
Statewide Assessment of Injury and Death Rates among Riders of Off-Road Vehicles Treated at Trauma Centers

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- BACKGROUND:** Injuries and deaths among riders of off-road motorized all-terrain vehicles are increasing in the US. We hypothesized that serious injuries in Oregon have increased among riders of both four-wheel and two-wheel vehicles.
- STUDY DESIGN:** We analyzed the Oregon Trauma Registry. Seriously injured patients treated in the state's designated urban and rural trauma centers were identified using E-codes (821.0 to 821.9), which indicate whether patients were riding either an off-road all-terrain four-wheel vehicle (ATV) or off-road two-wheeled motorcycle (ORMC). Second, we performed a supplemental analysis of similar patients in the trauma registry of Oregon's University-based tertiary care trauma center. Patients in earlier time periods were compared with those in later time periods.
- RESULTS:** Patients injured riding off-road vehicles and needing treatment in Oregon's trauma centers increased 76%. Sixty percent of patients were injured riding an ATV, and 35% were injured riding an ORMC. Children (aged younger than 15 years) were 20% and 23% of patients in the earlier and later years. At Oregon's University-based Level I trauma center, in the years 2002 to 2005, more than twice as many patients needed tertiary care for severe injuries caused by off-road vehicle crashes compared with the previous 4 years.
- CONCLUSIONS:** There has been an alarming increase in the number of both ATV and ORMC riders requiring treatment in Oregon's trauma centers. Surgeons need to join a coalition of health care providers, citizens and public officials to implement a comprehensive injury-prevention response to this epidemic. (J Am Coll Surg 2007;204:216–224. © 2007 by the American College of Surgeons)
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An increasing number of patients injured in off-road vehicle crashes have required treatment at Oregon's only University-based, urban, tertiary care trauma center. Many were transferred from rural hospitals. We hypothesize that in the state of Oregon, the number of riders seriously in-

jured while operating both four-wheel all-terrain vehicles (ATV) and two-wheel off-road motorcycles (ORMC) has increased substantially over the past 6 years.

To evaluate this hypothesis, we analyzed data from two trauma registries. We studied information compiled by urban and rural trauma centers participating in Oregon's statewide trauma system and submitted to the trauma registry compiled by personnel working at the State of Oregon's Health Division, who have statutory oversight of the trauma system. In addition, we analyzed data recorded in the trauma registry of Oregon Health and Science University (OHSU), a designated Level I trauma center. We specifically sought to determine if annual rates of injury have increased in Oregon. Additionally, we sought to analyze if the characteristics have changed among hospitalized patients injured while riding ATV and ORMC vehicles.

In the US, injuries and deaths of ATV riders is increasing.¹ Authorities at US Consumer Product Safety

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Abbreviations and Acronyms

ATV	= all-terrain vehicle
CPSC	= Consumer Product Safety Commission
ED	= emergency department
OHSU	= Oregon Health and Science University
ORMC	= off-road motorcycle

Commission (CPSC) report that 136,000 patients in 2004 needed medical treatment for ATV-related injuries. In 2004, over 500 ATV riders in the US were killed and, alarmingly, children represent one-third of these decedents.^{2,3} Clinicians report a rise among their patients in serious injury and death caused by ATV crashes.^{4,5} Rodgers and Adler,⁶ surveyed the general population of ATV riders and determined that the risk factors for drivers were younger age, male gender, inexperience, drivers riding as a recreational activity, and larger engine size.

ATVs currently manufactured in the US have four large, soft tires designed for traction in a variety of soft and rocky terrains, a central bicycle seat ridden in a straddle manner, and handle bars to steer the vehicle. Three-wheeled vehicles, identified by the CPSC as intrinsically unstable, are no longer manufactured. Two-wheel ORMCs are often called "dirt bikes" and are increasingly popular off-road vehicles.^{7,8} ORMCs are designed to be driven on wilderness trails and motocross race tracks, and laws in most states, including Oregon, prohibit ORMCs on public highways or roads. Although initially designed as work vehicles, both four- and two-wheel off-road vehicles are increasingly popular for recreational purposes. ATV sales have tripled in the past 6 years. Consensus is growing among health care providers that effective injury-prevention programs are needed to mitigate what some consider to be an epidemic of injuries and mortality caused by off-road vehicle crashes.^{2-6,9}

Our goals with these analyses are to identify trends that might provide guidance about injury-prevention initiatives. We will compare causes and patterns of injury after crashes of four-wheeled ATV versus two-wheeled ORMC. We seek to determine if there are practicable injury-prevention strategies that, if implemented, can reduce the risk to riders of both ATV and ORMC vehicles in Oregon.

METHODS

Oregon Trauma Registry data for the 6 most recent available complete years (1998 to 2003) were ob-

tained from the Oregon Health Division. All trauma centers in Oregon submit information on patients entered into the trauma system and transported to their hospital to the Oregon Trauma Registry. We reasoned this database enables an estimate of the annual prevalence of off-road vehicle injuries treated in Oregon's hospitals that participate in the trauma system. Patients with E-codes in the range 821.0 to 821.9 were selected from the Oregon Trauma Registry as having an off-road vehicle-related mechanism of injury. A substantial proportion of injuries sustained in crashes of off-road vehicles occur in rural locations and the majority of injured patients are transported to local hospitals that are rural trauma centers in Oregon's statewide trauma system. Patients in Level III and IV trauma centers identified as seriously injured are usually transferred to a trauma center that provides a higher level of care. For these analyses, patients initially treated in the ED of a Level II, III, or IV trauma center, and subsequently transferred to a second Oregon trauma center, are categorized based on the final hospital where they were treated. Patients injured in states adjacent to Oregon, and who were transferred to Oregon trauma centers are retained in the analyses. Over 95% of patients injured in Oregon are designated in Oregon Trauma Registry by their county of injury. Patients injured in Washington, California, or Idaho, and treated in an Oregon trauma center do not have the county where they were injured recorded. All trauma centers in Oregon submit to the Oregon Trauma Registry, information on patients entered into the trauma system and transported to their hospital. We reasoned that this database enables an estimate of the annual prevalence of off-road vehicle injuries treated in Oregon's hospitals that participate in the trauma system.

Patient Injury Severity Score is calculated in the Oregon Trauma Registry using the standard method of summing the top three Abbreviated Injury Scales after these values had been squared.^{10,11} Annual gender-specific incidence rates of Oregon citizens injured riding off-road vehicles were calculated as the number of patients injured in Oregon divided by the US Census estimated Oregon population for that year. The Office of Management and Budget has divided Oregon's 36 counties into 8 that constitute Metropolitan Statistical Areas. The remaining counties were collectively considered rural.

To supplement the analyses of off-road crashes in the

Table 1. Demographics of Patients Injured in Off-Road Crashes and Recorded in the Oregon Trauma Registry (1998–2003)

Variables	1998–2000 (n = 440)	2001–2003 (n = 762)	p Value
Type of vehicle by E-code			0.628
Four-wheel ATV, n (%*)	277 (63)	469 (62)	
Two-wheel, n (%*)	163 (37)	293 (39)	
Age (y) categories, n (%†)			0.360
≤ 15	78 (17.7)	160 (21.0)	
16–25	139 (31.6)	210 (27.6)	
26–49	175 (39.8)	301 (39.5)	
≥ 50	48 (10.9)	89 (11.7)	
Male gender, n (%†)	369 (83.9)	638 (83.7)	0.951
ISS‡	10 (9) ± 8.0	10 (9) ± 8.0	0.145
Hospital admission, n (%)	341 (77.5)	550 (72.2)	0.042
LOS (d)‡	5 (3) ± 7.1	4 (3) ± 5.9	0.463
ICU admission, n (%)	135 (39.6)	186 (33.8)	0.081
LOS‡	5 (3) ± 7.1	4 (3) ± 5.9	0.463
Outcomes, n (% died†)	4 (0.9)	10 (1.0)	0.530

Statistical comparisons are proportions of patients in the earlier and later cohorts.

*Percent of yearly total.

†Percent of total in group.

‡Mean (median) ± SD.

ATV, all-terrain vehicle; ISS, Injury Severity Score; LOS, length of stay.

entire state, we also analyzed data on a similar cohort in the OHSU trauma registry. The OHSU Trauma Registry is directly available to us after permission was obtained from the OHSU Research Integrity Board. We performed an analysis on 8 years of data of OHSU Trauma Registry data, 1998 to 2005. We performed these additional analyses because we reasoned that the OHSU Trauma Registry offers additional detailed information not included in the Oregon Trauma Registry, including operative treatments, injury mechanisms, and functional status at discharge. OHSU Hospital is one of the two Level I trauma centers designated in Oregon, and is mandated to always accept in transfer seriously injured patients in the state.

Descriptive analyses for continuous variables are presented as mean, median, and standard deviations. Comparisons of continuous terms were made using Mann-Whitney U tests. Chi-square tests are used to make comparisons of categorical variables. Data management and analysis was performed using SPSS version 14.0 (SPSS Inc).

RESULTS

Oregon Trauma Registry 1998 to 2003: statewide data for 6 years

Over the 6 years of study, 1,237 riders of off-road vehicles were injured in crashes and recorded in the Oregon

Trauma Registry. Sixty-two percent of patients were injured riding a four-wheel ATV. Thirty-eight percent of patients were injured riding a two-wheel ORMC. The remaining 35 patients (3%) were riding other motorized vehicles or were pedestrians struck by off-road vehicles. These 35 patients are not included in subsequent analyses or data tables.

We compared patients in the earlier 3 years with those in the later 3 years to identify trends. There were 440 patients injured riding off-road vehicles in the first 3-year period (Table 1). Injured patients increased 78% to 762 patients in the second 3-year period. Proportions of injured patients riding ATVs versus ORMCs were the same in the earlier and later periods. Characteristics of patients in the Oregon Trauma Registry who were injured riding off-road vehicles showed little change over the 6 years of observation (Table 1). More than 80% were male patients, and 20% were children. Injury Severity Score of patients did not change over time and the proportion of patients with an Injury Severity Score over 15 in the earlier years was 23% compared with 20% in the later years. Seventy-seven percent of patients evaluated in the earlier years in the ED of trauma centers were hospitalized, and their median length of stay was 3 days. Seventy-two percent of patients evaluated in

Table 2. Level of Trauma Center Where Patients Were Last Treated for Injuries Sustained in Off-Road Crashes, Recorded in Oregon Trauma Registry

Level of trauma center	No. of hospitals	n*	ED deaths	Hospital deaths	Recorded in Oregon Trauma Registry (%)	
					1998–2000* (n = 440)	2001–2003* (n = 762)
I	2	432	1	3	35	36
II	3	150	1	1	12	13
III	22	531	4	2	44	44
IV	17	89	2	0	9	7

*Hospital level where last evaluated.
ED, emergency department.

the later years in the ED of trauma centers were hospitalized, and their median length of stay was 3 days. Death rate was 1% in both the earlier and the later time periods.

Patients involved in off-road crashes, by level of trauma centers providing definitive treatment, are listed in Table 2. Fifty percent of patients were definitively treated at a rural Level III or Level IV trauma center. For patients transferred within the Oregon Trauma system, the vast majority were transferred from Level III or IV trauma centers to Level I or II trauma centers. Approximately 15% of patients in the Oregon Trauma Registry were transferred to an Oregon trauma center after first being treated in nontrauma center hospitals in Oregon or in hospitals in the neighboring states of Washington, California, or Idaho. Patients injured while riding off-road vehicles sustained a spectrum of injuries, from minor to lethal. Although most patients were hospitalized, 16% of patients had minor injuries, were evaluated only in the EDs, and then released home. The majority of deaths occurred in the ED, and the majority of patients died in Level III and IV trauma centers.

Annual gender-specific incidence rates were calculated for patients in the Oregon Trauma Registry who were injured in Oregon over the 6 years from 1998 to 2003 (Fig. 1). Annual incidence rates of injury among male patients increased 2.2-fold from 55 per million to 120 per million. Annual incidence rates of injury among female patients increased 2.8-fold from 9 per million to 25 per million. Sixty-four percent of ATV riders were injured in rural counties, and 52% of ORMC riders were injured in rural counties. Many ATV riders were injured while riding on sand dunes located on Oregon's coast (Fig. 2). There was a trend among ORMC patients for more patients to be injured in metropolitan counties in the later years; this shift might reflect the increasing popularity of motocross track racing near urban centers.

OHSU Trauma Registry, 1998 to 2005: data from a single Level I trauma center for 8 years

Two hundred eighty-nine patients were treated at OHSU over 8 years and 64% were transferred from other trauma centers for definitive care. We compared the pattern of injury in the two groups of patients injured while riding either an ATV or an ORMC (Table 3). One hundred ninety-seven patients were injured while riding an ATV, 92 patients were injured while riding an ORMC. Four patients were injured in other circumstances, including three pedestrians hit by an ATV or motorcycle and a patient riding a bicycle who was hit by a motorized cart. The majority of patients were men, and there was a trend for more ATV drivers to be over 50 years of age. Twenty-five percent and 23% of injured riders of ATVs and ORMCs, respectively, were under the age of 15 years. Patients injured riding ATVs and patients injured riding ORMCs shared similar patterns of injury, processes of care, and outcomes. Death rates for both ATVs and ORMCs were 2%. ORMC patients had a higher prevalence of disability at hospital discharge.

We compared patients treated at OHSU in the earlier 4 years with those in the later 4 years to identify trends (Table 4). The pattern of injury and processes of care were generally the same, with the exception that there was a sevenfold greater need for spine operations among patients injured in the later years. Fifty percent of patients riding ATVs sustained a head, neck, or face injury, and only 37% of patients riding ATV vehicles were wearing a helmet at the time of the crash. Forty-two percent of patients riding ORMCs sustained a head, neck, or face injury, and 71% of these patients were wearing a helmet at the time they crashed their ORMC. Positive ethanol levels were noted in 14% of ATV riders and 8% of ORMC riders, although ethanol levels were missing in 20% of patients. Patients were rarely screened

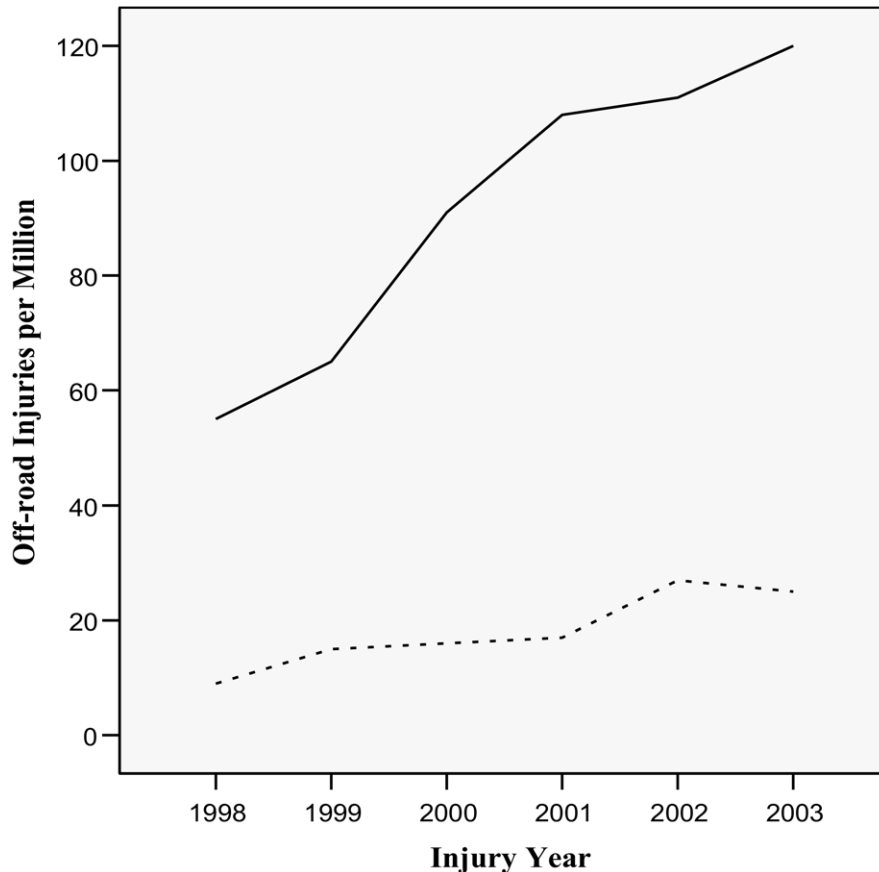


Figure 1. From the Oregon Trauma Registry, number of individuals in Oregon injured annually in crashes involving off-road vehicles, separated by gender, were used to calculate rates of injured patients per million populations. Solid line, male patients; dotted line, female patients.

for other drugs. A positive ethanol test was associated with a patient having a higher risk of head, neck, or face injury.

The eventual discharge disposition of 85% of patients was to home, 13% was to a skilled nursing facility, another hospital or rehabilitation, and 2% died. The insurance status of patients hospitalized showed 5% had no insurance, 17% had Medicaid coverage, and 78% reported having some form of commercial health insurance or Medicare.

DISCUSSION

The principal finding of these analyses was a substantial increase over the past few years in the number of patients treated in Oregon's statewide trauma system for injuries sustained while riding off-road vehicles. Particularly disturbing was an escalation in the number of children sustaining death and injury while riding either ATVs or ORMCs. Events in Oregon are consistent with the na-

tional data reported by the authors of the CPSC 2004 Annual Report of ATV Deaths.¹ The CPSC estimates that in the US, over a recent 6-year period, numbers of four-wheel vehicles doubled from 3.1 million to 6.9 million. In Oregon, a surge in popularity of recreational riding of off-road vehicles on summer weekends appears to have contributed to the injury epidemic. Previously, injury-prevention programs accomplished a reduction in death and disability caused by ATV crashes. In 1988, the US Department of Justice and ATV makers reached a consent decree that terminated manufacture of three-wheeled ATVs. This consent decree was credited with reducing death rates for ATV riders in the early 1990s. The consent decree has expired, but we expect renewed efforts at improving vehicle safety will have the potential to reduce the recent escalating rates of injury and death. We reason detailed data about the circumstances of crashes, and the pattern of injuries sustained, are needed to guide manufacturers' design of safer vehicles.⁹



Figure 2. Oregon patients injured in off-road accidents, 1998 to 2003, using the data field in the Oregon Trauma Registry, "county of injury." The eight counties designated as including major metropolitan statistical areas in Oregon are in white. Numbers of patients in Oregon Trauma Registry whose location of injury is in adjoining states are indicated.

Oregon's statewide trauma registry includes information collected at acute care hospitals in the major metropolitan region, cities, and rural communities in the state, and provides surgeons and public health authorities a valuable resource to monitor the rates of injury and outcomes after off-road vehicle crashes in the entire state. Although the number of injured patients has increased, both the proportion of crash patients who are seriously injured and the patterns of injuries sustained in crashes while riding off-road vehicles in Oregon has changed little over the past few years. We conclude that a predictable pattern of injury to patients involved in off-road vehicle crashes is an indication that newer vehicles have not been successfully designed to be safer. Nonetheless, a trend in later years for more patients requiring treatment for severe injuries to the spine, spinal cord, and eyes has been specifically worrisome, given the lifelong disability associated with these injuries. Riders need to be convinced by medical care providers that

caution is needed when riding off-road vehicles because these data indicate that riders involved in a crash have a fixed risk of grievous injury. Aitken and colleagues¹² conducted focus-group discussions on ATV injury in children and observed that "participants endorsed messages demonstrating graphic consequences as likely to get the attention of young riders." Surgeons should join other health care providers who are calling for a public health response to the growing problem demonstrated in these analyses that off-road vehicle crashes cause riders to experience prolonged disabilities, permanent disfigurement, and death.

Riders of both ATVs and ORMCs in Oregon have equivalent accelerating rates of injury. The four-wheeled ATV and two-wheeled ORMC are different in their design, but we propose that similarities in rider profile, injury pattern, and timing of injury make it best to develop injury-prevention programs that focus simultaneously on changing the behavior of the riders of these

Table 3. Demographics of Patients Injured in Off-Road Crashes 1998–2005 and Treated at the Oregon Health Sciences University Level I Trauma Center

Variables	ATV injuries (E-codes: 821.0–821.1) (n = 197)	Motorcycle injuries (E-codes: 821.2–821.3) (n = 92)	p Value
Patient designation, n (% transfers*)	129 (65.5)	56 (60.9)	0.447
Age (y) categories, n (%*)			0.046
≤ 15	50 (25.4)	21 (22.8)	
16–25	38 (19.3)	30 (32.6)	
26–49	85 (43.1)	36 (39.1)	
≥ 50	24 (12.2)	5 (5.4)	
Male gender, n (%*)	154 (78.2)	87 (94.6)	< 0.001
ISS [†]	14 (10) ± 10.3	14 (10) ± 10.5	0.595
Time of year injured, n (%*)			0.933
October–March	48 (24.4)	22 (23.9)	
April–September	149 (75.6)	70 (76.1)	
Day of week injured, n (%*)			0.604
Monday–Thursday	66 (33.5)	28 (30.4)	
Friday–Sunday	131 (66.5)	64 (69.6)	
AIS body region, n (%*)			
Head and neck	91 (46.2)	35 (38.0)	0.193
Face	31 (15.7)	17 (18.5)	0.560
Chest	61 (31.0)	28 (30.4)	0.928
Abdomen	44 (22.3)	27 (29.3)	0.197
Extremities	76 (38.6)	43 (46.7)	0.189
External	129 (65.5)	61 (66.3)	0.891
Disability in locomotion at discharge, [‡] n (%*)	69 (37.9)	47 (54.0)	0.013
Outcomes, n (% died*)	4 (2.0)	2 (2.2)	1.000

Statistical comparisons are proportions of patients in the all-terrain vehicle and off-road motorcycle cohorts.

*Percent of total in group.

[†]Mean (median) ± SD.

[‡]Twenty patients were not assessed for disability because they were either discharged from the emergency department or they died.

AIS, Abbreviated Injury Scale; ATV, all-terrain vehicle; ISS, Injury Severity Score.

two prototypical off-road vehicles. Riders of both types of vehicles are commonly injured on the weekends and in the summer months in rural regions of the state. One rationale for combining injury-prevention efforts is that recreational riders of both ATVs and ORMCs need to accept a similar caution: these vehicles, although exhilarating to ride, are not toys and pose a risk for serious injury and death. Riders of both ATVs and ORMCs require training in proper operation of these vehicles, which will minimize the rider's exposure to situations where they lose control of their vehicle. Riders of ATVs and ORMCs reduce, but do not eliminate, their risk when they successfully complete appropriate training in vehicle operation, wear protective clothing and safety equipment, and when they ride these vehicles on trails and in environments that are compatible with their skill and experience. Several observers in Oregon have noted that the rapid increase in popularity of off-road vehicles

has led to crowding in popular venues. We propose that when the millions of responsible citizens who ride ATVs and ORMCs are fully informed of the danger to all from reckless use of these vehicles, the majority will insist on implementation of public policies and laws that would make riding off-road vehicles a safer recreational experience.

Several injury-prevention programs were suggested to us after analyses of these data. Individuals who ride off-road vehicles intoxicated and without helmets expose themselves needlessly to death or permanent disability. Society and public authorities must develop regulations that reduce children's access to off-road vehicles that are inappropriate for their size or skills, and caution adults that children are not to ride as passengers on these vehicles. Children and adolescents must be convinced that these vehicles, although entertaining, are dangerous machines and not toys. Media or advertising images that

Table 4. Early and Later Years Comparison of Patients Injured in Off-Road Vehicles (All-Terrain Vehicle and Off-Road Motorcycle) Treated at Oregon Health Sciences University

No. and types of surgical procedures	1998–2001	2002–2005	p Value
n	80	209	
Type of vehicle by E-code, n (%*)			0.895
ATV (821.0–821.1)	55 (68.8)	142 (67.9)	
Motorcycle (821.2–821.3)	25 (31.3)	67 (32.1)	
ISS [†]	13 (11) ± 9.7	14 (10) ± 10.6	0.863
Admitted patients, n (% yes*)	74 (92.5)	185 (88.5)	0.321
LOS (d) [‡]	8 (6) ± 10.3	8 (5) ± 9.5	0.984
ICU stay, n (% yes*)	42 (52.5)	111 (53.1)	0.926
ICU LOS (d) [‡]	6 (2) ± 7.5	5 (3) ± 6.0	0.108
Area of procedure (n)			
Orthopaedic, including fasciotomy	41	103	
Soft tissue	18	40	
Abdominal viscera + GU	15	17	
Brain and skull	8	10	
Face, facial bones, and eye	16	32	
Larynx and trachea	2	2	
Pulmonary/chest/cardiac	18	15	
Major vascular	8	5	
Spinal cord and spine	9	69	
Requiring OR procedures (n/total number admitted)	40/74	93/185	0.582

Statistical comparisons are proportions of patients in the earlier and later cohorts.

*Percent of total in group.

[†]Mean (median) ± SD.

ATV, all-terrain vehicle; GU, genito-urinary; ISS, Injury Severity Score; LOS, length of stay; OR, operating room.

abet or aggrandize dangerous riding practices should be condemned and perpetrators sanctioned. Precise information about rates of injury in particular vehicles should be established and made available to the public so consumers purchasing vehicles are aware of the relative safety of particular models of off-road vehicles. The remote rural location where injury occurs in the majority of patients is a factor that influences patient's access to care. Improved care after injury can depend on refinements in the operation of Oregon's statewide trauma system. For example, these data indicate that immediate death is common among decedents, suggesting that excessive delays at the scene might be a factor. Emergency response vehicles and crews might be stationed at times and locations of highest risk and hasten their response to crashes. Although improvements in acute care of injured patients can have a favorable influence on the growing death and disability rate for riders, we are convinced injury prevention will provide the most effective response to the epidemic in off-road vehicle crash injuries. We propose several strategies, including strong advocacy for practicable injury-prevention programs by national professional med-

ical organizations, such as the Committee on Trauma of the American College of Surgeons (Table 5).

There are limitations to these analyses. Only seriously injured patients who were treated in Oregon's designated trauma centers are included in these analyses. Riders who were killed at the scene, patients treated at trauma centers whose minor injuries did not warrant inclusion in the trauma registry, and patients who were treated at hospitals that are not trauma centers, are excluded from these analyses. We expect our analyses underreport the magnitude of the problem. Nonetheless,

Table 5. Injury-Prevention Strategies Intended to Reduce Death and Injury among Riders of Off-Road Vehicles

Establish among key national professional medical associations consensus on responses to the epidemic
Advocate in concert for all-terrain vehicle and off-road motorcycle injury-prevention programs and legislation
Develop public media messages that urge caution among off-road riders and deliver these messages at times of highest risk
Target children in messages that urge caution riding off-road vehicles
Call for government agency and industry funding for research that leads to safer vehicle design

we advocate the Oregon Trauma Registry as a valuable source of data for monitoring trends in rates of serious injury and potentially preventable death caused by off-road vehicle crashes. A limitation of the information available in trauma registry data is a lack of precise and detailed description of the mechanism of crash. Additional information that could be useful includes the influence of terrain conditions, the proportion of riders injured when the vehicle flips or rolls and falls on them, and the proportion of riders thrown from the vehicle after a collision with objects or other vehicles. Detailed information about mechanism of crash would be valuable, we conclude it is impractical to expect that accurate crash information can be accurately described in trauma registries that are recorded by personnel who do not investigate the scene of injury. We reason that to collect this information, government agencies will need to fund research studies that are patterned after the Crash Injury Research and Engineering Network funded by the National Highway Traffic Safety Administration.¹³ We propose another goal of crash analyses should be to identify links between crash and vehicle characteristics and patterns of injury. We predict a comprehensive understanding of the circumstances of injury sustained in off-road vehicle crashes will provide a foundation for engineering safer vehicles, and designing trails and race courses that provide riders an entertaining ride without unreasonable risk.

In summary, data in Oregon's trauma registries confirmed that death and serious injuries, including trauma to the spine, spinal cord, and brain, are sustained statewide by riders of both ATVs and ORMCs. The growing problem in Oregon parallels a worrisome trend over the past decade across the US reported by the CPSC. Oregonians riding off-road vehicles are being killed at increasing rates annually, although others sustain life-long disabling injuries. These patients have substantially increased the need for Oregon's rural and urban trauma centers to provide emergency trauma care, particularly on summer weekends. Injury-prevention strategies and interventions must be developed and implemented that bring about a measurable decline in the epidemic of severe injuries sustained by users of these recreational vehicles. First priority must be assigned to children, whose risk of death is greatest. Injury prevention will be successful if a coalition of citizens who ride these vehicles,

manufacturers, safety engineers, and medical care providers working with their professional medical associations, join with government regulatory agencies to design and implement effective injury-prevention strategies.

Author Contributions

Study conception and design: Mullins, Lenfesty, Ham
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 Analysis and interpretation of data: Mullins, Brand, Lenfesty, Newgard
 Drafting of manuscript: Mullins, Lenfesty
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