Recording and Visual Oscillometry by a New Standardized Technic

By Julius A. Oshlag, M.D.,† and A. Wilbur Duryee, M.D.

Oscillometry offers knowledge of clinical importance, yet its value in presently used apparatus has recently been questioned. The criticisms include shifting base line, parallax in visual reading, aging of rubber parts with consequent loss of elasticity, friction and inertia of writing mechanisms, and failure to standardize. The method suggested below obviates these defects.

The clinical oscillometer measures the expansion of a segment of an extremity occasioned by the systolic inflow of blood, when that segment is subjected to various degrees of pressure. It has been stated that plethysmographic results represent the ultimate circulation while the oscillometer deals with the penultimate circulation. While total or ultimate flow cannot be determined with the oscillometer as yet, comparison of the systolic expansion of various segments of an extremity and of identical segments of the contralateral extremity offers clinical knowledge difficult to gain by other means.

Various investigators have questioned the value of the oscillometer in recent years. We believe that this has been the result of certain defects found in oscillometric apparatus available up to this time. In visually read oscillometers the frequent shifting of the base line of the moving needle, and to a lesser extent the phenomenon of parallax, make accurate reading extremely difficult. Standardization has not hitherto been provided for. Gross inaccuracy thus appears when comparison of readings taken on two different instruments is attempted. Indeed, inaccuracy is to be anticipated in comparison of readings taken on the same piece of apparatus when sufficient time has elapsed between the readings for aging to have affected the elasticity of the rubber cuff and other rubber parts. Inability to increase the sensitivity of previous oscillometers when needed constitutes an additional important defect. It has not been uncommon in the past to observe no oscillation when attempting to measure segments of some limbs in which the appearance of vitality or actual palpable pulsations gave strong evidence that a certain minimum of circulation existed. The instruments previously developed solely for visual reading have, of course, no means of making a permanent record. Those developed for the purpose of obtaining permanent records have been difficult to read visually, since no provision is made for the maintenance of pressure at any one level for a period long enough to permit accurate reading. Errors due to friction of pen and paper writing, to the overthrust of comparatively heavy writing arms, etc., are also to be found in older recorders. The expense of construction of the latter machines has been considerable.

The apparatus and method described below permit a standardized permanent record of the systolic expansion of segments of limbs to be made on photographic paper. Visual reading, though not preferred, may be made without the difficulty of shifting the base line and without error introduced by parallax. Sensitivity may be varied when needed. A minimum of moving parts has considerably reduced the possibility of error. Recording is without friction, being accomplished by a shadow within a beam of light. The expense of attaching the apparatus to a standard electrocardiographic camera is but very slightly more than the cost of the average visually read oscillometer.

† Deceased, November 9, 1949.

* As presently designed, apparatus and method is for use only with the Cambridge Simplitrol.
METHOD AND APPARATUS

Oscillometric readings are basically dependent upon the expansion of a segment of an extremity against a confined, encircling, mercury or aneroid manometer, inflating bulb, and valve remain attached, and the ordinary sphygmomanometer, thus, is utilized just as in measuring the blood pressure. Oscillometric

inflated rubber cuff. Since the single rather than the double cuff is recommended for measurement of the oscillometric index, the cloth-covered rubber bag of any sphygmomanometer is satisfactorily used. The measurements are made by amplifying and recording the pressure changes occurring within the rubber bag with each systolic inflow.

Pressure changes within the inflated rubber cuff are transmitted laterally to the walls of

Fig. 1. Diagram of apparatus, showing cuff applied around arm. The location of the cup in relationship to the artery is not important for comparison readings.
the cuff. When one section of the outer wall of the rubber cuff lies snugly against the open portion of a stationary rigid cup, the interior, of which is maintained at atmospheric pressure, the expansion of this section is appreciable and quantitatively measureable for it forms a responsive diaphragm for the rigid cup. The concavity surrounding the periphery of the central cup, the other leads to the central cup itself.

The plastic cup is slipped between the cover cloth and the outer wall of the rubber bag of the sphygmomanometer arm piece so that the opening of the cup lies against the rubber and

cup is made of a light plastic in the shape of a disc, is approximately $1\frac{2}{8}$ inches in outside diameter with a height of $\frac{3}{8}$ inches. The open face of the cup is double ridged at the edges. The diameter of the larger central concavity of the cup is $1\frac{7}{8}$ inches. Two metal leads project from the cup. One of these affords access of air at atmospheric pressure to the small so that the metal lead from the major cavity of the cup barely projects through the opening in the cloth cuff through which the tubes to the rubber cuff enter. The limb piece of the oscillometer thus consists of a sphygmomanometer with a small segment of the rubber cuff acting as a diaphragm beating with each expansion within the cuff against

![Oscillometric curve from left calf of normal subject. Deviations from lower base line indicate level of pressure at which reading was obtained. Each large deviation represents 30 mm. Hg., and each smaller one 10 mm. Hg. The curve starts at 200 mm. and in steps of 20 mm. drops to 40 mm. Oscillometric index is found at 80 mm. See text for standardization used in this and succeeding illustrations. A curve obtained immediately afterward under the same conditions with a visual oscillometer gave the following readings: 200 mm.: 0.2; 180 mm.: 0.5; 160 mm.: 0.75; 140 mm.: 1.0; 120 mm.: 1.6; 100 mm.: 2.7; 80 mm.: 4.0; 60 mm.: 2.4; 40 mm.: 0.6 Shifting of the base line noted in several recordings indicates the presence of a minute leak in the limb piece-sphygmomanometer system.](image-url)
serves the purpose of maintaining the recording system at atmospheric pressure at all times, except when it is desired to transmit oscillatory pressure waves from the rubber cuff to the recording tambour. The vent is small enough to be completely closed with the finger tip for this purpose.

The recording tambour was originally described by Henny, Boone, and Chamberlain for recording the carotid pulse simultaneously with the electrokymogram, and modified somewhat for ease in commercial manufacture by the engineers of the Cambridge Instrument Company. The tambour consists of a thin rubber diaphragm fastened to a plastic capsule. From one edge to the center of the diaphragm is cemented the base of a thin aluminum pointer. The pointer turned at right angles to the base projects away from but in the central axis of the diaphragm. When mounted on the electrocardiograph the pointer projects into the light beam and casts a shadow on the visible white scale and on the recording paper. Two brass screws are found on the supporting mechanism of the tambour. The first moves the entire tambour and its housing in or out of the light beam. The second, by rotating the rubber diaphragm permits rotation of the plane of movement of the pointer from one at right angles to the light beam to one that lies in the direction of the light beam. Thus the amplitude of motion of the shadow of the pointer varies

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**Fig. 3.—Tracings of right calf and lower leg above ankle taken immediately before and twenty minutes after removal of subject from high environmental temperature (84 F.; 29.0 C.) to air conditioned room (66 F.; 19.0 C). Oscillations were reduced 1.5 mm. in the calf tracing and 4.75 mm. in the lower leg. Only the oscillometric index is illustrated.**
from its maximum to no excursion. Standardization of the instrument and adjustments of sensitivity for almost all clinical work may be made easily by rotation of the rubber diaphragm.

Movements of the shadow of the pointer fall upon the white scale of the electrocardiograph. The phenomenon of parallax is therefore not involved, and if the entire system is without air leak, movements of the shadow are constant and without the shifting of the base line at each pressure measured. Reading of the oscillatory movements is comparatively simple, but recording by means of the electrocardiographic camera at normal speed is preferable. We have found it convenient to use the standardization current of the electrocardiographic

![Graph](image_url)

**Fig. 4.**—Subject with moderate symptoms of occlusive vascular disease in the left lower extremity. There is a difference in amplitude of oscillation amounting to 6 mm. in the lower thigh, 5 mm. at the calf, and 1.5 mm. at the foot when oscillometric indices here presented are compared.

string to indicate the air pressure levels within the rubber cuff, using 3 millivolts for each 30 mm. increment of pressure as measured by the mercury manometer and 1 millivolt for each 10 mm. increment.

In order to obtain a standardized record, calibration is necessary prior to any recording.
FIG. 5.—Subject with symptoms of severe occlusive vascular disease in the right lower extremity. Full oscillometric curves of the left and right calves are presented with tracings made on an older recording sphygmomanometer for comparison. The figures below each record represent the blood pressure in mm. Hg. at which the tracing was obtained. The curve is not a single tracing, each wave having been clipped from its own small recording.
Standardization may be accomplished by wrapping the sphygmomanometer cuff about a solid cylindrical object with a diameter of approximately 3½ inches. The cuff is then inflated to a specified level, the air vent closed and the pressure dropped slowly in the cuff. During this procedure the shadow of the needle will move. Amplitude of shadow movement for any specified drop in pressure may then be adjusted as desired by rotation of the rubber diaphragm. Our early records (and those used in the illustrations) were made using a tambour not possessed of the rotating mechanism necessary for varying the amplitude of the string shadow. Sensitivity for this apparatus was thus constant. Using one particular sphygmomanometer it was found that a drop of 4 mm. of the mercury column from 110 mm. to 106 mm. occasioned a movement of the needle shadow of 25 millimeters. For the past eight months at the New York University Hospital Clinic we have had the newer type of tambour available and have standardized our records so that a drop of 10 mm., from 100 mm. to 90 mm., caused a shift in the needle shadow of exactly 10 millimeters. It is to be noted that this method of calibrating the entire system compensates for variance in the elasticity of different rubber cuffs and diaphragms, and for the aging processes of these rubber parts in the same apparatus. As pointed out above, if gross changes in sensitivity seem desirable for some special problem, the size of the plastic cup may be varied. We have not found this necessary up to this time.

Following calibration and notation of the standard used, a record is made by applying the cuff of the sphygmomanometer to the part of the extremity to be studied, the cuff inflated to a point above the local systolic pressure, the air vent closed with the tip of the finger and the movements of the needle shadow observed. A camera recording of the oscillations and markings, indicating the amount of air pressure in the cuff, should be made at this time. Upon completion of the recording of several waves, the air leak should be opened at once. The pressure in the cuff should then be dropped in increments equivalent to 10 mm. of mercury, and recordings taken of oscillations occurring at each new lower pressure. For purposes of economy we have occasionally made visual readings and then recorded the oscillations which appeared largest as well as those 10 mm. above and those 10 mm. below the maximum excursions. The records above and below the observed maximum constitute a check on the accuracy of visual observation since on measurement of the finished records both should be smaller than the oscillations chosen visually as the largest.

Clinical Use

The apparatus and method described have now been in use for approximately eight months in the peripheral vascular disease clinic at the New York University Hospital and for over two years in the private practice of one of us (J.A.O.). Studies have been made of the progress of vascular disease, of the effectiveness of vasodilating drugs and of sympathetic blocking procedures. The instrument has proved of particular value in determining the amount of spastic component present in the major arteries in various peripheral vascular diseases by taking records before and after vasodilating procedures and in determining the level of effective circulation following acute vascular occlusions.

These observations have made it obvious that the role of oscillometry in the study of peripheral vascular disease must be re-evaluated, using this new technic. Studies for this purpose are under way and will be reported subsequently.

Comment

In developing this technic for oscillometry we have attempted to overcome the defects which we feel have hitherto made oscillometry unsatisfactory. Shifting of the base line does not occur if the system is leak-tight. Parallax in visual observation does not exist since the observed oscillations are those of a shadow thrown directly onto a fixed scale. Oscillation may be observed for as long a period as seems
necessary for accuracy. There are no mechanical joints nor is there friction in the writing mechanism. Amplification is produced by the increased excursions of the tip of a rigid pointer swinging through an arc and the optical system of the electrocardiograph. Distortion and error in amplification are thus reduced to an inappreciable minimum. Standardized records are obtainable and it is possible to vary the sensitivity of the apparatus grossly by using smaller or larger segments of the rubber cuff as a diaphragm. Finer adjustments in sensitivity may be made by rotating the plane of movement of the pointer in its relation to the fixed beam of light.

Summary

1. A new technic for obtaining oscillometric measurements is described in detail.
2. Standardized records are obtainable.
3. Several sample records are exhibited.

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