The American Journal of Surgery 220 (2020) 1319–1322

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Narrow pulse pressure is independently associated with massive transfusion and emergent surgery in hemodynamically stable trauma patients

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ARTICLE INFO

Article history:
Received 14 February 2020
Received in revised form
1 May 2020
Accepted 25 June 2020

Keywords:
Pulse pressure
Trauma
Blood transfusion

ABSTRACT

Introduction: Narrow pulse pressure (PP) is a sign of Class-II hemorrhage, but its clinical relevance is unknown. We hypothesized narrow PP is related to significant transfusion and need for emergent surgery.
Methods: Hemodynamically stable (SBP >/ = 90 mmHg) trauma patients were retrospectively reviewed. Narrow PP patients (<40 mmHg) were compared to normal patients (>/ = 40 mmHg). Outcomes included need for significant transfusion (>/ = 10 units) and emergent cavitary surgery.
Results: From 18,978 hemodynamically stable trauma patients admitted, 13% had narrow PP. They statistically required more massive transfusion, emergent surgery, or both ($p < 0.0001$), as well as higher mortality, longer hospital stay, and ICU stay ($p < 0.0001$). After controlling for age, gender, injury, ISS and GCS, NPP was independently associated with both significant transfusion and emergent surgery.
Conclusion: In hemodynamically stable trauma patients, narrow PP is independently associated with three-fold increase in significant transfusion need and two-fold increase in emergent surgery need. Early identification of these patients may lead to more accurate and optimal intervention.

Introduction

The significance of blood pressure as an indicator of intravascular volume, cardiac functionality and overall health status has been widely accepted and studied.[1,14] In the setting of trauma, hypotension hastens clinical decision-making, and yields early intervention such as blood transfusion[2,10] and operative intervention.[3] Extensive research has determined parameters of systolic blood pressure in a trauma setting that lead to increased mortality[4]; but to date, little research has been done on the clinical relevance of narrow pulse pressure (PP) in this same trauma population.[15-17]

Hemorrhage continues to be the leading cause of preventable death, and using physiologic parameters other than systolic blood pressure to identify hemorrhage early has significant clinical implications.[19,20] We hypothesize that narrow PP in normotensive trauma patients would be independently associated with an increased incidence for transfusion and emergent surgery. The specific aim of this study is to compare normotensive trauma patients with narrow vs. normal PP to determine differences in clinical outcomes.

Methods

The trauma registry at Dell Seton Medical Center at the University of Texas at Austin was retrospectively queried for all adult patients between January 1, 2010 and December 31, 2016. All hemodynamically stable (defined as pre-hospital and emergency department systolic blood pressure ≥ 90 mmHg) adult trauma patients were eligible for enrollment. Data collected included

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https://doi.org/10.1016/j.amjsurg.2020.06.042
0002-9610/

Table 1
Comparison of baseline characteristics.

	Narrow PP (<40 mmHg) N = 2486	Normal PP (>40 mmHg) N = 16492	p-value
Pre-hospital systolic (mmHg)	124 ± 27	138 ± 27	<0.0001
Pre-hospital pulse (beats per minute)	95 ± 21	92 ± 20	<0.0001
Pre-hospital GCS	13.5 ± 3.3	14 ± 2.6	<0.0001
ED systolic BP (mmHg)	118 ± 16	143 ± 21	<0.0001
ED pulse (beats per minute)	93 ± 22	88 ± 19	<0.0001
ED GCS	13.9 ± 3	14.4 ± 2.2	<0.0001
AIS head	.98 ± 1.6	.92 ± 1.5	0.07
AIS face	.29 ± .71	.28 ± 69	0.39
AIS chest	.95 ± 1.4	.69 ± 1.3	<0.0001
AIS abdomen	.59 ± 1.2	.34 ± 89	<0.0001
AIS extremities	1.3 ± 1.3	1.1 ± 1.2	<0.0001
AIS external	.65 ± .63	.59 ± .60	<0.0001
ISS	12 ± 11	10 ± 8	<0.0001

Continuous variables are presented as mean ± standard deviation.

demographics (age, gender, ethnicity), mechanism of trauma (blunt, penetrating), pre-hospital vital signs and Glasgow coma scale (GCS), emergency department vital signs and GCS, abbreviated injury scale (AIS) scores, and injury severity score (ISS). Patients with any narrow PP (<40 mmHg) readings on presentation were compared to those with a normal PP (≥40 mmHg). Continuous variables were dichotomized using clinically relevant cutoffs where appropriate; this included our normal PP value (40 mmHg).

The primary outcomes of the study were need for significant blood transfusion (defined as ≥10 units of blood at any time during presentation or hospitalization), emergent (requiring transfer of patient straight from emergency department to operating room during trauma activation secondary to hemodynamic instability or imaging findings) thoracoabdominal surgery (laparotomy, thoracotomy, or sternotomy), or combination of both significant blood transfusion and emergent surgery. Secondary outcomes measured were mortality, ICU length of stay, hospital length of stay, and ventilator days. Patients were excluded who had missing, 0, or negative PP. Statistical comparison of the two study groups (normal and narrowed PP) was then performed using univariate analysis with X^2 or Fischer exact test for proportions and *t*-test for comparison of means to identify significant differences in baseline characteristics. To derive outcome comparison between the study groups adjusting for differences in baseline characteristics, a multivariable analysis was performed for each of the outcomes of interest. The data were entered into a computerized spreadsheet and analyzed using SPSS version 9.4.

Adjusted outcome comparisons for age, gender, mechanism of injury, ISS, low GCS, and systolic blood pressure were derived from general linear model logistic regression. Adjusted mean differences with 95% confidence interval (CI) and adjusted p-values were derived from the equation. Values here are reported as mean ± standard deviation (SD), median (range) with interquartile range, or as raw percentage. Statistical significance was determined as $p < 00.05$ for all comparisons. The local institutional review board approved this study.

Results

Over six years, we identified 18,978 normotensive patients who were admitted to our trauma center, of which 2486 (13%) had a narrow PP (range 1–40 mmHg, mean 30 ± 17 mmHg). Patients with narrow PP were younger (43 vs. 46 years, $p < 0.0001$), more often female (68% vs. 63%, $p < 0.0001$), with no difference among ethnicities (72% vs. 71%, $p = 0.46$). Narrow PP patients more often sustained penetrating trauma (13% vs. 9%, $p < 0.0001$). In both the prehospital setting and the emergency department the narrow PP patients had a lower systolic blood pressure, higher pulse, and lower GCS (Table 1). In addition, narrow PP patients were more severely injured including higher AIS scores for all body regions (Table 1).

Table 2
Univariate comparison of narrow and normal pulse pressure.

	Narrow PP (<40 mmHg) N = 2486	Normal PP (>40 mmHg) N = 16492	p-value
Exploration[a]	181(7)	371(2)	<0.0001
Massive transfusion	133(5)	220(1)	<0.0001

[a] Defined as laparotomy, thoracotomy, or sternotomy.

Patients with narrow PP more often required laparotomy (7% vs. 2%, $p < 0.0001$), thoracotomy (0.8% vs. 0.3%, $p < 0.0001$), sternotomy (0.2% vs. 0.01%, $p < 0.0001$), or any emergent surgery (7% vs. 2%, $p < 0.0001$). Narrow PP patients more often received massive transfusion (5% vs. 1%, $p < 0.0001$) and the combination of significant transfusion and emergent surgery (3% vs. 0.43%, $p < 0.0001$). Narrow PP patients had a higher mortality (4% v 2%, $p < 0.0001$). Hospital length of stay (7 ± 9 v 5 ± 6, $p < 0.0001$), ICU length of stay (10 ± 8 v 1 ± 4, $p < 0.0001$), and ventilator days (0.9 ± 3.2 v 0.4 ± 2.1, $p < 0.0001$) were all longer in narrow PP patients, as well. Because the overwhelming majority of patients in this data set did not require ICU admission, only patients admitted to the ICU were considered for calculation of ICU LOS and days on the ventilator. Median hospital LOS was 3 days with interquartile range of 4. Using multivariate analysis and adjusting for age, gender, mechanism of injury, GCS, ISS, and systolic blood pressure, narrow PP was independently associated with the need for laparotomy, thoracotomy, sternotomy, and significant transfusion but was not associated with mortality (Tables 2 and 3).

Table 3
Adjusted outcomes.

Outcome	Adjusted OR[a]	Adjusted p-value[a]
Laparotomy	2.1 (1.7–2.6)	<0.0001
Thoracotomy	2.0 (1.1–3.4)	.02
Sternotomy	10.6 (1.9–58)	0.006
Any Exploration	2.2 (1.7–2.7)	<0.0001
≥10 units of blood	2.6 (2–3.3)	<0.0001
Exploration AND ≥10 units of blood	3.4 (2.3–4.9)	<0.0001
Death	1.3 (0.95–1.78)	0.1

[a] Variables included in the regression model: age, gender, mechanism of injury, ISS, GCS, systolic blood pressure.

Table 4
ATLS classes of hemorrhagic shock.

	Class I	Class II	Class III	Class IV
Blood Loss (%)	<15	15–30	30–40	>40
Pulse Rate (bpm)	<100	100–120	120–140	>140
Blood Pressure	Normal	Normal	Decreased	Greatly decreased
Pulse Pressure	Normal or Increased	**Decreased**	**Decreased**	**Decreased**
Respiratory Rate (respirations/min)	14–20	20–30	30–40	>35
Mental Status	Slightly anxious	Mildly anxious	Anxious, Confused	Confused, Lethargic
Urine Output (mL/hr)	>30	20–30	5–15	Minimal

Discussion

Our retrospective data assessing almost 19,000 normotensive trauma patients concludes that in this urban patient population, a narrowed PP was independently associated with significant blood product transfusion, emergent surgery, and the combination of both significant transfusion and emergent surgery. Its association with increased mortality, hospital stay, and ICU stay on univariate analysis is also worth recognizing.

Pulse pressure is defined as the difference between the systolic and diastolic blood pressures. Significant blood loss, as in the trauma population, can yield decreases in both stroke volume and preload with subsequent decreases in pulse pressure.[5,9,13] Advanced Trauma Life Support (ATLS) is a course taught by, and utilized for, medical professionals providing care to trauma patients in both pre-hospital and in-hospital settings.[6] Initial vital signs are the most utilized objective findings for quickly determining appropriate level of activation in trauma centers.[7,11] Traditionally, ATLS teaches that a narrowed PP, defined as the difference between systolic and diastolic blood pressure, can be an early sign of hemorrhagic shock despite a normal systolic blood pressure[8] (see Table 4).

Class II hemorrhagic shock (acute blood loss >750 ml, or >15% of patient's blood volume) is associated with a decreased PP, notable as this value is sometimes the first amongst other quantitative values to change.[18] Local trauma activations determine the amount of resources and personnel to be mobilized in order to care for a patient based on the expected level of acuity. A recent and growing body of evidence now shows the predictive value of narrow PP and its clinical relevance in a trauma setting to outcomes.[12,21–23]

Warren et al. studied a retrospective group of 957 patients with narrowed PP, and found these patients were more likely to require massive transfusion or emergent surgery as in our study, and more often had higher numbers of penetrating injuries. Zhu et al. assessed a smaller cohort of adult patients requiring massive transfusion, alternatively found their population with narrowed PP to more often have blunt injuries, and that narrowed PP was again a positive predictor for mortality. Finally, a recent study from Priestly et al. of 18,000 trauma patients examined retrospectively, showed that a narrow initial emergency department PP was an independent predictor of active hemorrhage.

Certain populations may have an elevated pulse pressure that exist at baseline. Young, athletic patients have progressively increased stroke volume and cardiac output during exercise, in addition to decreased total peripheral resistance; this combination yields a higher PP. The geriatric population may also have a higher PP, but secondary to decreased compliance of large arteries or left ventricle. These changes may yield cardiac contractility against a stiffer arterial system, worsening subsequent hypertrophy, and widening PP further. To this point, a cutoff analysis in the study from Priestly et al. showed an inflection at 55 mmHg for patients ≥61 years old, and 40 mmHg for adult patients <60 years old, but our patient population showed no statistical differences among varying ages.

There were several limitations to this study. Our data was collected from a single institution and retrospective in nature. Additionally, patients with unrecorded or negative PP were omitted, indicative of possible user technical or administrative error in the emergency room setting. Not included in this cohort are those who underwent angioembolization alone, or those with isolated vascular injuries to the extremity. Still, narrow PP is associated with the need for significant transfusion and emergent thoracoabdominal surgery despite normal blood pressure.

In normotensive trauma patients, a narrow PP in the emergency department setting is independently associated with a three-fold increase in the need for significant blood transfusion, and a two-fold increase in the need for emergent surgery. These findings support the use of narrow PP as an integral part of the initial trauma assessment for patients who may otherwise be considered to be hemodynamically stable based on their other presenting vital signs. Early and accurate identification of these patients may allow for more appropriate and opportune intervention, and education of trauma activation staff may improve mobilization of resources for these patients. Further evaluation is warranted to determine whether identification of narrow PP and the resulting early blood product transfusion or operative intervention yields improved outcomes.

Author statement

Bankhead-Kendall: design, statistics, manuscript authorship, manuscript revision; guarantor of integrity Teixeira: design, statistics, manuscript authorship, manuscript revision Roward: manuscript authorship, manuscript revision Ali: design, statistics. Ryder: manuscript authorship, manuscript revision. Sahi: manuscript authorship. Cardenas: manuscript revision. Aydelotte: manuscript revision. Coopwood: manuscript revision. Brown: design, statistics, manuscript revision; guarantor of integrity.

Declaration of competing interest

No conflict of interest, no funding received for this work.

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