Preliminary Investigation of Serious Injuries in Motorcycle-Roadside Barrier Crashes in the USA

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I. INTRODUCTION

Motorcycle riders are vulnerable road users (VRUs). In the event of a crash, motorcyclists have neither the structural enclosure of a passenger vehicle occupant compartment nor the restraints which provide crash injury protection to the occupants of four-wheeled vehicles. Previous research has shown that motorcyclists are at particular risk in collisions with roadside barriers, e.g. guardrail [1-5]. In collisions with guardrail in the US, motorcyclists now account for more fatalities than any other vehicle occupant. As shown in Fig. 1, in 2017 motorcyclists comprised 40% of all guardrail fatalities despite accounting for only 3% of registered vehicles.

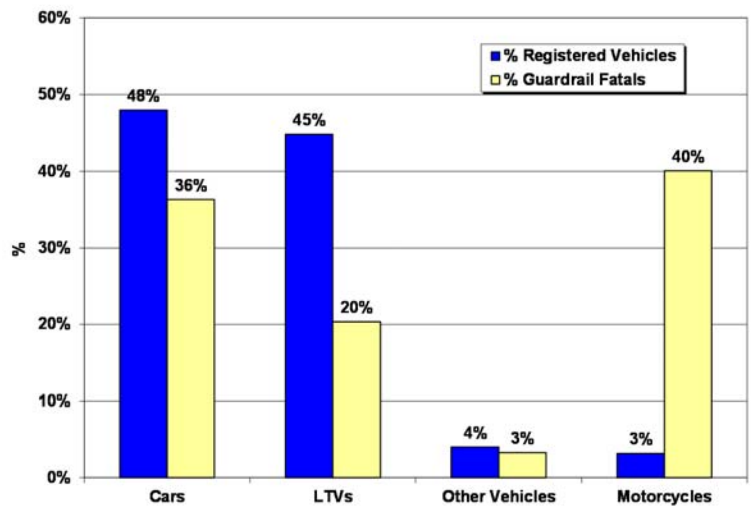

Fig. 1. Guardrail Fatalities by Vehicle Type (FARS 2017) [6].

Roadside barriers are primarily designed to keep errant cars and light trucks and vans (LTVs) from leaving the roadway and colliding with fixed objects, e.g. utility poles, or overturning on side slopes. While it is important to protect motorcyclists from these same hazards, the design of current barrier systems would appear to result in substantially greater risk of fatal injury for motorcyclist than other vehicle occupant. In order to develop countermeasures for improved motorcyclist protection, an investigation is needed into the nature of the injuries resulting from motorcyclist-barrier collisions. However, studies of this type have been challenging to conduct in America because of the near absence of in-depth motorcycle crash data in the US. Previous analyses have primarily been constrained to the analysis of fatalities using the Fatal Automotive Reporting System (FARS) and exposure using the National Automotive Sampling System/General Estimates System (NASS/GES) and the newer Crash Reporting Sampling System (CRSS), the replacement for NASS/GES. While useful, fatality data, e.g. from FARS, only indicate that a rider died in a collision. They do not provide the detailed injury data needed for countermeasure development.

Our previous research has shown that the severity of injury varies dramatically by roadside barrier design [7-8]. The design of roadside barriers can include: rigid barrier, i.e. concrete barrier; semi-rigid barrier, e.g. w-beam barrier; and semi-flexible barrier, e.g. cable barrier, sometimes referred to as wire-rope barrier. Again, due to the limited availability of motorcycle crash data in the US, little is known about how the characteristics of these injuries vary with barrier design on US roadways.

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The objective of this paper is to determine the characteristics of serious-to-fatal injuries in motorcycle collisions with roadside barrier. The longer term goal is for the findings of this study to serve as the basis for the implementation of improved barrier designs that can protect motorcyclists in barrier collisions while retaining the benefits of current roadside barriers for other road users.

II. METHODS

This study was conducted with the sponsorship of the US Transportation Research Board under NCHRP Project 22-26, which had two objectives. The first objective was to quantify the risk of serious-to-fatal injuries in motorcycle collisions with roadside barrier. The second objective was to determine the causes of those serious-to-fatal injuries. Our approach was to collaborate with the Level 1 trauma centre at the Wake Forest Baptist Medical Center to identify and investigate cases of seriously injured motorcyclists admitted to the trauma centre after experiencing a collision with a roadside barrier.

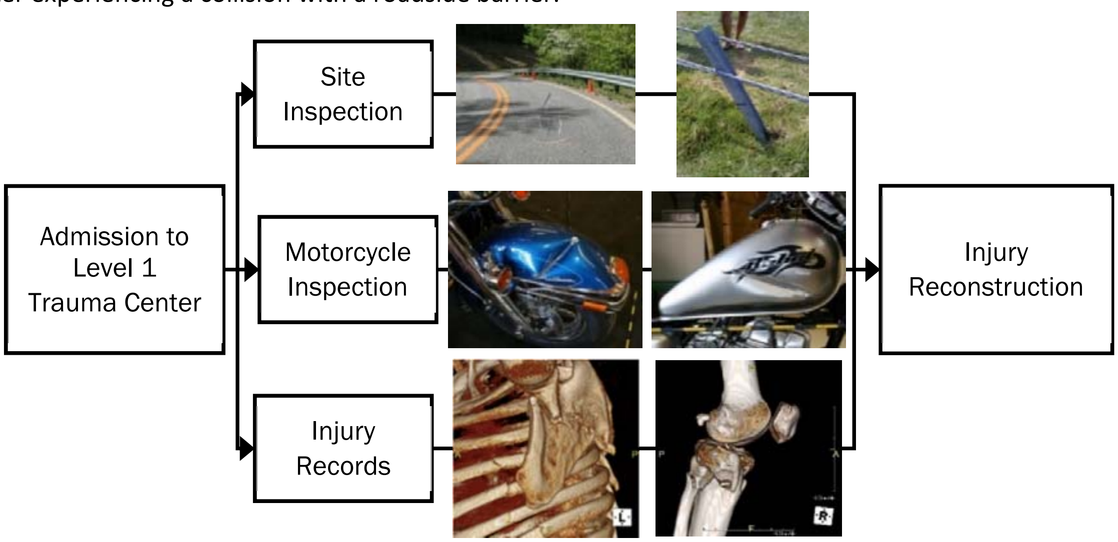


Fig. 2. Methodology for in-depth investigation of motorcycle-barrier collision.

Fig. 2 presents a schematic of the methodology for in-depth investigation of cases for the study. After identification of a potential case, the Wake Forest University (WFU) research team sought informed consent from the subject to participate in the study. After receiving consent, the WFU crash investigator visited the scene to take detailed measurements and photographs of the roadway geometry and the barrier itself, including barrier dimensions and any evidence of the contact between the barrier and either the motorcycle or the rider. The investigator then performed a detailed inspection of the motorcycle, which included extensive photographs of the vehicle and any evidence of interaction between the barrier and the vehicle. Finally, the WFU research team obtained the record of injuries suffered by the rider, including CT scans and external photographs of the subject. The severity of all injuries was coded using the Abbreviated Injury Scale (AIS) [9]. In selected cases, the team was also able to obtain photographs of the rider's clothing and helmet. To protect the identity of the subject, all personal identifying information was removed from all case materials prior to the case review.

After assembly of the case documentation, the research team at Virginia Tech and the crash investigation team at Wake Forest University met to conduct a review of each case. The goal was to review the circumstances of each case and the nature of the injuries, and then to reconstruct the likely injury contact sources that led to each injury. The team used the CIREN BioTab method of coding injuries and likely injury contact source [10] for this task.

III. INITIAL FINDINGS

The research program collected a total of 21 cases involving 22 riders striking roadside barrier. All cases were collected from the WFU catchment area, either in the states of North Carolina or Virginia, and date from 2010 to 2016. Table I presents the composition of the resulting dataset by rider.

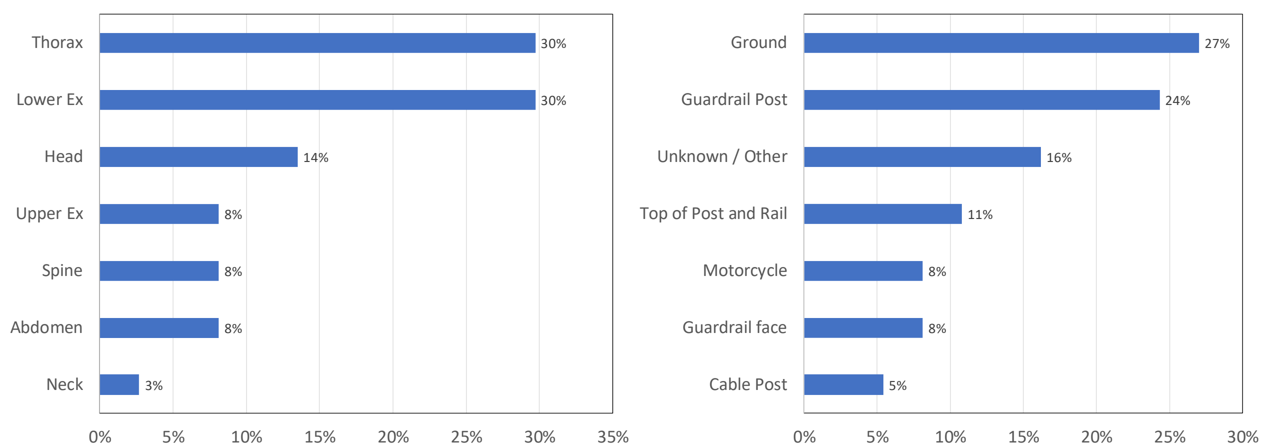
As shown in Table I, most collisions were with w-beam barrier (19), the most common form of barrier in the US. Three (3) cases involved collisions with cable-barrier, a barrier type typically installed in the median of divided highways to prevent cross-median crashes. Only one case involved concrete barrier, which is the least common barrier in the US. Our sample was primarily composed of male riders (81%) and was somewhat older (mean age = 50.1 y.o, std.dev. = 12.2 years). All riders were helmeted. With the exception of only one passenger, all subjects were the operator of the motorcycle. Most subjects in the sample (86%) were riding either large touring or cruiser motorcycles.

TABLE I

COMPOSITION OF DATASET BY RIDER

Category	**Description**	**Cases**
All	Number of Riders	22
Barrier Type	W-Beam Barrier	18
	Cable Barrier	2
	Cable + W-beam	1
	Concrete + W-beam	1
Rider Sex	Male	18
	Female	4
Rider Age (years old)	< 30	1
	30–39	3
	40–49	5
	50–59	9
	60+	4
Motorcycle Type	Touring	7
	Cruiser	12
	Sport	2
	Motocross	1

Injuries varied in severity from MAIS=2 to 5 (median=3). The injury severity score varied from ISS=9 to ISS=38 (median=19). There were no fatalities in the sample. Fig. 3 presents the distribution of serious injuries (MAIS3+) injuries by body region. When a subject suffered multiple AIS3+ injuries to a single body region, only the highest severity injury was counted in this tabulation. The most common serious injuries were to the thorax and the lower extremities. Together these two body regions accounted for nearly two-thirds of all injuries (60%).



a) Distribution of AIS3+ Injured Body Regions.

b) Distribution of Injury Contact Sources for AIS3+ Injured Body Regions.

Fig. 3. Distribution of AIS3+ Injuries by Body Region and Injury Contact Source.

Examination of the contact sources showed that most AIS3+ injuries resulted from impact of the rider with the posts supporting either the w-beam rail or the cable barrier (32%). Ground impacts resulting after a rider was ejected from the motorcycle comprised 27% of all AIS3+ injury body regions. Guardrail and cable barrier posts are designed to deform upon contact with cars and trucks, but crash site inspection showed that these posts deformed very little under loading from a motorcycle or rider. A substantial number of the AIS3+ injuries (11%) resulted when riders fell across the top of a barrier system while still seated and were then dragged down the length of the barrier before falling off the bike. Crash site inspection combined with examination of injury extent showed that rider contact with top of the w-beam rail and striking the unprotected tops of the posts resulted in laceration-type injuries to the riders.

IV. DISCUSSION

This study is one of the first in the US to investigate the factors leading to serious injury in motorcycle collisions with roadside barrier. The study has shown that the primary injury mechanisms in our sample were: (1) rider entanglement with posts; (2) lacerations from top of posts – both w-beam and cable barrier; and (3) laceration from the top of w-beam rail. Of note are our observations on cable barrier, i.e. wire-rope barrier, collisions. Wire-rope barrier is sometimes referred to by motorcyclists as a 'cheese-cutter'. However, we found no evidence of laceration injuries from the wire rope in these systems. Injuries were found in collisions with wire-rope barrier, but the injuries resulted from contact with the posts rather than with the wire rope. This clinical finding is consistent with the conclusions from our bulk accident study conducted using state crash data [7], which found no statistically significant difference between the injury risk of w-beam and cable-barrier, both systems supported by unprotected posts.

This study has important implications for US federal and state transportation agencies seeking ways to reduce the risk of serious-to-fatal injury for motorcyclists. The findings show the need for the adoption of motorcyclist protection systems which either pad or shield the posts to prevent motorcyclist entanglement. Motorcyclist protection systems have been implemented in both Europe and Australia that have tremendous potential to mitigate injuries in barrier collisions [11-12]. To date, however, these systems have not been adopted in the US despite the increasing evidence for their need.

This study has several limitations: (1) the findings are based on a small sample of cases; (2) the findings are based on a convenience sample of cases admitted to a Level 1 trauma centre; and (3) the sample was collected from only a single region of the US. The sample did, however, include all major barrier types encountered in the US. Both states in the catchment area for data collection have mandatory helmet laws. In contrast, only 20 states in the US have mandatory helmet laws. The results should not be interpreted as nationally representative of the US, rather, the findings should be used as a means to identify opportunities for countermeasure development and the need to prioritise the implementation of improved barrier designs.

V. REFERENCES

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