Impact of Clinic-Based Blood Pressure Approaches on Blood Pressure Measurement

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BACKGROUND

Clinic-based blood pressure (BP) is a closely-tracked metric of health care quality, but is prone to inaccuracy and measurement imprecision. Recent guidelines have advocated for automated office blood pressure (AOBP) devices to improve clinic-based BP assessments.

METHODS

Patients from a single hypertension clinic underwent a 3-day evaluation that included a 24-hour ambulatory blood pressure monitoring (ABPM), 2 manual clinic-based BP measurements (over 2 visits), and an unattended AOBP measurement (single visit). All measurements were compared to the average wake-time systolic BP (SBP) and diastolic BP (DBP) from ABPM.

RESULTS

Among 103 patients (mean age 57.3 ± 14.8 years, 51% women, 29% black) the average wake-time SBP was 131.3 ± 12.3 mm Hg and DBP was 78.3 ± 9.2 mm Hg. The average of 2 manual BPs was significantly higher than wake-time ABPM with mean differences of 5.5 mm Hg ($P < 0.001$) for SBP and 2.7 mm Hg ($P = 0.002$) for DBP. In contrast, the

averages of the last 2 AOBP measurements did not significantly differ from ABPM with mean differences of 1.6 mm Hg ($P = 0.21$) for SBP and -0.5 mm Hg ($P = 0.62$) for DBP. The estimated prevalence of SBP ≥ 140 or DBP ≥ 90 mm Hg based on wake-time ABPM was 27.2% vs. 49.5% based on the average of 2 manual measurements (difference 22.3%; $P < 0.001$) and 31.1% based on the average of the last 2 AOBP measurements (difference 3.9%; $P = 0.57$).

CONCLUSIONS

A single visit, unattended AOBP more precisely estimated BP and the prevalence of stage 2 and uncontrolled hypertension than even the average of 2 manual clinic visits, supporting guideline recommendations to use AOBP for clinic-based BP measurements.

Keywords: ambulatory blood pressure monitor; automatic blood pressure monitor; blood pressure; clinic-based blood pressure measurement; hypertension.

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Blood pressure (BP) is one of the most common measurements performed during clinic visits yet is also one of the most challenging to perform correctly.¹ Recent reports have documented that simply repeating a triage BP assessment within the same clinic visit can reduce BP by an average of 8 mm Hg.² However, this takes time and resources. Given the recognition of BP as an accountable care organization-Reported Quality Measure by the Centers for Medicare and Medicaid Services,^{3,4} rates of BP control are directly linked to clinic value-based performance incentives. Thus, medical practices urgently need to identify devices and processes that can efficiently measure BP without significantly slowing clinic throughput.

Automated office blood pressure (AOBP) is an emerging approach to clinic-based BP assessment. AOBP devices may be programmed to execute a timed rest period along with 3 replicate BP measurements without relying on the attendance of a health professional for measurement.⁵ Because of these advantages, AOBP has been endorsed by several international guidelines as a superior approach to minimize measurement inaccuracy.^{6,7} However, few studies have compared AOBP with typical clinic measurements using 24-hour ambulatory blood pressure monitoring (ABPM) as the gold-standard referent.

In this study of patients in a single hypertension clinic, we compare 2 distinct clinic-based BP measurement approaches, auscultation and AOBP, to a 24-hour ABPM measurement to determine the accuracy of measurement and their implications on the population-wide prevalence of stage 2 or uncontrolled hypertension.

METHODS

Population

We studied 106 patients of Beth Israel Deaconess Medical Center, who were referred to the Healthcare Associates Hypertension Clinic between 2018 and 2019. Healthcare Associates serves as the primary care practice for the hospital and cares for 39,056 patients, of whom more than 12,858 have hypertension. The Healthcare Associates Hypertension Clinic, embedded within a hospital-based academic general medicine ambulatory practice, is staffed by a multidisciplinary team of physicians, pharmacists, licensed practical nurses (LPNs), medical assistants (MAs), and internal medicine residents. Patients are referred from within the larger general medicine

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practice for the performance and interpretation of ABPM as well as complex hypertension management. LPNs and MAs undergo yearly manual and automated BP measurement training, which includes a didactic review of an 18-point quality checklist as well as live peer observation with remediation for those who do not pass standardized quality benchmarks.

Blood pressure measurement

The protocol for this study was reviewed by the Beth Israel Deaconess Medical Center Institutional Review Board and determined to be a quality improvement study and thus exempt research (for protocol details see [Supplementary Methods M1](#)). Patients referred to the Hypertension Clinic underwent a standardized measurement protocol over a 3-day period. On day 1, after 5 minutes of seated rest, a LPN performed a manual, aneroid measurement by auscultation, using a portable Welch Allyn sphygmomanometer (CE 0297; Skaneateles Falls, NY). Patients were then fitted with a 24-hour ABPM (SpaceLab 90227 or 90217A-1 of Spacelabs Healthcare, Snoqualmie, WA) and returned with the device on day 3 for interpretation. ABPMs were programmed to perform measurements every 20–30 minutes during the day and hourly during sleep. ABPMs were programmed based on patient's self-reported sleep and wake times.

On day 3, a MA performed another manual, aneroid assessment using a portable Welch Allyn sphygmomanometer (CE 0297) after 5 minutes of seated rest. Day 1 and day 3 manual BP measurements were later averaged together to reflect 2 auscultatory measurements over 2 clinic visits. Patients then underwent an unattended BP assessment with an automatic oscillometric device using an HEM-907XL (Omron Healthcare, Lake Forest, IL). Assessments were programmed for a 5 minute delay followed by 3 BP measurements, separated by 2 minutes between each measurement. Measurements were reported individually as well as the average of the last 2 measurements and the average of all 3 measurements.

All analyses were restricted to the 103 patients who completed all BP assessments.

Other covariates

Demographic information (age, sex, race) was abstracted from the patient record. Diabetes status, history of cardiovascular disease, history of sleep apnea, current antihypertensive medications, and smoking status (never, current, former) were self-reported as part of the standard clinic interview. Most recent body mass index and creatinine were abstracted from the medical record. In addition, we documented the following reasons for referral: new/white coat hypertension, uncontrolled hypertension, labile BP, orthostatic symptoms, or other.

Statistical analysis

Population characteristics were determined with means and proportions. We determined the mean and standard

deviation for systolic BP (SBP) and diastolic BP (DBP) by measurement type. We also determined the prevalence of $SBP \geq 140$ mm Hg, $DBP \geq 90$ mm Hg, or either elevation ($SBP \geq 140$ or $DBP \geq 90$ mm Hg, i.e., stage 2 or uncontrolled hypertension). All means and proportions were compared to the mean wake-time ABPM measurements as a reference. Means were compared using paired *t* tests and reported as mean differences. In addition, we determined root mean square errors. Proportions were compared using McNemar's χ^2 test. Analyses were performed using Stata 15.1 (StataCorp LP, College Station, TX).

RESULTS

The 103 patients were 51% women and 29% black with a mean age of 57.3 (SD, 14.8) years ([Supplementary Table T1](#)). The mean SBP based on ABPM-wake measurements was 131.3 (SD, 12.3) mm Hg and the mean DBP was 78.3 (SD, 9.2) mm Hg ([Table 1](#)). The measurements most closely reflecting ABPM-wake SBP were the second and third AOBP measurement with nonsignificant differences of 1.9 mm Hg ($P = 0.18$) and 1.4 mm Hg ($P = 0.32$), respectively. The measurements most closely reflecting ABPM-wake DBP was the average of 3 AOBP measurements with a nonsignificant difference of 0.2 mm Hg ($P = 0.86$) and the second AOBP measurement (mean difference of 0.3 mm Hg; $P = 0.77$). The greatest overestimation of SBP and DBP were the day 1 manual measurement, with significant differences of 6.4 mm Hg (SBP) and 3.6 mm Hg (DBP) (both P values < 0.001). The clinic-based BP measurements with the lowest root mean square errors were the average of the last 2 or the average of all 3 AOBP measurements.

On the basis of ABPM-wake measurements, the population prevalence of $SBP \geq 140$ or $DBP \geq 90$ mm Hg was 27.2%. The average of last 2 AOBP measurements estimated the population prevalence of either $SBP \geq 140$ or $DBP \geq 90$ mm Hg the most accurately at 31.1% with a mean difference of only 3.9% ($P = 0.57$).

DISCUSSION

In this study of 103 patients, the most accurate single measurement was the second AOBP measurement, and the most accurate average measurement used the last 2 AOBP measurements. With regards to identifying adults with either stage 2 or uncontrolled hypertension, the average of the last 2 AOBP measurements most closely approximated wake-time ABPM measurements. Given that a single-visit AOBP outperformed 2 manual readings at separate clinic visits, our findings support the perspective that AOBP represents a resource-sparing alternative to typical aneroid-based screening techniques.

Proper BP measurement is incredibly challenging to achieve in clinical settings.¹ Environment,⁸ patient factors (e.g., pain, illness, anxiety), and staff training all contribute to measurement variability that can bias results. This is confirmed by the wider variance and more biased estimates observed during single manual assessments in

Table 1. Comparison of mean blood pressure measurement, $N = 103$

	Systolic blood pressure			Diastolic blood pressure			Root square mean error	
	Mean (SD)	Difference	P	Mean (SD)	Difference	P	SBP	DBP
Manual, pre-ABPM	137.7 (15.4)	6.4	<0.001	81.9 (9.7)	3.6	<0.001	11.0	8.1
Manual, post-ABPM	135.9 (13.9)	4.6	0.004	80.0 (11.3)	1.7	0.09	11.8	7.7
Average manual	136.8 (12.2)	5.5	<0.001	80.9 (9.4)	2.7	0.002	11.1	7.5
AOBP measurement 1	135.8 (14.4)	4.5	0.002	79.7 (10.9)	1.5	0.11	11.2	7.4
AOBP measurement 2	133.2 (14.3)	1.9	0.18	78.6 (11.5)	0.3	0.77	11.1	7.5
AOBP measurement 3	132.7 (15.2)	1.4	0.32	77.1 (12.4)	-1.2	0.27	10.8	7.9
Average AOBP 2-3	132.9 (13.7)	1.6	0.21	77.8 (11.2)	-0.5	0.62	10.7	7.6
Average AOBP 1-3	133.8 (13.4)	2.5	0.05	78.4 (10.6)	0.2	0.86	10.8	7.4
ABPM wake	131.3 (12.3)	Reference	Reference	78.3 (9.2)	Reference	Reference	Reference	Reference
ABPM sleep	114.1 (14.4)	-17.1	<0.001	65.0 (8.7)	-13.1	<0.001	8.4	6.2
ABPM overall	126.5 (11.9)	-4.8	<0.001	74.6 (8.5)	-3.7	<0.001	3.1	1.9
% SBP ≥ 140			Difference	% DBP ≥ 90			% SBP ≥ 140 Or DBP ≥ 90	
							Difference	P
Manual, pre-ABPM	45.6	21.4	<0.001	25.2	13.6	0.00	53.4	<0.001
Manual, post-ABPM	37.9	13.6	0.02	23.3	11.7	0.02	47.6	0.001
Average manual	39.8	15.5	0.009	22.3	10.7	0.02	49.5	<0.001
AOBP measurement 1	30.1	5.8	0.38	19.4	7.8	0.13	41.7	0.02
AOBP measurement 2	32.0	7.8	0.19	15.5	3.9	0.50	38.8	0.07
AOBP measurement 3	28.2	3.9	0.54	13.6	1.9	0.80	33.0	0.36
Average AOBP 2-3	25.2	1.0	1.00	11.7	0.0	1.00	31.1	0.57
Average AOBP 1-3	26.2	1.9	0.85	14.6	2.9	0.61	35.0	0.20
ABPM wake	24.3	Reference	Reference	11.7	Reference	Reference	27.2	Reference
ABPM sleep	3.9	-20.4	<0.001	0.0	-11.7	<0.001	3.9	<0.001
ABPM overall	10.7	-13.6	<0.001	4.9	-6.8	0.02	12.6	<0.001

Abbreviations: ABPM, ambulatory blood pressure monitoring; AOBP, automated office blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.

our study. Taking the average of more than 1 visit is an important strategy to improve precision^{9,10} and minimize bias. Our study supports this strategy as there were notable reductions in bias and variance after averaging the manual measurements from 2 clinic visits. However, repeat visits require greater resources and delay the initiation of appropriate therapy. Our study supports the growing literature that a single-visit AOBP represents a less resource intensive yet equally or more precise measurement of BP than multiple clinic visits.⁵

We found that the average of the last 2 AOBP measurements was slightly more precise than the average of 3 AOBP measurements. This has been observed by others^{11,12} and may be due to physiologic adaptation responses to a first cuff compression.¹³ However, it should be noted that many AOBP devices do not provide an option to discard the first measurement, a logistic limitation, which may make the average of all 3 more practical in clinic settings.

Our study has limitations. First, we did not have AOBP assessments from multiple visits. It is possible that 2 AOBP measurements perform even better than a single-visit AOBP, but with the caveat of greater resource utilization. Second, clinic-based assessments were performed by LPNs and MAs. Measurement performance could differ when manual assessments are performed by health care professionals with different training backgrounds (e.g., registered nurses, physicians, pharmacists, nurse practitioners, or trainees), although our LPNs and MAs underwent standardized training and represent staff that often measure BP in clinic settings. Third, our study was performed among participants referred to a hypertension clinic. As a result the underlying distribution of BP may not reflect a general population of ambulatory adults. Finally, our sample was relatively small, precluding subgroup analyses.

Our study also has strengths. We assessed 2 best practices in BP measurement (manual measurements based on 2 clinic visits and AOBP) in a real-world setting. Furthermore, our population was diverse. We also used a gold standard means of assessing BP in close temporal relationship with other approaches and each person served as their own reference. This approach minimized the influence of time or patient-level confounders.

This study has important clinical implications. BP control has been adopted as a major accountable care organization benchmark for a clinic's population health performance and as a result is tied to substantial fiscal incentives. Although office-based BP measurements can overestimate BP, home BP assessments are limited by both patient and practice resources and are often not considered by payors in assessing BP control, placing incredible importance on BP measured in the clinic setting. However, our study demonstrates that simply changing measurement strategies from a manual to the average of the last 2 unattended AOBP measurements could reduce the prevalence of stage 2 or uncontrolled hypertension by an absolute magnitude of 15%. This may help prevent misclassification of hypertension and avoid overtreatment as well as more accurately depict population-wide control rates. However, the cost effectiveness of these approaches along with ways to shorten the time required

for AOBP assessments (e.g., smaller resting period or interval between measurements) without sacrificing precision should be evaluated in subsequent research.

In conclusion, a single visit, unattended AOBP assessment more precisely estimated BP and the prevalence of stage 2 or uncontrolled hypertension than 2 manual clinic visits. This approach to BP triage may reduce the resource burden surrounding BP measurement in the clinic setting and improve the quality of BP treatment for patients.

SUPPLEMENTARY DATA

Supplementary data are available at *American Journal of Hypertension* online.

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DISCLOSURE

The authors declared no conflict of interest.

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