UPPER EXTREMITY FRACTURES IN CAR ACCIDENTS

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ABSTRACT

Studying accidents with Volvo cars in Sweden, the reduction of AI2+ upper extremity injury risks is less than the overall MAIS2+ injury risk reduction over the last two decades. A subset of occupant injury cases with detailed information is used to identify and categorise the upper extremity fractures and by that enhance knowledge about probable mechanisms. This in turn, is an important step in the development of means of protection. Upper extremity fractures are found predominantly in frontal impacts and drivers tend to be more exposed. Factors such as age and the numerous possible arm positions influence the occurrence.

Key words: occupants, accident analysis, injury probability, automobiles

INJURY TRENDS IN CAR ACCIDENTS have changed over the years. A continuous improvement in car structure and implementation of different specialized safety systems have resulted in significant improvements in car safety over the past few decades. Isaksson-Hellman and Norin (2005) showed a reduction of the risk of MAIS2+ injury by more than two thirds in Volvo cars when comparing cars designed from 1970: ies to models of early 2000: ies. One of the body regions not specifically addressed is fractures to the upper extremities. In order to design preventive measures, an understanding of when and how these injuries occur is needed.

Otte (1998) studied the biomechanics of upper limb injuries of belted car drivers and emphasized the need for car developments and dummy test work. The study demonstrated two different mechanisms for upper limb fractures: direct impact with longitudinal and rotational load to hand, hand joint and lower arms resulting in a forward movement of the arm and rotational effects with injury risk for joints and lower arms; and lateral collisions with load transmission to lateral parts of the arm resulting in injuries of the whole upper limb.

Wraighte et al. (2007), studying sixty two in-depth cases of upper extremity injuries in UK, identified shoulder injuries mainly from lateral or axial compression forces, elbow injuries mainly as direct point loading, forearm fractures mainly via 3 point loading, and the wrist injuries mainly of a hyperextension pattern most likely from steering wheel or airbag contact.

Field data investigations and laboratory testing have been used in studying the possible effects of airbags inducing upper extremity fractures (Kuppa et al. 1997, Bass et al. 1997, Duma et al. 1998, Duma et al. 2002).

The objective of the present study is to identify and categorise upper extremity fractures from car accidents and by that enhance knowledge about probable fracture mechanisms, making means of protection possible.

METHODS

A two-fold study was carried out; an in-depth study in order to identify and categorise upper extremity fractures and a statistical analysis to relate influencing factors to the occurrence of upper extremity fractures.

Volvo's statistical accident database, covering accidents with Volvo cars in Sweden was used for both the statistical analysis and the in-depth study. The database is further described in Isaksson-Hellman and Norin (2005). The selected subset for the statistical analysis contains Volvo cars (850- models and all S and V models) involved in accidents 1994-2008; a total of 16142 occupants.

For the in-depth study occupants involved in car accidents 1998-2008 sustaining fractures to the upper extremities were selected. Upper extremity fractures include fractures to the hands (including fingers), ulna, radius, humerus, clavicle and the joints in-between. The selection resulted in a total of 291 fractures. Available information, such as medical records, questionnaires from the occupants and car damage were reviewed and for 99 of the 291 fractures there were enough information found to clearly understand the accident and fracture mechanisms. The 192 fractures not suitable for in-depth studies had either missing or incomplete medical records or were extreme crashes where fracture mechanism of the upper extremities could not be determined.

The fracture types for the 99 fractures of the 86 occupants were established using detailed medical information. Combinations of fractures were rather common, 15% of the occupants had more than one fracture to the upper extremity. For each upper extremity fracture, probable fracture mechanisms and identification of possible influencing factors were suggested based on the fracture types and the occupant, car and accident information. The 99 fractures were categorised into mechanism groups. The mechanism groups are defined as follows: A – trauma to an outstretched hand, B - trauma to an extended hand, C – trauma to a clenched fist, D- a direct blow, E – lateral impact on the shoulder causing clavicle fractures, and F- other. Since fractures in groups A, B and C occur in similar situations, i.e. when the occupant is moving forward with the arms held up in front of the body, the three groups are plotted as one in the graphs (called ABC). The distribution of gender and seating position for the 86 occupants with 99 fractures are seen in Table 1.

Table 1. Gender and seating position for the 86 occupants of the 99 upper extremity fractures in the in-depth study

	Drivers	*Front seat passengers*	*Rear seat passengers*	*Total*
Men	47	8	2	**57**
Women	13	12	4	**29**
	60	**20**	**6**	**86**

RESULTS

STATISTICAL ANALYSIS: Upper extremities account for 11% of the injured body parts of AIS2+ injury level, Figure 1. Comparing accidents occurring mid 1990: ies to those occurring mid 2000: ies, the AIS2+ upper extremity injury risk reduction is substantially less than the overall MAIS2+ injury risk reduction, Figure 2.

Upper extremity fractures distribution is compared to overall MAIS2+ injury distribution. They are found in all accident situations and follow generally the pattern of overall MAIS2+ injuries, except for a relative higher share in frontal impacts. A somewhat increased trend of upper extremity fractures for drivers as compared to passengers when compared to occupants with MAIS2+ injuries is seen. No significant differences were found, but the mean age is somewhat higher and the belt usage is slightly lower of the occupants with upper extremity fractures than of those without upper extremity fractures.

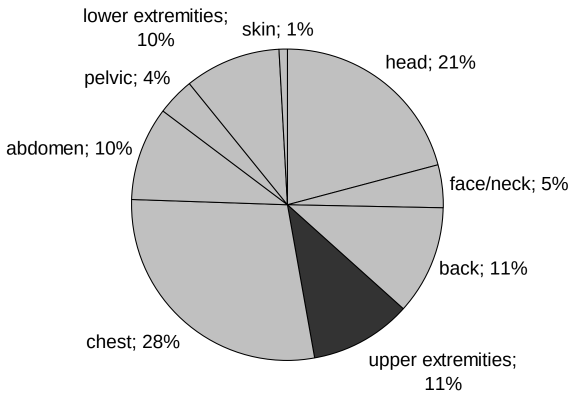

Fig. 1 – Distribution of injured body parts of AIS2+ injury level. Total of 1616 AIS2+ injured body parts.

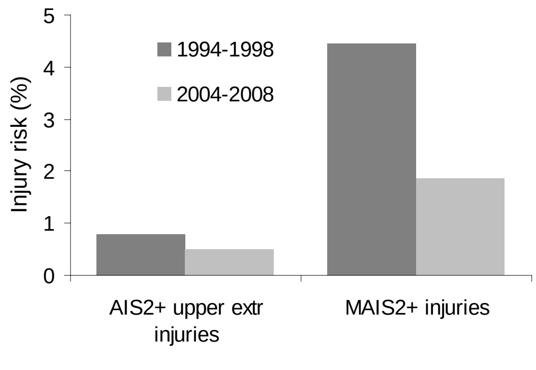

Fig. 2 – AIS2+ upper extremity injury risks and MAIS2+ injury risks for accident years 1994-1998 and 2004-2008.

IN-DEPTH STUDY: Although frontal impacts is the most common accident situation causing upper extremity fractures, side impacts and multiple impacts and events are also frequent causes, Figure 3. Frontal impacts mainly result in fractures to the forehand, wrist and hand as well as the clavicle. Side impacts are mainly related to fractures to the clavicle.

Figures 4 and 5 show that group D (direct impact) is the largest of the fracture mechanism groups, containing 52 fractures. They account for the majority of fractures from the hand, fingers, arm and elbow. Direct impact is also accountable half of the clavicle fractures occurring in frontal impacts. Twenty seven of the 52 fractures in group D occurred as a result of frontal impacts and 17 from multiple events or impacts. Not all, but the majority of the 18 drivers in frontal impact were exposed to a deployed driver airbag.

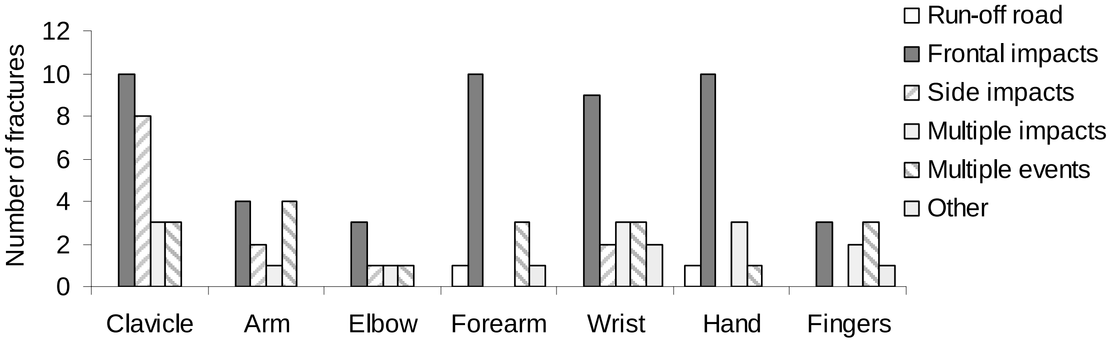

Fig. 3 – Distribution of the 99 fractures per upper extremity segment and accident situation for the 86 occupants with upper extremity fractures.

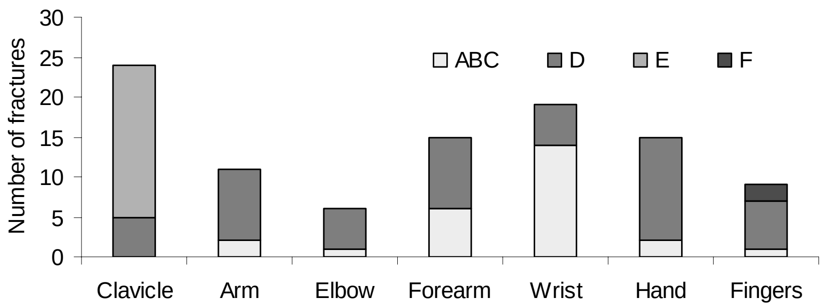

Fig. 4 – Distribution of the 99 fractures per upper extremity segment and mechanism group for the 86 occupants with upper extremity fractures

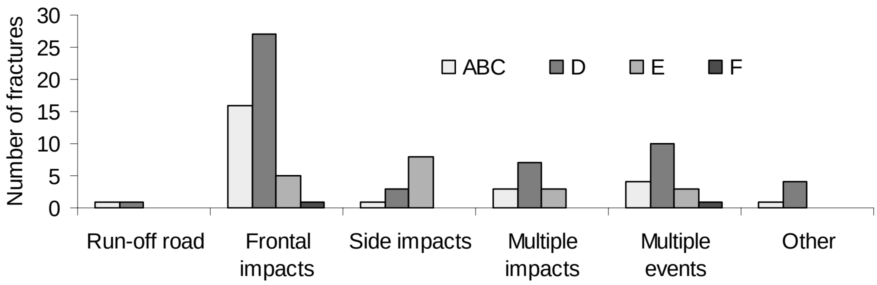

Fig. 5 – Distribution of the 99 fractures per accident situation and mechanism group for the 86 occupants with upper extremity fractures

The 2nd largest group of fractures results from trauma to an outstretched (group A), extended (group B) or clenched hand (group C). These are mostly fractures to the wrist and the forearm, occurring mainly in frontal impacts (Figures 3 and 5). Twenty two of the 26 in the group ABC are trauma to an outstretched hand (group A). The two cases in group B are one driver in frontal impact and one front passenger in a multiple event. The two cases in group C are one front passenger in a run-off event and one driver in a frontal impact.

Eight of the 19 clavicle fractures caused by lateral impact on the shoulder (group E) occur in pure side impacts and the rest in frontal impacts and multiple impacts or events, Figure 5. The five frontal impacts are three drivers, one front seat passenger and one rear seat passenger.

The two fractures in group F were two unique finger fracture types; one due to hyperextension and the other caused by both traction and torsional forces. These occurred in a frontal impact and a multiple event situation, respectively.

DISCUSSION

Upper extremity fractures are relatively infrequent and generally not life-threatening, but may result in long-term disability including chronic deformity, pain, weakness and loss of motion. The injury risk has only decreased to a small extent in the past decade, as compared to the overall injury risk reduction. As a knowledgebase for improvement possibilities for protection, this study presents enhanced information on upper extremity fractures from car accidents providing a general, as well as a specific picture categorised by different fracture mechanisms and situations of occurrence.

Although appearing in all types of situations, upper extremity fractures are predominant in frontal impacts and drivers tend to be more exposed. Seat belt usage seems to have a positive effect on the protection of the upper extremities. In some of the in-depth study cases it was obvious that the initial positions of the arms affected the outcome, thus it can be speculated that awareness of an impending accident probably is of importance. The high number of multiple impacts and events also support this. To some extent can upper extremity fractures be explained by factors such as age, crash severity and the numerous possible positions of the arms. A general statement regarding the influence of the airbags can not be determined in this study.

For the in-depth study only 99 out of the totally available 291 fractures could be used because of lack of detailed data. This is a limitation; however, when comparing the distributions of factors such as accident situation and seating position, the 86 occupants with the 99 fractures are sufficient representative as compared to the statistical data in this study.

More attention is needed in this area in the future and studying the mechanisms of upper extremities poses a special challenge; being the body part most difficult to restrain and control during an accident. With the use of methods such as monitoring the driver during normal driving, more knowledge can be obtained about the placements and the movements of the arms during driving and incidents.

By understanding the mechanisms and the situations in which upper extremities fractures mostly occur, this study provides information for further protection of occupants - aiming for the Zero Injury Vision.

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