Spine injuries in motor vehicle accidents - an analysis of 18353 traffic accidents between 1985 and 2004 with special consideration of injuries of the thoracolumbar spine in relation to injury mechanisms

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Abstract - This study aims to analyze spine injuries in motor vehicle accidents. Between 1985 and 2004 the Hannover accident research unit documented 18353 accidents. We identified 161 front passengers (0.53%) with cervical spine injuries, 84 (0.28%) with thoracic and 95 (0.31%) with lumbar injuries. Technical and medical data was reviewed. Patients' records were retrieved. X-rays were evaluated and fractures were classified according to the Magerl classification. 68% and 57% of thoracic and lumbar fractures occurred in accidents with multiple impacts. Delta-v was 50, 40 and 40 kph in passengers with cervical, thoracic and lumbar spine, resp. Passengers with spinal fractures frequently showed numerous concomitant injuries, e.g. additional vertebral fractures. The influence of seat belts and airbags is discussed. Patient work-up has to include a thorough investigation for additional injuries.

INTRODUCTION

Injuries of the spine are a considerable threat to life and quality of life in motor vehicle users. In comparison to injuries of other organ systems, spinal and spinal cord injuries are associated with the worst functional outcome and the lowest rate of reintegration into work life [1]. Great efforts have been spent to improve safety of car drivers and passengers. Overall mortality in traffic accidents has been markedly reduced during the last 20 years: In 1970, the "death toll" on German roads was more than 20.000, in 2007 4949 people were killed. Still, the number of injured people was more than 430.000 (Statistisches Bundeamt Wiesbaden, 2008). In this study, we aim to evaluate the current risk for spinal injuries in restrained front passengers and implications on car safety issues as well as on medical treatment at the scene and in the hospital.

METHODS

Data Collection by an Accident Research Unit

A local traffic accident research unit, that had been established in 1972 collected prospective data in regard to all reported traffic crashes within the area. 300 vehicular collisions per year up to 1987 and 1000 accidents per year since then were documented. Specially trained documentation personnel are notified by police dispatchers and arrive on scene, often simultaneously with the rescue personnel. The circumstances of the crash are investigated by taking photographs and using a 3D-laser scanner. Slide and skid marks of involved objects, vehicles and persons are measured for later reconstruction of the crash and calculation of collision speeds. Furthermore technical features of involved vehicles, e. g. weight and size are obtained as well as on-scene clinical data from injured persons. Additional data is collected at the hospital which admits the injured occupants, with documentation of x-ray films, diagnoses after the first in-hospital examination and estimation of injury severity. A report of each accident is written. The data collected and calculated is put into a data bank which comprises demographic data, type of road user (car/truck occupant, motorcyclist, cyclist, pedestrian), delta-v (km/h; change of velocity at the collision time as a basic force indicator) of motorized vehicle user; vehicle collision speed (km/h) of motorbikes, Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), Injury Severity Score (ISS) and incidence of serious and/or severe multiple injuries (polytrauma, ISS $\geq$ 16) [2-5]. The data base used in this study comprises 18352 traffic accidents which were documented between 1985 and 2004. Traffic crash reports were analyzed for the involvement of car occupants. In a first step, all reports were screened for front passengers who received a spinal injury were extracted.

Data was analyzed for collision speed, age, sex, AIS score, MAIS score, ISS, and incidence of other injuries.

Review of x-rays and medical records

In a second step, all victims of fractures of the thoracic or lumbar spine were extracted. All x-rays and medical records that were retrievable were analyzed. Fractures were classified according to the classification proposed by Magerl [6]. Crash circumstances were evaluated from the technical crash reports and correlated to the type of injuries.

RESULTS

The data base revealed 30421 front passengers who where involved in motor vehicle accidents. There were 161 persons (0.53%) with injuries of the cervical spine (209 fractures), 84 persons (0.28%) with injuries of the thoracic (117 fractures) and 95 persons (0.31%) with injuries of the lumbar spine (122 fractures).

Demographic data

The mean age of all front passengers was 35.5 years. The mean age in front passengers with injuries of the cervical, thoracic or lumbar spine was 35, 37 and 38 years, respectively. Overall, 60% were male, 37% female and 2% unknown. 61%, 68% and 60% of front passengers with injuries of the cervical, thoracic or lumbar spine, respectively, were male. Overall, 6.3 % were aged 65 and older. 8, 6 and 14% of front passengers with injuries of the cervical, thoracic or lumbar spine, respectively, were aged 65 and older. Children with vertebral fractures were extremely rare. All demographic data is shown in table 1.

	all front passengers		**fx cervical spine**		**fx throracic spine**		**fx lumbar spine**	
	30421	100,0%	**161**	100%	**84**	100%	**95**	100%
sex								
male	**18188**	59,8%	**98**	61%	**57**	68%	**57**	60%
female	**11347**	37,3%	**63**	39%	**27**	32%	**38**	40%
pregnant	**59**	0,2%	**0**	0%	**0**	0%	**0**	0%
unknown	**598**	2,0%	**0**	0%	**0**	0%	**0**	0%
age								
child up to 6y	**670**	2,2%	**1**	1%	**0**	0%	**0**	0%
child 6 to 12 years	**675**	2,2%	**2**	1%	**1**	1%	**1**	1%
adolescent 13-17	**760**	2,5%	**10**	6%	**0**	0%	**4**	4%
18 to 64 y	**24244**	79,7%	**132**	82%	**77**	92%	**77**	81%
65 y and older	**1918**	6,3%	**13**	8%	**5**	6%	**13**	14%
unknown	**1837**	6,0%	**2**	1%	**1**	1%	**0**	0%
safety belt usage								
used	**23792**	78,2%	**115**	71%	**53**	63%	**72**	76%
not used	**1986**	6,5%	**31**	19%	**22**	26%	**15**	16%
unknown	**4643**	15,3%	**15**	9%	**9**	11%	**8**	8%
airbag deployment								
none	**29132**	95,8%	**144**	89%	**77**	92%	**89**	94%
only front	**1159**	3,8%	**13**	8%	**5**	6%	**6**	6%
only side	**72**	0,2%	**1**	1%	**1**	1%	**0**	0%
front and side	**58**	0,2%	**3**	2%	**1**	1%	**0**	0%

Table 1: Demographic data

Crash mechanism

Overall, 45% of all front passengers had a head-on collision, 20% a side-collision, 9.9% a rear-end collision, 0.7% a roll-over and 24% sustained multiple collisions. Out of all front passengers with cervical, thoracic and lumbar spine injuries 29%, 17% and 28% had head-on collisions, 22%, 7% and 12% side-collisions, 2%, 5% and 0% rear-end collisions, 2%, 4% and 2% isolated roll-overs and 43%, 68% and 57%, resp., multiple collisions, cf. table 2.

	all front passengers		fx cervical spine		fx throracic spine		fx lumbar spine	
	30421	100,0%	**161**	100%	**84**	100%	**95**	100%
Collision partner								
car	**11293**	37,1%	**30**	19%	**9**	11%	**16**	17%
truck	**1662**	5,5%	**16**	10%	**7**	8%	**5**	5%
motorbike	**1801**	5,9%	**0**	0%	**0**	0%	**0**	0%
bicycle	**3753**	12,3%	**0**	0%	**0**	0%	**0**	0%
pedestrian	**2422**	8,0%	**0**	0%	**0**	0%	**0**	0%
object	**1959**	6,4%	**44**	27%	**10**	12%	**19**	20%
multiple	**7232**	23,8%	**70**	43%	**57**	68%	**54**	57%
unknown	**299**	1,0%	**1**	1%	**1**	1%	**1**	1%
Impact site								
front	**13560**	44,6%	**47**	29%	**14**	17%	**27**	28%
side	**6043**	19,9%	**35**	22%	**6**	7%	**11**	12%
rear	**2996**	9,8%	**4**	2%	**4**	5%	**0**	0%
isolated roll-over	**199**	0,7%	**5**	3%	**3**	4%	**2**	2%
multiple	**7232**	23,8%	**70**	43%	**57**	68%	**54**	57%
other	**385**	1,3%	**0**	0%	**0**	0%	**1**	1%
unknown	**6**	0,0%	**0**	0%	**0**	0%	**0**	0%

Table 2: Collision characteristics

As a parameter for the severity of the car crash the change of speed (delta-v) due to the collision was calculated. Delta-v was 21.4 km/h in all front passengers, 50 km/h in front passengers with cervical spine injuries and 40 km/h both in those with thoracic or lumbar spine injuries, resp., cf. figure 1.

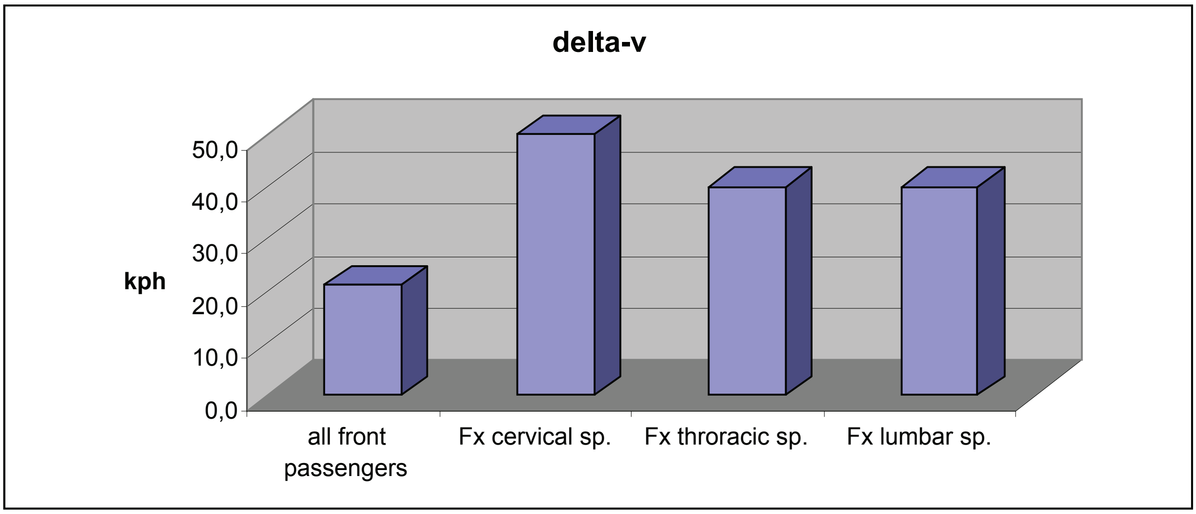

Figure 1: delta-v

Injury severity and associated injuries

In all occupants, ISS as well as AIS-head, AIS-neck, AIS-thorax, AIS-upper extremities, AIS-abdomen, AIS-pelvis and AIS-lower extremities and the resulting MAIS were determined. The ISS was 4.0 in front passengers without any spine injuries and 50, 23 and 10 in front passengers with fractures of the cervical, thoracic or lumbar spine, respectively. MAIS was 1.33 in front passengers without spine injuries and 4.3, 3.3 and 2.7 in those with cervical, thoracic or lumbar fractures. Figure 2 shows detailed data of AIS in front passengers with or without spine fractures, which reflects the high rate of associated injuries. Car occupants with spinal fractures in either part of the spine were more likely to have vertebral fractures in other regions of the spine: 7% and 3% of occupants with fractures of the cervical spine had additional fractures of the thoracic and lumbar spine. 14% and 11% of occupants with fractures of the thoracic spine had additional fractures of the cervical and lumbar spine. 5% and 9% of occupants with fractures of the lumbar spine had additional fractures of the cervical and thoracic spine.

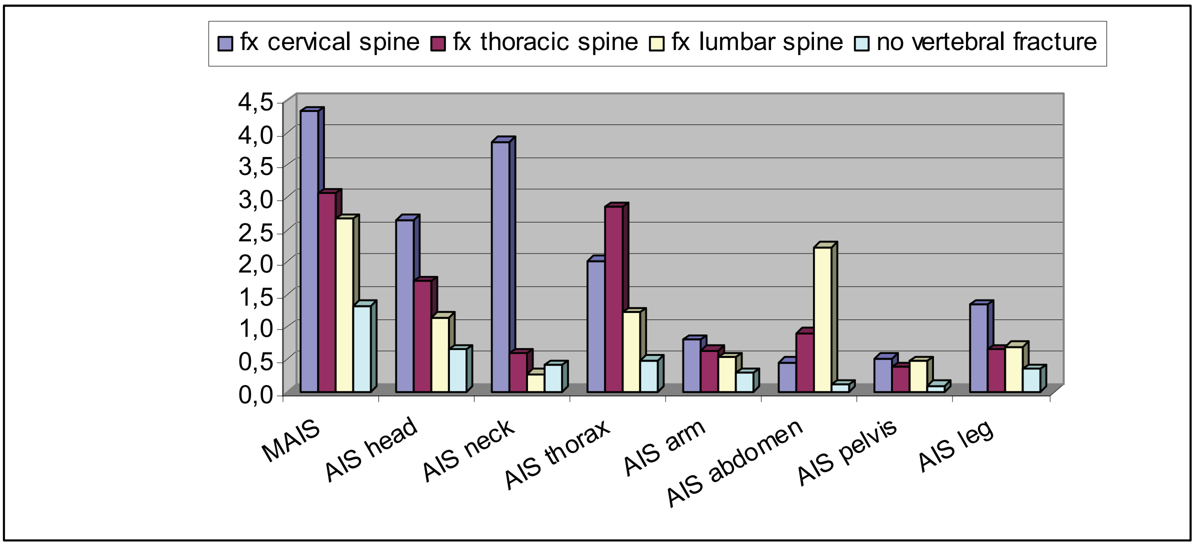

Figure 2: AIS

Fracture type classification

In 80 patients the type of fracture could be determined by x-rays, detailed patients' records or report of autopsy. 44 thoracolumbar fractures were classifiable after Magerl. There were 30 compression type fractures (A1.1 to A1.3), 2 slice fractures (A2), 5 burst fractures (A3.1 to A3.3) and 6 complex spinal injuries (B and C). 22 were fractures of the lateral processus of the vertebral body, 2 fractures pertained to the sacrum, the remaining were fractures of the upper cervical spine.

Crash mechanisms in severe thoracolumbar fractures

Five from six complex spinal injuries (B and C type) and four from five burst fractures (A3) were roll-overs or, mostly, multiple hits. There was no significant difference in delta-v. ISS and MAIS were higher in the more severe fractures. Seat belts had been used in all of these cases.

Case presentation

Figures 3 to 5 show the record of a belted driver of an Opel Astra. He was driving on a highway, suddenly decided to change lanes quickly without noticing a safety fence separating two lanes. He collided with a traffic sign and sustained multiple roll-overs before he collided with another safety fence. He sustained a compression fracture of the third thoracic vertebra which was treated conservatively. His additional injuries were epidural bleeding and multiple lacerations and decollement injuries of the left arm, which required multiple surgical revisions. He recovered fully. Figures show technical reconstruction, accident site and x-rays at admission.

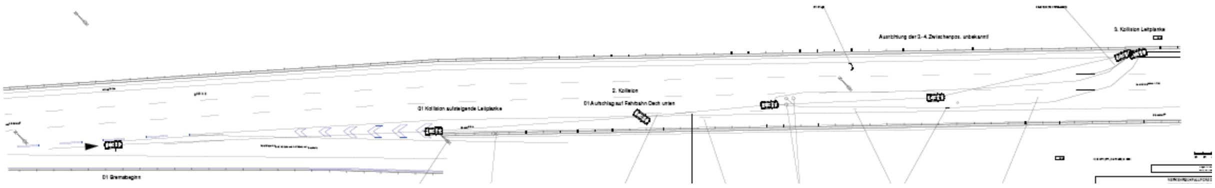

Figure 3: Technical reconstruction of accident site

Figure 4: Accident site

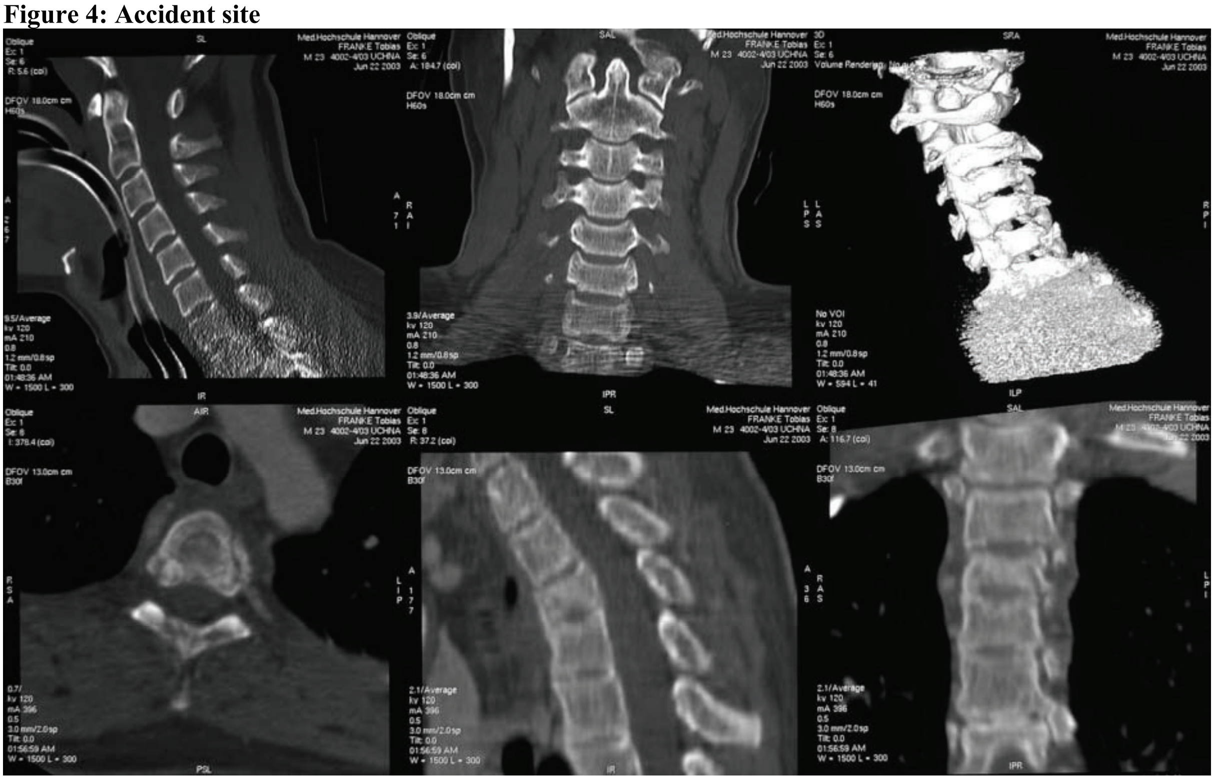

Figure 5: X-rays at admission

DISCUSSION

Crash mechanism

Significant injuries of the thoracolumbar spine typically occur in complex injury mechanisms like multiple hits or roll-over rather than in "simple" front collisions. These findings confirm data from Richards et al who found a low rate of 0.6% vertebral fractures in front collision below 60 kph by screening the data base of the National Automotive Sampling System (NASS)[7]. Still there were a number of compression fractures in front collisions below 20 kph. They compared these findings with data from crash-tests and found that axial forces in these crashes were well below forces which are found in lifting activities. In our data the mean delta-v was 40 kph which is approx. the double of what is found in car crashes without spinal injuries. Taking into account that most fractures occurred in multiple-hit-mechanisms, we conclude that the injury mechanism might be much more important than actual delta-v. This is supported by the finding that there is no clear correlation between fracture severity and delta-v on the one hand but there is an even higher proportion of multiple hits in the more severe fracture types.

Injury severity and associated injuries

In general, most fractures of the thoracolumbar spine are due to falls [8]. These patients usually present with single injuries. In contrast, almost all car passengers with vertebral fractures present with a number of additional injuries. Winslow et al found that passengers with significant injuries and fracture of the cervical spine were twice as likely to have fractures of the thoracolumbar spine as well [9]. This confirms our finding of an increased risk of additional vertebral fractures in those patients with fractures of the spine. This is even more apparent in passengers with fractures of the thoracic spine. Ball et al found up to 57% concomitant intraabdominal injuries with vertebral fractures in front collisions [10]. When comparing thoracic and lumbar fractures we find that only passengers with fractures of the lumbar spine but not those with injuries of the thoracic spine are older than passengers without vertebral fractures. This probably reflects a proportion of osteoporotic fractures which might easily occur in low-impact accidents and "simple" front collisions. Accordingly, we find a lower ISS in passengers with lumbar fractures and a higher proportion of front collisions.

The effect of safety belts

Earlier investigations at our department showed different fracture types according to the usage of safety belts. Unrestrained car occupants were more likely to sustain compression and chance fractures by an injury mechanism described as "forward and backward". Passengers with safety belts were more likely to show strain fractures of transversal processes due to the so-called "psoas effect" [11]. Safety belts used in this former study used to be mostly lap-belts only. Nowadays, three-point safety belts are mandatory in the EU. There has been a report about a series of four restrained car occupants with anterolateral wedge compression of a thoracolumbar vertebra with lateral compression occurring on the side opposite the restrained shoulder. The posterior elements were disrupted contralateral to the anterolateral body compression. The authors postulate a mechanism of injury, referred to as the „roll-out phenomenon" with flexion and rotation about the axis of the shoulder strap [12]. We were not able to show this phenomenon in our study but the question remains if 4-point fixation as used in motor sports might help to reduce the incidence of spine injuries in road traffic accidents. Airbag deployment was to rare to have a statistical influence in our study. Likewise, no difference could be shown in the study by Richards [7].

CONCLUSION

The overall risk for fractures of the spine in restrained front passengers is quite low, esp. for fractures of the thoracic and lumbar spine. Our data show clearly, that mainly complex injury mechanisms with multiple hits or roll-overs lead to fractures of the spine. Therefore the determination of the actual impact that leads to a spinal fracture or disruption remains difficult. Safety belts obviously play a major role in the prevention of injuries of the thoracolumbar spine. Car occupants frequently show severe additional injuries. The clinical management of polytraumatized victims of car crashes therefore has to include a thorough work-up of possible spine injuries, even if other injuries are more striking. Current protocols include CT scans of the complete spine in these patients.

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