Comparison Between an Automated and Manual Sphygmomanometer in a Population Survey

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BACKGROUND

An automated sphygmomanometer, the BpTRU, was used in a blood pressure (BP) survey of 2,551 residents in the province of Ontario. Automated BP readings were compared with measurements taken by a mercury sphygmomanometer under standardized conditions in a random 10% sample.

METHODS

BP was recorded in 238 individuals in random order using both a standard mercury device and an automated BP recorder, the BpTRU. All subjects rested for 5 min prior to the first BP reading, which was then discarded. The mean of the next three readings was obtained using the mercury device whereas the BpTRU was set to record a mean of five readings taken at 1 min intervals with subjects resting alone in a quiet room.

RESULTS

The mean s.d. BP with the automated device was 115 ± 16/71 ± 10 mm Hg compared to 118 ± 16/74 ± 10 mm Hg for the manual BP (P < 0.001). A systolic BP ≥140 mm Hg was present for 16 automated and 19 manual readings. Similarly, the diastolic BP was ≥90 mm Hg for 9 automated and 14 manual readings. Linear regression analysis showed that automated BP was a significant (P < 0.001) predictor of both manual systolic and diastolic BP.

CONCLUSION

Conventional manual BP readings can be replaced by readings taken using a validated, automated BP recorder in population surveys. The slightly lower readings obtained with the BpTRU device (in the context of reduced observer–subject interaction) may be a more accurate estimate of BP status.


Blood pressure (BP) surveys in the community have generally been performed using mercury sphygmomanometry. This approach requires extensive training for health professionals in order to standardize procedures for BP measurement, so that accurate readings can be taken for thousands of subjects by different study personnel. Rigorous programs for monitoring quality control also need to be initiated in order to ensure continued compliance with the study protocol for BP measurement until the survey is completed. The net result is an estimate of the BP status of a population based upon conventional BP readings, but obtained at great expense with extensive human resource efforts in training and execution.

The Ontario Survey on the Prevalence of High Blood Pressure (ON-BP) decided to consider alternatives to the conventional measurement of BP using the mercury sphygmomanometer, in order to simplify the process of evaluating the BP status of a large number of individuals in the community. An attractive alternative was the use of a validated automated BP recording device, which is designed specifically for the office or clinic setting. The most widely studied device to date is the BpTRU (BpTRU Medical Devices, Coquitlam, BC, Canada) which is able to perform five readings with subjects resting quietly and alone in an examining room, thus decreasing subject–observer interaction, reducing anxiety and decreasing observer measurement error, all of which would tend to give a better estimate of an individual’s BP status. In hypertensive populations, the BpTRU has been shown to reduce the white-coat effect with readings exhibiting a significantly higher correlation with the mean waking ambulatory BP, the current gold standard for assessing BP status, compared to BP readings obtained in routine clinical practice.1,2 Mean BpTRU readings have exhibited a close approximation to the manual BP in both validation studies3,4 and in clinical practice.5

The ON-BP was undertaken to record the BP of about 3,000 randomly selected subjects residing in the community in the province of Ontario. In a random sample of 10% of participants, BP readings were taken with both the BpTRU and a mercury sphygmomanometer under similar standardized conditions in order to compare the automated BP readings with the conventional standard for BP surveys, the mercury device.

METHODS

Patient population. Adult residents of the province of Ontario, aged 20–79 years, were randomly selected for enrollment in the ON-BP survey using census data from Statistics Canada.
Both men and women with and without high BP were eligible for the survey. Potential subjects were contacted by home visits to see if they were interested in participating in the survey and attending a BP clinic (F.H.L., J. Dumais, N.H.M., P. Turton, L. Stratychuk, K. Nemeth, MM. Lum-Kwong, G.J.F., unpublished data). A total of 2,551 individuals attended the special clinic for BP measurement. One of every 10 participants was selected to have their BP recorded using both the BpTRU device and a standard mercury sphygmomanometer. The order in which the devices were used was determined by the individual’s study number; those subjects with even last digits were measured with BpTRU first and those with odd last digits were measured with the mercury device first. The left arm circumference was measured and the appropriate cuff size was used for each device.

BP measurement. Manual BP was recorded by a registered nurse or registered nurse practitioner using a Baumanometer sphygmomanometer (W.A. Baum. Copiague, NY) according to the procedures of the Canadian Hypertension Education Program. Subjects remained seated with the back supported and left arm at heart level. They were allowed to rest for 5 min in a quiet room before the first reading was taken; this was then discarded. Three more readings were taken, each 1 min apart and the mean value and heart rate were recorded for each individual. Automated BP readings were obtained using the BpTRU (model BPM 300) after patients rested alone in a quiet room for 5 min. The device was set to take six readings at 1 min intervals with the first reading being discarded. The mean automated BP reading and heart rate were noted for each subject. The device was positioned in such a way as to prevent the subject from seeing the readings as they were taken. There was a 2-min break between automatic and manual BP readings. All measurements were obtained under similar conditions except for the two different BP recording techniques used.

Data analysis. Mean manual and automated systolic and diastolic BP values were tabulated as histograms showing the number of participants for each 5 mm Hg interval of BP. A paired t-test was used to assess the differences between the manual BP and automated BP readings. Delta values were calculated as manual systolic BP—automated systolic BP and manual diastolic BP—automated diastolic BP. A one way analysis of variance was used to analyze the differences between delta systolic and delta diastolic by age and cuff size. To assess the differences between males and females an independent t-test was used to analyze the delta systolic and delta diastolic values. A linear regression analysis was performed to examine the relationship between the automated and manual BP readings with the automated systolic and diastolic BPs as the independent variables. All data was analyzed using SPSS version 15.0.

RESULTS
A 10% sample (n = 238) of the entire survey population participated in this substudy. The subjects in this substudy comprised 96 males and 142 females, mean (±s.d.) age 50 ± 15 and 47 ± 15 years, respectively. Fifty-nine subjects remembered being told by a health professional that they had hypertension and, of these, 42 were receiving antihypertensive drug therapy.

Individual readings for systolic and diastolic BP for each of the two methods were tabulated and displayed as frequency histograms (Figures 1 and 2). Diastolic BP was ≥90 mm Hg for 14 manual and 9 automated BP readings. Systolic BP was ≥140 mm Hg for 19 manual and 16 automated measurements. Each data set was normally distributed.

Mean (±s.d.) BP taken with the automated BpTRU device was 115 ± 16/71 ± 10 mm Hg compared to 118 ± 16/74 ± 10 mm Hg for the manual BP readings (P < 0.001). Parameters such as age, sex, and cuff size did not predict the differences in systolic and diastolic BP between the automated and manual measurements. For the automated/manual order of readings, the automated and manual values (mm Hg) were 116 ± 14/72 ± 9 and 118 ± 15/75 ± 10, respectively. The corresponding results for participants having manual BP followed by automated BP readings was 113 ± 17/70 ± 11 for the automated versus 117 ± 17/74 ± 10, for the manual BP. The differences between systolic manual readings and systolic automated readings were significantly (P < 0.01) smaller when automated was used first.

The comparison of the manual versus the automated readings showed a high coefficient of correlation (r²) for systolic BP (r² = 0.84) and diastolic BP (r² = 0.70) readings (Figure 3). Linear regression analysis showed that the automated systolic BP is a significant predictor (β = 0.93, P < 0.001) of manual systolic BP.
with a regression equation (Adjusted systolic BP = 11.4 + 0.9 ×
amverted systolic). Automated diastolic BP was also a signifi-
cant predictor (β = 0.83, P < 0.001) of manual diastolic BP with
a regression equation (adjusted diastolic BP = 15.6 + 0.83 ×
automated diastolic). At lower BP values, readings taken with
the manual BP recorder were higher than corresponding read-
ings obtained using the automated device, with the difference
diminishing as BP values increased.

**DISCUSSION**

The automated BpTRU device was designed to minimize the
impact of observer–subject interaction on the measurement of
BP in the office/clinic setting.\(^7\) This approach removes
several aspects of bias associated with conventional BP mea-
urement using mercury sphygmomanometry.\(^8\) The role of
the observer in recording the BP is eliminated and replaced
with a validated, accurate, digital device programmed to take readings at specific time intervals, thus eliminating
imprecision due to factors such as digit preference, too rapid
deflation of the cuff, or reading up or down to influence the
patient’s BP status. The absence of the observer from the
room during readings also precludes conversation between
the subject and the observer, which is a factor known to
increase the BP.\(^9\) Many individuals exhibit a fall in BP within
a minute or two after being left alone in a quiet room espe-
cially in the context of a treatment setting such as a doctor’s
office or clinic.\(^5\)

The benefits of taking readings using an automated device
such as the BpTRU are generally applicable to population
surveys such as the ON-BP. Thus, one would anticipate lower
mean BP values for the automated device compared to con-
ventional manual readings obtained by a nurse, which is what
was observed in the Ontario survey. In this instance, manual
readings exceeded automated readings by 3/3 mm Hg.

This difference represents the white-coat effect for a ran-
dom sample of adult residents residing in Ontario. A similar
difference was observed in hypertensive patients when man-
ual readings recorded by a research technician outside of the
treatment setting were compared with the mean automated
readings taken using the BpTRU device.\(^1\) In this instance, the
manual readings were 3/2 mm Hg higher with the mercury
sphygmomanometer.

These differences between automated and manual readings
are substantially less than reported for other hypertensive
populations, when the manual readings were taken by physi-
cians. Under these circumstances, the “white-coat reaction”
tends to provoke a greater pressor response. In a series of
50 hypertensive patients referred to a specialty hypertension
centre for their management, the mean manual office BP was
20/5 mm Hg higher than the mean of five automated BpTRU
readings.\(^5\) Similarly, Beckett and Godwin\(^2\) noted a differ-
ence of 11/3 mm Hg between the last routine office BP taken
by a patient’s own family physician and the mean automated
BpTRU value. In a population survey of persons 65 years of age
and older with hypertension, Kaczorowski and colleagues\(^10\)
found systolic BP readings (taken in a community pharmacy
using the BpTRU device), produced a mean value 9 mm Hg
lower than the last routine office BP taken by the subject’s own
family doctor.

In the above studies, the automated readings were taken with
the BpTRU device with subjects resting alone in a quiet room
in order to minimize factors that tend to provoke a white-coat
reaction. However, if one performs the automated readings
and manual BP measurements under standardized conditions,
the mean values are quite similar. In a formal validation study
reported by Wright et al,\(^4\) mean BpTRU values for systolic
and diastolic BP differed from reference readings taken with a
standard mercury device by only –0.2 ± 4.3/–1.4 ± 4.2 mm Hg,
respectively. In a study in clinical practice,\(^5\) the mean ± s.d.
of two readings taken using a mercury sphygmomanometer
(163 ± 23/86 ± 12) was similar to the first BpTRU reading taken
in the presence of the observer (162 ± 27/85 ± 12). Thus, au-
mated readings taken with the BpTRU device closely approxi-
mate conventional measurements recorded with a mercury
sphygmomanometer when taken under similar conditions.

In the ON-BP, the mean BP of the subsample was substan-
tially lower than in previous studies involving hypertensive
patients with only 8.0/7.6% exhibiting high systolic/diastolic
readings using the manual recorder. Estimates of the cutoff
points for normal versus automated BpTRU values are still pre-
liminary but the available data suggest conventional office BP
at 140/90 mm Hg is equivalent to an automated BpTRU read-
ing of 135/85 mm Hg taken in the office with subjects resting
alone in a quiet room.\(^2\) In this population, 8.0/7.6% would be
designated as being hypertensive according to a cutoff value of
BP ≥140/≥90 mm Hg, for manual BP and 9.7/8.0% for BpTRU
≥135/85 mm Hg. The number of subjects in this subset of the
ON-BP was too small to provide reliable comparative esti-
mates of normal versus abnormal cutoff points for a diagnosis
of hypertension with the two methods of measurement.

Linear regression analysis of the automated and manual BP
data provided a “correction factor” to convert the automated
readings obtained in the survey into comparable manual BP
readings. This conversion makes it possible to compare data
derived from BP surveys performed using an automated BP
recorder with previous surveys that have employed manual BP
measurement techniques. According to the linear regression
in this sample from the ON-BP survey, automated systolic BP

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**Figure 3** A linear regression analysis was performed to examine the
relationship between the automated and manual blood pressure (BP)
readings with the automated systolic and diastolic BP as the independent
variables. The \( r^2 \) values for systolic and diastolic BP are 0.84 and 0.70,
respectively (\( P < 0.001 \)).
readings of 120 and 140 mm Hg are equivalent to manual readings of 123 and 142 mm Hg, respectively. Automated diastolic BP readings of 80 and 90 mm Hg are equivalent to manual readings of 82 and 90 mm Hg, respectively.

The results of the ON-BP have demonstrated that conventional manual BP readings taken using mercury sphygmomanometry can be replaced by a validated, automated recorder. If a major effect of using the BpTRU is to minimize the white-coat effect it would not be surprising to see lower BP readings in participants with high normal or mild hypertensive readings, possibly indicating a lower prevalence of hypertension. Instead of underestimating hypertension, the automated readings may actually reflect the true hypertension status in the population, by minimizing the white-coat effect when one takes into effect the close relationship between automated BP readings and mean waking ambulatory BP, the current gold standard for assessing cardiovascular risk.

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