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ORIGINAL RESEARCH CONTRIBUTION

Prehospital Systolic Blood Pressure Thresholds: A Community-based Outcomes Study

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Abstract

Objectives: Emergency medical services (EMS) personnel commonly use systolic blood pressure (sBP) to triage and treat acutely ill patients. The definition of prehospital hypotension and its associated outcomes are poorly defined. The authors sought to determine the discrimination of prehospital sBP thresholds for 30-day mortality and to compare patient classification by best-performing thresholds to traditional cutoffs.

Methods: In a community-based cohort of adult, nontrauma, noncardiac arrest patients transported by EMS between 2002 and 2006, entries to state hospital discharge data and death certificates were linked. Prehospital sBP thresholds between 40 and 140 mm Hg in derivation (n = 132,624) and validation (n = 22,020) cohorts and their discrimination for 30-day mortality, were examined. Cutoffs were evaluated using the 0/1 distance, Youden index, and adjusted Z-statistics from multivariable logistic regression models.

Results: In the derivation cohort, 1,594 (1.2%) died within 24 hours, 7,404 (6%) were critically ill during hospitalization, and 6,888 (5%) died within 30 days. The area under the receiver operating characteristic (ROC) curve for sBP was 0.60 (95% confidence interval [CI] = 0.59, 0.61) for 30-day mortality and 0.64 (95% CI = 0.62 0.66) for 24-hour mortality. The 0/1 distance, Youden index, and adjusted Z-statistics found best-performing sBP thresholds between 110 and 120 mm Hg. When compared to an sBP $\leq$ 90 mm Hg, a cutoff of 110 mm Hg would identify 17% (n = 137) more deaths at 30 days, while overtriaging four times as many survivors.

Conclusions: Prehospital sBP is a modest discriminator of clinical outcomes, yet no threshold avoids substantial misclassification of 30-day mortality among noninjured patients.

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Emergency medical services (EMS) personnel are often the first health care providers for acutely ill patients, providing initial triage and treatment to millions each year. Optimizing prehospital triage strategies can provide an important foundation to improve care.[1] Yet, observational data suggest that many emergency triage decisions are inconsistent, and this variation may derive from both subjective assessments and objective data available to prehospital providers.[2]

Prehospital providers often use systolic blood pressure (sBP) to assess patients. The presence of hypotension defined before hospital arrival is incorporated in

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the American College of Surgeons Committee on Trauma field physiologic criteria[3] and multiple prehospital risk scores for medical patients.[4,5] Although previously associated with mortality,[6,7] there is no consensus definition of prehospital hypotension, nor an initial sBP threshold that best identifies the highest-risk patients.[6,8,9] Such an optimal cutoff could guide future EMS research and clinical practice improvement.[10]

We sought to determine prehospital initial sBP cutoffs that best discriminated patient-centered outcomes of 30-day mortality, critical illness during hospitalization, and 24-hour mortality. We derived cutoff performance in a large consecutive registry of EMS encounters and then applied these to an external validation cohort to compare classification of patients to traditional thresholds.

METHODS

Study Design

This was a large, community-based cohort study among all EMS encounters. The institutional review boards of the Washington State Department of Health (DOH), King County EMS, and the University of Washington approved the study with waiver of written informed consent.

Study Setting and Population

This retrospective study used data from 2002 and 2006 in King County, Washington. We analyzed patients transported by King County EMS, a two-tier EMS system serving all of those who activate 9-1-1 in greater King County, a semiurban and rural catchment of over 1.7 million persons. We also evaluated records in 2006 from Seattle Medic One, an urban EMS system responding to all 9-1-1 encounters in metropolitan Seattle. Both King County EMS and Seattle MedicOne have a first response that is staffed by emergency medical technician-fire fighters trained to provide basic life support (BLS). The second tier is staffed by paramedics trained to provide advanced life support (ALS). King County EMS records served as the derivation cohort, while the Seattle MedicOne records served as the validation cohort—a geographically distinct database with separate EMS leadership, paramedics, first responders, and catchment area.

Study Protocol

We linked all EMS records to the Washington State Comprehensive Hospital Abstract Reporting System (CHARS) database from 2002 to 2007. CHARS is a statewide database of all hospitalizations, with detailed diagnostic, procedural, and discharge data. We linked encounters to the Washington State Death records. Further details on this cohort and success of record linkage success are previously described.[4,11] In brief, we used probabilistic matching to deduplicate and link EMS records with manual validation, followed by hierarchical deterministic matching of EMS to hospital and death records. As shown in Figure 1, we included all nontrauma, noncardiac arrest encounters in whom a physical exam was performed by EMS personnel. We then excluded encounters that were: 1) age < 18 years, 2) transported to a destination other than hospital (none, clinic, unknown), 3) missing or 0 mm Hg sBP, and 4) missing covariate data for multivariable models.

We used the first measured sBP in the EMS record of the first arriving EMS personnel (as determined by earliest on-scene times of either BLS or ALS truck) in the King County and Seattle databases of EMS encounters. Prehospital vital signs are recorded in computerized medical incident report forms and undergo routine quality checks on a quarterly basis by staff epidemiologists in King County. Encounters with missing sBP measurements, or sBP = 0 or sBP > 300 mm Hg sBP, were excluded.

Outcomes

The primary outcome of the study was 30-day mortality. We also evaluated how sBP thresholds discriminated secondary outcomes: 24-hour mortality and critical illness during hospitalization. We avoided critical illness or intensive care unit admission as a primary outcome as they are subject to local practice patterns, census, and discharge bias.[12] We defined 24-hour mortality as death within 1 day of the incident, using Washington state death certificates (for nonadmitted patients) or discharge disposition of death + 1-day length of stay in CHARS (for admitted patients). Death records allowed capture of all endpoints regardless of the location (e.g., EMS, emergency department, hospital, or home). Discharge disposition variables in CHARS are previously validated as an accurate measure of patient deaths.[13] We defined critical illness during hospitalization using a previously published algorithm, including delivery of mechanical ventilation, severe sepsis, or in-hospital death.[4] Both mechanical ventilation and severe sepsis were defined using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes.[14,15]

Additional Variables. We abstracted additional prehospital variables including dispatch, demographic, physiologic, and transport data. These included age, sex, prehospital location (e.g., home, street, nursing home), primary diagnosis by EMS personnel (e.g., abdominal, cardiovascular, respiratory), initial vital signs (respiratory rate, Glasgow Coma Scale score, pulse oximetry, heart rate), EMS call severity (life-threatening, urgent, or nonurgent as classified by the EMS personnel), the fire unit responding to each call, the mode of transport to the hospital (ALS ambulance, BLS ambulance, helicopter, or private automobile), and the hospital destination, among others. EMS call severity was subjectively determined and documented by personnel on scene. Certain primary diagnoses documented by EMS were also identified for sensitivity analyses, including “angina/suspected myocardial infarction,” “fever/infection,” or “shortness of breath.”

Data Analysis

We compared continuous data using means with standard deviation (±SD) or medians with interquartile range (IQR), as appropriate for the distribution of each variable. We compared proportions using the chi-square test. First, we evaluated the distribution of prehospital

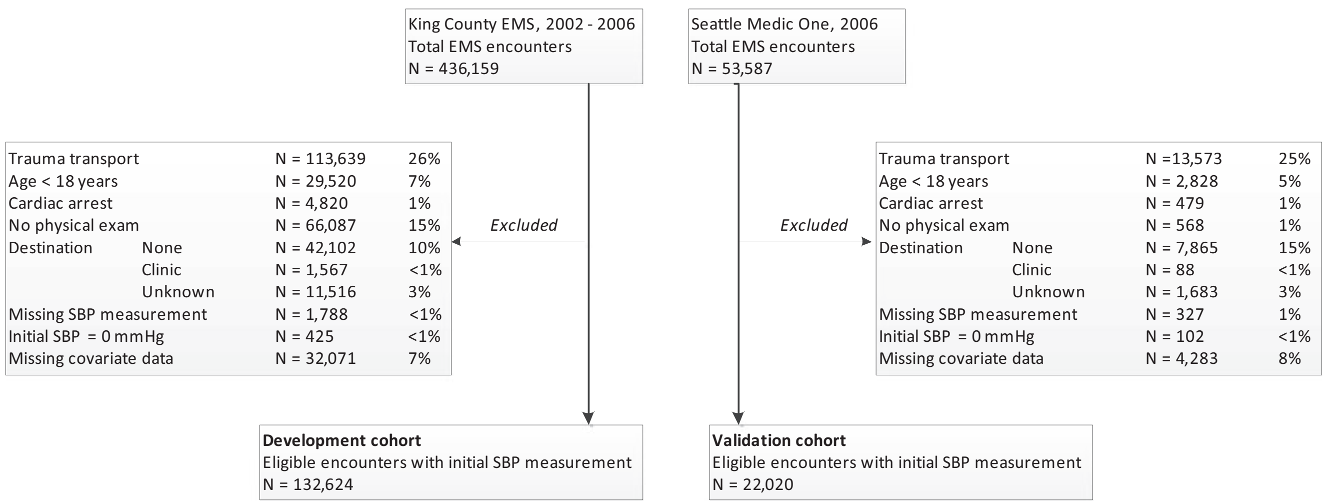

Figure 1. Subject accrual diagram for derivation and validation cohort. SBP = systolic blood pressure.

sBP and encounter characteristics across both derivation and validation cohorts. We tested crude association between prehospital sBP and primary and secondary outcomes using separate, unadjusted logistic regression models for each outcome. We modeled sBP using fractional polynomials. Although it is usually desirable to keep continuous variables in their original form, rather than categorizing them, expressing them in commonly used linear terms may not be accurate based on past research findings, the nature of the current data, or both. Fractional polynomials are an alternative way to specify predictors in a regression model that offers an advantage over a linear specification because it allows flexibility in the relationship between the modeled variable and the outcome. For example, it is known that the relationship between sBP and death is approximately "U"- or "J"-shaped. A linear sBP term may fail to accurately capture this relationship and alternative specifications, such as lumping sBP values into discrete categories, reduce power to detect a relationship with outcome.[16,17] We display the predicted probabilities (with 95% confidence intervals [CIs]) of each outcome across the range of sBP (40 to 300 mm Hg). We evaluated the overall discrimination of prehospital sBP for 30-day and 24-hour mortality using the area under the receiver operating characteristic (ROC) curve in both derivation and validation cohorts.

We tested thresholds of prehospital sBP for discrimination using two ROC-based methods and one regression method: 1) the shortest 0/1 distance on the ROC curve, 2) the greatest Youden index on the ROC curve, and 3) the maximum Z-statistic in logistic regression models.[18] These assessments (Data Supplement S2 eFigure 1, available as supporting information in the online version of this paper; a listing of the supplementary content for this article can be found in Data Supplement S1) were performed for all integer cutoffs between sBP 40 and 140 mm Hg. The 0/1 distance is the linear distance between the ROC curve and the upper left-most corner in a plot of sensitivity versus 1 – specificity. The Youden index is calculated as: Youden index = sensitivity + specificity – 1. We derived Z-statistics for sBP cutoffs in logistic regression models where the dichotomous sBP variable (at each cutoff value) was regressed on each outcome. We calculated Z-statistics as the beta estimate divided by the standard error of the beta, derived from multivariate models that included age, sex, prehospital vital signs (respiratory rate, SaO_2, Glasgow Coma Scale score, heart rate), transport mode, primary diagnosis category, and paramedic care (yes/no) and fixed effects for responding fire unit, receiving hospital, and year in cohort. These variables were selected a priori as known confounders from our prior work,[4,11] and parameterized as described in "additional variables." We did not categorize any ordinal or continuous variables other than prehospital sBP. We included responding fire units and receiving hospitals as fixed effects in the model to account for the nonindependence of observations. Model fit was assessed with the C-statistic and McKelvey and Zavoina's R^2.

We graphed 0/1 distance, Youden index, and adjusted Z-statistics for all cutoffs between 40 and 300 mm Hg to determine which thresholds in the derivation cohort performed best. We then applied best-performing thresholds from the derivation cohort as well as traditional cutoffs to the validation cohort and examined sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio.

Sensitivity Analyses. To determine how our results were affected by missing data, we analyzed the predicted probabilities from unadjusted logistic regression models for prehospital sBP and 30-day mortality when including patients previously excluded when building the derivation cohort. These included patients with sBP = 0 mm Hg (n = 425) and those with sBP measured but covariate data missing (n = 32,496). We also repeated our analysis of the 0/1 distance and Youden index when adding these patients to the cohort. We hypothesized that sBP measurements when missing (n = 1,788) were not missing at random. Hence, we used a flexible multivariable imputation procedure of multiple chained regression equations (MICE), which generated values for all missing data using the observed data for all patients in the derivation cohort.[19] This approach assumed that the missing data mechanism was random and conditional on observed covariates (please see Data Supplement S3, available as supporting information in the online version of this paper, for more details on our MICE procedure [eMethods]). Using imputed data, we reran our multivariable logistic regression models estimated Z-statistics using Rubin's rules.[20] Because documentation, sBP measurement, and outcomes may not be homogeneous across EMS conditions,[21] we also determined the performance of the sBP thresholds to specific conditions identified by EMS personnel: 1) suspected myocardial infarction or angina, 2) fever or suspected infection, and 3) shortness of breath. We used STATA 11.0 (StataCorp, College Station, TX) for analysis and deployed tests as two-sided with $p \leq 0.05$.

RESULTS

Among 436,159 encounters in the derivation cohort, we excluded 26% (*n* = 113,639) with trauma, 7% (*n* = 29,520) pediatric encounters, and 15% (*n* = 66,087) not examined by EMS personnel. Prehospital encounters for cardiac arrest or with missing data were a minority of those excluded (Figure 1). Exclusions were similar in the validation cohort, although fewer records were absent a physical examination (1%). As shown in Table 1, half of patients were women; many were found at home and were thought to have an undifferentiated medical (20%) or cardiovascular problem (19%). EMS personnel categorized a small minority of encounters with life-threatening illness (4%, *n* = 4,760). Approximately one in three encounters was admitted to a hospital. The mortality rate was 1.2% at 24 hours, 2% at hospital discharge, and 5% at 30 days after the encounter. The distribution of outcomes was similar even among patients excluded from analysis due to missing covariate data (Data Supplement S4 eTable 1, available as supporting information in the online version of this paper).

The initial mean (±SD) sBP during prehospital care was 140 (±33) mm Hg (Data Supplement S5 eFigure 2, available as supporting information in the online version of this paper). We observed 8,484 encounters (6.4%) with initial sBP ≤ 90 mm Hg and 16,617 encounters (12.5%) with initial sBP ≥180 mm Hg. The predicted probabilities of primary and secondary outcomes from unadjusted logistic regression models steadily increased for prehospital sBP below 100 mm Hg and for those above 200 mm Hg (Figure 2). Yet, prehospital sBP was only a modest discriminator of outcome. For example, the area under the ROC curve for 30-day mortality was 0.60 (95% CI = 0.59 to 0.61; Figure 3), for mortality within 24-hours was 0.64 (95% CI = 0.62 to 0.66; ROC curve in Data Supplement S6 eFigure 3, available as supporting information in the online version of this paper), and for critical illness during hospitalization was 0.59 (95% CI = 0.58 to 0.60).

The best-performing thresholds for prehospital sBP in the derivation cohort corresponded to low 0/1 distances and high Youden indices. This occurred for prehospital sBP between 110 and 120 mm Hg (Figure 4). Traditional thresholds such as ≤80 or 90 mm Hg were not optimal using these methods, a finding consistent for all outcomes (30-day mortality, 24-hour mortality, or critical illness). In the regression-based analyses (Data Supplement S7 eFigure 4A, available as supporting information in the online version of this paper), we observed adequate model fit (c-statistic ~ 0.82), while the maximum Z-statistics in fully adjusted logistic models identified best sBP thresholds between 110 and 115

Table 1
Demographics, Prehospital Characteristics, and Outcomes of Development and Validation Cohorts

Covariate	Derivation Cohort (*n* = 132,624)	Validation Cohort (*n* = 22,020)
Age, yr	61 ± 20.8	58 ± 20.3
Male sex, *n* (%)	55,791 (43)	10,194 (46)
Out-of-hospital location, *n* (%)		
Rout routine/home	88,433 (67)	9,521 (60)
Public building*	8,092 (6)	—†
Street/highway	5,462 (4)	41 (<1)
Adult family home*	3,896 (3)	—†
Medical facility	4,878 (4)	623 (3)
Nursing home	10,876 (8)	753 (5)
Highest level of prehospital care, *n* (%)		
ALS + BLS	50,193 (38)	10,521 (48)
BLS only	82,431 (62)	11,499 (52)
Initial out-of-hospital vital signs‡		
sBP, mm Hg	140 ± 33	141 ± 32
Heart rate, beats/min	91 ± 23	91 ± 24
Respiratory rate, breaths/min	18 [16–20]	18 [16–20]
Glasgow Coma Scale	14.2 ± 2.2	14.3 ± 2.0
Oxygen saturation,%*	98 [94–98]	—†
EMS impression (cause of disease), *n* (%)		
Cardiovascular	24,614 (19)	3,239 (15)
Respiratory	15,714 (12)	2,568 (12)
Neurologic	20,460 (15)	3,715 (17)
Medical–other	26,774 (20)	4,395 (21)
Abdominal	13,204 (10)	2,633 (12)
Unknown	9,264 (7)	172 (<1)
Alcohol/drug	7,937 (6)	2,174 (10)
Metabolic/endocrine	4,100 (3)	444 (2)
Psychiatric	5,336 (4)	1,180 (6)
Anaphylaxis/allergy	1,366 (1)	107 (<1)
Fall	1,260 (1)	350 (2)
Other	2,309 (2)	422 (2)
EMS severity code, *n* (%)*		
Life-threatening	4,760 (4)	—†
Urgent	63,273 (48)	—†
Nonurgent	64,591 (49)	—†
Mode of transport from scene, *n* (%)		
BLS	97,221 (74)	15,979 (73)
ALS	29,746 (22)	6,030 (27)
Helicopter	182 (<1)	—†
Private automobile	5,475 (4)	—†
Outcomes, *n* (%)		
Hospital admission	45,020 (34)	6,291 (29)
Critical illness during hospitalization	7,404 (6)	2,267 (10)
24-hour mortality	1,594 (1.2)	269 (1.2)
Hospital mortality	2,624 (2)	316 (1.4)
30-day mortality	6,888 (5)	822 (3.7)

ALS = advanced life support; BLS = basic life support.
*Data field not present in validation cohort.
†Data field not available in Seattle database.
‡Summary statistics are mean (±SD) or median [IQR], as appropriate

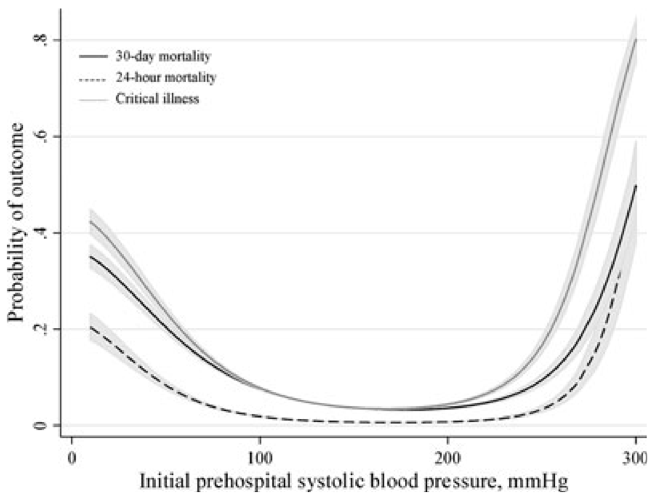

Figure 2. Unadjusted probability of outcomes over the range of prehospital sBP (mm Hg). *Black line* corresponds to 30-day mortality, *dashed line* to 24-hour mortality, and *gray line* to critical illness during hospitalization.

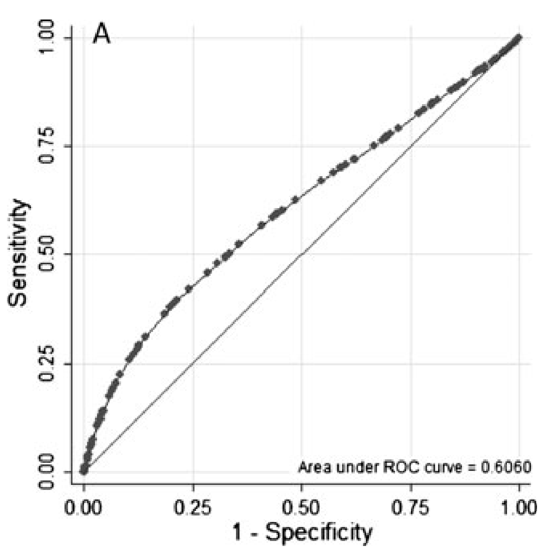

Figure 3. ROC curve of prehospital sBP (mm Hg) for 30-day mortality in the derivation cohort. ROC = receiver operating characteristic.

mm Hg. When accounting for missing data, our results were unchanged when including patients with sBP = 0 mm Hg or missing covariate data, and analyses of maximum Z-statistics were similar after multiple imputation procedures (Data Supplement S7 eFigure 4B).

When we applied the prehospital cutoff sBP identified in the derivation cohort (≤110 mm Hg), we observed a sensitivity of 29.9% (95% CI = 26.8% to 33.2%), specificity of 83.3% (95% CI = 82.8% to 83.8%), and positive likelihood ratio of 1.8 (95% CI = 1.6 to 2) for 30-day mortality (Table 2). Traditional cutoffs such as sBP ≤ 90 mm Hg corresponded to lower sensitivity (13%, 95% CI = 11% to 15.8%), greater specificity (95.7%, 95% CI = 95.4% to 96%), and greater negative likelihood ratio (0.91, 95% CI = 0.88 to 0.93). Compared to sBP ≤ 110 mm Hg, sBP ≤ 90 mm Hg would miss 17% (95% CI = 14.2% to 19.4%; *n* = 137) of patients who died at 30 days and 15% (95% CI = 10.5% to 10.2%; *n* = 39) of patients who died within 24 hours. On the other hand, sBP ≤ 110mm Hg would misclassify four times as many patients as high-risk who ultimately survived at 30 days, compared to sBP ≤ 90 mm Hg. In sensitivity analyses of specific conditions suspected by EMS, the performance of sBP thresholds was unchanged (Data Supplement S8 eTable 2, available as supporting information in the online version of this paper). We also observed similar operating characteristics for prehospital sBP for 24-hour mortality (Data Supplement S9 eTable 3, available as supporting information in the online version of this paper).

DISCUSSION

We observed that initial prehospital sBP alone is a modest classifier of 30-day mortality among noncardiac arrest, nontrauma encounters. Despite a strong association between prehospital hypotension and outcome, we found that traditional (≤90 mm Hg) and best-performing sBP thresholds in a data-driven analysis will substantially misclassify low-risk patients. Whether applied to prehospital triage or protocol-based care, most initial sBP thresholds are inadequate to identify patients at high risk for mortality.

Hypotension during emergency care occurs in acute myocardial infarction,[22,23] acutely decompensated congestive heart failure,[24,25] sepsis,[26] and many other conditions. With heterogeneous pathophysiology and variable presentation, the optimal clinical definition of prehospital hypotension is unknown. Investigators performing observational studies, and those designing clinical trials, use a broad range of sBP thresholds to identify subjects.[6,9,27] The epidemiology of prehospital hypotension and potential interventions are thus derived from a patchwork of nonoverlapping cohorts. Our study moves beyond previously published definitions to associate the entire range of prehospital sBP with patient-centered outcomes. These data offer a foundation for EMS policy-makers, researchers, and clinicians to develop evidence-based definitions of prehospital shock or high-risk hypotension by defining the performance of this simple measurement.[10,28]

Our data-driven methods identified best-performing thresholds for prehospital sBP that are higher than traditionally reported,[7] but identified by others.[8] Many clinical and research scenarios motivate the dichotomization of prehospital sBP, including the implementation of EMS protocols, triage tools for high-risk patients, or enrollment into clinical trials. Depending on the desired effect, each objective may necessitate a different "optimal" threshold. For simplicity, we defined thresholds that balance the consequences of false-positive and false-negative classification. We illustrate that traditional cutoffs (sBP ≤ 90 mm Hg) misclassify a large proportion of high-risk patients as having a low risk for a bad outcome, while higher thresholds (sBP ≤ 110 mm Hg) misclassify many low-risk patients as high risk for bad outcome. When the risks of falsely classifying a low-risk patient as high-risk are few (i.e., observational studies or safe interventions), these data support a higher threshold for sBP than is traditionally used. Conversely, when intensive resources are

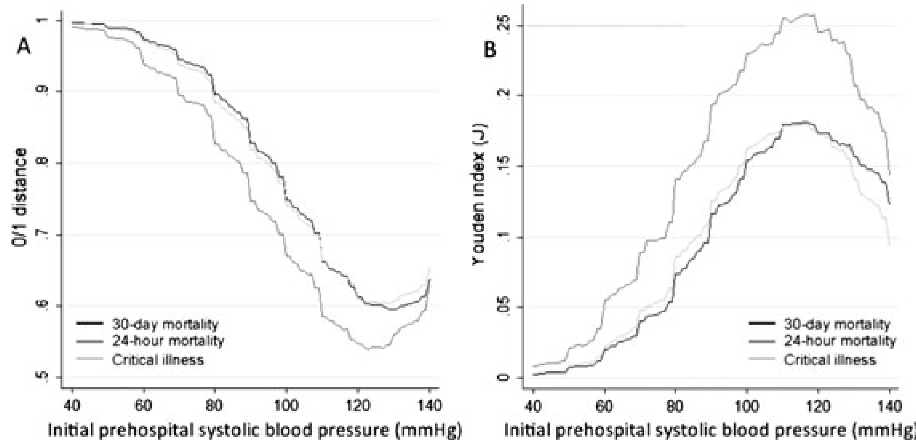

Figure 4. (A) 0/1 distance on the ROC curve for each outcome across the range of thresholds for prehospital sBP in the derivation cohort. Lower values of the 0/1 distance correspond to more optimal thresholds from the ROC curve. (B) Youden index for prehospital sBP thresholds for each outcome in the derivation cohort. Greater values of the Youden index (J) correspond to a larger vertical distance from the 45-degree line on the receiver operating characteristic curve. *Black line* corresponds to 30-day mortality, *dashed line* to 24-hour mortality, and *gray line* to critical illness during hospitalization.

Table 2
Operating Characteristics Prehospital sBP Thresholds for 30-day Mortality in the Validation Cohort

	Dichotomizing Threshold (mm Hg)			
Operating characteristics	≤ 80	≤ 90	≤ 100	≤ 110
True-positive (*n*)	63	109	173	246
False-positive (*n*)	438	913	1,816	3,543
True-negative (*n*)	20,760	20,285	19,382	17,655
False-negative (*n*)	759	713	649	576
Sensitivity,%	7.6 (5.9–9.7)	13.3 (11–15.8)	21 (18.3–24.0)	29.9 (26.8–33.2)
Specificity,%	98 (97.7–98.1)	95.7 (95.4–96.0)	91.4 (91.0–91.8)	83.3 (82.8–83.8)
Positive likelihood ratio	3.7 (2.9–4.8)	3.1 (2.6–3.7)	2.5 (2.1–2.8)	1.8 (1.6–2.0)
Negative likelihood ratio	0.94 (0.92–0.96)	0.91 (0.88–0.93)	0.86 (0.83–0.9)	0.84 (0.8–0.88)

Values in parentheses are 95% CI.

invoked or risky interventions are implemented, the high threshold (sBP ≤ 110 mm Hg) may be unacceptable, as it may classify too many low-risk patients as high-risk.

Our results are also consistent with the observation that strongly associated markers are not always good clinical discriminators.[29] Notably, prehospital hypotension is strongly associated with mortality in previous studies,[6,30,31] but only a modest discriminator of 30-day mortality herein. We specifically evaluated how well initial sBP classifies patients in the real world, rather than merely test an association between sBP and outcome. Taken together, prehospital sBP would not be considered acceptable as a singular tool for emergency triage, and additional clinical variables,[4] point-of-care biomarkers,[32,33] or advanced diagnostics[34] may be required to improve categorization. The combination of clinical variables and molecular diagnostic methods could augment classification of target phenotypes.

LIMITATIONS

Our data derive from two-tiered EMS agencies that serve a primarily urban and semiurban catchment. The external validity of the performance of prehospital sBP thresholds may be different among cohorts with longer transport distances, greater use of air medical transport or in other U.S. regions. We acknowledge that the duration or "worst" measurements of sBP during prehospital care may offer improved discrimination,[31] but these data are difficult to reproducibly define in "real-world" care. Future implementation of triage tools or prognostic models that incorporate "worst" sBP may be more difficult to implement in the ambulance, and we elected to study initial sBP measurements. Finally, the exclusion of records with missing covariate data may bias our cohort to a lower severity.[21] We found no differences in outcomes between patients who were missing or were not missing prehospital sBP, and our multiple imputation sensitivity analyses were unrevealing. We also note that measurements of sBP in austere environments may be less accurate than in controlled settings and may be nonindependent among repeat patients in the data set.[35] Additional unmeasured variables may also confound our analysis of Z-statistics for sBP thresholds, including do-not-attempt-resuscitation status, patient comorbidities, or preferences and deserve future study.

CONCLUSIONS

Prehospital systolic blood pressure was a modest discriminator of 30-day mortality among noninjured emergency medicine services encounters. Based on a range of analytical approaches, traditional and best-performing systolic blood pressure thresholds misclassify a substantial proportion of patients.

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Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. Supplementary content.

Data Supplement S2. Schematic of tests used to determine optimal dichotomizing threshold from the receiver operating characteristic curve.

Data Supplement S3. eMethods.

Data Supplement S4. Distribution of outcomes and discrimination of prehospital SBP among patients.

Data Supplement S5. Distribution of prehospital systolic blood pressure in the derivation (*top histogram*) and validation (*lower histogram*) cohorts.

Data Supplement S6. Receiver operating characteristic curve of prehospital SBP (mmHg) for 24-hour mortality in the derivation cohort.

Data Supplement S7. (A) Z statistic from fully adjusted logistic regression models of each outcome over the range of prehospital SBP thresholds in the derivation cohort. Model includes covariates for patient demographics, pre-hospital physiology, transport mode, level of service (ALS vs. BLS), and fixed effects for fire agency, receiving hospital, and year in cohort. Black line corresponds to 30-day mortality, dashed line to 24-hour mortality, and grey line to critical illness during hospitalization. (B) Z statistics from models in derivation cohort after multiple imputation of missing data.

Data Supplement S8. Operating characteristics prehospital SBP thresholds for 24-hour mortality in the validation cohort.

Data Supplement S9. Operating characteristics for prehospital SBP threshold ≤ 110mmHg in selected EMS conditions.