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Elevated Preoperative Blood Pressures in Adult Surgical Patients are Highly Predictive of Elevated Home Blood Pressures

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Abstract

Objective—Blood pressure (BP) measurement during the pre-surgical assessment has been suggested as a way to improve longitudinal detection and treatment of hypertension. The relationship between blood pressure measured during this assessment and home blood pressure (HBP), a better indicator of hypertension, is unknown. The purpose of the present study was to determine the positive predictive value (PPV) of presurgical blood pressure for predicting elevated HBP.

Methods—We prospectively enrolled 200 patients at a presurgical evaluation clinic with clinic blood pressures $\geq 130/85$ mmHg, as measured using a previously-validated automated upper-arm device (Welch Allyn Vital Sign Monitor 6000 Series), to undergo daily HBP monitoring (Omron Model BP742N) between the index clinic visit and their day of surgery. Elevated HBP was defined, per American Heart Association guidelines, as mean systolic HBP ≥ 135 mmHg or mean diastolic HBP ≥ 85 mmHg.

Results—Of the 200 participants, 188 (94%) returned their home blood pressure monitors with valid data. The median number of home blood pressure recordings was 10 (IQR 7–14). Presurgical clinic blood pressure thresholds of 140/90, 150/95, and 160/100 mmHg yielded PPVs (95% CI) for elevated HBP of 84.1% (0.78–0.89), 87.5% (0.81–0.92), and 94.6% (0.87–0.99), respectively. In contrast, self-reported blood pressure control, anti-hypertensive treatment, availability of primary care, and preoperative pain scores demonstrated poor agreement with elevated HBP.

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Conclusion—Elevated preoperative clinic blood pressure is highly predictive of longitudinally elevated HBP. BP measurement during pre-surgical assessment may provide a way to improve longitudinal detection and treatment of hypertension.

Keywords

Perioperative Medicine; Population Health; Hypertension screening; Home Blood Pressure; Preoperative Evaluation

Introduction

Despite concerted public health efforts, the failure to identify and control hypertension among patients who report repeated encounters with healthcare providers persists.¹ Undiagnosed hypertension is present among 28.6% of insured U.S. adults less than 65 years of age,² while approximately half of treated hypertensives continue to demonstrate poorly controlled blood pressure (BP).³ Among a subset of patients being treated for diabetes and coronary artery disease, undiagnosed hypertension was still found in 10.7%, conferring elevated mortality risk as compared with diagnosed hypertension.¹ Because of such widespread patterns of hypertension diagnostic and treatment failures, efforts directed toward unconventional contexts of healthcare system engagement with BP screening and management may contribute toward reducing hypertension-associated morbidity.^{4, 5}

The surgical encounter has been heralded as one such context that could be harnessed for improvements in preventive medical care.^{6–9} Indeed, the recently released Merit-Based Incentive Payment System (MIPS) from the Centers for Medicare and Medicaid Services (CMS) has recognized that perioperative screening for high BP - MIPS measure 317 - constitutes one element of quality anesthesia care.¹⁰ The surgical encounter is notably brief in comparison to long-term preventive medical care. Also, there is a common perception that factors associated with the surgical encounter may make preoperative BP screening unreliable,¹¹ a perception we have questioned.^{6, 12, 13} Nonetheless, it remains unclear what BP threshold(s) during the presurgical evaluation should be referenced to identify the patient with hypertension.

Using a large retrospective dataset from the Veterans Health Administration we previously reported that patients with a preoperative BP >150/95 mmHg were likely to demonstrate elevated clinic BP in the year following surgery (positive predictive value 51.5%; 95% CI 51.0–52.0).¹³ This finding was limited by retrospective reliance on electronically recorded BP's. Thus, the need for a rigorously established, context-specific algorithm to guide preoperative BP screening has persisted. In the present study, we prospectively enrolled 200 ambulatory patients during their presurgical visit, and conducted home blood pressure (HBP) monitoring to more accurately ascertain longitudinal hypertension status¹⁴ with reference to American Heart Association guidelines for the interpretation of home blood pressure.^{15–17} The primary aim of the study was to determine the positive predictive value (PPV) of presurgical clinic blood pressure (CBP) for determining hypertension status based on HBP. Secondary outcomes included agreement between patient self-report of BP control and hypertension status according to HBP, and the association of self-reported availability of

primary care, the presence of anti-hypertensive medical therapy, and acute pain at the time of pre-surgical assessment, with HBP-based hypertension status.

Materials and Methods

After approval by the Yale School of Medicine Institutional Review Board and registration on Clinicaltrials.gov (NCT02136810), a convenience sample of 200 ambulatory patients scheduled for surgery was recruited during their preadmission visit at Yale-New Haven Hospital between November 2015 and December 2016. Inclusion criteria were age ≥ 21 years and a screening BP $\leq 130/85$ mmHg. Participants who were unable or unwilling to independently operate a brachial artery HBP monitor were excluded. The BP during the preadmission visit was measured using the Welch Allyn 6000 Series blood pressure monitor, a widely used monitor among major hospital systems that has been previously validated.^{18, 19} During measurement, participants were resting in a seated position with feet on the floor and without manual measurement in accordance with prior literature that has demonstrated automated measurement to more accurately reflect non-clinical measurements as compared with manual sphygmomanometry.²⁰ Where possible within clinic workflow – as was the case with 95.5% of subjects – the CBP was calculated as the mean of two successive measurements five minutes apart. The preoperative clinic that was the site of enrollment does not typically see patients for minor outpatient procedures. Thus included patients were scheduled for major surgeries likely to necessitate a hospital admission.

After informed consent was obtained, participants were instructed in the use of an oscillometric brachial artery home blood pressure monitor (HBPM) that has been validated previously (Omron Model BP742N; Omron Healthcare, Inc. Lake Forest, IL)²¹ and instructed to conduct a resting HBP in the morning and evening of each day until the day of surgery. They were then instructed to return the device on the day of surgery. HBPM devices stored up to 50 BP measurements. Participants proceeded through their standard preadmission visit during which time all were asked the following questions: 1) Has anyone ever told you that you have high blood pressure or hypertension? 2) Do you take medication for your blood pressure? 3) Is your blood pressure typically high, normal, or low? 4) On a 5-point scale, how available are primary care services for you (0=never/rarely available; to 4=always available). 5) From 1 to 10, please rate how much pain you are experiencing now (1=no pain; 10=terrible pain). 6) Do you have a primary care doctor/practice?

Statistical analysis

HBP recordings were averaged for each participant and the outcome “poorly controlled blood pressure” was defined according to the American Heart Association home blood pressure measurement guidelines, as either a mean home systolic blood pressure (SBP) >135 mmHg or diastolic blood pressure (DBP) >85 mmHg.¹⁷ While specific thresholds for defining poorly controlled blood pressure are controversial,²⁰ a similar HBP cutoff of 137/84 mmHg has previously been associated with a 10% increase in the adjusted relative hazard of mortality relative to ideal BP.²²

The primary analysis concerned the prediction of poorly controlled HBP based on 3 specific thresholds of SBP or DBP assessed during the preadmission visit, 140/90 mmHg,

150/95mmHg, and 160/100mmHg; these thresholds were previously suggested for such screening and are consistent with our prior work. For completeness, our PPV analysis also includes the enrollment threshold of 135/85mmHg. The predictive value of BP assessed during the presurgical visit was further assessed at increasing 10mmHg increments of systolic and diastolic values beginning at 140mmHg and 80mmHg, respectively. Predefined subgroup analyses in parallel with these metrics were calculated among participants with vs. without a prior diagnosis of hypertension.

Secondary analyses concerned the agreement between participant's self-reported BP (i.e. high vs. normal or low) and self-reported anti-hypertensive medication use with the presence of poorly controlled HBP were assessed via Cohen's kappa.^{23, 24} Cohen's kappa was interpreted to indicate excellent, fair, or poor agreement at the thresholds of >0.75, 0.4–0.75, and <0.4, respectively.²⁵ In exploratory analyses, the association of self-reported availability of primary care and of acute pain with poorly controlled HBP were each examined by the Mann-Whitney test, with a $p < 0.05$ suggestive of a possible association for each of these secondary endpoints.

Results

Demographic characteristics

The mean (SD) age of the sample was 64.3 years (± 12.20), 114 (57%) were female, 12 (6%) identified as Hispanic or Latino ethnicity, 36 (18%) identified as Black or African American, 149 (74.5%) as White or Caucasian; 157 (78.5%) had a history of diagnosed hypertension in the medical record (see Table 1). The mean ($\pm$ SD) SBP/DBP at the time of the presurgical visit was 156.25mmHg (± 14.1)/88.39mmHg (± 9.8), respectively. Of the 200 enrolled participants, 188 (94%) returned the HBPM with at least one valid BP reading. The median number of HBP readings among these participants was 10 (IQR= 7–14). A summary table of the cohort with and without valid HBP readings is shown in Table 1. Overall, the mean bias in home vs presurgical visit SBP/DBP was $-9.2\text{mmHg}/-1.1\text{mmHg}$ (see Bland-Altman Analysis in Figure 1).

Primary Outcome—Among participants with valid HBP readings ($N=188$), the PPV (95%CI) of a presurgical BP $\geq 140/90\text{mmHg}$ to predict poorly controlled HBP was 84.1% (0.78–0.89). A threshold presurgical BP $\geq 150/95$ carried a PPV of 87.5% (0.81–0.92) for predicting poorly controlled HBP, and a threshold of $\geq 160/100\text{mmHg}$ carried a PPV of 94.6% (0.87–0.99). See Table 2 for a summary of these data, and stratified by self-reported hypertension diagnostic status. We further analyzed the utility of presurgical BP to determine HBP status by graphing the proportion of participants who demonstrated elevated HBP at increasing 10mmHg ranges of SBP and DBP separately (see Figure 2). The Pearson's correlation coefficient between Clinic and Home SBP was 0.52 and for DBP was 0.51 (see Table 3).

Secondary Outcomes—Agreement between self-reported BP status (i.e. high vs. normal or low) and mean HBP was poor: Cohen's Kappa = 0.158 (95% CI 0.062–0.254). There was no significant agreement between self-reported medication use and HBP control (Cohen's Kappa = 0.052 (95% CI -0.098 –0.202)). There was also no significant relationship between

self-reported primary care access and HBP control (p-value = 0.62 by Wilcoxon Rank Sum Test), nor was there a significant relationship between acute pain at the time of presurgical visit and HBP (p-value = 0.26 by Wilcoxon Rank Sum Test).

While the primary analysis concerned the PPV for elevated home blood pressure among patients with versus without a history of hypertension, we further performed a multivariable logistic regression analysis in order to better understand the relationship between other presurgical factors and home blood pressure status. Specifically, we sought to examine whether common patient demographic factors, as well as the number of days of measurement or the total number of readings of HBPM affected the relationship between clinic and home BP status. For this secondary analysis, we used multiple logistic regression and again sought to predict the outcome of elevated home blood pressure (SBP/DBP > 135/85) while controlling for the following predictors: clinic SBP and DBP, age, sex, ethnicity, race, BMI, history of hypertension, and number of home blood pressure readings. Interestingly, the only independent predictors of elevated home BP at the p<0.05 level were the clinic blood pressures themselves. (See Table 4 for full model results.).

Sensitivity Analysis

One of the challenges of preoperative BP screening is the difficulty of getting full sets of HBPM – particularly when many patients present only a few days prior to surgery. The variability of HBPM numbers of readings may impact the ability to establish a gold standard determination of patients' true hypertension status. Accordingly, we performed a sensitivity analysis of our PPV calculations using the subset of patients who had at least 12 HBPM readings (See Table 5). Of note, these results are quite similar to the results from Table 2 above. This finding is consistent with the findings from the multiple logistic regression which also did not find number of readings to significantly predict home BP status.

Discussion

In the present study, we tested the PPV of three presurgical visit BP thresholds - 140/90, 150/95, and 160/100 - for determining poorly controlled home blood pressure, defined as an average greater than or equal to 135/85, according to AHA guidelines. The observed PPVs ranged from 84.1% to 94.6%, thus demonstrating that patients who are found to have hypertensive BP at the presurgical visit have a high likelihood of being hypertensive outside of the presurgical assessment environment. The present exploratory study indicates the potential promise of BP screening in the context of routine presurgical assessment for determining either undiagnosed or poorly controlled hypertension. In contrast, patient reported blood pressure status, hypertension medication status, and level of acute pain demonstrated poor agreement with HBP status and are unlikely to be useful in making screening decisions regarding follow-up for BP management.

Notably, the PPVs found in the present study are substantially higher than what we have reported previously using a large, retrospective electronic health record (EHR) cohort.¹³ In that prior study, which was limited to the use of BP measurements recorded in structured EHR fields during outpatient medical visits at the presurgical visit and after the surgical encounter, it was observed that a preoperative BP greater than or equal to 150/95mmHg

carried a PPV for an elevated outpatient BP of 51.5% as compared to 87.5% in the present cohort. The more powerful findings in the present study are likely due to several factors. We implemented HBP monitoring, a more rigorous method to determine longitudinal BP status that has been shown to predict cardiovascular morbidity independent of office BP measurements.²⁶ Also, because the AHA threshold for determining hypertension status are different for home vs. clinic measured BP, our findings may in part reflect the more prevalent and rigorous AHA threshold associated with HBP. Last, the prior study was conducted using data from a group of United States Veterans within an integrated healthcare system, and thus these data may have lacked generalizability to a population that was largely non-Veteran.²⁷

An additional limitation of our present study – and indeed of perioperative HBPM screening – is that it is often the case that patients are first seen by the preoperative anesthesiology team only a few days to hours before the actual surgical encounter. Thus, HBPM readings may often not be as numerous as guidelines would recommend for traditional HBPM screening. Despite this limitation, it is interesting to note that neither the number of days between screening and scheduled surgery, nor the actual number of HBPM readings obtained appeared to affect the prognostic utility of preoperative clinic BP measurements to determine the presence of elevated home BP. While the relevant logistic regression model in the present study was merely a secondary analysis of pilot data, it suggests that the preoperative visit and accompanying home BP screening may perhaps demonstrate utility even in cases where patients undergo suboptimal numbers of home BP readings, or when surgical dates follow closely after presurgical visits.

The present study findings may be specific to ambulatory patients undergoing major surgical procedures, and it has yet to be established whether these findings can be generalized to the outpatient setting where patients are evaluated immediately prior to minor surgical procedures.

While further study is needed to implement and test appropriate BP screening algorithms for use during presurgical assessment and in accordance with quality mandates such as MIPS 317, our data offer several important guideposts toward that effort. We have demonstrated feasibility, by obtaining HBP information among patients presenting from home for surgery. Our recovery of 94% of participants' data with a median number of HBP self-measurements of 10 (IQR 7–14) demonstrates that this type of monitoring intervention is generally well-accepted by patients. It is notable that other researchers have reported that many primary care doctors site concerns about their patients willingness to do HBP monitoring as a barrier to using this method.²⁸ Although HBP monitoring has long been recognized as a useful tool to help differentiate sustained hypertension vs. short-lived contextual hypertension,¹⁴ our successful use of it in the presurgical period constitutes a novel avenue for further research.^{15–17, 29–31} Although our results require replication in other cohorts, we have shown that elevated BP during a presurgical visit is a valid indicator of true longitudinal BP status. This finding may challenge the predominant alternative thinking that the presurgical visit may be too stressful for such assessments.

Conclusion

In conclusion, the present study found that BP thresholds of 140/90, 150/95, and 160/100 during a presurgical visit yielded a PPV for poorly controlled HBP of 84.1%, 87.5%, and 94.6%, respectively. Despite the potential for changes in preoperative BP related to medications, pain, and other factors, our data indicate that patients with significantly elevated presurgical BP may be highly likely to demonstrate elevated HBP. Future studies are warranted to replicate these results in other, larger samples, and to test how best to make presurgical visit BP data actionable. While identifying patients who are likely to demonstrate longitudinally elevated BP is valuable, it remains to be established what interventions or novel care pathways that will effect improvements in long-term BP control are implementable in the busy perioperative period at an acceptable cost. Such interventions may have the potential to tangibly reduce long-term morbidity from unrecognized or poorly controlled hypertension among surgical patients.

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Highlights

- Presurgical evaluations frequently identify undertreated chronic health conditions.
- Blood pressure at the presurgical evaluation predicts home blood pressure status.
- Home blood pressure monitoring is well-accepted by presurgical patients.
- Elevated presurgical blood pressure tends to continue in the home environment.
- Self-report, medications, and pain are poor predictors of home blood pressure.

Figure 1.

Bland-Altman analysis showing the bias between paired home blood pressures and presurgical clinic blood pressures as a function of their paired means. Panels A and B show systolic and diastolic blood pressures, respectively. Shaded areas indicate the 95% confidence intervals of the bias. The overall mean bias is depicted as a horizontal dotted line in each panel. Histograms at the right of each panel indicate the N of paired measurements observed at each level of bias.

Figure 2.

The proportion (95%CI) of participants who demonstrated elevated home blood pressures at increasing clinic blood pressures. Panel A: Elevated Home Blood Pressure as a function of 10mmHg increments of Systolic Blood Pressure (SBP). Panel B: Elevated Home Blood Pressure as a function of 10mmHg increments of Diastolic Blood Pressure (DBP). N=188.

Table 1

Summary of Cohort Stratified by Presence of Home Blood Pressure Data

	Valid Home Blood Pressure Data		Total
	Yes	No	
	(N = 188)	(N = 12)	(N = 200)
Age	64.65 (12.16)	60.67 (12.33)	64.42 (12.18)
Male Sex	82 (43.62%)	4 (33.33%)	86 (43.00%)
Hispanic or Latino Ethnicity	12 (6.38%)	0 (0.00%)	12 (6.00%)
Black or African American Race	34 (18.18%)	2 (16.67%)	36 (18.09%)
BMI (Kg/m ²)	30.14 (7.09)	29.15 (7.99)	30.08 (7.13)
Pain score (1–10)	2.27 (2.44)	1.42 (1.44)	2.20 (2.40)
Self reported BP status			
Usually High	80 (42.55%)	6 (50%)	86 (43.00%)
Usually Normal or Low	108 (57.45%)	6 (50%)	114 (57.00%)
Primary Care Availability			
0 (rarely available)	2 (1.06%)	0 (0.00%)	2 (1.00%)
1	1 (0.53%)	0 (0.00%)	1 (0.50%)
2	8 (4.26%)	1 (8.33%)	9 (4.50%)
3	40 (21.28%)	0 (0.00%)	40 (20.00%)
4 (easily available)	137 (72.87%)	11 (91.67%)	148 (74.00%)
History of Hypertension	149 (79.26%)	9 (75%)	158 (79.00%)
Taking Blood Pressure Medication	147 (78.19%)	9 (75%)	156 (78.00%)
Clinic Hemodynamics:			
Mean Clinic SBP	156.22 (14.04)	156.88 (15.79)	156.26 (14.11)
Mean Clinic DBP	88.15 (9.76)	92.25 (10.30)	88.39 (9.81)
Mean Clinic HR	75.25 (12.43)	72.33 (9.88)	75.08 (12.29)
Home Hemodynamics:			
Mean Home SBP	146.73 (17.86)	NA	146.73 (17.86)
Mean Home DBP	87.04 (10.66)	NA	87.04 (10.66)
Mean Home HR	75.56 (11.07)	NA	75.59 (11.05)

Note: Data are presented as mean (SD), or n (%).

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Table 2

Primary Outcome Stratified by History of Hypertension

	Positive predictive value (PPV) (95% CI) of poorly controlled blood pressure (SBP/DBP > 135/85 mmHg)		
Clinic Blood Pressure (mmHg)	All patients N = 188	Known history of hypertension N = 149	No known history of hypertension N = 39
130/85	83.0 (76.8, 88.1)	85.2 (78.5, 90.5)	74.4 (57.9, 87.0)
140/90	85.8(79.8, 90.6)	87.3 (80.7, 92.3)	79.4 (62.1, 91.3)
150/95	87.5 (81.0, 92.4)	88.0 (80.7, 93.3)	85.2 (66.3, 95.8)
160/100	94.6 (86.7, 98.5)	95.4 (87.1, 99.0)	88.9 (51.8, 99.7)

Table 3

Pearson Correlation Coefficients Between Clinic and Home Blood Pressures (N=188):

Variables	Mean Home DBP	Mean Home SBP
Mean Clinic DBP	0.51 (p<0.0001)	0.05 (p = 0.516)
Mean Clinic SBP	0.16 (p = 0.113)	0.52 (p<0.0001)

Table 4

Multiple logistic regression analysis of elevated home blood pressure (Home SBP/DBP > 135/85 mmHg)

Independent variables	Odds Ratio (95%CI)	P-value
Mean Clinic SBP	1.08 (1.04 – 1.13)	< 0.001
Mean Clinic DBP	1.07 (1.01 – 1.13)	0.032
Age	1.00 (0.95 – 1.04)	0.829
Male Sex	1.06 (0.45 – 2.55)	0.888
Hispanic or Latino Ethnicity	4.76 (0.67 – 103.03)	0.188
Black or African American Race	2.37 (0.68 – 11.26)	0.215
BMI (Kg/m ²)	1.03 (0.96 – 1.10)	0.459
History of Hypertension, Yes	1.61 (0.58 – 4.639)	0.353
Number of Readings	0.97 (0.93 – 1.02)	0.214
Number of days between evaluation and scheduled surgery	1.00 (0.91 – 1.06)	0.574

Table 5Primary Outcome Stratified by History of Hypertension in patients with ≥ 12 reading numbers (N = 69)

	Positive predictive value (PPV) (95% CI) of poorly controlled blood pressure (SBP/DBP > 135/85 mmHg)		
Clinic Blood Pressure (mmHg)	All patients N = 69	Known history of hypertension N = 54	No known history of hypertension N = 15
130/85	82.61 (71.6, 90.7)	81.5 (68.6, 90.8)	86.7 (59.6, 98.3)
140/90	85.9 (75.0, 93.4)	84.0 (70.9, 92.8)	92.9 (66.1, 99.8)
150/95	85.2 (72.9, 93.4)	83.3 (68.6, 93.0)	91.7 (61.5, 99.8)
160/100	92.6 (75.7, 99.1)	91.7 (73.0, 99.0)	1 (29.2, 1)