error are constant. Thus in the study of drugs like alcohol, digitalis, strychnine, ether, chloroform, nitroglycerin, and others which are supposed either to raise or to lower blood pressure, these instruments have, I think, a great field before them.