The epidemiology of vertebral fractures in the adult German population and an analysis of the socio-economic burden: Trends from 2009 to 2019.

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Abstract

Objective

To present nationwide rates of hospitalized patients with vertebral fractures over one decade and a comprehensive analysis of treatment characteristics and incurred costs in 2019.

Methods

Trends in the incidence were quantified based on annual ICD-10 diagnosis codes from all German medical facilities between 2009 and 2019, provided by the Federal Statistical Office (Destatis). The ICD-10 Codes "S12.0-2; S22.0; S32.0; S32.1-2" were evaluated. The relative change from 2009 through 2019 was determined and data on the secondary diagnoses, OPS-codes, treatment on an intensive care unit (ICU), in-hospital mortality, proportion of G-DRGs and cumulative costs were assessed based on the Institute for the Hospital Remuneration System (InEK) data for 2019.

Results

The incidence increased by 45.6% between 2009 and 2019 to 150.7 per 100,000 inhabitants. Lumbar spine fractures showed the highest incidence in 2019 with 70.5/100,000 inhabitants (46.8% of all vertebral fractures). The highest increases were seen in subaxial cervical fractures (+121.2%) and sacral fractures (+306.6%). 63.7% of vertebral fractures in 2019 were diagnosed in women and 69.0% in patients ages 70 years or older. Osteoporosis was documented in 17.9% of cases. In 10.1% of cases an ICU treatment was documented. The in-hospital mortality was 2.0%. The most frequently applied G-DRG code was I68D (33.3%). The total costs in 2019 were €589,205,715.

Conclusion

The evaluation of 955,091 vertebral fractures showed a sharp increase in the incidence rate with incurred cost of approximately €590 million in 2019. The age and gender distribution suggests an increase in the diagnosis of osteoporotic fractures.

Introduction

Injuries of the spine make up a relevant share in trauma patients and thoracolumbar fractures rank among the severest injuries of the human skeleton^{1,2}. Around 2-3% of all accident victims have an injury to the cervical spine^{3,4}. The most common cause of traumatic vertebral injury are traffic accidents, followed by falls from low and higher heights (>2m)^{5,6}. Injuries to the spine have been reported to be associated with spinal cord injuries (SCI) in up to 20% of cases, with this occurring more frequently in injuries to the lower cervical spine and upper to middle thoracic spine⁶. Further, it is reported that the quality of life of patients suffering thoracolumbar fractures is compromised, mostly independent from the treatment modalities, but seems to be determined by the severity of the injury⁷⁻⁹. Although many individuals who experience a vertebral fracture can be managed on an outpatient basis, a considerable number of patients must be hospitalized, resulting in substantial costs. However, current knowledge about the epidemiology of vertebral fractures is largely based on relatively small populations and only a few nation-wide analyses exist^{2,10}. The influence of geriatric injuries and osteoporotic spontaneous fractures on the prevalence of vertebral fractures is not sufficiently clarified. It is recognized that vertebral fractures are one of the most common skeletal fractures associated with low bone mass and other causes of skeletal fragility¹¹. Nation-specific epidemiological analyses are essential as incidences, the hospital supply structure and reimbursement systems vary country-wise: Discharge rates of hospitalised patients with vertebral fractures can vary by more than 4-fold between European countries¹². Detailed analyses of epidemiologic data, current treatment maxims and cost incurred are a valuable resource for stakeholders in the health systems, which can assist decision making of health services and give insights into effects of current prevention and therapeutic strategies.

Therefore, the aim of this study was (1) to determine the development of the nationwide incidence of vertebral fractures as a function of age, gender and anatomical localization for Germany between 2009 through 2019 (2) to provide a comprehensive overview of the treatment characteristics based on documented OPS-codes, secondary diseases, in-hospital mortality rates and intensive care unit (ICU) treatments. (3) Lastly annual costs of vertebral fractures were to be evaluated for the German health care insurance system based on a G-DRG code analysis.

Results

(1) The development of the nationwide incidence of vertebral fractures from 2009 to 2019.

In total 955,091 fractures of the spine were registered between 2009 and 2019. In comparison to the year 2009, in which 70,235 fractures were listed, the incidence increased by 45.6% from 105.8/100,000 inhabitants to 150.7/100,000 inhabitants (Figure 1). Of the overall vertebral fractures more occurred in women (57%) and 69.0% were calculated for patients aged 70 years or older (Table 1).

Table 1: Development of fracture incidence from 2009 to 2019. Male/female ratio and ratio aged <70 years and ≥70 years. Changes were calculated relative to the incidence in 2009.

Year	Total number	Incidence per 100,000 inhabitants	Change relative to 2009 [%]	Ratio male/female	Ratio aged <70years/ ≥70years
2009	70,235	105.8	0.00	0.62	0.71
2010	74,588	112.1	6.20	0.60	0.67
2011	78,065	119.4	11.15	0.61	0.61
2012	79,426	121.0	13.09	0.60	0.57
2013	83,992	127.4	19.59	0.60	0.56
2014	86,865	130.3	23.68	0.60	0.52
2015	89,221	133.0	27.03	0.61	0.51
2016	94,706	140.4	34.84	0.58	0.49
2017	96,648	143.1	37.61	0.58	0.48
2018	99,060	146.3	41.04	0.59	0.48
2019	102,285	150.7	45.63	0.57	0.45

Figure 1 provides an overview of the distributions of vertebral fractures by anatomical location comparing data from 2009 and 2019. Fractures of the lumbar spine remain the most common vertebral fractures with a share of 56.0% in 2009 and 46.8% in 2019, followed by fractures of the thoracic spine (30.2% in 2009 and 27.4% in 2019). Whereas sacro-coccygeal fractures made up for 5.8% of all vertebral fractures in 2009 their proportion raised to 14.9% in 2019.

The most frequently occurring fractures in 2019 were at the lumbar spine with 47,874 registered cases and an incidence of 70.5 cases per 100,000 inhabitants. The most frequently documented fractures were L1 fractures in 21.9% of all cases. Followed by Th11 and Th12 fractures (cumulative 16.4%) and sacrum fractures (14.3%). Further, in 8.9% of all cases a L1 fracture was documented as secondary diagnosis. Lumbar spine fractures mainly affected women (61.7%). Here, 38.8% of all lumbar spine fractures occurred in female patients in the age group 80-89 years, 26.4% were registered in the age group 70-79 years and 9.7% involved female patients aged 90 years or older (Figure 2D). Men in the age group 80-89 years suffered from lumbar spine fractures in 28.4% of all cases (Figure 2D). Second, fractures of the thoracic spine were common with 28,057 hospitalized cases in 2019 and an incidence of 41.3 per 100,000 inhabitants. Of all the cases 63.6% were female and 36.4% male. Highest incidences were registered in women aged 80-89 years (38.6%), 70-79 years (25.9%) and female patients aged 60-69 years (11.5%), whereas 23.6% of all fractures occurred in men aged 80-89 years and 20.0% in men aged 70-79 (Figure 2C). These were followed by fractures of the sacrum and coccyx, which together affected 14,748 patients with an incidence of 21.7 cases per 100,000 inhabitants in 2019. More women than men suffered from fractures at this site (81.9% vs. 18.1%), whereby female patients in the age group 80-89 years comprised the largest cohort (45.4%), followed by women aged 80-89 years (30.2%) and older than 90 years (15.3%). For male patients most of the cases occurred in the age group 80-89 years with 30.2% of all fractures (Figure 2E). From all sacro-coccygeal fractures, when not differed by sex 78.8% of fractures were documented in patients 70 years or older.

With 5,593 cases and an incidence of 8.2 per 100,000 inhabitants, fractures of the axis were the fourth most common fractures of the spine in 2019, mainly affecting female patients (57.8%). Together with fractures of the atlas they made up for 6.8% of all vertebral fractures in 2019 (Figure 1). Again, most Atlas & Axis fractures were seen in females (56.6%) and of all Atlas & Axis fractures 67.0% were seen in patients older than 70 years. Most cases of Atlas & Axis fractures in females were listed for the increment 80-89 years (45.4%), 70-79 years (21.0%) and in patients older than 90 years (21.0%) (Figure 2A). In male patients most cases were documented in patients aged 80-89 years (37.8%), 70-79 years (23.7%) and 60-69 years (13.6%). In 2019, fractures of the subaxial cervical fractures made up for 6.8% of all registered spine fractures of hospitalized patients. 4,201 fracture cases were documented, resulting in an incidence of 6.2 per 100,000 inhabitants. Only in subaxial cervical spine fractures more patients were male (66.0%) than in female patients (34.0%). The majority of subaxial spine fractures in male patients was seen at the increment 80-89 years (24.7%), 70-79 years (18.6%) and 50-59 years (15.7%). In females most fractures were documented in patients aged 80-89 years (32.3%), 70-79 years (20.3%) and 60-69 years (10.9%) (Figure 2B).

Comparing the fracture incidences by location of the year 2009 to the year 2019 (Table 2), the highest increase was found in fractures of the sacrum (+306.6%) and at the subaxial cervical spine (+121.2%), followed by atlas (+106.4%) and axis fractures (+82.5%). Also, numbers considerable heightened for thoracic spine fractures (+32.2%) and lumbar spine fractures (+21.7%). There was only a slight increase of the

incidence coccygeal fractures (+4.4%). A detailed analysis of the incidences and total numbers of vertebral fractures from 2009 to 2019 broken down according to the anatomical location, sex and age is provided in

Table 2
Fracture incidence divided by anatomical localization in 2019

Anatomical localization	Total number	Incidence per 100,000 inhabitants	2019 relative to 2009 [%]	Ratio male/female	Ratio aged <70years/ ≥70years
Atlas (C1)	1385	2.0	+ 106.4	0.93	0.31
Axis (C2)	5593	8.2	+ 82.5	0.73	0.23
Subaxial cervical spine	4201	6.2	+ 121.2	1.94	0.87
Thoracic spine	28057	41.3	+ 32.2	0.57	0.54
Lumbar spine	47874	70.5	+ 21.7	0.62	0.47
Sacrum	14748	21.7	+ 306.6	0.22	0.26
Coccyx	427	0.6	+ 4.4	0.33	0.78

(2) Secondary diagnoses, OPS codes and mortality of vertebral fractures in 2019.

In 2019, a total of 1,016,897 secondary diagnoses were documented, which equates to 9.7 documentations per case at average. N= 6,282 different ICD-10 codes for secondary diagnoses were used. In 18,773 (17.9%) cases a form of osteoporosis (M80.- and M81.-) was documented as secondary diagnosis. Type II diabetes mellitus (E11.-) was documented as secondary diagnosis in 17,006 (16.2%) cases. Summed up secondary diagnoses of malignant neoplasms were documented in 2.5% of cases. In 61,306 (58.4%) cases a concomitant vertebral fracture was documented as secondary diagnosis, most frequently located at the lumbar spine (28.9%). The most common secondary diagnoses, concomitant vertebral fractures and SCIs are listed in Table 3. In sum, 1,148 (1.1%) cases with SCIs, mainly at the cervical spine (0.5% of all fractures and 47.1% of all cases).

Table 3: Most common secondary diagnoses in vertebral fracture: Total numbers and share of all cases in 2019

	Secondary diagnosis	ICD-10 code	[n]	Percentage of all cases
Secondary disease	Hypertension	I10.-	55,387	52.8%
	Osteoporosis	M80.-; M81.-	18,773	17.9%
	Atrial fibrillation	I48.-	18,238	17.4%
	Type II diabetes	E11.-	17,006	16.2%
	Chronic kidney disease	N18.1-; N19	15,876	15.1%
	Congestive heart failure	I50.-	13,243	12.6%
	Hypokalemia	E87.6	12,892	12.3%
	Coronary arterial disease	I25.0; I25.10-19	10,610	10.1%
Concomitant vertebral fractures	Axis	S12.0	1,025	1.0%
	Atlas	S12.1	2,372	2.3%
	Subaxial cervical spine	S12.21-.25; S12.7	4,664	4.4%
	Thoracic spine	S22.-	18,420	17.5%
	Lumbar spine	S32.-	30,293	28.9%
	Sacrum	S32.1	4,532	4.3%
SCI	Cervical spine	S14.10-13; S14.70-77	541	0.5%
	Thoracic spine	S24.10-12; S24.70-77	412	0.4%
	Lumbar spine	S34.10-11; S34.70-75	195	0.2%

The use of 1,833 different OPS codes resulted in the documentation of N=493,043 OPS codes in 2019, which equates 5.0 codes per case at average. The analysis of OPS-codes of all documented cases of vertebral fractures showed a total number of approaches to the spine of 27,314 (26.1% of cases; Table 4). A rate of instrumentation procedures (5-83b.-) of 21.3% was documented. A kyphoplasty (5-839.a0-3) was conducted in 15.2% of cases, whereas a vertebroplasty was documented in 1.6% of cases. In 4.7% of cases screws were augmented. An autograft was used more often (2.8% of cases) than an allograft (1.7%) of cases. In 60.5% of cases a native computed tomography (CT) of the spine (3-203; 47.7%) or the pelvis (3-206; 12.8%) was documented. Native Magnet-resonance imaging (MRI) of the

Table 4: Frequencies and percentages of documented procedures according the OPS of vertebral fracture cases in 2019

Procedures	OPS code	[n]	Percentage of all cases
Approach to the cervical spine	5-030.-	4,890	4.7%
Approach to the thoracic spine	5-031.-	8,671	8.3%
Approach to the lumbar spine	5-032.-	13,753	13.1%
Instrumentation	5-83b.-	22,330	21.3%
Kyphoplasty	5-839.a0-3	15,904	15.2%
Fusion surgery	5-836.-	6,479	6.2%
Screw augmentation	5-83w.0	4,882	4.7%
Implant removal	5-839.0	4,165	4.0%
Use of autograft	5-835.9	2,947	2.8%
Vertebral canal decompression	5-033.0; 5-839.60-63	2,260	2.7%
Vertebral body replacement	5-837.-	2,343	2.2%
Use of allograft	5-835.a-x	1,801	1.7%
Vertebroplasty	5-839.9-5	1,714	1.6%

The overall in-hospital mortality rate associated with vertebral fractures was 2.0%. The highest mortality rate (6.7%) was seen in cases of patients with Atlas & Axis fractures. Similar, cases with Atlas & Axis fractures were most associated with a treatment on an ICU (27.9% of cases). Overall, in 10.1% of cases patients received ICU treatment. Detailed numbers on in-hospital deaths and treatment on an ICU are displayed in Table 5.

(3) The economic burden of vertebral fractures for inpatient cases based on a G-DRG analysis in 2019.

Considering all vertebral fractures, the mean hospital stay was 10.7 ± 9.6 days. In cases with sacrum fractures the longest mean hospital stay (13.9 ± 9.8 days per case) was documented. At average in 16.8% of all cases high clinical complexity levels (PCCL ≥ 3) were seen. In patients with Atlas & Axis fractures 24.4% of cases were classified PCCL ≥ 3 , in patients with subaxial cervical fractures 24.7% and in patients with fractures of the sacrum 28.8%. Table 6 provides an overview of the mean hospital stay and the proportion of cases according to the PCCL for vertebral fractures.

The most frequently used G-DRG code in cases with vertebral fractures in 2019 was I68D (Diseases and injuries of the spine not treated surgically) in 33.3% of all cases. Second common was I41Z (Geriatric early rehabilitation and complex treatment for diseases and disorders of the musculoskeletal system and connective tissue) in 10.3% of the cases and third I09I (Specific operations on the spine without complicating factors) in 8.6% of the cases. A detailed list of the 50 most used DRG codes (in 98.9% of cases, only codes used in at least 0.05% of cases were considered), costs per case and their share of overall costs is provided in the supplementary material (Supplementary material 3).

The cost per case of the G-DRG codes that were analyzed ranged from $\text{€}719 \pm 262$ (I68E: Diseases and injuries in the spine not treated surgically, one occupancy day) to $\text{€}67,782 \pm 16,714$ (A09B: Ventilation > 499 hours or > 249 hours with intensive complex treatment). By multiplication of the number of cases with the respective average cost per case according to the used G-DRG code the approximately costs per G-DRG code were calculated: Summed up, in 2019 total costs of $\text{€}589,205,715$ were produced by the treatment of 103,773 inpatients with vertebral fractures (98.9% of all cases in 2019). This gives a mean cost of $\text{€}5,612$ per case. The DRG code accounting for the largest share of overall costs was I09F: Mean costs per case: $\text{€} 10,160.00 \pm 3,169.00$; 13.4% of overall costs. Second was I41Z: Mean costs per case: $\text{€} 5,878.00 \pm 1,317.00$; 10.8% of overall costs. Third ranked I68D: Mean costs per case: $\text{€} 1,708.00 \pm 636.00$; 10.2% of overall costs. 40.7% of the total costs are attributable to G-DRG codes used in each <3.0% of all vertebral fracture cases (n=41 different G-DRG codes, supplementary material 3). Table 7 lists the cost per case and the share of total costs of the G-DRG codes in 2019 without cases accounting for <3.0% of cases. Summing up cases with applied codes for non-surgical treatment of vertebral disorders and injuries (I68A-E) results in 51,724 cases (49.3%). These codes accounted for $\text{€}108,066,426$ representing 18.3% of the overall costs. The entirety of cases in which codes for specific surgeries of the spine (I09A-I) were applied consisted of 27,381 (26.1%) cases but was accountable for 44.4% of the overall costs of the in-hospital treatment of vertebral fractures in 2019 ($\text{€}261,532,171$).

Table 5: Percentages of in-hospital deaths and cases with ICU treatment depending on the anatomical location of the fracture in 2019

	Atlas & Axis		Subaxial cervical spine		Thoracic spine		Lumbar spine		Sacrum	
	n	%	n	%	n	%	n	%	n	%
Number of in-hospital deaths	475	6.7	207	4.7	486	1.6	655	1.3	253	1.7
Cases with ICU treatment	1972	27.9	198	4.5	3157	10.7	4026	8.2	1243	8.3

Table 6: Mean hospital stay and distribution of the PCCL scoring depending on the anatomical location of vertebral fractures in 2019

	All vertebral fractures		Atlas & Axis		Subaxial cervical spine		Thoracic spine		Lumbar spine		Sacrum	
Mean hospital stay [d]	10.7		10.8		10.6		10.1		10.3		13.0	
Standard deviation	9.6		11.2		13.4		9.3		9.0		9.8	
PCCL	0	58.4%	50.3%		47.1%		61.4%		67.0%		31.6%	
	1	14.1%	13.7%		16.7%		13.0%		12.1%		22.4%	
	2	10.6%	11.5%		11.6%		9.9%		8.8%		17.2%	
	3	10.4%	13.7%		12.8%		9.3%		7.9%		18.2%	
	4	5.1%	7.8%		8.7%		4.9%		3.5%		8.5%	
	5	1.2%	2.5%		2.9%		1.3%		0.7%		1.9%	
	6	0.1%	0.4%		0.3%		0.1%		0.1%		0.2%	

Table 7: Overview of the codes that each represent more than 3.0% of the cases.
Sorting according to frequency of use in 2019.

G-DRG code	Original german description	English summary	Cases [n]	Share of cases	Mean Cost per case [€]	Standard [€] deviation	Overall costs [€]	Share of overall costs
I68D	Nicht operativ behandelte Erkrankungen und Verletzungen WS, mehr als ein Belegungstag oder andere Femurfraktur, außer bei Diszitis oder infektiöser Spondylopathie, ohne Kreuzbeinfraktur, ohne best. mäßig aufw., aufw. od. hochaufw. Beh.	Non-surgically treated disorders and injuries of the spine, more than one day of occupancy or other femur fracture, except for discitis infectious spondylopathy, without sacral fracture, without specific moderately complex, complex or highly complex treatments.	35,000	33.3%	1,708	636	59,780,000	10.1%
I41Z	Geriatrische frührehabilitative Komplexbehandlung bei Krankheiten und Störungen an Muskel-Skelett-System und Bindegewebe	Geriatric early rehabilitation complex treatment for disorders and disorders of the musculoskeletal system and connective tissue	10,825	10.3%	5,878	1,317	63,629,350	10.8%
I09I	Bestimmte Eingriffe an der Wirbelsäule ohne komplizierende Faktoren	Specific surgery of the spine without complicating factors	9,050	8.6%	5,180	1,642	46,879,000	8.0%
I09F	Best. Eingriffe WS und best. kompl. Faktoren od. best. andere Eingriffe WS mit best. anderen kompl. Faktoren od. Alter kl. 16 J., oh. Eingriffe ZNS, oh. transpleuraler Zugang BWS, oh. best. langstreckige Spondylodese/Osteosynthese, oh. Diszitis	Specific surgery of the spine and specific complicating factors or specific other spinal procedures with specific other complicating factors or age less than 16 years, without central nervous system procedures, without transpleural access to the thoracic spine, without specific long spondylodesis/osteosynthesis, without discitis	7,785	7.4%	10,160	3,169	79,095,600	13.4%
I68C	Nicht operativ behandelte Erkrankungen und Verletzungen WS, > 1 BT od. and. Femurfraktur, bei Para- / Tetraplegie od. mit auß. schw. CC od. schw. CC od, Alter > 65 J., oh. kompl. Diagn. od. Kreuzbeinfraktur od. best. mäßig aufw., aufw. od. hochaufw. Beh.	Non-surgically treated disorders and injuries of the spine, > 1 day of occupancy or other femur fracture, in case of para- / tetraplegia or with extremely severe CC or severe CC or, age > 65 y., without complicating diagnosis or sacral fracture or specific moderately complex, complex or highly complex treatment.	7,190	6.8%	3,297	1,604	23,705,430	4.0%
I68E	Nicht operativ behandelte Erkrankungen und Verletzungen im Wirbelsäulenbereich, ein Belegungstag	Disorders and injuries in the spine not treated non-surgically, one occupancy day	5,069	4.8%	719	262	3,644,611	0.6%
I68B	Nicht operativ behandelte Erkrankungen und Verletzungen im Wirbelsäulenbereich, mehr als 1 BT, mit auß. schw. oder schw. CC od. bei Para- / Tetraplegie, mit kompl. Diagn. oder ohne auß. schw. oder schw. CC, ohne Para- / Tetraplegie bei Diszitis	Non-surgically treated disorders and injuries in the spinal region, > 1 day of occupancy, with extremely severe or severe CC or with para- / tetraplegia, with complicating diagnoses or without extremely severe or severe CC, without para- / tetraplegia with discectomy	4,465	4.3%	4,689	2,334	20,936,385	3.6%
I09E	Bestimmte Eingriffe an der Wirbelsäule und best. komplizierende Faktoren oder best. Eingriffe an der WS mit best. anderen kompl. Faktoren und Eingriffe ZNS oder transpleuraler Zugang BWS oder best. langstreckige Spondylodese/Osteosynthese oder Diszitis	Specific surgery of the spine and specific complicating factors or specific surgeries of the spine with specific other complicating factors and operations of the central nerve system or transpleural access to the thoracic spine or specific long spinal fusion / osteosynthesis or discitis	3,925	3.7%	13,194	3,892	51,786,450	8.8%
Other (each < 3.0% of overall cases)			20,464	19.5%	18,441		239,748,889	40.7%

Discussion

In this cross-sectional study, the development of vertebral fracture incidence was determined as a function of age, gender, and differentiated by anatomical locations. An outstanding characteristic is that the analysis is based on registry data consisting of ICD-10 diagnosis codes from all German medical institutions showing the development of fracture rates over ten years. Additionally, nationwide data on secondary diagnoses, procedures (based on OPS-codes), and the G-DRG distribution were assessed based on the InEK data and report browsers for the year 2019. Whereas studies relying on data from single hospitals may yield skewed results, the findings presented here are based on nationwide reports from the largest country of the European Union.

In 2019, a total of 102,285 fractures were registered depicting an increase by 45.6% since 2009. The incidence of all vertebral fractures was 151 per 100,00 inhabitants. We recently showed, that fractures of the thoracic and of the lumbar spine are among the ten most common fractures in Germany in 2019¹³. We demonstrated that most fractures can be found in the elderly population: The ratio of documented fracture cases in patients aged younger than 70 years over patients aged 70 years or older was 0.45. This indicates, that more than twice as many vertebral fractures are seen in the population older than 70 years. Further, more females than males suffered from vertebral fractures (ratio male/female = 0.57). In accordance with the literature the most common locations of fractures were the lumbar and thoracic spine with L1 being the most commonly affected vertebral body in 21.9% of all cases^{14,15}. Similar to our findings Blecher et al. reported an overall increase of vertebral fractures of 64% between 2003 and 2017 in a longitudinal trend analysis of discharged patient state database¹⁶. They also underlined the uptrend in the vertebral fractures of the elderly and found the highest increase in cervical spine fractures (+123%)¹⁶. Den Ouden et al. reported on an increasing amount of vertebral fractures in a level 1 trauma center in a 10 year period¹⁷. Consistent with our results they found a larger increase in amount of spine fractures in patients over 65 years of age compared with younger patients. In their cohort of exclusively traumatic vertebral fracture patients, 40.8% were female and 59.2% were male, with a mean age of 52.0 years and most fractures occurred at the lumbar spine¹⁷. In a nationwide analysis of traumatic vertebral fractures in the Netherlands from 2010 to 2017 Smits et al. showed an incidence of vertebral fractures of 24.0 per 100,000 inhabitants in 2017². The currently presented data consist of the totality of documented hospitalized cases with vertebral fractures, including elderly patients and cases suffering minor trauma. The age and gender distribution of the current study population underlies this fact. The essential role of insufficiency fractures can be most obviously seen in the increase of the incidence of sacral fractures by 307% compared to 2009. Vertebral fractures are a hallmark of osteoporosis. They represent the most frequent osteoporotic fracture¹⁸. An aging EU population, especially in the age group over 80 years where the incidence of osteoporotic fractures is greatest, is expected to increase the incidence of osteoporosis and associated fractures. The number of prevalent vertebral fractures is expected to rise from 23.7 million in 2000 to 37.3 million by 2050¹¹. However, it must be assumed that the sharp increase in the total number of vertebral fractures is not only due to the aging population structure in Germany. The improved availability and quality of CT and MRI must be considered to contribute to the increased documentation of vertebral and sacral fractures^{19–21}. Recently, Graul et al. demonstrated the sensitivities for sacral insufficiency fractures to be 14% in X-ray, 88% in CT, and 100% in MRI²². They further figured out that additional pathologies were identified in MRI of the lumbar spine in 51% and pelvis in 18%, respectively²². They consequently advocated for extensive MRI diagnostic of the lumbar spine including the sacrum for symptomatic elderly patients²². In the current population in 60.5% of the cases a CT and in around 30% of the cases an MRI of the spine or the pelvis were applied in 2019.

The most documented secondary diagnoses were hypertension, osteoporosis, atrial fibrillation, type II diabetes and chronic kidney disease. These can be assumed to be indicative for the elderly German population^{23,24}. We found 18,773 (17.9%) cases in which osteoporosis was documented as a secondary diagnosis. Noteworthy, it has not been screened for "M80.-" and "M81.-" as main diagnoses. In Europe, a prevalence of 18-26% of osteoporotic vertebral fractures is reported, with women being affected in the majority in Germany^{25,26}. In their recent systematic review Spiegl et al. point out the role of osteoporotic fractures of the spine and the importance of tailored diagnostic and therapeutic strategies²⁷. Besides, the use kyphoplasty or vertebroplasty in around 17% of cases and the use of screw augmentation in around 5% of cases underline the importance of osteoporotic vertebral fractures and indicate the challenges in surgical management. Lastly several authors have put effort into the development of new classifications systems of osteoporotic vertebral fractures and of therapy algorithms^{28,29}.

Interestingly concomitant vertebral fractures were documented as secondary diagnoses in a high share of cases. These fractures were seen at the lumbar spine in around 29% of cases and at the thoracic spine in around 18% of cases. Hypothetically these fractures partly can be accounted to poor bone quality in patients with osteoporosis: The incidence of concomitant vertebral fractures at first contact in patients with osteoporotic vertebral fractures has been reported to be 26% in a register based epidemiological study³⁰. Further, multilevel contiguous osteoporotic lumbar compression fractures have been described³¹. Also in non-osteoporotic patients multilevel vertebral injuries are common and incidences around 20-30% have been reported^{32–34}. Especially occult, non-continuous vertebral injuries bare the risk of delayed diagnosis. Therefore some authors advocate for considering whole spine MRI in vertebral trauma patients^{32,34}.

We found 1.1% cases of vertebral fractures to be associated with SCIs. In concordance with the findings of Smits et al. SCI were associated with cervical fractures in most cases. Den Ouden reported on a SCI rate of 8.5% in their population of traumatic vertebral fracture patients in 2016 ¹⁷. In their nationwide analysis of traumatic vertebral fractures Smiths et al. showed a SCI rate of 5.5%, mainly associated with cervical spine fractures ². A reason for the comparatively low rate of SCIs of our study could be the heterogenous population, including also low-energy trauma mechanisms and elderly patients. It can be hypothesized, that the association with SCI partly accounts for the severity of cases with cervical spine trauma.

Based on the most used G-DRG codes the overall cost of hospitalized patients with vertebral fractures was calculated €590 million in 2019. We calculated average costs per case of €5,612. This represents a cross section of the different cases complexities ranging from €719 to €67,782 depending on the G-DRG codes. The most often applied G-DRG was I68D coding for non-surgical treatment of vertebral fractures in around 33% of cases. I09F coding for specific surgical vertebral procedures with complicating factors only made up 7.4% of cases but accounted for around 13.4% of the overall costs. Cases with codes for non-surgical treatment of vertebral fractures accounted for 18.3% of the overall costs, representing 49.3% of all cases. In contrast, cases with codes for specific surgical treatment made up for 44.4% of the overall costs, while only representing 26.1% of the cases. In cases with cervical spine fractures and fractures of the sacrum the highest shares of high clinical complexity levels (PCCL ≥ 3) were seen.

The data on up-to-date nationwide cost-analysis for vertebral fractures is sparse. An analysis of approximately 200,000 hospitalizations in the U.S. demonstrated that the total national charges associated of cervical spine fracture cases with and without SCIs combined exceeded \$1.3 billion US in 2006 ³⁵. In the EU the total hospital costs for vertebral fractures has been estimated at €377 Million per year in a study, published in 2003 ³⁶. Based on an analysis of 491 patients treated conservatively for vertebral fractures between 1999 and 2008 Aras et al. estimated the total health cost at €18,919, €8571 and €5526 for cervical, thoracic, and lumbar regions, respectively ³⁷. In 2004 van der Roer estimated the average costs for stable fractures without neurological deficits treated nonoperatively at €5,100, for unstable fractures without neurological deficits, treated either nonoperatively, at €12,500 or operatively at €19,700 ³⁸. The costs for unstable fractures with neurological deficits were estimated at €31,900 ³⁸. These estimations are in range of the average cost for the respective G-DRG on which our analysis is based on.

The increase in fracture incidence poses a challenge for stakeholders in the health care systems. Fragility fractures were projected to 928,000 in 2025 with an estimated socioeconomical burden of €11,261 million [20]. Vertebral fractures, even treated conservatively, incur substantial health-care utilization and costs. However, the costs of work absenteeism and disability add to the overall costs, associated with vertebral fractures, and could not be accessed in this study. Further studies on the cost-effectiveness, cost utility and long-term costs of vertebral fractures are necessary to comprehend the total economic burden. The current analysis summarizes the up-to-date costs of vertebral fractures of the German population in 2019 and therefore provides important information for the planning of preventive and treatment strategies.

Strengths and limitations

The main strength of the current study is the nationwide analysis over one decade. To provide comprehensive information on different aspects of the inpatient treatment of vertebral fractures two data source were employed: Data based on the Destatis analysis (2009-2019) and data based on the InEK data and report browser (2019). The study is limited by the fact, that, although ICD-10 codes as a function of age and gender were available, it was not possible to determine the trauma mechanisms. Whereas correct coding of diagnosis can be assumed since DRG lump sum payment relies on it, which is strictly controlled by the Medical Service of Health Funds. Further, only inpatient data was available. Even though hospitalization is required in many cases, the reported fracture incidences may be underestimated as fractures treated in an outpatient setting are not included in the analysis. Moreover, a detailed analysis was conducted only for primary diagnoses. We showed, that in this population in 58.4% of cases an additional vertebral fracture was documented as a secondary diagnosis. The overall number of vertebral fractures might be underestimated, because secondary diagnoses were not screened for all relevant primary diseases.

The evaluation of 955,091 vertebral fractures between 2009 and 2019 showed a relevant increase in the incidence rate to 151 cases per 100,000 inhabitants, highlighting the challenge for stakeholders in the health care systems. This is underlined by the costs incurred of approximately €590 million in 2019. The age and gender distribution suggests an increase in the diagnosis of insufficiency vertebral fractures. Considering the relevant share of complex cases with the need of surgical and ICU treatment the expanding nationwide implementation of vertebral care centres appears reasonable and necessary.

Methods

Federal Statistical Office of Germany (Destatis)

Data consisting of annual ICD-10 diagnosis codes from German medical institutions between 2009 through 2019 was provided by the Federal Statistical Office of Germany (Destatis). Total number of vertebral fractures were quantified using the ICD-10 Codes "S12.0", "S12.1", "S12.2", "S22.0", "S32.0", "S32.1" and "S32.2" (Table 8) and analyzed as a function of anatomical localization, gender and age in 10-year increments for

patients older than 20 years from 2009 through 2019, respectively. Incidences were calculated based on Germany's historical population aged 20 years or older provided by Destatis ³⁹. Here, the number of inhabitants in each of the 16 German federal states was considered by year of birth for each year of the period 2009 through 2019. The deadline of each year was December 31.

Table 8
Used ICD-10 codes for vertebral fractures with descriptions.

ICD-10 Code	Description
S12.0	Atlas (C1)
S12.1	Axis (C2)
S12.2	Subaxial cervical spine (C3- C7)
S22.0	Thoracic spine
S32.0	Lumbar spine
S32.1	Sacrum
S32.2	Coccyx

Institute for the Hospital Remuneration System (InEK GmbH)

In accordance with Section 17b of the German Hospital Financing Act (KHG), a universal, performance-based, and flat-rate remuneration system has been introduced for general hospital services. The basis for this is the G-DRG system (German Diagnosis Related Groups system), whereby each inpatient case of treatment is remunerated by means of a corresponding DRG lump sum payment.

The InEK GmbH provides detailed data on the main diagnoses (based on ICD-10 codes), secondary diagnoses (based on ICD-10 codes), procedures (based on OPS-codes), and the G-DRG distribution. Data is accessible via the InEK Data Browser ⁴⁰. The Browser enables analysis back to the year 2019. The following comprehensive analysis was made only for the year 2019: Based on the ICD-10 codes for vertebral fractures, displayed in Table 8 data for total case numbers, numbers of in-hospital deaths, and numbers of cases treated on an ICU were extracted. Further, the data on secondary diagnoses, OPS-codes, time of hospital stay (mean ± standard deviation) and G-DRG codes were analyzed. A specific G-DRG code corresponds to each one case that was determined based on the ICD code. Cases that were treated for the same diagnosis within the same year were grouped together. Thus, no duplicates were recorded.

To estimate the cost for inpatient treatment of vertebral fractures the G-DRG Report browser was employed ⁴¹. The G-DRG Report Browser 2019 displays the calculation results for the G-DRG system 2019 on DRG level. The share of cases according to the Patient Clinical Complexity Level (PCCL) was adopted from the InEK Data Browser. The PCCL value is calculated in a complex procedure from the secondary diagnosis values (complication or comorbidity level values - CCL) and indicates the severity of the complication or comorbidity based on results between 0 (no CC) and 6 (most severe CC). Costs according to the distribution of applied G-DRG codes, that were used in at least 0.05% of cases were added up proportionally and calculated as mean value per case.

Declarations

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Ethics declarations

Methods were carried out in accordance with local data privacy guidelines and ethical regulations.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by S.L., N.W. and V.F. The project was supervised by M.L., C.N., and V.A. The first draft of the manuscript was written by S.L., N.W., M.L., and M.R. and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability statement

The datasets analysed during the current study are available from the corresponding author on reasonable request. The raw data is publicly available and provided by Destatis and the InEK data browser.

References

1. Katsuura, Y., Osborn, J. M. & Cason, G. W. The epidemiology of thoracolumbar trauma: A meta-analysis. *J Orthop* **13**, 383–388 (2016).
2. Smits, A. J., Ouden, L. P. den, Deunk, J., Bloemers, F. W., & LNAZ Research Group. Incidence of Traumatic Spinal Fractures in the Netherlands: Analysis of a Nationwide Database. *Spine (Phila Pa 1976)* **45**, 1639–1648 (2020).
3. Roberge, R. J. *et al.* Selective application of cervical spine radiography in alert victims of blunt trauma: a prospective study. *J Trauma* **28**, 784–788 (1988).
4. Hasler, R. M. *et al.* Epidemiology and predictors of cervical spine injury in adult major trauma patients: a multicenter cohort study. *J Trauma Acute Care Surg* **72**, 975–981 (2012).
5. Singh, A., Tetreault, L., Kalsi-Ryan, S., Nouri, A. & Fehlings, M. G. Global prevalence and incidence of traumatic spinal cord injury. *Clin Epidemiol* **6**, 309–331 (2014).
6. Högel, F., Vastmans, J., Vogel, M. & Bühren, V. Verletzungen des Rückenmarks – Akutbehandlung. *Orthopädie und Unfallchirurgie up2date* **11**, 451–479 (2016).
7. Briem, D. *et al.* Pain regulation and health-related quality of life after thoracolumbar fractures of the spine. *Eur Spine J* **16**, 1925–1933 (2007).
8. Schnake, K. J., Stavridis, S. I. & Kandziora, F. Five-year clinical and radiological results of combined anteroposterior stabilization of thoracolumbar fractures. *J Neurosurg Spine* **20**, 497–504 (2014).
9. Lang, S. *et al.* Radiological and mid- to long-term patient-reported outcome after stabilization of traumatic thoraco-lumbar spinal fractures using an expandable vertebral body replacement implant. *BMC Musculoskelet Disord* **22**, 744 (2021).
10. Alluri, R. *et al.* A Nationwide Analysis of Geriatric Odontoid Fracture Incidence, Complications, Mortality, and Cost. *Spine* **Publish Ahead of Print**, (2020).
11. *Report on osteoporosis in the European Community: action for prevention.* (Office for Official Publications of the Europ. Communities, 1998).
12. Johnell, O., Gullberg, B. & Kanis, J. A. The hospital burden of vertebral fracture in Europe: a study of national register sources. *Osteoporos Int* **7**, 138–144 (1997).
13. Ärzteblatt, D. Ä. G., Redaktion Deutsches. Inzidenz von Frakturen in der Erwachsenenpopulation in Deutschland. *Deutsches Ärzteblatt* <https://www.aerzteblatt.de/archiv/221388/Inzidenz-von-Frakturen-in-der-Erwachsenenpopulation-in-Deutschland> (2021).
14. Reinhold, M. *et al.* [Operative treatment of traumatic fractures of the thorax and lumbar spine. Part II: surgical treatment and radiological findings]. *Unfallchirurg* **112**, 149–167 (2009).
15. Jansson, K. Å. *et al.* Epidemiology of thoracolumbar spine fractures—a nationwide study in sweden. *Orthopaedic Proceedings* **91-B**, 22–23 (2009).
16. Blecher, R. *et al.* Uptrend of cervical and sacral fractures underlie increase in spinal fractures in the elderly, 2003–2017: analysis of a state-wide population database. *Eur Spine J* **29**, 2543–2549 (2020).
17. den Ouden, L. P. *et al.* Epidemiology of Spinal Fractures in a Level One Trauma Center in the Netherlands: A 10 Years Review. *Spine (Phila Pa 1976)* **44**, 732–739 (2019).
18. Nevitt, M. C. *et al.* The association of radiographically detected vertebral fractures with back pain and function: a prospective study. *Ann Intern Med* **128**, 793–800 (1998).
19. Kumar, Y. & Hayashi, D. Role of magnetic resonance imaging in acute spinal trauma: a pictorial review. *BMC Musculoskeletal Disorders* **17**, 310 (2016).
20. Rajasekaran, S. *et al.* The value of CT and MRI in the classification and surgical decision-making among spine surgeons in thoracolumbar spinal injuries. *Eur Spine J* **26**, 1463–1469 (2017).
21. Lentle, B. C., Hammond, I., Firth, G. B. & Sutton, R. A. L. Imaging of Osteoporotic Fractures on XR, CT, and MR. *Curr Radiol Rep* **2**, 32 (2013).
22. Graul, I., Vogt, S., Strube, P. & Hölzl, A. Significance of Lumbar MRI in Diagnosis of Sacral Insufficiency Fracture. *Global Spine J* **11**, 1197–1201 (2021).

23. Puth, M.-T., Weckbecker, K., Schmid, M. & Münster, E. Prevalence of multimorbidity in Germany: impact of age and educational level in a cross-sectional study on 19,294 adults. *BMC Public Health* **17**, 826 (2017).
24. The bone evaluation study (BEST): patient care and persistence to treatment of osteoporosis in Germany - PubMed. <https://pubmed.ncbi.nlm.nih.gov/24040854/>.
25. Ballane, G., Cauley, J. A., Luckey, M. M. & El-Hajj Fuleihan, G. Worldwide prevalence and incidence of osteoporotic vertebral fractures. *Osteoporos Int* **28**, 1531–1542 (2017).
26. Bässgen, K. *et al.* Population-based prospective study on the incidence of osteoporosis-associated fractures in a German population of 200,413 inhabitants. *J Public Health (Oxf)* **35**, 255–261 (2013).
27. Ärzteblatt, D. Ä. G., Redaktion Deutsches. Osteoporotische Frakturen der Brust- und Lendenwirbelkörper: Diagnostik und konservative Therapie. *Deutsches Ärzteblatt* <https://www.aerzteblatt.de/archiv/221386/Osteoporotische-Frakturen-der-Brust-und-Lendenwirbelkoerper-Diagnostik-und-konservative-Therapie> (2021).
28. Blattert, T. R. *et al.* [Nonsurgical and surgical management of osteoporotic vertebral body fractures: Recommendations of the Spine Section of the German Society for Orthopaedics and Trauma (DGOU)]. *Orthopade* **48**, 84–91 (2019).
29. Rajasekaran, S. *et al.* Osteoporotic Thoracolumbar Fractures-How Are They Different?-Classification and Treatment Algorithm. *J Orthop Trauma* **31 Suppl 4**, S49–S56 (2017).
30. Lenski, M., Büser, N. & Scherer, M. Concomitant and previous osteoporotic vertebral fractures. *Acta Orthop* **88**, 192–197 (2017).
31. Sabo, A., Hatgis, J., Granville, M. & Jacobson, R. E. Multilevel Contiguous Osteoporotic Lumbar Compression Fractures: The Relationship of Scoliosis to the Development of Cascading Fractures. *Cureus* **9**, e1962 (2017).
32. Atsina, K.-B., Rozenberg, A. & Selvarajan, S. K. The utility of whole spine survey MRI in blunt trauma patients sustaining single level or contiguous spinal fractures. *Emerg Radiol* **26**, 493–500 (2019).
33. Green, R. A. R. & Saifuddin, A. Whole spine MRI in the assessment of acute vertebral body trauma. *Skeletal Radiol* **33**, 129–135 (2004).
34. Kanna, R. M., Gaike, C. V., Mahesh, A., Shetty, A. P. & Rajasekaran, S. Multilevel non-contiguous spinal injuries: incidence and patterns based on whole spine MRI. *Eur Spine J* **25**, 1163–1169 (2016).
35. Baaj, A. A. *et al.* Health care burden of cervical spine fractures in the United States: analysis of a nationwide database over a 10-year period: Presented at the 2009 Joint AANS/CNS Spine Section Meeting. *Journal of Neurosurgery: Spine* **13**, 61–66 (2010).
36. Finnern, H. W. & Sykes, D. P. The hospital cost of vertebral fractures in the EU: estimates using national datasets. *Osteoporos Int* **14**, 429–436 (2003).
37. Aras, E. L., Bunger, C., Hansen, E. S. & Sogaard, R. Health-care costs of conservative management of spine fractures in trauma patients. *Eur Spine J* **26**, 1438–1446 (2017).
38. van der Roer, N., de Bruyne, M. C., Bakker, F. C., van Tulder, M. W. & Boers, M. Direct medical costs of traumatic thoracolumbar spine fractures. *Acta Orthopaedica* **76**, 662–666 (2005).
39. Statistisches Bundesamt Deutschland - GENESIS-Online. <https://www-genesis.destatis.de/genesis/online> (2021). (accessed December 16, 2021).
40. InEK DatenBrowser. <https://datenbrowser.inek.org/DRG2019>. (accessed December 8, 2021)
41. G-DRG-Report-Browser 2019. 37 (2019). (accessed December 8, 2021)

Figures

Figure 1

The distributions of vertebral fractures by anatomical location comparing data from 2009 and 2019 (designed with Inkscape 1.1 and Microsoft PowerPoint software).

Figure 2

Age distribution of the fractures in 2019 as a function of gender in cranio-caudal order of the anatomical location at the spine (A-E).

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