Safety restraint injuries in fatal motor vehicle collisions

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TITLE:

Safety Restraint Injuries in Fatal Motor Vehicle Collisions

RUNNING HEAD:

Safety restraint injuries

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ABSTRACT

Background: This study focused on whether there are clear indications of seat belt use to be found at autopsy, evaluating the sensitivity and specificity of seat belt marks (SBM), and whether use of seat belt and seating location affects the type and severity of injuries sustained.

Methods: Information on the type of injuries sustained and seatbelt use was retrieved from autopsy reports and police reports respectively, for cases of fatal motor vehicle collisions occurring in Sydney, Australia over a 5 year period.

Results: A SBM was only found on restrained occupants. The proportion of restrained occupants with evidence of a SBM was 36% (sensitivity), whilst unrestrained occupants showed no evidence of a SBM (100% specificity). A SBM was also found to reliably reflect seating position of occupant.

Conclusion: Restrained occupants can be expected to show evidence of the seat belt in just over 1/3 of cases. A spurious SBM is very unlikely to be present if the occupant was unrestrained.

KEY WORDS

Seat Belt Mark (SBM), Safety Restraints, Fatal Motor Vehicle Collisions

Fatal motor vehicle collisions are a common, universal phenomenon and it is estimated that more than a million people are killed worldwide annually as a result, with road traffic accidents remaining the most common cause of death in adults below the age of 50 years (*1*). As a direct consequence of the introduction of the compulsory fitting and wearing of seat belts for drivers, front seat passengers and even rear seat passengers, a large body of evidence has documented worldwide a significant decrease in the incidence of severe and fatal injuries amongst the occupants of motor vehicles (*1*).

The distribution, type and severity of injuries sustained by occupants in motor vehicle collisions depends on the various forces to which they are subjected, which will be directly related to the speed of the vehicle on impact. Other contributory factors include direction from which these forces arise, vehicle design, behaviour of the vehicle after impact (e.g. overturning), intervention of some other hazard (e.g. penetration by an external object), whether there is ejection from the vehicle, use of seat belts and seating position.

The most popular and efficient seat belt is the three-point lap and shoulder belt, which consists of a diagonal and transverse strap of the “inertia-reel type” which allows for slow movement but jams at a sudden tug. Reference to the seat belt in this study assumes this type. Strap restraints act by restraining the occupant back against the seat during deceleration, so that forward projection is prevented, preventing ejection from the vehicle, extending the deceleration time and distance and spreading the force of sudden deceleration over a greater area.

It is estimated that three-point seat belts reduce the risk of fatal injury to the front seat car occupants by 45% and the risk of moderate to critical injuries by 50%. (*2*). This finding agrees with another study (*3*), which estimates a decline in fatalities of (43+3)%.

A prospective crash study (*4*) investigated the effectiveness of seat belts in protecting school age children and found that the odds of sustaining fatal or moderate severe injury for children in the front passenger seat was more than nine times higher for unbelted children than for belted ones.

The term seat belt mark (SBM) sign was first coined in 1962 by Garrett & Braunstein and refers to a linear pattern of bruising across the abdomen seen on an individual who had been wearing a seatbelt in a car crash (*5*). The term seat belt syndrome (SBS) expands the definition to include injuries to the neck and chest due to a three–point restraint system (*6*).

A SBM is thought to indicate the magnitude of the impact. Some authors, however, have found no correlation between the severity of the SBM and likelihood of internal damage (*7*). However, SBMs are associated with an increased incidence of internal damage and depending on their location (abdomen, chest, neck) suggest a particular pattern and type of injury. It has been suggested that in fact seat belts cause more injuries than any other source of direct impact (eg steering wheel), although these injuries are often relatively minor. Furthermore, seat belts prevent contact with the car interior and thus likely reduce the severity of injury (*8*).

A major issue to be addressed at autopsy of victims of motor vehicle accidents is whether or not the person was restrained at the time of impact, and one obvious clue is the presence of abrasions and/or bruising in the distribution of the seat belt. However deciding on whether or not the pattern of external injuries does in fact represent the so-called SBM is not always so straightforward. This study focuses on the significance of a SBM and its role as a likely indicator of occupant restraint. In addition the effects of restraint use and seating position will be addressed.

This study has 2 aims: To assess whether there are clear indications of seat belt use to be found on examination of the decedent at autopsy, evaluating the sensitivity and specificity of various injuries said to be characteristic of seat belt use; and to investigate whether the type and severity of injuries sustained by vehicle occupants in fatal motor vehicle collisions depends on the use of seat belts and/or seating position.

SUBJECTS AND METHODS

Two hundred and fifteen deaths involved in fatal motor vehicle collisions in a five year period referred to the New South Wales State Coroner's Court and the Department of Forensic Medicine, Glebe for medicolegal autopsy were analysed. Cases referred to these organisations are from the eastern two thirds of metropolitan Sydney, an exclusively urban area. Exclusion criteria included burns victims (whose external injuries would have precluded identification of the presence or absence of a SBM), infants in child restraints, death occurring more than 7 days after collision, cases where there was airbag deployment, and cases where information in relation to whether the subject was restrained or unrestrained was unknown. This left a total of 106 subjects.

Age, height, weight, seating position and blood alcohol levels of subject were recorded, together with the cause of death and types of injuries sustained.

Types of injures were divided into 6 regions: head, abdominal, chest, cardiovascular (including heart), spinal and pelvis. Limb fractures and injuries of minor severity such as other bodily bruising/abrasions were not included.

Evidence of a SBM at autopsy was recorded by assessing descriptive evidence of any abrasion/bruising in the seatbelt distribution (diagonally across the chest and/or transversely across the lower abdomen) together with any corresponding diagrammatic illustrations and autopsy photographs. Where such descriptions were absent, it was assumed the subject had no evidence of a SBM.

Type of impact (head on/side impact/roll over) was recorded from the Police Investigation Report, which contained a narrative of the collision from a police officer present at the scene.

Information on whether the subject had been restrained or unrestrained and whether or not the subject had been ejected was obtained from Police Reports. Where such information was unavailable, Death Investigation files held at the Office of the New South Wales State Coroner were accessed. Relevant evidence from eyewitness statements and/or photographic evidence of the scene of the collision were reviewed. Information from this source was also used to further clarify the exact sequence of events that took place during the motor vehicle collision.

Statistical analysis was performed using the Mann Whitney test and Chi-Squared test. A p value of less than 0.05 was considered statistically significant.

The research protocols had been submitted for approval to the Central Sydney Human Ethics Committee and the New South Wales State Coroner prior to commencement of this study. All work was conducted in accordance with their respective requirements.

RESULTS

Demographics: There were 70 males (66%) and 36 females (34%) in total, of which 74 (70%) were restrained. Males were less likely to be restrained than females; 47(67%) males were wearing seatbelts at the time of impact, compared with 27 (75%) females. There were no statistically significant sex differences between restrained and unrestrained occupants.

The mean age of all occupants was 40.8 years (standard deviation (S.D.) 24.7), with a peak frequency occurring amongst 21-30 year olds. There was no significant age difference between unrestrained and restrained occupants. The mean age of unrestrained occupants was 38.1 years (S.D. 22.8) and the mean age of restrained occupants was 42.0 years (S.D 25.3).

The mean body mass index (BMI) of all occupants was 25.7 kg/m^2 (S.D. 5.36). The mean BMI of unrestrained occupants was 25.5 (S.D. 5.41) and the mean BMI of restrained occupants was 25.8 (S.D. 5.38). These differences were not significant. Most occupants had a BMI in the normal range of 20 to 25 kg/m^2.

Seat belt marks: Examples of descriptions of seat belt marks included those where the pathologist's report mentioned the presence of the SBM itself e.g. "an area of bruising *consistent with a seat belt* extending from the left shoulder and across the right breast". Cases were also included where the description of the external injury fitted with that of a seat belt mark e.g. "a 400mm obliquely orientated linear abrasion from the right anterior lower chest to the left shoulder".

The proportion of restrained occupants who also had evidence of a SBM was 36%

(sensitivity), 95% CI, 0.26-0.47. The proportion of unrestrained occupants who had no evidence of a SBM was 100% (specificity). These differences between the restrained and unrestrained occupants in terms of presence/absence of a SBM were found to be significant ($X2=15.57$, df 1, $p<0.001$).

No unrestrained subject had evidence of a SBM. All subjects with a SBM (n=27, 100%) had been restrained at time of impact. Over one third of restrained occupants showed evidence of a SBM at autopsy. Table 1 show the number and percentages of restrained and unrestrained occupants with a SBM.

*** TABLE 1 ABOUT HERE ***

Intuitively one would expect to find a SBM in head-on collisions more often than in any other type of impact. However this study found type of impact made no statistically significant difference to presence or absence of a SBM.

The orientation of the sash component of the seat belt was found to be consistent in all cases with the seating position of the occupant. An abrasion running obliquely from right to left was only found in occupants seated on the right-hand side of the vehicle whereas an abrasion extending from left to right was only found on occupants seated on the left. In other words, all cases of oblique abrasions taken to represent a SBM were found to be consistent with the lateralisation of the occupant seating position.

Severity of injury: Severity of injury was broadly categorized according to the number of body regions injured (head, chest, abdominal, cardiac, spinal, pelvic). The minimum value was 0 (meaning none of the categorized injuries were present, *not* that the subject received no injuries) and the maximum value was 6 (meaning there was injury to multiple body regions).

No statistically significant difference in severity of injuries was found between restrained and unrestrained occupants. Table 2 shows the number and percentage of restrained and unrestrained occupants with 0-6 categories of injury.

*** TABLE 2 ABOUT HERE ***

Overall, head and chest injuries were the most common type of injury. Unrestrained occupants were more likely than restrained occupants to sustain head, chest, cardiac and abdominal injuries. Pelvic injuries were found to be the least common type of injury in both groups but were nearly twice as common in restrained occupants. In addition, less than a third of occupants had spinal injuries. Table 3 shows the type of injury in restrained and unrestrained occupants. No statistically significant difference in any type of injury sustained between belted and non-belted occupants was found.

*** TABLE 3 ABOUT HERE ***

Rib fractures were by far the most commonly sustained injury to the chest in both restrained (59%) and unrestrained (69%) occupants. Liver and/or spleen lacerations were the most frequently reported injury in the abdomen and were seen in equal proportions (47%) in restrained and unrestrained occupants. The differences between restrained and unrestrained occupants with regard to specific cardiac and spinal injuries were minimal. Head injuries were common in both restrained and unrestrained occupants. 56% of unrestrained occupants and 41% of restrained occupants sustained a skull fracture. A basal skull fracture was the most commonly documented fracture (50% and 34% of restrained and unrestrained occupants respectively).

*** TABLE 4 ABOUT HERE ***

Table 4 illustrates how severity of injury varied with occupant position. As before severity of injury was broadly categorized in to number of body regions injured. In general, rear seat passengers sustained fewer injuries than front seat passengers. Two thirds of rear seat passengers received fewer than two injuries. The severity of injury was similar in front seat passengers and drivers. 56% of front seat passengers and 59% of drivers received 3 or more injuries. No significant relationships were found. Rear seat passengers had notably fewer chest and spinal injuries than front seat occupants. Rear seat occupants, however, were more likely to have sustained head injuries. As expected, drivers were more likely than any other occupant to have pelvic injuries. Despite these trends (see table 5), no significant relationship between type of injury and seating position was found.

*** TABLE 5 ABOUT HERE ***

Ejection from vehicle: There were a total of 20 ejections from the vehicle at the time of the collision. Of these, 5 (25%) had been restrained and the remaining 15 (75%) were unrestrained. Unrestrained occupants were significantly more likely to be ejected during collision than restrained occupants (X^2=23.5, df 1, $p<0.001$).

Alcohol intoxication: Occupants who had blood alcohol levels above the legal limit for driving (>0.05g/dL) were significantly less likely to be wearing seatbelts than those who were not found to have blood alcohol levels above the legal limit (X^2=5.78, df 1, $p< 0.025$). Twenty four occupants (22.6% of the total) had blood alcohol levels above the legal limit for driving and of those, 12 (50%) were restrained and 12 (50%) were unrestrained at the time of impact. Of the remaining 82 (77.4%) occupants whose blood alcohol levels were below the legal limit for driving, 62(69.8%) were restrained compared with 20 (30.2%) who were not.

DISCUSSION

The main objective of this study was to assess the significance of a SBM as an indicator of occupant restraint. This study found that the proportion of restrained occupants with evidence of the seatbelt mark was 36% (sensitivity), whilst the proportion of unrestrained occupants without a SBM was 100% (specificity). In other words, a SBM was never present in cases of unrestrained occupants in this study. Furthermore, every occupant found with a SBM had been restrained suggesting that a SBM is an excellent indicator of seatbelt use.

This said, SBMs were seen in just over a third of restrained occupants, i.e. the majority of restrained occupants did not show external evidence of seat belt use. Other studies have found that 12% of restrained occupants in non-fatal automobile collisions had a SBM across the abdomen, neck or chest (*7*). It may be that SBMs are more commonly seen in fatal car collisions than in non-fatal ones but this may need to be explored further.

The sash portion of a SBM was always consistent with the position of the occupant, Therefore a SBM, if present, can be said to reliably reflect the seating position of the occupant.

Unsurprisingly, unrestrained occupants were significantly more likely than restrained occupants to be ejected and were also significantly more likely to have alcohol levels over 0.05g/dL.

No statistically significant differences in severity or type of injury between restrained and unrestrained subjects were found in this study, which only examined deaths. Research in this area is inconsistent. Some studies report that all types of injuries are reduced in restrained occupants (*2*). Others suggest that in fact seat belts cause more injuries (albeit minor) than any other source of direct impact such as a steering wheel (*8*).

In this study unrestrained occupants were more likely than restrained occupants to sustain head, chest, cardiac and abdominal injuries. Trends in types of skull fractures were found with facial, vault and basal skull fracture seen more commonly in unrestrained passengers. These relationships were not however statistically significant.

Previous research has found that *fatality* risk is lower in rear seat occupants (*9*). In particular, the centre seat is associated with lower fatality risks than outboard seats in both front and rear seating position (*10*). This study supports the concept of the protective effect of the rear seating position; rear seat passengers were found to have fewer injuries (specifically chest and spinal) than front seat passengers.

Findings from studies on *injury* risk in drivers and front seat occupants have been mixed with some data suggesting no difference in risk of injury between the two groups and others reporting a lower injury risk for drivers (*11*). The current study found that drivers and front seat occupants sustained similar types and severity of fatal injuries. One study in particular found that there was no difference in *fatality* risk between front seat passengers and drivers and that this was true of collisions from any direction (*10*). The current study found that drivers and front seat passengers sustained equally severe injuries. This supports the concept that the outcome for front-seated occupants (driver or front seat passenger) is similar.

This study focused only on fatalities of motor vehicle collisions and therefore had an inherent selection bias. Non-fatally injured occupants were not considered. Therefore results from this study cannot be generalized to survivors of motor vehicle collisions.

Since all these cases involved fatalities, it was difficult to categorize injuries as mild, moderate and severe. The method employed in this study may have been too generalized to capture any differences with respect to severity of injury. Another limitation was the small number of subjects, partly due to the exclusion criteria applied. It is also important to note that numbers of restrained occupants out numbered unrestrained occupants by about 2:1.

This is the first medical study systematically investigating the relationship between a SBM and occupant restraint in fatal motor vehicle accidents. Considerable emphasis is placed on the nature of, and the presence or absence of SBMs in some instances of litigation, and this study provides data to back up aspects of expert testimony in such cases. In summary, a SBM is a highly specific marker but has a low sensitivity. The finding of a SBM at autopsy is an excellent indication of restraint use, and the oblique component of the SBM also reliably reflects seating position. However, a SBM will not be present in the majority of restrained occupants.

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Table 1: *Seat Belt Marks in Restrained and Unrestrained Occupants (total n = 106)*

	Seat Belt Mark Present **n (%)**	Seat Belt Mark Absent **n (%)**
Restrained	27 (36.5)	47 (63.5)
Unrestrained	0 (0)	32 (100)

Table 2: *Severity of Injuries in Restrained and Unrestrained Occupants (total n = 106)*

	Number of Body Regions Injured n (%)						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Restrained	7 (9.5)	11 (16.2)	17 (23)	11 (14.9)	17 (23)	5 (8.1)	4 (5.4)
Unrestrained	1 (3.1)	5 (15.6)	5 (15.6)	10 (32)	7 (21.8)	3 (9.4)	1 (3.1)

Table 3: *Type of Injury in Restrained and Unrestrained Occupants (total n = 106)*

	Region of Body of Injured n (%)					
	Head	**Spinal**	**Chest**	**Abdominal**	**Cardiac**	**Pelvic**
Restrained	44 (59)	23 (31)	53 (72)	38 (51)	25 (34)	16 (22)
Unrestrained	22 (69)	10 (31)	25 (78)	19 (59)	15(47)	4 (12)

Table 4: ***Severity of Injuries and Seating Position (total n = 106)***

	Number of Body Regions Injured n (%)						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Driver	8 (12.1)	8 (12.1)	11(16.7)	16 (24.2)	13 (19.7)	8 (12.1)	2 (3)
Front seat passenger	1 (4)	2 (8)	8 (32)	6 (24)	5 (20)	2 (8)	4 (4)
Rear seat passenger	0 (0)	6 (40)	4 (26.7)	1 (6.7)	2 (13.3)	1 (6.7)	1 (6.7)

Table 5: *Type of Injury and Seating Position (total n = 106)*

Region of Body Injured	**Head**	**Spinal**	**Chest**	**Abdominal**	**Cardiac**	**Pelvic**
			n (%)			
Driver	40 (61)	21 (32)	50 (76)	36 (54)	26 (39)	14 (21)
Front seat passenger	14 (56)	10 (40)	20 (80)	14 (56)	9 (36)	4 (16)
Rear seat passenger	12 (80)	2 (13)	8 (53)	7 (47)	5 (33)	2 (13)