JAMA Internal Medicine | Original Investigation | LESS IS MORE

Treatment and Outcomes of Inpatient Hypertension Among Adults With Noncardiac Admissions

Radhika Rastogi, MD, MPH; Megan M. Sheehan, BS; Bo Hu, PhD; Victoria Shaker, BA; Lisa Kojima, BSE; Michael B. Rothberg, MD, MPH

IMPORTANCE Despite high prevalence of elevated blood pressure (BP) among medical inpatients, BP management guidelines are lacking for this population. The outcomes associated with intensifying BP treatment in the hospital are poorly studied.

OBJECTIVES To characterize clinician response to BP in the hospital and at discharge and to compare short- and long-term outcomes associated with antihypertensive treatment intensification.

DESIGN, SETTING, AND PARTICIPANTS This cohort study took place from January 1 to December 31, 2017, with 1 year of follow-up at 10 hospitals within the Cleveland Clinic Hospitals health care system. All adults admitted to a medicine service in 2017 were evaluated for inclusion. Patients with cardiovascular diagnoses were excluded. Demographic and BP characteristics were used for propensity matching.

EXPOSURES Acute hypertension treatment, defined as administration of an intravenous antihypertensive medication or a new class of an oral antihypertensive treatment.

MAIN OUTCOMES AND MEASURES The association between acute hypertension treatment and subsequent inpatient acute kidney injury, myocardial injury, and stroke was measured. Postdischarge outcomes included stroke and myocardial infarction within 30 days and BP control up to 1 year.

RESULTS Among 22 834 adults hospitalized for noncardiovascular diagnoses (mean [SD] age, 65.6 [17.9] years; 12 993 women [56.9%]; 15 963 White patients [69.9%]), 17 821 (78%) had at least 1 hypertensive BP recorded during their admission. Of these patients, 5904 (33.1%) were treated. A total of 8692 of 106 097 cases (8.2%) of hypertensive systolic BPs were treated; of these, 5747 (66%) were treated with oral medications. In a propensity-matched sample controlling for patient and BP characteristics, treated patients had higher rates of subsequent acute kidney injury (466 of 4520 [10.3%] vs 357 of 4520 [7.9%]; $P < .001$) and myocardial injury (53 of 4520 [1.2%] vs 26 of 4520 [0.6%]; $P = .003$). There was no BP interval in which treated patients had better outcomes than untreated patients. A total of 1645 of 17 821 patients (9%) with hypertension were discharged with an intensified antihypertensive regimen. Medication intensification at discharge was not associated with better BP control in the following year.

CONCLUSIONS AND RELEVANCE In this cohort study, hypertension was common among medical inpatients, but antihypertensive treatment intensification was not. Intensification of therapy without signs of end-organ damage was associated with worse outcomes.

JAMA Intern Med. doi:10.1001/jamainternmed.2020.7501
Published online December 28, 2020.

Supplemental content

Author Affiliations: Children's Hospital of Philadelphia, Philadelphia, Pennsylvania (Rastogi); Cleveland Clinic Lerner College of Medicine of Case Western Reserve University, Cleveland, Ohio (Sheehan, Kojima); Lerner Research Institute, Cleveland Clinic, Cleveland, Ohio (Hu); Center for Value-Based Care Research, Cleveland Clinic, Cleveland, Ohio (Shaker, Rothberg).

Corresponding Author: Michael B. Rothberg MD, MPH, Cleveland Clinic, 9500 Euclid Ave, Mail Code G10, Cleveland, OH 44195 (rothbem@ccf.org).

In 2018, there were 36.4 million hospitalizations in the United States.[1] In this setting, the prevalence of hypertension is estimated to be 50% to 72%.[2] Despite strong evidence for blood pressure (BP) management in primary care, analogous evidence to support treatment in the hospital, to our knowledge, is lacking.[3,4] The harms of hypertension, including heart attacks, strokes, and kidney disease, typically occur after decades of exposure to moderately elevated BP.[5] Extremely high symptomatic BP can be associated with acute organ damage,[6] and treating hypertensive emergency is standard practice. However, treatment varies by physician, and the effect of treatment is unknown.[7,8] Among asymptomatic outpatients, emergency treatment of even very high BP is not associated with better outcomes.[9] Additionally, factors related to hospitalization, such as pain, nausea, fever, and stress, can elevate BP independent of underlying hypertension.[10] It is unknown whether such elevations are adaptive or harmful.

Surveys indicate that physicians often treat moderately increased BP with medication, even in the absence of symptoms.[11] Treatment often involves intravenous medications that are associated with hypotension and prolonged hospital stays,[12-14] but it remains unknown whether treatment has benefits, such as reducing the risk of myocardial injury or stroke. Intensification of therapy, if continued after discharge, might also promote better long-term control. Although antihypertensive intensification after discharge has been linked to short-term harms,[15-18] studies to date have not considered the inpatient BP that may have prompted treatment and confounded outcomes. We aimed to quantify the prevalence of inpatient hypertension, to characterize hospitalists' response to elevated BPs, and to compare short- and long-term outcomes between patients who were and were not treated at comparable hypertensive severities.

Key Points

Question Among adults with noncardiac admissions, is treatment of hypertension during the admission or antihypertensive treatment intensification at discharge associated with better outcomes?

Findings In this cohort study of 22 834 adults, inpatient hypertension treatment, both oral and intravenous, was associated with higher rates of subsequent acute kidney and myocardial injury. There was no blood pressure interval in which treatment was associated with better outcomes, and medication intensification at discharge was not associated with improved blood pressure control.

Meaning In this study, in the absence of evidence of end-organ damage, conservative management of inpatient hypertension was associated with improved outcomes compared with more intensive management.

Methods

We performed a retrospective cohort study using electronic health record data from patients at 10 Cleveland Clinic Hospitals between January 1 and December 31, 2017. The Cleveland Clinic's institutional review board approved study activities. A consent waiver was granted because the research involved no more than minimal risk to the study participants. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Cohort

We included patients older than 18 years admitted to a medicine service. Exclusion criteria included (1) admission for a cardiovascular diagnosis or admission within the past 30 days for a cerebrovascular event or acute coronary syndrome, as these have well-defined BP guidelines; (2) pregnancy; and (3) length of stay less than 2 or greater than 14 days. For patients with multiple admissions, a single admission was chosen at random. Patients without outpatient medication data were also excluded.

Measures

We collected all systolic BPs (SBPs), diastolic BPs (DBPs), and heart rates. Measurements from the intensive care unit were excluded. An SBP measurement of at least 140 mm Hg[3,5] was used to define hypertension.

Adjusters

We collected patient characteristics that might be associated with treatment, including demographic details (age, sex, and race/ethnicity) obtained from medical records, comorbidities (cardiovascular disease, diabetes, and chronic kidney disease), and BP characteristics, including the maximal SBP and DBP, time from admission in hours, hospital shift during which the BP was measured, change from prior SBP, and proportion of the previous 2 measures that were elevated. Race/ethnicity was included for analysis, because disparities in rates and control of hypertension as well as antihypertensive intensification are well established.[18-20] Options for race/ethnicity were defined by the health system.

Medications

We collected all medications administered before, during, and after admission. We classified medications based on the 2017 Guideline for High Blood Pressure in Adults.[5] We excluded spironolactone and loop diuretics. Antihypertensive drug classes included angiotensin-converting enzyme inhibitors, calcium channel blockers, angiotensin receptor blockers (subtype 2), β-blockers, direct-acting vasodilators, central α2-receptor agonists, potassium-sparing diuretics, thiazide diuretics, and peripheral α1-receptor blockers. Route was categorized as intravenous (IV), oral, or other (eg, transdermal or intramuscular).

Outcomes

In our first analysis, the outcome was acute treatment of an elevated BP, defined as administration of an IV antihypertensive or a new pharmacologic class of oral antihypertensive. Medication that was initially prescribed before admission was considered a continuation of outpatient therapy rather than

treatment of a specific BP. The BP reading immediately before treatment was considered the treated measure. At the patient level, we identified a single measurement as the index BP for purposes of determining subsequent outcomes: for treated patients, it was the highest treated BP; for untreated patients, it was the highest BP during admission. Index BPs were then matched using both patient and blood pressure characteristics, as described below.

For our second analysis, outcomes were inpatient events evidencing end-organ damage, including acute kidney injury (AKI), myocardial injury, stroke, and a composite of all 3. These outcomes were considered only if they occurred after the index BP. Strokes were identified by discharge diagnosis and confirmed by chart review. Acute kidney injury was defined using the AKI Network definition (serum creatinine increase by ≥0.3 mg/dL or 1.5 × the initial value).[21] Myocardial injury was based on elevated troponin (>0.029 ng/mL for troponin T and >0.045 ng/mL for troponin I).

Last, we investigated medication intensification at discharge. We defined intensification as the prescription of an antihypertensive class at discharge that was not present preadmission. Because another study found that intensification at discharge was associated with short-term adverse events,[18] we examined myocardial infarction and stroke within 30 days. We also assessed BP control in the year after discharge.

Statistical Analysis

At the patient level, we provide descriptive statistics for demographic variables and comorbidities by treatment status, as well as BP characteristics. Separately, we compared characteristics of treated and untreated BPs, including the measured SBP, previous SBP, and change from previous systolic measure. Blood pressure measurements taken after treatment were excluded from this analysis.

To assess the association between treatment and outcomes, we built a propensity model to predict treatment of an index measurement (either a patient's highest BP or highest treated BP). Covariates in the model included demographics, individual comorbidities, and index BP characteristics, including interval of measurement, hospitalist shift, time since admission, and change from prior SBP. A generalized linear model was created, and propensity score matching was performed 1:1 using the nearest neighbor method without replacement with a caliper width of 0.1. Covariates and postmatch comparisons are presented in **Table 1**. Patients were rematched for analyses of treatment route and treatment interval. The propensity model for intensification at discharge also included discharge BP, proportion of hypertensive SBP during admission, and maximum SBP. Distribution of propensity scores and calculation of standardized mean differences were used to assess strength of matching. Analyses used *t* tests and χ^2 tests as appropriate. In a sensitivity analysis, we also performed an inverse probability of treatment weighted analysis to determine the average treatment effect in the entire population. Statistical significance was defined by a 2-sided $P < .05$.

As a falsification test, we examined rates of AKI and myocardial injury before index BP among matched patients, because such a relationship could not be causal. All analyses were conducted from February 1, 2019, to September 15, 2020, using R Studio (R Foundation).

Results

Patient-Level Analysis

Of 35 618 patients admitted to a medicine service, 12 784 (35.9%) were excluded based on length of stay or diagnosis. The final cohort included 22 834 patients (mean [SD] age, 65.6 [17.9] years; 12 993 women [56.9%]; 15 963 White patients [69.9%]) who were hospitalized for noncardiac diagnoses; 17 821 (78%) had at least 1 elevated SBP. Subsequent analyses were limited to patients with an elevated SBP. Table 1 shows patient characteristics by treatment status; 5904 of 17 821 patients (33.1%) received a new treatment: 4378 of 5904 (74.2%) received only oral treatment, 1516 of 5904 (25.7%) received at least 1 dose of IV medication with or without oral medication, and the remaining 10 (0.17%) were treated by an alternative route, eg, patch. Treated patients had longer lengths of stay than nontreated patients (mean [SD], 5.2 [2.7] days vs 5.0 [2.6] days; $P < .001$), as well as higher rates of chronic kidney disease (854 of 5904 [14.5%] vs 1604 of 11 917 [13.5%]; $P < .001$) and hypertension (3100 of 5904 [52.5%] vs 5749 of 11 917 [48.2%]; $P < .001$), but they were less likely to have asthma (412 of 5904 [7%] vs 1191 of 11 917 [10%]; $P < .001$) or chronic obstructive pulmonary disease (899 of 5904 [15.2%] vs 2334 of 11 917 [19.6%]; $P < .001$).

Treated patients had more hypertensive SBP measurements (mean [SD], 13.0 [10.3] mm Hg vs 6.8 [6.6] mm Hg; $P < .001$), more measurements per day (mean [SD], 5.3 [1.9] vs 5.0 [1.9]; $P < .001$), and a higher proportion of hypertensive SBPs (mean [SD], 0.5 [0.3] vs 0.3 [0.3]; $P < .001$) (eTable 1 in the Supplement). Patients with higher maximum BP were more likely to be treated; 128 of 152 (84.2%) patients in the 210 to 219 mm Hg range were treated, whereas only 578 of 4176 (13.8%) patients in the 140 to 149 mm Hg range were treated. A similar pattern was observed among DBP intervals.

Blood Pressure–Level Analysis

At the BP level, 157 273 of 531 933 (29.6%) SBP readings were 140 mm Hg or higher, and 23 398 of 531 933 (4.4%) DBP readings were 90 mm Hg or higher. **Table 2** compares treated and untreated BP measurements, including only BP measurements from untreated patients or those taken before treatment. Of 106 097 hypertensive readings, 8692 (8.2%) elicited treatment: 5747 (66.1%) with oral antihypertensives and 2928 (33.7%) with IV medication. Higher BPs were more likely to be treated; among SBPs greater than 220 mm Hg, 54 of 114 (47.4%) received treatment, whereas 78 of 275 (28.4%) DBPs greater than 120 mm Hg were treated. Among patients receiving BP treatment, the previous 2 SBP readings were more often elevated (44.4% vs 35.4%, $P < .001$). Oral treatment included calcium channel blockers (1488 of 5747 [25.9%]), β-blockers (1414 of 5747 [24.6%]), and angiotensin-converting enzyme inhibitors (925 of 5747 [16.1%]). Intravenous treatment included direct-acting vasodilators (1623 of 2928 [55.4%]), β-blockers (945 of 2928 [32.3%]), and α-β blockers (322 of 2928 [11.0%]).

Table 1. Patient-Level Characteristics by Treatment Status[a]

Characteristic	Full cohort No. (%) No treatment (n = 11 917)	Full cohort No. (%) Treatment (n = 5904)	*P* value	Propensity-matched cohort No. (%) No treatment (n = 4520)	Propensity-matched cohort No. (%) Treatment (n = 4520)	Standardized mean difference
Demographic						
Age, mean (SD), y	66.5 (17.2)	70.8 (15.4)	<.001	69.8 (16.0)	69.7 (15.7)	0.01
Male	5137 (43.1)	2558 (43.3)	.79	1988 (44)	1955 (43.3)	0.02
Race/ethnicity						
White	8301 (69.7)	3972 (67.3)	<.001	3109 (68.8)	3052 (67.5)	0.03
Black	2927 (24.6)	1634 (27.7)		1174 (26)	1215 (26.9)	
Other	279 (2.3)	109 (1.8)		82 (1.8)	90 (2)	
Unknown	410 (3.4)	189 (3.2)		155 (3.4)	163 (3.6)	
BMI, mean (SD)	29.8 (8.7)	29.9 (8.6)	.16	29.8 (8.8)	29.9 (8.4)	0.01
Smoking status						
Current smoker	2306 (19.4)	1018 (17.2)	<.001	836 (18.5)	802 (17.7)	0.02
Nonsmoker	9278 (77.9)	4685 (79.4)		3538 (78.3)	3571 (79)	
Unknown	333 (2.8)	201 (3.4)		146 (3.2)	147 (3.3)	
Length of stay, mean (SD), d	5.0 (2.6)	5.2 (2.7)	<.001	5.01 (2.6)	4.98 (2.6)	0.06
Length of stay after index BP, mean (SD), d	2.7 (2.2)	4.0 (2.5)	<.001	3.56 (2.55)	3.60 (2.27)	0.01
Comorbidities						
Atrial fibrillation	1428 (12)	679 (11.5)	.61	558 (12.3)	533 (11.8)	0.02
Aortic dissection	20 (0.2)	10 (0.2)	>.99	9 (0.2)	8 (0.2)	0.01
Asthma	1191 (10)	412 (7)	<.001	338 (7.5)	347 (7.7)	0.01
Coronary artery disease	1565 (13.1)	823 (13.9)	.05	616 (13.6)	627 (13.9)	0.01
Carotid stenosis	198 (1.7)	97 (1.6)	>.99	72 (1.6)	75 (1.7)	0.01
Chronic kidney disease	1604 (13.5)	854 (14.5)	<.001	666 (14.7)	648 (14.3)	0.01
COPD	2334 (19.6)	899 (15.2)	<.001	722 (16)	747 (16.5)	0.02
Diabetes	2964 (24.9)	1540 (26.1)	.01	1208 (26.7)	1204 (26.6)	0.00
Heart failure	1137 (9.5)	533 (9)	.46	420 (9.3)	436 (9.6)	0.01
Hyperlipidemia	3929 (33)	1822 (30.9)	.02	1455 (32.2)	1443 (31.9)	0.01
Hypertension	5749 (48.2)	3100 (52.5)	<.001	2394 (53)	2369 (52.4)	0.01
Myocardial infarction	203 (1.7)	87 (1.5)	.35	82 (1.8)	75 (1.7)	0.01
Peripheral vascular disease	825 (6.9)	408 (6.9)	.79	312 (6.9)	320 (7.1)	0.01
Cerebrovascular disease	882 (7.4)	402 (6.8)	.27	324 (7.2)	326 (7.2)	0.00
Index BP characteristics						
Change from prior SBP, mean (SD)	20.4 (15.7)	9.1 (17.4)	<.001	12.99 (13.1)	12.08 (17.2)	0.06
Time from admission to index BP, mean (SD), h	20.4 (15.7)	28.8 (41.9)	<.001	34.21 (38.1)	32.83 (45.7)	0.03
Measured shift (% night)	7277 (61.1)	3743 (63.4)	.003	2829 (62.6)	2821 (62.4)	0.00
Index BP interval, mm Hg						
140-149	3598 (30.2)	2083 (35.3)	<.001	1412 (31.2)	1463 (32.4)	0.06
150-159	3576 (30)	1393 (23.6)		1121 (24.8)	1148 (25.4)	
160-169	2194 (18.4)	766 (13)		732 (16.2)	670 (14.8)	
170-179	1421 (11.9)	651 (11)		580 (12.8)	548 (12.1)	
180-189	750 (6.3)	529 (9)		408 (9)	403 (8.9)	
190-199	261 (2.2)	259 (4.4)		171 (3.8)	183 (4)	
200-209	73 (0.6)	118 (2)		61 (1.3)	62 (1.4)	
210-219	24 (0.2)	59 (1)		21 (0.5)	20 (0.4)	
≥220	20 (0.2)	46 (0.8)		14 (0.3)	23 (0.5)	

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure; COPD, chronic obstructive pulmonary disease; SBP, systolic blood pressure.

[a] Values presented as No.(%) unless otherwise specified.

Table 2. Blood Pressure–Level Characteristics by Treatment Status

Characteristic	No. (%)[a]		P value
	No treatment (97 405 measurements)[b]	Treatment (8692)	
BP, mean (SD), mm Hg			
Systolic	152.3 (11.5)	161.3 (16.1)	<.001
Diastolic	75.0 (13.5)	78.7 (16.1)	<.001
HR, mean (SD)	79.6 (15.1)	82.1 (17.5)	<.001
SBP interval (row %), mm Hg			
140-149	48 020 (94.4)	2838 (5.6)	<.001
150-159	28 724 (93.4)	2034 (6.6)	
160-169	11 703 (90.6)	1212 (9.4)	
170-179	5576 (83.2)	1122 (16.8)	
180-189	2275 (42.8)	849 (27.2)	
190-199	752 (68.3)	349 (31.7)	
200-209	215 (57.3)	160 (42.7)	
210-219	80 (51.9)	74 (48.1)	
≥220	60 (52.6)	54 (47.4)	
DBP interval (row %), mm Hg			
<80	61 176 (92.9)	4703 (7.1)	<.001
80-89	22 421 (92.3)	1865 (7.7)	
90-99	11 109 (89.7)	1273 (10.3)	
100-109	1979 (79.4)	515 (20.6)	
110-119	523 (67)	258 (33)	
≥120	197 (71.6)	78 (28.4)	
Change from previous SBP, mean (SD), mm Hg	8.7 (16.8)	8.6 (19.3)	.44
Elevation of previous 2 SBPs			
0	47 724 (49)	4021 (46.3)	<.001
1	15 161 (15.6)	816 (9.4)	
2	34 520 (35.4)	3855 (44.4)	

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

[a] Values presented as No. (%) unless otherwise specified.

[b] Includes all vital sign measurements for untreated patients and vital sign measurements occurring prior to the index BP for treated patients.

Table 3. Inpatient Outcomes by Treatment Status[a]

Characteristic	Unmatched cohort			Matched cohort		
	No treatment (n = 11 917)	Treatment (n = 5904)	P value	No treatment (n = 4520)	Treatment (n = 4520)	P value
Composite outcome	728 (6.1)	738 (12.5)	<.001	371 (8.2)	499 (11)	<.001
Stroke	10 (0.1)	6 (0.1)	.92	4 (0.1)	4 (0.1)	>.99
AKI	690 (5.8)	690 (11.7)	<.001	357 (7.9)	466 (10.3)	<.001
Myocardial injury	51 (0.4)	76 (1.3)	<.001	26 (0.6)	53 (1.2)	.003
Length of stay after index BP, mean (SD), d	2.69 (2.2)	4.00 (2.53)	<.001	3.56 (2.55)	3.60 (2.27)	.36

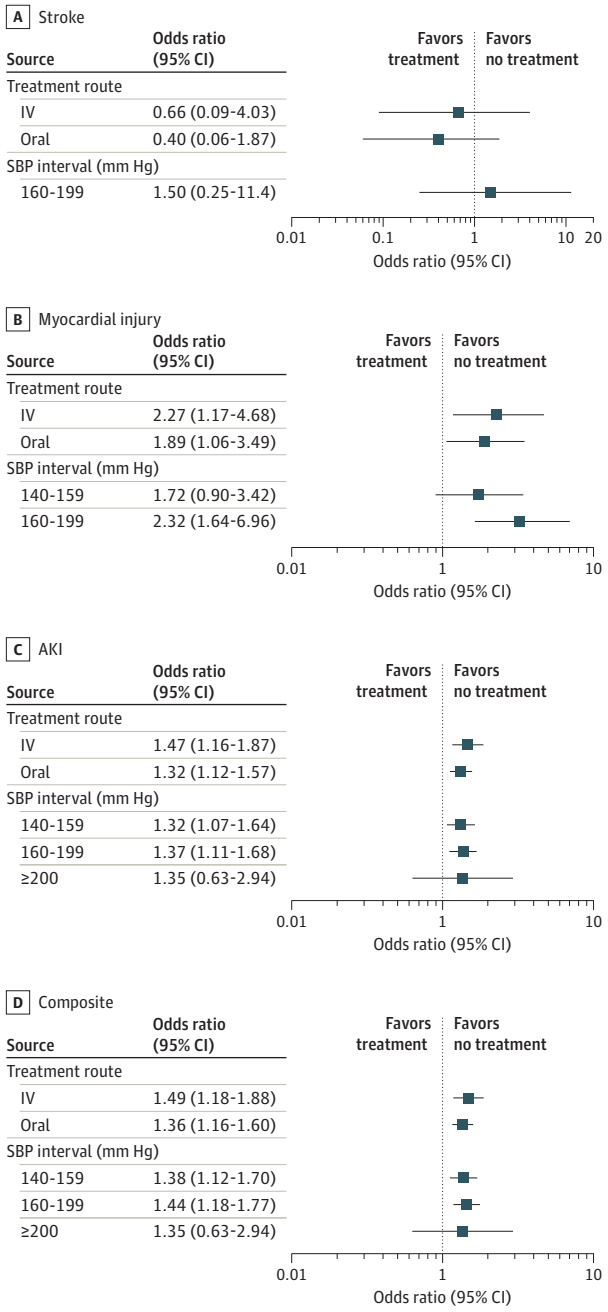
Abbreviations: AKI, acute kidney injury; BP, blood pressure.

[a] Values presented as No. (%) unless otherwise specified.

Inpatient Outcomes

Using propensity scores, we matched 4520 treated patients to untreated ones. In the matched sample, there were no significant differences in any variables. Standardized mean differences appear in Table 1. **Table 3** includes inpatient outcomes by treatment status in matched and unmatched cohorts. Compared with propensity-matched patients who did not receive treatment, those who did were more likely to experience the composite outcome (499 of 4520 [11%] vs 371 of 4520 [8.2%]; $P < .001$), AKI (466 of 4520 [10.3%] vs 357 of 4520 [7.9%]; $P < .001$), and myocardial injury (53 of 4520 [1.2%] vs 26 of 4520 [0.6%]; $P = .003$). Inpatient stroke was extremely rare (4 of 4520 [0.1%] of treated and 4 of 4520 [0.1%] of untreated patients; $P > .99$). Length of stay after the index BP did not differ between treated and untreated patients (mean [SD], 3.60 [2.27] days vs 3.56 [2.55] days; $P = .36$). The inverse probability of treatment weighted analysis produced almost identical results—treatment was

Figure. Inpatient Outcomes for Treated vs Untreated Patients by Treatment Route and SBP Interval



Whiskers indicate 95% CIs; AKI, acute kidney injury; IV, intravenous; and SBP, systolic blood pressure.

associated with increased odds of the composite outcome (odds ratio [OR], 1.42; 95% CI, 1.27-1.59), AKI (OR, 1.36; 95% CI, 1.21-1.52), and myocardial injury (OR, 2.23; 95% CI, 1.56-3.20).

The **Figure** presents outcomes by route of administration and interval of index BP in matched cohorts. Both IV and oral medications were positively associated with the composite outcome, AKI, and myocardial injury. There were no significant differences by route of administration. Increased odds of all 3 outcomes were seen at each BP interval. Stroke did not differ by treatment route or index BP. Among patients with an index SBP greater than 160 mm Hg, treated and untreated patients were similarly likely to see the next SBP decline by 20 mm Hg or more (1152 of 1909 [58%] vs 1214 of 1987 [61%]). Untreated patients had a shorter time to the next SBP measure (4.4 vs 6.2 hours; $P < .001$).

Finally, in our falsification test, rates of AKI before the index BP did not differ between treated and untreated patients (185 of 4520 [4.1%] vs 158 of 4520 [3.5%]; $P = .12$). Myocardial injury prior to index BP was actually slightly higher in untreated patients (7 of 4520 [0.2%] vs 1 of 4520 [0%]; $P = .03$).

Outpatient Outcomes

Among all 17 821 patients with hypertension, 1645 (9.2%) had a new class of oral antihypertensives prescribed at discharge. This number represents 27.9% of those who received additional antihypertensive treatment in the hospital. Compared with patients intensified in the hospital but not at discharge, patients with intensification at discharge were more likely to be Black (516 of 1645 [31.4%] vs 1118 of 4259 [26.3%]; $P < .001$) but less likely to have coronary artery disease (183 of 1645 [11.1%] vs 640 of 4259 [15%]; $P < .001$) and hypertension preadmission (752 of 1645 [45.7%] vs 2348 of 4259 [55.1%]; $P < .001$). During admission, patients with intensification at discharge also had higher maximum SBPs (176 mm Hg vs 170.7 mm Hg; $P < .001$) and a greater proportion of hypertensive SBPs (0.57 vs 0.48; $P < .001$) and more often had a maximum SBP of 200 mm Hg or greater (164 of 1645 [10%] vs 258 of 4259 [6.1%]; $P < .001$).

Of 17 821 patients who were hypertensive in the hospital, 15 303 (85.9%) had follow-up BP data available. Characteristics of patients lost to follow-up and those with follow-up are shown in eTable 2 in the Supplement. Inpatient BP characteristics and outpatient outcomes for 4964 patients treated in the hospital and stratified by intensification at discharge are shown in eTable 3 in the Supplement. In a matched cohort, patients with and without intensification at discharge had almost identical characteristics (eTable 4 in the Supplement), including SBP at discharge, proportion of hypertensive SBPs during admission, and maximum SBP. In the 30 days postdischarge, patients with and without intensification had similar rates of myocardial infarction (2 of 1367 [0.1%] vs 3 of 1367 [0.2%]; $P > .99$) or stroke (7 of 1367 [0.5%] vs 6 of 1367 [0.4%]; $P > .99$) (**Table 4**). In the following year, patients with and without intensification had nearly identical BP control, including proportion of hypertensive systolic (0.41 vs 0.40; $P = .86$) and diastolic (0.13 vs 0.12; $P = .05$) pressures and maximum SBP (157.2 mm Hg vs 157.8 mm Hg; $P = .54$) and DBP (86.5 mm Hg vs 86.1 mm Hg; $P = .49$). Both groups had slight reduction of average SBP compared with their discharge SBP (-2.5 mm Hg vs -2.3 mm Hg; $P = .83$).

Discussion

In this cohort study of 22 834 patients at 10 hospitals, we found that among adults admitted for noncardiovascular diagno-

Table 4. Outpatient Cardiovascular Outcomes and BP Characteristics of Patients With Hypertension by Antihypertensive Treatment Intensification at Discharge

Characteristic	No intensification (n = 1367)	Intensification (n = 1367)	*P* value
No. of BP measurements, mean (SD)	11.1 (13.8)	10.8 (13.0)	.53
At least 1 SBP >139 mm Hg, No. (%)	1105 (80.8)	1092 (79.9)	.56
At least 1 DBP >89 mm Hg, No. (%)	520 (38)	563 (41.2)	.10
At least 1 SBP >139 mm Hg or 1 DBP >89 mm Hg, No. (%)	1133 (82.9)	1129 (82.6)	.88
Proportion of SBP >139 mm Hg, mean (SD)	0.40 (0.32)	0.41 (0.32)	.86
Proportion of DBP >89 mm Hg, mean (SD)	0.12 (0.22)	0.13 (0.23)	.05
Highest measurement, mean (SD), mm Hg			
SBP	157.8 (22.2)	157.2 (23.3)	.54
DBP	86.1 (13.4)	86.5 (14.6)	.49
Lowest measurement, mean (SD), mm Hg			
SBP	116.1 (19.5)	116.5 (19.5)	.58
DBP	61.6 (12.7)	61.7 (13.2)	.91
Change from discharge BP, mean (SD), mm Hg	−2.3 (21.2)	−2.5 (21.2)	.83
Myocardial infarction, No. (%)	3 (0.2)	2 (0.1)	>.99
Stroke, No. (%)	6 (0.4)	7 (0.5)	>.99

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.

ses, 78% had at least 1 elevated BP reading, and one-third of these patients were treated with medication, primarily oral antihypertensives. Treated patients were at higher cardiovascular risk (eg, they were older and more likely to be Black) and had higher BP. After controlling for these factors, we found that following treatment, patients were more likely than matched controls to experience AKI and myocardial injury. Associated harms were similar for oral and IV treatments and occurred across SBP intervals. We did not find any group of patients whose outcomes were better with treatment. Most patients who received treatment in the hospital were not discharged with intensification. Those who were did not experience better BP control in the following year.

We found that despite a high prevalence of elevated BP in the hospital, few patients and even fewer hypertensive measures prompted treatment. Even SBPs of 220 mm Hg or greater elicited treatment only 47% of the time, which is surprising, because Axon et al[11] found that 80% of resident physicians believed that inpatient hypertension was a high priority, and Weder[4] reported that one-third of house staff and hospitalists believe asymptomatic hypertension (using an example of 182/100 mm Hg) merits transfer to the intensive care unit. The lower rates of treatment we observed may reflect newer evidence regarding hypertensive urgency in the ambulatory setting,[9] better appreciation of BP lability during acute illness,[4,5,10] and growing recognition of the potential harms of IV treatment.[12-14] The lack of harms among untreated patients appears to support this conservative approach.

Our study adds to the evidence suggesting harms associated with treating inpatient hypertension. Whereas prior studies examined proxies for hypotension-related harms, such as hypotension, rapid reduction in BP, tachycardia, or the need to provide IV fluids,[13,14] our study, to our knowledge, is the first to directly assess end-organ damage, including AKI, myocardial injury, and stroke. Our finding that the harms associated with treatment persist into higher intervals of BP, even those categorized as hypertensive urgency, strengthens the case for conservative management.[22] Moreover, although prior studies have described harms with IV treatment, we included oral and IV agents and analyzed outcomes by route.[12-14] That there was harm associated with IV treatment at all BP intervals lends support to quality initiatives to reduce IV antihypertensive orders.[23,24] However, that the majority of treated patients received only oral antihypertensives—also associated with harm—suggests a need to reduce oral antihypertensives as well.

We found that most elevated SBPs dropped at least 20 points by the next measurement. Follow-up measurements were taken sooner in patients who remained untreated, suggesting that simply repeating the BP 4 hours later may substitute for treatment. BP elevations tended to be transient, and fewer than 1 in 3 patients who had their medication intensified were discharged on the new regimen. Mean SBP at discharge was less than 140 mm Hg in both treated and untreated patients.

For some chronic conditions, hospitalization presents an opportunity to initiate long-term therapy. For example, patients with hip fracture can be prescribed bisphosphonates for osteoporosis, and patients with coronary disease who receive statins at discharge are more likely to be taking them 1 year later.[25-27] For hypertension, this does not appear to be the case, as conditions surrounding hospitalization almost certainly do not represent ambulatory BP control. This is important because intensification at discharge may be associated with harm. Anderson et al[18] found that patients at US Veterans Affairs hospitals who underwent intensification at discharge had more serious adverse events within 30 days. That study was limited by a lack of access to inpatient treatment. In contrast, we compared patients who received intensified treatment during hospital admission with those who received intensified treatment at both

admission and discharge. We found no increase in adverse events within 30 days, but intensification of treatment at discharge also was not associated with better control at 1 year. Appropriate follow-up with a primary care physician could better ensure proper treatment while limiting unnecessary medication.

Limitations

Our definition of treatment excluded dose intensification. As a result, we may have undercounted the treated patients in our cohort. This potential misclassification should bias our findings toward the null; thus, actual harms associated with antihypertensive treatment may be greater than observed. Additionally, although we excluded patients with cardiovascular diagnoses that require specific BP management, such as acute coronary syndrome or cerebrovascular accident, we included others, such as patients with atrial fibrillation or heart failure, who may be treated with antihypertensive medications. Other unmeasured differences between treated and untreated patients could confound the results if clinicians treat patients they believe to be at higher risk of end-organ damage. However, our propensity match included a large number of patient characteristics, including diagnoses and BP characteristics; all were well-balanced between groups. Furthermore, our falsification tests suggest that our outcomes were not confounded by clinical status before the index BP. Finally, even if treatment of elevated BP in the hospital does not result in harm, we found no indication that it was beneficial. It was, at best, a waste of time and resources.

Conclusions

In summary, this cohort study found that 78% of adult patients admitted for noncardiovascular diagnoses had at least 1 hypertensive BP measurement, but fewer than 1 in 3 had their medication intensified. More surprisingly, only 8% of hypertensive BP readings prompted medication intensification, and even readings over 220 mm Hg systolic were treated less than half of the time. Paradoxically, treatment, which presumably was meant to prevent end-organ damage, was associated with higher rates of AKI and myocardial injury. In fact, we found no benefit associated with any treatment route or at any BP interval. Our findings suggest that hypertension among medical inpatients should be managed conservatively. Intensification of treatment on discharge also does not appear to be helpful.

ARTICLE INFORMATION

Accepted for Publication: October 24, 2020.

Published Online: December 28, 2020. doi:10.1001/jamainternmed.2020.7501

Author Contributions: Dr Rastogi and Ms Sheehan had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr Rastogi and Ms Sheehan contributed equally and are considered co-first authors of this work.
Concept and design: Rastogi, Rothberg.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Rastogi, Sheehan, Hu.
Critical revision of the manuscript for important intellectual content: Rastogi, Sheehan, Shaker, Kojima, Rothberg.
Statistical analysis: Rastogi, Sheehan, Hu.
Administrative, technical, or material support: Shaker, Rothberg.
Supervision: Rothberg.

Conflict of Interest Disclosures: None reported.

REFERENCES

1. Health Forum. *AHA Hospital Statistics*. 2020 ed. American Hospital Association; 2020.

2. Axon RN, Cousineau L, Egan BM. Prevalence and management of hypertension in the inpatient setting: a systematic review. *J Hosp Med*. 2011;6(7):417-422. doi:10.1002/jhm.804

3. James PA, Oparil S, Carter BL, et al. 2014 Evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8). *JAMA*. 2014;311(5):507-520. doi:10.1001/jama.2013.284427

4. Weder AB. Treating acute hypertension in the hospital: a lacuna in the guidelines. *Hypertension*. 2011;57(1):18-20. doi:10.1161/HYPERTENSIONAHA.110.164194

5. 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*. 2018;71(19):e127-e248. doi:10.22141/2307-1257.7.1.2018.122220

6. Janke AT, McNaughton CD, Brody AM, Welch RD, Levy PD. Trends in the incidence of hypertensive emergencies in US emergency departments from 2006 to 2013. *J Am Heart Assoc*. 2016;5(12):e004511. doi:10.1161/JAHA.116.004511

7. Cherney D, Straus S. Management of patients with hypertensive urgencies and emergencies: a systematic review of the literature. *J Gen Intern Med*. 2002;17(12):937-945. doi:10.1046/j.1525-1497.2002.20389.x

8. Perez MI, Musini VM. Pharmacological interventions for hypertensive emergencies: a Cochrane systematic review. *J Hum Hypertens*. 2008;22(9):596-607. doi:10.1038/jhh.2008.25

9. Patel KK, Young L, Howell EH, et al. Characteristics and outcomes of patients presenting with hypertensive urgency in the office setting. *JAMA Intern Med*. 2016;176(7):981-988. doi:10.1001/jamainternmed.2016.1509

10. Brook RD, Weder AB, Rajagopalan S. "Environmental hypertensionology" the effects of environmental factors on blood pressure in clinical practice and research. *J Clin Hypertens (Greenwich)*. 2011;13(11):836-842. doi:10.1111/j.1751-7176.2011.00543.x

11. Axon RN, Garrell R, Pfahl K, et al. Attitudes and practices of resident physicians regarding hypertension in the inpatient setting. *J Clin Hypertens (Greenwich)*. 2010;12(9):698-705. doi:10.1111/j.1751-7176.2010.00309.x

12. Weder AB, Erickson S. Treatment of hypertension in the inpatient setting: use of intravenous labetalol and hydralazine. *J Clin Hypertens (Greenwich)*. 2010;12(1):29-33. doi:10.1111/j.1751-7176.2009.00196.x

13. Campbell P, Baker WL, Bendel SD, White WB. Intravenous hydralazine for blood pressure management in the hospitalized patient: its use is often unjustified. *J Am Soc Hypertens*. 2011;5(6):473-477. doi:10.1016/j.jash.2011.07.002

14. Lipari M, Moser LR, Petrovitch EA, Farber M, Flack JM. As-needed intravenous antihypertensive therapy and blood pressure control. *J Hosp Med*. 2016;11(3):193-198. doi:10.1002/jhm.2510

15. Jankowski P, Kawecka-Jaszcz K, Bilo G, Pajak A. Determinants of poor hypertension management in patients with ischaemic heart disease. *Blood Press*. 2005;14(5):284-292. doi:10.1080/08037050500239962

16. Gattis WA, O'Connor CM, Gallup DS, Hasselblad V, Gheorghiade M; IMPACT-HF Investigators and Coordinators. Predischarge initiation of carvedilol in patients hospitalized for decompensated heart failure: results of the Initiation Management Predischarge: Process for Assessment of Carvedilol Therapy in Heart Failure (IMPACT-HF) trial. *J Am Coll Cardiol*. 2004;43(9):1534-1541. doi:10.1016/j.jacc.2003.12.040

17. Anderson TS, Wray CM, Jing B, et al. Intensification of older adults' outpatient blood pressure treatment at hospital discharge: national retrospective cohort study. *BMJ*. 2018;362:k3503. doi:10.1136/bmj.k3503

18. Anderson TS, Jing B, Auerbach A, et al. Clinical outcomes after intensifying antihypertensive medication regimens among older

adults at hospital discharge. *JAMA Intern Med*. 2019;179(11):1528-1536. doi:10.1001/jamainternmed.2019.3007

19. Gu A, Yu Y, Desai RP, Argulian E. Racial and ethnic differences in antihypertensive medication use and blood pressure control among US adults with hypertension: the National Health and Nutrition Examination Survey, 2003 to 2012. *Circ Cardiovasc Qual Outcomes*. 2017;10(1):e003166. doi:10.1161/CIRCOUTCOMES.116.003166

20. Musemwa N, Gadegbeku CA. Hypertension in African Americans. *Curr Cardiol Rep*. 2017;19(12):129. doi:10.1007/s11886-017-0933-z

21. Mehta RL, Kellum JA, Shah SV, et al; Acute Kidney Injury Network. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. *Crit Care*. 2007;11(2):R31. doi:10.1186/cc5713

22. Breu AC, Axon RN. Acute treatment of hypertensive urgency. *J Hosp Med*. 2018;13(12):860-862. doi:10.12788/jhm.3086

23. Pasik SD, Chiu S, Yang J, et al. Assess before Rx: reducing the overtreatment of asymptomatic blood pressure elevation in the inpatient setting. *J Hosp Med*. 2019;14(3):151-156. doi:10.12788/jhm.3190

24. Jacobs ZG, Najafi N, Fang MC, et al. Reducing unnecessary treatment of asymptomatic elevated blood pressure with intravenous medications on the general internal medicine wards: a quality improvement initiative. *J Hosp Med*. 2019;14(3):144-150. doi:10.12788/jhm.3087

25. Fonarow GC, Gawlinski A, Moughrabi S, Tillisch JH. Improved treatment of coronary heart disease by implementation of a Cardiac Hospitalization Atherosclerosis Management Program (CHAMP). *Am J Cardiol*. 2001;87(7):819-822. doi:10.1016/S0002-9149(00)01519-8

26. Muhlestein JB, Horne BD, Bair TL, et al. Usefulness of in-hospital prescription of statin agents after angiographic diagnosis of coronary artery disease in improving continued compliance and reduced mortality. *Am J Cardiol*. 2001;87(3):257-261. doi:10.1016/S0002-9149(00)01354-0

27. Byszewski A, Lemay G, Molnar F, Azad N, McMartin SE. Closing the osteoporosis care gap in hip fracture patients: an opportunity to decrease recurrent fractures and hospital admissions. *J Osteoporos*. 2011;2011:404969. doi:10.4061/2011/404969