K. Knobloch, S. Wagner, C. Haasper, C. Probst, C. Krettek, M. Richter
Trauma Department, Medical School Hannover, Germany

D. Otte
Accident Research Unit, Medical School Hannover, Germany

Sternal Fractures Occur Most Often in Old Cars to Seat-Belted Drivers without any Airbag Often with Concomitant Spinal Injuries – Clinical Findings and Technical Collision Parameters among 42.055 Crash Victims

Abstract

The incidence and treatment of sternal fractures among traffic accidents are of increasing importance to ensure best possible outcomes.

Analysis of technical indicators of the collision, preclinical and clinical data of patients with sternal fractures from 1985-2004 among 42,055 injured patients were assessed by an Accident Research Unit. Two time groups were categorized: 1985-1994 (A) vs. 1995-2004 (B).

267/42,055 patients (0.64%) suffered a sternal fracture. Regarding the vehicle type, the majority occurred after car accidents in 0.81% (251/31,183 pts), followed by 0.19% (5/2,633pts) driving motorbike, and 0.11% (4/3,258pts) driving a truck. 91% wore a safety belt. Only 13% of all passengers suffering a sternal fracture had an airbag on board (33/255 car/trucks), with an airbag malfunction in 18%. The steering column was deformed in 39%, the steering wheel in 36%. Cars in the recent years were significantly older (7.67±5 years (B) vs. 5.88±5 years (A), p=0.003). Cervical spine injuries are frequent (23% vs. 22%), followed by multiple rib fractures (14% vs. 12%) and lung injuries (12% vs. 11%). We found 9/146 (6%) and 3/121 patients (3%) with heart contusion among the 267 sternal fractures. MAIS was 2.56±1.3 vs. 2.62±1.3 (A vs. B, p=0.349). 18% of patients were polytraumatized, with 11.2% dying at the scene, 2.3% in the hospital.

Sternal fractures occur most often in old cars to seat-belted drivers often without any airbag. Severe multiple rib fractures and lung contusion are concomitant injuries in more than 10% each indicating the severity of the crash. Over a twenty-year period, the injury severity encountered was not different with 18% polytrauma patients suffering sternal fractures.

Introduction

Throughout the last decades, the rate of sternal fractures has increased due to the introduction of seat-belts [1] in cars and trucks as well as by further thorough clinical investigations in the emergency room using sternal sonography [2] and thoracic computertomography [3] (CT) after traffic accidents. The role of airbags in reducing thoracic injuries is still debated controversely [4, 5].

Among 200 sternal fractures [6] with predominant traffic accidents (83%), 179 sternal fractures were located in the corpus sterni, 21 fractures in the manubrium sterni, and 11 in the xiphoid process. Another study supported the predominant location of the sternum body (83%), followed by 11% manubrium sterni and 6% xiphoid fractures among 100 patients [7]. While 67% of these patients had isolated sternal fractures, one third had concomitant injuries. Rib fractures have been reported in 28% without any clarification regarding the number of ribs involved, cardiac injury as hemopericardium was encountered in 1%.

FOWLER [8] found that 43% of sternal fractures were associated with a spinal injury. Other reports are limited due to small sample groups, with one study of blunt trauma by HILLS [9] reporting that out of 27 patients with thoracic spine fractures, five had associated sternal fractures. BROOKES showed 4.8% incidence of thoracic spine fractures in patients with sternal fractures [10]. In a retrospective study between 1981 and 1987, JONES [11] discovered eight patients with indirect sternal fractures and concomitant fractures of the spine (5 thoracic and 3 lumbar).

However, the evidence regarding concomitant multiple rib fractures as well as lung contusion associated with sternal fractures is limited. Furthermore, to date no thorough information is available regarding the circumstances of collisions causing a sternal fracture in traffic accidents. A technical analysis of the accident scene and the vehicle are pending. We therefore performed a thorough analysis among 20 years of accident

research in a given regional area around Hannover in Germany with special emphasis regarding to technical accident analysis as well as to clinical information and outcome among 267 patients suffering a sternal fracture among 42,055 injured and documented patients from 1985-2004 in a rural area around Hannover, Germany.

Methods

In a statistical retrospective analysis of car collision files from January 1st, 1985 to December 31st, 2004, the incidence and mechanism of 267 sternal fractures among a total number of 42.055 injured patients involved in a vehicle accident were examined. Regarding the data used from this governmental database, local ethical committee agreed to use the data without the individual consent of each patient, all data were used anonymously. The accident files had been prepared by scientific teams of the Accident Research Unit, which is run by the government. The teams had been informed through police dispatch and quickly arrived at the accident scenes in their own squad vehicles.

Since 1972, this local traffic accident research unit has collected prospective data for all reported traffic accidents in the rural area of Hannover, Germany [12]. The Accident Research Unit is alarmed randomly on every third traffic accident with casualties regardless of the type of injury, number of injured patients or severity of injuries. In addition to technical indications and an evaluation of the damage to the car, the files also included medical records outlining the types and severity of the injuries to the occupants. Seat-belt use was determined by history or assessment of the injury pattern. The first medical institution providing care for the injured people documented the diagnosis and types of injury. Pictures of the vehicular collision scene and the inside and outside of the cars and the relevant radiographs were collected by the staff of the Accident Research Unit.

Through this database, we were able to reconstruct the injury mechanisms in detail. This reconstruction was performed by the staff of the Accident Research Unit under the direction of the technical author (D.O.). The injury severity was classified with the abbreviated injury scale (AIS). These classifications were performed by the staff of the Accident Research Unit. To estimate the relevance of the improvements of the passive car safety and any change over time, accidents occurring from January 1st, 1985 to December 31st, 1994 (Group I) and from January 1st, 1995 to December 31st, 2004 (Group II) were compared.

Statistics

The data is presented as median and range for continuous variables or number and percentages for dichotomous variables. Median values were displayed for the percent change of parameters of microcirculation. Univariate analysis of categorical data was carried out using the chi-square or Fisher exact tests. Univariate analysis of metrical data was carried out by one way ANOVA, Student´s t-test and Mann-Whitney-U-Test. Student´s t-test for paired-samples was used for parametric, ordinal and metrical variables of connected samples. The SPSS statistical software package 11.5 for Windows (SPSS Inc., Chicago, Ill, USA) was used for statistical analysis.

Results

42,055 injured patients were included in this study from 1985-2004, where technical and medical information was available for assessment. 267 patients suffered a sternal fracture, while 41,788 patients were injured in a traffic accident and assessed without a sternal fracture (0.64%). The distribution regarding the type of vehicle in sternal fractures is displayed in Table 1, demonstrating cars as the main vehicle involved in sternal fractures.

Type of vehicle	Total	No sternal fracture	Sternal fracture	% sternal fracture
Car	31,183	30,932	251	0.81%
Truck	3,258	3,524	4	0.11%
Motorbike	2,633	2,628	5	0.19%
Bicycle	4,971	4,965	6	0.12%
Others	10	9	1	10.00%
Total	42,055	41,788	267	0.64%

Table 1: Distribution of 42,055 injured patients assessed over a 20-year period (1985-2004) in the region of Hannover, Germany, regarding the vehicle type among sternal fractures

Safety-belt and airbag in patients suffering sternal fractures

91.2% of all patients wore a safety belt at the time of the accident. Only 13% of all passengers injured with a sternal fracture had an airbag on board (33/255 patients driving cars or trucks). Among those 33 patients with an airbag on board, a malfunction of the airbag was evident in 6/33 (18.2%). Side airbags at the top were only in 1% of the vehicle without any activation during the accidents at all. Due to the small sample size of only 33 cases with airbags on board, we did not attempt to determine any effect of time over the studied twenty-year period in this study.

Seating position of patients suffering sternal fractures

65.4% of all car passengers were seated at the driver's position, 26.7% at the front right position. 92.1% of all patients suffering a sternal fracture were therefore seated in the front row.

Crash vehicle characteristics

Cars in the recent years between 1995 and 2004 were significantly older than in between 1985 and 1994 (7.67±5 years (B) vs. 5.88±5 years (A), p=0.003) with patients suffering sternal fractures. The majority of crashes were head-on crashes into another vehicle, followed by crashes by leaving the road, crossing vehicle crashes and rear-end crashes, as indicated in Table 2.

Patients trapped in the vehicle suffering sternal fractures

Among the patients suffering a sternal fracture, we found 10% (26/250 car/truck patients) trapped in the car/truck at the scene needing technical rescue by the fire department.

Polytrauma and Glasgow coma scale at the scene among patients with sternal fractures

47/267 patients (17.6%) were classified as polytraumatized, where at least one or the combination of more injuries was supposed to be life threatening. Mean Glasgow coma scale (GCS) at the scene was 13.1±4: 85.1% (n=223) were GCS 11-15, 1.9% (n=5) were GCS 6-10, 13% (n=34) were GCS<5.

Concomitant injuries in 267 patients with sternal fractures

The major concomitant injury associated with sternal fractures were bruises of soft tissue with 84/146 cases (57.5%) in 1985-94 and 65/121 cases (53.7%) in 1995-2004 (Table 3). The second frequent concomitant injury to sternal fractures were spine injuries with 47/146 (32.2%) and 32/121 (26.5%), respectively. Regarding spine injuries, the cervical spine was most often involved (22.6% vs. 22.3%) with distortions predominantly. There was no change in the frequency of cervical spine injuries over the 20-year observation period. Injuries of the thoracic spine followed the cervical spine injuries without any change over time (9.6% vs. 8.3%), but thoracic spine injuries were almost all fractures. Lumbar spine injuries accounted for 4.8% and 1.7% as a concomitant injury to sternal fractures with lumbar fractures being often encountered.

Vehicle crased	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
Rear-end crash	23	17.9%	22	18.3%
Head-on crash	48	37.5%	44	36.6%
Crossing car crash	25	19.5%	20	16.7%
Crash w/o other car by leaving the road	28	21.8%	34	27.5%
By another way	4	3.1%	1	0.8%
Unknown	18		1	

Table 2: Crash circumstance among 267 sternal fractures suffering an accident over a 20-year period in the region of Hannover, Germany

Injury	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
Bruise of soft tissues	84	58%	65	54%
Brain injury	41	28%	22	18%
Multiple rib fracture	20	14%	15	12%
Injury of lungs	18	12%	13	11%
Injury of heart	9	6%	3	2%
Injury of spine overall	47	32%	32	26%
Injury of cervical spine	33	23%	27	22%
Injury of thoracic spine	14	10%	10	8%
Injury of lumbar spine	7	5%	2	2%

Table 3: Concomitant injuries among 267 sternal fractures in regard to the time periods 1985-94 and 1995-2004 in Hannover, Germany, among 42,055 injured patients

Following bruises and spinal injuries head injuries were found third as concomitant injury among the 267 sternal fractures (28% vs. 18%), followed by multiple rib fractures (13.7% vs. 12.4%) and lung injuries (12.3% vs. 10.7%). We found 9/146 patients (6.2%, 1985-94) and 3/121 patients (2.5%, 1995-2004) with myocardial contusions among the 267 sternal fractures.

Abbreviated injury scale (AIS)

Maximal abbreviated injury scale (MAIS) was at mean 2.56±1.3 in 1985-1994 and 2.62±1.3 from 1995-2004 (p=0.349). Mean AIS chest was 2.5±1.1 in 1985-94 vs. 2.5±1 in 1995-2004 without a statistical difference over time (p=0.451). The distribution was aS followed: AIS 0 none, AIS 1 5/146 patients (3.4%) vs. 3/121 patients (2.5%), AIS 2 109/146 patients (75.2%) vs. 89/121 patients (74.8%), AIS 3 12/146 patients (8.3%) vs. 6/121 (5%), AIS 4 6/146 patients (4.1%) vs. 13/121 patients (10.9%), AIS 5 4/146 patients (2.8%) vs. 4/121 patients (3.4%), AIS 6 9/146 patients (6.2%) vs. 4/121 patients (3.4%). Mean AIS for the head injury was 1.2±1.6 (1985-94) vs. 1.0±1.4 (1995-2004) without any statistical change over time (p=0.135). Distribution of head AIS was aS followed: AIS 0 72/146 patients (49.3%, 1985-94) vs. 65/121 patients (55.6%, 1995-2004), AIS 1 27/146 (18.5%) vs. 22/121 (18.8%), AIS 2 29/146 (19.9%) vs. 17/121 (14.5%), AIS 3 3/146 (2.1%) vs. 4/121 (3.4%), AIS 4 6/146 (4.1%) vs. 4/121 (3.4%), AIS 5 2/146 (1.4%) vs.2/121 (1.7%), and AIS 6 7/146 (4.8%) vs. 3/121 (2.6%).

AIS for the thorax/shoulder injury was on average 2.47±1.1. Categorized, 75% of all 267 patients suffering a sternal fracture were AIS 2 (Tables 4). AIS arms was 0.5±0.8 vs. 0.6±0.8 (p=0.312). 97/146 patients (66.9%, 1985-94) vs. 75/121 patients (62%, 1995-2004) were rated AIS arms 0, the highest scores were AIS 3 with 9/146 (6.2%, 1985-94) vs. 4/121 (3.3%, 1995-2004). AIS abdomen was 0.62±1.5 in 1985-94 and 0.29±1 in 1995-2004, which was significantly decreased over time (p=0.016). 81.4% (118/146 patients) vs. 89.5% (102/121) were AIS 0. While 12/146 (8.3%) were AIS 5 in 1985-94, no one was AIS 5 in 1995-2004.

Hemodynamics at admission in the emergency room

At hospital admission in the emergency room, mean systolic blood pressure was 130±29mmHg with a corresponding heart rate OF 89±8bpm. 89.5% had regular and normfrequent heart rate at ER admission, 5.7% had tachycardia, 2.6% (n=6) had asystole. At ER admission 5.6% were mechanically ventilated.

AIS chest/shoulder				
AIS chest / shoulder	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
0	0	0.0%	0	0.0%
1	5	3.4%	3	2.5%
2	109	75.2%	89	74.8%
3	12	8.3%	6	5.0%
4	6	4.1%	13	10.9%
5	4	2.8%	4	3.4%
6	9	6.2%	4	3.4%
unknown	1		2	
mean	2.5 ±1.1		2.5 ±1.1	
α=0.451				
AIS abdomen				
AIS abdomen	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
0	118	81.4%	102	89.5%
1	7	4.8%	2	1.8%
2	3	2.1%	5	4.4%
3	3	2.1%	1	0.9%
4	2	1.4%	3	2.6%
5	12	8.3%	0	0.0%
6	0	0.0%	1	0.9%
unknown	1		7	
mean	0.6 ±1.5		0.3 ±1	
α=0.016				
AIS head				
AIS head	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
0	72	49.3%	65	55.6%
1	27	18.5%	22	18.8%
2	29	19.9%	17	14.5%
3	3	2.1%	4	3.4%
4	6	4.1%	4	3.4%
5	2	1.4%	2	1.7%
6	7	4.8%	3	2.6%
unknown	0		4	
mean	1.2 ±1.6		1.0 ±1.4	
α=0.135				

Table 4: Abbreviated injury scale (AIS) for the chest, the abdomen and the head among 42,055 patients with 267 sternal fractures over a 20-year period in the region of Hannover, Germany

Procedures performed in the hospital

195/267 patients suffering a sternal fracture had no operation at all during the hospital stay (79.6%). 12.7% were operated within the first 24 hours of admission, 2% within the 2nd to the 7th hospital day.

Hospital stay and ICU stay

Hospital stay was on average 9.7±16.5 days, with 18.7% being on an outpatient basis (n=29), 11% admitted for 48 hours (n=17), 22.6% admitted from 3 to 5 days (n=35), 25.8% for 6 to 10 days (n=40), and 21.9% for more than 10 days (n=34). Among 121 patients, 5% were up to 48h admitted to the ICU (n=6), 4.1% 3 to 5 days (n=5), 1.7% for 6 to 10 days (n=2) and 5% were longer than 10 days on the ICU (n=6, Table 5).

duration	1985-1994		1995-2004	
	n (∑=146)	percentage of known cases	n (∑=121)	percentage of known cases
0 days	83	88%	20	71%
< 3 days	3	3%	3	11%
3 - 5 days	2	2%	3	11%
6 - 10 days	2	2%	0	0%
> 10 days	4	4%	2	7%
Unknown	52		93	
Mean	1.7 ±7.4		2.7 ±8.1	
α=0.280				

Table 5: Days on the intensive care unit among 267 sternal fractures among 42,055 injured patients over a 20-year period

Vertebra	Total		Fracture		Distorsion		Others	
	1985-1994	1995-2004	1985-1994	1995-2004	1985-1994	1995-2004	1985-1994	1995-2004
C1								
C2		2		2				
C3		2		2				
C4								
C5	2	1	1	1			1	
C6	5		2		2		1	
C7								
Cervical spine w/o further details	35	26		1	35	22		3
TH1	3		3					
TH2								
TH3		1		1				
TH4		1		1				
TH5	2	2	2	2				
TH6	2	2	2	2				
TH7	1	2	1	2				
TH8	2	1	2	1				
TH9	1	1	1	1				
TH10	1		1					
TH11								
TH12								
Thoracic spine w/o further details	4	5		2	4	2		1
L1	1		1					
L2								
L3	1		1					
L4	1		1					
L5		1		1				
Lumbal w/o further details	6	1	2		2	1	2	
Total	67	48	20	19	37	22	4	4
Note: Every count represents an injury of the vertebra shown in the first column. As one person may have more than one injured vertebra, there is no correlation given between the number of injured vertebras in this table and the number of persons having an injury at their spine								

Table 6: Distribution of concomitant spinal injuries in 267 sternal fractures

	ΔV mean 1985-1994 [km/h]	ΔV mean 1995-2004 [km/h]	ΔV mean total [km/h]
no polytrauma	37,94 ± 15,40	36,75 ± 16,81	37,43 ± 16,03
polytrauma	62,77 ± 15,78	58,00 ± 16,73	60,07 ± 16,49
overall	40,60 ± 17,25	40,44 ± 18,62	40,53 ± 17,88
p [t-test]	0,00000014	0,0000045	0,0000000000076
Correlation between survival andΔV by 219 victims of car-crashes			
	ΔV mean 1985-1994 [km/h]	ΔV mean 1995-2004 [km/h]	ΔV mean total [km/h]
survived	39,10 ± 16,02	37,07 ± 16,90	38,24 ± 16,43
died	65,14 ± 17,98	59,07 ± 16,63	61,00 ± 17,30
overall	40,60 ± 17,25	40,44 ± 18,62	40,53 ± 17,88
p [t-test]	0,000037	0,0000064	0,0000000024

Table 7: Correlation among patients suffering a polytrauma or not and ΔV among 219 victims of car crashes

Survival

230/267 patients (86.1%) suffering sternal fractures survived the accident and the hospital, 30/267 patients (11.2%) died at the scene. One patient with a sternal fracture died on the transport to the hospital, 6 further patients died within the hospital (2.3%). Among those patients dying at the scene, 43% had fatal head injuries, 32% had fatal thoracic injuries (n=37).

Discussion

Sternal fractures occur most often in old cars to seat-belted drivers. Severe multiple rib fractures and lung contusion are concomitant injuries in more than 10% indicating the severity of the crash. 18% of all patients suffering a sternal fracture were classified as polytrauma patients with an overall survival rate of 86.1%. While 11.2% die at the scene, we found a 30-day mortality of 2.3%.

These data reveal that sternal fractures often are associated with concomitant significant injuries and a remarkable mortality rate. The high mortality rate found in our study may indicate that a sternal fracture could be interpreted as a marker lesion for a severe trauma. A recent autopsy study [13] after fatal falls from height found sternal fractures to be present in 25 cases involving heart injuries (76%) with 16% of these with multiple sternal fractures, and in only 5 cases without heart injuries (18%). It was concluded that the presence of severe sternal fractures can be used as an indicator of possible cardiac trauma, which is supported by data of De WAELE et al. [14] as well as by our high overall mortality rate.

Concomitant injuries

The major concomitant injuries associated with sternal fractures in our study among 42.055 patients were bruises of soft tissue without any significant change over time within the 20 years of observation. The second frequent concomitant injury associated with sternal fractures were spine injuries in one-third of all cases, with cervical whiplash injuries dominating, followed by thoracic and lumbar spine fractures. Others reported a lower rate of whiplash injury (3%, ATHANASSIADI et al, 15.5%, von GARREL et al.) and fractures of the spine (4%, ATHANASSIADI et al., 13%, von GARREL et al.) with predominant thoracic spine fractures.

Concomitant spinal injuries are evident in case of sternal fractures with certain implications for the spinal stability. In a cadaver study [15] to determine the amount of stability the rib cage imparts to the thoracic spine and to show the amount of stability lost by a sternal fracture it was recently found that the rib cage and sternum provide 40% of the stability of the thoracic spine in flexion-extension, 35% of the stability in lateral bending, and 31% in axial rotation. An indirect flexion-compression type of sternal fracture decreases the stability of the thoracic spine by 42% in flexion/extension, 22% in lateral bending, and 15% in axial rotation. A sternal fracture decreases therefore the stability of the thorax dramatically, thus a sternal fracture associated with a thoracic spine injury or a multiple rib fracture could be an unstable combination of injuries after accidents, as seen in a case of multiple thoracic spine wedge fractures and sternal fracture [16]. Multiple rib fractures have been reported in 10.5% by von GARREL, which have somehow the same occurrence rate than observed by us (1985-94 13.7%, 1995-2004 12.4%). Regarding the 11.2% of patients dying at the scene with a sternal fracture, 39.1% had fatal thoracic injuries, 13% fatal head injuries, 8.7% fatal abdominal injuries, 34.8% died because of a combination as polytraumtized. Among 99 patients with sternal fractures, no significant increase of aortic ruptures was reported by STURM et al. [17]. However, currently no data regarding these preclinical dead patients have been reported after car crashes yet.

Treatment

Sternal fractures are most often treated conservatively with reasonable results regarding complete bony union and pain control [18]. Surgery is indicated in case of severe displacement, impairment due to severe pain limiting ventilation or in case of non-union of the sternum due to a pseudarthrosis sterni [19], often in a delayed fashion. Different operative techniques have been reported only in small series yet, such as circumferential wiring as in cardiac surgery or plates [20]. Based on our results one cannot derive a straight and strong recommendation for a surgical approach to stabilize any sternal fracture occurring in traffic accidents. However, given the significant loss of thoracic spine stability after a sternal fracture, which itself is often associated with spinal injuries in one-third of the cases, the restoration of the thoracic cage supports the goal of sternal and spinal repair. Future outcome studies should focus on this issue in more detail.

Limitations

Certain limitations have to be mentioned. The data collection was done by special trained personnel of the Accident Research Unit. Nevertheless, the data collected by the specialized personnel might be influenced by the fact that patients were transported and treated by different physicians in various hospitals in the Hannover region. It has been shown that diagnosis can be made best with computertomography and ultrasound rather that conventional x-ray, but we cannot exclude from our data that patients might be undiagnosed regarding a sternal fracture. Furthermore, the important question of preclinical rescue time in case of polytraumatized patients might affect outcome, which has to be taken into account regarding the mortality rate. Based on the fact that the patients were transferred in different hospitals, the indications for sternal and/or spinal surgery might vary to some degree. However, this study among a patient group of 42,055 patients over a 20-year period adds information regarding the effect of evolutional aspects of the vehicles as well as the distribution of concomitant injuries.

Conclusion

Sternal fractures occur most often in old cars to seat-belted drivers in frontal crashes. Severe multiple rib fractures and lung contusion are concomitant injuries each in more than 10% indicating the severity of the car crash. Concomitant spinal injuries, occurring in one-third of all cases, may deteriorate thoracic stability significantly with further emphasis on a thorough clinical examination in case of a sternal fracture.

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