The Criterion for Diastolic Pressure—Revolution and Counterrevolution

The publication in this issue of the new recommendations of a committee of the American Heart Association on the clinical determination by sphygmomanometer of the blood pressure represents, as to the best criterion for diastolic pressure, not a revolution but a counterrevolution. On the many other important matters discussed in the report there is likely to be little controversy.

The original International Committee of 1939 quite definitely stated that the point of "muffling," not of "disappearance," of the Korotkoff sounds was the more reliable. In 1951, a committee of the American Heart Association, this time exclusively a U. S. committee rather than an International committee, put out its report. This was published simultaneously in three different journals and given to all U. S. medical students as a pamphlet. This second report reversed the original opinion, stating that "muffling" was to be regarded as less reliable than "disappearance" as an index of diastolic pressure. This U. S. committee in 1951 had the advantage of many more published results in which direct measurements of blood pressure by arterial catheter were compared with the indirect method. In 1939, practically no such data were available on man and the original decision was based mainly on the theoretical basis of many studies of the origin of the Korotkoff sounds, such as the classical work of Joseph Erlanger, who preferred the "muffling" to the "disappearance" as the diastolic criterion.

The recommendations of this second committee achieved very little adoption outside the United States. The Canadian Heart Association asked Dr. G. W. Manning of the Department of Medicine in our University, to help them decide what to advocate in Canada. He made tests (and published a paper!), using interns as observers, of the indirect method in cases in which catheter measurements were also available. He and his co-workers concluded that in a subject at rest "muffling" was on the average 4 mm Hg above the total diastolic pressure, while "disappearance" was about 6 or 7 mm Hg below it. After exercise the muffling point remained close to the true diastolic pressure, but the disappearance point dropped to values far below this, even to as low as zero. Believing that the theory of the origin of the
sounds indicated that the correspondence of disappearance with diastolic pressure (found only at rest) was accidental and not basic, the Canadians adopted a typical compromise, that is, that both muffling and disappearance points should if possible be recorded, but that of the two criteria the muffling was more reliable. This is the recommendation of the present Committee.

Thus the new Committee of the Association, after 2 years of meeting periodically, apparently settling and then reopening the argument on both sides, has reverted to the original 1939 decision. The recommendation is the same as that of the Canadian group, and of the World Health Organization, that whenever possible both criteria should be recorded (for example, B.P. 120/80, 75), and that when they differ significantly, the muffling point is to be relied upon rather than the disappearance. Whichever is chosen, it is important that the approximate character of the measurement be realized. It is a question of the “best we can do” by indirect methods.

The Importance of the Decision

Although, as will be shown, we are forced to rely upon basic theory of the origin of the sounds, and insight into what is happening to the artery and blood flow during the measurement of blood pressure, the decision has far more than academic importance. While in most normals at rest, the two values are close enough not to matter much clinically, in exercise no one could rely on the disappearance point, and some healthy persons show a very large split between the two values even in resting conditions. At the time of his work on the subject, Manning had a young man referred to him, from a routine insurance examination, for suspected aortic incompetence. This examination had recorded a very low diastolic pressure (about 20 mm Hg, as I recall). The insurance examiner had used the orthodox U. S. criterion of disappearance. Cardiac investigation showed no trace of insufficiency, and the muffling criterion gave diastolic pressure in the normal range of 80 mm Hg. The velocity of flow determines, with the size of channel, the existence of nonlaminar flow, and thus of any sound at all. Presumably this man had unusually narrow arteries, in which the velocity of flow was high enough to produce sounds even when the artery was only slightly compressed by the cuff. If we use the wrong diastolic criterion, we may be wasting time and money and, more importantly, will be guilty of raising doubts about their cardiac status in the minds of perfectly healthy persons (a very serious crime from the point of view of a nonmedical customer like me).

The Empirical Approach

One would think that the argument could be settled, as is usual in science, by the actual evidence from measurements of true diastolic pressure, simultaneously by arterial catheterization and by sphygmanometry. The number of such published studies is now impressive, and more data on this point appear every month. Yet all evidence on this is really inconclusive, for two reasons:

1. Practically all the data are on healthy young men (usually medical student volunteers). In Medicine we must deal, by its nature, with abnormal physiology, and with persons of all ages. Validation of any method on normal young subjects is no guarantee of reliability in clinical use.

2. There is a most remarkable lack of agreement in the results as successive papers appear, so much so that there would be little point in publishing any more studies until the cause of the discrepancy is understood (we now think it is, see below). The majority of studies find that the two criteria bracket the true diastolic pressure, the muffling point being 0 to 10 mm Hg above while, in conditions of rest only, the disappearance is 0 to 10 mm Hg below the true diastolic pressure. However, the most recent paper that I have read actually reports that both criteria gave values above the true diastolic pressure. Many papers report no detectable difference between muffling and disappearance points, and some say that muffling is very hard to identify (though Roberts and associates1

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found that ordinary interns were just as consistent or better on muffling as on disappearance). How can such contradictions occur in good experimental researches? Will we have a counter-counterrevolution in future years as to measuring diastolic pressure, when more papers have been published?

The Clue as to the Experimental Discrepancies. What Is Muffling?

It is very hard to define what is meant by "muffling," though most people who have heard it are sure they can recognize it. Analogies to a change of the sound from a piano to an organ, from hard to soft pedal, staccato to continuous, thud to thump are not really very helpful, compared to listening oneself.

It is an enormous gain that we now know, in physical terms, what occurs to the sound at muffling. McCutcheon and associates (published only as an abstract) showed by frequency analysis of the Korotkoff sounds as the cuff pressure fell, that at muffling there was a sharp decrease of the higher frequency components (above 60 cps), while the low frequency components persisted until disappearance. The recent paper by McCutcheon and Rushmer greatly elucidates the whole problem. We have verified this change in frequency content (fig. 1) and find that the low frequencies may even continue to increase in amplitude at muffling while the higher frequencies are dropping out. There is a logical reason why we might expect this drop-out of higher frequencies to occur at cuff pressures near the diastolic pressure. At higher cuff pressures the artery, presumably, is closed briefly at the end of each cycle; at below diastolic pressure the artery will remain open throughout the cycle. The sound, generated by the nonlaminar condition of the flow, can then be continuous, not interrupted. Fourier analysis of a wave form which drops abruptly (as of the interrupted sound) involves high frequency components, not present in the Fourier components of a continuous sound which has less abrupt starts and stops.

Now we can see why different researches have differed so much as to the gap between muffling and disappearance. The microphones, amplifiers, loudspeakers, and indeed each type of stethoscope, particularly as to the receiver (bell or diaphragm), all act as frequency filters, attenuating the sounds differently according to their frequency range. An apparatus that passes the low frequencies with relatively the same attenuation as the frequencies above 120 cps will indicate a change in quality of the sound when high frequencies drop out at the muffling point, and allow the persistent low frequencies to

![Figure 1](image-url)

Illustrating the changing acoustic spectrum of the Korotkoff sounds as the cuff pressure falls. The ordinate values, which represent relative sound amplitudes, were obtained by playing back through high-pass, low-pass filters the recordings made as the cuff pressure was held at the various levels shown. The frequency ranges on the right hand side are the same as shown at the upper left hand side. Direct measurement of blood pressure was made simultaneously by catheter. Note that just above the diastolic pressure in the cuff, the higher frequencies abruptly diminish in amplitude, while the low frequencies persist below the diastolic pressure. (From unpublished work with J. Laing, medical student.)
be heard to a much lower point of disappearance.

On the other hand, if this apparatus has a high frequency pass, while attenuating low frequencies greatly, the sounds will disappear at the same point as the muffling, which will not be interpreted as a significant change in quality of the sound. Hence the report in this case will be that muffling is hard to recognize or that muffling and disappearance are simultaneous. This was brought home to me last year, when, as is our custom, we demonstrated to a class of medical students the indirect measurement of blood pressure with a microphone and loudspeaker so that all could hear. For the first time in many years, we could not get any difference between muffling and disappearance, even after exercise. We noticed, however, that the sounds were of much higher frequency than those we have usually heard, that is, that the apparatus was acting as a high-pass frequency filter and was suppressing the lower frequencies. This explained our failure compared to our success in previous yearly demonstrations.

Clearly then, knowledge of the frequency characteristics of the stethoscope or the electronic devices used in each research is essential to the problem, and there would be little point in further experimental approaches to the problem until this knowledge is available.

This discovery as to the importance of frequency response of the stethoscope and other apparatus offers an eventual solution of the problem to the satisfaction of everyone. If, when diastolic pressure is being measured, we could ensure that the stethoscope passed the high frequencies, say above 120 cps while suppressing the lower frequencies, muffling and disappearance would coincide, and the criterion would become sharper and easier to apply (as indicated by figure 1). On an electronic stethoscope it is very easy to add a switch labeled “diastolic” which would provide such filtering, but we doubt if such a stethoscope will ever be universally used. It is not impossible that a simple acoustic filter, used only for diastolic pressure determination, might be added to the nonelectronic stethoscope to achieve the same end. We are at present doing research on this.

The Logical Approach

In view of the above, we must be willing to decide between muffling and disappearance, until acoustic filtering may remove the discrepancy, on the basis of logic rather than of empirical data. To the writer, the logic consists of three convincing arguments against disappearance as a criterion.

1. Disappearance as a criterion depends on how good may be the hearing of the doctor and the efficiency of the stethoscope, and on the proper placing of the receiver over the artery. In contrast, muffling is a change in the quality of sound, and as long as the sound can be heard sufficiently to detect this, it is independent of the factors above.

2. While, in most normal subjects at rest, disappearance occurs just as close to the true diastolic pressure as does muffling, in exercise it occurs at pressures far below the true diastolic pressure. In exercise muffling remains about as close to true diastolic pressure as it was at rest. We cannot assume that the hemodynamics of patients at rest are the same as those of normals.

3. No one has been able to advance any reason why disappearance, which means that sound has ceased, should logically be related to the diastolic pressure. The existence of sound in the circulation depends on the conditions determining whether flow is laminar or nonlaminar (streamline flow is completely silent). These conditions concern velocity of flow and geometry of the tube and have no connection whatever with diastolic pressure except by accident. On the other hand, we now have good reason, in the change of frequency content, to connect muffling with conditions in the artery existing at diastolic pressure in the cuff.

Thus if the decision must be made on logic alone, disappearance as a criterion of diastolic pressure is certainly without support.

Though disappearance is less reliable than muffling as a criterion, it is still worthwhile recording both. When they differ markedly, we
have added new information about the cardiovascular system of the patient that should contribute to our diagnostic armament. Perhaps we cannot yet interpret this finding explicitly, but we should wonder what factors in that patient tend to favor persistence of a nonlaminar type of flow.

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References


History of Clinical Blood Pressure Estimations

In 1903 Harvey Cushing suggested the addition of blood pressure measurements to the fever chart that had been introduced by Wunderlich in 1868. . . . Although many methods had been proposed for the indirect measurement of blood pressure, at the time of Cushing's recommendation there was no practical and reliable method for clinical use. The methods generally available originated with Marey's observations of the blanching of an arm enclosed in a fluid-filled glass chamber. . . .

The occluding cuff technique, introduced almost simultaneously by Riva-Rocci (1896) in Italy and Hill and Barnard (1897) in England, provided a convenient method of occluding the brachial artery and obtaining systolic blood pressure. Palpation of the radial artery while releasing cuff pressure from a level above assumed systolic pressure permitted reading systolic pressure when the radial pulse could be felt. . . .

Korotkoff's complete paper (1905) was presented at a meeting of the Imperial Military Medical Academy. As published, it occupied less than half of one page. The discussion which followed required considerably more space and from the translation which follows, it is obvious that a few in the audience were willing to accept so obvious a phenomenon. A few believed that the sounds were heart sounds which appeared when the artery opened, permitting a communication between the heart and the stethoscope. Korotkoff had his own views on this belief. Others merely wanted an accurate explanation for the phenomenon, which of course was not available at the time, nor even at present.—L. A. Geddes, H. E. Hoff, and A. S. Badger: Introduction of the Auscultatory Method of Measuring Blood Pressure—Including a Translation of Korotkoff's Original Paper. Cardiov Res Cent Bull Baylor U Coll Med 5: 57, 1966.
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