ATV Overturn

Engineering Controls to Prevent Crush Injuries

By Melvin L. Myers

IN BRIEF

- **All-terrain vehicle crashes have killed more than 10,000 and injured hundreds of thousands of riders since 1985; most were related to overturns.**
- **Behavior-based interventions have been implemented over decades reaching their limit of success.**
- **As with tractors, engineering controls have the potential to mitigate or prevent most of these fatal and nonfatal injuries.**
- **In this regard, much controversy has surrounded a single potentially effective crush prevention device.**

On June 6, 2014, in Scottsdale, AZ, Amy Van Dyken-Rouen, an Olympic gold-medal-winning swimmer, was driving an all-terrain vehicle (ATV) in a restaurant parking lot when the machine hit a curb. It tipped over a 5- to 7-ft drop-off. She was seen lying on the ground unconscious next to the machine and received help from a firefighter and off-duty emergency room doctor, both of whom were at the restaurant. The ambulance arrived 15 minutes later. She had a severed vertebra. Vikas Patel, a doctor at the University of Colorado hospital, said, "It's a huge amount of force required to, basically, take on half of the spine and go one direction and the other half go the other direction. . . . To me, to have a fracture like this means that most likely there was so much force involved that the ATV was on top of her" (Stanley & Zelinger, 2014). She was paralyzed from the waist down. By August 2014 with a powered exoskeleton, she was able to stand up and walk (Mazza, 2014).

Such events are part of a modern epidemic: injuries from ATV-related overturns. CDC (2011) defines an epidemic as:

> [T]he occurrence of more cases of disease, injury or other health condition than expected in a given area or among a specific group of persons during a particular period. Usually, the cases are presumed to have a common cause or to be related to one another in some way.

Once upon a time (perhaps many times), a farmer who survived death from a tractor overturn said, "Well, that never happened before." That is an individual's perspective, but with a broader, population-based perspective, studies have shown that tractor overturns occur often. Indeed, they were the highest cause of death from injury on farms for many years, including up to the present.

Like tractors, Garland (2014) found that ATV overturns are the highest cause of death associated with crashes of these machines at 60.6%. From 1985 to 2009, 10,561 people were killed by ATV-related incidents (Figure 1, p. 38). One possible explanation for the decrease in the number of fatalities during 2008 and 2009 is the recession, which may have reduced the number of new ATVs purchased (Clapperton, Herde & Lower, 2013). Consumer Product Safety Commission (CPSC) is still collecting decedent data beyond 2009. This article addresses the problem and controversy that surrounds the epidemic of serious injury and death regarding the design, manufacture and use of ATVs.

Consumer Product Safety Commission

CPSC defines an ATV as an off-road, motorized vehicle having three or four low-pressure tires, a straddle seat for the operator and handlebars for steering control (Topping & Garland, 2014). In 1985, CPSC commenced rulemaking to address hazards associated with ATVs, declaring that ATVs are an "imminently hazardous consumer product" (CPSC, 2006). By 1988, the final consent decree included the prohibition of the sale of three-wheeled ATVs, which were known to be more unstable regarding rollovers than four-wheeled ATVs (David, 1998). The consent decree included other agreements for providing labeling and education programs.

A dip in the number of ATV-related deaths occurred during the period of the consent decree likely because of the removal of three-wheeled ATVs from

Melvin L. Myers, M.P.A., is an associate adjunct professor at Emory University Rollins School of Public Health in Atlanta, GA. He has been a design engineer, a U.S. Public Health Service commissioned officer for 30 years (20 years with NIOSH), and a cost and research engineer at University of Kentucky College of Public Health as an associate professor (visiting). He has taught environmental and occupational health policy at Emory University for 24 years, and authored the 2015 book *Occupational Safety and Health Policy*. Myers is a professional member of ASSE's Georgia Chapter.

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In 1985, CPSC declared that all-terrain vehicles (ATVs) are an "imminently hazardous consumer product." ATV crashes have killed more than 10,000 and injured hundreds of thousands of riders since 1985; most were related to overturns.

the market, and thereafter a steady rise of deaths occurred, supposedly because of the sale of millions of additional ATVs to consumers (Figure 1, p. 38).

In response to the 2008 Consumer Product Safety Improvement Act, CPSC promulgated a mandatory consumer product safety standard regarding ATVs. The standard reaffirmed the ban established under the expired consent decree of three-wheeled ATVs in U.S. commerce (CPSC, 2008). Provisions in this standard may have also contributed to the decrease in fatalities starting in 2008.

In October 2012, CPSC convened an ATV Safety Summit in Bethesda, MD. Nesteruk (2013) reports that the summit provided information on the rulemaking proceding and engaged stakeholders to explore potential ways to increase ATV safety. Overturn protection was the dominant technology issue. However, Garland (2014) found that overturns caused 60.3% of ATV-related emergency-department-treated injuries and at least 60.6% of ATV-related fatalities. For the period 2001 through 2013, emergency-department-treated injuries totaled 1,616,800 cases. Other medical facilities such as clinics and physician offices are estimated to treat an additional 60.4% of injury cases (Miller, Lawrence, Jensen, et al., 2000).

Work-Related Injuries

CPSC does not address occupational injuries, but ATVs are used in rural and remote areas for general transportation as well as in manufacturing, farm and ranch activities, and in the construction and oil production industries. They are also used for tasks such as pesticide applications, and for traversing rough terrain such as ditches, lifeguard patrols and utility line maintenance (GAO, 2010).

Helmkamp, Marsh and Aitken (2011) conducted a study of ATV-related occupational fatalities among civilian employees age 18 and older, which was based on Bureau of Labor Statistics data for the years 1992 through 2007. For that period, 297 occupational ATV-related deaths occurred, half of which involved overturns; 60% occurred on farms and 20% occurred on highways. A dramatic increase in deaths occurred between 1992 with 11 decedents to 2007 with 41 decedents, a 300% increase in the fatality rate.

Missing from this study were children. Goldcamp, Myers, Hendricks, et al. (2006), examined farm-related injuries among youth younger than age 20 for the year 2001. As many as 42% of ATV-related injuries among this population may be work related. Government agencies also use ATVs, such as U.S. Census Bureau, military, land management agencies, police and search-and-rescue units (GAO, 2010).

Hierarchy of Controls

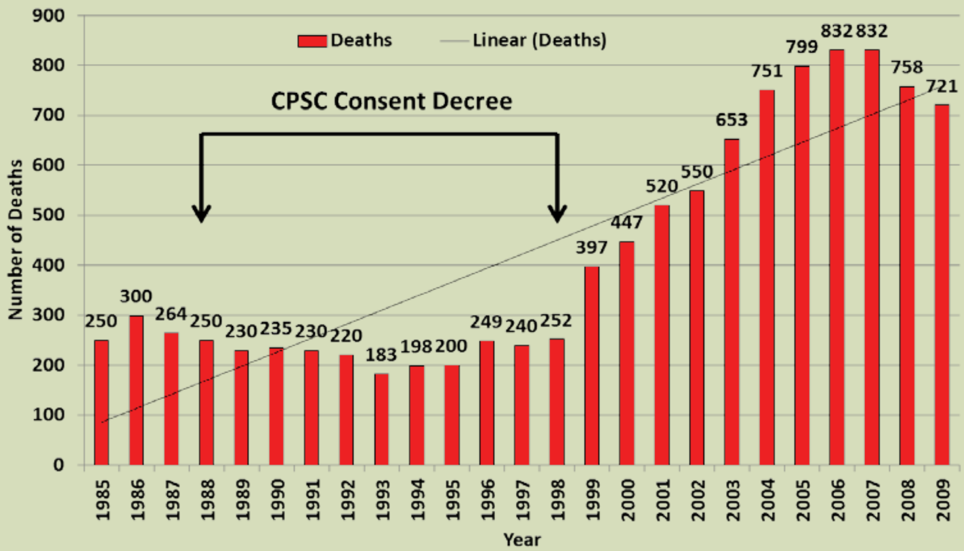
The hierarchy of controls is well known in engineering design. Aldrich (1997, pp. 115-117) describes a long-held principle in safety of "engineering revision" dating to 1917. This revision was a shift from blaming the victim for carelessness, known as "fundamental attribution error" according to Myers (2015), to an emphasis on the cause of the injury and its prevention. In her analysis, Tebeaux (2010a; b) found that many warnings are designed as a legal shield against strict liability—a blame-the-victim strategy.

Consistent with the engineering revision concept, Haddon (1974) developed a two-level hierarchy of controls, passive and active, in which preferred passive controls require no personal intervention by the potential victim of an injury [e.g., rollover protective structures (ROPS) on tractors], as compared to active controls, which require a personal intervention (e.g., fastening a seat belt). Two legacies with these controls in opposition are described in Table 1 (p. 38).

This hierarchy led design engineers to adopt a precedence ordering of controls for protecting people from injury. Wogalter (2006) describes the hierarchy in three steps, from the most to the least protective control: 1) eliminate the hazard; 2) control the hazard; and 3) warn of the hazard. OSHA adopted a

Figure 1

Number & Trend Line of ATV-Related Deaths, 1985-2009



Note. *Number and trend line of ATV-related deaths, 1985-2009, and a depiction of the length of the 10-year CPSC consent decree,* n = *10,561. Data from "2013 Annual Report of ATV-Related Deaths and Injuries," by J. Topping and S. Garland, 2015, Bethesda, MD: CPSC.*

Table 1

Two Legacies in Protecting ATV Riders From Overturn-Related Injuries

Motorcycle legacy	ATV	Tractor legacy
Active controls →	Protect riders from injury in an overturn event	← Passive Controls
1) Warnings: keep off of pavement, supervise youth, no passengers, do not speed, age appropriate machine, designated trails only, do not drive under the influence 2) Wear a helmet 3) Training		1) Three wheels → four wheels 2) Eliminate ATVs 3) Rollover protective structures 4) Crush prevention devices

Note. *Adapted from "Strategy in preventive medicine," by W. Haddon, 1974,* The Journal of Trauma: Injury, Infection and Critical Care, 14*(4), pp. 353-354.*

similar hierarchy of controls in writing its standards, and in 2005, ANSI approved a consensus standard that included a hierarchy of controls (Myers, 2015).

The Motorcycle Legacy—Active Controls

Osamu Takeuchi built the first ATV in 1967 from motorcycle parts in response to a request from America Honda Motor Corp. to its parent company in Japan. The ATV first entered U.S. markets in 1970 (Kitzes, 1989). Australians know the ATV as a quad-bike—a four-wheel version of a two-wheeled motorcycle (Photo 1a; b). Regarding ATVs, a coroner inquest record in Australia states:

> Active riding refers to the operator moving [his/her] pelvis laterally and/or longitudinally on the seat, or vertically off the seat, while keeping both hands on the handlebars and both feet on the footrests throughout a maneuver, increasing the stability of the quad bike, and thereby reducing the chances of a rollover. (Lock, 2015)

Warnings against ATV riding on paved surfaces have failed with more than 10% of emergency department-treated injury cases and nearly 35% of ATV-related deaths (Table 2). Warnings to ban children younger than age 16 have failed with nearly 26% of all of the emergency-department-treated injuries and nearly 18% of ATV-related deaths recorded. Warnings to not carry passengers on vehicles not designed to do so were caught short and involved 32% and 23% nonfatal and fatal injuries, respectively. Lack of helmet use by the injured was problematic with 57% and 66% of the emergency-department-treated patients and decedents, respectively. Most distressing, only 2.5% and 0.2% of emergency-department-treated patients and decedents, respectively, were known to have received training.

In a presentation at the ATV Safety Summit, Grzebieta and Rechnitzer (2012) reported the following conclusion from their rollover crash performance tests conducted at University of New South Wales in Australia:

> ATVs, although based on motorcycle structures with two wheels added, have significant differences in handling, usage and collision modes. Despite these major differences, ATV safety philosophy retains and promotes, quite inappropriately, a motorcycle-based and rider-centered perspective on safety, rather than a vehicle one. That is, ATV safety is considered to depend on rider separation from the vehicle and the addition of protective clothing and helmet. Simply put, such safety philosophies are ill conceived and dangerous for ATV riders. They do not offer any protection in the most common modes of injury with ATV rollovers or collisions.

The Tractor Legacy: Passive Controls

Much is left to be done to prevent these injuries, thus a different perspective is needed. The hierarchy of controls provides that perspective.

Elimination of the Injury Hazard

Grzebieta, Rechnitzer, Simmons, et al. (2015), identified a path to eliminate the ATV hazard by influencing a shift to four-wheeled off-road utility or recreational vehicles fitted with a ROPS and seat belt, which in Australia are called side-by-side vehicles (Photo 2, p. 40). A shift to alternative vehicles may already be underway in the U.S. indicated by

Photo 1a and 1b: The genesis of the ATV design came from the motorcycle, both of which arguably depend on active riding as a safety measure.

Table 2

Rules Promoted for Safe ATV Operation & Associated Injury/Fatality Prevalence

CPSC rules of the road	ATV Safety Institute golden rules	ATV crash data
1) Do not drive on paved roads.	1) Never ride on paved roads except to cross when done safely and permitted by law—another vehicle could hit you. ATVs are designed to be operated off-highway.	•10.4% of injuries and 34.4% of fatalities occurred on paved roads/surfaces.
2) Do not allow a child younger than 16 years of age to drive or ride with an adult.	2) Supervise riders younger than 16; ATVs are not toys.	•25.8% of injuries and 17.8% of fatalities were children younger than age 16.
3) Do not drive with a passenger or ride as a passenger.	3) Never carry a passenger on a single-rider ATV, and no more than one passenger on an ATV specifically designed for two people.	•31.5% of injuries and 23.0% of fatalities involved multiple riders.
4) Always wear a helmet and other protective gear such as eye protection, boots, gloves, long pants and a long-sleeved shirt.	4) Always wear a DOT-compliant helmet, goggles, long sleeves, long pants, over-the-ankle boots and gloves.	•56.9% of injuries and 66.0% of decedents wore no helmet.
5) Take a hands-on safety training course.	5) Take a hands-on ATV RiderCourse and the free online e-course.	•2.5% of injured and 0.2% of dead drivers were trained.
	6) Never drive under the influence of alcohol or drugs.	•5.1% of injuries and 10.2% of dead drivers were under the influence of alcohol.
	7) Ride on an ATV that is right for the rider's age.	•3.1% of injuries and 0.7% of fatalities occurred on youth ATVs.
	8) Ride only on designated trails and at a safe speed.	•25.8% of injuries occurred at speeds > 20 mph.

Note. *Data from "ATV Safety Information Center," by U.S. Consumer Product Safety Commission, 2016, retrieved from www.cpsc.gov/en/Safety-Education/Safety-Education-Centers/ATV-Safety-Information-Center; "The ATV Safety Institute's Golden Rules," by ATV Safety Institute, 2016, retrieved from www.atvsafety.org; and "National Estimates of Victim, Driver and Incident Characteristics for ATV-Related, Emergency-Department-Treated Injuries in the United States from January 2010-August 2010 With an Analysis of Victim, Driver and Incident Characteristics for ATV-Related Fatalities From 2005 Through 2007," by S. Garland, 2014, Bethesda, MD: CPSC.*

fewer ATVs in use (Statiata, 2015) as well as reports of declining ATV-related deaths and injuries from an apex in 2007 and 2008 (Figure 1).

Side-by-side (utility) vehicles have a ROPS attached but the passenger is known to hold onto the ROPS upright, while the driver holds onto the steering wheel as the machine travels over rough areas. However, in an overturn, some passengers suffer crush-related avulsion injuries, known as roll-bar hand, which leaves only the thumb on the hand. Most of these vehicles now have a handhold mounted on the ROPS (Charters & Davis, 1978).

The Australian proposal is a star ratings system to extend testing beyond ATVs to include utility vehicles. The proposal includes performance crash tests from which up to five stars can be earned, thus, a star rating for each vehicle model. The safer the vehicle, the more stars earned.

Photo 2 (top): A light utility vehicle fitted with a ROPS but with no passenger handhold on the upright. Photo 3 (bottom): "Wheelie bar" used on a tractor to stop a rear overturn.

According to Rechnitzer, Grzebieta, McIntosh, et al. (2013), the aim of that system is to improve ATV safety similar to the U.S.'s new car assessment program used by National Highway Traffic Safety Administration to inform consumers about the relative safety of vehicles. Grzebieta, Rechnitzer, Simmons, et al. (2015), state that this program stimulated competition based on engineering innovations for designs that improved automobile safety. These authors observe that the U.S. program resulted in a great improvement in motor vehicle safety by developing information that led to voluntary improvements in vehicle safety.

Since the proposed star ratings system would extend testing beyond ATVs to utility vehicles such as side-by-side vehicles, the program may shift consumer behavior away from ATV designs to other quadricycles that are tested for safety while meeting consumer needs. Nonetheless, even with a shift to utility vehicles, millions of ATVs would remain in use for which crush prevention devices (CPDs) could be retrofitted to improve protection in the event of an overturn. ATV ownership has been reported at 13.3 million U.S. households in 2015 (Statiata, 2015).

Rollover Protection on ATVs

The principle guarding device for protection against injury in the event of an overturn is the roll bar, or ROPS. Roll bars are a proven protective device on race cars, automobiles and trucks. ROPS are proven protective devices on tractors and other off-road vehicles. Indeed, ROPS have been shown to be 98% effective at preventing death from tractor overturns (Springfeldt, Thorson & Lee, 1998).

Johnson, Wright, Carpenter, et al. (1991), identify ATV hazards that include overturns forward, sideways and to the rear. They modified ATVs to increase stability by widening the track width, lengthening the wheel base and lowering the seat base on the four-wheeled units. A roll cage and "wheelie bar" were added to the ATV (Photo 3). Stability was greatly increased, especially in the longitudinal directions. Backflips were eliminated even with a 200-lb operator, and the restrained operator was uninjured in dozens of side rollovers.

Piziali, Fowler, Merala, et al. (1994), evaluate the Johnson design. They list the function of a ROPS: 1) arrest motion in an overturn; 2) provide an operator with an envelope of protection against crushing or impact injury; and 3) restrain the operator within the envelope in the event of an overturn. They added nine operational criteria to safety, and also postulated injuries associated with the ROPS, specifically the mousetrap and flyswatter effects.

The mousetrap effect assumes an unbelted rider in a lateral overturn would fall under the ROPS before it hit the ground and sustain crushing injuries. In the flyswatter effect, a belted operator is restrained at the waist and upon the ROPS impact with the ground, the operator's head would smash against the ground. These additional modes of injury did not consider the counterfactual: Without the ROPS, would the machine roll over the operator? The postulated injury modes and operational factors led them to conclude that the Johnson ROPS was impractical and harmful.

To demonstrate that it could be built for ATVs and utility vehicles, Berry, Severt and Severt (1999) developed ROPS for ATVs and light utility vehicles. They recognized that from the 1960s, the best method for preventing overturn-related injuries was a safety frame or roll bar. They addressed unique characteristics for developing a ROPS for these vehicles, such as the unlikelihood of axle-mounted ROPS, none of which were insurmountable. The frames that were developed were less robust and lighter than the Johnson ROPS, and when completed met the OSHA standards for ROPS. The design included seat belts. Berry, et al. (1999), observed that while these were four-post ROPS, two-post ROPS with limb sweeps could also be developed.

Crush Prevention Devices

Nevertheless, the ATV industry strongly opposed any type of ROPS or crush prevention device (CPD). McDonald (2012) defined a CPD as a technology to provide space under an overturned vehicle to prevent crushing injuries to the rider. CPDs do not include occupant restraints and, thus, do not aim to prevent impact-related injuries (except by the rider holding tightly onto the machine). According to Rechnitzer, et al. (2013), opposition is based on the argument that these devices cause more harm than good. The controversy for and against these controls was evident at CPSC's ATV Safety Summit, much of which was leveled at one CPD design. Comments at the summit also stressed that ROPS would do more harm than good (Table 3). This was in contrast with a 2003 Monash University Accident Research Center study in Australia that proposed that a ROPS for ATVs was ideal for rider protection from both overturns and collisions.

Moore (2008) observes rear post frames mounted on ATVs in New Zealand with many CPD designs that range in concept from T-bars to staple-shaped designs ($n = 31$). Rechnitzer, et al. (2013), previously considered these designs deficient as halfway measures in 2003, but in hindsight concluded that a more pragmatic approach was needed to provide protection in increments based on minimizing harm. This viewpoint sanctioned CPDs as an incremental step for saving lives. According to Lambert (2012), CPD designs should include design criteria as follows:

1) Safety requirements:

•effective in protecting the rider in rear and side overturns;

•improved safety in front overturns;

•high enough clearance to provide survival space in the upside-down position;

•safe distance away from the rider to minimize impact with the rider in the event of an overturn;

•minimize the chance of pinning or spearing a rider in the event of an overturn.

2) Operational considerations:

•should not restrict access and egress from the ATV or driver visibility;

•have minimal impact on stability with low weight and low center of gravity;

•be low enough to not catch overhead branches.

An exemplar of the CPD that meets these criteria and is on the market in Australia is the Quadbar (QB) (Photo 4, p. 42). Industry reports have criticized this device for its harmful unanticipated consequences (Table 3). Wordley and Field (2012) met these challenges in a literature review report that addressed the deficiencies of several tests aimed at discrediting the QB, as follows:

•No computer simulations of crashes of QB-equipped ATVs could predict asphyxiations, which account for 40% of ATV overturn-related deaths in Australia.

•Computer simulations contained insufficient information to define incident scenarios.

•Assumptions and interpretations significantly altered the simulation results.

•Potential inaccuracies were apparent in modeling terrains, selection of ground stiffness and friction coefficients, and common use of extreme lengths of slopes.

•There were unexplained shifts in over-predicting head injuries while virtually eliminating chest injuries.

•Susceptibility of an ISO method for calculating benefit ratios involved extreme selection bias in the use of test scenarios, inherent variability in individual cases and comparisons of minor injuries to fatalities.

Table 3

Stakeholder Comments on CPD & ROPS

Crush prevention devices	Rollover protection structures
•The Quadbar[a] does not cause injury; this is based on years of Quadbar use. •A sample of rollover simulation showed increased risk for people to be impaled by a Quadbar. •Studies have also shown the Quadbar has prevented injury. We need to look at where they have been installed and their usage to determine outcomes. •Australia's research pertaining to CPDs does not consider front rollover situations, which is a glaring omission. •The Quadbar is not a silver bullet and has not been reviewed comprehensively enough. •The Quadbar CPD, after looking at all safety aspects of that device, and similar devices in the U.K. and New Zealand, is the best design device currently commercially available anywhere in the world. •The introduction of CPD is the most important single initiative that could be taken. Manufacturers have invested heavily in opposing such action and the negativity they have developed against such fitment needs to be counteracted. The evidence they have used over many years to support their opposition is conceptually and technically unsound. The evidence against their advocacy of training as a control measure is presented. •Retrospective fitment of CPDs is required.	•Data are not complete. The percentage of incidents cited in studies is not included in the CPSC's in-depth investigations, which cover injury or fatality scenarios. Any credible review of ROPS must take into account scenarios in which there is no injury. •Individual ATV buyers should have the freedom to decide whether to purchase a vehicle equipped with a ROPS or not. •In addition to the presence of ROPS, rider behavior still plays a role in preventing crush injuries. •CPSC and other independent reviewers have not proven that ROPS provide a benefit or whether there is a trade-off between potential benefit and potential harm. There is no methodology or justification for making those trade-offs. •The viability of installing it on an ATV should be based on clear demonstration of benefit. •Investigation and research into various proposed ROPS for ATVs over more than 20 years has found them to be unsuitable for their intended use. Each such device would raise the center of gravity of the ATV, thereby degrading vehicle stability. These proposed structures may also entail injury risks similar to, or greater in magnitude than, any prospective safety benefits.

Note. *Data from "ATV Safety Summit: Keeping Families Safe on ATVs" (Staff Report), by H.E.J. Nesteruk, 2013. Comments from CPSC's ATV Safety Summit, 2012. [a]Quadbar is a commercial product that is part of the public discourse and has become a focal point of controversy.*

Nonetheless, results of 2009 field tests using the QB as the specimen at University of Southern Queensland in Australia supported the effectiveness of CPDs. Snook (2009) concludes:

> The QB did not impede rider operation of the quad bike during normal operation. In low speed sideways rollovers, the QB arrests the rollover and prevents the ATV from resting in a position that could trap and asphyxiate the rider. In higher speed sideways rollover, the QB impedes the rollover and prevents the ATV from resting in a position that could trap and asphyxiate the rider. In all tests the QB provided some clearance between the ground surface and the ATV seat so the rider would be unlikely to be trapped in this space. In all back flip tests, the QB arrested the back flip and the quad bike fell to one side. There were no conditions where the ATV with the QB fitted rested in a position that was more detrimental to rider safety than the ATV without protection. (Snook, 2009)

Moreover, Grzebieta, Rechnitzer and McIntosh (2015) conducted crashworthy tests regarding ATVs with overturns to the rear, the front and the side. Typically, in the absence of an overturn protection device, the ATV came to rest on the test dummy, but when a QB was present, the ATV came to rest away from the dummy or the QB supported the ATV above the dummy.

Photo 4: A crush prevention device mounted on an ATV.

In summary, while the CPD does not protect against impacts, tests show that the QB provides survival space under an overturned ATV. An additional benefit is its ability to stop a continuous overturn beyond 90° to the rear or to the side in low-energy overturns. Moreover, in rear overturns, it has the added feature of shifting the motion to the side away from the rider. Even in front overturns based on laboratory tests, the operator lands within the survival space provided by the bar.

Furthermore, the real-world experience with the QB has proved promising. Lambert reported in 2015 that QBs in use on ATVs number 3,700 with no fatalities over an average of 2.8 years (Arnold, 2015). Of two reported injuries, one was a fracture related to the QB, although with unknown circumstances. At least 20 individuals claimed that the QB saved their lives, three from frontal overturns (Arnold, 2015). Three years earlier, Lambert (2012) opined that the QB is an ideal start for reducing deaths and serious injuries associated with overturns by 80%. Anderson (2015) reported on a more conservative estimate extracted from a computer simulation report from a U.S. company regarding the QB of a nonstatistically significant net benefit of the QB at 12%. This estimate had an expanded denominator that included all crashes and not just overturns.

Conclusion

Active controls such as warnings, while potentially useful with training, fall short of curtailing fatal and nonfatal injuries associated with ATV riding. Passive controls include ROPS and CPDs, which are engineered interventions. Since ROPS have been cited as impractical, the CPD has become the next line of defense against injury but it faces intense controversy.

While a CPD does not necessarily stop impact-type injuries, it has a positive potential for preventing fatal and nonfatal crush-related injuries and deaths from asphyxiation. One brand of CPD has successfully sold nearly 4,000 units in Australia. The use of these units provides a real-world demonstration of CPD effectiveness—to date, it has been associated with no deaths. Moreover, at least 20 testimonials bear witness to the CPD saving their lives.

Indeed, one recent incident brings to the fore a story of another life saved in a forward overturn, considered the most hazardous condition regarding CPD use. A 24-year-old woman ATV driver wore a helmet when the machine overturned to the front. Police credit the roll bar with saving her life. She was sent to the hospital with nonlife-threatening injuries (Crawley, 2015).

Active controls have reached their limit of effectiveness. Policies, whether by the public or user, need to focus on requiring passive controls such as alternative but safer vehicles compared to ATVs and equipping or retrofitting ATVs with CPDs. CPDs provide passive protection while seat belts are active protection. Seat belts are secondary protection after CPDs (Baker, 1998). The lack of seat belts should not negate the use of CPDs. **PS**

References

Aldrich, M. (1997). *Safety first: Technology, labor and business in the building of American work safety, 1870-1939*. Baltimore, MD: John Hopkins University Press.

Anderson R. (2015, Aug. 3). Associate professor Anderson's review of DRI's 2012 and 2014 computer simulation reports on the Quadbar. In Coronial findings: Inquest into nine (9) deaths caused by quad bike accidents, Brisbane, Australia (pp. 42-44). Retrieved from www.courts.qld.gov.au/__data/assets/pdf_file/0018/432306/cif-quadbikeaccidents-20150803.pdf

Arnold, A. (Reporter), Whitfeld, A. (Researcher) & McGinness, L. (Producer). (2015, April 5). The trouble with quad bikes [Transcript, Television series episode]. In *Background Briefing*. Australia: ABC RN. Retrieved from www.abc.net.au/radionational/programs/backgroundbriefing/2015-04-05/6359984#transcript

ATV Safety Institute. (2016). The ATV Safety Institute's golden rules. Retrieved from www.atvsafety.org

Baker, L.D. (1998, Nov.). Comment: ROPS and seatbelts: Keeping the order right. *Journal of Agricultural Safety and Health*, *4*(4), 203.

Berry, T.A., Severt, J.B. & Severt, K.B. (1999). Operator protection for ATVs and light utility vehicles (Paper No. MC99-106). Presented at the 1999 Mid-Central Meeting of the American Society of Agricultural Engineers, USA.

CDC. (2011). *Principles of epidemiology in public health practice: An introduction to applied epidemiology and biostatistics* (3rd ed.). Retrieved from www.cdc.gov/ophss/csels/dsepd/ss1978

Charters, A.C. & Davis, J.W. (1978). The roll-bar hand. *The Journal of Trauma: Injury, Infection and Critical Care*, *18*(8), 601-604. doi:10.1097/00005373-197808000-00008

Clapperton, A.J., Herde, E.L. & Lower, T. (2013). Quad bike related injury in Victoria, Australia. *The Medical Journal of Australia*, *199*(6), 418-422. doi:10.5694/mja12.11456

Consumer Product Safety Commission (CPSC). (2006, Aug. 10). Standards for all terrain vehicles and ban of three-wheeled all-terrain vehicles; Notice of proposed rulemaking. *Federal Register*, *71*(154), 45904-45962.

CPSC. (2008). 15 U.S. Code § 2089—All-terrain vehicles. Retrieved from www.law.cornell.edu/uscode/text/15/2089

CPSC. (2016). ATV safety information center. Retrieved from www.cpsc.gov/en/Safety-Education/Safety-Education-Centers/ATV-Safety-Information-Center

Crawley, J. (2015, Aug. 30). Roll bar saved ATV rider's life, police say. *The Mercury*. Retrieved from www.themercury.com.au/news/tasmania/roll-bar-saved-atv-riders-life-police-say/story-fnj4f7k1-1227505225635

David, J. (1998, April). Part III: Report on all-terrain vehicle-related deaths, Jan. 1, 1985 - Dec. 31, 1996. Bethesda, MD: CPSC.

Garland, S. (2014, May). National estimates of victim, driver and incident characteristics for ATV-related, emergency department-treated injuries in the United States from January 2010-August 2010 with an analysis of victim, driver and incident characteristics for ATV-related fatalities from 2005 through 2007. Bethesda, MD: CPSC.

Goldcamp, E.M., Myers, J., Hendricks, K., et al. (2006). Nonfatal all-terrain vehicle-related injuries to youths living on farms in the United States, 2001. *The Journal of Rural Health*, *22*(4), 308-313. doi:10.1111/j.1748-0361.2006.00051.x

Grzebieta, R. & Rechnitzer, G. (2012, Oct.). Rollover crash performance testing: Quad bikes (ATVs). Presented at ATV Safety Summit. Retrieved from http://documents.mx/business/atv-safety-summit-vehicle-tech-roll-over-protection-rollover-crash-performance-testing.html

Grzebieta, R., Rechnitzer, G. & McIntosh, A. (2015, Jan.). Part 3: Rollover crashworthiness test results. Retrieved from www.tars.unsw.edu.au/research/Current/Quad-Bike_Safety/Reports/Quad_Project_Final_Report3_Crashworthiness_Test_Results_Jan-2015.pdf

Grzebieta, R., Rechnitzer, G., Simmons, K., et al. (2015). The Australian terrain vehicle assessment program (ATVAP) (Paper No. 15-0144). Retrieved from www.tars.unsw.edu.au/research/Current/Quad-Bike_Safety/24ESV-000144.pdf

Haddon, W. (1974). Strategy in preventive medicine. *The Journal of Trauma: Injury, Infection and Critical Care*, *14*(4), 353-354. doi:10.1097/00005373-197404000-00022

Helmkamp, J.C., Marsh, S.M. & Aitken, M.E. (2011). Occupational all-terrain vehicle deaths among workers 18 years and older in the United States, 1992-2007. *Journal of Agricultural Safety and Health*, *17*(2), 147-155. doi:10.13031/2013.36498

Johnson, F.H., Wright, R.R., Carpenter, T.G., et al. (1991, Sept.). A safer ATV (SAE No. 911945). Presented at Passenger Car Conference and Exposition, U.S. doi:10.4271/911945

Kitzes, W.F. (1989). ATVs—The hidden danger. *The Journal of Law, Medicine & Ethics*, *17*(1), 86-93. doi:10.1111/j.1748-720x.1989.tb01076.x

Lambert, J. (2012, Sept. 28). Public discussion paper: Review of design and engineering control for improving quad bike safety (QB028). Retrieved from www.safeworkaustralia.gov.au/sites/SWA/whs-information/agriculture/quad-watch/Documents/Discussion-paper-PC/Public-submissions-L/QB028-John_Lambert_and_Associates_Pty_Ltd.PDF

Lock, J. (2015, Aug. 3). Coronial findings: Inquest into nine (9) deaths caused by quad bike accidents, Brisbane, Australia. Retrieved from www.courts.qld.gov.au/__data/assets/pdf_file/0018/432306/cif-quadbikeaccidents-20150803.pdf

Mazza, E. (2014, Aug. 22). Amy Van Dyken-Rouen, Olympic gold medalist, walks for the first time since ATV accident. *The Huffington Post*. Retrieved from www.huffingtonpost.com/2014/08/22/amy-van-dyken-rouen-walks_n_5698679.html

McDonald, G.L. (2012, Sept. 26). Quad bike safety: In search of good theory (QB019). Retrieved from https://submissions.swa.gov.au/SWAforms/Archive/quad-bike/Documents/QB019-Geoff_McDonald_and_Associates_Pty_Ltd.PDF

Miller, T.R., Lawrence, B.A., Jensen, A.F., et al. (2000, Dec.). The Consumer Product Safety Commission's revised injury cost model. Retrieved from www.cpsc.gov/PageFiles/100269/costmodept1.PDF

Moore, D.J. (2008). *A systems analysis of quadbike loss of control events on New Zealand farms* (Unpublished master's thesis). Massey University. Retrieved from http://mro.massey.ac.nz/handle/10179/624

Myers, M.L. (2015). *Occupational safety and health policy*. Washington, DC: American Public Health Association.

Nesteruk, H.E.J. (2013, Sept.). ATV safety summit: Keeping families safe on ATVs (Staff report). Retrieved from www.cpsc.gov/PageFiles/26/Regulations,%20Laws%20Standards/Rulemaking/ATVs/Final%20Report ATVSafetySummitfinal.pdf

Piziali, R.L., Fowler, G.F., Merala, R., et al. (1994). Evaluation of a proposed ATV design modification (SAE No. 940276). Presented at the International Congress and Exposition, U.S. doi:10.4271/940276

Rechnitzer, G., Grzebieta, R.H., McIntosh, A.S., et al. (2013). Reducing all-terrain vehicle injuries (ATVs) and deaths—A way ahead (Paper No. 13-0213). Presented at the 23rd International Technical Conference on the Enhanced Safety of Vehicles, South Korea. Retrieved from www-nrd.nhtsa.dot.gov/pdf/esv/esv23/23ESV-000213.PDF

Snook, C. (2009, Oct. 12). An assessment of passive roll over protection for quad bikes (Report No. TR-2009-CS04). Retrieved from www.quadbar.com.au/page/attachment/1/qb_industries_report

Springfeldt, B., Thorson, J., & Lee, B.C. (1998). Sweden's thirty-year experience with tractor rollovers. *Journal of Agricultural Safety and Health*, *4*(3), 173-180. doi:10.13031/2013.15355

Stanley, D. & Zelinger, M. (Writers). (2014, June 9). *Colorado's Olympic swimmer Amy Van Dyken-Rouen severed spine in ATV crash* [Transcript, Television broadcast]. The Denver Channel.

Statiata. (2015). ATV ownership: Number of people living in households that own an ATV (all-terrain vehicle) in the United States (USA) from spring 2008 to spring 2015 (in millions). Retrieved from www.statista.com/statistics/228874/people-living-in-households-that-own-an-atv-all-terrain-vehicle-usa

Tebeaux, E. (2010a). Improving tractor safety warnings: Readability is missing. *Journal of Agricultural Safety and Health*, *16*(3), 181-205. doi:10.13031/2013.32042

Tebeaux, E. (2010b). Safety warnings in tractor operation manuals, 1920-1980: Manuals and warnings don't always work. *Journal of Technical Writing and Communication*, *40*(1), 3-28. doi:10.2190/tw.40.1.b

Topping, J. & Garland, S. (2014, April). 2012 annual report of ATV-related deaths and injuries. Bethesda, MD: CPSC.

Topping, J. & Garland, S. (2015, Feb.). 2013 annual report of ATV-related deaths and injuries. Bethesda, MD: CPSC.

U.S. Government Accountability Office (GAO). (2010, April). All-terrain vehicles: How they are used, crashes and sales of adult-sized vehicles for children's use (Report No. GAO-10-418). Washington, DC: Author. Retrieved from www.gao.gov/assets/310/302950.pdf

Wogalter, M.S. (2006). Purposes and scope of warnings. In M.S. Wogalter (Ed.). *Handbook of Warnings* (pp. 3-10). Mahwah, NJ: Lawrence Erlbaum Associates.

Wordley, S. & Field, B. (2012, Feb. 3). Quad bike safety devices: A snapshot review (Report No. C-i-11-022-010). Retrieved from www.worksafe.vic.gov.au/__data/assets/pdf_file/0019/158032/Quad-Bike-Safety-Devices-Evidence-Review.pdf

ATV Update

Australia's safety agency, SafeWork New South Wales, is taking steps to reduce ATV-related farm injuries and fatalities. The agency's latest budget includes funding for a Quad Bike Safety Improvement Program to encourage adoption of preventive strategies. Learn more at **http://bit.ly/29TwHc3**.