Teen trauma without the drama: Outcomes of adolescents treated at Ohio adult versus pediatric trauma centers

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BACKGROUND: The optimal treatment facility for adolescent trauma patients is controversial. We sought to investigate risk-adjusted outcomes of adolescents treated at adult-only trauma centers (ATCs) versus pediatric-only trauma centers (PTCs) in a state system with legislated American College of Surgeons–verified institutions to determine ideal prehospital referral patterns.

METHODS: The Ohio Trauma Registry was queried for patients 15 years to 19 years with a length of stay (LOS) greater than 1 day at ATC (Level 1) or PTC (Levels 1 and 2) from 2008 to 2012. Race, sex, emergency department vital signs, Injury Severity Score (ISS), computed tomography, and ultrasound imaging were reviewed. Outcomes by mechanism of injury included ventilator days, intensive care unit LOS, hospital LOS, and mortality. Statistical analysis was performed using χ^2 test, *t* test, and Wilcoxon rank-sum test. Propensity score–based risk adjustment matching was used to compare groups (propensity score within 0.01, ISS within 5).

RESULTS: Of 5,793 adolescents examined, (84% blunt, 16% penetrating) 66% were treated at an ATC. In unmatched comparisons, age, ISS, vital signs, and mortality differed significantly between centers ($p < 0.01$). For adolescents with blunt injury, more males (71.6% vs. 66.3%, $p < 0.01$) and nonwhites (19.2% vs. 15.8%, $p < 0.01$) were seen at PTCs. For penetrating trauma, more males (88.6% vs. 50.8%, $p < 0.01$) and nonwhites (66.4% vs. 34.3%, $p < 0.01$) were admitted to ATCs. In 873 propensity-matched pairs for blunt trauma and 95 propensity-matched pairs of penetrating injuries, no differences were seen in a priori outcomes. Imaging (blunt, head computed tomography and abdominal ultrasound, $p < 0.01$; penetrating, abdominal ultrasound, $p = 0.02$) was more common at ATCs.

CONCLUSION: Major outcome differences for injured adolescents do not exist between ATCs and PTCs, regardless of injury pattern. Imaging remains more prevalent at ATCs. In a state system with mandatory American College of Surgeons–verified centers, injury patterns need not dictate triage decisions for adolescents. (*J Trauma Acute Care Surg*. 2014;77: 109–116. Copyright © 2014 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Pediatric trauma center; adult trauma center; adolescent; trauma outcome.

Unintentional injury is the leading cause of morbidity and mortality for adolescents in the United States.[1] In 2010, there were 4,537 unintentional injury–related deaths and 1,832 homicides recorded for 15-year-olds to 19-year-olds.[1] According to the Center for Disease Control, motor vehicle collisions and gunshot-related injuries remain the most common causes of mortality and nonfatal injuries in this population.[1] Furthermore, unintentional injury is responsible for the highest percentage of years of potential life lost.[2] Prehospital providers must consider a multitude of factors for the appropriate triage of adolescent patients (age, 15–19 years). One such factor is the correct site of transfer. In Ohio, patients age 0 year to 15 years should be brought to pediatric centers, while those 16 years and older should be taken to adult centers. In the setting of severe trauma, the age of an adolescent may be unclear. Regional trauma systems, especially urban networks, have both adult-only trauma centers (ATCs) and pediatric-only trauma centers (PTCs) that are capable of definitive care of this unique patient population. PTCs have evolved during the past several decades to provide specialized care for children, although they are often found only in major urban areas and are thus limited in the population and region that they serve.[3] Nonetheless, the optimal treatment facility for adolescent trauma patients remains controversial.

Review of the existing literature revealed no studies addressing the optimal treatment facility for the adolescent age group in question. Previous studies, however, have sought to determine the ideal treatment setting for pediatric trauma patients in statewide systems. Early studies used the Trauma and Injury Severity Score (TRISS) method to compare standardized outcomes of PTCs and ATCs.[4] These studies varied, with some reporting improved survival for children treated at a PTC[5] while others demonstrated higher mortality rates for pediatric trauma patients treated in a rural setting with no difference between pediatric and urban adult centers.[6] Additional studies demonstrated equivalent outcomes of children triaged to a PTC versus ATC[7] yet improved functional outcomes with care at

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pediatric centers.[8] Potoka et al.[9] examined outcomes in the Pennsylvania state system and demonstrated a lower mortality in children treated at PTCs or adult centers with added qualifications to treat children versus treatment at an ATC alone. Similarly, in a study of Florida's system, Pracht et al.[10] concluded that children treated at PTC had a significant reduction in mortality. However, both of these studies failed to control for injury severity as a confounder for outcomes or clarify the American College of Surgeons' Committee on Trauma (ACS COT) verification status or level. More recently, Wang et al.[11] performed a retrospective study of severely injured children, defined as injuries that could result in death, which did not demonstrate a statistically significant difference in mortality for children treated at adult versus pediatric trauma centers. Universal to all of these studies was the evaluation of trauma patients within the entire pediatric age range, from 0 year to 19 years, rather than a focus on adolescents treated at capable centers.

The examination of large national data sets failed to clarify the location of optimal adolescent trauma care. Notrica et al.[12] used data from the Center for Disease Control and Prevention and demonstrated that states with ACS-verified PTC had decreased pediatric injury mortality. However, Osler et al.[13] failed to find a difference in mortality rates between PTCs and ATCs after controlling for Injury Severity Score (ISS), Pediatric Trauma Score, age, mechanism of injury, and ACS verification status when using the National Pediatric Trauma Registry. Again, neither study focused on adolescents and instead examined outcomes associated with all pediatric patients.

The objective of this study was to investigate risk-adjusted outcomes of adolescents treated at an ATC versus a PTC in a state system with legislated ACS-verified institutions to determine the ideal prehospital referral pattern. We sought to look at the trauma system as a whole to determine if emergency medical service providers were appropriately triaging this group of patients. We hypothesized that adolescent patients, age 15 years to 19 years, have equivalent outcomes, regardless of mechanism of injury, in systems where both pediatric and adult trauma centers are ACS COT verified and available for care.

PATIENST AND METHODS

Study Population

Retrospective discharge data were queried from the Ohio Trauma Registry with support provided by the Ohio Department of Public Safety, Division of Emergency Medical Services. Criteria for analysis included adolescents, age 15 years to 19 years, with a length of stay (LOS) at least 1 day treated at an ATC or PTC in the state of Ohio from 2008 to 2012. The primary objective was to identify outcome differences between risk-adjusted adolescents treated at an ATC versus a PTC by the mechanism of injury in a state with a mature verification and designation system.

All adult and pediatric trauma centers in Ohio are verified by the ACS COT and designated by the state after successful consultation and/or reverification. Stand-alone adult Level 1 centers (n = 10) were compared with stand-alone pediatric centers that included both Level 1 (n = 3) and Level II (n = 2) institutions. Level 1 and 2 PTCs were included to maintain blinding despite a low number of institutions. Furthermore, Level 1 and 2 PTCs are located near ATCs (average distance in Ohio is 7 mi). The distinction between a Level 1 and 2 PTC is based on the annual number of treated patients younger than 15 years, a population outside of age group of interest and thus could be grouped without concern.[14] In Ohio, a more substantial distance exists between a Level 2 ATC and a PTC. As such, Level 2 ATCs may care for a greater number of adolescents by location default as opposed to age-based triage protocols.

Ohio Emergency Medical Services Prehospital Trauma Triage Rules dictate the transportation of patients to PTCs versus ATCs by age as follows: pediatric (0–15 years), adult (16–69 years), and geriatric (≥70 years).[15] Patients recognized to be 14 years or younger at the time evaluation at an ATC are transferred to a PTC.

Centers with combined pediatric and adult trauma verifications were excluded from the analysis to be able to strictly compare stand-alone PTCs with ATCs in communities that contain both.

Patient Characteristics

Data abstracted from the Ohio Trauma Registry included demographic and clinical variables related to outcomes. Demographic data included age, sex, and race. Race was divided into African American, white, and others. Emergency department (ED) physiologic parameters, specifically systolic blood pressure (ED SBP), respiratory rate (ED RR), and Glasgow Coma Scale (ED GCS) were recorded. The incidence of ED spinal immobilization and ED imaging was reported. Diagnostic imaging, which included computed tomography (CT) scan of the head and abdomen and abdominal ultrasound (U/S), were compared between centers. The mechanism of injury was gathered and classified as blunt, penetrating, burn, or asphyxia. The severity of injury between cohorts was determined using the ISS.

Patients were excluded from this study if their mechanism of injury was classified as burn or asphyxia or if care was transferred during the course of treatment.

Outcomes

Primary outcomes examined included ventilator days, intensive care unit (ICU) LOS, hospital LOS, and mortality. Outcomes were analyzed by mechanism of injury (blunt vs. penetrating).

Statistical Analysis

For each mechanism of injury, individuals admitted to an ATC were compared with those admitted to a PTC. χ^2 test, t tests, and Wilcoxon rank-sum tests were used to compare baseline characteristics of center type.

Because of possible between-center differences at baseline and prehospital provider triage bias, a propensity score–matched analysis was performed. Propensity score matching is a well-accepted and valid method used in observational studies to decrease bias and the effects of cofounders.[16] For each mechanism of injury, propensity scores were created using logistic regression using SAS version 9.3 (SAS Institute Inc., Cary NC). Specifically, trauma center type (ATC vs. PTC) was modeled in terms of age, ISS, sex, and race. The predicted probabilities from these logistic models were then used as propensity scores. We

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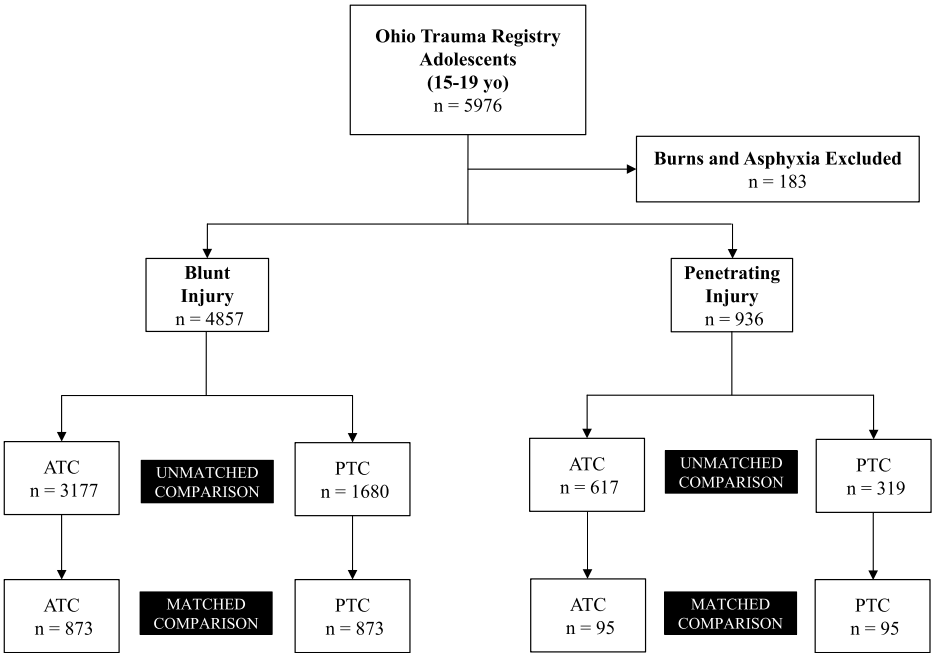

Figure 1. Derivation of adolescent study sample from the Ohio Trauma Registry (2008–2012).

created matched adult/pediatric pairs using the GMATCH SAS macro.[17] Because propensity scores alone were not sufficient to achieve strong matches, the macro was rerun using both propensity scores (within 0.01) and ISS (within 5 points). Wilcoxon signed-rank and McNemar tests were then used on the within-pair differences to assess the matching strategy's ability to achieve comparable groups. Finally, the two groups were compared on four outcome measures: ventilator days, ICU LOS, hospital LOS, and mortality. Significance was defined as $p < 0.05$.

RESULTS

A total of 5,976 adolescents were treated for trauma at a stand-alone Level I ATC or a Level I or II PTC in Ohio during the 5-year study period and had an LOS of greater than 1 day. Patients with burn (n = 147) or asphyxia (n = 36) injuries were excluded. Of the 5,793 patients who were further analyzed, 66% were treated at a Level I ATC, while the remaining 34% were treated at a Level I or II PTC. Eighty-four percent sustained blunt injury, while the remaining 16% sustained a penetrating injury (Fig. 1).

Demographics of the two groups were compared to determine baseline differences (Table 1). On average, patients treated at an ATC were older (17.6 years vs. 15.9 years, $p < 0.01$) and underwent more imaging studies, including abdominal U/S (28.9% vs. 0.9%, $p < 0.01$), head CT (27.8% vs. 10.9%, $p < 0.01$), and abdominal CT (21.7% vs. 13.0%, $p < 0.01$) than those treated at a PTC. Adolescents taken to ATC seemed to be more seriously ill with lower ED GCS scores in all three categories (eye, 3.6 vs. 3.9; verbal, 4.4 vs. 4.8; motor, 5.4 vs. 5.8; all $p < 0.01$). Although median ISS was greater at ATCs versus PTCs (9 vs. 4, $p < 0.01$), the majority of adolescents

TABLE 1. Demographics of Ohio Adolescent Trauma Patients (n = 5,976)

	ATC (n = 3,887)	PTC (n = 2,089)	*p*
Age, y	17.6 (1.2)	15.9 (1.0)	<0.01*
Male sex	70.2%	68.3%	0.12
Race			0.13
African American	20.1%	18.2%	
White	76.3%	78.7%	
Other	3.6%	3.1%	
Injury type			<0.01*
Blunt	81.7%	80.2%	
Penetrating	15.9%	15.3%	
Burn	2.1%	3.1%	
Asphyxia	0.3%	1.2%	
ED SBP	133.6 (22.3)	129.1 (16.9)	<0.01*
ED RR	18.2 (5.9)	19.7 (5.7)	<0.01*
ED GCS score			
Eye	3.6 (1.0)	3.9 (0.6)	<0.01*
Verbal	4.4 (1.3)	4.8 (0.8)	<0.01*
Motor	5.4 (1.5)	5.8 (0.8)	<0.01*
ISS	9 (4–14)**	4 (4–9)**	<0.01*
ED spinal immobilization	5.2%	6.8%	0.11
ED head CT	27.8%	10.9%	<0.01*
ED abdominal CT	21.7%	13.0%	<0.01*
ED abdominal U/S	28.9%	0.9%	<0.01*
Mortality	2.29%	0.67%	<0.01*

*$p < 0.05$.
**Nonparametric variables.
Values are presented as mean (SD).

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injured had an ISS less than 25, independent of mechanism of injury or center of treatment (blunt: PTC, 96.8% vs. ATC, 89.7%, $p < 0.01$; penetrating: PTC, 99.4% vs. ATC, 91.1%, $p < 0.01$)(Fig. 2*A–D*). Mortality was also higher in patients taken to an ATC as opposed to a PTC (2.29% vs. 0.67%, $p < 0.01$). Furthermore, ED SBP was higher in the ATC group (133.6 mm Hg vs. 129.1 mm Hg, $p < 0.01$) and ED RR was lower in the ATC group (18.2 breaths per minute [bpm] vs. 19.7 bpm, $p < 0.01$) than in the PTC group. Sex and race did not statistically differ between those adolescents treated at an ATC versus a PTC.

When we performed unmatched comparisons of blunt trauma patients, we found that 65% were treated at an ATC and 35% were treated at a PTC (Fig. 1). Patients treated at an ATC were older (17.6 years vs. 15.9 years, $p < 0.01$), underwent more imaging (head CT, 32.3% vs. 14.2%; abdominal CT, 24.6% vs. 17.2%; and abdominal U/S, 30.2% vs. 1.1%, all $p < 0.01$), had lower ED GCS scores (eye, 3.6 vs. 3.9; verbal, 4.4 vs. 4.8; motor, 5.4 vs. 5.8; all $p < 0.01$), had higher ISSs (9 vs. 5, $p < 0.01$), had higher ED SBP (134 mm Hg vs. 129.3 mm Hg, $p < 0.01$), had lower ED RR (18.0 bpm vs. 19.7 bpm, $p < 0.01$), and had higher mortality (1.73% vs. 0.6%, $p < 0.01$) (Table 2). In contrast to the overall demographics, sex and racial disparities were seen in this subgroup analysis, with more males (71.6% vs. 66.3%, $p < 0.01$) and nonwhites (19.2% vs. 15.8%, $p < 0.01$) treated at a PTC.

Unmatched comparisons of penetrating trauma patients revealed that 66% were treated at an ATC and 34% were treated at a PTC (Fig. 1). Adolescents treated at an ATC were older (17.8 years vs. 16.0 years, $p < 0.01$), underwent more imaging (head CT, 6.5% vs. 0.4%; abdominal CT, 8.5% vs. 0.4%; and abdominal U/S, 23.9% vs. 0.4%; all $p < 0.01$), had lower ED GCS scores (eye, 3.7 vs. 4.0; verbal, 4.5 vs. 5.0; motor, 5.6 vs. 6.0; all $p < 0.01$), had higher ISS scores (9 vs. 1, $p < 0.01$), had higher ED SBP (131.2 mm Hg vs. 128 mm Hg, $p < 0.01$), and had higher mortality (5.2% vs. 0.3%, $p < 0.01$) (Table 3). In addition, more males (88.6% vs. 50.8%, $p < 0.01$) and nonwhites (66.4% vs. 34.3%, $p < 0.01$) were admitted to an ATC.

To more directly compare similar patients, we performed propensity matching for patients sustaining either blunt or penetrating injuries. In blunt trauma patients, we found statistically significant, but not likely clinically significant, differences in baseline variables, with ATC patient cohorts including more males (67.5% vs. 65.8%, $p = 0.03$), higher ED SBP (134.9 mm Hg vs. 128.5 mm Hg, $p < 0.01$), lower ED RR (18.2 bpm vs. 19.8 bpm, $p < 0.01$), and lower ED GCS score (eye, 3.7 vs. 3.9, $p < 0.01$; verbal, 4.6 vs. 4.8, $p = 0.01$; motor, 5.7 vs. 5.8, $p < 0.01$) (Table 2). ATCs performed more abdominal U/S (27.5% vs. 0.3%, $p < 0.01$) and head CTs (31.8% vs. 17.8%, $p < 0.01$) as well. No difference existed between pairs for age, race, or ISS after matching for blunt trauma patients treated at a PTC versus an ATC. Furthermore, there was no significant difference in mortality between the ATC and PTC groups (0.8% vs. 0.3%, $p = 0.21$).

Statistically significant differences in baseline variables for penetrating trauma patients after matching were limited and included higher use of abdominal U/S (23.5% vs. 1.6%, $p = 0.02$) and lower ED RR (19.0 bpm vs. 20.6 bpm, $p = 0.049$) at an ATC (Table 3). No significant differences existed in age, sex,

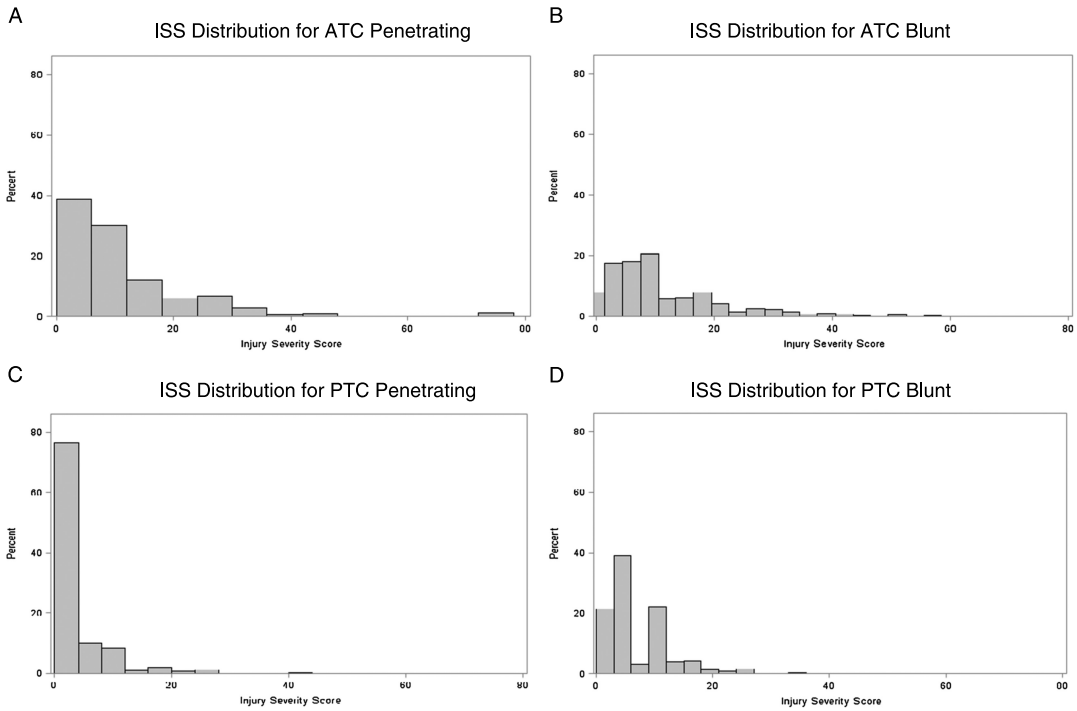

Figure 2. ISS distribution by mechanism of injury and trauma center of adolescent study sample. *A*, Penetrating trauma treated at adult trauma centers (ATCs). *B*, Penetrating trauma treated at pediatric trauma centers (PTCs). *C*, Blunt trauma treated at ATCs. *D*, Blunt trauma treated at PTCs.

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TABLE 2. Demographics of Unmatched (n = 4,857) and Matched (n = 873) Blunt Trauma Patients in the State of Ohio

	Unmatched			Matched		
	ATC (n = 3,177)	PTC (n = 1,680)	*p*	ATC (n = 873)	PTC (n = 873)	*p*
Age, y	17.6 (1.2)	15.9 (0.9)	<0.01*	16.3 (1.0)	16.3 (1.0)	exact match
Male sex	66.3%	71.6%	<0.01*	67.50%	65.8%	0.03*
Race			<0.01*			0.2
African American	12.4%	15.7%		13.8%	15.6%	
White	84.2%	80.8%		83.2%	81.4%	
Other	3.4%	3.5%		3.1%	3.0%	
ED SBP	134 (20.9)	129.3 (16.9)	<0.01*	134.9 (18.9)	128.5 (16.4)	<0.01*
ED RR	18.0 (5.7)	19.7 (5.8)	<0.01*	18.2 (4.5)	19.8 (6.0)	<0.01*
ED GCS score						
Eye	3.6 (1.0)	3.9 (0.6)	<0.01*	3.7 (0.8)	3.9 (0.6)	<0.01*
Verbal	4.4 (1.4)	4.8 (0.8)	<0.01*	4.6 (1.1)	4.8 (0.8)	0.01*
Motor	5.4 (1.5)	5.8 (0.8)	<0.01*	5.7 (1.2)	5.8 (0.8)	<0.01*
ISS	9 (4–14)**	5 (4–9)**	<0.01*	7.5 (6.3)	7.5 (6.3)	0.63
ED head CT	32.3%	14.2%	<0.01*	31.8%	17.8%	<0.01*
ED abdominal CT	24.6%	17.2%	<0.01*	27.6%	20.1%	0.06
ED abdominal U/S	30.2%	1.1%	<0.01*	27.5%	0.3%	<0.01*
Mortality	1.73%	0.6%	<0.01*	0.8%	0.3%	0.21

*$p < 0.05$.
**Nonparametric variables.
Values are presented as mean (SD) for normally distributed variables and median (interquartile range) for nonparametric variables (ISS).

race, ED GCS score, ISS, or abdominal CT scan rate. Of note, the significance of the difference between head CT incidence and mortality could not be calculated due to n = 0 at PTC for both categories.

Propensity-matched pairs were subsequently used to examine differences in common outcomes (Table 4). In both the blunt and penetrating adolescent cohorts, no difference was seen in mechanical ventilation duration, ICU LOS, hospital

TABLE 3. Demographics of Unmatched (n = 936) and Matched (n = 95) Penetrating Trauma Patients in the State of Ohio

	Unmatched			Matched		
	ATC (n = 617)	PTC (n = 319)	*p*	ATC (n = 95)	PTC (n = 95)	*p*
Age, y	17.8 (1.2)	16.0 (1.0)	<0.01*	16.6 (1.2)	16.5 (1.2)	0.34
Male sex	88.6%	50.8%	<0.01*	75.8%	80.0%	0.48
Race			<0.01*			0.52
African American	61.7%	32.3%		40.0%	46.3%	
White	33.6%	65.7%		56.8%	50.5%	
Other	4.7%	2.0%		3.2%	3.2%	
ED SBP	131.2 (28.3)	128 (16.0)	<0.01*	132.7 (26.2)	127.9 (18.0)	0.18
ED RR	19.3 (6.8)	19.8 (4.5)	0.09	19.0 (5.1)	20.6 (5.0)	0.049*
ED GCS score						
Eye	3.7 (0.9)	4.0 (0.2)	<0.01*	3.8 (0.6)	4.0 (0.3)	0.16
Verbal	4.5 (1.2)	5.0 (0.1)	<0.01*	4.8 (0.9)	5.0 (0.2)	0.08
Motor	5.6 (1.3)	6.0 (0)	<0.01*	5.8 (0.8)	6.0 (0.0)	0.055
ISS	9 (4–14)**	1 (1–2)**	<0.01*	5.4 (6.6)	5.3 (6.9)	0.7
ED head CT	6.5%	0.4%	<0.01*	10.8%	0.0%	†
ED abdominal CT	8.5%	0.4%	<0.01*	9.1%	1.6%	0.38
ED abdominal U/S	23.9%	0.4%	<0.01*	23.5%	1.6%	0.02*
Mortality	5.2%	0.3%	<0.01*	2.1%	0.0%	†

*$p < 0.05$.
**Nonparametric variables.
†Not applicable.
Values are presented as mean (SD) for normally distributed variables and median (interquartile range) for nonparametric variables.

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TABLE 4. Outcomes for Matched Blunt and Penetrating Trauma Patients In the State of Ohio

	Blunt			Penetrating		
	ATC (n = 873)	PTC (n = 873)	*p*	ATC (n = 95)	PTC (n = 95)	*p*
Ventilator days	0.4 (2.3)	0.3 (1.9)	0.18	0.3 (1.7)	0.2 (1.4)	0.67
ICU LOS, d	0.7 (2.0)	0.5 (2.5)	0.3	0.7 (2.5)	0.5 (2.4)	0.5
Hospital LOS, d	4.6 (4.4)	4.4 (4.6)	0.34	4.6 (5.5)	6.1 (6.5)	0.08
Mortality	0.3%	0.8%	0.21	2.1%	0.0%	**

**Not applicable.
Values are presented as mean (SD).

LOS, or mortality. Significance could not be calculated for the difference in mortality for penetrating injuries because there were no deaths at PTCs after matching.

DISCUSSION

Unintentional injury remains the leading cause of death in adolescents, with more than 6,000 deaths occurring annually from unintentional injury and homicide in this age group.[18] ACS-verified trauma centers, such as those legislatively mandated in Ohio, have previously been shown to decrease pediatric mortality compared with nonverified centers.[13] However, few studies have specifically assessed the adolescent population (15–19 years). Teens constitute a portion of the adolescent population, while those 15 years to 19 years old are an additional subgroup at the end of the teenage spectrum. Prehospital first responder bias is inevitably present in this age group. The adolescent population was of interest as Ohio triage rules dictate that patients 16 years and older are transferred to an ATC, but parental preferences and decisions made at the time of emergency medical services assessment may lead to varied practice. We attempted to clarify the optimal center for adolescent treatment despite triage differences by using the statistical method of propensity matching. In our work, the initial analysis of unmatched data revealed a higher mortality rate at ATC; this difference disappeared after propensity matching was used to compare similar pairs of patients. The results of this study demonstrate that the ICU LOS, hospital LOS, days requiring mechanical ventilation, and overall mortality of adolescents did not depend on whether care was provided at an ATC or a PTC in communities that have both ACS COT–verified options.

No significant difference in mortality existed after propensity scores were used to create matched pairs for blunt trauma. This conclusion supports the findings of several studies, which failed to detect a decrease in mortality for children (0–18 years) treated at an ATC versus a PTC with the use of regression or TRISS models that controlled for ISS, trauma score, age, mechanism, and ACS verification status.[6,11,13,19] Our findings are inconsistent, however, with reports from Pennsylvania, Florida, and Quebec, which detected a reduction in mortality for children treated at a PTC.[8,11,20] These studies failed to control for either injury severity or verification status. Of note, a difference in mortality rate could not be calculated for penetrating injuries because there were no deaths at PTCs after matching.

In Ohio, adolescents treated at an ATC were slightly older, were more severely injured, and received significantly more imaging studies compared with those treated at a PTC. These findings are consistent with a recent study by Matsushima et al.[19] of adolescents treated in Pennsylvania. This study demonstrated that trauma patients between 13 years and 18 years treated at an ATC were older, had higher ISS, and more frequently underwent admission diagnostic CT. Osler et al.[13] also noted that children treated at adult centers were more severely injured. Age and injury severity differences are likely attributable to triage, while the differences in imaging are likely differences in institutional norms.

A significant difference in the use of imaging exists between the PTCs and ATCs, with far more adolescents treated at ATCs undergoing head CT for blunt trauma and abdominal U/S for both blunt and penetrating injuries. Numerous reports have evaluated the use of CT in pediatric trauma patients and stress the importance of selective use in an attempt to minimize radiation exposure because of concerns for increased cancer risks.[21–23] Kharbanda et al.[24] demonstrated that the majority of radiation exposure of pediatric trauma patients was secondary to CT scans. Aside from concerns relating to radiation, others question the utility of abdominal CT for blunt injury evaluation in pediatric patients because of high false-negative rates.[25] In addition, Focused Abdominal Sonography for Trauma (FAST) examinations have not gained popularity in pediatric institutions, with only 15% of children's hospitals reporting the use of FAST as compared with 96% of adult hospitals in 2009.[26] This may be caused by the historically low reported rate of sensitivity for intra-abdominal free fluid of pediatric patients (0–18 years) after blunt injury.[27,28] Recent work has reinforced this concern. In a study by Scaife et al.,[29] the sensitivity of the FAST examination for a significant amount of fluid to indicate an underlying intra-abdominal injury was 50% in pediatric trauma patients age 0 year to 17 years. Therefore, our results may be a reflection of reduced imaging secondary to the inherent poor study sensitivities understood by institutions and pediatric trauma providers.

Several limitations exist in this study. In the examination of the study population, Level 1 and 2 PTCs were combined. Because of a small number of Level 1 PTCs, which could potentially allow for identification of a specific center and thus compromise blinding, Level 2 centers were included in this distinction of PTC. The primary difference between pediatric Level 1 and Level 2 trauma centers is volume (annual admission of >200 versus >100 injury children age <15 years, respectively). Although our population of interest is outside this ACS COT pediatric criterion, the volume of adolescents treated may affect outcomes at PTCs by level of verification, making the summation of outcomes inaccurate. However, data reflecting differences in outcomes by PTC ACS COT level are lacking in the literature.

In addition, as depicted in Figure 2, the distribution of ISS at an ATC versus a PTC is not equivalent. A greater proportion of more severely injured patients, with resultant higher ISS, seem to be treated at a ATCs (ISS > 25 at ATC, 8.9–10.3%). Because few (0.63–3.2%) patients with an ISS greater than 25 are treated at PTCs, the propensity-matched

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pairs are based on patients with the commonality of lower ISS scores. As a result, the outcomes of pediatric trauma patients with severe injury, especially penetrating injuries, are not taken into account in this analysis.

Finally, there are several nontraditional outcomes that were not evaluated in this study, which may be instrumental in determining the best location of care. Posttraumatic stress disorder evaluation and management,[30] subtypes of injury patterns and treatment,[31] and institutional ability for physical and psychological rehabilitation[32] are outcomes to consider. Additional outcomes including discharge location and functional status, patient and family satisfaction, cost, and readmission rates were unable to be analyzed with this data set but warrant future investigation. Depending on the maturity of the adolescent, better functional results for adolescents treated at PTCs versus ATCs may exist.

In conclusion, we were unable to detect a difference in the state of Ohio under an ACS-verified trauma system in outcomes of adolescents treated at PTCs versus ATCs after blunt or penetrating traumatic injury. For prehospital triage after trauma, the delivery of care to adolescents is appropriate at both PTCs and ATCs when both options are ACS verified and readily accessible. Further work needs to examine possible outcome variability after severe injury (ISS > 25) for ATCs versus PTCs by mechanism of injury in this unique patient population.

AUTHORSHIP

A.E.W. contributed to all portions of the study as follows: literature search, study design, data collection, data analysis, data interpretation, manuscript revision, and critical revision. T.A.P. contributed to the literature search, study design, data interpretation, manuscript writing, and critical revision. R.A.F. contributed to the literature search, study design, data interpretation, manuscript writing, and critical revision. D.J.H. contributed to the study design, data collection, data analysis, data interpretation, manuscript revision, and critical revision. B.R.H.R. contributed to all portions of the study as follows: literature search, study design, data collection, data analysis, data interpretation, manuscript revision, and critical revision.

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DISCLOSURE

The authors declare no conflicts of interest.

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EDITORIAL CRITIQUE

I would like to commend the group from Cincinnati for looking at trauma outcomes in a unique group of patients, adolescents, who have largely been ignored in the standard trauma literature. "Adult" trauma is defined as those 18 years and older, whereas the definition of pediatric trauma includes children 14 years of age and younger. So, where do the teens fit in? Are they big kids or small adults? In other areas of medicine, there is data to suggest that adolescents are a unique population, with outcomes that differ from older patients. For example, in the emerging field of adolescent and young adult oncology, it has been noted adolescents treated with the same regimen do better when treated by pediatric oncologists and in pediatric centers, and they are much more likely to be enrolled in a clinical trials. Reasons for these differences are likely due to a combination of biologic, social, and environmental factors.

In this study, the authors have compared care rendered to adolescent patients admitted to stand alone Level I adult trauma centers to those admitted to Level 1 and 2 pediatric trauma centers in Ohio. Victims of blunt and penetrating trauma were compared, and propensity matching was used to account for demographic differences between centers. Essentially the study determined that adolescents seen in adult centers tend to be older and have a higher ISS than those admitted to pediatric centers. Unmatched mortality was higher in the adult centers, but this difference was eliminated when patients were propensity matched. The one process measure that was evaluated was the use of imaging. Adult centers more frequently obtained CTs of the head and the abdomen than pediatric centers (although with matching, this difference did not reach statistical significance with a p value of 0.06). Interestingly, the adult centers also obtained more abdominal ultrasounds as well.

Leaving aside the obvious questions related to the validity of propensity matching, it appears that adolescents in a state such as Ohio with a mature trauma system do well when treated at a trauma center. What this study fails to address is the real question: what is the best care for the adolescent patient, regardless of the center that renders it? For example, from the data presented, it is clear that there is a different approach to imaging at the two types of centers; which practice is associated with the most cost-efficient, high quality care? Is there some mechanism of injury or some type of injury that is better treated at one type of center than another, and what are those differences in care? What about other types of outcomes (for example, return to school or injury recidivism)?

I challenge the authors (and others) to begin to study the unique physical, psychological, and social characteristics of adolescents in order to ultimately provide this group of patients with the best care regardless of the type of trauma center.

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