ATV-Related Trauma in the Pediatric Population

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Background: All-terrain vehicles (ATVs) are prevalent in Appalachia and cause significant morbidity and mortality in the pediatric population. This study investigated the injury types and severity in pediatric patients over a 15-year period.

Methods: A retrospective chart review was performed on pediatric ATV-related traumas presenting to our institution from 2005 to 2020. Patients were divided into 3 age groups (0–7, 8–12, and 13–17 y) to evaluate differences in accident demographics, hospitalization, Glasgow Coma Scale, Injury Severity Score, substance use, characterization of orthopaedic and nonorthopaedic injuries, and procedures performed.

Results: Inclusion criteria were met by 802 patients. Males represented 71.7% (n = 575) and females 28.3% (n = 227); the mean age was 12.4 years. The majority (88.5%, n = 710) of patients admitted following their accident had a mean stay length of 3.3 days. Of admissions, intensive care unit admission was required by 23.8%, n = 191 (mean stay 4.0 d). There were 7 fatalities. The vast majority of accidents occurred between May and September (79.2%, n = 635). In patients with documented helmet status, 45% (n = 271) were helmeted. Roughly half of all patients (n = 393) sustained a fracture (excluding fractures to the head), 370 sustained an injury to the head/face, 129 sustained intra-abdominal/intra-thoracic injuries, and 29 sustained injuries to all 3 systems. The most common fractures involved the forearm (n = 98), femur (n = 65), and spine (n = 59). The most common open fractures were the tibia (n = 12), humerus (n = 8), and forearm (n = 8). The oldest group was more likely than the middle or younger groups to sustain spine ($P < 0.0001$), pelvis ($P = 0.0001$), hand ($P = 0.0089$), and foot ($P = 0.0487$) fractures. Ethanol testing was positive in 5.0% (n = 25) of the oldest group and cannabinoids were present in 6.8% (n = 34). The youngest group was significantly more likely to sustain a fracture of the humerus than the middle or older groups ($P < 0.0001$). Orthopaedic surgical management was required in 24.4% (n = 196) of patients.

Conclusions: Pediatric ATV accidents present a significant source of morbidity and mortality. Further intervention is necessary to minimize pediatric ATV injuries.

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The authors declare no conflicts of interest.

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All-terrain vehicle (ATV) accidents are a common cause of trauma, with an estimated 81,800 ATV emergency department-treated injuries reported in the United States in 2018; 26% of these accidents involve children under the age of 16.[1] West Virginia accounts for 5.2% of ATV fatalities despite accounting for 0.55% of the US population.[1,2] Children who present to trauma centers and emergency departments with injuries secondary to ATV accidents utilize significant resources for diagnosis and treatment.[3] The cost of these injuries is estimated to be more than $2 billion annually for emergency department visits and hospital visits alone.[4]

Since the introduction of ATVs in the early 1970s, their use and popularity have continued to rise.[5] A disproportionately high rate of ATV accidents affects children, and the summer months account for the majority (67%) of ATV accidents.[3,6] Despite serious injuries and hospitalization, many children continue to ride ATVs, and safety behaviors are unaltered by serious accidents.[5,7] Few children wear helmets, and legislation requiring helmet use in urban populations has not shown increased compliance.[8,9] In addition, unhelmeted riding has been associated with increased rates of traumatic brain injury, fatality, and injury to the neck and face region.[10] The United States Consumer Product Safety Commission has made numerous recommendations, including that all drivers should take an ATV safety course, never drive ATVs on paved surfaces, always wear a Department of Transportation certified helmet, never allow more riders than the ATV was designed for, never operate ATVs under the influence of drugs or alcohol, and never let children under 6 years of age on ATVs—even as a passenger.[11] West Virginia law aligns with some of these recommendations, including requiring a safety course for drivers under 18 years of age on public trails and helmet use; until March 2020, ATV use was not allowed on streets.[12]

The purpose of this study was to evaluate differences in accident demographics, hospitalization, Glasgow Coma Scale, Injury Severity Score, and substance use and to characterize both the orthopaedic and nonorthopaedic injuries and procedures performed.

METHODS

Following approval from the Institutional Review Board (IRB), a query of our institution's Level I trauma center Trauma Registry was performed for ATV accidents in the pediatric population (17 y and under) from January 2005 to June 2020. The patients were identified as involved in ATV/UTV (utility terrain vehicles) accidents by means of external cause of injury codes (E-codes) E815, E815.1, E821, and E821.1. Patient records were evaluated, and the following data were recorded: age, sex, injury setting, passenger or driver, admission, admission class, Intensive Care Unit days, total hospital days, intubation, ventilator days, discharge disposition, mortality, Glasgow Coma Score (GCS), Injury Severity Score (ISS), ethanol presence, drug screen results (including cannabinoids, benzodiazepines, amphetamines, and opioids), base deficit, date of birth, date of injury, weight, body mass index, helmet status, injuries sustained, and interventions performed. Patients were stratified by age groups 0 to 7, 8 to 12, and 13 to 17 years of age. A manual review was performed to eliminate injuries sustained while not riding an ATV/UTV (eg, struck by ATV, riding a dirt bike). Injuries were then classified by anatomic location and as orthopaedic injuries, intra-abdominal/intra-thoracic injuries, and head-/neck injuries. Data collection and management were performed utilizing Research Electronic Data Capture (REDCap) and Microsoft Excel 2019. Statistical analysis was performed utilizing JMP Pro, Version 15 (SAS Institute Inc., Cary, NC). For continuous data, analysis of variance (ANOVA) testing was performed. For bivariate data, likelihood ratios were calculated unless the total count was <5 in which case Fisher exact tests were utilized. All *P* values were deemed statistically significant at <0.05.

RESULTS

Inclusion criteria were met by 802 patients. (Table 1) Males represented 71.7% (n = 575) and females 28.3% (n = 227), with a mean age of 12.4 years. The white race comprised 98.7% (n = 745) of the population, with a race documented. Patients were divided into age groups of 0 to 7 years (n = 128), 8 to 12 years (n = 177), and 13 to 17 years (n = 497). The youngest patient was 88 days old, and 34 of the patients were 3 years of age or younger. Of these toddlers, 26.5% (n = 9) were driving at the time of their accident. Across all age groups, the patient was driving in 71.2% (n = 571) of our cohort. The majority (88.5%, n = 710) of patients were admitted following their accident with a mean stay length of 3.3 days (range 0–40). Intensive care unit admission was required by 23.8% (n = 191) of admissions with a mean stay of 4.0 days (range 0–40). There were 7 fatalities (0.87%); 4 of them were not wearing helmets, and helmet status was unknown for the remaining 3. All fatalities presented with an initial GCS of 3. Fatalities were spread throughout the study period, with 2 in 2006, 1 in 2007, 1 in 2010, 1 in 2015, 1 in 2017, and 1 in 2018. The fatalities were ages 8, 9, 10, 12, 16, 17, and 17 years old. The youngest was a female passenger; all others were male drivers. Two fatalities were on-road, and 4 had head injuries (3 closed-head injuries and 1 skull fracture). There was a statistically significant difference in GCS ($P = 0.0315$), ISS ($P = 0.0028$), and base deficit ($P < 0.0001$) between age groups with GCS and ISS demonstrating worse injuries in older children, while the base deficit was worse in younger children.

TABLE 1. Patient Demographics by Age Group (y)

	0-7 (n = 128)*	8–12 (n = 177)*	13–17 (n = 497)*	*P*†‡
Sex	—	—	—	0.6063
Male	91 (71.1)	122 (68.9)	362 (72.8)	—
Female	37 (28.9)	55 (31.1)	135 (27.2)	—
Driver/Passenger	—	—	—	**< 0.0001**
Driver	52 (40.6)	116 (65.5)	403 (81.1)	—
Passenger	75 (59.4)	61 (34.5)	94 (18.9)	—
Helmet	—	—	—	0.1992
Yes	38 (29.7)	69 (39.0)	164 (33.0)	—
No	63 (49.2)	66 (37.3)	202 (40.6)	—
Unknown	27 (21.1)	42 (23.7)	131 (26.4)	—
Injury setting	—	—	—	**0.0300**
Off-road	*118 (92.2)*	171 (96.6)	453 (91.1)	—
On-Road/Street	*5 (3.9)*	1 (0.6)	26 (5.2)	—
Unspecified	*5 (3.9)*	5 (2.8)	18 (3.6)	—
Race	—	—	—	0.3823
White	123 (96.1)	159 (89.8)	463 (93.2)	—
American Indian or Alaskan Native	0 (0)	0 (0)	2 (0.4)	—
Asian	0 (0)	0 (0)	1 (0.2)	—
Black or African American	0 (0)	3 (1.7)	3 (0.6)	—
Hispanic or Latino	0 (0)	0 (0)	1 (0.2)	—
Unknown	5 (3.9)	15 (8.5)	27 (5.4)	—

Numbers in bold indicate statistical significance.
*Count and (%) within age group.
†Likelihood Ratio Probability $> \chi^2$.
‡Fisher Exact when appropriate.

The vast majority of accidents occurred between May and September (79.2%, n = 635). In patients with documented helmet use (75% known, n = 602), 45% (n = 271) were helmeted at the time of the accident. We performed a subgroup analysis of injury area separated by both year and age group, which yielded no readily identifiable trends or patterns. Only 4.1% (n = 32) of accidents were noted to occur on a road. Roughly half of the patients (49%, n = 393) sustained a fracture (excluding fractures to the head), 46.1% (n = 370) sustained an injury to the head/face, 16.1% (n = 129) sustained intra-abdominal/intra-thoracic injuries, and 3.6% (n = 29) sustained injuries to all 3 systems. (Table 2, Fig. 1) Older children were significantly more likely to sustain any body/extremity fracture ($P < 0.0001$) and, more specifically, fractures of the axial skeleton ($P < 0.0001$) or lower extremity ($P = 0.0101$). They were also significantly more likely to sustain multiple fractures ($P = 0.0005$). The most common fractures overall (open and closed) involved the forearm (n = 98, 12.2%), femur (n = 65, 8.1%), and spine (n = 59, 7.3%). (Appendix 1, Supplemental Digital Content 1, http://links.lww.com/BPO/A618) The tibia (n = 12, 1.5%), humerus (n = 8, 1%), and forearm

TABLE 2. Injury Categories by Age Group (y)

	0-7 (n = 128)*	8–12 (n = 177)*	13–17 (n = 497)*	P†‡
Head/Face/Neck injury	54 (42.2)	78 (44.1)	238 (47.9)	0.4221
Abdominal/Thoracic injury	17 (13.3)	28 (15.8)	84 (16.9)	0.5959
Any Body/Extremity fracture	45 (35.2)	76 (42.9)	272 (54.7)	**< 0.0001**
Closed fracture	42 (32.8)	71 (40.1)	256 (51.5)	**0.0001**
Open fracture	4 (3.1)	9 (5.1)	24 (4.8)	0.6499
Axial fracture	2 (1.6)	14 (7.9)	99 (19.9)	**< 0.0001**
Lower extremity fracture	13 (10.2)	29 (16.4)	104 (20.9)	**0.0101**
Upper extremity fracture	33 (25.8)	42 (23.7)	124 (24.9)	0.9133
No fractures	83 (64.8)	101 (57.1)	225 (45.3)	**< 0.0001**
Single fracture	37 (28.9)	56 (31.6)	182 (36.6)	0.1793
Multiple fractures	8 (6.3)	20 (11.3)	90 (18.1)	**0.0005**

Numbers in bold indicate statistical significance.
*Count and (%) within age group.
†Likelihood Ratio Probability > χ^2.
‡Fisher Exact when appropriate.

(n = 8, 1%) represented the most common open fractures. Spinal cord injuries were sustained in 7 patients, with 1 resultant paraplegia at the thoracic level. Two additional patients presented with cauda equina. Both underwent decompression and fusion and had full recovery of bowel-/bladder and motor; 1 reports residual numbness in the posterior thigh.

When examining specific injuries, children in the oldest group (13–17 y) were more likely than those in the middle (8–12 y) or younger (0–7 y) groups to sustain spine (OR 9.97, $P < 0.0001$), pelvis (OR 4.91, $P = 0.0001$), hand (OR 10.4, $P = 0.0089$), and foot (OR 3.48, $P = 0.0487$) fractures. Positive drug screens were significantly more common in older children ($P < 0.0001$), as were the individual components of cannabinoids ($P < 0.0001$), opioids (0.0002), and benzodiazepines ($P = 0.0010$). In the oldest group, ethanol testing was performed in 285 (57.3%) and cannabinoid testing in 193 (38.8%). Of those tested, ethanol was positive in 8.8% (n = 25) and cannabinoids were present

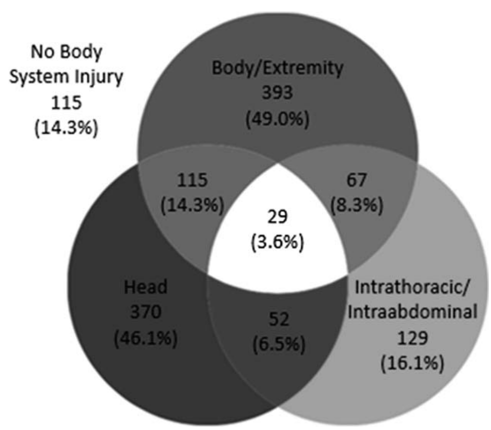

FIGURE 1. Injuries by Body System.

in 17.6% (n = 34). Children in the youngest group were significantly more likely to sustain a fracture of the humerus than those in the middle or older groups (OR 2.07 and OR 3.88, respectively, $P < 0.0001$). Orthopaedic surgical management, including closed reduction, was required in 24.4% (n = 196) of patients. (Appendix 2, Supplemental Digital Content 2, http://links.lww.com/BPO/A619).

DISCUSSION

More than 21,000 pediatric ATV accidents requiring treatment in the emergency department were sustained in 2018.[1] West Virginia possesses an extensive ATV trail system and consistently is in the highest per capita for ATV fatality rates.[1,2] In addition, the cost of these injuries is estimated to be more than $2 billion annually for emergency department visits and hospital visits alone.[4] Males represented 71.7% (n = 575) of the accidents, which is consistent with previous literature.[5,6,13] In our population, 4.1% (n = 32) of the accidents were noted to occur on a roadway, which is much lower than the previously reported 15% in the literature.[6] Legislation likely did prohibit some on-road use before legalization in March 2020; however, there is also extensive off-road work and recreational use in the state. We hope to address this topic in follow-up studies to monitor the impact of the legislation changes. There were no additional law changes/factors addressed that seemed to impact the injury pattern. This finding establishes an important baseline for further evaluation following legislation changes in West Virginia allowing ATV utilization on most roads, as ATV use on roadways has been associated with higher mortality rates in children.[14,15]

Orthopaedic injuries are very common in ATV accidents. Consistent with previous reports, roughly half (49%, n = 393) of our cohort sustained a fracture at or below the cervical spine.[6] There were no trends identified when subgroup analysis was performed on injury area (fracture excluding head, head/face injury, intra-abdominal/intrathoracic injuries) by age group per year. Orthopaedic surgical management, including closed reduction, was required in 24.4% (n = 196) of patients. In this study, 45% (n = 271) of patients with documented helmet status (75% known, n = 602) were helmeted at the time of the accident, which is in line with literature estimates of pediatric helmet use ranging from 9% to 54%.[5,6,9,13,16,17,18] In 2004, West Virginia legislation mandated helmet use for those under 18 years of age while riding ATVs. While there was an initial increase in helmet use at this institution from 33% to 45% in 2008, unfortunately, accidents per year and pediatric helmet use have essentially remained stagnant in our population since that time.[9]

There were 7 fatalities (0.87%) in our population. Of these, 4 were noted to not be wearing helmets, and helmet status was unknown for the remaining 3. All fatalities were a GCS of 3 on presentation. Of the fatalities, 42.8% (n = 3) were dead on arrival or passed in the emergency department, 28.6% (n = 2) passed within the first 24 hours, and 28.6% (n = 2) passed after 24 hours, which is consistent with previous literature reports of 44.4%, 25.6%, and 30%, respectively, for pediatric trauma patients <14 years of age.[19]

Glasgow Coma Score [GCS ($P = 0.0315$)], ISS ($P = 0.0028$), and base deficit ($P < 0.0001$) were all significantly different between age groups with GCS and ISS demonstrating worse injuries in older children, while the base deficit was worse in younger children. Though statistically significant, there was likely little clinical difference as mean GCS remained > 14 in all groups, mean ISS in all groups was between 5.9 and 8.3 (classified as mild <9), and the base deficit was within normal limits in older children and just outside the normal range (−2 to 2 mEq/L) in the youngest group (−2.25).[20]

Older children (13–17 y) were significantly more likely to sustain any body/extremity fracture ($P < 0.0001$) and, more specifically, fractures of the axial skeleton ($P < 0.0001$) or lower extremity ($P = 0.0101$). They were also significantly more likely to sustain multiple fractures ($P = 0.0005$). The forearm (n = 98, 12.2%), spine (n = 69, 8.6%), and femur (n = 65, 8.1%) were the most common fractures in our population. Age-related injury patterns have been proposed in previous literature, including younger children (12 y and younger) sustaining more lower extremity fractures (OR 3.2, $P < 0.03$), specifically, femur fractures (OR 6.5, $P < 0.01$) than children 13 to 16 years of age, while the older children were slightly more likely to sustain pelvic fractures (OR 1.108, $P < 0.04$).[6,13] In contrast to these published results, older children in our population were significantly more likely to sustain a lower extremity fracture (OR 1.52, $P = 0.0101$) compared with the other groups and far more likely to sustain pelvic fractures (OR 4.91). To speculate, a higher rate of speed/ejection likely impacts the probability of these types of injury, but maximum speed was not captured in this study. Children in the middle age group (8–12 y) were actually the most likely to sustain a femur fracture (9.6%, n = 17) when compared with older children (OR 1.22) or the youngest group (OR 1.37).

Another study focusing on spinal injury noted older children (16–18 y) sustained more spine injuries than younger ones, females more than males, and that older children more commonly injured their thoracic spine while younger patients tended to injure the lumbar levels.[21] The majority of spine fractures (94.2%) as well as pelvic fractures (88.8%) were seen in the older children in our population, which is consistent with previous literature; however, in contrast, older children sustained significantly more thoracic and lumbar spine fractures in our cohort ($P = 0.0036$ and $P < 0.0001$, respectively).[6,13,21] There was a substantial number of head injuries. This cohort is being sub-grouped for further evaluation.

As one might expect, substance use was more prevalent in older children. In the oldest group, ethanol testing was performed in 285 (57.3%) and cannabinoid testing in 193 (38.8%). Of those tested, ethanol was positive in 8.8% (n = 25) and cannabinoids were present in 17.6% (n = 34), both significantly different from the younger groups ($P < 0.0001$ and $P < 0.0001$, respectively). There were also significantly more positive opioids ($P = 0.0002$) and benzodiazepines ($P = 0.0010$) in the older children; however, we were unable to differentiate between Emergency Medical Services/hospital administration and substance abuse in these therapeutic medications.

The study has several limitations, the largest of which is that patients may present to smaller local hospitals or not seek medical care, evading our trauma registry database. In addition, due to the retrospective nature of the study, some information may be missing from medical documentation, such as helmet status, which was unknown in 25% of our cohort. Long-term patient follow-up is also lacking in this study, which may influence treatment documentation. Due in part to the expanded use of ATVs on roads in our region, past injury pattern trends may not predict future trends.

ATV-related trauma continues to be a significant cause of morbidity and mortality, especially in this region of the country. By presenting a summary of pediatric injuries and treatments at our institution over the last 15 years, we hope to further categorize injury patterns that can be utilized for targeted intervention in the future. Legislative efforts like those that have historically been in place in West Virginia may provide some protection from these injuries. Helmet use in organized competitions/racing is universal at this time but much more difficult to enforce at home and in the wilderness. Top-down enforcement is unlikely to make significant further headway due to the rural nature of much of the use of ATVs; however, maintaining reasonable legislation is also likely important for not backsliding on this issue. Creating more significant improvements will likely necessitate cultural changes surrounding ATV use. Engaging with the ATV community and organizations to find ways to support a greater interest in safety may be beneficial.

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