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An Eastern Association for the Surgery of Trauma multicenter trial examining prehospital procedures in penetrating trauma patients

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BACKGROUND:	Prehospital procedures (PHP) by emergency medical services (EMS) are performed regularly in penetrating trauma patients despite previous studies demonstrating no benefit. We sought to examine the influence of PHPs on outcomes in penetrating trauma patients in urban locations where transport to trauma center is not prolonged. We hypothesized that patients without PHPs would have better outcomes than those undergoing PHP.
METHODS:	This was an Eastern Association for the Surgery of Trauma–sponsored, multicenter, prospective, observational trial of adults (18+ years) with penetrating trauma to the torso and/or proximal extremity presenting at 25 urban trauma centers. The impact of PHPs and transport mechanism on in-hospital mortality were examined.
RESULTS:	Of 2,284 patients included, 1,386 (60.7%) underwent PHP. The patients were primarily Black (n = 1,527, 66.9%) males (n = 1,986, 87.5%) injured by gunshot wound (n = 1,510, 66.0%) with 34.1% (n = 726) having New Injury Severity Score of ≥16. A total of 1,427 patients (62.5%) were transported by Advanced Life Support EMS, 17.2% (n = 392) by private vehicle, 13.7% (n = 312) by police, and 6.7% (n = 153) by Basic Life Support EMS. Of the PHP patients, 69.1% received PHP on scene, 59.9% received PHP in route, and 29.0% received PHP both on scene and in route. Initial scene vitals differed between groups, but initial emergency department vitals did not. Receipt of ≥1 PHP increased mortality odds (odds ratio [OR], 1.36; 95% confidence interval [CI], 1.01–1.83; *p* = 0.04). Logistic regression showed increased mortality with each PHP, whether on scene or during transport. Subset analysis of specific PHP revealed that intubation (OR, 10.76; 95% CI, 4.02–28.78; *p* < 0.001), C-spine immobilization (OR, 5.80; 95% CI, 1.85–18.26; *p* < 0.01), and pleural decompression (OR, 3.70; 95% CI, 1.33–10.28; *p* = 0.01) had the highest odds of mortality after adjusting for multiple variables.
CONCLUSION:	Prehospital procedures in penetrating trauma patients impart no survival advantage and may be harmful in urban settings, even when performed during transport. Therefore, PHP should be forgone in lieu of immediate transport to improve patient outcomes. (*J Trauma Acute Care Surg.* 2021;91: 130–140. Copyright © 2021 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)
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The establishment of Advanced Life Support (ALS) by emergency medical services (EMS) has led to an increasing number of procedures carried out in the field.[1] These procedures, such as intravenous (IV) fluid administration and intubation, may be beneficial in cardiac arrest, traumatic brain injury (TBI), and in rural settings where transportation to definitive care is prolonged.[2–4] Prehospital procedures (PHP) continue to be performed regularly in the United States for penetrating trauma patients despite numerous retrospective studies showing that these interventions in urban locations are not beneficial and perhaps even harmful.[1,2,5–7]

The prehospital (PH) care of acutely injured patients in the United States continues to evolve. The use of blood products in the PH setting has been shown to be beneficial in trauma patients undergoing air transport, which is not applicable to urban penetrating trauma.[8] The Control of Major Bleeding After Trauma trial evaluated PH plasma in urban trauma but was underpowered to study penetrating trauma.[9] The use of extremity tourniquets is now well established in PH care and has already been shown to improve mortality, particularly when applied before the onset of hemorrhagic shock.[10,11] Formal guidelines have been established for the use of tourniquets in the civilian setting for control of severe bleeding of penetrating as a measure of lower limb injuries.[12]

The optimal care for penetrating trauma in the urban setting may actually involve minimal PH intervention.[1,2,4,5] It is imperative to have a more complete understanding of the potential risks and benefits of PHP in this discrete patient population to appropriately tailor interventions to those who will most benefit and to abstain from performing procedures in populations in which they may be harmful or provide no benefit.

The deleterious effects of PHP in urban penetrating trauma are likely multifactorial.[3,4] Prehospital procedures, especially those carried out before transport, may delay transport to definitive care and, by extension, increase the time to definitive hemorrhage control.[1] In addition, animal studies have shown that some procedures such as endotracheal intubation may inherently cause physiological changes in exsanguinating penetrating trauma patients that exacerbate the shock state.[13–15] The goal of this study was to evaluate the influence of PHPs on outcomes in penetrating trauma patients in urban locations. We hypothesized that PHP would be associated with decreased survival in penetrating trauma patients in urban locations.

PATIENTS AND METHODS

This was an Eastern Association for the Surgery of Trauma (EAST)–sponsored, multicenter, prospective, observational trial of adults (18+ years) with penetrating trauma to the torso and/or proximal extremity who presented to 1 of the 25 participating urban trauma centers from May 2019 to May 2020. Torso was defined as the area between clavicles and above inguinal ligaments, pubic symphysis, and gluteal folds; proximal extremity was defined as proximal to elbow or knees. Patients were included if they presented with a gunshot or stab wound to the torso and/or proximal extremity. Patients with torso and/or proximal extremity penetrating injury combined with distal extremity penetrating injury or patients with penetrating torso and/or proximal extremity injury combined with a blunt injury were also included. This included patients with traumatic brain injury who also had penetrating injury to the torso and/or proximal extremity. Exclusion criteria included patients with isolated injury above the clavicle (including head or neck [including TBI]), distal extremity injury only (distal to elbows or knees), isolated blunt mechanism of injury, patients transferred from outside institutions, and known age 17 years or younger.

Data collected included patient demographics, type of PH transport (private vehicle, police vehicle, Basic Life Support [BLS crew], ALS crew), PH interventions, injuries and New Injury Severity Score (NISS), initial vital signs, initiation laboratory values, resuscitation requirements, mortality, location of and time to death (if applicable), hospital length of stay, intensive care unit length of stay, duration of mechanical ventilation, and complications as acute respiratory distress syndrome, venous thromboembolic events, acute kidney injury, and cerebrovascular accident. The specific PHP examined included the following: IV access, intraosseous access, fluid administration, bladder catheterization, endotracheal intubation, cervical spine immobilization, pleural decompression, tourniquet placement, pressure dressing application, cricothyrotomy, and pelvic stabilization. This study was conducted following approval from the appropriate institutional review board at each collaborating center.

Statistical Analysis

Patients were dichotomized into two groups based on whether they received PHP or not. Demographics, injury data, PH and emergency department (ED) variables, and in-hospital outcomes were compared between groups. Categorial values were described as frequencies, reported as n (%), and compared using χ^2 analysis or Fisher's exact test, where appropriate. Continuous variables were described as mean (SD) and compared using the Independent Samples t test. Percent survival of patients per number of PHP was examined and plotted. For each plot, χ^2 analysis with Yates' correction was used to determine if any number of PHP given was associated with probability of mortality. Univariate and multivariate logistic regression analyses were used to examine the relationship between patient variables and odds of mortality. The primary outcome of interest was in-hospital mortality. Incidence of in-hospital complications was the secondary outcome of interest. A p value of <0.05 was considered statistically significant. All statistical analyses were conducted using SPSS version 26 (IBM, Armonk, NY).

RESULTS

Patient Demographics

A total of 2,352 patients met inclusion criteria. Subjects with missing or unknown method of transport (n = 68) were excluded, yielding 2,284 patients for inclusion into the analysis (Fig. 1). Method of transport from most to least frequent was as follows: EMS ALS (n = 1,427, 62.5%), private vehicle (n = 392, 17.2%), police (n = 312, 13.7%), and EMS BLS (n = 153, 6.7%). Within the overall cohort, 60.7% (n = 1,386) received PHP and 39.3% (n = 898) did not. Demographic characteristics, injury data, and PH vitals are detailed in Table 1. Those who received PHP had significantly higher mean age and NISS (both $p < 0.001$), were more likely than the no prehospital procedure (N-PHP) group to be injured in the chest (47.0% vs. 39.6%; $p = 0.001$) and abdomen (39.7% vs. 33.3%; $p = 0.002$), and were less likely than the N-PHP group to be injured by gunshot (63.3% vs. 70.5%; $p < 0.001$). The proportion of patients with NISS of >15 was significantly higher in the PHP cohort (38.6% vs. 27.5%; $p < 0.001$), but the mean NISS in this subgroup did not differ between the PHP and N-PHP cohorts (32 vs. 33; $p = 0.84$). Mean initial PH Glasgow Coma Scale (GCS) and systolic blood pressure were both significantly lower in the PHP cohort ([14.3 vs. 13.7; $p = 0.02$] and [128 mm Hg vs. 121 mm Hg; $p = 0.03$], respectively), while mean initial heart rate and respiratory rate did not differ between the groups.
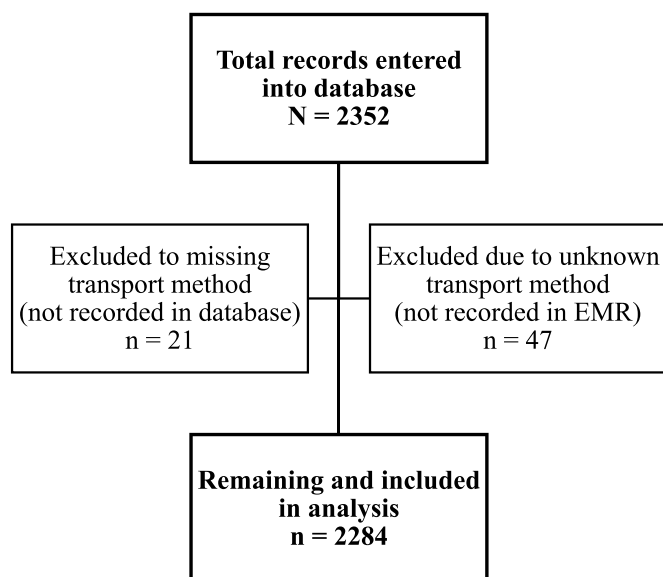
Figure 1. Flow chart detailing study inclusion.

Prehospital Procedures

Frequency and location of use of individual PHP are detailed in Table 2. The most commonly performed procedure was IV access (n = 1,211 of 1,386 patients, 87.4%) followed by fluid resuscitation (n = 666 of 1,386 patients, 48.1%) and application of pressure dressing (n = 409 of 1,386 patients, 29.5%). Endotracheal intubation was performed in 7.1% (n = 99) of PHP patients. The vast majority of those who received PH fluid resuscitation (n = 656 of 666 patients, 98.8%) received crystalloids. Only two patients received pelvic stabilization, and no patient received bladder catheterization or cricothyrotomy in this study. Of the PHP patients, 69.1% received PHP on scene, 59.9% received PHP in route, and 29.0% received PHP both on scene and in route. All PHP examined except for fluid resuscitation were more frequently performed while on scene than during transport. Univariate logistic regression was performed to examine the odds of mortality associated with each PHP. Intubation, intraosseous access, fluid resuscitation, cervical spine immobilization, and pleural decompression were all significantly associated with increased odds of mortality. Conversely, application of pressure dressings was found to be significantly associated with decreased odds of mortality (odds ratio [OR], 0.58; 95% confidence interval (CI), 0.38–0.90; $p = 0.01$) as was IV access (OR, 0.54; 95% CI, 0.40–0.72; $p < 0.001$). Tourniquet application was not found to be associated with mortality ($p = 0.30$). Receipt of any PHP increased odds of mortality (OR, 1.38; 95% CI, 1.27–1.51; $p < 0.001$). Number of procedures performed on scene, number performed during transport, and total number received in the PH arena were all found to be significantly associated with increased odds of mortality.

ED Resuscitation

The clinical condition of patients upon arrival to the ED as well as ED procedures and resuscitation requirements were examined (Table 3). The initial ED vital signs and shock index were similar between both subgroups. Only mean initial GCS differed significantly and was lower in the PHP cohort (13.5 vs. 14.0;

$p = 0.01$). Examination of the mean (SD) ED shock index in those who received PH fluids versus those who did not revealed no significant difference between the groups (0.79 [0.31] vs. 0.77 [0.28], respectively; $p = 0.06$). Resuscitation requirements for the first 24 hours were also similar between the groups despite massive transfusion protocol activation occurring more frequently in the PHP cohort compared with the N-PHP group (13.7% vs. 7.0%; $p < 0.001$). Compared with no PHP, the PHP group was significantly less likely to undergo ED procedures (29.0% vs. 11.6%; $p < 0.001$) and more likely to undergo emergent surgery (40.9% vs. 28.8%; $p < 0.001$). Logistic regression analysis of all patients with NISS of >15 revealed that emergent

TABLE 1. Descriptive Details of Patient Demographics, Injury Characteristics, and PH Vitals and Procedures

Demographics	Total (N = 2,284)	No PHP (n = 898, 39.3%)	PHP (n = 1,386, 60.7%)	p
Age, y*	32.5 (12.4)	31.2 (11.6)	33.3 (12.9)	<0.001
Male	1,986 (87.5)	803 (89.5)	1,183 (86.1)	0.02
Race				
White	446 (19.5)	116 (12.9)	330 (23.8)	<0.001
Black/AA	1,527 (66.9)	637 (71.0)	890 (64.3)	
Asian	16 (0.7)	5 (0.6)	11 (0.8)	
>1 Race	6 (0.3)	1 (0.1)	5 (0.4)	
Unknown	275 (12.1)	136 (15.2)	139 (10.0)	
Hispanic	248 (11.2)	97 (11.3)	151 (11.1)	0.12
Injury variables				
Gunshot wound	1,510 (66.0)	633 (70.5)	877 (63.3)	<0.001
Knife stab wound	777 (34.0)	266 (29.6)	511 (36.9)	<0.001
Injury location				
Chest	1,006 (44.1)	355 (39.6)	651 (47.0)	0.001
Abdomen	849 (37.2)	299 (33.3)	550 (39.7)	0.002
Pelvis	329 (14.4)	160 (17.8)	169 (12.2)	<0.001
Proximal extremity	1,128 (49.4)	489 (54.5)	639 (46.1)	<0.001
TBI	12 (0.5)	4 (0.4)	8 (0.6)	0.67
NISS*	14 (17)	12 (16)	16 (18)	<0.001
NISS >15	726 (34.1)	234 (27.5)	492 (38.6)	<0.001
NISS >15*	32 (19)	33 (18)	32 (19)	0.84
PH variables				
Method of transport				
ALS transport	1,427 (62.5)	149 (10.4)	1,278 (89.6)	<0.001
BLS transport	153 (6.7)	52 (34.0)	101 (66.0)	
Police transport	312 (13.7)	306 (98.1)	6 (1.9)	
Private vehicle	392 (17.2)	392	—	
Glasgow Coma Scale	13.8 (3.4)	14.3 (2.6)	13.7 (3.5)	0.02
Systolic blood pressure	121.7 (39.1)	128.0 (32.9)	121.0 (39.6)	0.03
Heart rate	93.8 (30.1)	93.3 (33.0)	93.9 (29.8)	0.50
Respiratory rate	18.8 (7.9)	18.4 (8.4)	18.8 (7.8)	0.81
Shock index (HR/SBP)	0.8 (0.4)	0.7 (0.2)	0.8 (0.4)	<0.001

*indicates mean (SD).

All other variables are frequencies presented as n (%).

AA, African American; ALS, Advanced Life Support; BLS, Basic Life Support; HR, heart rate; SBP, systolic blood pressure; TBI, traumatic brain injury.

TABLE 2. Frequency and Location of PHP Performed Followed by Univariate Logistic Regression Analysis Examining Association of Individual PHP With Odds of Mortality

PHP	n (%)	On Scene	Transport	OR	95% CI	*p*
Intubation	99 (7.1)	77 (5.6)	22 (1.6)	52.58	31.74–81.09	<0.001
IV access	1,211 (87.4)	673 (48.6)	587 (42.4)	0.54	0.40–0.72	<0.001
IO access	105 (7.6)	75 (5.4)	36 (2.6)	33.13	21.14–51.29	<0.001
Fluid resuscitation	666 (48.1)	216 (15.6)	437 (31.5)	1.52	1.14–2.04	0.01
Cricothyrotomy	0	0	0			
C-spine immobilization	78 (5.6)	63 (4.5)	15 (1.1)	4.42	2.66–7.36	<0.001
Pleural decompression	113 (8.2)	64 (4.6)	56 (4.0)	8.21	5.47–12.34	<0.001
Pelvic stabilization	2	1	1			
Pressure dressing	409 (29.5)	325 (23.4)	161 (11.6)	0.58	0.38–0.90	0.01
Tourniquet	108 (7.8)	86 (6.2)	29 (2.1)	0.66	0.30–1.44	0.30
Other	124 (8.9)	66 (4.7)	58 (4.2)	3.09	1.81–5.26	<0.001
No. scene PHP				1.66	1.48–1.87	<0.001
No. transport PHP				1.17	1.02–1.34	0.03
Total no. PHP				1.38	1.27–1.51	<0.001

All values for on-scene and transport PHP are frequencies presented as n (%). Percent was calculated using the number of patients who received PHP as the denominator.
C, cervical; IO, intraosseous.

surgery was associated with significantly reduced odds of mortality (OR, 0.17; 95% CI, 0.11–0.27; *p* < 0.001). Frequency of intubation, resuscitative balloon occlusion of the aorta (REBOA), ED thoracotomy, and tourniquet application did not differ between the groups.

Hospital Outcomes

In-hospital outcomes are detailed in Table 3. Patients who received PHP had longer mean lengths of stay (5.6 days vs. 4.0 days; *p* < 0.001) compared with the N-PHP group. The N-PHP cohort was more likely to not develop any complications during hospitalization compared with their PHP peers (95.3% vs. 92.2%, *p* < 0.01), while the PHP group was significantly more likely to develop acute respiratory distress syndrome (1.4% vs. 0.4%; *p* = 0.02), venous thromboembolism (1.9% vs. 0.6%; *p* < 0.01), and urinary tract infections (0.9% vs. 0.1%; *p* = 0.02). Other complications examined demonstrated no significant differences between the N-PHP and PHP groups, specifically acute kidney injury (1.1% vs. 1.9%; *p* = 0.15), pneumonia (0.8% vs. 1.4%; *p* = 0.09), cerebrovascular accident (0 vs. 0.2%; *p* = 0.16), and multiple organ dysfunction syndrome (0.3% vs. 0.5%; *p* = 0.55). Overall in-hospital mortality was higher in the PHP group compared with those who did not receive PHP (10.3% vs. 7.8%; *p* = 0.04), but there was no significant difference in time to death between the groups (*p* = 0.88).

Survival

Logistic regression examining variables associated with mortality are shown in Table 4 (A). The number of PHP carried out on scene (OR, 1.64; 95% CI, 1.38–1.96; *p* < 0.001) and during transport (OR, 1.33; 95% CI, 1.10–1.61; *p* < 0.01) were associated with mortality. Variables associated with mortality included increasing age, increasing injury severity, gunshot wounds, and injury to the chest. Logistic regression examining individual PHP in the PHP population is shown in Table 4 (B). Prehospital intubation was strongly associated with mortality (OR, 10.76; 95% CI, 4.02–28.78; *p* < 0.001). Other procedures found to be

associated with mortality included fluid resuscitation (OR, 1.00; 95% CI, 1.00–1.01; *p* = 0.01), C-spine immobilization (OR, 5.80; 95% CI, 1.85–18.26; *p* < 0.01), and pleural decompression (OR, 3.70; 95% CI, 1.33–10.28; *p* = 0.01). Prehospital IV placement was associated with survival (OR, 0.27; 95% CI, 0.10–0.76; *p* = 0.01). Other variables found to be associated with mortality in this model included increasing age, increasing NISS, and gunshot wounds. Increasing PH systolic blood pressure was associated with survival.

To further analyze PH crystalloid use, volumes of PH crystalloid given were categorized into groups by 250-mL increments, and logistic regression was performed. Prehospital crystalloid volumes of less than 250 mL, 251 to 500 mL, and 501 to 750 mL were not significantly associated with mortality when compared with no crystalloids. However, administration of crystalloid volumes larger than 750 mL was associated with mortality (OR, 3.10; 95% CI, 1.85–5.18; *p* < 0.001).

Logistic regression analysis of method of transport with private vehicle transport as the reference group revealed increased odds of mortality for both ALS (OR, 3.62; 95% CI, 1.99–6.59; *p* < 0.001) and police transport (OR, 5.50; 95% CI, 286–10.58; *p* < 0.001), while BLS transport was not found to be associated with odds of mortality (OR, 1.99; 95% CI, 0.82–4.83; *p* = 0.13). When age, injury severity, and mechanism of injury were accounted for, there were no longer any significant differences associated with method of transport and odds of mortality.

Percent survival was plotted against total number of PHP per patient, total number of on-scene PHP per patient, and total number of PHP performed during transport (Fig. 2A–C). Within the PHP cohort, PH providers/first responders performed 2.2 ± 1.2 (mean ± SD) procedures. The cohort received 1.1 ± 1.0 procedures on the scene and 1.0 ± 1.0 during transport. Trendlines in the plots suggest an inverse relationship between decreasing survival and number of PHP increases, and this trend is particularly evident within the examination of PHP performed on scene (Fig. 2B). In total number of PHP (Fig. 2A) and total

TABLE 3. Description of ED Vitals, Resuscitation Requirements, Procedures, and In-hospital Outcome Measures

Parameter	Total (N = 2,284)	No PHPs (n = 898)	PHPs (n = 1,386)	p
Direct OR admit, n (%)	81 (3.5)	25 (2.8)	56 (4.1)	0.10
ED vitals				
SBP	122.7 (40.7)	122.9 (42.0)	122.4 (39.7)	0.81
HR	90.6 (32.3)	91.4 (31.9)	89.9 (32.6)	0.36
Temp	36.6 (2.3)	36.7 (0.7)	36.5 (2.8)	0.15
RR	19.3 (8.4)	19.0 (7.9)	19.6 (8.7)	0.16
Shock index	0.77 (0.29)	0.78 (0.28)	0.77 (0.30)	0.67
GCS	13.7 (3.5)	14.0 (3.2)	13.5 (3.7)	0.01
Resuscitation, 1st 24 h				
PRBC, U	2.1 (16.0)	1.6 (6.5)	2.4 (19.8)	0.23
FFP, U	1.2 (4.8)	1.1 (5.5)	1.2 (4.4)	0.83
Platelets	0.5 (2.9)	0.4 (2.4)	0.6 (3.1)	0.17
Crystalloid, mL	2,032.5 (2,760.8)	1,943.2 (2,923.0)	2,090.1 (2,650.4)	0.28
MTP activation, n (%)	252 (11.0)	63 (7.0)	189 (13.7)	<0.001
ED procedures, n (%)				
None	505 (22.1)	105 (11.6)	400 (29.0)	<0.001
Intubation	238 (10.4)	89 (9.8)	149 (10.8)	0.44
IV access	1,439 (63.0)	749 (82.6)	690 (50.1)	<0.001
Foley	118 (5.2)	27 (3.0)	91 (6.6)	<0.001
Chest tube	396 (17.3)	137 (15.1)	259 (18.8)	0.02
REBOA	5 (0.2)	2 (0.2)	3 (0.2)	0.99
Thoracotomy	136 (6.0)	56 (6.2)	80 (5.8)	0.72
Tourniquet	24 (1.1)	5 (0.6)	19 (1.4)	0.06
Other	188 (8.2)	33 (3.6)	155 (11.3)	<0.001
Emergent surgery, n (%)	794 (36.1)	251 (28.8)	543 (40.9)	<0.001
Outcomes				
LOS, d	5.0 (8.8)	4.0 (6.6)	5.6 (10.0)	<0.001
ICU-free days	3.5 (5.6)	3.0 (4.5)	3.7 (6.2)	<0.01
Ventilator-free days	4.1 (6.5)	3.6 (5.5)	4.5 (7.1)	<0.01
Highest BD, 24 h	−3.4 (7.1)	−3.3 (7.9)	−3.5 (6.6)	0.65
Highest lactate	5.1 (4.3)	5.7 (4.7)	4.7 (3.8)	<0.001
Mortality, n (%)	213 (9.4)	70 (7.8)	143 (10.3)	0.04
Time to death, n (%)				
In ED	126 (61.2)	43 (61.4)	83 (61.0)	0.88
In OR	33 (16.0)	13 (18.6)	20 (14.7)	
≤24 h	27 (13.1)	8 (11.4)	19 (14.0)	
≤7 d	11 (5.3)	4 (5.7)	7 (5.1)	
≤30 d	7 (3.4)	2 (2.9)	5 (3.7)	
>30 d	2 (1.0)	0	2 (1.5)	

Values are mean (SD) unless otherwise noted.

BD, base deficit; FFP, fresh frozen plasma; GCS, Glasgow Coma Scale; HR, heart rate; ICU, intensive care unit; LOS, length of stay; MTP, massive transfusion protocol; OR, operating room; PRBC, packed red blood cells; REBOA, resuscitative balloon occlusion of the aorta; RR, respiratory rate; Temp, temperature.

number of scene procedures (Fig. 2B), survival was observed to be increased for those who received only one PHP before ED arrival. Further examination revealed that the procedure given to the majority of this group (83%) was IV access, which was found to be beneficial in logistic regression analysis. As seen in Figure 2A, three or more total procedures worsened survival. As seen in Figure 2B, two or more on-scene procedures worsened survival.

We further examined those patients who received IV access only and no PH fluids and sought to determine if this subgroup presented to EMS as physiologically better than those who received IV + fluids. The mean (SD) NISS in the IV only group was significantly lower than the IV plus fluids cohort

(12.1 [15.3] vs. 17.1 [15.0]; $p < 0.001$). However, in a multivariable logistic regression, which controlled for age, NISS, presence of chest injury, and injury by gunshot, fluids were still found to be associated with increased odds of mortality. Furthermore, excluding those who only received IV access and no other procedure, PHP were still found to be significantly associated with higher odds of mortality (OR, 2.09; 95% CI, 1.05–4.15; $p = 0.036$).

DISCUSSION

In this multicenter study examining the effect of PHP in urban penetrating trauma patients, PHP were found to be largely

TABLE 4. Multivariate Logistic Regression Examining Odds of Hospital Mortality (A) Among Number of PHP and (B) Among Individual PHP Within the PHP Population

Parameter	OR	95% CI	*p*
A.			
Age, y	1.03	1.01–1.04	0.001
NISS	1.07	1.05–1.07	<0.001
GSW	2.94	1.65–5.23	<0.001
Chest injury	2.49	1.52–4.07	<0.001
No. scene PHPs	1.64	1.38–1.96	<0.001
No. transport PHPs	1.33	1.10–1.61	<0.01
B.			
Age, y	1.04	1.02–1.07	<0.01
NISS	1.07	1.04–1.09	<0.001
GSW	4.01	1.38–11.66	0.01
Chest injury	0.65	0.27–1.53	0.32
Higher PH SBP	0.97	0.96–0.98	<0.001
PH intubation	10.76	4.02–28.78	<0.001
PH IO access	1.74	0.63–4.86	0.29
PH IV placement	0.27	0.10–0.76	0.01
PH fluids, mL	1.00	1.00–1.01	0.01
PH C-spine immobilization	5.80	1.85–18.26	<0.01
PH tourniquet	0.70	0.14–3.93	0.65
PH pressure dressing	0.80	0.34–1.87	0.60
PH pleural decompression	3.70	1.33–10.28	0.01

C, cervical; GSW, gunshot wound; IO, intraosseous; SBP, systolic blood pressure.

associated with increased mortality, whether performed on the scene or en route to a hospital. The largest increase in odds of mortality was observed in patients who received endotracheal intubation. Prehospital use of tourniquets and pressure dressings were not associated with benefit on adjusted analysis. Use of most PHP, particularly intubation and crystalloid-based resuscitation, should be reconsidered, and rapid transport should be prioritized for urban penetrating trauma patients.

The development of a well-trained PH emergency response system in the United States has helped improve morbidity and mortality, whether by BLS (spine stabilization, bag-valve mask ventilation, etc.) or ALS (airway management, cardiac defibrillation, vascular access, intravenous fluid resuscitation, delivery of medications, etc.).[3] This is particularly true with medical conditions such as respiratory arrest, myocardial infarction, and cardiac arrest.[16–18] In trauma patients, where the concept of the golden hour emphasizes the importance of rapid transport, the tradeoff between PHP and rapid transport has been extensively debated. Given the importance of rapid transport in penetrating trauma and the potential benefit of PHP, developing an efficient system that selects the appropriate transportation strategy is difficult. This study set out to evaluate the influence of PHP on outcomes in penetrating trauma patients in urban locations.

We found that intubation is the PHP performed in the urban penetrating trauma patient that is by far the most strongly associated with mortality. Prior studies have corroborated the deleterious effects of PH intubation in penetrating trauma patients.[1–3] Animal studies have shown that, in severe hemorrhagic shock, intubation exacerbates end-organ perfusion.[13] The evidence to support the systematic airway, breathing, and circulation approach to injured patients is based on expert consensus[19] but has very little evidence to support it, especially in trauma patients. This airway, breathing, and circulation paradigm has recently come under challenge in the trauma literature.[20] An American Association for the Surgery of Trauma multicenter trial showed that many trauma centers are already initiating circulation through resuscitation with blood products, before intubation, without worse outcomes.[21] Despite all of this evidence, a significant number of penetrating trauma patients in urban locations are still being intubated in the field, with 7.1% of patients receiving PHP getting intubated in this study and as high as 9.8% in other studies.[5] National guidelines by major trauma societies are warranted, and open discussion with EMSs on a local basis may lead to improved PH practice and improved survival.

Interestingly, we found that PH IV access was associated with survival, while IV fluid resuscitation was associated with mortality. While those who received IV fluid resuscitation were more severely injured in terms of higher mean NISS, increasing volumes of IV fluids remained significantly associated with greater odds of mortality when examined in the context of injury severity, age, presence of gunshot wound and chest injury. Furthermore, ED shock index was not different between those who received fluids and those who did not, suggesting that PH fluid resuscitation is at best not useful in this population. A selection bias may affect these results because patients who received IV access without IV fluid resuscitation were less severely injured than those that did receive IV fluids. To account for this possibility, we performed our analysis after excluding patients who received IV access without IV fluids and found that this did not change the results of our findings. Retrospective studies have shown that PH IV fluids are associated with death and that this association is especially increased in penetrating trauma patients.[2] Tenants of permissive hypotension suggest that the negative effects of aggressive IV fluids in the PH setting are not due to a time cost but instead are a result of dilution of clotting factors and exacerbation of uncontrolled bleed.[6] Our results reinforce the idea that permissive hypotension should be maintained in the PH setting where crystalloid fluid remains the predominant fluid of resuscitation. With an increasing role of blood transfusion in the PH setting, the need for permissive hypotension may change for EMS crews with transfusion capabilities. However, in urban, penetrating trauma, where transport to a trauma center may be quicker than placing an IV and initiating a blood transfusion, further studies are needed to determine if PH blood products provides a benefit. Our study does show that IV access appears to be helpful. Unfortunately, the reason behind this finding could not be determined from the data set. One potential explanation is because it allows for delivery of helpful drugs such as vasoactive medications or tranexamic acid. An important finding is that more than half of the IV access placements occurred on the scene. Prior research has shown that IV placement increases scene time and overall hospital time.[22] In addition, placement of IV access during transport has high success rates.[23] For trauma patients with penetrating torso injury, IV placement during transport to trauma centers appears to be the most prudent practice and should be foregone on scene. Scene placement of an IV is not recommended, while en route placement of an IV is advocated by an EAST practice management guideline.[24]
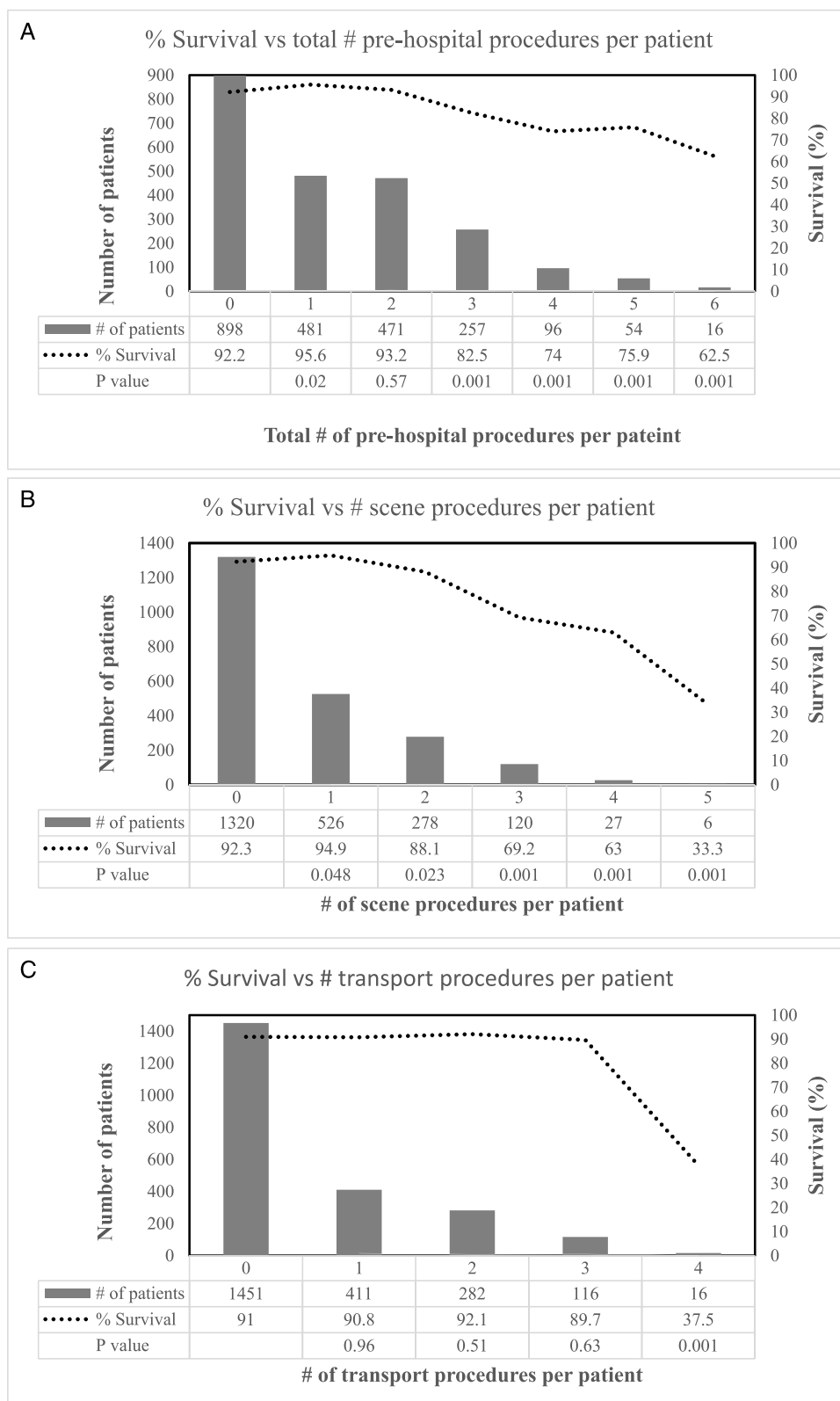
Figure 2. Line graph illustration of survival percentage versus number of PHP per patient. *p* Values were generated by Pearson's χ^2 analyses with a Yates' correction. Those who received no PHP served as the reference group. (*A*) Survival versus total number of PHPs per patient. (*B*) Survival versus number of on-scene PHP per patient. (*C*) Survival versus number of PHP performed during transport.

Other procedures found to be associated with mortality in this multicentered trial included cervical spine immobilization and pleural decompression. The negative effects of cervical collars have been demonstrated in numerous studies with increased risk of pressure ulcers, increased intracranial pressure, and increased difficulty in obtaining a definitive airway.[25–27] Most penetrating cervical spine collars are complete spinal cord injuries, such that PH cervical collar placement will not change outcomes.[28] Eastern Association for the Surgery of Trauma practice management guidelines and the Prehospital Trauma Life Support Executive Committee have gone so far as to formally recommend against cervical collars in penetrating trauma patients.[29,30] Pleural decompression was also found to be associated with mortality even after accounting for chest injury and injury severity. The use of needle thoracostomy and, more recently, finger thoracostomy by paramedics in the field has been described.[31,32] In this study, of the 113 pleural decompressions, the vast majority (n = 108; 95.6%) were with needle thoracostomy. Needle decompression is known to have a significant failure rate[33,34] and is often ineffective and overused in the trauma population.[35,36] In patients with penetrating chest trauma in urban locations, pleural decompression should be foregone in favor of immediate transportation.

Volume preserving procedures such as tourniquets and pressure dressings did not appear to be helpful in the PH setting for this specific patient population. Military tourniquet application has been shown to provide a survival benefit.[37,38] Studies of civilian tourniquets have shown that they can be applied safely and effectively,[10] yet the benefits of PH tourniquet use in civilian, urban, penetrating trauma have not been described. Importantly, we found that pressure dressings and tourniquets did not provide benefit to penetrating trauma patients in urban locations. Stopping active hemorrhage preserves physiology; however, delays in transport of bleeding, penetrating trauma patients to definitive care may increase mortality. The use of volume preserving procedures in the setting of urban penetrating trauma remains an open question, and their roles in this setting will need to be refined through further scientific study. Invasive interventions to control life-threatening bleeding in the PH setting have been described in physician-led PH responder systems. This includes thoracotomy for aortic cross-clamping and the use of REBOA for larger bleeding of the trunk and pelvis. Prehospital thoracotomy for penetrating trauma is an established intervention in a physician-led emergency system and is associated with 18% survival rates in selected patient groups.[39,40] However, performing these interventions are not applicable to the current US PH transport system, and all efforts should be focused on rapid transit to the trauma center to obtain definitive surgical treatment for penetrating trauma patients. Institution of these invasive procedures to EMS in the United States would require a vast systemic change from the current paradigm.

To determine if true "scoop and run" results in better outcomes, we examined the influence of mode of transportation. Transport by BLS crew, police, or private vehicle did not result in a survival advantage when compared with ALS transport. This is consistent with prior studies that have shown that ALS transfer of penetrating trauma patients does not improve survival in certain patient populations.[41] In the city of Philadelphia, the police department is instructed to immediately transfer penetrating trauma patients to trauma centers in traditional vehicles. This policy has led to improved outcomes in patients with gunshot and stab wounds.[42] However, national data have shown no difference for patients transported by police.[43] Our data show no difference for mortality in patients transported by private vehicle once relevant covariates were considered, which does not match data from larger studies from the National Trauma Data Bank that have reported higher survival for these patients.[44,45]

Interestingly, the study showed that the percentage of Black patients who got no PHP was higher than the percentage of White patients not receiving PHP. While the reason(s) behind this finding could not be determined based on the data available in this study, it is one that needs further investigation. Prior work has shown that underutilization of medical resources in Black patients in the United States is a significant societal problem.[46,47] Further studies are needed to determine if explicit or implicit racism plays a role in this finding.

This study was not without limitation. The influence on PHP on transport time could not be examined in this multicenter trial. True transport times are impossible to determine in private vehicle and police transport, which made up the vast majority of our patient population. In addition, accurate time from injury to arrival of EMS often cannot be determined. Prior studies have indicated that procedures like intubation and wound care do increase transport time.[20] In addition, the study is subject to an inherent selection bias, as patients receiving PHPs were more severely injured as indicated by mean NISS. Finally, there are likely other relevant confounders that exist and were not captured in this trial that may influence outcomes.

In conclusion, PHP continue to be performed in urban penetrating trauma. The volume preserving procedures of tourniquets and pressure dressing were not associated with harm and may be beneficial. In addition, obtaining IV access in the PH setting also seems to be beneficial, and consideration should be given to performing this procedure in route to the hospital. These remaining PHP examined were found to impart no survival advantage and may be harmful in urban settings, even when performed during transport. These procedures should be foregone in favor of rapid transport, where definitive surgical control of bleeding and resuscitation with blood products can be performed. Guidelines by national trauma organizations to decrease PHP in urban penetrating trauma may help change practice and save lives.

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DISCLOSURE

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DISCUSSION

Dr. Taghavi and colleagues have conducted a prospective multicenter trial that closely examines the association between prehospital procedures (PHP) and mortality in penetrating trauma patients in urban locations. The authors found that mortality was increased with each PHP performed regardless of location – either on scene or in route – and concluded that prehospital providers should prioritize rapid transport to a trauma center over PHP.

While the study is well done and the data analysis is robust, a significant concern is that the baseline characteristics of the two comparison groups – those who received PHP and those who did not – are significantly different with respect to factors related to severity of illness, including age, shock index, New Injury Severity Score, and need for emergency surgery. Thus, the conclusions drawn may be subject to bias. Another key variable that may confound the results is transport time. The authors address the reason why this was excluded from the analysis, as it could not easily be obtained, and there were a large number of patients transported by police or private vehicle. While a rapid transport time may be presumed due to the urban environment, variations in this parameter may explain why some patients had more PHP done or why some had poorer outcomes. In addition, although these data show that there is an association between PHP and mortality in these patients, causation cannot be assumed.

I commend the authors and believe that their study strengthens the argument against PHP in urban penetrating trauma patients. As prehospital protocols and provider abilities evolve over time, I look forward to definitive recommendations regarding PHP in this population as well as instruction on implementing change. Studies such as this one will be essential to the formulation of such guidance, and subsequent provider education remains crucial in improving patient outcomes.

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