Comparison of Arm and Leg Blood-pressures in Aortic Insufficiency: an Appraisal of Hill's Sign

EMIL F. PASCARELLI,* M.D.; CHARLES A. BERTRAND,† M.D.

With the technical assistance of MARIE LOPEZ‡

Brit. med. J., 1965, 2, 73-75

The measurement of blood-pressure differences between the arms and legs is difficult because of the inaccuracy of existing leg cuffs. Although there has been considerable difference of opinion in the literature, use of the direct intra-arterial method has shown that all components of arm and leg blood-pressures in supine subjects are virtually the same (Pascarelli and Bertrand, 1963, 1964).

Hill and Flack (1909) reported that indirectly measured leg systolic pressures were considerably higher than arm systolic pressures in subjects with aortic insufficiency. Further studies (Hill *et al.*, 1909; Hill and Rowlands, 1911-12) described this phenomenon in hyperthyroidism after vigorous exercise and in old age. Cuffs were placed below the knee, and by palpation of the posterior tibial or dorsalis pedis arteries the systolic pressures were measured. In several of their cases differences of 100 mm. Hg were noted. In one case a difference of 150 mm. Hg was reported. The usual difference is thought to be between 60 and 100 mm. Hg (Friedberg, 1956). Hill's

sign, or the Hill-Flack sign, was also labelled disproportionate femoral systolic hypertension in aortic insufficiency (Friedberg, 1956), even though it was the popliteal artery and its branches which were compressed.

The validity of this sign has been challenged by intra-arterial studies. Leiner and Wachstein (1937) used a mercury column and optical system on four persons with aortic insufficiency, and found no significant directly recorded arm-leg pressure difference. Kotte *et al.* (1944) used the Hamilton manometer to study 10 persons with aortic insufficiency, and found great variability in consecutively recorded compared brachial and femoral systolic pressures. In some instances brachial systolic pressures were actually found to be higher than femoral pressures. Because of the small number of cases no definite conclusions were reached.

The purpose of this study is to ascertain whether Hill's sign can be verified by the intra-arterial method, using electronic equipment at present available. Seventy subjects were studied, 20 patients with dynamic aortic insufficiency (high pulse pressure) and 50 controls. In addition, some of the problems of blood-pressure measurement in the lower extremities will be discussed.

Method

Brachial and femoral blood-pressures of 20 persons with aortic insufficiency and 50 controls were measured by the direct technique. All pressures were measured in the supine position. In 7 of the 20 subjects with aortic insufficiency and in 33 of the 50 controls the pressures were recorded simultaneously with gauges of matched sensitivity. In the remaining persons the same strain gauge was used to measure arm and leg pressures consecutively, not more than eight minutes apart.

Criteria for inclusion in the aortic insufficiency group included the characteristic high-pitched decrescendo diastolic murmur, low diastolic and high pulse-pressures related to such signs as Corrigan's pulse and visible arterial pulsations, and evidence of left ventricular enlargement. Various causes were found for aortic insufficiency, but rheumatic and luetic heart disease were the most common. No person with aortic valvular disease was included in the control group.

* Junior Assistant Attending in Medicine, the Roosevelt Hospital, New York.

† Director, Cardiopulmonary Laboratory, the Roosevelt Hospital, New York.

‡ Department of Medicine, the Roosevelt Hospital, New York.

FIG. 1.—Brachial systolic pressures (ordinate) plotted against femoral systolic pressures (abscissa). While there is slightly greater variability in the aortic-insufficiency group (A) as compared with controls (B), the pressures are similar.

FIG. 2.—Brachial diastolic pressures (ordinate) plotted against femoral diastolic pressures (abscissa). Pressures in the aortic-insufficiency group (A) are similar to those in the controls (B).

Number 20 gauge Riley needles were used for arterial punctures. When a pulsatile jet of blood appeared, matched sensitivity Statham strain gauges, attached to a photographic multi-channel recorder,¹ were inserted directly into the needle hubs. Calibrations of the various pressure components were plotted on a 100 by 200 cm. specially prepared graph to minimize calculation error. Mean blood-pressures were electronically integrated. The final corrected values for all blood-pressure components were transferred to IBM punch cards and subjected to programmed statistical analyses. Absolute and average differences of brachial and femoral blood-pressures were also calculated. Absolute differences were derived from individual arm-leg pressure values regardless of whether they were positive or negative; therefore they are a function of individual blood-pressure difference variability. Average differences were obtained by subtracting arm and leg group pressure component averages from each other. In addition, systolic and diastolic values for both groups of subjects were depicted on scatter-graphs for ease of comparison (Figs. 1 and 2), and to serve as a graphic illustration of their relation to correlation coefficients (r).

Results

Systolic Pressures.—Systolic blood-pressures in general appear to be more labile than other pressure components, and are in the hypertensive range in the aortic-insufficiency group. Average brachial systolic pressure is 179.5 mm. Hg and average femoral systolic pressure is 182.7 mm. Hg in the aortic-insufficiency group. There is no distinct tendency for average femoral systolic pressures to be significantly greater than brachial systolic pressures in aortic insufficiency (Table I),

TABLE I.—Summary of Data with Appropriate Mean Values and Standard Deviations

Group	Controls	Aortic Insufficiency
No. of subjects	50	20
Age	53.5 years S.D. 14.5 years	57.7 years S.D. 14.8 years
Pulse rate	84.1/min. S.D. 13.8/min.	81.7/min. S.D. 14.0/min.
Systolic blood-pressure in brachial artery	Mean 144.8 mm. Hg S.D. 28.7	Mean 179.5 mm. Hg S.D. 28.1
Diastolic blood-pressure in brachial artery	Mean 74.6 mm. Hg S.D. 14.9	Mean 59.0 mm. Hg S.D. 14.8
Mean blood-pressure in brachial artery	Mean 99.3 mm. Hg S.D. 17.9	Mean 99.7 mm. Hg S.D. 15.5
Pulse pressure in brachial artery	Mean 70.3 mm. Hg S.D. 21.5	Mean 120.3 mm. Hg S.D. 25.3
Systolic blood-pressure in femoral artery	Mean 146.5 mm. Hg S.D. 29.0	Mean 182.7 mm. Hg S.D. 29.7
Diastolic blood-pressure in femoral artery	Mean 71.6 mm. Hg S.D. 15.2	Mean 54.9 mm. Hg S.D. 15.2
Mean blood-pressure in femoral artery	Mean 97.8 mm. Hg S.D. 18.6	Mean 98.3 mm. Hg S.D. 16.6
Pulse pressure in femoral artery	Mean 74.6 mm. Hg S.D. 21.7	Mean 127.8 mm. Hg S.D. 25.9

since there is an average difference of 3.2 mm. Hg; however, slightly greater variations in differences are noted (Fig. 1 A) when compared with controls (Fig. 1 B). This simply means that differences are greater in aortic insufficiency irrespective of whether brachial or femoral systolic pressure is higher, and is reflected in the values for absolute differences, which are 9.3 mm. Hg for the aortic-insufficiency group and 5.5 mm. Hg for the controls. Correlation coefficients (r) are 0.91 for the aortic-insufficiency group and 0.97 for the controls, and are remarkably similar and very high for both groups. Were all the brachial and femoral pressures identical (Fig. 1) they would fall along the 45-degree line and the correlation coefficient (r) would be 1.

Diastolic Pressures.—Comparison of Figs. 2 A and 2 B shows that when brachial diastolic pressures are plotted against femoral diastolic pressures similar patterns emerge in both the

aortic-insufficiency group and the controls. Total average differences between brachial and femoral arteries are 4.1 mm. Hg and 3 mm. Hg for the aortic insufficiency and control groups respectively. Absolute differences (Table II) are remarkably similar, unlike the systolic values, and reflect a more consistent relation between brachial and femoral diastolic pressures. Similar correlation coefficients of 0.96 for the aortic-insufficiency group and 0.95 for the control group confirm this. In both groups the number of cases is greater in which the diastolic pressure is higher in the brachial artery; the total average differences are small and of dubious significance in view of the slightly greater possibility for errors, such as damping, which might occur in brachial-artery punctures.

TABLE II.—Differences of Brachial and Femoral Blood-pressure Components

Group	Absolute Difference	Average Difference
Controls	Systolic 5.5 mm. Hg Diastolic 4.1 mm. Hg Mean 3.9 mm. Hg	1.7 mm. Hg 3.0 mm. Hg 1.5 mm. Hg
Aortic insufficiency	Systolic 9.3 mm. Hg Diastolic 4.9 mm. Hg Mean 4.2 mm. Hg	3.2 mm. Hg 4.1 mm. Hg 1.4 mm. Hg

Mean Blood-pressures.—These reflect the same pattern seen in the systolic and diastolic components, and average out to illustrate that there is no significant difference in the brachial and femoral blood-pressures in either group (Tables I and II). Correlation coefficients are 0.92 for the aortic-insufficiency group and 0.95 for the control group. The total average mean pressure in both groups is almost identical; average differences and absolute differences in both groups are similar (Table II).

Discussion

The present study indicates that in aortic insufficiency, as well as in a group of normal controls, all components of blood-pressures in the arms and legs are virtually the same. This is exemplified in aortic insufficiency by Fig. 3. Slightly greater variability in systolic blood-pressure in aortic insufficiency is demonstrated by the fact that 8 out of 20 persons in this group actually had slightly higher brachial systolic pressures. This was found in 14 out of 50 instances in the control group. In both groups these differences were small and probably not significant. "Hill's sign" therefore does not appear to be related to intra-arterial pressures.

FIG. 3.—Simultaneous femoral and brachial pressure curves, illustrating similar levels of pressure in a patient with aortic insufficiency.

In Hill's original work indirect measurements were made from the popliteal artery and its branches, which are comparable in size to the brachial artery. As a result Hill's sign cannot be completely explained as a manifestation of cuff artifact. Further confusion results from the fact that in virtually all subsequent papers the thigh cuff was used.

¹ Electronics for Medicine, White Plains, New York.

Attempts have been made to explain Hill's sign on the basis of flow phenomena. Friedberg (1956) writes: "Since the femoral artery is in a direct line with the aortic stream, while the brachial issues from the aorta at a right angle, the femoral artery receives not only the pressure head but also the velocity head of the aortic stream . . . in aortic insufficiency the velocity head is considerable, there is a pronounced excess of pressure on the femoral as compared with the brachial artery." Sodeman (1961) offers essentially the same hypothesis to explain differences in arm and leg systolic and diastolic pressures thought to exist in normals. He states that leg systolic pressure is commonly 20–30 mm. Hg higher and leg diastolic pressure is 10 mm. Hg or more higher than arm pressure. Such arm-leg pressure differences cannot be confirmed by intra-arterial measurements; therefore explanations of this sort must be viewed with scepticism.

There is also reason to question seriously the validity of results derived from cuff measurements correlating arm and leg pressure differences to severity of aortic insufficiency (Frank *et al.*, 1964), degree of cardiac decompensation in aortic insufficiency (Pont *et al.*, 1953), or distinction of functional from organic aortic insufficiency (Loewenberg, 1940). Intra-arterial studies do not confirm any of these impressions, and suggest that virtually no differences in arm and leg blood-pressures exist in supine persons with aortic insufficiency or in normal controls.

A clinical sign based upon indirect cuff blood-pressure measurements should withstand the comparison test of direct measurement. In this study such discrepancies between direct and indirect pressures were encountered that the leg cuff was finally abandoned. A cuff that fits poorly or is too narrow can give pressure readings that are too high. This is especially true when using the leg cuff, where variations in the consistency of the large fat-and-muscle mass create a need for variable amounts of pressure to compress a relatively deep artery of large calibre (Trout *et al.*, 1956). Most available leg cuffs fit the conical shape of the thigh poorly, and contribute to artifact by actually compressing only a narrow band of tissue. In addition, auscultation or palpation of leg arteries is often difficult. All of the various factors mentioned probably contribute to the inaccuracy of indirect leg-pressure measurement.

The problem of when to use a cuff on the lower limbs is a practical one. Existing leg cuffs are inaccurate. Perhaps their use should be abandoned until a better cuff is designed,

in order to avoid being misled. Palpation of the femoral artery affords a quick and easy appraisal of the situation, and can give valuable clues to the existence of aortic coarctation or aorto-iliac stenosis. When doubt exists, direct arterial puncture can give accurate data safely and easily. If strain gauges and a multichannel recorder are not readily available for intra-arterial measurements, an inexpensive device such as that described by de Bono (1963) can be employed.

Summary

Disproportionate femoral systolic hypertension in aortic insufficiency (Hill's sign) is based upon values obtained by indirect cuff determinations made in the arms and legs. Direct arterial punctures, using strain gauges and a multichannel recorder, in 20 persons with aortic insufficiency compared with 50 controls failed to reveal the presence of this sign. As in the normal supine controls, blood-pressures in the arms and legs in aortic insufficiency were found to be virtually the same. Various explanations for Hill's sign were discussed and found to be inadequate. It is suggested that until a better leg cuff is devised diagnostic problems should be resolved by intra-arterial punctures of the femoral arteries.

We are indebted to Mr. Theodore A. Basel, of Tabulating and Business Services, New York City, for programming the statistical analyses.

REFERENCES

- de Bono, E. F. (1963). *Lancet*, **1**, 1142.
 Frank, M. J., Casanegra, P., and Levinson, G. (1964). *Circulation*, **28**, 723.
 Friedberg, C. K. (1956). *Diseases of the Heart*, 2nd ed., p. 677. Saunders, Philadelphia.
 Hill, L., and Flack, M. (1909). *Brit. med. J.*, **1**, 272.
 ——— and Holtzman, W. (1909). *Heart*, **1**, 73.
 ——— and Rowlands, R. A. (1911–12). *Ibid.*, **3**, 219.
 Kotte, J. H., Iglauer, A., and McGuire, J. (1944). *Amer. Heart J.*, **28**, 476.
 Leiner, G., and Wachstein, M. (1937). *Klin. Wschr.*, **16**, 822.
 Loewenberg, S. A. (1940). *Ann. intern. Med.*, **14**, 991.
 Pascarelli, E. F., and Bertrand, C. A. (1963). *Circulation*, **28**, 783.
 ——— (1964). *New Engl. J. Med.*, **270**, 693.
 Pont, Morneix, and Ackins, H. (1953). *J. Méd. Lyon*, **34**, 925.
 Sodeman, W. A. (1961). *Pathologic Physiology*, 3rd ed., p. 366. Saunders, Philadelphia.
 Trout, K. W., Bertrand, C. A., and Williams, M. H. (1956). *J. Amer. med. Ass.*, **162**, 970.

Jaundice in Severe Infections

A. ELEY,* M.B., F.R.C.S.; T. HARGREAVES,† M.D., B.SC., M.C.PATH; H. P. LAMBERT,‡ M.D., M.R.C.P.

Brit. med. J., 1965, **2**, 75–77

"Many systemic infections produce structural and functional changes in the liver which occasionally are accompanied by jaundice. Fortunately, these are seldom of sufficient severity to alter the course of the underlying disease or to require special treatment. It is important to note, however, that unless their relationship to infection is recognized they may lead to serious diagnostic errors. Jaundice is particularly likely to be misleading, since it may be misinterpreted as a sign of primary hepatic or biliary tract disease and thus divert attention from the underlying infection and lead to inappropriate treatment"

(Klatskin, 1963). Diagnostic errors of this kind are especially likely if the jaundice is "obstructive" in its biochemical pattern. We wish to report a group of five patients in whom the jaundice of severe infection showed many "obstructive" features. In four of them the nature of the infection was obscure when jaundice appeared, the patients presenting with fever of unknown origin.

Case 1

A Jamaican housewife aged 35 gave a history of generalized abdominal pain with fever for a month before admission. The pain began suddenly, was at first colicky in nature, and had radiated

* Surgical First Assistant, St. George's Hospital, London.

† Senior Lecturer in Chemical Pathology, St. George's Hospital Medical School, London.

‡ Physician, St. George's Hospital, London.