The Clinical Measurement of Blood Pressure

The original source of the material in this booklet is the basic textbook "PRIMER OF CLINICAL MEASUREMENT OF BLOOD PRESSURE" by George E. Burch, M.D., and Nicholas P. DePasquale, M.D. of Tulane University School of Medicine, New Orleans, La.; published by The C. V. Mosby Company, St. Louis. Permission to use this material was graciously granted by the authors and the publisher.

Verbatim sections are set off by quotation marks and appear in italic type. Several of the more important illustrations and tables from the book are also presented.

INTRODUCTION

"Although the arterial blood pressure is measured many times a day by doctors all over the world, few physicians have devoted much thought to the problems and principles involved in measuring blood pressure accurately . . . From

the very beginning, the student must learn to record the blood pressure properly. Accurate blood pressure recording will then become a habit that will remain with the physician for his lifetime."

WHAT IS BLOOD PRESSURE?

The arterial blood pressure is the lateral pressure, or force, exerted by the blood on a unit area of the blood vessel wall. The arterial blood pressure is constantly changing during the course of the cardiac cycle. The highest pressure in this cycle is the *systolic* blood pressure; the lowest is the *diastolic* pressure.

The numerical difference between the two is the *pulse pressure*. A typical blood pressure is expressed thus: 120/80 mm Hg.

A number of factors, acting in dynamic equilibrium and integrated through the central nervous system, determine the arterial blood pressure:

- Cardiac output
- Peripheral vascular resistance
- Volume of blood in the arterial system
- Viscosity of the blood
- Elasticity of the arterial walls

The exact contribution of each factor is not known, but peripheral resistance and cardiac output have the greatest influence on blood pressure.

BLOOD PRESSURE APPARATUS

"Measuring arterial blood pressure with the sphygmomanometer is accurate, safe, and easy." The manometers used have always been of the mercury-gravity

or aneroid type, and both have been improved with time. Each consists of (1) a pressure manometer, (2) a compression cuff consisting of an inflatable rubber bladder enclosed within an inelastic covering, and (3) a pressure source consisting of a rubber hand bulb and pressure control valve.

The mercury-gravity manometer consists of a straight glass tube in assembly with a reservoir containing mercury. The pressure chamber of the reservoir communicates with the compression cuff through a rubber tube. When pressure is exerted on the mercury in the reservoir it falls, and the mercury in the glass tube rises. Since the weight of the mercury is depended upon gravity, which is constant, a given amount of pressure will always support a column of mercury of the same height in the straight tube of uniform diameter.

"Once the mercury manometer is calibrated, recalibration is unnecessary. The mercury manometer is the most reliable recorder available for the clinical measurement of blood pressure."

Table 1. The Advantages of mercury and aneroid sphygmomanometers.

Type	***Advantages***
Mercury-gravity	Great accuracy
	Permanent accuracy
	Standard for pressure
	measurement
	Easily replaceable parts
	Does not require recalibration
Aneroid	Ease of portability

The aneroid manometer consists of a metal bellows the inside of which is connected to the compression cuff.

Variations of pressure within the system cause the bellows to expand and contract. Movement of the bellows rotates a gear that turns a needle, pivoted on bearings, across a calibrated dial.

"Obviously, the adjustment of the mechanical system of the aneroid manometer is more easily disturbed than that of a mercury manometer. For this reason the aneroid manometer must be calibrated against a mercury manometer at regular intervals. Since the blood pressure recorded with the aneroid manometer depends upon the elasticity of the metal bellows, it is subject to errors inherent in the elastic properties of metals, such as 'seasoning', hysteresis, and drift. Remember, the mere fact that the needle points to zero on the dial of the aneroid manometer when the compression cuff is deflated does not necessarily mean that the instrument is accurate over the entire pressure

range."

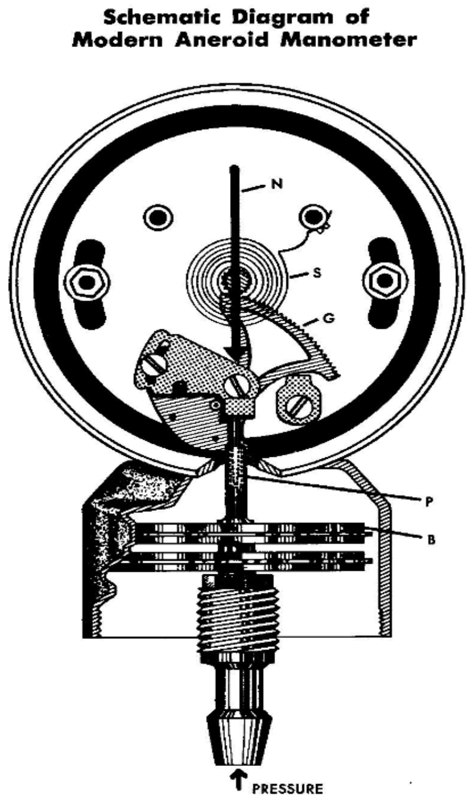

Fig. 1 - A schematic diagram of the construction of pocket aneroid manometer. Variations in pressure within the bellows, B, activate a pin, P, which sets a gear, G, into motion. The gear, in turn, operates the spring, S, which causes the needle, N, to move across the face of a calibrated dial.

The compression cuff consists of an inflatable rubber bladder within an inelastic covering. The compression cuff must be the correct width for the diameter of the patient's arm. If it is too narrow, the blood pressure reading will be erroneously high; if too wide, the reading will be erroneously low.

The inflatable rubber bladder should be long enough to encircle at least half the limb. The center of the rubber bladder should rest over the artery being compressed. For the average adult, an inflatable bladder 13 cm (5.1 inches) wide and 23 cm (9.1 inches) long is generally satisfactory.

The covering that encloses and encircles the inflatable bladder must be of inextensible material and provide uniform compression over its full width. With a 12 cm wide bladder, the cuff should be 14 cm wide.

Table 2. Recommended widths of compression cuffs for infants and children.

Age	***Width of inflatable bladder***
Newborn infants	2.5 cm (1 inch)
One year to four years	6 cm (2.3 inches)
Four to eight years	9 cm (3.5 inches)

Corrections in the width of the compression cuff must be made for extremely obese or unusually thin arms. A recognized rule is that the width of the inflatable bladder be 20% grater than the diameter of the limb on which it is used. The thoughtful physician should use cuffs which a snug fit and uniform compression of the arm.

TECHNIQUE OF MEASUREMENT

"In the everyday practice of medicine, a combination of the palpatory and auscultatory methods is used".

1 - Application of the compression cuff

The blood pressure is generally recorded in the arm with the patient in a sitting or recumbent position. The physician should arrange his desk and chair or examining table so the patient's right arm is always and inevitably presented for recording of the blood pressure. The arm should be abducted, slightly flexed, and supported by a smooth, firm surface. The artery over which the blood pressure is to be recorded should be at a level with the heart. *It is not necessary for the manometer to be at heart level.*

The deflated compression cuff is applied evenly and snugly, but without constriction, around the right arm. The lower edge of the cuff should be one inch above the point at which the bell of the stethoscope is to be placed.

2 - Palpatory Method

The radial or popliteal pulse is palpated and the rate and rhythm are noted. The compression cuff is then inflated to about 30 mm Hg above the pressure at which the radial pulse disappears. (When the cuff is inflated, it should not bulge nor become displaced.) The cuff is then deflated at a rate of 2 to 3 mm Hg per heartbeat. The level of pressure at which the pulse in the radial artery returns is noted and recorded as the systolic arterial blood pressure. The diastolic blood pressure is difficult to measure by palpation and is not generally determined by this method.

3 - Auscultatory Method

After the systolic blood pressure has been determined by the palpatory method, the blood pressure is then determined by auscultation over the artery at a point below the compression cuff, which has remained on the arm. The artery is first palpated, and then the receiver of the stethoscope is applied lightly but snugly over it to produce an airtight seal. The receiver must not come into contact with the patient's clothing nor with the compression cuff. The compression cuff is then inflated rapidly to about 30 mm Hg above the systolic pressure as previously determined by the palpatory method. The cuff is then deflated at a rate of 2 to 3 mm Hg per heartbeat. While the physician is watching the meniscus of the mercury column, or the pointer of the aneroid gauge, the pressure at which characteristic changes in the Korotkoff sounds occur is noted. From the changes in the quality of these sounds, the *systolic* and *diastolic* blood pressure are determined.

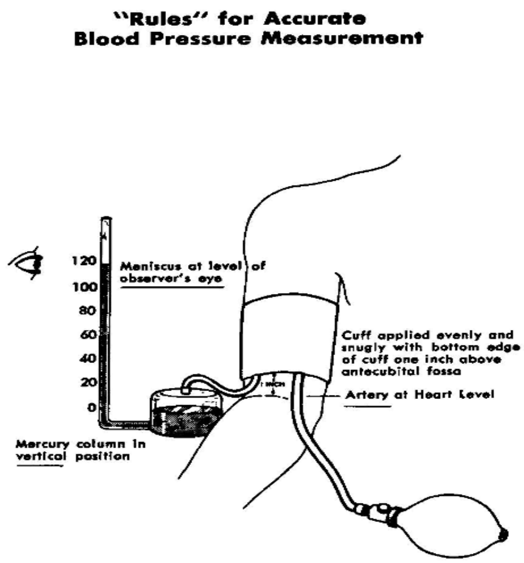

Fig. 2 - Important "rules" for accurate recording of arterial blood pressure

The systolic blood pressure

The pressure within the compression cuff indicated by the level of the mercury column, or the pointer of the aneroid gauge, at the moment the Korotkoff sounds are first heard, represents the systolic blood pressure. This is the start of Phase 1 (Fig. 3) which begins with faint, clear and rhythmic tapping or thumping sounds that gradually increase in intensity.

The diastolic blood pressure

The pressure within the compression cuff indicated by the level of the mercury column, or the pointer of the aneroid gauge, at the moment the sound suddenly becomes muffled, represents the *first diastolic pressure* (beginning of Phase 4). The *second diastolic pressure* is the pressure within the compression cuff at the moment the sounds finally disappear (beginning of Phase 5).

"Some physicians consider the diastolic pressure to be equal to the pressure in the compression cuff at the moment the first sound of Phase 4 is heard. This has been found to be somewhat higher than the pressure recorded directly and simultaneously… Until more is known, it is advisable to record two diastolic pressures; the first at the onset of Phase 4 and the second upon the development of faint sounds in Phase 4 or at the moment of disappearance of the Korotkoff sounds. With experience and clinical judgment, serious errors in measuring diastolic blood pressure can usually be avoided."

Phases of the Korotkoff Sounds

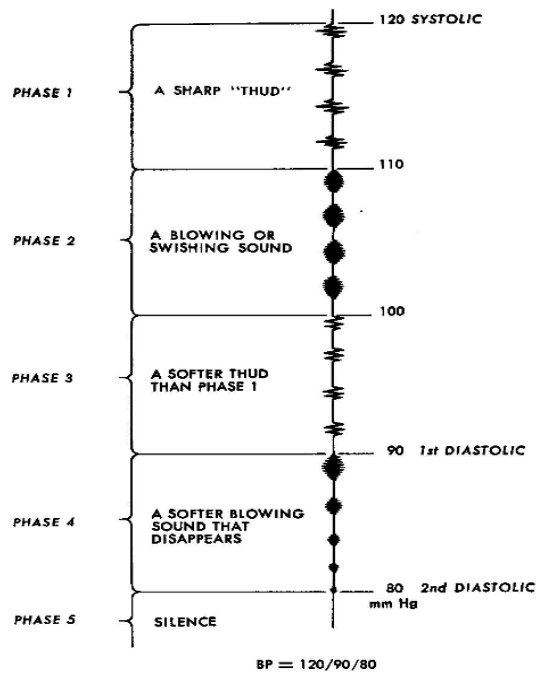

Fig. 3 - The various phases of the Korotkoff sounds.
Consult text for details.

SUMMARY

Steps in taking blood pressure

1 - Snug application of compression cuff.

2 - Palpation of radial artery as compression cuff is inflated.

3 - Palpation of radial artery as cuff is deflated at 2 to 3 mm Hg per heartbeat.

4 - Careful placement of stethoscope receiver.

5 - Inflation of compression cuff above systolic pressure.

6 - Deflation of the cuff at a rate of 2 to 3 mm Hg per heartbeat to determine systolic and diastolic blood pressure.

"Regardless of the mechanism responsible for the production of the Korotkoff sounds and the pros and cons for employing the beginning of Phase 4 or of Phase 5 to measure diastolic pressure, the auscultatory method for obtaining arterial blood pressure is the clinical method **par excellence***. The wise, careful, and thoughtful physician will not make serious clinical errors in diagnosis and treatment if the uses the ausclultatory method properly."*

SOURCES OF ERROR

"Errors that can be avoided in the clinical measurement of arterial blood pressure are committed not only by undergraduate students, but also by physicians. So much of the technique for the measurement of blood pressure has been taken for granted that few physicians have given much thought to the many problems concerned with sphygmomanometery…The arterial pressure is fickle, and the ill-informed and unprepared physician is readily confused and his patient erroneously treated…Therefore, to make the reading as accurate as accurate as possible, it is important to eliminate all sources of avoidable error. The indirect method will then compare favorably with the direct method of measurement."

In general, errors in blood pressure measurement are due to the following:

A - Faulty Technique

1 - **Improper positioning of the extremity**. Whether the patient is sitting, standing, or supine the position of the artery in which the blood pressure is measured must be at

the level of the heart. However, it is not necessary that the sphygmomanometer be at the level of the heart.

2 - **Improper deflation of the compression cuff**. The pressure in the cuff should be lowered at about 2 mm Hg per heartbeat. At rates slower than this venous congestion will develop and the diastolic reading will be erroneously high. If the cuff is deflated too quickly, the column of mercury may fall 5 or 10 mm Hg between successive Korotkoff sounds, resulting in erroneously low readings.

3 - **Recording the first blood pressure**. Spasm of the artery upon initial compression and the anxiety and apprehension of the patient can cause the first blood pressure reading to be erroneously high. After the cuff has been applied, the physician should talk quietly to the patient for a few minutes in an effort to make him relax before the blood pressure is recorded. Several measurements should be made at each examination; generally, the third value recorded is the most basal.

4 - **Failure to have the mercury column vertical**. It is not necessary that the mercury column be at heart level, but the mercury column must be vertical. This applies especially when measuring the blood pressure of a patient in bed since the bed often does not provide a level surface.

5 - **Auscultatory gap**. In some patients the Korotkoff sounds disappear as the pressure is lowered and reappear well above the diastolic pressure. This interval of silence is known as the "auscultatory gap." Erroneously low systolic readings can be avoided by first recording the blood pressure by the palpatory method.

6 - **Improper application of the cuff**. In the rubber bladder bulges beyond its covering, the pressure will have to be excessively high to compress the arm effectively. If the cuff is applied too loosely, central ballooning of the rubber bladder will reduce the effective width, thus creating a narrow cuff. Both bulging and ballooning result in excessively high readings.

"The importance of a smooth and even application of the

compression cuff cannot be overemphasized. The physician should develop the habit of always applying the cuff properly. Hurried and careless application will result in inaccurate blood pressure determinations. In many ways it would be better not to record the blood pressure at all than to allow an improperly recorded blood pressure to influence clinical judgment or to be entered as part of a patient's record. The insurance and legal implications of erroneously high blood pressure values are well known."

B - Defective Apparatus

A defective air release valve or porous rubber tubing connections make it difficult to control the inflation and deflation of the cuff. The mercury and vertical glass tube should always be clean. If an aneroid manometer is used, its accuracy must be checked regularly against a mercury manometer. The needle should indicate zero when the cuff is fully deflated. However, an accurate zero reading is not a guarantee that the aneroid manometer is accurate throughout the entire pressure range.

SUMMARY

"Blood pressure values obtained by the indirect method can be as reliable and as consistent as those obtained by the direct method if the indirect blood pressures are recorded properly and a perfectly functioning manometer is used....The alert physician should be skeptical of any abnormal blood pressure values and should ask himself if any sources of error were present at the time of the determination. Only after he has made certain that the blood pressure was measured properly in all respects should he accept an abnormal blood pressure value as representative of the patient's blood pressure."

CONCLUSION

"Of the many objective procedures that physicians employ to obtain quantitative data on their patients, none is used as often as the measurement of arterial blood pressure. The fact that every physician, regardless of his specialty, records blood pressure repeatedly during the course of a day attests to the importance of the blood pressure determination and the reliance

of the physician on the information it provides. Therefore, the importance of accurate blood pressure determinations cannot be over-emphasized."

"If proper habits, proper equipment, and proper techniques are used routinely in recording blood pressure, it will then be found that it is just as easy to record blood pressure accurately and reliably as it is to record it haphazardly and erroneously."
"REMEMBER - NO DATA IS BETTER THAN WRONG DATA!"

Additional material appears in the textbook "PRIMER OF CLINICAL MEASUREMENT OF BLOOD PRESSURE."* The following Chapter headings indicate the range of interests covered.

History of the Recording of Blood Pressure (an illustrated discussion of types of apparatus used from 1733 to the present).

Physiology of the Arterial Blood Pressure (complete discussion of the factors which determine blood pressure; brief coverage of the regulation of arterial blood pressure).

The Clinical Measurement of Arterial Blood Pressure (detailed discussion of apparatus and techniques; also, the theoretic bases of blood pressure measurement).

Source of Error in the Clinical Measurement of the Arterial Blood Pressure (pitfalls in technique, faulty apparatus, physician error, and failure to consider the patient adequately).

Factors that Affect Arterial Blood Pressure (comprehensive discussion of blood pressure variations caused by age, weight, heredity, pregnancy, diet - 14 factors in all).

Normal Values of Arterial Blood Pressure (charts and tables of normal averages for various age groups, presented with the

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* The C. V. Mosby Company, St. Louis, 1962; 141 Pages, 50 Illustrations, 9 Tables.

author's warning: "Statistics are no substitute for sound clinical judgment.")

Diagnostic Applications of Arterial Blood Pressure Measurements (practical information on changes in arterial blood pressure which indicate certain physiologic conditions).

Closing Remarks (appear complete in this booklet).

Bibliography (261 references classified generally by topics covered in the book, providing the reader with sources for detailed study of particular fields of interest).

* The C.V. Mosby Company, St. Louis, 1962; 141 Pages, 50 Illustrations, 9 Tables.

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