NEW AND OLD DEFINITIONS OF NORMAL BLOOD PRESSURE: CLINICAL SIGNIFICANCE OF THE NEWLY ESTABLISHED LIMITS*

ARTHUR M. MASTER, ISAC GOLDSTEIN and MAX BENJAMIN WALTERS

"In December, I caused a mare to be tied down alive on her back . . . having laid open the left crural artery about three inches from her belly. I inserted into it a brass pipe whose bore was 1/6 of an inch in diameter and to that, by means of another brass pipe which was fitly adapted to it, I fixed a glass tube, of nearly the same diameter, which was nine feet in length; then untying the ligature on the artery, the blood rose in the tube 8 feet 3 inches perpendicularly above the level of the left ventricle of the heart."[1] This skillful experiment, the first direct measurement of the blood pressure, was performed in 1733 by an English clergyman, Stephen Hales. Measurements of pressure that he carried out in sheep and dogs are still considered correct today. It is interesting to note that Hales estimated the blood pressure in man to be seven and one-half feet of blood expressed according to his system of measurement. This corresponds to about 170 mm. of mercury and, considering the crudeness of his methods and the fact that his work was done on experimental animals only, this was indeed a remarkably accurate deduction.

The measurement of blood pressure in clinical practice at the present day is a relatively simple procedure, easily performed on each patient. However, this procedure is the result of many studies and experiments, lasting almost a century, which dealt not only with the technical problems involved in devising an accurate and practical apparatus but also with the clinical value and interpretation of the blood pressure readings obtained. A few of the more important steps in the evolution of the blood pressure machine will be briefly presented.

The first instrument for indirect measurement of blood pressure in man, termed the Sphygmometer, was invented in 1834 by Julius Héris-

* From the Cardiographic Department of The Mount Sinai Hospital, New York.

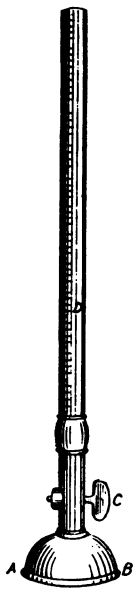

Fig. 1. Hérisson Sphygmometer. 1834. A B half of a metal sphere with a membrane at its base; D capillary tube partly filled with mercury. Membrane placed on radial artery.

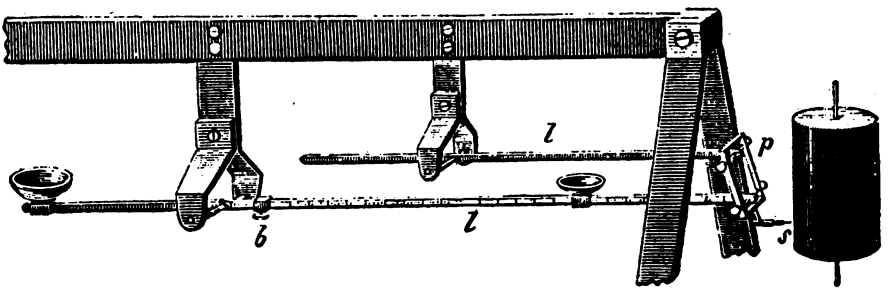

Fig. 2. Vierordt's Sphygmograph. 1855. Metal button (b) placed on on radial artery and weighted down by weights placed in two plates on metal bar (L). Writing point (S) inscribes radial pulse on Ludwig kymograph. Systolic pressure equals weight needed to obliterate radial pulse.

son,[2] a Paris physician (Fig. 1). By placing the membrane on the radial artery, Hérisson was able to discern the oscillations of the mercury column produced by the pressure in the radial pulse. From the amount of oscillation, Hérisson attempted to compute the intraarterial blood pressure. This was, of course, a very rough and inaccurate method.

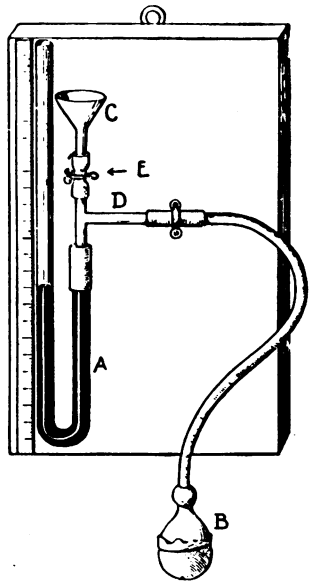

Fig. 3. Von Basch Sphygmomanometer 1876. A pelotte (B) consisting of a glass funnel covered with an elastic membrane is connected to a mercury manometer (A). Pelotte and tubing filled with water through glass funnel (C). Radial or temporal artery compressed with pelotte and at the instant that the pulse disappears, the systolic pressure is read off from the mercury manometer.

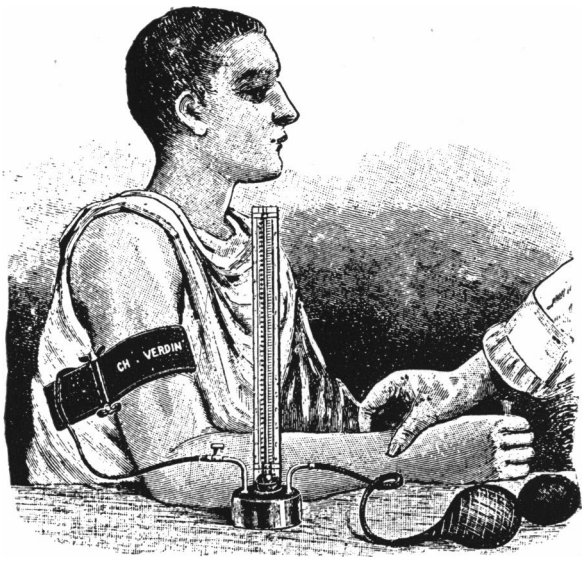

Fig. 4. Riva-Rocci Sphygmomanometer 1896. 5 cm. armlet used to compress arm. Readings about 10 per cent too high.

In 1855 Karl Vierordt,[3] a physiologist in Germany, devised an ingenious apparatus, the Sphygmograph (Fig. 2). This was the first instrument devised to register by an indirect method the pulsations in the radial artery and to estimate the systolic blood pressure by compression of this artery.

The first to make the indirect blood pressure reading a practical procedure in man was Von Basch,[4] a Viennese physician. By introducing an apparatus that could be used to estimate blood pressure by the average physician in his daily practice, Von Basch will always be remembered as the inventor and father of clinical sphygmomanometry. In 1876, he constructed an apparatus that was widely used (Fig. 3).

In 1896, an advance in clinical sphygmomanometry was made by the introduction of a new technique by Riva Rocci[5] (Fig. 4). For the first time an armlet was employed to compress the arm and this apparatus, as introduced by Riva Rocci, is the same as the one we use today except that a wider 12 cm. armlet is employed.[6]

Until 1904, the systolic pressure was determined by the palpatory method only and attempts were made to estimate the diastolic pressure by using radial pulse oscillations. In 1904 Korotkow,[7] a Russian physician, described the auscultatory method for determining the blood pressure. This is the method we use in our everyday clinical practice.

The Evolution of Blood Pressure Limits

In 1902, Potain published the first extensive work on blood pressure and its limits, "La Pression Artérielle de l'Homme."[8] Although his readings today are considered too high because of the technique employed, this book has great historical interest. This was the first time that blood pressure levels were correlated with factors which might influence the results, such as age, sex, weight, activity, altitude, etc.

The data which will be presented henceforth may be considered to be more or less accurate, as they have been obtained with standardized apparatus of the type used at the present time. In 1907, Theodore C. Janeway, of New York, using his own and some of his famous father's data, published a monograph entitled, "The Clinical Study of Blood Pressure."[9] He stated that a blood pressure above 145 mm. before middle age, or 160 mm. after this age, was definitely pathological if constantly present as the average reading.

About 1910 Brunton[10] of England, and Cook[11] of Johns Hopkins,

lowered these limits to 135 up to middle life, and 145 to 150 mm. thereafter. In 1915, Janeway[12] accepted these new criteria. We believe that 150 mm. mercury as the upper limit of normal systolic pressure in people over middle age became widespread largely because of Janeway's great reputation as an authority in this field.

In the past four decades, a number of life insurance companies have presented their statistics which have received wide publicity and which have played an important role in establishing the limits of normal blood pressure accepted today. In a study presented by Fisher,[13a] based on an analysis of 65,000 accepted risks, the maximum acceptable systolic pressure was placed at 131 mm. mercury at 16 years of age, and 151 mm. mercury at 65 years of age. In an insurance study of 150,000 men who were apparently healthy, Symonds[13b] concluded that the normal systolic blood pressure in males under 40 years, is below 140 mm. mercury. A number of other studies based on insurance company statistics have reported 150 mm. mercury as the maximal normal systolic pressure.[13]

There are several reasons for not accepting these insurance company statistics in clinical medicine. In the first place, they represent a very select part of the entire population. In addition, they are concerned primarily with group prognosis and mortality. For this reason, these data are not entirely applicable to the question of the relationship between blood pressure readings and the individual expectation of life.

All this material forms the basis for the accepted limits of blood pressure at the present time. However, it has been a common observation that people with blood pressure readings, above the commonly accepted limits, may live out their normal life span without complications related to their blood pressure. Bechgaard[14] followed 1,000 patients with blood pressures higher than 180 systolic and 100 diastolic, for a period ranging from 4 to 11 years. Some had pressures as high as 240/130! He found that half of them were in good health, and one-fourth were symptom-free at the end of this period. He noted that excess mortality from hypertension, definitely diminished with advancing age. Blood and Perera[15] likewise reported that long survival of people with so-called "high" blood pressure is far from rare and that elevated arterial pressure may not be associated with symptoms or rate of progression. Burgess[16] followed 100 patients with blood pressures of 180/100 or more, for at least eight years. He concluded that even severe hypertension, if it has been present eight years or more, and is not associated with well-estab-

lished cardiac or renal disease, usually does not indicate a poor prognosis. In fact, the patient may live to within three or four years of his normal life expectancy.

These results suggest that the accepted limits are too low and must be liberalized. Furthermore, a number of published studies of blood pressures in normal persons indicate that the limits of normality may be higher than we think. One of the first to publish data not conforming to the widely accepted limits of normal, 150/90, was Alvarez in 1923.[17] In a routine examination of approximately 6,000 young, healthy freshmen on entry into college, 22 per cent were found to have a systolic pressure above 140 mm. mercury. In a later study, Diehl and Sutherland[18] found that 11.5 per cent of 5,100 young college students without symptoms had a systolic pressure over 140 mm. mercury. These two large studies indicate that a number of presumably healthy young men have systolic blood pressures over 140 mm. mercury.

From the studies cited above (Bechgaard, Blood and Perera, Burgess, Alvarez, Diehl and Sutherland), we can see the handwriting on the wall. It seems essential to investigate and, if necessary, to change some of the old concepts concerning the limits of blood pressure in normal people. This is true not only of young and middle-aged people but particularly of the older age groups.

A number of studies have indicated that systolic blood pressure normally increases with age. A few of these will be mentioned. A study by Richter[19] in 1923, of 165 people 60 to 89 years of age, excluding those suffering from nephritis and heart disease, showed that the average systolic pressure increased with age from 138 to 161 mm. mercury.

A very important study was published in 1928 by Saller[20] in which he suggested that the increase in blood pressure in old age should be considered part and parcel of the aging process and may be likened to other changes, such as those in hair, teeth, eyes, libido, etc. He took the blood pressure in 4,200 patients in an out-patient clinic in Kiel, excluding all patients with heart or kidney disease, anemia, diabetes, fever and endocrinologic diseases. Saller's results are indicated in the following Table (Table I).

The salient finding of Saller was a gradual increase in blood pressure after the age of 47 so that between 68-89 years of age, the range of systolic blood pressure in the male was between 86-186 mm. mercury,

TABLE I—RANGES OF BLOOD PRESSURE AS DETERMINED BY SALLER IN 4,200 AMBULATORY PATIENTS

Age in Years	*Systolic B.P.* *Men*	*Women*
21-35 } 35-47 }	98-144	99-138 } 100-155
48-53	96-154	100-190
54-59	97-159	104-196
60-67	93-173	102-216
68-89	86-186	112-222

while in the female it was from 112-222 mm. mercury. Saller did not claim that all blood pressures lying within these limits were normal. It was his conclusion, however, that if the blood pressure was not outside these limits, one could not be sure that it would have any influence upon the length of life. Saller's study was a very extensive one and is cited in all papers on blood pressure in older age groups.

In an extensive study published in 1937, Kylin[21] agreed with the rule that the normal blood pressure may be estimated by adding the age in years to 100 mm. mercury. Furthermore, he gave as the maximum normal systolic blood pressure 170 mm. mercury. It is interesting that this rule, which enjoyed wide popularity for a time and then was discarded, is again coming into vogue as a rough "rule of thumb."

In 1943 Master, Marks and Dack[22] published findings in 15,000 blood pressure readings in persons over 40 years of age who formed a fairly representative group of the population. Using the definition of hypertension as 150/100 or over, they found that 1/3 of the male population and 2/5 of the female population 40 years of age and over are hypertensive. These proportions increase rapidly with age, so that high blood pressure is present in the majority of men 60 and over, and in women 50 and over. Therefore, they suggested that the usual definition of hypertension might have to be changed and the upper limit of normal in middle and later life revised upward. There have been a number of other studies tending to substantiate this point of view, e.g., Wishard,[23] Russek,[24] Gavey.[25]

George Perera and Dana Atchley[26] have emphasized the wide and inconsistent normal range of blood pressure. They point out that a

systolic blood pressure between 160-180 mm. mercury and a diastolic blood pressure between 90-100 mm. mercury may be found in a normal aged person. East and Bain[27] in 1948 employed a limit of 160 mm. systolic. while Evans[28] also in 1948, used 180 mm. systolic and 110 mm. diastolic.

The material which we have presented includes a large number of studies made by many physicians, in different countries, and in a large and varied section of the population. From their studies it is clear that new limits of what constitutes the normal systolic blood pressure must be established. The same considerations hold true for the diastolic pressure.

Diastolic Pressure

Before 1900 the main interest in blood pressure centered about the systolic pressure. In 1907, Janeway[9] stated that the systolic pressure alone was necessary for routine use and the diastolic only under certain circumstances. However today the pendulum has swung the other way, and more attention is paid to the diastolic pressure than to the systolic.

The insurance company statistics of the 1920's were the basis for the commonly accepted limit of up to 95 mm. mercury as the normal limit for diastolic pressure. However, in 75,000 university students, Boynton and Todd[29] found that about 4,500 (5 to 7 per cent) of these presumably healthy persons under 40 years of age had a diastolic pressure over 90 mm. mercury.

In the article by Master, Marks and Dack,[22] it is also shown that the diastolic pressure rose with age so that at ages 60-69, over one-quarter of those tested had a diastolic pressure over 95 mm. mercury. These studies indicate that the increase of the diastolic pressure with age is less marked than the systolic. This is in keeping with the well-known fact that the pulse pressure increases with age. It is evident that there is a need for reevaluating the criteria of what constitutes the normal limits of diastolic pressure as well as that of systolic pressure.

Presentation of New Limits

The preceding presentation has indicated the historical evolution of blood pressure limits up to the present day. It has been clearly shown that from time to time, clinicians and investigators, concerned with the average individual patient and not with data from selected groups, have

TABLE II—NORMAL RANGE AND LIMITS OF HYPERTENSION

Systolic	*Normal Range*		*Hypertension Lower Limit*	
Age	*Male*	*Female*	*Male*	*Female*
16	105-135	100-130	145	140
17	105-135	100-130	145	140
18	105-135	100-130	145	140
19	105-140	100-130	150	140
20-24	105-140	100-130	150	140
25-29	108-140	102-130	150	140
30-34	110-145	102-135	155	145
35-39	110-145	105-140	160	150
40-44	110-150	105-150	165	165
45-49	110-155	105-155	170	175
50-54	115-160	110-165	175	180
55-59	115-165	110-170	180	185
60-64	115-170	115-175	190	190

indicated the necessity of altering some of our concepts of what constitutes normal limits.

There are two methods available for the establishment of limits of normal blood pressure. One method is to follow the course of a large number of people with what are considered to be normal and elevated blood pressures, over many years, until death. The use of this method is limited by the extreme difficulty and expense of following very large numbers of people, year by year, until death. Even at postmortem examination, it is often very difficult to say whether the cause of death is related to the elevated blood pressure.

A second method, which we have employed, consists in surveying the blood pressure in large representative groups of the healthy population. This is a more advantageous technique. This method has been employed by many physicians to obtain averages, ranges and trends of blood pressure, correlated with age and sex, etc. However, none of these physicians have actually presented limits defining normal and abnormal blood pressure.

During World War II, the opportunity arose to obtain blood pressure readings in 74,000 persons who were in average good health and able to work regularly. These readings were obtained in industrial plants in various sections of the country in as representative a group as possible.

TABLE III—NORMAL RANGE AND LIMITS OF HYPERTENSION

Diastolic	*Normal Range*		*Hypertension Lower Limit*	
Age	*Male*	*Female*	*Male*	*Female*
16	60-86	60-85	90	90
17	60-86	60-85	90	90
18	60-86	60-85	90	90
19	60-88	60-85	95	90
20-24	62-88	60-85	95	90
25-29	65-90	60-86	96	92
30-34	68-92	60-88	98	95
35-39	68-92	65-90	100	98
40-44	70-94	65-92	100	100
45-49	70-96	65-96	104	105
50-54	70-98	70-100	106	108
55-59	70-98	70-100	108	108
60-64	70-100	70-100	110	110

Executive, clerical and manual workers, both skilled and unskilled, male and female, were used. As to the accuracy of the figures obtained, detailed correspondence with the numerous physicians involved, as well as personal observation, convinced us that the figures were reliable. Where any doubt existed the data were not used. The results of this survey were subject to statistical analysis and published recently by Master, Dublin and Marks.[30] The data actually tabulated covered a sample of 16,000 persons (8,000 men and 8,000 women). The age range was 16 to 65 years.

Tables II and III summarize the results of this study. They indicate the normal range of systolic and diastolic pressure by sex and age, and the limits beyond which the readings are probably abnormal.

From these tables it will be noted that the range of systolic pressure increases gradually with age. Also the range and limit of normal systolic pressure starts at a slightly lower level in women as compared to the men, and continues in this manner until the age of 40 when they are equal. After the age of 50 it is slightly higher in the women than in the men. Thus at 16 years of age the lower limits of systolic hypertension for the male is given as 145 mm. mercury (normal range 105-135) and in the female it is 140 mm. mercury (normal range 100-130). At 55-59 years

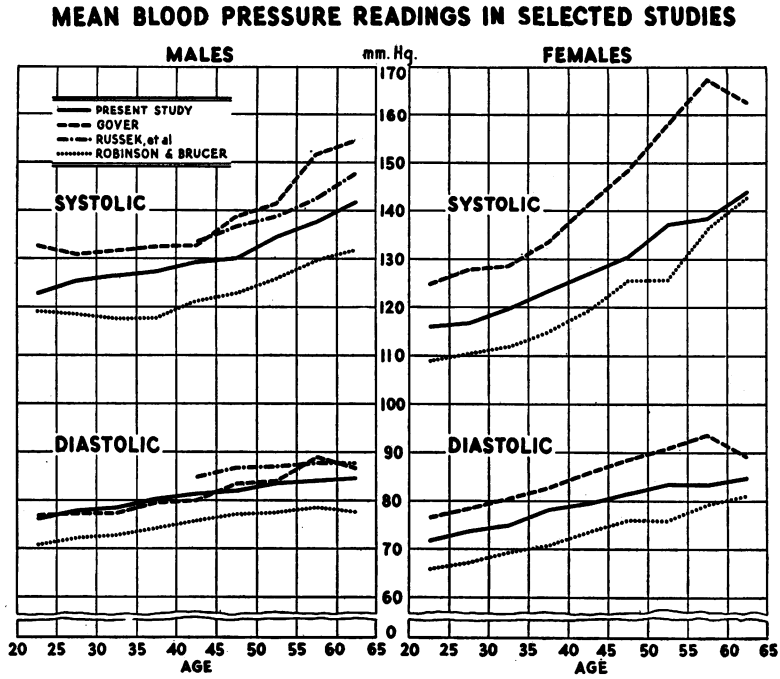

Fig. 5. Mean blood pressures in several selected studies.[24,31]

of age the lower limit of systolic hypertension for the male is 180 mm. mercury (normal range 115-165) and for the female it is 185 mm. mercury (normal range 110-170). All the cases falling between the maximum value given for the normal range and the lower limit of systolic hypertension are considered as borderline cases. They may belong to the normal or hypertensive group depending upon their clinical status (history, physical examination, cardiac enlargement, kidney disease, etc.).

The same gradual increase may be noted in the diastolic readings, but here the increase is less marked than in the case of the systolic pressure. Thus at 16 years of age 90 mm. mercury (normal range 60-86) and at 64 years of age 110 mm. mercury (normal range 70-100) are given as the lower limits of diastolic hypertension.

In comparing our new limits with those given by two other investigators in this field,[31] it will be evident, from the following figure, that our limits occupy a midposition between the other two (Figure 5).

Discussion

The predominant ideas about what constitutes normal blood pressure readings have been built up largely by data relating blood pressure readings to group mortality figures. These studies have been produced mainly by the life insurance companies. We have shown that the practice of using selected group mortality to delineate what constitutes normal limits for blood pressure, cannot be employed in the analysis of the significance of the blood pressure reading in the individual case. From time to time, clinicians have pointed out the fallacy of accepting these rigid and fixed criteria to delimit the normal from the pathological. Accordingly, the problem of obtaining new limits of normal and abnormal blood pressure is paramount. We have analyzed and presented data based on 74,000 blood pressure readings, which raise the normal limits of blood pressure usually accepted today.

In evaluating blood pressure readings, based on these new limits, it is to be emphasized that these readings must not be interpreted too literally. The blood pressure is only one factor to be considered in the determination of the clinical status of the patient and it must be evaluated in the light of the history, physical examination, eyeground changes, x-ray examination, functional tests of the heart, etc.

The acceptance of the new limits may have an effect in many fields. In the medical field it may be necessary to revise much data based on the correlation between moderate "hypertension," according to the old criteria, and various conditions—for example, coronary artery disease and coronary occlusion, cardiac enlargement, arteriosclerosis and diabetes. Many of these supposed relationships are being studied, using the new limits, and will be presented at a future date.

In other fields too, the importance of the new limits is considerable. At the present time, not only physicians but also laymen have become alert to the importance and significance of the blood pressure reading. In clinical practice, every physician sees many patients who are greatly disturbed by blood pressure levels which are moderately "hypertensive." With the new limits, these patients will be relieved by the knowledge that their blood pressure may be within normal limits and is not incompatible with an average expectation of life. In addition, much therapy which is being employed to try to lower the blood pressure of these patients will no longer be considered necessary.

The application of the new limits must also have widespread effect in industrial and military medicine, and in the life insurance field. In the industrial field, many men, particularly those over middle age, who have been rejected because of so-called hypertension, will have the opportunity to become gainfully employed. Present concepts of hypertension, as related to Workmen's Compensation, will have to be revised. These changes will mark important gains for the individual and for the community in which he lives. In the military field a number of rejectees may be considered fit for service when the new criteria are used; this will allow better utilization of our manpower.

It is not at all our intention to minimize the importance of true hypertension and its complications. The effects of the malignant form, in particular, are only too well known. There must be no slackening of the effort to learn the causes of high blood pressure and to develop a prevention or cure.

Conclusion

A short history has been given of the development of our knowledge of blood pressure and apparatus used to register it.

A historical and critical evaluation of the development of blood pressure limits has been presented and new limits of normal blood pressure proposed. The importance of application of these new limits in various fields has been emphasized.

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