

Isolated prehospital hypotension correlates with injury severity and outcomes in patients with trauma

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ABSTRACT

Objective Patients normotensive in the trauma bay despite documented prehospital hypotension may not be recognized as significantly injured. The purpose of this study was to determine whether isolated prehospital hypotension portends poor outcomes and correlates with injury severity.

Methods Prospective cohort study conducted at a level 1 university trauma center. The lowest recorded prehospital systolic blood pressure (SBP) and the first recorded SBP on hospital arrival were used to divide patients into either the normotensive (NP) or hypotensive (HP) group. Patients who failed to achieve normotension on hospital arrival were excluded. Hypotension was defined as $SBP \leq 110$ mmHg.

Results Compared to NP (n=206), HP (n=81) had lower Glasgow Coma Scores both prehospital (12.81 ± 0.44 vs 14.38 ± 0.13) and at hospital admission (12.78 ± 0.47 vs 14.37 ± 0.14). Injury Severity Score positively correlated with prehospital hypotension (HP 12.27 ± 1.12 vs NP 9.22 ± 0.49). Prehospital hypotension positively correlated with intensive care unit (ICU) admission (HP 56.79% vs NP 22.82%), ICU length of stay (LOS) (HP 3.23 ± 0.71 vs NP 0.71 ± 0.17), hospital LOS (HP 8.58 ± 1.39 vs NP 4.86 ± 0.33), ventilator days (HP 3.38 ± 1.20 vs NP 0.27 ± 0.08 days), and repeat hypotensive episodes during their hospital stay (HP 81.71% vs NP 38.16%). HP also required more packed red blood cells in the first 24 hours after admission (22% vs 6%). Significance was set at $p < 0.05$.

Conclusions Isolated prehospital hypotension in patients in the trauma and emergency department correlates with increased injury severity and portends worse outcomes despite a normal blood pressure reading at admission. Prehospital hypotension must be given heavy consideration in triage, as these patients may be transiently hypotensive and appear less critical than their true status.

Level of Evidence Level II, Prognostic study.

BACKGROUND

Among the principal vital signs, blood pressure offers medical providers valuable insight into certain aspects of their patients' clinical status, such as intravascular volume and degree of hemorrhagic shock. Hypotension has also been found to correlate with injury severity, morbidity, and mortality.^{1–3} Therefore, blood pressures recorded in the emergency department (ED) are given strong consideration in triage decision-making.⁴

Of the traumatically injured patients evaluated in the trauma bay or ED with normal blood pressure readings, there exists a subset of patients who have transient documented hypotension prior to arrival (eg, at the referring hospital or en route with

emergency medical services (EMS)). Previous retrospective research has shown that this group of patients may be at risk for undertriage and delayed treatment.⁵ Other studies, however, have shown that EMS blood pressure recordings are not always accurate, pointing to factors such as environmental noise and distractions at the scene.^{6–8} As a result, the value of EMS blood pressure recordings remains controversial.

The purpose of our study is to evaluate the relationship of isolated prehospital hypotension to injury severity and ultimate outcome in patients with trauma who arrive normotensive. The use of a prospective cohort was implemented to minimize recall bias and confounders, as well as to offer a more accurate analysis compared to previous retrospective studies. In addition, our study takes place in a predominantly urban setting, which serves as a contrast to similar studies conducted in the rural population.⁵ We hypothesize that isolated prehospital hypotension portends negative outcomes and serves as an indicator of injury severity.

METHODS

This prospective cohort study was conducted at The Nebraska Medical Center (TNMC), a 735-bed, level 1 trauma center averaging ~1400 patients with trauma each year. Data were collected between May and August 2014 from the TNMC trauma registry, patient charts, the Electronic Nebraska Ambulance Rescue Service Information System, and referring hospitals. From these sources, we obtained patient demographics, prehospital and admission systolic blood pressure (SBP), prehospital and admission Glasgow Coma Scores (GCS), injury severity score (ISS), injury location and mechanism, hospital length of stay (LOS), intensive care unit (ICU) admission rate and ICU LOS, ventilator days, repeat hypotensive episodes, and administration of packed red blood cells (PRBC) during the hospital stay (tables 1–3). Unless otherwise stated, 'admission' refers to arrival at the trauma bay or ED. Patients were excluded if they remained hypotensive on admission, if they were transferred by a non-EMS service and thus had no prehospital SBP documentation, or if they had incomplete data (figure 1). Approval for this study was obtained from the University of Nebraska Medical Center Institutional Review Board.

While hypotension has traditionally been defined as an $SBP \leq 90$ mm Hg, recent studies suggest that higher values are more accurate. Therefore, we defined hypotension as an $SBP \leq 110$ mm Hg, consistent with current evidence.^{9–11} For comparison, we also analyzed outcomes using the traditional hypotension definition of $SBP \leq 90$ mm Hg. For

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Table 1 Patient demographics

	Hypotensive patients (n=81)	Normotensive patients (n=206)	p Value
Sex	Female: 33 Male: 48	Female: 82 Male: 124	0.77
Age	38.8±2.7	51.1±1.6	<0.0001
Method of transport	Ambulance: 62 Helicopter: 19 Police: 0	Ambulance: 184 Helicopter: 20 Police: 2	0.0078
Injury mechanism	Blunt: 73 Burn: 1 Penetrating: 7	Blunt: 190 Burn: 2 Penetrating: 14	0.7593
Injury location	Head: 27 Head, thorax: 2 Head, appendage: 10 Thorax: 4 Back: 4 Other: 34	Head: 65 Head, thorax: 11 Head, appendage: 19 Thorax: 10 Back: 11 Other: 90	0.8649

Data are presented as mean±SE.

Table 2 Injury severity data

	Hypotensive patients	Normotensive patients	p Value
Average prehospital SBP	99.11±1.75 mm Hg	143.44±1.59 mm Hg	<0.0001
Average ED SBP	132.65±1.39 mm Hg	148.47±1.69 mm Hg	<0.0001
Average prehospital GCS	12.81±0.44	14.38±0.13	<0.0001
Average ED GCS	12.78±0.47	14.37±0.14	<0.0001
ISS	12.27±1.12	9.22±0.49	<0.0001

Data are presented as mean±SE.

ED, emergency department; GCS, Glasgow Coma Score; SBP, systolic blood pressure.

each patient, the lowest recorded prehospital SBP (either from EMS or the referring hospital) and the first recorded SBP on arrival at the trauma bay or ED were used. Statistical methods for linear models were used for continuous variables.¹² χ^2 or Fisher exact tests were used for categorical variables depending on whether or not the observed number in each cell was >5 .¹³ t-Test was used for the comparisons of two continuous samples, but if data were skewed and sample sizes small, then the Mann-Whitney-Wilcoxon test was used. This is a non-parametric method, which was used for testing if two samples were from the same distribution.¹⁴ Statistical significance was defined as $p<0.05$. All the analyses were performed using SAS 9.4.

RESULTS

Two hundred eighty-seven patients met the inclusion criteria. Patients normotensive in the trauma bay or ED were divided into either the normotensive group (NP) or hypotensive group (HP) based on prehospital SBP. Patient sex, injury mechanism, and injury location did not significantly differ between the NP and HP groups. Patients in the HP cohort tended to be younger and were more likely to be transported via helicopter compared to the NP group (table 1).

Compared to NP (n=206 patients), hypotensive patients (HP) (n=81 patients) had lower GCS both prehospital (12.81±0.44 vs 14.38±0.13, $p<0.05$) and at hospital admission (12.78±0.47 vs 14.37±0.14, $p<0.05$). ISS positively correlated with

Table 3 Outcomes data, hypotension defined as SBP ≤ 110 mm Hg

	Hypotensive patients	Normotensive patients	p Value
ICU admissions	56.79%	22.82%	<0.0001
ICU LOS (days)	3.23±0.71	0.71±0.17	<0.0001
Hospital LOS	8.58±1.39	4.86±0.33	0.0105
Ventilator days	3.38±1.20	0.27±0.08	0.0001
Repeat hypotensive episodes	81.48%	38.35%	<0.0001
PRBC in first 24 hours	22%±8%	6%±2%	0.0114

Data are presented as mean±SE or percent (patients).

ICU, intensive care unit; LOS, length of stay; PRBC, packed red blood cells; SBP, systolic blood pressure.

prehospital hypotension (HP 12.27±1.12 vs NP 9.22±0.49, $p<0.05$) (table 2).

With regard to medical outcomes, prehospital hypotension had a positive correlation with ICU admission (HP 56.79% vs NP 22.82%, $p<0.05$), ICU LOS (HP 3.23±0.71 vs NP 0.71±0.17, $p<0.05$), hospital LOS (HP 8.58±1.39 vs NP 4.86±0.33), ventilator days (HP 3.38±1.20 vs NP 0.27±0.08 days, $p<0.05$), and repeat hypotensive episodes during hospital stay (HP 81.71% vs NP 38.16%, $p<0.05$). HP also required more packed red blood cells in the first 24 hours after admission (22% vs 6%) (table 3).

The outcome variables for HP compared to NP were also investigated using the traditional hypotension definition of SBP ≤ 90 mm Hg, and similar results were observed (table 4).

DISCUSSION

The most important findings of this prospective cohort study is that isolated prehospital hypotension is an indicator of injury severity in patients who arrive normotensive at the ED or trauma bay and also portends worse outcomes in these patients. These conclusions are supported by previously published retrospective reviews.^{3,5} Our study also supports the use of SBP ≤ 110 mm Hg as the definition for hypotension in patients with trauma.

HP patients were found to have significantly lower EMS and ED GCS and had higher ISS, all indicating that the HP group suffered more critical injuries than did the NP group. Neither the ISS nor GCS is calculated using SBP; therefore, the correlation between the three may be considered independent yet accurate measures of injury severity. ISS and GCS also have been shown to be valuable predictors of ICU LOS;¹⁵ therefore, our study supports that ISS may be considered both a marker of injury severity and a predictor of patient outcomes.

HP were shown to have worse outcomes after admission than NP, as HP were more likely to be admitted to the ICU and had a higher LOS in the ICU and in the hospital, spent over nine times more days on the ventilator, experienced more episodes of repeat hypotension during their hospital stay, and required more PRBC than did the NP group. Not only are these negative outcomes in themselves, but they also each pose further potential complications. For example, ICU LOS has been found to positively correlate with increased risk of iatrogenic infections, hospital mortality, and costs.^{16,17} Repeat hypotension during the hospital stay itself has been found to be a reliable predictor of adverse hospital outcomes and mortality, especially if prolonged.^{18,19}

As expected, sex, injury mechanism, and injury location did not significantly differ between our group of HP and NP. HP

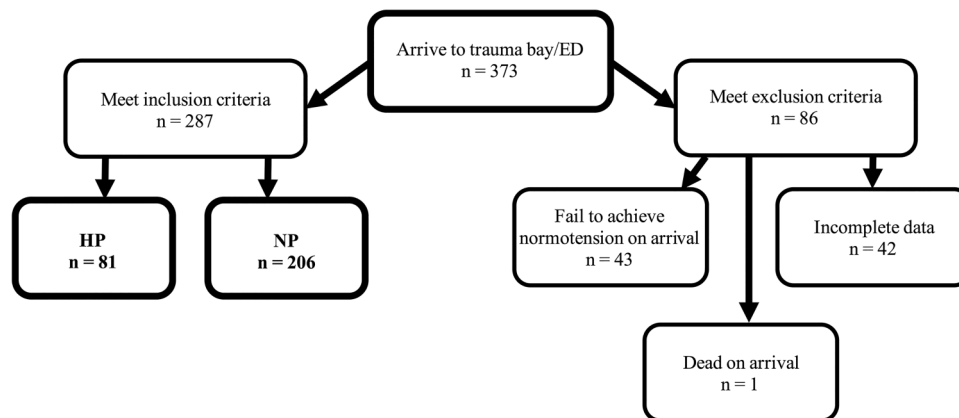


Figure 1 Flow diagram illustrating breakdown of exclusion and inclusion criteria. ED, emergency department; HP, hypotensive; NP, normotensive.

however, were younger compared to NP. This is perhaps a function of age, as SBP is known to increase with age.²⁰ However, given that younger age historically portends improved outcomes for any given ISS,²¹ this finding relative to transient prehospital hypotension is significant.

Until now, similar studies have used the traditional definition of hypotension as SBP ≤ 90 mm Hg; however, the current literature suggests that this definition may be too low. For this reason, we used the hypotension threshold of SBP ≤ 110 mm Hg and compared those outcomes using the traditional SBP ≤ 90 mm Hg definition. It is highly significant that we observe similar results using a greater hypotension threshold, even though this expansion increased the likelihood of including more 'healthy' patients in the hypotensive group. Therefore, emergency and trauma physicians should take prehospital hypotension seriously and also not be quick to judge a patient with an admission SBP between 90 and 110 mm Hg as being simply 'normotensive.'

Though they may appear euvoletic based on admission SBP, patients with isolated prehospital hypotension are at risk for undertriage. Conceivably, this may lead to improper level of care assignment, inadequate treatment, and ultimately poorer outcomes. Better recognition and appropriate triage of patients with trauma with documented prehospital hypotension, therefore, may help minimize poor outcomes in patients with trauma.

Our study provides further evidence for the value of assessing prehospital hypotension in patients with trauma and does so in different ways than previous similar studies. As a prospective cohort, we were able to minimize recall bias and other

confounders. Our research adds further support to the conclusions of previous retrospective reviews such as the study by Schenarts *et al.*⁵ Additionally, it provides a nice comparison between the urban and rural population and their associated differences in transport times. Potential limitations to our study include lack of discharge disposition data in evaluating outcomes, that is, discharge to home, rehabilitation center, nursing home, etc. We also did not evaluate mortality rate between HP and NP groups, which would certainly be of value in future studies. In addition, the exclusion of patients with incomplete data may have led to a selection bias in our sample population.

Prehospital SBP should be highly considered in trauma center and emergency department triage decisions. Compared to the historic ISS and GCS, prehospital SBP proves to also offer a valuable assessment of injury severity and a patient's status without the need of a formula or calculation. For patients transferred in from referring hospitals or by EMS, it is not uncommon for the trauma physician to receive incomplete information regarding the patient. EMS crews should be encouraged to make their best efforts in recording accurate SBPs, and all episodes of prehospital hypotension need to be relayed to the receiving trauma team. For patients who are transferred from other hospitals, records should be sent promptly and in their entirety, especially records of vital signs. In the process of our research, we found that documentation from transferring hospitals was often incomplete. With the continued implementation of electronic medical charting systems, it is tenable that this information will be more easily accessible.

Table 4 Outcomes data, hypotension defined as SBP ≤ 90 mm Hg

	Hypotensive patients (n=20)	Normotensive patients (n=272)	p Value
ICU admissions	70%	30.51%	0.0008
ICU LOS (days)	1	0	0.0002
Hospital LOS	6.5	4	0.0011
Ventilator days	0	0	0.0024*
Repeat hypotensive episodes	85%	48.53%	0.0019
PRBC in first 24 hours	20%	3.69%	0.0105

Data are presented as median or percent (patients).

*HP were found to have significantly higher ventilator days compared to NP based on the Mann-Whitney-Wilcoxon test despite equivalent medians. Detailed explanation is provided in the Methods section.

ICU, intensive care unit; LOS, length of stay; PRBC, packed red blood cells; SBP, systolic blood pressure.

CONCLUSIONS

This study demonstrates that isolated prehospital hypotension in patients at the trauma and emergency department, defined by an SBP ≤ 110 mm Hg, correlates with increased injury severity and also portends poor outcomes for patients despite normal blood pressure readings on admission. These outcomes include increased hospital LOS, increased admissions to the ICU and increased LOS in the ICU, increased risk of future hypotensive episodes during the hospital admission, increased ventilator days, and increased frequency of blood transfusions. Prehospital hypotension must be given heavy consideration in triage, as these patients may be transiently hypotensive and appear less critical than their true status.

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Competing interests None declared.

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REFERENCES

- Shapiro NI, Kociszewski C, Harrison T, Chang Y, Wedel SK, Thomas SH. Isolated prehospital hypotension after traumatic injuries: a predictor of mortality? *J Emerg Med* 2003;25:175–9.
- Lipsky AM, Gausche-Hill M, Henneman PL, Loffredo AJ, Eckhardt PB, Cryer HG, de Virgilio C, Klein SL, Bongard FS, Lewis RJ. Prehospital hypotension is a predictor of the need for an emergent, therapeutic operation in trauma patients with normal systolic blood pressure in the emergency department. *J Trauma* 2006;61:1228–33.
- Codner P, Obaid A, Porral D, Lush S, Cinat M. Is field hypotension a reliable indicator of significant injury in trauma patients who are normotensive on arrival to the emergency department? *Am Surg* 2005;71:768–71.
- Lehmann R, Brounts L, Lesperance K, Eckert M, Casey L, Beekley A, Martin MA. A simplified set of trauma triage criteria to safely reduce overtriage: a prospective study. *Arch Surg* 2009;144:853–8.
- Schenarts PJ, Phade SV, Agle SC, Goettler CE, Sagraves SG, Newell MA, Rotondo MF. Field hypotension in patients who arrive at the hospital normotensive: a marker of severe injury or crying wolf? *N C Med J* 2008;69:265–9.
- Prasad NH, Brown LH, Ausband SC, Cooper-Spruill O, Carroll RG, Whitley TW. Prehospital blood pressures: inaccuracies caused by ambulance noise? *Am J Emergency Med* 1994;12:617–20.
- Low RB, Martin D. Accuracy of blood pressure measurements made aboard helicopters. *Ann Emerg Med* 1988;17:604–12.
- Hunt RC, Allison EJ Jr, Whitley TW, Robinson MJ, Smart TL. Comparison of EMT blood pressure measurements with an automated blood pressure monitor: on scene, during transport, and in the emergency department. *Ann Emerg Med* 1985;14:871–5.
- Bruno B, Gentilello L, Elliott A, Shafi S. Prehospital hypotension redefined. *J Trauma* 2008;65:1217–21.
- Eastridge BJ, Salinas J, McManus JG, Blackburn L, Bugler E, Cooke W, Concertino V, Wade C, Holcomb J. Hypotension begins at 110 mm Hg: redefining “hypotension” with data. *J Trauma* 2007;63:291–9.
- Berry C, Ley EJ, Bukur M, Malinoski D, Margulies D, Mirocha J, Salim A. Redefining hypotension in traumatic brain injury. *Injury* 2012;43:1833–7.
- Little R, Stroup W, Freund R. *SAS for Linear Models*. 4th Ed. Cary, NC: SAS Institute, 2002.
- Agresti A. *Categorical data analysis*. 3rd edn. Hoboken, New Jersey: John Wiley & Sons, 2013.
- Randels RH, Wolfe DA. *Introduction to the theory of nonparametric statistics*. New York: John Wiley & Sons, 1979.
- Böhmer AB, Just KS, Lefering R. Factors influencing lengths of stay in the intensive care unit for surviving trauma patients: a retrospective analysis of 30,157 cases. *Crit Care* 2014;18:R143.
- Vincent JL, Rello J, Marshall J, Silva E, Anzueto A, Martin CD, Moreno R, Lipman J, Gomersall C, Sakr Y. International study of the prevalence and outcomes of infection in intensive care units. *JAMA* 2009;302:2323–9.
- Wunsch H, Gershengorn H, Scales DC. Economics of ICU organization and management. *Crit Care Clinics* 2012;28:25–37.
- Jones AE, Aborn LS, Kline JA. Severity of emergency department hypotension predicts adverse hospital outcome. *Shock* 2004;22:410–14.
- Bilello JF, Davis JW, Lemaster D, Townsend RN, Parks SN, Sue LP, Kaups KL, Groom T, Egbalieh B. Prehospital hypotension in blunt trauma: identifying the “Crump Factor”. *J Trauma Acute Care Surg* 2011;70:1038–42.
- Pinto E. Blood pressure and ageing. *Postgrad Med J* 2007;83:109–14.
- Perdue PW, Watts DD, Kaufmann CR, Trask AL. Differences in mortality between elderly and younger adult trauma patients: geriatric status increases risk of delayed death. *J Trauma* 1998;45:805–10.