Back

IDENTIFYING THORACIC AND LUMBAR SPINAL INJURIES IN CAR ACCIDENTS

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ABSTRACT

This study identifies and categorises AIS2+ thoracic and lumbar spine injuries based on 189 occupants who sustained spinal injuries from a subset of 21 034 adult occupants in Volvo cars during 1991-2005, including 95 in-depth cases. Injuries to the lumbar and thoracic spine are found in all accident situations and are mostly found in multiple events; a high proportion of the cases are run-off road scenarios. Several different factors that cause spinal injuries are identified, emphasizing the role of both occupant characteristics as well as occupant posture during load transfer through the spine at impact.

Key words: Spine, accident analysis, epidemiology, injuries

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 1970s to the most recent models. One of the AIS2+ injury types not specifically addressed is injuries to the thoracic and lumbar spine. In order to design preventive measures, an understanding of when and how these injuries occur is needed.

The main functions of the spine are to transfer movements and bending moments from the upper parts of the body, head and trunk down to the pelvis and to enable movements between different parts of the body as well as to protect the spinal cord (White and Panjabi, 1990). The spine is a complex structure consisting of a total of 24 vertebrae (12 thoracic and 5 lumbar), discs in between the vertebrae, muscles and ligaments as well as the spinal cord running through the spinal canal.

When the spine is exposed to stresses beyond those considered normal, the vertebral bodies carry the main part of the load. Different forces and movements applied to the spine give rise to different types of fractures. Injuries to the vertebral column can be classified into eight different categories: Compression fractures, Anterior wedge fractures of vertebral bodies, Burst fractures of vertebral bodies, Dislocations and fracture-dislocations, Chance fractures, Hyperextension injuries, Process fractures and Soft tissue injuries (Nahum and Melvin, 1993). Compression fractures are a result of the vertebrae being exposed to a purely compressive load causing the endplates to collapse and the vertebral body to compress. The mechanism of an anterior wedge fracture is a combination of flexion and axial compression and it results in compression of the anterior part of the vertebra. In burst fractures, also called comminuted fractures, the vertebral body is broken into two or more segments, usually as result of high load levels. Chance fractures are usually related to lap-belt situations when the occupant is exposed to rapid deceleration and is virtually wrapped around the lap belt. Because of hyperflexion, a vertebra commonly splits into two parts in the transverse plane. Transversal process fractures result from rotation or extreme lateral bending and can also be associated with a vertical shearing force. When an x-ray does not show any fracture to the vertebrae but the patient still experiences pain, it can be due to soft tissue injury usually classified as AIS1.

The objective of this study is to identify and categorise AIS2+ thoracic and lumbar spine injuries from car accidents based on in-depth studies and put into the overall injury context by statistical analysis of a larger dataset.

METHODS

Subsets of occupants in Volvo's statistical accident database were analysed. Crashes involving Volvo cars in Sweden in which the repair costs exceed a specified level (currently SEK 45 000, approx. 4900 EUR) are identified by the insurance company Volvia (If P&C Insurance). Photographs and technical details of the cars (eg, damage) are sent to Volvo's traffic accident research team. The owner of the car completes a questionnaire (within a couple of months after the accident) to provide detailed information about the crash and the occupants. With the consent of the occupant, injury data is gathered from medical records and analyzed by a physician within Volvo's traffic accident research team. Injuries are coded according to the Abbreviated Injury Scale (AIS, AAAM 1985). This ongoing data collection process forms the basis of Volvo's statistical accident database. Volvo regularly performs in-depth accident investigations of accidents of special interest parallel to the statistical data collection and as a part of the database. For these in-depth cases, on-site investigations are carried out and highly detailed information is collected and recorded, such as, the course of events, detailed photographs of the scene of accident and of the car, police reports, detailed documentation of all the damage to the car, as well as medical records, if applicable.

A two-fold study was carried out; an in-depth study in order to identify and categorise AIS2+ thoracic and lumbar spine injuries and a statistical analysis to relate influencing factors to the occurrence of spinal injuries.

STATISTICAL ANALYSIS: Occupants 15 years old and above involved in accidents occurring from 1991 to 2005 were selected from Volvo's statistical accident database; a total of 21 034 occupants. Table 1 shows the distribution of gender, age, stature and weight. Of the 21 034 occupants, 1293 occupants experienced AIS2+ injuries and of these, 189 occupants sustained AIS2+ thoracic or lumbar spine injuries. Table 2 shows the distribution according to gender, age, stature and weight in the subset of occupants with spinal injuries.

In the statistical analysis, the distribution and influence of accident type, seating position, seat belt usage and occupant factors, including BMI (Body Mass Index) were studied. BMI is calculated as weight/stature^2 (kg/m^2). AIS2+ spinal injury risk is defined as the number of occupants with AIS2+ thoracic or lumbar spine injuries divided by the total number of occupants. MAIS2+ injury risk is the number of occupants with a maximum body injury of AIS2+ or higher divided by the total number of occupants.

Table 1. Occupant factor - distribution of the 21 034 occupants

	gender	mean age ± stdev	mean stature ± stdev	mean weight ± stdev
Male	67%	41.9 ± 16.6 y	179.4 ± 6.9 cm	80.7 ± 11.0 kg
Female	33%	42.2 ± 16.8 y	166.4 ± 6.5 cm	64.7 ± 10.4 kg

Table 2. Occupant factor - distribution of the 189 occupants with AIS2+ spinal injuries

	gender	mean age ± stdev	mean stature ± stdev	mean weight ± stdev
Male	59%	48.2 ± 16.7 y	179.2 ± 7.3 cm	82.7 ± 12.5 kg
Female	41%	49.2 ± 18.5 y	166.9 ± 9.0 cm	65.7 ± 12.2 kg

IN-DEPTH STUDY: For the in-depth study, occupants (without age limit) involved in accidents 1991-2005 with AIS2+ injuries of the thoracic or lumbar spine were selected from Volvo's statistical accident database. All types of spinal fractures are coded as AIS2+. AIS1 spinal injuries are not covered in this study, nor are cervical spinal injuries. The selection resulted in a total of 192 cases (including three occupants under 15 years old), for which the information available was reviewed, including medical records from hospitals and questionnaires from the occupant and information about car damage. In 95 of the 192 cases, enough information was available to clearly understand the accident and the injuries to the occupant. The other 97 cases could not be used as in-depth cases, due to missing or unclear information about the accident or medical records (57%) or extreme crashes with trains or when the occupant was thrown out of the car and no spinal injury mechanism could be determined (43%).

Table 3 shows the distribution of gender, age, stature and weight for adults from the selected in-depth cases. Table 4 shows the distribution of seating positions.

Table 3. Occupant factor - distribution of the 93 adult occupants in the in-depth cases

	gender	mean age ± stdev	mean stature ± stdev	mean weight ± stdev
Male	57%	47.4 ± 16.5 y	178.5 ± 5.3 cm	81.8 ± 11.6 kg
Female	43%	52.4 ± 16.7 y	168.3 ± 4.8 cm	66.6 ± 9.3 kg

Table 4. Distribution of seating position of the 95 in-depth cases

	Number	%
Driver	54	57%
Front seat passenger	22	23%
Rear seat passenger	19	20%

For all the 95 in-depth cases, x-rays were requested from the hospitals. A total of 45 were obtained. Nearly half of the missing 50 cases were accidents older than ten years, which is the maximum time most hospitals keep their records. In the rest of the missing cases, the x-rays were not available for other reasons. The cases were studied and analysed carefully, determining the accident situation and putting this in relation to the fracture types identified. The probable body movement was assumed based on facts about the accidents and information about the motion pattern of the cars during the events. The information about the accidents was taken from the questionnaires describing the sequence along with photographs of the cars and, when available, the on-site accident investigation reports made by Volvo's accident research team.

A modified accident classification was made for the in-depth cases to identify a run-off road event if any occurred. In the ordinary accident classification, a run-off road event (usually of minor importance than the impacts) may be included in the other accident types. Details of each in-depth case are found in Appendix 1.

RESULTS

STATISTICAL ANALYSIS: The MAIS2+ injury risks and AIS2+ injury risks, respectively, are shown for two time periods in Figure 1 with the aim of illustrating the difference in injury risks over the past decade. For MAIS2+ injury risks, a substantial and statistically significant reduction is seen when comparing accidents occurring 2001-2005 than with those occurring 1991-1995, confirming the trend shown by Isaksson-Hellman and Norin (2005). For the same time period only a small, not statistically significant, reduction in the risk of AIS2+ thoracic and lumbar spine injury is seen.

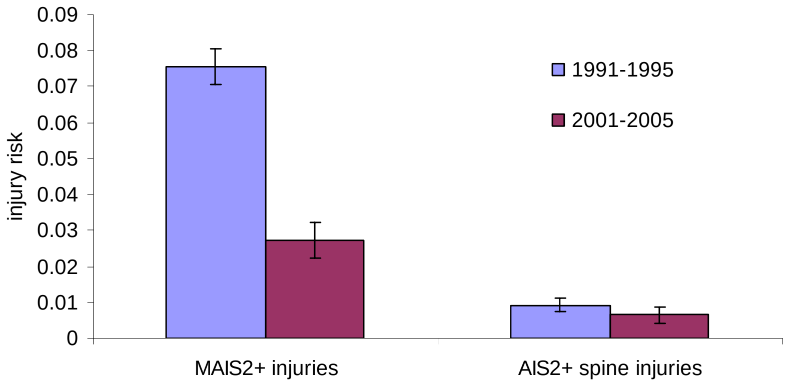

Figure 1. MAIS2+ injury risks and AIS2+ thoracic and lumbar spine injury risks (incl. 95 %-ile confidence intervals) for accident years 1991-1995 and 2001-2005

Figure 2 displays the distribution of accident types, comparing all occupants, all occupants with MAIS2+ injuries, as well as occupants with AIS2+ spinal injuries. For all the three subsets, frontal impacts are the most frequent accident type, accounting for 39% of the 189 occupants with AIS2+ spinal injuries. Side impacts are the second largest cause of occupants with MAIS2+ injuries (25%), they are responsible for a lower proportion of the occupants with AIS2+ spinal injuries (19%), while the opposite can be seen for multiple impacts, run-off road, and roll or turnover events.

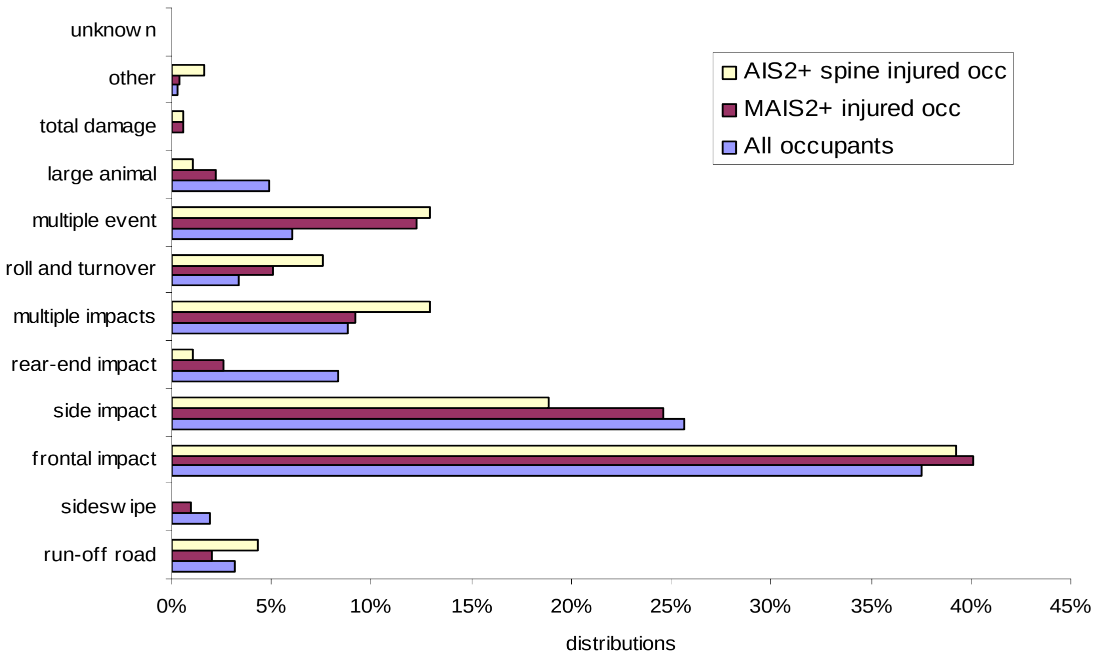

Figure 2. Distributions of accident types comparing all occupants, all occupants with MAIS2+ injuries and those with AIS2+ spinal injuries

In Figure 3, the distribution of seating positions can be seen, comparing the three subsets of occupants. There is a slightly higher proportion of passengers (37%) among the occupants with AIS2+ spinal injuries as compared to the total dataset (32%) as well as the occupants with MAIS2+ injuries (32%). Among the rear passengers, three of the occupants with AIS2+ spinal injuries were seated in the mid-seat position, wearing a 2-point lap belt.

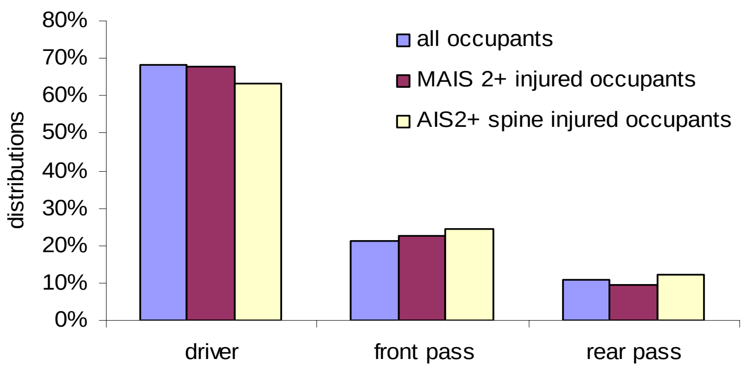

Figure 3. Distribution of seating positions comparing all occupants, all occupants with MAIS2+ injuries and those with AIS2+ spinal injuries

The overall known seat belt usage in the dataset is 92%, 5% are unbelted and 3% have unknown seat belt usage. Among the occupants with AIS2+ spinal injuries , 79% stated that they were restrained by seatbelts, as compared to 9% unrestrained (12% unknown). The seat belt use distribution among the occupants sustaining spinal injuries does not differ considerably as compared to occupants in the subset for MAIS2+ injuries.

Comparing the distributions / risks of injury due to occupant factors, such as, gender, age, stature, weight and BMI, there are no substantial different distributions / risks for the group with spinal injuries as compared to the overall group with injuries. As for the risk of MAIS2+ injury, women have a statistically significantly higher AIS2+ spinal injury risk as compared to men. There is no systematic influence of stature or weight, while there is a slightly increased proportion of overweight and obese (BMI 24.5 or above) occupants among those with spinal injuries (52%) as compared to those with MAIS2+ injuries (49%) and all occupants (45%). Figure 4 shows, there is a larger proportion of the elderly among those with AIS2+ spinal injuries. This is in line with the general picture of injuries sustained (occupants with MAIS2+ injuries as compared to all occupants), although it is somewhat more pronounced.

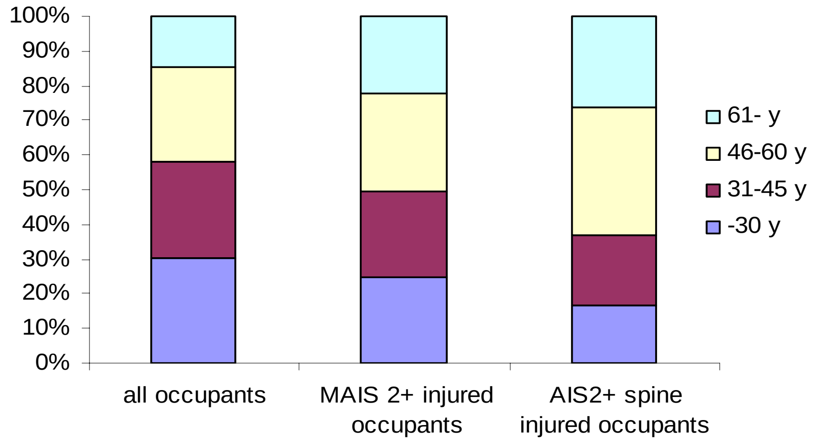

Figure 4. Distribution of age groups comparing all occupants, all occupants with MAIS2+ injuries and those with AIS2+ spinal injuries

For the 189 occupants with AIS2+ spinal injuries, a total of 203 AIS2+ thoracic and lumbar spine injuries occur. The 203 injuries are distributed along the spine as shown in Figure 5. The most frequently injured vertebrae are L1-L5, accounting for 51% of the injuries. 24% were located in the lower thoracic spine (Th7-Th12) and 19% in the upper thoracic spine (Th1- Th6). 3% of the injuries in this subset were located in the sacrum, none of them were included in the in-depth cases.

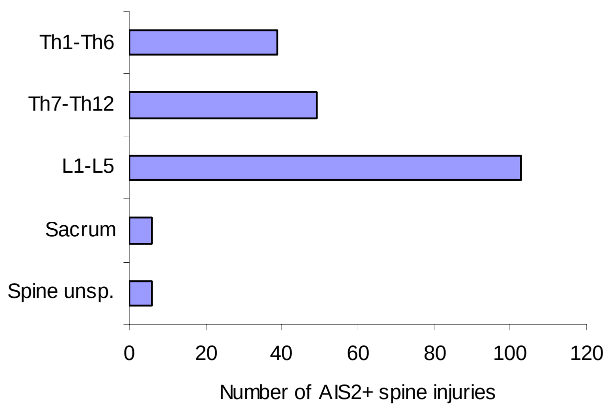

Figure 5. Number of AIS2+ injuries along the spine for the 189 occupants with 203 AIS2+ spinal injuries

IN-DEPTH STUDY: For the 95 AIS2+ thoracic and lumbar spine injured occupants in the in-depth data selection, the 125 injured vertebrae (including 1 disc injury) are distributed along the thoracic and lumbar spine as shown in Figure 6. The distribution of injuries along the spine is concentrated around the transition between the thoracic spine and the upper part of the lumbar spine, 68% are found in Th11-L3. When compared to the statistical subset (Figure 5), a larger proportion of injuries are found in the lumbar region (58%) and the lower part of the thoracic spine (30%). All injuries, in this study, are fractures, except one disc injury. Multiple fractures are quite common, 26% of the occupants have more than one injured vertebra and in most cases the injured vertebrae are adjacent to each other.

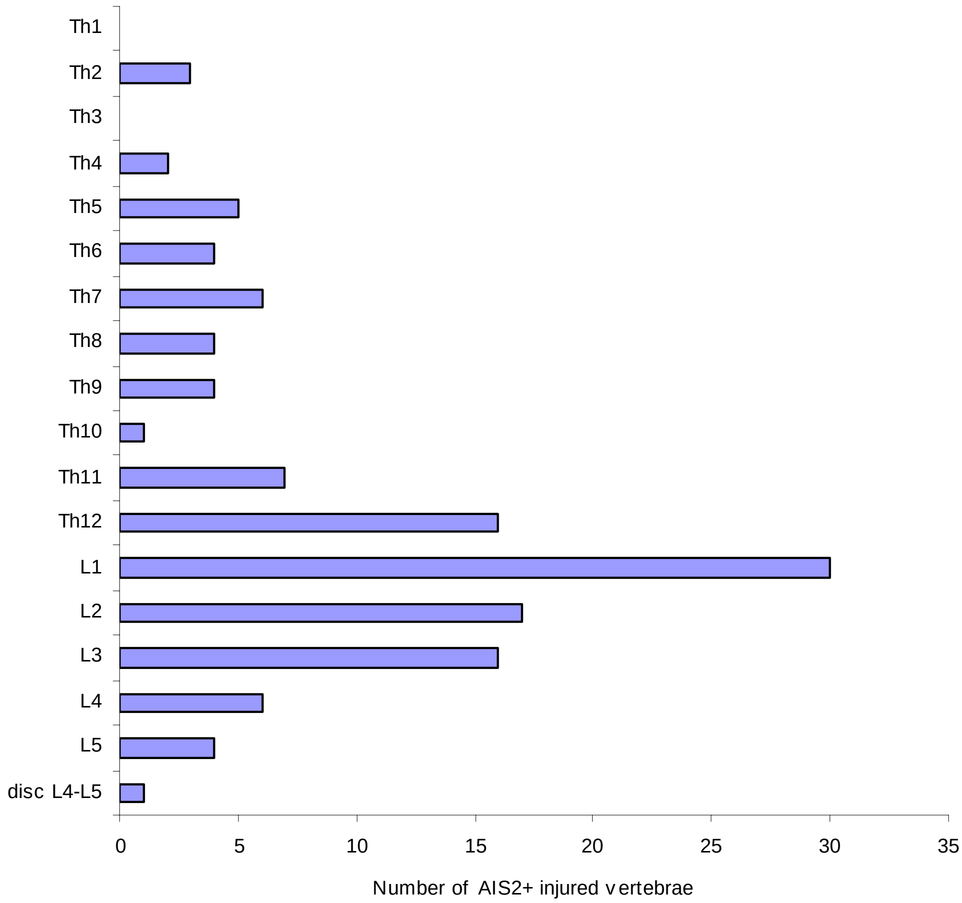

Figure 6. Number of AIS2+ injured vertebrae for the 95 occupants from the in-depth cases

Figure 7 shows the distribution of the accident situations among the in-depth cases. In nearly 70% (65 out of 95) of the cases, run-off road events occurred. These events are found in the run-off road, roll or turnover and multiple events situations in Figure 7. Only in 18 frontal impacts, 5 side impacts, 1 rear-end impact and 6 multiple impacts, no run-off road events occurred. In Figure 7, the 43 cases categorised as run-off road include "pure" run-off road situations as well as cases of run-off road events with subsequent single impacts (23 frontal, 4 side and 3 rear-end) and 8 cases of run-off road events together with multiple impacts. All the 6 roll or turnover cases include run-off road events. In the 16 multiple event cases, run-off road, roll or turnover occur as well as one or two impacts.

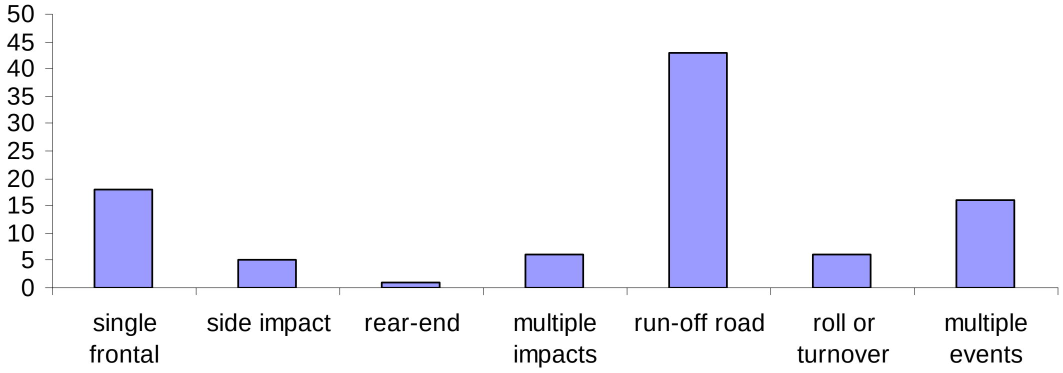

Figure 7. Distribution of accident situations from the 95 in-depth cases

Figure 8 shows the distribution of different fracture types. Five different fracture types are found among the in-depth cases in the present study. Compression fractures account for 42%, anterior wedge fractures are somewhat less frequent, followed by burst fractures, process fractures and one case of a Chance fracture. Five injured vertebrae (3 occupants) consist of a combination of compression fractures and either anterior wedge or transverse process fractures. Multiple vertebrae injuries occur for 25 occupants (26%). Two of the occupants had injuries to the spinal cord, case 69 and 80. Details regarding each in-depth case are found in Appendix 1.

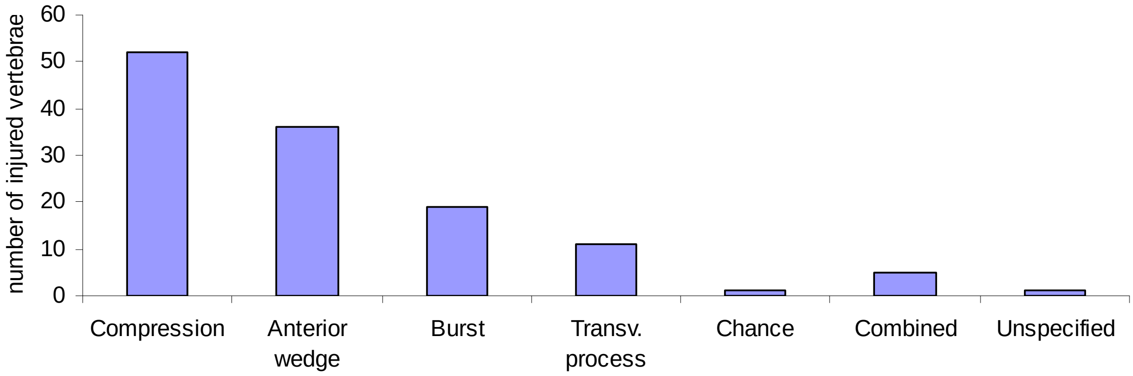

Figure 8. Distribution of types of spine fractures (125 vertebrae)

Compression fractures : Compression fractures are the most common type of fracture in this study, which can occur throughout the spine, although they mainly occur at the transition of the lumbar and thoracic segment (69% in Th11-L3). These types of fractures are found in 44 occupants, with a total of 52 injured vertebrae. Compression fractures are found in combination with wedge and transverse process fractures. Compression fractures occur in all the accident situations in this study, 61%, including run-off road events. For 10 out of the total 18 single frontal impacts, compression fractures occurred, all occupants were passengers, except for two cases.

Anterior wedge fractures : Anterior wedge fractures are the most frequent fracture type after compression fractures in this study, this is represented by the 25 occupants with 36 injured vertebrae. Anterior wedge fractures most frequently occur in Th12 and L1 but are found in the middle and lower part of the thoracic spine and the upper part of the lumbar spine as well as in some cases, in conjunction with compression fractures. Anterior wedge fractures occur in most of the accident situations, though they are more common than compression fractures in run-off road events (72%). In several of the in-depth cases, large occupant flexion was seen as an influencing factor.

Burst fractures : Nineteen occupants sustained burst fractures. Fourteen of the 19 burst fractured vertebrae are lumbar vertebrae, three in Th12 and only two in the rest of the thoracic spine. In 79% of the cases, run-off road events are involved in the accident situation. Several of the cases are high severity situations. Occupants incurring burst fractures represent a larger share of the older occupants as well as drivers as compared to the other fracture types.

Transverse process fractures : Only seven occupants sustained transverse process fractures, including a total of 11 injured vertebrae, some combined with compression and burst fractures. In this study, transverse process fractures are found in the lumbar spine, except for one case in Th2. The seven cases occurred in multiple impacts, run-off road and multiple events, usually involving complex kinematics. In several of the cases, statements of pre-rotated occupant posture were noted.

Chance fractures : Only one case of a Chance fracture (at level L3) was found in the data. This case was typical of an occupant wearing a 2-point lap belt only in a single frontal impact.

DISCUSSION

AIS2+ thoracic and lumbar spine injuries are relatively infrequent and generally not life-threatening, but the injury risk has only decreased to a small extent in the past decade. This study offers a general, as well as a specific picture of the occurrence of different AIS2+ spinal injuries in car accidents, categorised by different fracture types and situations of occurrence.

The data used is limited to accidents involving Volvo cars in Sweden. Unfortunately no study could be found to confirm how representative this data is in a more general context. Thus, this study should be regarded as a qualitative study rather than a quantitative study. However, the data is restricted to a limited type of car models which is an advantage for studies of injury occurrence, reducing the influence of several factors and also improving the quality in the in-depth analysis performed by experts of these specific car models.

The two sections in this two-fold study complement each other. The statistical analysis of the larger statistical subset provides distribution data and shows influencing factors in a general sense. The in-depth study makes it possible to identify fracture types and thus injury mechanisms, helping to clarify further details of the sequence of events. It also gives an indication of influencing factors, both supporting and complementing the statistical analysis. The redefinition of accident situations in the in-depth cases as compared to the accident types used in the statistical study, makes it difficult for the reader to get a clear picture of how representative the in-depth cases are. The largest difference is the proportion of side impacts being smaller among the in-depth cases (9%) as compared to occupant spinal injuries in the statistical subset (19%). The reason for this is that the side impact cases are overrepresented among the cases which were disregarded due to extreme severity (eg, impact by train). Thus, the results from the in-depth study should thus not be seen as totally representative in quantity and distribution.

An analysis of the in-depth cases using medical records, including x-rays, provided an opportunity to identify different fracture types and injury mechanisms and to estimate possible load transfers causing these injuries. By studying the information available from photographs, questionnaires and notes, accident situation and probable car kinematics were estimated. This was combined with the fracture type and injury mechanism information whereby the probable scenario of occupant kinematics could be estimated and influencing factors identified. In many cases this process was complicated. The information taken from the questionnaire was mostly factual, such as, gender, occupant characteristics and seating position. In some cases, the occupants provided information about their sitting posture and behaviour, etc, before the moment of impact. If this information was consistent with the theoretical reconstruction of other information, it was also used. Although the in-depth cases proved beneficial, more precise information about the accidents and occupants could provide a more accurate analysis. More detailed information about accident circumstances, occupant sitting postures, clothing worn and occupant constitution would be helpful leading to a greater understanding of the event.

Unfortunately, x-rays were not accessible in all the cases for the in-depth cases. Even though most of the medical records contained quite detailed information on the fractures, it was highly valuable to have an exact picture of the fractures. The large number of compression fractures may have occurred because this fracture type is overrepresented among the cases where only medical records were available without x-rays. This may indicate that this group might contain a few cases that actually consist of other fracture types. According to the case records, many of the compression fractures, are not homogenous but the height of the vertebrae is further reduced frontally. The difference between compression and anterior wedge fractures is not obvious. In cases where the statements in the x-ray reports differ from the medical reports, the fracture type was chosen based on the x-rays with the help of medical experts. The number of transverse process fractures might be underrepresented, since these fractures are often difficult to see in x-rays.

The vertebrae closest to the transition between the lumbar and thoracic segment of the spine are most frequently injured. This was clearly seen in this study, indicating that this area is weaker than the rest of the spine and therefore more vulnerable to mechanical loading.

Many factors influence the probability of suffering an AIS2+ thoracic or lumbar spinal injury in car accidents. Age was found to be influential in both the statistical analysis and the in-depth cases where only the oldest occupant in the car was injured in the crash, where there was no other obvious explanation for injuries sustained apart from age. No relation to the risk of spinal injury was found for weight or stature, as separate factors, however indications were seen of increased risk of injury with increased BMI. The influence of seat belt usage on the risk of spinal injury was found to be similar to that of the overall risk of injury in the statistical analysis. The in-depth cases indicate the importance of seat belt wear. In several of the cases, the spinal injuries were a result of extensive forward bending of the upper body during impact, which indicates a probable slack in the seat belt restraint system. Indications were seen that factors such as body constitution and bulky clothing influenced injury occurrence. Other factors that seem to influence the risk of spinal injury are sitting posture of the occupant and seating position in the vehicle. Several of the occupants with spinal injuries from the in-depth cases stated they were incorrectly positioned or asleep at the time of the accident, which differed from the others in the same car, without spinal injuries. Drivers were underrepresented in the group of those with spinal injuries as compared to passengers, when compared to the overall risks of injury. This fact is to some extent influenced by the distribution of women and elderly among passengers. However, it might also be because the driver is more aware of the impending event and might therefore be seated in a more upright and stable posture holding the steering wheel. The overrepresentation of run-off road events with subsequent single or multiple impacts or events also supports the important influence of sitting posture, supported by the biomechanical knowledge that the spine can sustain higher loads in a straight posture rather than when curved or rotated.

The numerous combinations of fracture types and accident situations reveals a large number of different occupant loading mechanisms. Thus, a variety of different car safety measures are involved in order to significantly reduce the total number of spinal injuries. More research is required in order to know what specific improvements are needed. Based on the method used in this study, specific occupant loading mechanisms could be identify, followed by development of test methods. Also, dummies need to be checked and possibly improved in order to measure spinal loads similar to those sustained by humans in the occupant loading mechanisms identified.

Spinal injuries are not the most frequent injury types from car accidents: However, contrary to most other injuries, they have not been substantially reduced over the past decade. In many cases they can be explained by factors, such as, advanced age, badly positioned posture and high impact severity. Nevertheless, understanding the mechanisms underlying spinal injuries is a highly complex task that requires further attention. Further studies are needed to select and develop preventive measures. This study used a feasible approach successfully identifying possible injury mechanisms in the first step towards protection of spinal injuries in car accidents.

CONCLUSIONS

In this study the following was found with respect to AIS2+ thoracic and lumbar spine injuries in car accidents:

- Only a slight reduction in risk the last decade, in contrast to the significant MAIS2+ injury risk reduction.
- Overrepresentation in accidents involving run-off road, multiple impacts and multiple events.
- Occupant characteristics as well as occupant posture, during load transfer through the spine at impact, are influencing factors.
- Most of the fractures are found in the area of transition between the thoracic and lumbar spine.
- Compression fractures are the most common fracture type, occurring in all accident situations, run-off road as well single frontal impacts, exposing the body to axial loads.
- Anterior wedge fractures are the second most frequent type, occurring at a higher proportion of run-off road events than compression fractures, resulting from a combination of axial load and flexion.
- Burst fractures are the third most frequent type, caused by high loads involving a combination of axial loading and flexion, often as a result of events associated with run-off road combined with frontal impact.
- Transverse process fractures are often associated with complex events and further studies are necessary to ascertain the mechanisms of occurrence.

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Appendix 1. In-depth case details.

case #	accident type	year	seat pos.	gender	age	stature	weight	Volvo car	belt	airbag	MAIS	vertebra	fracture type	vertebra	fracture type
1	run-off road	1992	rear left	m	21	183	80	944, -91	yes	no	2	Th8	compression		
2	mult event	1996	driver	m	52	180	99	855, -96	no	no	3	Th5	compression	Th6	compression
3	run-off road	1992	driver	m	64	180	98	744, -87	yes	no	3	L1	compression		
4	run-off road	1992	driver	m	56	187	91	945, -91	yes	no	3	L3	compression		
5	side impact	1995	driver	m	37			854, -95	yes	yes	5	Th11	compression	L3	compression
6	mult event	1996	driver	f	28	162	70	945,- 95	unkn.	yes	2	TH12	compression	L1	fragm.disl.
7	mult event	1991	front pass	m	45	176	67	944, -91	yes	no	3	L1	compression		
8	run-off road	1998	driver	m	52	174	78	S80, -99	yes	yes	3	Th7	compression	Th8	compression
8												L3	compression		
9	single frontal	1993	front pass	f	52	169	60	744	yes	no	3	L5	compression		
10	single frontal	1993	rear left	f	59	169	79	744	yes	no	3	L3	compression		
11	run-off road	2000	driver	m	62	174	80	S80, -99	yes	yes	2	Th12	compression		
12	single frontal	1992	driver	m	48	185	79	854, -92	yes	no	3	Th2	compression		
13	side impact	2000	rear right	f	82	170	60	944, -97	no	no	3	Th4	compression		
14	rear-end	1991	rear right	f		175	75	480, -91	no	no	3	Th5	compression		
15	roll and turnover	1996	front pass	m	19	180	73	854, -95	yes	no	3	Th8	compression		
16	run-off road	1991	rear right	m	18			244, -80	no	no	3	L3	compression		
17	single frontal	1992	rear left	f	17	175	50	244, -83	yes	no	2	Th2	compr. + trans. proc.		
18	single frontal	1993	driver	m	74			242, -84	yes	no	3	Th11	compression		
19	run-off road	1999	front pass	f	77	168	88	964, -96	yes	no	2	Th11	anterior wedge	Th12	compression
20	single frontal	1991	rear right	m	15	180	60	700, -87	yes	no	4	L2	compression	L3	compression
21	single frontal	1991	rear mid	f	9	140	25	745, -87	yes	no	3	L4	compression		
22	mult event	1992	front pass	m	85			700, -87	yes	no	3	L1	compression	L2	compression
23	run-off road	1991	driver	m	55	176	85	744, -88	yes	no	2	L1	compression		
24	roll and turnover	1991	front pass	f	74			345, -88	yes	no	3	L1	compression		
25	single frontal	1992	rear left	m	15			745, -88	unkn.	no	4	Th7	compression		
26	run-off road	1995	driver	m	63	187	87	745, -88	yes	no	2	L3	compression		
27	run-off road	1995	front pass	f	60	164	70	745, -88	yes	no	3	Th12	compression	L1	compression
28	single frontal	1994	rear right	f	52	180	60	744, -88	no	no	3	Th5	compression	Th6	compr. + trans. proc.
29	single frontal	1992	front pass	f	62	160	56	744, -89	yes	no	3	L1	compression		
30	run-off road	1999	driver	m	74			700, -90	yes	no	3	L3	compression		
31	side impact	1994	front pass	m	68	174	59	744, -89	yes	no	2	L1	compression		
32	side impact	1994	driver	f	58	174	79	744, -89	yes	no	2	L1	compression		
33	run-off road	2001	front pass	f	59	165	60	V40, -00	yes	no	3	Th11	compression		
34	mult impacts	1994	rear left	f	30	165	75	854, -93	yes	no	3	Th7	compression	Th8	burst
35	mult event	1994	front pass	f	70	166	64	854, -94	yes	no	3	Th12	anterior wedge	L4	compression
36	run-off road	1994	driver	m	51	178	85	944, -93	yes	yes	3	L2	compression		
37	run-off road	1993	driver	f	61	167	69	854, -92	yes	no	3	L3	compression		
38	run-off road	2004	driver	m	40	185	80	S80, -00	yes	yes	2	L1	compression		
39	mult impacts	2000	driver	f	53			S40, -01	yes	yes	3	L2	compression		
40	run-off road	2002	rear right	f	59	165	65	V70, -01	yes	no	3	Th7	anterior wedge	Th9	anterior wedge
40												L2	compression		
41	run-off road	2004	driver	m	48			S60, -02	yes	yes	2	L1	compression		
42	run-off road	2004	driver	f	28	168	59	V40, -03	yes	no	3	Th12	compression	L1	compression
43	mult event	2004	front pass	f	86	168	53	S60, -04	yes	no	3	L3	compression		
44	run-off road	2005	driver	m	31	180	105	V70, -04	yes	yes	3	L2	compression		
45	run-off road	1998	driver	m	60	180	99	855, -96	no	yes	2	L1	anterior wedge		
46	run-off road	2001	front pass	f	64	162	50	V40, -98	yes	no	3	L1	anterior wedge	L2	compression
47	single frontal	1995	front pass	m	19	178	75	855, -95	yes	no	3	Th12	anterior wedge		
48	mult event	1993	driver	m	53	183	75	944,- 91	yes	no	3	Th7	anterior wedge	Th9	anterior wedge
49	mult impacts	2001	driver	m	32	175	70	S40, -00	yes	yes	3	L1	anterior wedge		
50	mult event	1994	front pass	f	30	162	60	945, -91	yes	no	3	Th12	anterior wedge		
51	run-off road	2000	rear mid	m	10	140	30	850, -98	yes	no	3	Th4	anterior wedge	Th5	anterior wedge
51												Th6	anterior wedge		
52	run-off road	1993	driver	f	18	173	62	944, -91	yes	no	3	Th6	anterior wedge	Th7	anterior wedge
53	roll and turnover	1998	driver	m	50	183	74	855, -97	yes	yes	2	L2	anterior wedge		
54	mult impacts	1992	driver	f	46	169	65	245, -82	yes	no	3	L1	anterior wedge		
55	roll and turnover	1994	driver	m	30	190	99	745, -86	yes	no	3	Th9	anterior wedge	Th10	anterior wedge
55												Th11	anterior wedge	Th12	anterior wedge
56	run-off road	1996	driver	m	63	184	92	245, -86	yes	no	3	L4	anterior wedge		
57	run-off road	1995	front pass	f	59	170	70	744, -88	yes	no	3	L1	anterior wedge		
58	single frontal	1991	driver	m	41	178	72	744, -88	yes	no	3	L2	anterior wedge		
59	run-off road	1997	driver	f	55	170	75	744, -88	yes	no	3	L1	burst + ant. wedge		
60	mult event	1992	driver	m	26	165	62	744, -90	yes	no	3	Th11	anterior wedge	Th12	anterior wedge
61	run-off road	1992	front pass	f	62	164	70	744, -90	yes	no	3	Th11	anterior wedge		
62	side impact	1992	driver	m	50	173	73	745, -90	yes	no	3	Th9	anterior wedge		
63	run-off road	2001	driver	m	64	187	92	V40, -00	yes	yes	3	L2	anterior wedge	L3	anterior wedge
64	single frontal	2001	driver	m	43	184	99	S80, -00	yes	yes	3	L1	anterior wedge		
65	roll and turnover	2000	driver	m	58	173	94	V40, -00	yes	no	3	Th12	anterior wedge		
66	single frontal	2003	front pass	f	66	172	64	V70, -01	yes	no	2	L1	anterior wedge		
67	run-off road	2002	driver	m	63	180	90	V70, -01	yes	yes	3	Th12	anterior wedge	L1	anterior wedge
68	run-off road	1991	rear left	f	53	171	82	245, -90	yes	no	3	L1	burst		
69	run-off road	1994	front pass	m	43			244, -79	yes	no	5	L1	burst		
70	run-off road	1998	driver	m	52	173	67	945, -94	yes	yes	3	L1	burst		
71	run-off road	1996	driver	m	41	178	73	744, -84	yes	no	3	Th12	burst		
72	run-off road	1993	driver	m	70	170	75	744, -87	yes	no	3	L4	burst		
73	run-off road	1997	driver	f	47	163	66	965, -96	yes	no	3	L1	burst		
74	mult event	1996	front pass	f	48	167	62	945, -95	yes	no	3	L2	burst		
75	roll and turnover	1994	front pass	f	61			854,- 92	yes	no	3	Th5	burst		
76	run-off road	1992	driver	f	56	168	55	944, -92	yes	no	3	L1	burst		
77	single frontal	1993	rear left	f	34			245, -78	yes	no	3	L3	burst		
78	run-off road	2002	driver	m	79			S40, 98	yes	yes	3	L2	burst		
79	run-off road	1994	driver	m	60	179	74	944, -92	yes	no	3	L3	burst		
80	mult event	1996	driver	m	44	180	93	854, -94	yes	yes	4	L2	burst		
81	single frontal	1992	rear mid	f	43	173	60	244, -83	yes	no	3	L5	burst		
82	mult event	1997	driver	m	55	178	75	944, -92	yes	no	3	Th12	burst		
83	mult event	1995	driver	f	58	169	72	745, -88	yes	no	3	L1	burst		
84	run-off road	2001	driver	m	58	174	78	V40, -01	yes	yes	3	L1	burst + transv. proc.	L2	transv. process
85	single frontal	2000	driver	m	39	172	75	XC70, -00	yes	yes	3	L2	burst		
86	run-off road	2004	driver	m	80	178	78	S60, -02	yes	no	3	Th12	burst		
87	mult event	1996	rear left	f	68	161	75	944, -94	yes	no	2	L3	transv. process		
88	mult impacts	2003	driver	m	22	181	95	S40, -99	yes	yes	2	L1	transv. process		
89	run-off road	2000	driver	m	59	168	93	744, -90	unkn.	no	3	L4	transv. process	L5	transv. process
90	run-off road	2004	driver	f	31	166	62	850, -00	yes	yes	3	L2	transv. process	L4	transv. process
90												L5	transv. process		
91	run-off road	2000	rear right	m	46	177	86	S60, -01	yes	no	2	Th2	transv. process		
92	mult event	2004	front pass	f	34	168	75	V70, -01	yes	no	2	L2	transv. process	L3	transv. process
93	single frontal	1993	rear mid	f	42	179	80	245, -85	yes	no	3	L3	chance		
94	mult impacts	2003	driver	m	53	175	78	S60, -01	yes	yes	2	disc L4-L5			
95	mult event	2000	driver	m	65	180	88	850, -94	yes	no	3	Th12	unspec		

Back