Published in final edited form as:

High Blood Press Cardiovasc Prev. 2019 February ; 26(1): 45–53. doi:10.1007/s40292-019-00300-0.

Emergency department-provided home blood pressure devices can help detect undiagnosed hypertension

Elizabeth M. Goldberg, MD, ScM^{1,2}, Taneisha Wilson, MD, ScM¹, Bianca Jambhekar, MPH³, Sarah J Marks, MS⁴, Michael Boyajian, BA⁵, and Roland C. Merchant, MD, MPH, ScD^{1,5}

¹department of Emergency Medicine, Brown University, Providence, RI

²Department of Health Services, Practice and Policy, Brown University School of Public Health, Providence, RI

³New York Medical College, Valhalla, NY

⁴Department of Emergency Medicine, Brigham and Women's Hospital, Boston, MA

⁵Alpert Medical School of Brown University, Providence, RI

Abstract

Introduction—Emergency departments (EDs) are critical sites for hypertension (HTN) screening. Home blood pressure (BP) monitoring (HBPM) is used routinely in outpatient settings, yet its utility after the ED visit for those with elevated BP in the ED is unclear. In this pilot study, we assessed if HBPM could detect HTN in patients with elevated in-ED BP.

Methods—From September 2014 to July 2017, we recruited adult patients at an urban, academic ED with a triage BP $\geq 120/80$ mm Hg and no history of HTN into this prospective cohort observational study. After their ED visit, participants obtained BP measurements for two weeks using a validated HBPM. HTN was considered probable if the average HBPM BP was $\geq 135/85$ mm Hg. We calculated the proportion of participants whose ED BP measurement accurately predicted HTN using HBPM after discharge.

Results—Of 136 participants enrolled, 93 (68%) returned the HBPM with at least four home BP measurements (mean number of measurements obtained: 29 (SD: 17, range 4–59)). Participants' median age was 40 years-old (IQR 34–48); 55% were female, 19% were black, and 58% were white. Forty-six percent of participants with elevated in-ED BP had HTN in follow-up.

Conclusion—For patients with elevated BP in the ED, HBPM could be valuable for determining which patients have HTN and require expedient follow-up.

Keywords

hypertension; quality; measurement; guidelines; cardiovascular disease; blood pressure

Corresponding Author: Elizabeth M. Goldberg, MD, ScM, Department of Emergency Medicine & Department of Health Services, Policy and Practice, Brown University, 55 Claverick Street, Providence, RI 02903, Phone number: 401-444-7975, Elizabeth_goldberg@brown.edu.

Financial Disclosures: There are no disclosures.

INTRODUCTION

Hypertension (HTN) is the leading modifiable risk factor for stroke and heart disease.¹ Emergency departments (EDs) commonly evaluate patients with elevated blood pressure (BP), with recent research showing that one fifth of ED visits are HTN-related.² Although EDs serve as a health care safety-net and could play an essential role in HTN screening and treatment, the validity of ED BPs and their potential predictive value for HTN is unknown. A common perception remains that HTN management and treatment should occur outside the ED.^{3–6} However, most ED patients with an elevated initial BP will continue to have elevated BPs after discharge, regardless of the severity of the presenting condition, pain or anxiety.⁷

ED visits for elevated BP are increasing² and rates of HTN awareness and control remain low in the United States¹. As a result, in the past decade the Center for Medicare & Medicaid Services (CMS)⁸, the American College of Emergency Physicians⁹, and hypertension experts^{10–12} have cited EDs as important sites for HTN screening and control. ED-based elevated BP management has been limited to performing evaluations for HTN-related end organ damage, and providing patient education and referral for further testing.^{13,14} However, recent advances and enthusiasm for digital health initiatives and technology-assisted self-management, have created new opportunities for patients to take an active role in disease diagnosis and management.¹⁵ An example of these advances in the HTN realm include the increased adoption of home BP monitoring (HBPM).¹⁶

HBPM is recognized as a helpful adjunct to office-based measurements for monitoring and diagnosing HTN, as well as the identification of white coat HTN.^{17–20} HBPM are a cost-effective and readily available alternative to ambulatory BP monitoring, can help titrate antihypertensive medication, promote patient engagement with care, and can expedite a diagnosis of HTN.^{21–23} This is particularly important for ED patients who often cannot secure short-term follow-up for HTN.²⁴ Very little is known about using HBPM for patients after an ED visit in which they had elevated BP as a means to detect HTN after the ED visit.⁷

The objective of this pilot study was to evaluate using ED-provided HBPM to detect HTN after discharge and determine whether ED attending physicians could accurately predict HTN in their patients based on in-ED BP readings. Prior research shows that ED physicians provide little education to patients regarding the meaning of their elevated BP readings in the ED,²⁵ but this discussion is critical to motivate patients to make lifestyle modifications to decrease BP and seek follow-up for HTN after the ED visit. If ED physicians can accurately predict which of their patients will have HTN after the ED visit, then they could provide patients with valuable data on their cardiovascular risk and begin to motivate behavior change. We also tested the hypothesis that in-ED BPs could be used to predict HTN after discharge.

MATERIALS AND METHODS

Study Design

This prospective observational cohort study was conducted between September 2014 and July 2017 among adult ED patients without a known diagnosis of HTN who had a triage BP 120 mm Hg systolic and/or 80 mm Hg diastolic. The hospital institutional review board approved this study.

Study Setting And Population

The study was conducted in New England at a level I, tertiary referral academic ED with an annual volume of over 110,000 adult patient visits. Patients had to be at least 18 years-old, speak English, and have a triage BP 120 mm Hg systolic and/or 80 mm Hg diastolic. Patients were ineligible if they had a known HTN diagnosis or were taking antihypertensive medication, receiving dialysis, pregnant, prisoners, intoxicated, admitted, or in infectious disease isolation. Additional exclusion criteria included having atrial fibrillation, chest pain, shortness of breath, unilateral weakness or numbness, altered mental status, an acute psychiatric problem, or using cocaine in the previous 30 days. We excluded patients with atrial fibrillation as HBPM may not provide an accurate BP for these patients. Patients with cocaine use may have elevated BP due to substance use rather than essential HTN. Patients who received any antihypertensive medication between the triage BP measurement and the BpTRU measurement were excluded. Patients who were unable to record at least four home BP measurement after ED discharge or who did not return their HBPM device were not included in the analyses. We based our study protocol on a previously published study that included ED patients.⁷ According to this protocol, participants who were not able to obtain at least four BP measurements using the HBPM were excluded.⁷

Study Protocol

Research assistants (RAs) reviewed a random sample of the electronic health records of patients present in the ED during data collection periods. Prior to the study, the research staff created a randomized list of the study sites' ED treatment rooms. The RAs used this sequence to select which patient's record would be reviewed next for eligibility, reviewed those records for the triage BP and other criteria for study eligibility, and approached those who were potentially study eligible. Patients who met study criteria and provided consent could participate in the study. ED attendings caring for those participants also provided consent to be in the study.

Measurements

ED Visit Procedures—The triage BP was collected by nurses or certified nursing assistants at patient arrival using an automated BP device. No attempt was made by the study personnel to standardize or alter the collection of this measurement. The RA used the triage BP only as marker of study eligibility. After study enrollment, the RA obtained BP readings of each participant using the BpTRU device. The BpTRU device is considered the “gold standard” for office-based BP measurement as it has superior accuracy to other automated devices.²⁶ After patient consent, the RA checked the BP in both arms of the participant, and

then obtained measurements from the arm with the higher BP measurement, as suggested in the BpTRU user manual.²⁷ After the initial BP measurement, the RA exited the room while the BpTRU device took five more readings at one-minute intervals. The RA's exit was intended to reduce "white coat" BP elevations. The BpTRU device omits the initial BP measurement and averages the latter five to produce a single measurement. Patients who did not have a BpTRU measurement of ≥ 120 mm Hg systolic or ≥ 80 mm Hg diastolic were excluded.

After ED Visit Procedures—After their ED visit, participants obtained their morning and evening BPs for two weeks using a validated HBPM device, the Omron BP760.^{28,29} The HBPM stored up to 60 measurements obtained by participants. Participants also completed logs of their BP readings. The HBPM and participant-completed BP logs were returned to the research staff in pre-addressed postage-paid boxes or returned to the ED in-person.

Study Definition Of HTN Using HBPM—For study purposes, if the calculated average of all collected HBPM measurements was $\geq 135/85$ mm Hg, the patient was considered to have HTN.^{29,30} Guidelines on making a HTN diagnosis using HBPM vary in the quantity and timing of measurements deemed necessary; in some it is recommended to average twelve or more BP measurements over at least seven days, while in others it is recommended to perform only three days of measurements.^{30–32} However, a mean BP $\geq 135/85$ mm Hg is recommended uniformly, therefore this was the threshold used for our study definition of HTN. At the conclusion of the study, we provided primary care providers with the participant-completed HBPM log, so they could use the patient's measurements to make treatment decisions.

ED Attending Physician Survey

Emergency medicine board-certified attendings completed a brief in-person survey after their initial encounter with the enrolled participant. They were asked if they believed their patient would have HTN in follow-up (yes/no) after reviewing all the participants BP measurements taken as part of routine ED care.

Data Analysis

We reported participant and visit characteristics using descriptive statistics. In-ED BpTRU measurements were categorized by HTN stage. We calculated the proportion of participants whose ED BpTRU measurement accurately predicted HTN using HBPM. Proportions of participants whose mean at-home BP met the $\geq 135/85$ mm Hg HTN threshold were calculated by in-ED HTN stage³³, as follows: Pre-HTN was systolic BP 120–139 or diastolic BP 80–89 mm Hg, Stage I HTN was systolic BP 140–159 or diastolic BP 90–99 mm Hg, and Stage II HTN was systolic BP ≥ 160 mm Hg or diastolic BP ≥ 100 mm Hg.^{6,34} An $\alpha=0.05$ level of significance was used for comparisons. Data were recorded into the REDCap application and analyzed using SAS 9.4 (SAS Institute, Cary, NC).

We also used ROC analysis to determine whether in-ED BP measurements (by both BpTRU and standard automated BP devices) could be used to predict HTN. We used the same approach with ROC analysis to determine whether ED attending physicians could accurately

predict whether their patient with elevated in-ED BP would have HTN after discharge. Since ED attending physicians were provided with the participants' in-ED BP values prior to the ED attending physician survey, we included the participant's initial BP in our prediction model. Therefore, we report what *additional* predictive value physician gestalt provides over the use of in-ED BPs alone to make a determination of HTN in follow-up. We calculated areas under the curve with Wald confidence intervals. We examined the sensitivity, specificity, positive predictive value and negative predictive value for ED attending physician prediction along with 95% confidence intervals. Additionally, we examined factors associated with a HTN diagnosis at two weeks using logistic regression.

RESULTS

Of the 452 patients approached with elevated triage BP, 189 did not meet eligibility criteria and 112 declined enrollment. The remaining 151 patients were enrolled in the study, but eleven were excluded due to hospital admission, three withdrew, and one was started on antihypertensive medication in the ED. Of 136 participants, 93 (68%) returned the HBPM device and had at least four valid home BP measurements (Figure 1). Participants obtained a mean of 29 measurement using the HBPM (SD: 17, range 4–59).

Patient And Visit Characteristics

Among the 93 participants, the median age was 40 years-old (IQR 34–48); 55% were female, 19% were black, 58% were white, and 9% did not have health insurance. Sixty-nine percent of participants had a family history of HTN, and 60% presented to the ED for a medical problem while 36% had an injury. At study enrollment, more than half of the participants had at least one BP reading obtained within the past month (Table 1). Participants who were not included in the analysis (n=58), did not differ significantly from included participants in terms of demographics, health history, healthcare access, and visit characteristics with some exceptions: females were more likely to be included and included participants were more likely to be insured.

How Accurate Is ED-measured BP In Predicting HTN After Discharge?

Among the 39 participants who's in-ED BP was in the pre-HTN range, 31% (95% CI: 52%–83%) had HTN after discharge. Of the 38 subjects with in-ED BP in the stage I range, 50% (95% CI: 33%–67%) had HTN after discharge. Of the sixteen participants with in-ED BPs in the stage II range, 75% (95% CI: 48%–93%) had HTN following ED discharge (Table 2).

How Accurate Is Physician Gestalt In Predicting HTN After Discharge?

Fifty eight percent of participants whose ED attending physician predicted they would meet criteria for HTN, met the study definition after discharge (Table 3a). The sensitivity of physician gestalt was 54% (95% CI: 37% - 71%). The specificity was better at 66% (95% CI: 49% - 80%). The positive predictive value was 58% (95% CI: 45% - 70%) and negative predictive value was 63% (95% CI: 53% - 72%) (Table 3b).

Comparison Of Methods To Predict HTN After Discharge

Using in-ED BpTRU measurements, HTN in follow-up could be predicted accurately in 71% (95% CI: 60%–81%) of participants. The mean in-ED BP value, recorded by automated BP devices during the ED visit as part of routine ED care, as well as the method using only triage BP had similar accuracy: 70% (95% CI: 59%–81%) and 68% (90% CI: 57%–79%), respectively (Table 4). In comparison, ED attending physician prediction accuracy was lower.

Patient and visit factors associated with a HTN diagnosis at two weeks

We examined factors that were associated with HTN diagnosis at two weeks including highest education obtained, insurance type, last time BP was measured, reason for ED visit, family history of HTN, smoking, alcohol use, pain during visit, and anxiety during visit. After controlling for BP (using BpTRU measurements), the only factor that was significantly associated with a HTN diagnosis using HBPM was insurance status. Specifically, compared to participants with private health insurance, those with government-based insurance had an aOR of 4.33 (95% CI: 1.49–12.25) of being diagnosed with HTN.

DISCUSSION

In this pilot study, we found that ED-provided HBPM could be a valuable tool to detect HTN after discharge. While ED attending physician assessment was a poor predictor of post-discharge HTN, averaging in-ED BPs or using triage BP alone provided a fair estimate of HTN after discharge. ED clinicians could use this approach to advise patients on their risk of having HTN vs. spuriously elevated in-ED BP.

Prior Research On ED-provided HBPM

Previous research on this topic is limited. No other studies have been published that evaluate ED-provided HBPM for detecting HTN or the ability of ED attending physicians to correctly classify patients as likely to have HTN in follow-up. A 2008 study by Tanabe et al. enrolled 189 ED patients without previously diagnosed HTN with two in-ED BP measurements 140/80 mm Hg.⁷ Participants were instructed to obtain their BP at home using HBPM and return the monitors after a seven-day period. Of the study cohort, 51% had elevated mean BP in follow-up. Increased pain and anxiety were not associated with a decrease in BP after the ED visit. Our study builds on this foundational research by including patients with pre-HTN range BP, which is now recognized as an important risk factor for cardiovascular disease and is the recommended screening threshold for HTN in EDs.^{35–38} Additionally, we extended the seven-day period of BP measurements used in the aforementioned study to address the concern that BPs may be spuriously elevated immediately after an ED visit.

In this pilot study, patients with higher in-ED BPs were more likely to have HTN in follow-up. Consistent with prior research on ED patients with elevated BP, 75% of participants with in-ED BP 160/100 mm Hg had persistently elevated BP in follow-up.³⁴ ED physicians, insurers, and other stakeholders should be aware that patients with higher in-ED BPs are an important group to target with more intense resources such as ED-provided HBPM. A

population-based strategy that includes ED screening and management is necessary given the prevalence and cardiovascular morbidity that results from undiagnosed HTN.

Potential Benefits Of HBPM For ED Patients

This pilot study demonstrates that HBPM is a viable option for patients with elevated BP when follow-up is not immediately available. While all patients with an elevated in-ED BP and no history of HTN should be referred for further HTN testing,⁹ many might experience a long latency period before they can be reevaluated. In a recent study, ED patients without an established primary care provider were able to secure an appointment only one third of the time for HTN.²⁴ Even patients with established primary care providers have difficulty obtaining urgent follow-up after leaving the hospital.^{24,39} HBPM allows patients to collect BP data on their own while awaiting primary care visits. Primary care providers can use this data to make an HTN diagnosis, start antihypertensive medication, and determine which patients need to be prioritized for follow-up care.

HBPM can promote patient engagement and can be combined with visits to HTN clinics, mHealth BP self-management systems,^{15,40} and pharmacist-led BP monitoring and medication adjustment programs.⁴¹ HTN-related ED visits are increasing², which may indicate that there is a greater need for patient self-efficacy in monitoring and managing HTN. Wearable monitoring devices are becoming more prevalent and patients may embrace HBPM as an option when other follow-up is not immediately available. HBPM is also endorsed by European guidelines as an alternative to office-based measurements, in patients with presumed white-coat HTN, those at high risk of masked HTN, and those with BP variability.⁴²

Policy And Practice Implications

ED physicians at this large academic medical center had poor accuracy in predicting whether participants would have HTN in follow-up even after being provided a list of the patient's in-ED BPs. Lack of accuracy may be due to the widely-held physician belief that the pain and anxiety of acute conditions invalidates in-ED BPs or the perception that primary care providers are exclusively responsible for HTN diagnosis and management.^{43,44} Our results indicate that ED clinicians should not rely on gestalt but instead on objective measures, such as the mean in-ED BP, to give patients advice on their risk of HTN and needed follow-up. This study underscores the usefulness of HBPM in patients who can follow through with recommended HBPM protocols. Other patients may need to rely on in-person visits or ambulatory BP monitoring, for which a several-day protocol of twice daily BP measurement is not required.

The cost of HBPM may be prohibitive for patients. However, integrated health care systems and EDs that have quality incentives or alternative payment models in place, could make HBPM available to their ED patients with elevated BP. The cost of validated HBPM devices range from USD \$40 to \$60 and prior studies show that HBPM can improve outcomes for patients with HTN.^{22,23} Office visits can be avoided for patients with controlled HTN or those with BPs that average < 135/85 mm Hg at home. Therefore, ED-provided HBPM

could be a cost-effective approach to HTN diagnosis and management even if only two thirds of patients comply with HBPM protocols.

LIMITATIONS

Although we aimed to recruit patients with a wide range of in-ED elevated BPs, our final sample included a greater percentage of participants with pre-HTN or stage I range BPs. Including admitted patients in our study would have allowed us to recruit more patients with stage II range in-ED BPs. However, this strategy would have also increased our likelihood of including patients with hypertensive emergencies rather than our target group of patients with undiagnosed asymptomatic HTN.

Our definition of HTN using HBPM might vary from other studies and we could have classified patients as having HTN, who would not be diagnosed with HTN by their primary care providers. There is no universally accepted definition of HTN using HBPM.^{30,46,47} Additionally, surveys of primary care providers and specialists reveal that there is practice variability among clinicians in the recommended frequency and timing of HBPM measurements.^{48,49} However, we believe misclassification of HTN using our protocol is minimal, as our study participants obtained a mean of 29 HBPM measurements during the study period. Further research on the ideal frequency and timing of HBPM measurements after an ED visit is necessary.

CONCLUSION

In this study, HBPM after ED discharge was valuable for detecting patients with HTN. However, interventions are needed to maximize device return and compliance with frequent HBPM measurements. ED-based HTN screening and HBPM may help reduce rates of untreated and undiagnosed HTN.

Caption: See Supplementary Table 1 for thresholds using the new American Heart Association /American College of Cardiology HTN guidelines that define HTN as a BP 130/80 mm Hg rather than 140/90 mm Hg.⁴⁵

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

We have received funding for this work from the Agency for Healthcare Research and Quality (T32 HS000011), Brown Emergency Medicine; and the Rhode Island Foundation.

REFERENCES

1. CDC/National Center for Health Statistics. Vital signs: awareness and treatment of uncontrolled hypertension among adults--United States, 2003–2010. MMWR Morb Mortal Wkly Rep. 2012;61:703–709. [PubMed: 22951452]

2. McNaughton CD, Self WH, Zhu Y, Janke AT, Storrow AB, Levy P. Incidence of Hypertension-Related Emergency Department Visits in the United States, 2006 to 2012. *Am J Cardiol*. 2015;116(11):1717–1723. [PubMed: 26454813]
3. Lebbly T, Paloucek F, Dela Cruz F, Leikin JB. Blood pressure decrease prior to initiating pharmacological therapy in nonemergent hypertension. *Am J Emerg Med*. 1990;8(1):27–29. [PubMed: 2293829]
4. Karras DJ, Kruus LK, Cienki JJ, et al. Evaluation and treatment of patients with severely elevated blood pressure in academic emergency departments: a multicenter study. *Ann Emerg Med*. 2006;47(3):230–236. [PubMed: 16492489]
5. Karras DJ, Ufberg JW, Heilpern KL, et al. Elevated blood pressure in urban emergency department patients. *Acad Emerg Med*. 2005;12(9):835–843. [PubMed: 16141017]
6. Backer HD, Decker L, Ackerson L. Reproducibility of increased blood pressure during an emergency department or urgent care visit. *Ann Emerg Med*. 2003;41(4):507–512. [PubMed: 12658251]
7. Tanabe P, Persell SD, Adams JG, McCormick JC, Martinovich Z, Baker DW. Increased blood pressure in the emergency department: pain, anxiety, or undiagnosed hypertension? *Ann Emerg Med*. 2008;51(3):221–229. [PubMed: 18207606]
8. Centers for Medicare & Medicaid Services. Physician Quality Reporting System. 2014; https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/PQRS/Downloads/2015_PQRS_CrosscuttingMeasures_12172014.pdf.
9. Wolf SJ, Lo B, Shih RD, Smith MD, Fesmire FM. Clinical policy: critical issues in the evaluation and management of adult patients in the emergency department with asymptomatic elevated blood pressure. *Ann Emerg Med*. 2013;62(1):59–68. [PubMed: 23842053]
10. Levy PD, Cline D. Asymptomatic hypertension in the emergency department: a matter of critical public health importance. *Acad Emerg Med*. 2009;16(11):1251–1257. [PubMed: 19845553]
11. McNaughton CD, Self WH, Levy PD, Barrett TW. High-Risk Patients with Hypertension: Clinical Management Options. *Clin Med Rev Vasc Health*. 2013;2012(4):65–71. [PubMed: 23888121]
12. Brody A, Rahman T, Reed B, et al. Safety and efficacy of antihypertensive prescription at emergency department discharge. *Acad Emerg Med*. 2015;22(5):632–635. [PubMed: 25904073]
13. Goldberg EM, Shah K, Shayne P. An Evidence-Based Approach To Managing Asymptomatic Elevated Blood Pressure In The Emergency Department. *Emerg Med Pract*. 2015;17(2):1–20;
14. Baumann BM, Cline DM, Cienki JJ, Egging D, Lehrmann JF, Tanabe P. Provider Self-Report and Practice: Reassessment and Referral of Emergency Department Patients With Elevated Blood Pressure. *Am J Hypertens*. 2009;22(6):604–610. [PubMed: 19265789]
15. Goldberg EM, Levy PD. New Approaches to Evaluating and Monitoring Blood Pressure. *Curr Hypertens Rep*. 2016;18(6):49. [PubMed: 27137524]
16. Parati G European Society of Hypertension practice guidelines for home blood pressure monitoring. *J Hum Hypertens*. 2010;24(12):779. [PubMed: 20520631]
17. Pickering TG, Hall JE, Appel LJ, et al. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Hypertension*. 2005;45(1):142–161. [PubMed: 15611362]
18. Nasothimiou EG, Tzamouranis D, Rarra V, Roussias LG, Stergiou GS. Diagnostic accuracy of home vs. ambulatory blood pressure monitoring in untreated and treated hypertension. *Hypertens Res*. 2012;35(7):750–755. [PubMed: 22357523]
19. Niiranen TJ, Hanninen MR, Johansson J, Reunanen A, Jula AM. Home-measured blood pressure is a stronger predictor of cardiovascular risk than office blood pressure: the Finn-Home study. *Hypertension*. 2010;55(6):1346–1351. [PubMed: 20385970]
20. Siu AL. Screening for High Blood Pressure in Adults: U.S. Preventive Services Task Force Recommendation Statement Screening for High Blood Pressure in Adults. *Ann Intern Med*. 2015;
21. Parati G, Stergiou GS, Asmar R, et al. European Society of Hypertension guidelines for blood pressure monitoring at home: a summary report of the Second International Consensus Conference on Home Blood Pressure Monitoring. *J Hypertens*. 2008;26(8):1505–1526. [PubMed: 18622223]

22. Agarwal R, Bills JE, Hecht TJ, Light RP. Role of home blood pressure monitoring in overcoming therapeutic inertia and improving hypertension control: a systematic review and meta-analysis. *Hypertension*. 2011;57(1):29–38. [PubMed: 21115879]
23. Breaux-Shropshire TL, Judd E, Vucovich LA, Shropshire TS, Singh S. Does home blood pressure monitoring improve patient outcomes? A systematic review comparing home and ambulatory blood pressure monitoring on blood pressure control and patient outcomes. *Integr Blood Press Control*. 2015;8:43–49. [PubMed: 26170715]
24. Chou SC, Deng Y, Smart J, Parwani V, Bernstein SL, Venkatesh AK. Insurance Status and Access to Urgent Primary Care Follow-up After an Emergency Department Visit in 2016. *Ann Emerg Med*. 2018;71(4):487–496.e481. [PubMed: 29032870]
25. Baumann BM, Abate NL, Cowan RM, Chansky ME, Rosa K, Boudreaux ED. Characteristics and referral of emergency department patients with elevated blood pressure. *Acad Emerg Med*. 2007;14(9):779–784. [PubMed: 17652640]
26. Beckett L, Godwin M. The BpTRU automatic blood pressure monitor compared to 24 hour ambulatory blood pressure monitoring in the assessment of blood pressure in patients with hypertension. *BMC Cardiovasc Disord*. 2005;5(1):18. [PubMed: 15985180]
27. BPTru Operator's Manual. 2015; http://www.medaval.ie/devices/img/devices/BPMs/BPTRU/BPM%20AMP%20BpTru%20BPM-100/BPTRU%20BPM_100%20Manual.pdf. Accessed October 25, 2016.
28. Dabl Educational Trust. 2016; <http://www.dableducational.org>. Accessed July 17, 2018.
29. Omron. Omron 7 series Blood Pressure Monitor Instruction Manual. <https://omronhealthcare.com/wp-content/uploads/BP760N-IM.pdf>. Accessed August 3, 2018.
30. Parati G, Stergiou GS, Asmar R, et al. European Society of Hypertension practice guidelines for home blood pressure monitoring. *J Hum Hypertens*. 2010;24(12):779–785. [PubMed: 20520631]
31. Shimamoto K, Ando K, Fujita T, et al. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH 2014). *Hypertens Res*. 2014;37(4):253–390. [PubMed: 24705419]
32. Almeida AE, Stein R, Gus M, et al. Improved diagnostic accuracy of a 3-day protocol of home blood pressure monitoring for the diagnosis of arterial hypertension. *Blood Press Monit*. 2013;18(2):119–126. [PubMed: 23406684]
33. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure - The JNC 7 Report. *Jama-Journal of the American Medical Association*. 2003;289(19):2560–2572.
34. Dieterle T, Schuurmans MM, Strobel W, Battagay EJ, Martina B. Moderate-to-severe blood pressure elevation at ED entry: hypertension or normotension? *Am J Emerg Med*. 2005;23(4):474–479. [PubMed: 16032614]
35. Huang Y, Cai X, Li Y, et al. Prehypertension and the risk of stroke: A meta-analysis. *Neurology*. 2014.
36. Hsia J, Margolis KL, Eaton CB, et al. Prehypertension and cardiovascular disease risk in the Women's Health Initiative. *Circulation*. 2007;115(7):855–860. [PubMed: 17309936]
37. Goldberg EM, Wilson T, Saucier C, et al. Achieving the BpTRUth: emergency department hypertension screening and the Centers for Medicare & Medicaid Services quality measure. *J Am Soc Hypertens*. 2017;11(5):290–294. [PubMed: 28412275]
38. Vasan RS, Larson MG, Leip EP, et al. Impact of high-normal blood pressure on the risk of cardiovascular disease. *N Engl J Med*. 2001;345(18):1291–1297. [PubMed: 11794147]
39. DeLia D, Tong J, Gaboda D, Casalino LP. Post-discharge follow-up visits and hospital utilization by Medicare patients, 2007–2010. *Medicare Medicaid Res Rev*. 2014;4(2).
40. McGillicuddy JW, Gregoski MJ, Weiland AK, et al. Mobile Health Medication Adherence and Blood Pressure Control in Renal Transplant Recipients: A Proof-of-Concept Randomized Controlled Trial. *JMIR Res Protoc*. 2013;2(2):e32. [PubMed: 24004517]
41. Magid DJ, Olson KL, Billups SJ, Wagner NM, Lyons EE, Kroner BA. A pharmacist-led, American Heart Association Heart360 Web-enabled home blood pressure monitoring program. *Circulation Cardiovascular Quality & Outcomes*. 2013;6(2):157–163. [PubMed: 23463811]

42. Williams B, Mancia G, Spiering W, et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension. *Eur Heart J*. 2018;39(33):3021–3104. [PubMed: 30165516]
43. Brody AM, Sharma VK, Singh A, et al. Barriers to emergency physician diagnosis and treatment of uncontrolled chronic hypertension. *Am J Emerg Med*. 2016.
44. Shayne P Against Routine Initiation of Antihypertensive Therapy in the Emergency Department. *Ann Emerg Med*. 2009;54(6):792–793. [PubMed: 19942066]
45. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2017.
46. Ntineri A, Nasothimiou E, Kollias A, Roussias L, Achimastos A, Stergiou GS. 3C.05: Diagnostic Agreement of the European Society of Hypertension Home Blood Pressure Monitoring Schedule with Ambulatory Blood Pressure Monitoring in Untreated and Treated Subjects *J Hypertens*. 2015;33 Suppl 1:e38.
47. Niiranen TJ, Rissanen H, Johansson JK, Jula AM. Overall cardiovascular prognosis of isolated systolic hypertension, isolated diastolic hypertension and pulse pressure defined with home measurements: the Finn-home study. *J Hypertens*. 2014;32(3):518–524. [PubMed: 24477096]
48. Setia S, Subramaniam K, Teo BW, Tay JC. Ambulatory and home blood pressure monitoring: gaps between clinical guidelines and clinical practice in Singapore. *Int J Gen Med*. 2017;10:189–197. [PubMed: 28721085]
49. Logan AG, Dunai A, McIsaac WJ, Irvine MJ, Tisler A. Attitudes of primary care physicians and their patients about home blood pressure monitoring in Ontario. *J Hypertens*. 2008;26(3):446–452. [PubMed: 18300854]

Figure 1:
Inclusion flow chart (BP: Blood Pressure, ED: Emergency Department)

Table 1:

Sample demographics, health care access, health history, and ED blood pressure measurements (IQR: Interquartile range, n: number of subjects, SD: standard deviation, GED: general education diploma, PCP: primary care provider, ED: emergency department, BMI: body mass index)

Demographics	N(%) or mean (SD)
Age median (IQR)	40 (34–48)
Male n(%)	42 (45.1)
Race n(%) ¹	
White non-Hispanic	54 (58.1)
Black	18 (19.4)
Other (including multiple races)	21 (22.6)
Education level n(%)	
Did not finish high school	13 (14.0)
High school graduate/GED	31 (33.3)
Some college or technical school	25 (26.9)
College graduate or more	24 (25.8)
Visit characteristics	
Reason for ED visit n(%)	
Injury	33 (35.5)
Medical problem	56 (60.2)
Other reason	4 (4.3)
Pain present n(%)	59 (63.4)
Anxiety or nervousness present n(%)	35 (37.6)
Healthcare access	
Insurance n(%) ²	
Private	48 (51.6)
Governmental	36 (38.7)
None	8 (8.6)
Usual place for medical care n(%)	
PCP in a private clinic practice	56 (58.1)
PCP in a hospital or community health clinic	14 (15.1)
ED or urgent care center	24 (25.8)
Other	1 (1.1)
Last blood pressure check n(%)	
Within the last month	50 (53.8)
One month to less than six months ago	21 (22.6)
Six months or more ago or don't know	22 (23.7)
Health History	
Diabetes n(%)	
High cholesterol n(%)	12 (12.9)
Kidney disease n(%)	2 (2.2)
Angina n(%)	1 (1.1)

Demographics	N(%) or mean (SD)
Myocardial infarct n(%)	1 (1.1)
Stroke n(%)	1 (1.1)
Family history of hypertension n(%)	64 (68.8)
BMI median (IQR)	28.3 (26.3–33.9)
Currently smoke n(%)	21 (22.6)
ED Blood Pressure Measurements	
BpTRU BP systolic/diastolic (mean(SD))	138(18)/ 90(11)
Triage BP, systolic/diastolic (mean(SD))	151(22)/ 92(14)
Mean in-ED BP, systolic/diastolic (mean(SD))	148(20)/ 90(10)

¹ Race missing for three participants; Black includes Black Hispanics

² Insurance missing for one participant; participants with both private and governmental insurance were classified as having private insurance

Table 2:

How many participants with elevated BP in the ED had HTN (elevated mean BP 135/85 mm Hg on HBPM) in the follow-up period (HTN: hypertension, SBP: systolic blood pressure, DBP: diastolic blood pressure, HBPM: home blood pressure monitor)

ED BP Measurement by BpTRU	N	Mean BP by HBPM <135/85 mm Hg n(%)	Mean BP by HBPM 135/85 mm Hg n(%)
Pre-HTN - SBP:120–139 or DBP:80–89	39	27 (69.2)	12 (30.8)
Stage I HTN - SBP:140–159 or DBP:90–99	38	19 (50.0)	19 (50.0)
Stage II HTN - SBP: 160 or DBP: 100	16	4 (25.0)	12 (75.0)

Caption: See Supplementary Table 1 for thresholds using the new American Heart Association / American College of Cardiology HTN guidelines that define HTN as a BP 130/80 mm Hg rather than 140/90 mm Hg.⁴⁵

Table 3a:

Misclassification of physician estimation³ (ED: Emergency Department, BP: blood pressure, HBPM: Home blood pressure monitoring)

ED BP Measurement by BpTRU	N	Mean BP by HBPM <135/85 mm Hg n(%)	Mean BP by HBPM 135/85 mm Hg n(%)
Physician did not predict hypertension	43	27 (62.8)	16 (37.2)
Physician predicted hypertension	33	14 (42.4)	19 (57.6)
Physician did not make prediction	14	8 (57.1)	6 (42.9)

³Physician did not respond to prediction questions

Table 3b:

Test characteristics of attending ED physicians' prediction of HTN (PPV: Positive Predictive Value, NPV: Negative Predictive Value, CI: Confidence Interval)

Test characteristic	Physician Prediction Parameter (95% CI)
Sensitivity	0.54 (0.37–0.71)
Specificity	0.66 (0.49–0.80)
PPV	0.58 (0.45–0.70)
NPV	0.63 (0.53–0.72)

Table 4:

Accuracy of different methods to predict HTN after discharge (AUC: Area under the curve, CI: Confidence Interval, ED: emergency department, BP: blood pressure)

Model	All participants (n=93)	Participants with physician prediction (n=76)
		AUC (95%CI)
BpTRU systolic and diastolic BP	0.71 (0.60, 0.81)	0.69 (0.56, 0.81)
Triage BP	0.68 (0.57, 0.79)	0.66 (0.53, 0.79)
Mean in-ED BP	0.70 (0.59, 0.81)	0.68 (0.55, 0.80)
Physician prediction	N/A	0.59 (0.48, 0.71)