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ORIGINAL RESEARCH

Association of Elevated Blood Pressure in the Emergency Department With Chronically Elevated Blood Pressure

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BACKGROUND: Emergency department (ED) visits for hypertension are rising, but the importance of elevated blood pressure (BP) measured during the ED visit is controversial. We evaluated the relationship between ED BP and mean BP over the subsequent year.

METHODS AND RESULTS: We performed a retrospective cohort study from January 1, 2010 to December 31, 2013 of 8105 adult patients who made 1 visit to an academic medical center ED with ≥2 ED BPs and ≥2 BPs measured in the subsequent year. The primary exposure was lowest ED systolic BP. The primary outcome was mean systolic BP ≥140 mm Hg over the year following the index ED visit. Diastolic BP was examined as a secondary exposure and outcome. Multiple logistic regression was performed adjusting for several covariates, with interaction terms for hypertension diagnosis, ED disposition, pain-related ED chief complaint, and sex. Patients whose lowest ED systolic BP was 140 to 159 mm Hg had an adjusted odds ratio of having a mean SBP ≥140 mm Hg in the subsequent year of 10.9 (95% CI, 7.6–15.6). Patients without diagnosed hypertension and ED BP 140/90 to 159/99 mm Hg were more likely to have elevated BP in the following year. Hospitalization increased the likelihood of persistently elevated systolic BP but not diastolic BP. There was no effect modification by pain-related ED complaint.

CONCLUSIONS: When ED BP is consistently elevated, BP is highly likely to remain elevated in the subsequent year, regardless of pain, and particularly among patients without diagnosed hypertension. Further research is needed to determine the optimal management of elevated ED BP.

Key Words: blood pressure ■ emergency department ■ emergency medicine ■ hypertension ■ population science

Hypertension affects more than one-third of adults in the United States, and hypertension-related emergency department (ED) visits are increasing.[1,2] Although the spectrum of acuity for hypertension-related ED visits ranges widely, true hypertensive emergencies, such as acute heart failure in which acute BP reduction (<24 hours) is warranted, are rare.[3,4] For the much more common ED visits with asymptomatic elevated BP, rapid BP reduction can cause significant harm by impairing cerebral blood flow and has not been shown to improve clinical outcomes.[5–9] The American College of Emergency Physicians' policy recommendation on asymptomatic elevated BP in the ED reflects current lack of evidence to guide evaluation and treatment; based on expert opinion or panel consensus (level C evidence), it states that although all patients with asymptomatic elevated BP should be referred for follow-up, routine ED testing and treatment are not needed but can be considered for those with poor follow-up.[10]

The risk of elevated BP after an ED visit and thresholds for classifying BP in the ED were not addressed by the American College of Emergency Physicians policy recommendation. Recent American College of

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CLINICAL PERSPECTIVE

What Is New?

- Among a sample of emergency department (ED) patients, having ≥2 ED blood pressure (BP) measurements with systolic BP values ≥140 mm Hg was associated with increased risk of elevated mean follow-up BP (≥2 BP measurements with systolic BP values ≥140 mm Hg) in the subsequent year.
- Patients with elevated ED BP who were not diagnosed with hypertension at the time of the ED visit were more likely to have elevated blood pressure in the subsequent year.
- Hospitalization increased the risk of having persistently elevated systolic BP at follow-up, but pain-related ED chief complaint did not modify the risk of elevated post-ED BP.

What Are the Clinical Implications?

- For patients with elevated ED BP, our findings highlight the need to ensure short-term follow-up, improve appropriate diagnosis of hypertension after an ED visit, and consider initiating therapy to improve long-term management given the high likelihood of sustained BP elevation over the subsequent year.

Nonstandard Abbreviations and Acronyms

DBP	diastolic blood pressure
ED	emergency department
SBP	systolic blood pressure

Cardiology/American Heart Association guidelines revising the threshold for hypertension to 130/80 mm Hg among high-risk patients adds urgency to addressing this evidence gap, as many ED patients are likely to meet these new criteria for hypertension and also have insufficient access to other sources of care.[11]

There are several long-standing barriers to using BP measured in the ED as part of diagnosing and treating hypertension. One barrier is uncertainty regarding the validity of BP measured in the ED. Despite some evidence to the contrary, BP measured in the ED is often disregarded because of concerns about measurement accuracy or because BP elevations attributed to pain, anxiety, or illness are presumed to be temporary and clinically unimportant.[12,13] Questions about whether the ED can or should serve as a location of care to manage chronic diseases, such as hypertension, contribute to variation in how elevated BP in the ED is evaluated and treated.[14–16] Such variations in practice patterns due to lack of evidence are likely to result in worse health outcomes overall.[17]

We therefore evaluated the relationship between ED systolic BP (SBP) and the risk of having mean SBP ≥140 mm Hg in the subsequent year after the ED visit, after accounting for multiple patient demographic and clinical conditions, including an existing diagnosis of hypertension, ED disposition, and pain-related ED chief complaint. Diastolic BP (DBP), alternative post-ED BP thresholds, different time intervals of post-ED follow-up (within 6 months and months 4–12 after the ED visit), and stratification by diagnosed hypertension were examined in secondary and sensitivity analyses.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request. We constructed a retrospective cohort study of all patients with a single visit to the adult ED at an academic medical center in the United States (Vanderbilt University Medical Center) from January 1, 2010 to December 31, 2013. Data were extracted from the electronic data warehouse or the synthetic derivative, which is a de-identified shadow of the electronic health record. The study was approved by the institutional review board with a waiver of informed consent.

Patients were included if they were ≥18 years of age, had a single ED visit between January 1, 2010 and December 31, 2013 with at least 2 recorded BPs, had prior encounters in the medical system (defined as at least 1 clinical encounter between January 1, 2003 and the index ED visit), and had at least 2 clinic or hospital BPs recorded within 365 days after the ED visit. Patients were excluded if there were multiple hospitalizations after the ED visit; were pregnant during the study time frame or 9 months before the start of the study; or had end-stage renal disease on hemodialysis, end-stage liver disease, cancer undergoing active therapy, or hospice care at the time of the ED visit.

Exposure and Outcome Measurement

The primary exposure was the lowest of at least 2 recorded ED SBP values, categorized as <140 mm Hg, 140 to 159 mm Hg, and ≥160 mm Hg. Primary analyses used SBP because of its relationships with cardiovascular, stroke, and mortality risk.[18–20] Two recorded ED BPs were required because BP has been shown to decrease after the first measurement, with a more accurate measurement 60 to 80 minutes after ED arrival.[21] Vanderbilt University Medical Center follows national policies regarding ED vital

sign measurement frequency, which recommend that vital signs be reassessed no less frequently than every hour for the first 4 hours for patients of high severity and no less frequently than every 2 to 4 hours for patients of average or low severity, which comprise the majority of ED visits.[22] We excluded the following BP values (<1%) as they are physiologically implausible and likely represent data entry errors: SBP ≥400 mm Hg, difference between SBP and DBP ≤10 mm Hg, and DBP ≥ SBP.

The primary outcome was mean post-ED SBP over the year following the index ED visit, computed using all available BPs extracted from the electronic health record for 365 days after the index ED visit, including clinic and hospital BPs. We categorized mean post-ED SBP as <140 mm Hg or ≥140 mm Hg.[23] In a sensitivity analysis, the SBP threshold of 150 mm Hg was also examined, as routine office BP measurements have been shown to be >10 mm Hg higher than more accurate methods of BP measurement.[24] In another sensitivity analysis, we examined the effect of a shorter follow-up time interval of 6 months within the ED visit, as well as the effect of limiting the follow-up period to 4 to 12 months after the ED visit. In a final sensitivity analysis, we stratified the models by evidence of an existing diagnosis of hypertension. In secondary analyses, we categorized ED BP by DBP (<90 mm Hg, 90–99 mm Hg, and ≥100 mm Hg), and dichotomized mean post-ED DBP as <90 mm Hg or ≥90 mm Hg.

Variable Definitions

Covariates were chosen a priori. Details of variable definitions are found in Table S1. Age, sex, race, and insurance status were extracted from the electronic health record at the time of the ED visit. Disposition from the ED was categorized as discharged or not discharged, and median body mass index was used as a continuous variable. Comorbid conditions were identified by *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) and Current Procedural Terminology codes (Table S2). Prescribed antihypertensive medications were identified by natural language processing of clinical notes and extraction of prescriptions 15 months before the ED visit.[25] Antihypertensive medications were classified into 7 categories: beta blockers, calcium channel blockers, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, loop diuretics, thiazide diuretics, alpha antagonists, and other (ie, clonidine, hydralazine, methyldopa, minoxidil).

Statistical Analysis

Patients were the unit of analysis; demographics and clinical characteristics were examined with summary statistics, frequencies, and proportions as appropriate. Multiple logistic regression models were used to examine the relationship between lowest ED SBP category and mean post-ED SBP ≥140 mm Hg. Models were adjusted for age, sex, race, insurance status, body mass index, comorbid conditions, and number of prescribed antihypertensive classes. Because of the potential to influence the relationship between ED and post-ED SBP, we decided to include interaction terms a priori for hypertension diagnosis, ED discharge status, and pain-related ED chief complaint (defined as any chief complaint related to pain or injury, ie, chest pain, abdominal pain, headache, trauma, laceration). In post hoc analyses, we also examined whether there were interactions with age, sex, and race. Unadjusted and adjusted logistic regression models were constructed, and model fit was evaluated with model diagnostics. Separate models were used for SBP and DBP.

We imputed the missing clinical variables body mass index (33% missing) and white/non-white race (1% missing) (both of which appeared to be missing at random) with multiple imputation using chained equations.[26,27] The variables included in the analysis models were included in the imputation models because including many auxiliary variables has been shown to provide imputations that are more efficient and have less bias.[28] Twelve imputations were performed using logit for the binary variable white/non-white race and using linear regression for the continuous variable body mass index.

We performed 3 sensitivity analyses: (1) we examined the outcome of mean post-ED SBP 150 mm Hg to account for the possibility of white coat hypertension at follow-up measurements after the ED visit; (2) we examined shorter follow-up periods limited to within 6 months and months 4 to 12 after the ED visit in order to investigate the effect of both isolating and separating the period immediately following the ED visit, respectively; and (3) we stratified by evidence of diagnosed hypertension rather than including it as an interaction term. Statistical analyses were performed with Stata, version 15.1 (StataCorp).

RESULTS

Characteristics of Study Subjects

Over the 3-year study period, 26 769 unique ED visits occurred among eligible patients (Figure). Of these, 17 198 (64.2%) had only a triage ED BP and 145 (0.5%) had only a single post-triage ED BP recorded. Of 9426 patients with ≥2 ED BPs recorded, at least 2 post-ED BPs were recorded within 365 days of the index ED visit for 8105 patients, within 6 months (182 days) for 7799 patients, and from months 4 to 12 (85–365 days) for 2487 patients. Mean ED triage SBP was 140.0 mm Hg (SD 23.4 mm Hg), and mean post-triage ED SBP was 128.7 mm Hg (SD 20.1 mm Hg).

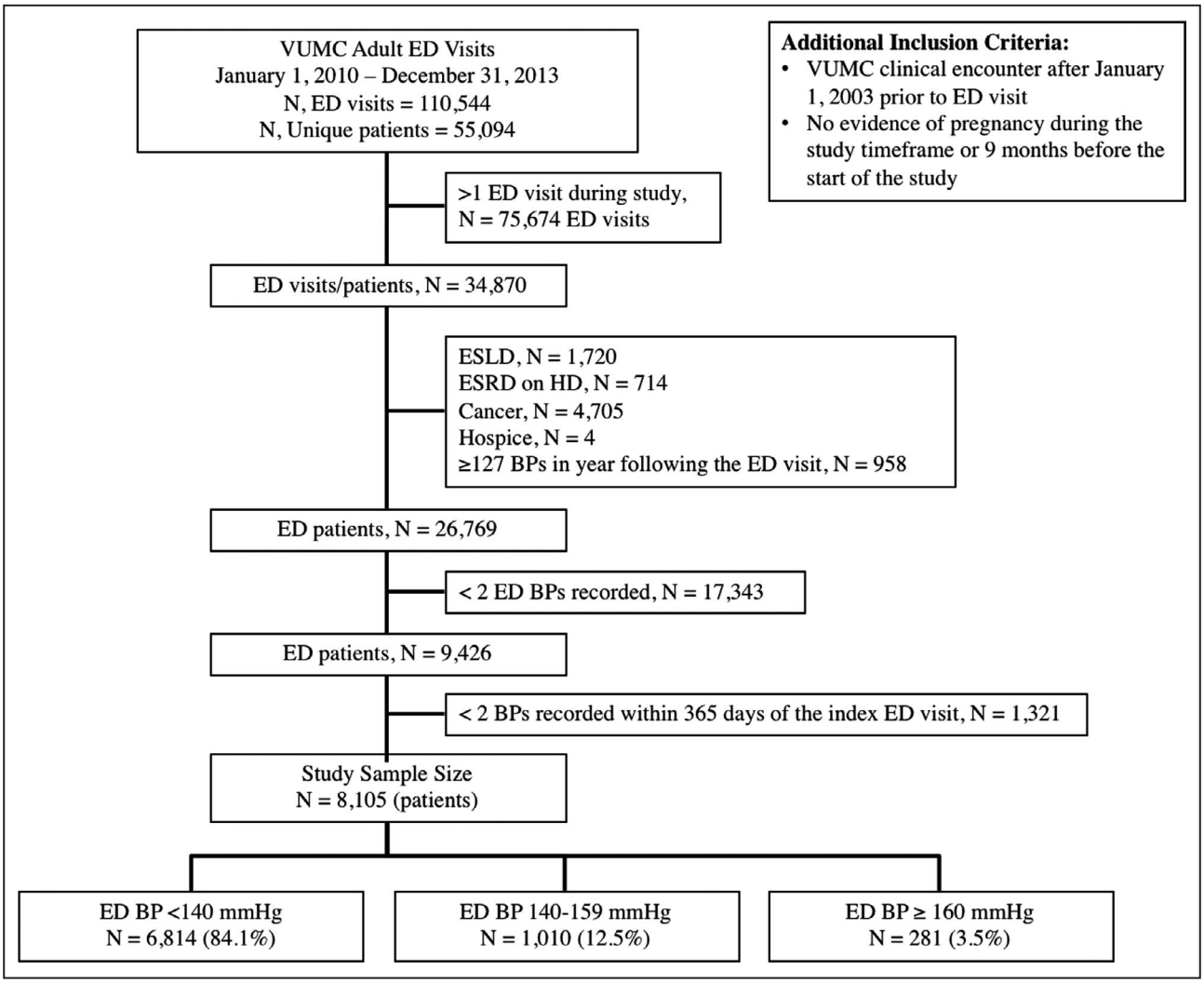

Figure. Cohort construction.
BP indicates blood pressure; ED, emergency department; ESLD, end-stage liver disease; ESRD, end-stage renal disease; HD, hemodialysis; and VUMC, Vanderbilt University Medical Center.

Patient demographics and clinical characteristics by category of lowest ED SBP are shown in Table 1 (and by ED DBP category in Table S3). With increasing categories of ED SBP, patients were older, had more comorbidities, and were more frequently prescribed BP medications. Additionally, as ED SBP increased, a lower proportion of patients were white, privately insured, and discharged from the ED.

Main Results

For patients discharged from the ED, the median time to first post-ED BP measurement was 21 weeks (interquartile range 9–35 weeks), and time to follow-up increased as minimum ED SBP increased: 20 weeks (interquartile range 9–34 weeks) for ED SBP <140 mm Hg, 25 weeks (interquartile range 12–39 weeks) for ED SBP 140 to 159 mm Hg, and 28 weeks (interquartile range 13–41 weeks) for ED SBP ≥160 mm Hg.

Having a minimum ED SBP of 140 to 159 mm Hg was strongly associated with increased risk of a mean SBP ≥140 mm Hg over the following year, with an unadjusted odds ratio (OR) of 6.3 (95% CI, 5.5–7.4) and adjusted OR of 10.9 (95% CI, 7.6–15.6) (Table 2). Having a minimum ED SBP ≥160 mm Hg was also strongly associated with a mean SBP ≥140 mm Hg over the following year (adjusted OR, 20.7; 95% CI, 9.8–43.7). We found evidence for effect modification by hypertension diagnosis, with undiagnosed patients having a higher risk of mean SBP ≥140 mm Hg in the following year compared with patients with diagnosed hypertension (interaction term $P<0.01$ for ED SBP 140–159 mm Hg; $P=0.10$ for ED SBP ≥160 mm Hg). There was also evidence for effect modification by hospitalization, with hospitalization increasing the risk of elevated post-ED SBP (interaction term $P<0.01$ for ED SBP 140–159 mm Hg, $P = 0.01$ for ED SBP

Table 1. Cohort Characteristics, Categorized by Lowest Emergency Department Systolic Blood Pressure

Characteristic	Lowest of ≥2 ED SBPs		
	<140 mm Hg(N=6814)	140–159 mm Hg(N=1010)	≥160 mm Hg(N=281)
Age in y, mean (SD)	48.8 (19.0)	57.5 (18.3)	62.2 (16.8)
Female, no. (%)	3746 (55.0)	496 (49.1)	160 (56.9)
White, no. (%)	5691 (83.5)	799 (79.1)	202 (71.9)
Insurance, no. (%)			
Commercial	1436 (21.1)	164 (16.2)	37 (13.2)
Medicare/Medicaid/Federal	4830 (70.9)	770 (76.2)	224 (79.7)
Self-Pay/unknown	548 (8.0)	76 (7.5)	20 (7.1)
Discharged from the ED, no. (%)	2054 (30.1)	258 (25.5)	67 (23.8)
Admitted to an ICU, no. (%)	206 (3.0)	42 (4.2)	11 (3.9)
Comorbid conditions, no. (%)			
Hypertension	2675 (39.3)	659 (41.6)	234 (83.3)
Diabetes mellitus	1151 (16.9)	243 (24.1)	86 (30.6)
Heart failure	254 (3.7)	52 (5.1)	25 (8.9)
HIV	143 (2.1)	16 (1.6)	3 (1.1)
Organ transplant	75 (1.1)	8 (0.8)	0 (0)
Number of comorbidities, mean (SD)	0.7 (0.8)	1.0 (0.8)	1.3 (0.8)
Body mass index, kg/m^2, mean (SD)	28.1 (7.3)	30.2 (7.6)	30.1 (7.6)
Prescribed BP medications (at the time of ED visit), no. (%)			
Angiotensin converting enzyme inhibitor/angiotensin receptor blocker	1177 (17.3)	274 (27.1)	86 (30.6)
Beta blocker	945 (13.9)	183 (18.1)	68 (24.2)
Calcium channel blocker	457 (6.7)	124 (12.3)	43 (15.3)
Loop diuretic	557 (8.2)	108 (10.7)	38 (13.5)
Thiazide diuretic	762 (11.2)	158 (15.6)	41 (14.6)
Alpha adrenergic blocker	66 (1.0)	12 (1.2)	9 (3.2)
Other	280 (4.1)	77 (7.6)	28 (10.0)
Number of ED BPs measured after triage, mean (SD)	2.7 (3.5)	2.0 (1.6)	2.1 (2.5)
Mean post-ED SBP ≥140 mm Hg within 1 y after the ED visit, no. (%)	673 (9.9)	414 (41.0)	184 (65.5)
Diagnosed hypertension*	436 (16.3)	297 (45.1)	158 (67.5)
No diagnosed hypertension†	237 (5.7)	117 (33.3)	26 (55.3)

BP indicates blood pressure; ED, emergency department; ICU, intensive care unit; and SBP, systolic blood pressure.
*Denominator represents those with evidence of an existing hypertension diagnosis at the time of the ED visit
†Denominator represents those with no evidence of an existing hypertension diagnosis at the time of the ED visit

≥160 mm Hg). There was no evidence for interaction by pain-related ED complaint (P≥0.10 for all). In post hoc analyses, we found no interaction with age or race (P≥0.10 for all). Although there was no evidence for interaction by sex for ED SBP ≥160 mm Hg (interaction term P=0.57), there was interaction by sex for ED SBP 140 to 159 mm Hg (interaction term P=.03), so we included sex as an interaction term in our final model.

Sensitivity analyses for follow-up periods limited to within 6 months and months 4 to 12 after the ED visit are also shown in Table 2. Similar to the 1-year follow-up period, minimum ED SBP 140 to 159 mm Hg or ≥160 mm Hg was also strongly associated with a mean SBP ≥140 mm Hg for the follow-up period limited to the first 6 months after the ED visit (adjusted OR for ED SBP 140–159 9.8; 95% CI, 6.8–14.1; for ED SBP ≥160 mm Hg 15.4; 95% CI, 7.2–32.8). For the follow-up period limited to months 4 to 12 after the ED visit, having a minimum ED SBP of 140 to 159 mm Hg was still associated with increased risk of a mean post-ED SBP ≥140 mm Hg (adjusted OR, 4.1; 95% CI, 2.0–8.4). With the follow-up period limited to months 4 to 12 after the ED visit, having a minimum ED SBP ≥160 mm Hg was associated with increased risk of mean post-ED SBP ≥140 mm Hg although the confidence interval spanned 1.0 (adjusted OR, 2.9; 95% CI, 0.7–12.4). Sensitivity analyses using a higher threshold for mean follow-up SBP of ≥150 mm Hg are shown in Table S4, with comparable associations in the unadjusted and adjusted models.

Table 2. Post-Emergency Department Blood Pressure Time to First Measurement, Count, Mean and Association by Lowest Emergency Department Systolic Blood Pressure Category

	Lowest of ≥2 ED SBPs		
	<140 mm Hg	140–159 mm Hg	≥160 mm Hg
Within 1 y after the ED visit	**N=6814**	**N=1010**	**N=281**
Number of BPs measured, mean (SD)	17.5 (20.3)	19.9 (22.3)	22.6 (22.4)
Discharged	5.4 (8.8)	5.5 (6.0)	8.1 (11.5)
Not discharged	22.7 (21.6)	24.8 (23.6)	27.1 (23.1)
Post-ED SBP, mean (SD), mm Hg	122.8 (13.4)	137.4 (12.7)	146.8 (14.7)
Discharged	122.5 (13.6)	136.3 (13.3)	144.0 (16.8)
Not discharged	122.9 (13.3)	137.7 (12.4)	147.6 (13.8)
Association with mean post-ED SBP ≥140 mm Hg, OR (95% CI)			
Unadjusted	…	6.3 (5.5–7.4)	17.3 (13.4–22.4)
Adjusted*,†	…	10.9 (7.6–15.6)	20.7 (9.8–43.7)
Diagnosed hypertension‡	…	5.8 (4.2–8.0)	9.1 (5.5–14.8)
No diagnosed hypertension‡	…	9.7 (5.8–16.3)	37.5 (10.3–136.3)
Within 6 Months After the ED Visit	**N=6552**	**N=973**	**N=274**
Number of BPs measured, mean (SD)	17.2 (20.0)	19.4 (21.9)	21.8 (22.0)
Discharged, N=2088	4.9 (8.4)	4.6 (5.0)	6.5 (9.0)
Not discharged, N=5711	21.9 (21.0)	23.7 (23.0)	26.1 (22.6)
Post-ED SBP, mean (SD), mm Hg	122.7 (13.5)	137.6 (12.9)	147.3 (14.9)
Discharged	122.4 (13.8)	137.0 (14.1)	145.2 (17.6)
Not discharged	122.8 (13.4)	137.8 (12.6)	147.9 (14.1)
Association with mean post-ED SBP ≥140 mm Hg, OR (95% CI)			
Unadjusted	…	6.6 (5.7–7.7)	17.3 (13.3–22.5)
Adjusted*,†	…	9.8 (6.8–14.1)	15.4 (7.2–32.8)
Diagnosed hypertension‡	…	5.7 (4.1–7.9)	9.1 (5.5–15.0)
No diagnosed hypertension‡	…	9.2 (5.4–15.4)	26.8 (7.6–95.1)
Months 4–12 After the ED Visit	**N=2062**	**N=335**	**N=90**
Number of BPs measured, mean (SD)	6.5 (10.9)	6.7 (9.5)	8.2 (11.6)
Discharged, N=1128	5.0 (7.9)	4.5 (4.2)	8.3 (12.9)
Not discharged, N=1359	7.7 (12.7)	8.2 (11.7)	8.2 (10.5)
Post-ED SBP, mean (SD), mm Hg	123.8 (14.4)	134.2 (14.1)	139.4 (16.9)
Discharged	122.3 (14.0)	136.1 (13.1)	140.4 (16.6)
Not discharged	125.1 (14.6)	132.7 (14.6)	138.5 (17.3)
Association with mean post-ED SBP ≥140 mm Hg, OR (95% CI)			
Unadjusted	…	3.1 (2.4–4.0)	4.3 (2.8–6.6)
Adjusted*,†	…	4.1 (2.0–8.4)	2.9 (0.7–12.4)
Diagnosed hypertension‡	…	1.8 (1.1–3.1)	2.0 (0.9–4.7)
No diagnosed hypertension‡	…	1.7 (0.5–6.2)	3.7 (0.2–54.7)

ED indicates emergency department; OR, odds ratio; and SBP, systolic blood pressure.

*Multiple logistic regression models were adjusted for age, sex, race, insurance status, body mass index, comorbid conditions, and number of prescribed antihypertensive classes; and included interaction terms for evidence of an existing hypertension diagnosis, pain-related chief complaint, discharge status, and sex.

†Multiple imputation was performed for body mass index and white/non-white race to substitute missing data with imputed data.

‡Multiple logistic regression models were adjusted for age, sex, race, insurance status, body mass index, comorbid conditions, and number of prescribed antihypertensive classes; included interaction terms for pain-related chief complaint, discharge status, and sex; and were stratified by evidence of diagnosed hypertension.

Finally, we also stratified by evidence of diagnosed hypertension instead of including it as an interaction term (Table 2). This revealed greater risk of elevated post-ED SBP among patients without diagnosed hypertension who had ED SBP ≥160 mm Hg compared with those who had ED SBP 140 to 159 mm Hg; the

Table 3. Association of Lowest Emergency Department Diastolic Blood Pressure With Mean Post-Emergency Department Diastolic Blood Pressure ≥90 mm Hg

	Lowest of ≥2 ED DBPs	
	90–99 mm Hg	≥100 mm Hg
Within 1 y after the ED visit		
Unadjusted OR (95% CI)	11.0 (8.5–14.3)	20.6 (13.8–30.8)
Adjusted OR*,† (95% CI)	20.0 (11.1–36.2)	23.5 (7.8–71.2)

ED indicates emergency department; OR, odds ratio; and SBP, diastolic blood pressure.

*Multiple logistic regression models were adjusted for age, sex, race, insurance status, body mass index, comorbid conditions, number of prescribed antihypertensive classes, and included interaction terms for evidence of diagnosed hypertension, pain-related chief complaint, discharge status, and sex.

†Multiple imputation was performed for body mass index and white/non-white race to substitute missing data with imputed data.

relationship was consistent across categories of ED SBP for patients with diagnosed hypertension. This finding suggests that there may be a 3-way interaction between ED SBP, hypertension diagnosis, and time after the ED visit, although in light of multiple interaction terms and small number of patients in several strata, confidence intervals were wide.

Results for analyses using DBP are shown in Table 3 and are consistent with patterns for ED SBP, with the exception that hospitalization did not increase the risk of persistently elevated DBP (P≥0.05 for both categories of ED DBP).

DISCUSSION

Among 8105 adults with a single ED visit during the study who had ≥2 BP measurements and ≥2 follow up BP measurements in the subsequent year, elevated ED BP was associated with increased risk of elevated mean follow-up BP, after adjusting for multiple patient demographic and clinical factors. Importantly, patients whose lowest ED SBP was ≥140 mm Hg who were not diagnosed with hypertension at the time of the ED visit were more likely to have elevated blood pressure in the subsequent year. Hospitalization increased the risk of having persistently elevated SBP but not DBP at follow-up, but pain-related ED chief complaint did not modify the risk of elevated post-ED BP for all levels of SBP and DBP. These findings highlight the need to ensure short-term follow-up, improve appropriate diagnosis of hypertension after an ED visit, and consider initiating therapy to improve long-term management of elevated ED BP given the high likelihood of sustained BP elevation over the subsequent year.

Previous smaller studies also found that elevated BP in the ED predicts chronically elevated BP. In a study by Chernow et al of discharged patients with 2 ED BPs ≥160/95 mm Hg, 68% of 107 patients self-reported having a BP ≥140/90 mm Hg after discharge.[29] Backer et al obtained follow-up data in 266 ED patients with triage BP ≥140/90 mm Hg, and 70% had at least 1 post-ED follow-up BP ≥140/90 mm Hg.[30] Dieterle et al enrolled 41 patients in the ED and found that BP ≥165/105 mm Hg measured 60 to 80 minutes after ED arrival was >90% specific for hypertension at follow-up, whereas BP <130/85 mm Hg was 90% sensitive for excluding hypertension.[21] Finally, Goldberg et al enrolled 91 patients and compared BP in the ED measured by multiple automated measurements, with chronic BP assessed by home BP monitoring devices.[24,31] Of 38 patients with ED BP 140/90 to 159/99 mm Hg, 50% had home BP monitoring BP ≥135/85 mm Hg; of 16 patients with ED BP ≥160/100 mm Hg, 75% had hypertension. All but 1 of these prior studies excluded patients with a known diagnosis of hypertension, and all of the studies excluded patients who were hospitalized from the ED.

This is the first study to use a large sample size (8105 total and 1291 with elevated ED BP), to follow patients for 1 year, and to include hospitalized patients. In addition, included patients were required to have at least 2 BP measures during and after the ED visit. We used the lowest ED SBPs because it can be easily translated into clinical practice without additional equipment or calculations.

Our finding that patients with elevated BP who do not already carry a diagnosis of hypertension at the time of their ED visit are even more likely to have persistently uncontrolled BP suggests that ED visits may present opportunities to fill a crucial public health role in hypertension diagnosis, especially among patients without reliable access to primary care, many of whom are underinsured or racial minorities.[11] This is especially important given that delays in hypertension treatment of as little as >1.5 months increase the risk of a major adverse cardiovascular event including death.[32] Prescribing antihypertensive medications in the ED setting is effective and can be done safely.[33] Although it is critical to continue management of elevated ED BP beyond the ED, the first step is recognizing the patient may have uncontrolled hypertension and determining how the ED can contribute to improving diagnosis and treatment. Several innovative approaches to managing elevated ED BP have been explored, including the use of a mobile health intervention, home BP monitoring, and community health workers.[31,34,35]

As outpatient visits for primary care continue to decline and hypertension-related ED visits continue to rise, EDs will be increasingly called upon to manage hypertension and other chronic conditions[2,36–38]; this may require actions beyond those recommended in the most recent American College of Emergency

Physicians guidelines.[10] Like single measures of BP in the clinic setting, a single measure of BP in the ED may be inaccurate[39–42]; unlike outpatient clinic settings, however, ED visits provide the opportunity and time to perform repeated BP measures over minutes to hours. Patients with multiple elevated ED BP readings that are taken while the patient is calm and not talking are more likely to have chronically elevated BP, even more so if the patient has a recent record of elevated BP from prior ED or outpatient visits.

Finally, our result that elevated ED BP is associated with elevated follow-up BP even for admitted patients underscores the need to address elevated ED BP regardless of disposition in order to combat clinical inertia or the "bystander effect" from care fragmentation.[43–45] Although elevated BP is often attributed to pain, we found no evidence to support the hypothesis that high BP in the ED setting should be attributed to pain. Furthermore, in patients with pain-related chief complaints, elevated ED BP was just as likely to be associated with elevated BP after an ED visit. This is supported by prior work. In the Chernow et al study of 239 patients, the proportion of patients with elevated BP and pain-related complaints in the ED were similar among those with and without elevated follow-up BPs.[29] In the Backer et al study of 407 patients, patients who did not have pain-related complaints in the ED were as likely as patients with a pain-related complaint to have elevated follow-up blood pressures.[30]

This study has several limitations. First, we used clinically measured BP values rather than BP assessed by research staff, so BP may have more measurement error as has often been noted with clinically obtained BP.[24] Our methods attempt to reduce the influence of measurement error by requiring at least 2 measures of BP both during and after the ED visit. Although this approach makes the findings more generalizable, it is still possible that persistent measurement error (ie, patients with white coat effect would have it both in the ED and during subsequent visits) may bias our estimates away from the null. To mitigate this bias, we conducted stratified analysis by diagnosed hypertension, which revealed stronger associations between ED and follow-up BPs in patients without diagnosed hypertension; however, the associations persisted for those with diagnosed hypertension, so it is unlikely that measurement error would account for all our findings. In addition, we do not have the exact time of ED BP measurements, so it is possible that a small number of repeat BP measurements may have been taken soon after ED arrival and initial BP was measured in triage, potentially leading to falsely high BP readings as ED BP has been shown to take around an hour after ED arrival to stabilize. However, very few patients at our institution have an ED length of stay under an hour, so we believe the vast majority of repeat BP measurements occurred at least 1 hour after the initial measurement. Second, although it is possible that medications were changed at the time of an ED visit and could have influenced post-ED BP, ED physicians rarely address asymptomatic elevated BP, so this was not included as a covariate.[46] Third, our results may be subject to selection bias, as patients in our cohort had to have at least 2 post-ED BPs recorded in our medical system. To mitigate this bias, we required patients in our cohort to have at least 1 clinical encounter between January 1, 2003 and the index ED visit as a marker of using the system as a source of care. We are not able to determine whether our findings are broadly applicable to those patients who may be less sick and did not return to the medical center. Fourth, given the parameters of our cohort and our study at a single academic medical center, our findings may not be generalizable to other ED populations. Fifth, patients with resistant hypertension represent a unique subgroup within this cohort and are not specifically studied as such here. Finally, in our sensitivity analysis that limited the follow-up period to months 4 to 12 after the ED visit, the magnitude of the association with mean post-ED SBP ≥140 mm Hg was attenuated for minimum ED SBP of 140 to 159 mm Hg, and the association did not reach statistical significance for minimum ED SBP ≥160 mm Hg. Possible explanations for these findings for the follow-up period limited to months 4 to 12 after the ED visit include (1) appropriate follow-up and treatment for those with ED SBP ≥160 mm Hg, given that our population includes only those with ≥2 post-ED BP measurements and does not differentiate between those who were treated vs. not treated for elevated ED BP; (2) ED SBP ≥160 mm Hg more frequently represents falsely elevated BP than when ED SBP is 140 to 159 mm Hg; (3) undertreatment for those with ED SBP 140 to 159 mm Hg; and/or (4) the substantial reduction in sample size for those with ED SBP ≥160 mm Hg overall (N=281), when further reduced by stratification by evidence of diagnosed hypertension (N=47 for those without diagnosed hypertension) and even more so when the follow-up time period was limited (N=21 for the follow-up period limited to months 4 to 12 after the ED visit and without diagnosed hypertension), resulting in wide CIs and calling for further investigation in a larger population.

In summary, when BP is elevated in the ED, there is a high likelihood that BP will remain elevated in the subsequent year, particularly among patients without diagnosed hypertension. Although hospitalization modified the relationship between ED and post-ED BP, there was no evidence of effect modification by pain-related ED chief complaint. Improving identification, follow-up, and optimal ED management of elevated BP measured in the ED is needed.

ARTICLE INFORMATION

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Supplementary Materials

Tables S1–S4

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SUPPLEMENTAL MATERIAL

Table S1. Variable Definitions.

Variable*	Definition
Age	Years, at the time of ED visit
Sex	Female, male
Race	White, non-white
Insurance status	Commercial, Medicare/Medicaid/federal/worker's comp, uninsured/self-pay; at the time of ED visit.
ED disposition	Discharged, admitted, other. Patients discharged from the ED were identified by both their location of discharge ("ED") and by <3 BPs recorded in Week 1 after the index ED visit. Number of post-ED BPs was used as additional criteria to identify ED discharge status because hospitalized patients who boarded in the ED through their entire hospitalization were coded in the electronic health record as having been discharged from the ED.
Comorbid conditions	Number of comorbid conditions by ICD-9 CM and CPT codes extracted from billing and procedure codes after January 1, 2007.
BMI	Median BMI from all BMIs prior to the ED visit; where 5-year median BMI was lower than overall median BMI, this was used.
BP medications	Number of BP medication classes prescribed as of 3 months before the ED visit. To identify medications 3 months prior to the ED visit, data was abstracted for the year prior to the 3 months before the ED visit.
ED chief complaint	Text describing the patient's reported reason for seeking ED care

ED, emergency department; BP, blood pressure; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; CPT, Current Procedural Terminology; BMI, body mass index.

*The earliest date for data extraction for covariates was January 1, 2007.

Table S2. Comorbid Condition Identification by ICD-9 and CPT Codes.

Comorbid Condition	Definition	ICD-9 or CPT codes
Diabetes		ICD-9 CM diagnosis code: 250
Cerebrovascular disease	Carotid revascularization	ICD-9 CM procedure codes: 38.12, 38.11, 00.61, 00.63, 39.28 CPT procedure code: 35301
	TIA	ICD-9 CM diagnosis codes: 435.X
	Stroke	ICD-9 CM diagnosis codes: 430.X, 431.X, 434.X, 436.X, 433.1
Cardiovascular disease	MI	ICD-9 CM diagnosis codes: 410, 412, 429.7
	Obstructive coronary disease	ICD-9 CM diagnosis codes: 411, 413, 414.X ICD-9 CM procedure codes: 36.01, 36.02, 36.03, 36.05, 36.09, 36.10-36.19 CPT codes: 33533-36, 33510-23, 30, 92980-82, 84, 92995-6
Congestive heart failure		ICD-9 CM diagnosis codes: 428, 402.02, 402.11, 402.91, 425.xx DRG: 127
Cancer		ICD-9 CM diagnosis codes: 140-208, except 173
Organ transplant	Kidney, heart, lung, liver, bone marrow, pancreas	ICD-9 CM diagnosis codes: V42.0, V42.1, V42.6, V42.7, V42.81, V42.83 ICD-9 CM procedure codes: 33.5, 33.6, 37.5, 41.0, 50.5, 52.8, 55.6 CPT procedure codes: 50320, 50360, 50365, 50370, 50380, 33935, 33940, 33945, 32851, 32852, 32853, 32854, 47135, 47136, 38240, 38241, 48554, 48556
Renal disease	ESRD on dialysis	ICD-9 CM diagnosis code: 585.6
	Dialysis treatment	CPT procedure codes: 3993, 5498, 90935, 90937, 90945, 90947, 90989, 90993, 90921, 90925
	Encounter for dialysis & dialysis catheter care	ICD-9 CM diagnosis code: V56.X, V45.1
HIV		ICD-9 CM diagnosis codes: 042, 079.53
Hypertension		ICD-9 CM diagnosis codes: 401.X-405.X

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; CPT, Current Procedural Terminology; DRG, diagnosis related group.

Table S3. Cohort Characteristics, Categorized by Lowest Emergency Department Diastolic Blood Pressure.

	Lowest of ≥2 ED DBPs		
Characteristic	**<90 mmHg (N = 7,640)**	**90-99 mmHg (N = 358)**	**≥100 mmHg (N = 107)**
Age in years, mean (SD)	50.5 (19.5)	48.1 (15.0)	48.4 (13.1)
Female, no. (%)	4,219 (55.2)	135 (37.7)	48 (44.9)
White, no. (%)	6,356 (83.2)	269 (75.1)	67 (62.6)
Insurance, no. (%)			
Private	1,531 (20.0)	90 (25.1)	16 (15.0)
Medicare/Medicaid/Federal	5,505 (72.1)	237 (66.2)	82 (76.6)
Self-Pay/unknown	604 (7.9)	82 (22.9)	9 (8.4)
Discharged from the ED, no. (%)	5,378 (70.4)	277 (77.4)	71 (66.4)
Admitted to an ICU, no. (%)	246 (3.2)	12 (3.4)	1 (0.9)
Comorbid Conditions, no. (%)			
Hypertension	3,281 (42.9)	209 (58.4)	78 (72.9)
Diabetes	1,397 (18.3)	63 (17.6)	20 (18.7)
Heart Failure	317 (4.1)	11 (3.1)	3 (2.8)
HIV	148 (1.9)	8 (2.2)	6 (5.6)
Organ Transplant	80 (1.0)	1 (0.3)	2 (1.9)
Number of Comorbidities, mean (SD)	0.7 (0.8)	0.8 (0.8)	1.0 (0.8)
BMI, kg/m^2, mean (SD)	28.4 (7.3)	29.9 (7.8)	30.8 (8.0)
Prescribed BP medications (at the time of ED visit), no. (%)			
ACE/ARB	1,438 (18.8)	83 (23.2)	16 (15.0)
Beta blocker	1,130 (14.8)	56 (15.6)	10 (9.3)
Calcium channel blocker	589 (7.7)	28 (7.8)	7 (6.5)
Loop diuretic	666 (8.7)	30 (8.4)	7 (6.5)
Thiazide diuretic	900 (11.8)	48 (13.4)	13 (12.1)
Alpha adrenergic blocker	81 (1.1)	4 (1.1)	2 (1.9)
Other	354 (4.6)	24 (6.7)	7 (6.5)
Number of ED BPs measured after triage, mean (SD)	2.7 (3.3)	1.9 (1.6)	2.1 (1.8)
Mean post-ED DBP ≥90mmHg within 1 year after the ED visit, no. (%)	270 (3.5)	103 (28.8)	46 (43.0)
Diagnosed hypertension*	147 (4.5)	53 (25.4)	36 (46.2)
No diagnosed hypertension†	123 (2.8)	50 (33.6)	10 (34.5)

ED, emergency department; DBP, diastolic blood pressure; ICU, intensive care unit; BMI, body mass index; BP, blood pressure.

*Denominator represents those with evidence of an existing hypertension diagnosis at the time of the ED visit

†Denominator represents those with no evidence of an existing hypertension diagnosis at the time of the ED visit

Table S4. Association of Lowest Emergency Department Systolic Blood Pressure With Mean Post-Emergency Department Systolic Blood Pressure ≥150 mmHg.

	Lowest of ≥2 ED SBPs	
	140-159 mmHg	≥160 mmHg
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Within 1 year after the ED visit		
Unadjusted	6.7 (5.3 - 8.4)	23.2 (17.5–30.7)
Adjusted*,†	8.9 (5.0–15.7)	16.8 (7.1–39.7)
Within 6 months after the ED visit		
Unadjusted	7.3 (5.8–9.1)	24.5 (18.4–32.5)
Adjusted*,†	9.9 (5.6–17.5)	21.6 (9.1–51.3)
Months 4 to 12 after the ED visit		
Unadjusted	4.6 (3.2–6.7)	7.2 (4.2–12.4)
Adjusted*,†	8.6 (3.1–23.8)	4.1 (0.6–28.9)

ED, emergency department; SBP, systolic blood pressure; OR, odds ratio.

*Multiple logistic regression models were adjusted for age, sex, race, insurance status, body mass index (BMI), comorbid conditions, and number of prescribed antihypertensive classes, and included interaction terms for evidence of diagnosed hypertension, pain-related chief complaint, discharge status, and sex.

†Multiple imputation was performed for BMI and white/non-white race to substitute missing data with imputed data.