Nurse- and Automatic Machine-Measured Blood Pressure Readings: a Comparative Study

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AUTOMATIC BLOOD PRESSURE monitors are used in clinics and mass screening programs, as well as in public and private settings, as a public service or a commercial enterprise. They appear in shopping centers, drugstores, airports, and health spas. Although these coin-operated machines are being used widely, most have not been evaluated for accuracy in a field setting. We therefore conducted a study in 1979 to compare blood pressure readings as measured by one brand of these machines with blood pressure readings as measured by a nurse using the more traditional mercury sphygmomanometer.

Literature Review

Automatic blood pressure monitors have been tested by a variety of methods and with varying results. A number of comparisons have been made to readings obtained by use of the standard mercury sphygmomanometer. Labarthe and associates (*1*) concluded from a study of five automatic devices that none compared favorably with the traditional method. In a comparison study by Ilyas and associates (*2*), the battery-operated Stanley B-200 Pulpet showed significantly higher readings, which resulted in falsely classifying subjects as hypertensive, when operated simultaneously with a mercury sphygmomanometer. Similarly, in a simultaneous test of automatic devices and a mercury sphygmomanometer, Hoobler and associates (*3*) found significantly different readings for the Bosomat, the Arteriosonde Model 1213, and the Sphygmo Stat B-300. Webber and associates (*4*), in a comparison of five automatic devices with the mercury sphygmomanometer, also found significant differences in each instance. On the other hand, some studies disclosed no differences between automatic and traditional measurements (*5,6*).

When we began our study, we found only one report of a study that actually compared blood pressure measurement by a coin-operated machine with blood pressure measured by a nurse using a mercury sphygmomanometer. In that unpublished study, the Filac 1400 was evaluated positively, and the researchers concluded that it could be substituted for the mercury sphygmomanometer if it were used carefully; however, the method of statistical analysis was not given ("The Comparison of Blood Pressure Recorded by an Automatic Machine With a Mercury Sphygmomanometer," by F. A. Finnerty, J. B. Greenhouse, and L. W. Shaw, Hypertension Center of Washington, D.C., Department of Medicine, Biostatistics Center, George Washington University, 1978).

At the end of our study, a second

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literature search revealed a study that evaluated the coin-operated machine manufactured by Vita-Stat, Inc. (7). The investigators reported statistically significant differences between machine and human readings for both systolic and diastolic measurements, but they concluded that the differences had little practical significance for blood pressure screening.

To our knowledge, no evaluations of the reliability of the coin-operated monitor manufactured by Life Care Systems, Inc., have been reported. We used this machine for our study.

The two research hypotheses for the study were:

1. There will be no difference between nurse-measured and automatic machine-measured systolic blood pressure.
2. There will be no difference between nurse-measured and automatic machine-measured diastolic blood pressure.

Study Design and Methods

The subjects consisted of 97 volunteers aged 18 and older. They were not restricted to any sex, race, ethnic group, or age category. However, they were predominantly white, female, and middle class. Since the study was done on a university campus, many of the subjects were students or staff. Each subject was fully informed of the nature of the study.

Two nurses were the investigators. Both were faculty members of the university's school of nursing, held master's degrees in nursing, and had previously taught modules on blood pressure measurement.

Although the room in which the study was carried out was occupied only by the nurses and one subject at a time, the noises and vibrations in the surrounding area were typical of those in an outpatient clinic.

Table 1. Machine-measured and nurse-measured blood pressures, in mmHg, for 97 subjects

Type of reading	*Systolic*	*Diastolic*
Mean average machine reading	109.9	71.8
Mean average nurse reading	113.0	70.0
Standard deviation of difference	10.18	7.32
Standard error of mean difference	[1]1.04	0.75
First reading by nurse	113.4	69.7
Second reading by nurse	112.6	70.2
Standard deviation of difference	7.42	6.25
Standard error of mean difference	0.76	0.64

[1] Significant difference.

For this study, the first and final audible sounds in the blood pressure measurements were recorded. The mercury sphygmomanometer used by the nurses was a floor model Baumanometer that had been cleaned and calibrated in the laboratory before the study. Each nurse used her personally owned stethoscope.

The automatic monitor was the second-generation model manufactured by Life Care Systems, Inc. It is an attractive molded fiberglass chair with an attached inflatable cuff for left arm insertion and a panel that produces a digital readout of blood pressure and pulse. The coin mechanism of this monitor was bypassed for this study. This particular machine had been used in the field for 1 month and had not been recalibrated for the study.

The machine readout interprets blood pressure in a manner similar to the standard auscultatory method. A sensitive microphone in the cuff of the machine senses Korotkoff sounds when positioned over the upper arm. The signal from the microphone is processed by a bandpass filter and amplifier that allow the electronic circuits to distinguish sounds having the correct frequency content and amplitude to be considered Korotkoff sounds; thus, these sounds are distinguished from random noise and vibration. The digital readout circuitry on the display panel holds the systolic and diastolic pressures as they are recorded and displays the readings and the pulse rate at the conclusion of the measurement.

The subjects were seated comfortably in the Life Care Systems chair and asked to remain silent during the measurements. Five blood pressure measurements were recorded for each of the 97 subjects; 3 were measured by the machine and 2 by the nurses. Replicating Finnerty and associates' methodology, two sequences of measurements were used alternately. One sequence was machine, machine, nurse, machine, nurse, and the other was nurse, machine, machine, machine, nurse. All readings were determined while the subject was seated in the chair. The left arm was used for the readings; there was a 1-minute interval between each reading. The maximum initial inflation in the trials by both the nurse and the machine was 180 mmHg.

One nurse recorded the blood pressure measurements — reading them from the monitor panel and hearing them announced by the nurse using the traditional method. The first and second nurse-measured readings for each subject were completed by the same nurse; this nurse was not informed of the machine measurement until the entire trial had been completed. The sub-

jects were alternated between the two nurses.

Results

Analyses of data were based on the two readings by the nurse and the last two readings by the machine. The first machine reading was not incorporated in the analyses on the assumption that the initial experience with the automatic machine might realistically alter blood pressure because of anxiety associated with the new experience. All of the subjects had previous experience with nurse-measured blood pressure readings.

The average of the two machine readings was compared with the average of the two nurse readings for each subject. In addition, the first reading by the nurse was compared to the second reading by the nurse. Further, tests for paired observations were performed to determine differences in each group for systolic and diastolic measurements. The 0.01 level of significance was used. The means, standard deviations, and standard errors of the mean differences for systolic and diastolic readings are shown in table 1.

A t test performed to determine differences between the average machine reading and the average nurse reading of systolic blood pressure revealed a significant difference ($t=3.04$; $df=96$; $P<0.01$). The test applied to determine the differences between the average machine reading and the average nurse reading of diastolic blood pressure showed no significant differences ($t = 2.24$; $df = 96$).

Hypothesis 1—no difference between nurse-measured and machine-measured systolic blood pressure — was not supported. The sample mean consisting of the average of the two machine readings was 3.1 mmHg lower than the sample mean consisting of the average of the two nurse readings. Although the difference is statistically significant, for practical purposes this difference is of little concern for a normotensive population. However, the difference assumes more significance when it results in a categorical change from normal to hypertensive.

Table 2. Variations in blood pressure readings, in mmHg, by nurse and machine for 97 subjects, in percentages of subjects

Systolic and diastolic readings (mmHg)	Variations between—	
	First and second readings by nurse	Average machine and average nurse readings
Systolic		
Within 5	54.6	45.4
6–10	29.9	30.9
11–15	9.3	11.3
16–20	5.2	5.2
More than 20	1.0	7.2
Diastolic		
Within 5	58.7	58.7
6–10	36.1	25.8
11–15	3.1	11.3
16–20	2.1	2.1
More than 20	0.0	2.1

Hypothesis 2—no difference between nurse-measured and machine-measured diastolic blood pressure—was supported. The sample mean consisting of the average of the two machine readings was 1.8 mmHg higher than the sample mean consisting of the average of the two nurse readings. This difference was not statistically significant.

Since blood pressure is relatively inconstant in sequential readings, it is important to note the variations in these readings. The variations in mmHg between the first and second nurse readings and between the average machine and average nurse readings are shown in table 2. Of the subjects tested, 15.5 percent varied more than 10 mmHg between the first and second readings by the nurse, and 23.7 percent varied more than 10 mmHg between the average machine and average nurse systolic readings. Similarly, for diastolic measurement, 5.2 percent of the subjects varied more than 10 mmHg between the first and second nurse readings, and 15.5 percent varied more than 10 mmHg between the average machine and average nurse readings. For both systolic and diastolic measurements, the variation between machine and nurse readings was greater than the variation between nurse readings.

The variation between machine and nurse readings may be an artifact of the situation, that is, the nurse possibly may remember her first reading and thus expect the second reading to be similar, while the machine has no such recall. Efforts to eliminate such human bias were incorporated into the study design, and we question that bias was indeed operative. Moreover, the subjects' differential response to the machine and the nurse may be a factor inherent in the experimental setting. We do not know whether these two factors influenced the results.

For the purposes of mass screening, it is important to determine

Table 3. Percentage of 194 readings [1] categorized by machine and nurse as normotensive or hypertensive

Systolic and diastolic readings (mmHg)	Machine	Nurse
Systolic		
Below 120	75.2	64.9
120–139	18.6	30.4
140–159	6.1	4.7
160 and above	0.0	0.0
Diastolic		
Below 80	79.4	77.3
80–89	12.9	16.5
90–94	1.0	4.1
95 and above	6.7	2.1

[1] Table is based on each reading by the nurse and the machine, rather than on average readings; thus, the sample size was 194.

NOTE: The systolic criteria were normal, below 140; borderline, 140–159; hypertensive, 160 and above. The diastolic criteria were normal, below 90; borderline, 90–94; hypertensive, 95 or above.

categories of normotension and hypertension and whether the machine and the nurse differ in placing subjects in these categories. This kind of classification is shown in table 3. The systolic criteria for normal, borderline, and hypertensive were less than 140, 140–159, and 160 or higher. The diastolic criteria were less than 90, 90–94, and 95 or higher. Table 3 is based on each reading by the nurse and the machine, rather than on average readings; thus, the sample size was 194. The agreement in categorization is apparent when one considers that the nurse placed only 1.4 percent fewer subjects in the category of higher than 140 mmHg systolic blood pressure than did the machine. Similarly, the nurse placed only 1.5 percent fewer subjects in the category of higher than 90 mmHg diastolic blood pressure. The differences in classification frequencies of machine-measured and nurse-measured diastolic blood pressure in the categories of 90–94 mmHg and 95 mmHg or higher may be attributed to the minute difference of 1 mmHg that arbitrarily separates these categories. When collapsed, the categories resulted in a 1.5 percent variation between nurse-measured and machine-measured readings.

The machine did not produce a reading 10 percent of the time, which is not a problem in the field because the machine is equipped with a cuff release and an automatic coin return in such instances. On the other hand, the nurses were not able to determine blood pressure readings 2 percent of the time. Although the nurse failures were limited to one per subject, the machine failures tended to cluster around given subjects. Repeat trials were successful for all but two subjects, and they were eliminated from the study. For these two subjects, the machine failed to obtain readings two or three times in succession—which may point to something inherent in the individuals rather than to machine failure. Although no analyses were made, the nurses noted difficulties or differences in blood pressure measurements in persons with scar tissue, very thin or very fat arms, and in athletes, particularly joggers.

Comments

This study was limited by the narrow range of blood pressure readings obtained on the subjects and should be replicated with a hypertensive sample to assess machine reliability further. We suggest that replication be done when other monitors of the same model become available.

The results of this study indicate that the Life Care Systems monitor (model II) could be a reasonable substitute for nurse-measured blood pressure in mass screening programs or in commercial areas. The extent of difference between nurse and machine readings was not sufficient to warrant concern. We agree with Berkson and associates (*7*) that literature on the meaning of blood pressure measurement, limitations of machines, and hazards of self-diagnosis should be available to the public wherever the machines are located.

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