Investigation of Real-World Serious Brain Injuries in the Absence of Skull Fractures

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I. INTRODUCTION

Improvements to vehicle interior, restraint and airbag designs have reduced head injuries [1,2]. However, serious head injuries continue to occur in real-world crashes [3,4], and the risk of severe brain injuries is higher (7%) than the risk of skull fractures (3%)[5]. The mechanisms of brain injuries without skull fractures and the population sustaining such injuries have not been explored using real-world crash data. This study compares crashes in which the driver sustained a serious brain injury accompanied by a skull fracture with crashes in which a serious brain injury occurred but no skull fracture.

II. METHODS

This study used real-world crash data from the Crash Investigation Sampling System (CISS)[6]. CISS is a nationally representative, in-depth dataset of tow-away passenger vehicle crashes that took place in the United States from 2017 to 2022. The dataset includes basic information from police reports such as road geometry, vehicle characteristics and occupant demographics. For this study, only belted drivers or right-front passengers with known injury information in non-rollover crashes were selected for further analysis, resulting in 6,187 sampled occupants weighted to represent a population of 3,434,123 occupants. Abbreviated Injury Scale (AIS) 2015 codes were used to determine if an occupant sustained a skull fracture or an AIS3+ brain injury [7]. Using the AIS codes, a skull fracture included vault and base fractures only and did not include fractures in the face. Roughly 80% of occupants with either type of injury were drivers. The analysis of involved physical components (IPC) for AIS3+ brain injuries was restricted to drivers in frontal crashes.

III. INITIAL FINDINGS

Most (82.5%) of the AIS3+ brain injuries among front-seat occupants were in the cerebrum. The AIS coding for brain injuries defaults to the cerebrum unless the cerebellum is explicitly specified. Most (68%) of the AIS 3+ brain injuries were not accompanied by a skull fracture (Table I). Of the 301 occupants with diffuse axonal injury, zero had an associated skull fracture and only eight injuries were coded as AIS3+. Occupants who sustained an AIS3+ brain injury and a skull fracture were involved in a higher proportion of near-side impacts (39.6%), while those without a skull fracture were involved in a higher proportion of rear impacts (14.0%) and frontal impacts (64.8%) (Table I). The median age of drivers and right-front passengers who received an AIS3+ brain injury but no skull fracture was 57 years old, which was 14 years older than occupants who sustained both an AIS3+ brain injury and a skull fracture (Figure 1).

TABLE I
COUNT, AGE AND IMPACT DIRECTION FOR DRIVERS AND RIGHT-FRONT PASSENGERS BY HEAD INJURY TYPE

		AIS 3+ Brain Injury with Skull Fracture	AIS 3+ Brain Injury without Skull Fracture	Skull Fracture without AIS 3+ Brain Injury	Neither AIS 3+ Brain Injury nor Skull Fracture
Cases	Unweighted	46	80	27	6,034
	Weighted	7,557	15,704	4,555	3,406,306
Age	Median (years)	43	57	45	38
Model year	Median	2008	2012	2008	2010
Impact Direction	Frontal	52.4%	64.8%	65.9%	69.8%
	Near-side	31.6%	14.5%	10.6%	11.2%
	Far-side	15.0%	6.6%	22.2%	8.5%
	Rear	1.1%	14.0%	1.3%	10.5%

For the 103 AIS3+ brain injuries sustained by drivers in frontal collisions, there were 120 assigned IPCs. The distribution of IPCs for AIS3+ brain injuries was different among drivers in frontal crashes who also sustained a

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skull fracture compared with those without a skull fracture (Figure 2). The majority (64.7%) of head IPCs for drivers sustaining both an AIS3+ brain injury and a skull fracture were from contacts with the A-pillar, while only 20.9% of the IPCs was assigned to the A-pillar for drivers with an AIS3+ brain injury and no skull fracture. A larger proportion of IPCs were assigned to the frontal airbag for drivers with an AIS3+ brain injury and no skull fracture (20.8%) than for those who sustained both an AIS3+ brain injury and a skull fracture (11.4%). Contacts with the steering wheel (11.0%) and instrument panel (22.3%) were common among drivers with an AIS3+ brain injury and no skull fracture, but neither steering wheel nor instrument panel contacts were observed among those with both an AIS3+ brain injury and a skull fracture.

IV. DISCUSSION

These results indicate that older occupants may be more susceptible to AIS3+ brain injuries, especially in the absence of a skull fracture. This is consistent with other research showing that the risk of AIS3+ brain injuries is as much as eight times higher for older occupants and that they are particularly susceptible to bleeding injuries [8]. The crash impact direction among occupants with AIS3+ brain injuries and no skull fracture was distinct from the skull fracture groups and may indicate differences in the mechanism of injury. However, some of the vehicles in this sample were not equipped with side airbags or the restraint and structure changes that have been instituted in response to the IIHS small overlap test. In addition, this study only considered skull fractures and not facial fractures that could also indicate a head impact. When no skull fracture occurred, AIS3+ brain injuries often stemmed from contacts with the airbag and not a hard surface. This was not the case for brain injuries accompanied by a skull fracture (Figure 2). Nevertheless, hard surfaces still account for the majority of all AIS3+ head injuries. Together with the findings of both Sato [9] and Mueller [10], who demonstrated in crash tests that contacts with the frontal airbag can result in head rotations that lead to elevated rotational injury metrics, these results may indicate that an improvement in restraint design could reduce AIS3+ brain injuries and improve outcomes for older drivers.

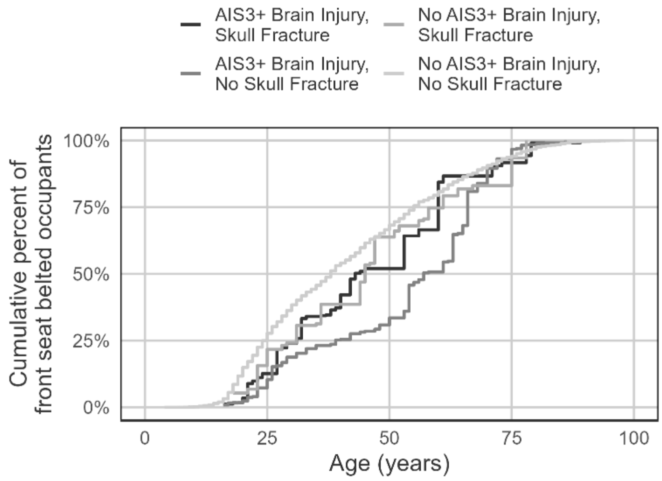

Figure 1. Age distribution of occupants by type of head injury.

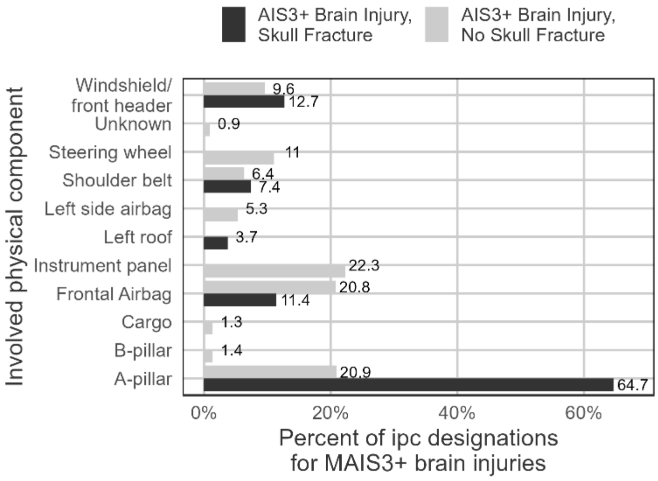

Figure 2. Distribution of involved physical components for AIS3+ brain injuries among drivers in frontal crashes.

V. REFERENCES

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