Single Versus Triplicate Measurements of Blood Pressure and Heart Rate

TIMOTHY C. FAGAN, KENNETH A. CONRAD, PAULA V. MAYSHAR, MARY J. MACKIE, AND ROBERTA M. HAGAMAN

SUMMARY The mean of rapidly repeated duplicate or triplicate measurements is often used in studies of antihypertensive drugs. Forty patients with hypertension had triplicate measurements of blood pressure and heart rate on two occasions, 1 week apart, during placebo treatment. The average difference between the first measurement and the mean of the triplicate measurements was 0.3 mm Hg. The average coefficient of variation for supine and standing, systolic and diastolic blood pressures was 8.4% for the single measurements and 8.0% for the mean of triplicate measurements. The correlations between the first measurements and the mean of triplicate measurements ranged from 0.90 to 0.98 (all p<0.01). The average difference between the two visits for all four blood pressure parameters was 0.6 mm Hg for the single measurements and 0.5 mm Hg for the mean of triplicate measurements (all p=NS). These results indicate that 1) blood pressure does not change further after 1 week of placebo treatment, and 2) use of the mean of triplicate measurements of blood pressure and heart rate gives the same result as use of single measurements, and the results are no less variable. (Hypertension 11: 282-284, 1988)

KEY WORDS * blood pressure • hypertension • repeated measurements

THE mean of duplicate or triplicate measurements of blood pressure, made at short intervals by sphygmomanometer, is often used in place of single measurements as the estimate of arterial pressure in studies of antihypertensive drugs. The mean of repeated measurements would be superior to single measurements only if they were different from or more reproducible than single measurements.

Patients and Methods

Forty patients with hypertension (22 men, 18 women), aged 34 to 79 years, were enrolled in the study. Informed consent was obtained, antihypertensive medications were discontinued, and the patients began taking placebo once daily. One and 2 weeks after the last dose of antihypertensive medication, the patients returned to the clinic in the morning before the dose of placebo. Supine and standing blood pressure measurements were taken by mercury sphygmomanometer according to American Heart Association recommendations, and heart rate was estimated by 60-second pulse count. In each patient, the same arm was used throughout the study. After 5 minutes with the patients in the supine position, measurements were made in triplicate at 1-minute intervals. The patients stood for 2 minutes, and triplicate measurements were then repeated at 1-minute intervals. Neither the patients nor the professional staff measuring the blood pressure and heart rates were aware that single and triplicate measurements were to be compared.

All calculations were made using the first measurement at each point in time in each patient and the mean of the triplicate measurements. Repeated-measures analysis of variance, Pearson correlation, and paired t tests were used as appropriate using SPSSX (Chicago, IL, USA). Adjustment for multiple tests was done by the Bonferroni technique.

Results

The range of differences between the first and mean of triplicate measurements for all four blood pressure parameters (supine and standing, systolic and diastolic) at both visits was +0.6 to −1.4 mm Hg. Only supine systolic blood pressure showed any difference among the six measurements. The only significant dif-
The average coefficient of variation for all four blood pressure parameters at both visits was 8.4% for the single measurements and 8.0% for the mean of triplicate measurements. The relationships between the first measurements and the mean of triplicate measurements for Visits 1 and 2 are shown in Figure 1. The range of correlations for all four blood pressure parameters at both visits was 0.90 to 0.98.

The range of differences for all four blood pressure parameters between Visit 1 and Visit 2 was —0.3 to —1.1 mm Hg for the single measurements and 0 to —1.1 mm Hg for the triplicate measurements. There were no significant differences between Week 1 and Week 2 in any parameter by either single or triplicate measurement.

Discussion

Use of the mean of duplicate or triplicate determinations of blood pressure and heart rate at short intervals (1–2 minutes) is a common practice in antihypertensive drug studies, but no available data show that this practice provides more accurate results than those obtained from a single measurement. One justification has been the erroneous belief that this is a requirement of the United States Food and Drug Administration. This is not the case (personal communication, 1987, from Raymond Lipicky, M.D., Director of the Division of Cardio-Renal Drug Products, FDA). Bias can be introduced in repeated measurements where the results of the previous measurements are known.

In this limited study, supine and standing measurements were taken during two visits in 40 patients. In all, 480 actual measurements were performed because of the triplicate determinations, whereas only 160 measurements would have been taken if single measurements had been used. In a study with 10 visits, there could easily be 2400 blood pressure determinations. While difficult to quantitate, the role of fatigue and decreased attention in reducing the accuracy of blood pressure determinations cannot be ignored and would appear to favor single over triplicate measurements.

With the exception of the 2.2 mm Hg decrease between the first and second measurements of supine systolic blood pressure at Week 1, there were no differences between any determinations of any parameter at any visit. The average difference between the first and mean of triplicate measurements was only —0.3 mm Hg. This difference is far less than that allowed for the accuracy range of the blood pressure measurements themselves. In addition, the average correlation between the first and mean of triplicate measurements was 0.96, explaining 92% of the variance. Furthermore, the variability of the single measurements was not greater, with an average coefficient of variation of 8.4%, compared with 8.0% for the mean of triplicate measurements. When the measurements after 1 week off antihypertensive medications were compared with the measurements after 2 weeks off medications, the mean difference was —0.6 mm Hg for the single measurements and —0.5 mm Hg for the mean of triplicate measurements; measurements were equally stable using single measurements or the mean of triplicate measurements. In studies of antihypertensive drugs, placebo periods before active treatment are often as long as 4 weeks. However, blood pressure does not appear to increase during the second week of placebo treatment, suggesting that a 1- or 2-week placebo period is adequate to obtain a stable blood pressure after discontinuing most antihypertensive drugs.

There are a number of potential technical problems with rapidly repeated measurements by sphygmomanometer. Pooling of blood in the arm may lead to decreased audibility of the Korotkoff sounds. In addition, pain and tissue hypoxia related to repeated cuff inflation within a short period of time potentially could alter blood pressure.

Blood pressure measurements averaged over longer intervals than those measured in this study may have increased utility in certain circumstances. Measurements averaged over 30 minutes, 2 hours, or an entire waking period may better predict later development of hypertension, average 24-hour blood pressure, or cardiovascular morbidity and mortality. However, none of these studies employed the mean of duplicate or triplicate blood pressures measured at 1- to 2-minute intervals.

Several conclusions can be drawn from our results. Placebo periods of 2 weeks are probably adequate to obtain stable blood pressure after discontinuation of most antihypertensive drugs. Single, careful determinations of blood pressure give the same results as the mean of triplicate measurements and are no more vari-

![Figure 1. Relationship between the first measurement of systolic (■) and diastolic (●) blood pressure and the mean of triplicate measurements after 1 week of placebo treatment in 40 supine (A) and standing (B) subjects and after 2 weeks of placebo treatment in 40 supine (C) and standing (D) subjects.](http://hyper.ahajournals.org/DownloadedFrom/)
able. The possibility of introducing bias and the likelihood of error due to fatigue with rapidly repeated measurements weigh against their use. Duplicate or triplicate measurements are neither more accurate nor less variable, and their use is of no additional value in antihypertensive drug studies or studies of the effects of other interventions on blood pressure and heart rate.

References
Single versus triplicate measurements of blood pressure and heart rate.
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